Recent Advances in Acoustics & Music

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Proceedings of the 11th WSEAS International Conference on ACOUSTICS & MUSIC: THEORY & APPLICATIONS (AMTA '10)

"G. Enescu" University, Iasi, Romania, June 13-15, 2010

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Preface

This year the 11th WSEAS International Conference on ACOUSTICS & MUSIC: THEORY & APPLICATIONS (AMTA '10) was held at "G. Enescu" University, Iasi, Romania, June 13-15, 2010. The conference remains faithful to its original idea of providing a platform to discuss mathematical models in acoustics, acoustics measurements, sound insulation, space acoustics, electronics for sound art and technology, ambiophonics, psychoacoustics, mathematical models in music, computers in music composition, pattern recognition in music, automatic music composition, biological effects of music, mathematical analysis of musical instruments etc. with participants from all over the world, both from academia and from industry.

Its success is reflected in the papers received, with participants coming from several countries, allowing a real multinational multicultural exchange of experiences and ideas.

The accepted papers of this conference are published in this Book that will be indexed by ISI. Please, check it: www.worldses.org/indexes as well as in the CD-ROM Proceedings. They will be also available in the E-Library of the WSEAS. The best papers will be also promoted in many Journals for further evaluation.

A Conference such as this can only succeed as a team effort, so the Editors want to thank the International Scientific Committee and the Reviewers for their excellent work in reviewing the papers as well as their invaluable input and advice.

The Editors

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Plenary Lecture 1

Synthesized Music Instruments can Play a Significant Role in Digital Signal Processing Education

Professor Roxana Saint-Nom
Electrical Engineering Department
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Abstract: Teaching signal processing to senior undergraduate students can be an enjoyable task, provided that you are willing to spend some time to introduce them to digital music.
Leaded by a motivated R+D group in Acoustics or Audio, all you need is signal processing students who have good MATLAB programming skills and filter theory.
My talk will be focused in two topics:
1. How to emphasize Signal Processing concepts through digital music.
I will describe a laboratory assignment where students have to synthesize musical instruments in different ways: additive, FM, through physical modeling and using wavetables. I will give examples and achievements along the years.
2. Digital Music as Audio and Acoustics' research themes source
Music projects in electrical engineering environments tend to be well received. I will show several subjects that became appropriate for sponsored projects or students contents.
It is interesting to remark that mixing engineering and music help develop the cultural brackground of students, creates an unstructured space where new ideas emerge easily, and turns mathematics into a more friendly resource.

Brief Biography of the Speaker:
She received her Electrical Engineering degree in 1987 from the University ITBA (Buenos Aires Institute of Technology), Argentina. She achieved a Masters degree in Speech Processing from the "Universidad Politecnica de Madrid", Spain, where she is currently finishing her Ph.D thesis on Speaker Verification.
Since 1988 she has been holding academic positions in Argentina, until she became tenured faculty in the rank of the Full Professor in 2004. Since 2007 she is the Electrical Engineering Department Chair at ITBA. She is also the Director of a Master's degree joint program on Engineering Education (ITBA-Universidad de Mendoza- Universidad de Granada, Spain).
Her research area is primarily Signal Processing, Speech and Education as subareas. In recent years she started research groups in different areas, such as speaker verification, acoustics, DSP applications and EMC.
She is the author of more than 20 papers, mostly in the area of signal processing education, published in reviewed journals or presented at international conferences such as IEEE ICASSP, IEEE ISCAS, IASTED and WSEAS. She is a technical reviewer for the IEEE Transactions on Circuits and Systems and IEEE ICASSP Proceedings and SSIP IASTED Proceedings.
She is an active senior member of the IEEE. She is the founder of the IEEE Signal Processing Society (SPS) Argentina Chapter, from which she is currently Chair (2008-2009), she is the IEEE SPS Education Technical Committee Chair (2007-2009), she is a SPS Conference Board Member and an IEEE SPS Lensing Oversight Committee Member.

Plenary Lecture 2

Conceiving Music Today: Manifold Compositions, DISSCO and Beyond

Professor Sever Tipei
Manager Computer Music Project of the University of Illinois Experimental Music Studios
Composition-Theory Division
School of Music
University of Illinois at Urbana Champaign
IL, USA
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Abstract: Manifold compositions consist of all actual and potential variants of a work that contains elements of indeterminacy and is generated by a computer reading the same data for each variant. The relationship between manifolds and classes of composition is discussed and a tool (DISSCO) unifying composition and sound synthesis is presented along with some of its components such as stochastic distributions and sieves. Deterministic and random processes facilitate by DISSCO are shown to correspond to an implicit worldview and the role of the computer is described as that of a collaborator complementing the skill of the human composer. It is also shown how musical compositions can be described as complex dynamic systems and two related projects are proposed: a "sound fountain", an ever changing stream of sounds, and a "brewing" piece continuously re-arranging its parts in search of an nonexistent optimal solution.

Brief Biography of the Speaker:
Sever Tipei is a composer and theorist whose main fields are Computer Music and Music Formalization. He teaches at the University of Illinois and manages the Computer Music Project of the Experimental Music Studios. Most of his compositions were produced with software he designed and implemented at Argonne National Laboratory and at the National Center for Supercomputing Applications on high performance computers and in the CAVE virtual environment.
Tipei's papers have appeared in the Computer Music Journal, Leonardo, and in proceedings of various International Computer Music Conferences. His music is recorded on Centaur, Veriatza, and University of Illinois albums. As a pianist, he has performed in the United States, Korea, France, Italy, Belgium, the Netherlands, and Romania, and recorded for the ORION label.

Soundscape Music: Sub-genre of New-age Music

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Abstract: Since the concept of Soundscape brought forth by Canadian composer R. Murray Schafer in the 1960s, researchers and musicians in different realms started to study the new term. In most instances, researchers prefer to pay attention to Soundscape effects on noise control, but nowadays, some issues related to Soundscape begin to focus on the Soundscape expression in music which enlarges the Soundscape extensional meaning. In music realm, Soundscape researchers investigate its musical expression methods and the intersection between Soundscape expression type and the others. In the International Computer Music Conference2009, there was an article strived to discuss the methods of classification of the electroacoustic soundscape. Then based on the works, we consider that whether or not soundscape should be a musical genre, and if we got a positive answer, which attribution should it equipped with?

Key-Words: Soundscape New-age music Sub-genre Musicality Good-quality Sensitivity

1 Introduction

Nowadays, soundscape is used in different areas. Generally speaking, the application can be divided into noise standard which is uniform and composition which is full of musicality. On the base of soundscape features and purposes used in composition, we present soundscape music concept. Thereby, we are wondering that if there should be a clear feature of soundscape to differentiate some other close music genres. To make soundscape music easy to be recognized, I mean, not only in the soundscape recordings, but in the soundscape music concept, we need to classify unique features to distinguish soundscape music from other music genres. We notice that soundscape and some other quasi genres like new-age music have a lot of things in common. Then, how is about the link between the two genres? The relationship type is inclusive or parallel? Is it necessary to sum soundscape music features to differentiate it from the other genres? The questions should be answered by our study..

2 The development of soundscape in music

The term "soundscape" was stated in 1960s by Canadian composer and environmentalist R. Murray Schafer for acoustic ecology[1]. He defined soundscape with three main elements: keynote sounds, sound signals and soundmark. In the three main elements, the soundmark plays the most important role which Schafer wrote in the book "The Turning of the World", which says "once a soundmark has been identified, it deserves to be protected, for soundmarks make the acoustic life of a community unique".[2]

Since the original purpose of soundscape is to make a noise control standard, researchers treat soundscape as a tool to rule the circumstances in different areas since there is a tight relationship between soundscape and noise pollution. But in the last few years, we found there were some issues exploring soundscape in music which should be regarded as a great progress in the development of soundscape.

To show the obvious improvment, we tabulate statistics data about the issues related to soundscape in ICMC2009, and the detailed data is stated in the table1(serial number from [1] to [13],the titles are listed in the reference from [9] to [21]).

[1] http://en.wikipedia.org.wiki/R._Murray_Schafer

[2] http://en.wikipedia.org/wiki/Soundscape

Table 1 Statistical data of Research issues related to Soundscape in ICMC2009

Different Sessions			
Subject	serial number	page number	quantity
History/Education	[1] [2]	137 141	2
Synthesis	[3]	155	1
Education/Synthesis/Sonification	[4]	187	1
Aesthetics	[5] [6] [7]	343 351 355	3
Composition Systems	[8]	379	1
Perception	[9]	455	1
Performance System 2	[10]	505	1
Performance Systems/Perception	[11] [12] [13]	541 553 557	3
The Main Author's Nationality			
Nationality	serial number		quantity
Austria	[11]		1
Germany	[5] [6] [7]		3
Mexico	[9]		1
United Kingdom	[1] [8]		2
United States of American	[2] [3] [4] [10] [12] [13]		6
The Class of Establishment of The Main Author			
Type of the institution	serial number		quantity
Research Institutions	[10]		1
University	[1] [2] [3] [4] [5] [7] [8] [9] [11] [12]		10
Others	[6] [13]		2

3 The relationship between soundscape music and new-age music

As we all know, "new age music is peaceful music of various styles, which is intended to create inspiration, relaxation, and positive feelings while listening. Studies have determined that new age music can be an effective component of stress management.[3] Some new age music albums come with notes to encourage use in meditation. New age music evolved to include a wide range of styles from electronic space music and acoustic instrumentals using Western instruments to spiritual chanting from other cultures – including Native American flutes and drums, synthesizers, and instrumental world music sounds."[4]

Soundscape concept originally intended to solve the problem of noise, with awareness of public, more and more people treat it as a new mode of music expression, or a new composition tool. Then, soundscape is divided into hi-fi as used in expression, and low-fi used in noise standard. The most evident feature of hi-fi soundscape is full of musicality. "From an ecological standpoint, the hi-fi soundscape is populated by many individual 'species' which are the result of local conditions. They are information rich, and most importantly, are most richly interpreted by locals who understand their contextual meanings."[5] While, "almost everything about technology promotes standardization and uniformity, right from the micro level of hums and broad-band noise, through to the influences that produce 'lo-fi' soundscapes in every urban centre, as well as their surroundings (Schafer 1977, 1993)." [6]Therefore, we suppose to make a definition of so-called "hi-fi" soundscape. Considering the attribute of hi-fi soundscape and the general soundscape concept, we put forward a soundscape music definition instead of hi-fi soundscape as a genre which full of musicality utilizing sound materials to express local eco-environment and culture environment as a representation or a tool in music category.

New-age music has much in common with soundscape music. One significant kind of new-age music is similar with soundscape music which utilizes nature sound or electro sound as materials to compose too. Further, both of them don't have core lyrics, and even the purposes of the two genres (I mean new-age music genre and soundscape music genre) have a lot in common: new-age music aims at relieving human pressure——"the intention is to consciously create a soundtrack that resonates at a higher frequency and serves at a higher level of bringing harmony and peace to body, mind, spirit."However, soundscape music tends to improve human sensitivity to sound, reinforcing their reorganization to ambient sound. Therefore, the goal of soundscape music and new-age music, striving to refresh human mind and body into their natural condition by using music adjusting human physiological psychology under the background of feeling tired build on the same final purpose. For instance, the album "moonlight festival" delivered a night-soundscape in Taiwan to us. (See figure 1)In the song "moonlight festival", producer chose crocking of frog and cello as music components, intertwining and antistrophic, making us enjoy the serene Taiwan night and sweet atmosphere.

[3] Lehrer, Paul M.; David H. (FRW) Barlow, Robert L. Woolfolk, Wesley E. Sime (2007). *Principles and Practice of stress management, Third Edition.*New York: Guilford Press. pp. 46–47. ISBN 159385000X.

[4] http://en.wikipedia.org/wiki/New_Age

[5] http://www.sfu.ca/~truax/OS7.html

[6] http://www.sfu.ca/~truax/OS7.html

Fig. 1 the cover of album “moonlight festival”[7]

Of cause, there are some differences between the two. Comparatively speaking, soundscape music expresses lifeway that sound conveys while new-age music works equipped with more obvious musicality. Setting the matter of soundscape used in noise standard aside, just considering pure soundscape music, I reckon that soundscape music prefer uniqueness to generality. R. Murray Schafer (1969, 1977) pointed the soundscape concept as the 'universal' composition of which we are all composers.[8] Obviously, soundscape music provides cultural meanings from different angles of view, because everybody observes the chosen objective in their own opinions, while new-age music, in most cases, appears to be more general due to the fact that there is no limitation for new-age music materials' utilization, from nature sound to jazz elements, etc, everything can be used in mixing new-age music.

Prefer pursuing uniform function or purpose, not the same in technology, is new-age music's highlight lying in its essence. The music type should be classified to new-age music category as long as its function and purpose meet new-age music's feature, in spite of differences in a thousand and one ways in composition technology and performance skills.

Aiming at increasing human sensitivity to acoustic sound, the ultimate end of soundscape music is to recover human natural condition. Then, in my opinion, soundscape music is a sub-genre of new-age music.

[7] http://t.douban.com/lpic/s2622490.jpg

[8] http://www.sfu.ca/~truax/OS7.html

4 soundscapes in different areas demonstrate different features

With more and more record companies and individuals interesting in soundscape recording, we need judgment criteria to tell the difference between the satisfying one and the disappointing one. The soundscape concept at beginning refers to the music in environment, aiming at enhancing people's acoustic sensitivity. Then we consider that the purpose not only contains increasing acoustic sound sensitivity, but also rouse people's discrimination related to various soundscape with different characteristics. Leaving “low-fi” soundscape that used in making noise standard aside, based on the utilization of soundscape components, we separate soundscape music into two parts: using soundscape material as a tool in composition, and just record the pure natural sound completely (I put human's voice in the sound environment into the later one). (See figure 2) So, no matter the on-the-spot soundscape music records or the mixing using the soundscape materials, the good records should including clear sound details at least you can identify every factor and component, and the local individual soundscape characteristics.

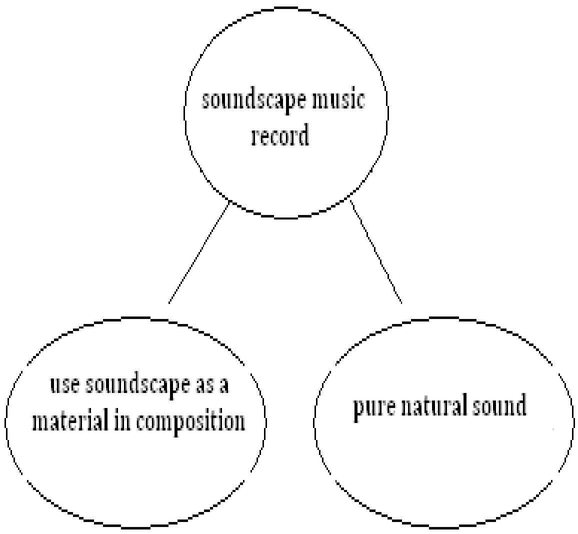

Fig. 2 two types of soundscape record

The good-quality soundscape music record should describe every sound detail by careful processing. The record must express the subtle gradation, because the acoustic sound shows variation with time going by, including the total system varying and slight or huge dynamic change in every part. So, to strengthen audiences' acoustic sensitivity based on hearing experience, there are two essential points to do:

Firstly, the recording must keep high fidelity as well as possible so as to the audiences could rebuild the soundscape recording environment while listening to the recording. If the reproduced soundscape environment is quite other than the real recording environment, the work is not worth being called "good-quality". For instance, the audiences image the acoustic sound source as a huge one, while the truth is not, then the work should be put down as a failure. Therefore, the recorder should choose the right pick-up method, and use appropriate microphones according to different materials or parts when it comes to recording the soundscape. After that, the recorder still can't ease off, because in the processing of editing, he must be very careful and use the pan-shift reasonably at least not to destroy the original soundscape recording environment.

Secondly, the works should show recording environment variations as far as they can. For this reason, recording should be optimized in dynamic and EQ adaption. The more details conveyed, the better the work is.

A good soundscape music record should present the local soundscape character. Not to demand the producer to choose the most representative soundscape, but to let audiences reproduce environment that the soundscape recordings want to express at least with typical soundscape or just some general nature sound materials. The recorder should try their best to achieve the goal that "outline the character of the people living there" (Schafer).[1]

No matter how to handle the after-treatment, to produce an excellent soundscape music record, do remember that the most extreme feature of soundscape music is musicality. The record should provide the audiences a "melodious" soundscape which express the local eco-environment and culture environment.

5 Conclusion

Considering the different soundscape features based on different purposes, we divide soundscape into hi-fi as soundscape music and low-fi as noise standard. With music expressions tending to be more and more diversified, we are wondering that we should make a definition of soundscape music, which should be classified as a sub-genre of new-age music by comparison. To state soundscape music features and functions, we discuss the definition as a genre which full of musicality utilizing acoustic sound to express local eco-environment and culture environment as a representation or a tool in music category. And no matter how to use the recording technology, the foremost important principle is keeping soundscape's musicality.

6 Acknowledgments:

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[1]http://en.wikipedia.org.wiki/R._Murray_Schafer

[2]http://en.wikipedia.org/wiki/Soundscape

[3] Lehrer, Paul M.; David H. (FRW) Barlow, Robert L. Woolfolk, Wesley E. Sime (2007). *Principles and Practice of stress management, Third Edition*.New York: Guilford Press. pp. 46–47. ISBN 159385000X.

[4]http://en.wikipedia.org/wiki/New_Age 2009-10-9

[5]-[7]http://www.sfu.ca/~truax/OS7.html 2009-10-9

[8] http://t.douban.com/lpic/s2622490.jpg

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Design of an Acoustic Anechoic Chamber for Application in Hearing Aid Research

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Abstract: - An acoustic anechoic chamber is a shielded room designed for performing sound measurements under conditions close to free space. This short paper summarises the design and construction of a low cost anechoic chamber, with a focus on hearing aid research. Under these conditions, small scale and a predominant axis of measurement are the major factors of consideration. Insulation, absorption and construction issues are detailed and addressed, preliminary results and proposals for future work are included.

Key-Words: - anechoic chambers, sound insulation, sound absorption, sound measurements, hearing aids

1 Introduction

Acoustic anechoic chambers are environments with a high acoustic insulation from the nearby environment, used to measure systems under conditions close to free-space. Due to the generic requirements of these measurements, anechoic chambers tend to be of considerable size, in order to attain an acceptable response. This leads to high construction and maintenance costs, and the requirement of an appropriate physical space.

However, if an anechoic chamber is designed for a specific set of applications, many of these limitations can be overcome. In the context of the hearing aid project our group is engaged in, a chamber was required for measuring the response of two, possibly mismatched, microphones from a directional source.

In this context the physical size of the chamber can be kept within constraints, since the frequency range of interest is 250 Hz - 4000 Hz, small scales are predominant and a predominant axis of measurement is involved. The insulation of the chamber to external sources of sound and the reflective behaviour of the walls can also be given special consideration. It is even possible to comply with parts of ISO 3745 [1], a standard for performing sound pressure level measurements in anechoic rooms.

2 Chamber Design

2.1 Shape

Large anechoic chambers are usually constructed in the shape of a rectangular cuboid, mainly due to architectural limitations. Even though this set-up is prone to standing waves, the fundamental frequency of resonance is usually low enough to be disregarded.

In the case of a smaller chamber this effect is not negligible, thus a non-regular shape is preferred. In spite of this recommendation a rectangular cuboid was chosen as the shape of the design, as it simplifies simulation and construction.

2.2 Dimensions

The dimensions of the chamber are a critical design factor. If chosen wisely, the standing wave problem can be mitigated and certain parts of ISO 3745 can be observed.

For determining the internal width, height and length, a common scale was multiplied by three small prime numbers. This achieves a mix of standing wave modes that do not overlap in the frequency range of interest.

The chosen dimensions led to a volume of 1.103 m^3. ISO 3745 recommends a chamber volume (V_c) of at least 200 times the volume of the sound source (V_s), thus devices of up to 5515 cm^3 can be measured.

In order to find the chamber's cut-off frequency, the source is assumed to be directional, facing the major *d* dimension. In this case the geometric cut-off frequency can be obtained as [2]:

(1) $$a + 4a + \lambda/2 + 2l_w = d$$

a represents the size of the sound source in the *d* dimension, and l_w is the wedge height (see 2.4 Absorption).

The sound source used in the set-up has $a = 0.1$ m. Solving for λ, the geometric cut-off frequency in the *d* direction is found to be 211.7 Hz. This falls below the lower frequency of interest.

2.3 Insulation

To determine the necessary acoustic insulation, the maximum SPL level at the site of our sound lab was determined with a Brüel&Kjær 2250 sound level meter. It was determined that the maximum SPL is 60 dB(A) in the frequency band of interest.

Simulations were initially carried out with a single wall insulation. If it is assumed that wave-fronts are flat, interfaces infinite and there is no dissipation, the transmission loss at the interfaces can be calculated as

(2) $$TL = -10\ log_{10}(\ |T|^2\ )$$

T being the quotient of two phasors that represent the complex amplitude of the incident and transmitted pressure waves, respectively [3]. The wall width was varied in order to comply with the noise criteria curve NC-10.

The resulting width was unacceptably large, thus a double wall insulation was considered. Simulations were repeated for this configuration, and wall widths and separation were varied. Best values for these parameters were determined by constraining the first high frequency transmission zero above the maximum frequency of interest, and forcing the low-frequency zero to a low as possible value (Figure 1). The values found were 30 mm thickness for both walls, and 50 mm for the air gap.

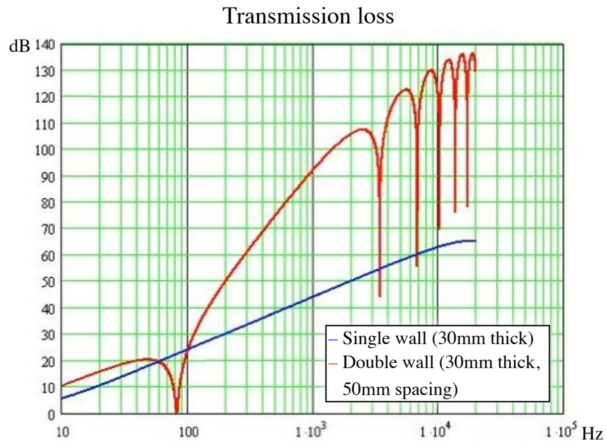

Fig. 1 - Single and double wall transmission loss

Transmission loss is also highly dependant on the wall material's density, increasing with materials of higher density. A survey of available materials was realised, and MDF (Medium Density Fibreboard) was determined to be the best material matching our constraints.

The choice of a double wall insulation results in a chamber that consists of a box inside a box (Figure 2).

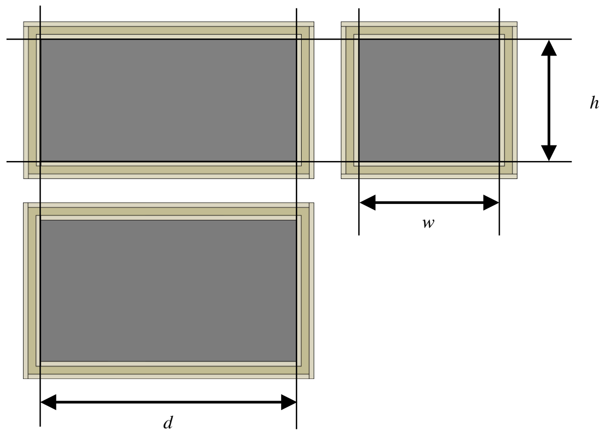

Fig. 2 - Chamber structure

In order to improve the characteristics of the chamber even further, glass wool was added to the air gap between the walls. The quality factor of such zeroes is quite high, thus a small amount of absorption is capable of mitigating the effect of these zeroes.

2.4 Absorption

To minimise echoes inside the chamber, an internal wall lining is necessary.

At first a survey of anechoic wedges was produced. Several factors were considered: absorption cut-off frequency, absorption coefficients, material, dimensions, shape and safety. None of the materials found on the local market was suitable, and importing foreign material was determined to be prohibitive. It was thus decided to design and construct our own anechoic wedges.

The design is based on Beranek's wedge structure *A* [4]. A very important design factor is wedge height, as it is directly correlated to the wedge's lower cut-off frequency. This frequency can be approximated by the following expression:

(3) $$f_c = c / 4h$$

where c is the speed of sound in the chamber, and h the height of the wedges [2].

In order to meet the lower frequency of interest, the value of h has to be at least 0.34 m. This, along with the geometric cut-off frequency and the requirement of a working space, imposes constraints on the smallest dimensions of the chamber.

Unfortunately the space in our lab was not sufficient for a larger chamber, so it was decided to lower the wedge height to 0.15 m. This raises the cut-off frequency of absorption to 571.6 Hz, and is above the lowest frequency of interest for our research. Even though a certain level of absorption is expected in the 250 Hz - 571.6 Hz region, the effect of this decision has yet to be evaluated.

A second design factor is the wedge's angle, a parameter related to base area. A small angle leads to a better acoustical gradient, yet a larger angle simplifies manufacturing, handling and mounting. It also reduces the total number of wedges necessary in the chamber.

Low-density polyurethane (25 kg/m^3) of low-stiffness was chosen as the material for the wedges. This material is commonly used for the purpose of absorbing sound, is easy to cut, easy to adhere to surfaces, and automatically fills voids, avoiding sound leakage. Fibreglass-based wedges were determined to be too expensive and difficult to manufacture. Melamine foam was also disregarded for being too costly.

The design is presented in Figure 3.

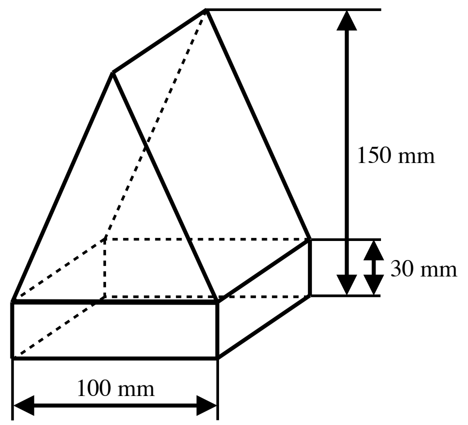

Fig. 3 - Anechoic wedge

The response of the wedges is yet to be evaluated. The intended method of measurement is the impedance tube method. A loudspeaker is located at one end of the tube, and the material at the other. Sound waves travelling down the tube are reflected on the material to be studied. By moving a microphone inside the tube, the pressure differences of the standing wave pattern inside the tube can be measured and used to calculate the amount of sound reflection.

For the purpose of a preliminary simulation of the chamber, the response of a commercial absorbing material resembling our design was used.

3 Simulation

The distribution of sound power inside the chamber was simulated in MATLAB with the source-image method. The method consists of replacing the chamber's walls with phantom sources, located at the equivalent geometric points from where the echoes of the walls would originate.

Only first reflections were considered in this work, thus six phantom sources were used.

The pressure distribution of a single source of frequency f is [5]:

(5) $$p(r) = A \sin(\omega t + kr)$$

where r is the distance to the source, and A follows the inverse square law.

It is very easy to calculate the power distribution by evaluating the pressure field at some arbitrary time t and at time $t + 1/(4f)$.

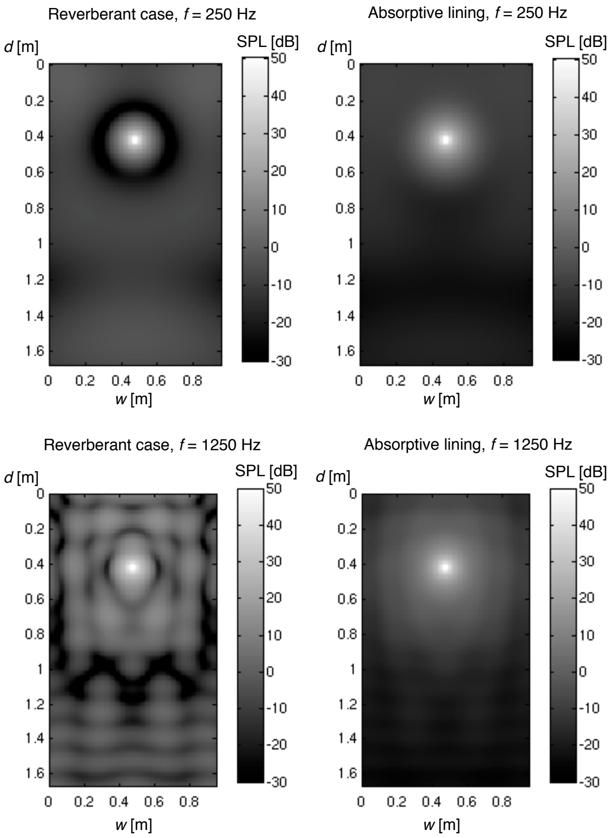

Fig. 4 – SPL simulations

The simulations were carried out for a source located at mid-width, mid-height and at a length of 0.44 m. Perfectly reflective walls (the reverberant case), and walls treated with our absorptive lining were compared. The frequency was swept within the range of frequencies of interest, and the horizontal distribution of power for different values of *h* (height) was calculated. The resulting power distribution was also compared to the distribution of the inverse square law.

It was determined that the best location for measurements is in the area close to the opposite corner of the chamber. There, variations in frequency response are minimal.

4 Construction

4.1 Structure

The parts of the structure were cut from industrial MDF panels with a computer controlled saw fence to 0.5 mm precision. The inner box was constructed on top of the base of the outer box, and properly sealed.

In order to isolate the inner box from the outer box, and to keep the necessary air gap of 50 mm, four double-deflection neoprene mounts of rated capacity 136-272 kg were used (the inner box's weight being 220 kg). Cork mounts were considered, but they did not match the working conditions.

The outer box was constructed last. Glass wool was added to the boxes' air gap.

4.2 Interface

In order to access the inside of the chamber some interface is necessary, both for physical access to the working area, as well as for transmitting power and signals.

For the purpose of physical access, a double door was devised for the front of the chamber. The inner door consists of a rectangular cut to the inner box's front panel, a rubber seal and a rectangular panel. This panel can be screwed tightly on top of the inner box, in order to guarantee a good seal. The outer door is constructed likewise but larger, so the inner door can pass through. Due to the larger weight of the outer door, a sliding mechanism was required (Figure 5).

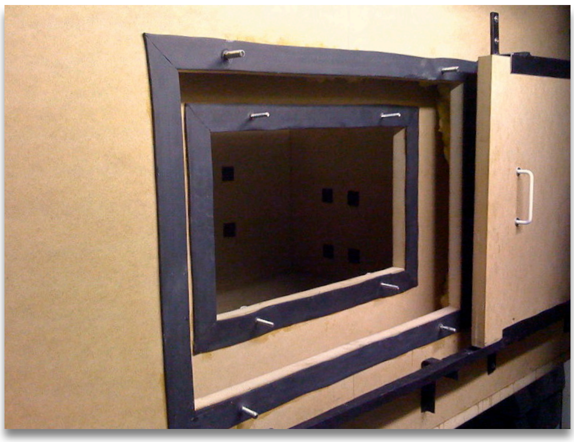

Fig. 5 – Access door

The electrical interface consist of power and shielded signal cables that were routed through sealed holes in the inner and outer boxes. Standard BNC connectors were used for signals.

4.3 Anechoic Wedges

The 450 wedges of polyurethane required for lining the inside of the chamber were fabricated using a pantograph hot-wire cutter.

Modules of 2x3 wedges were constructed by placing wedges in alternating orientations on top of a plywood base. The modules are fastened to the walls

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through Velcro. It is thereby easy to convert the anechoic chamber to a reverberant one.

Special care was given to covering the corners as well as possible. Where necessary, strips of polyurethane were applied. The wedges were also slightly compressed, in order to avoid sound leakage.

4.4 Stands

Small wooden stands were designed in order to locate the objects to be measured inside the chamber's working space.

5 Results

Preliminary measurements of the chamber show very promising results.

At this stage the outer box has not yet been sealed, nevertheless the acoustic insulation response (Figure 6) is superior to the insulation of a single wall insulation in the frequencies of interest. The response above 6 kHz is slightly below expectations. This result can be attributed to an improper seal of the inner box.

Preliminary impulse response measurements [6] show a T_{60} reverberation time of under 50ms. The frequency response was found to be flat within 3 dB in the frequency range of interest.

6 Conclusions

A design of a small, low-cost and application specific anechoic chamber was presented. Preliminary results are very promising, but several questions remain to be answered.

The first issue to be addressed is whether the effect of the geometric cut-off frequency in the directions of width and height do not pose a limitation to the usefulness of the chamber in low frequencies.

The absorption response of the custom-designed anechoic wedges is to be measured. It also remains to be seen what the effect of limiting the wedge height to 0.15 m is. The preliminary impulse response measurements look promising, but a proper study of the absorbing material should be carried out.

More simulation experiments should be realised, like calculating the mean and variance of the SPL among

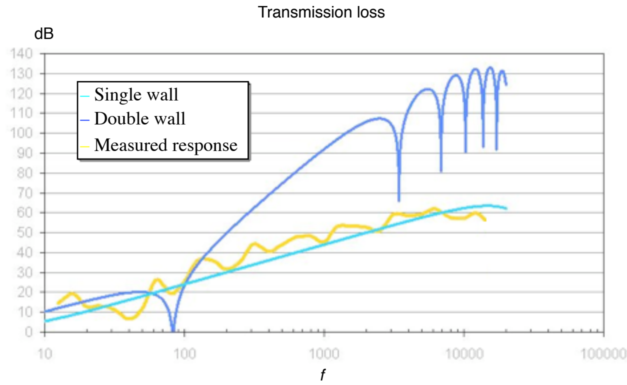

Fig. 6 – Preliminary insulation result (outer box not sealed)

the frequency band of interest. It would also be of interest to determine the optimum chamber parameters through simulations.

The simulations should be verified experimentally.

7 Acknowledgements

The authors gratefully acknowledge Pedro Bontempo and Marcelo García Barrese for their work in the design and construction of the anechoic chamber.

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Measurement of the sound-absorption coefficient on egg cartons using the Tone Burst Method

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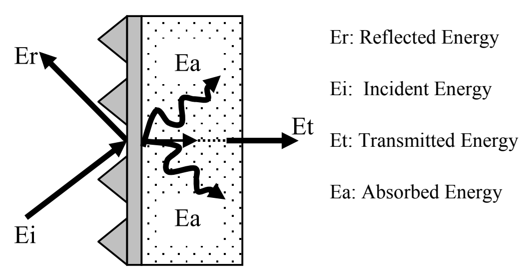
Abstract: A low-cost solution for noise level reduction in an enclosed space, such as a room, is the installation of egg carton materials or fruits box materials (for example apple, pear or peach tree). The Tone Burst method may be used to measure the sound absorption coefficient of a material at any desired angle of incidence. The goal for this paper is to demonstrate that egg cartons are a myth when they are used to reduce sound level in an enclosed space.

Key-words: Tone Burst – Absorption Materials – Reflection Factor - Egg Cartons – NRC - Sound Power Level.

1. Introduction

The basic parameters of acoustic materials are impedance and surface shape. Other information such as angle-dependent impedance, porosity, and tortuosity are required. Material data include all necessary information essential to calculate reflected and transmitted field. In many sound prediction cases, however, the absorbed or transmitted energy is a sufficient quantity [1].

The law of the conservation of energy states that energy can neither be created nor destroyed, but it can be changed from one form to another. Absorption converts sound energy into heat energy. It is useful when reducing sound levels within rooms but not between rooms. Each material interacting with a sound wave absorbs some sound. The most common measure is the absorption coefficient, typically denoted by the greek letter α. The absorption coefficient is a ratio of absorbed (Ea) to incident sound energy (Ei). The reflect coefficient is a ratio of reflect (Er) to incident sound energy (Ei). A material with an absorption coefficient of 0 reflects all incident waves. On the contrary, if a material absorbs all incident sound, its absorption coefficient is 1. An opposite coefficient τ, denotes reflection of sound waves on a surface. If the reflection coefficient is near zero, then the transmitted energy is minor. Therefore, both coefficients range between 0 and 1. See figure 1.



Absorption coefficient range $0 \leq \alpha \leq 1 \rightarrow \alpha = Ea / Ei$

Reflection coefficient range $0 \leq \tau \leq 1 \rightarrow \tau = Et / Ei$

Fig. 1. Sound Absorption and Sound Reflection

In practice, all materials absorb some sound, so this is a theoretical limit [2]. Sound absorptive materials are widely used for the control of noise in a variety of different situations. Sound-absorptive materials exist in many different forms: Glass-fiber materials, open-cell acoustical foams, fiber board, hanging baffles, felt materials, curtains and drapes, thin porous sheets, head liners, carpets and hollow concrete blocks with a small opening to the outside – to create a Helmholtz resonator. One characteristic common to nearly all sound-absorptive materials is that they are porous. That is, there is air flow through the material as a result of a pressure difference between the two sides of the material. Porous materials are frequently fragile, and, as a result, it is necessary to protect the exposed surface of the material. Typical protective surfaces include: thin impervious membranes of plastic or other material; perforated facings of metal, plastic or other material; fine wire-mesh screens; spayed-on materials such as neoprene, and thin porous surfaces [3]. An egg carton is a carton designed for carrying and transporting whole eggs, no for acoustic. These cartons have a dimpled form in which each dimple accommodates an individual egg and isolates that egg from eggs in adjacent dimples. This structure helps protect eggs against stresses exerted during transportation and storage by absorbing a lot of shock and limiting the incidents of fracture to the fragile egg shells. An egg carton can be made of various materials, including Styrofoam, clear plastic or may be manufactured from recycled paper and molded pulp by means of a mechanized Papier-mâché process. An “egg crate mattress”, while following a similar form, is not used for egg transport. It is a light weight camping mattress which makes use of the dimpled structure to distribute and cushion human weight. This foam structure is also occasionally used in packaging to dampen impact of sensitive material during travel.

Fig 2. Egg Carton

Similarly, acoustic foam tiles help in sound absortion and the limitation of acoustic resonance have a similar characteristic to egg crates. For that reason, egg crate mattresses are occasionally used as an inexpensive substitute [4].

Sound absorption coefficients are frequently measured in octave bands, and the noise reduction coefficient (NRC) is the average absorption in the 250 Hz, 500 Hz, 1000 Hz and 2000 Hz bands. This average is expressed to the nearest multiple of 0.05.

Reflection can occur when a wave impinges on a boundary between two media with different wave propagation speeds. Some of the incident energy (Ei) of the wave is reflected back into the original medium, and some of the energy is transmitted (Et) and refracted (Er) into the second medium (See Fig. 1). This means that the wave incident on a boundary can generate two waves: a reflected wave and a transmitted wave, whose direction of propagation is determined by Snell’s law.

2. Measurement Methodology

At a given frequency, the absorption coefficient of any material varies with the angle of incidence of the sound waves. In a room, sound waves strikes materials at many different angles. For this reason, published coefficients of commercial materials are generally measured in a laboratory reverberation room in which sound waves are nearly diffuse, so that they strike the test sample from many directions.

A tone burst is a short signal used in acoustical measurements to make possible differentiating desired signals from spurious reflections. The American Society for Testing and Materials (ASTM) has developed this method; in Acoustics the technique is applicable in many areas such as measurement of distortion, early reflections, absorption, and phase response [5]. In our experiment the tone burst was generated with the Spectral Lab software and the loudspeaker is a E-MU's PM5 Precision Monitor.

One of the basic problems in room acoustic measurements has always been to determine the direction of a certain reflection, and more important, its frequency content. For example, ¿what is the acoustic influence of an eggs carton in an enclosed space?

The simple implementation of the Tone Burst measurement procedure, as described in [5], is:

1. Place the loudspeaker and measuring microphone (B&K Type 2250) along the longest axis of the room. Center the microphone/loudspeaker combination with respect to all three axes of the room. Assume a room (see Fig. 3.) with the transducers equally spaced between floor and ceiling (h, the height of the room is assumed the smallest of the room's dimensions). First, we will only consider reflections from side walls, ceiling and floor. The pulse length (t) must then be shorter than the difference between the time it takes to travel the reflected ($2l/c$) and the direct path (d/c). Hence

$$t \le \frac{2l-d}{c} = \frac{\sqrt{h^2+d^2}-d}{c} \qquad (1)$$

$$d = \frac{h^2 - c^2t^2}{2ct} \qquad (2)$$

The criterion that the microphone should be at least one wavelength from the loudspeaker gives

$$d \ge ct \qquad (3)$$

where t is the period at the lowest frequency which also corresponds to the pulse length. It contains one period at the lowest frequency. Setting Equations (2) and (3) equal we obtain the optimum pulse length and corresponding transducer spacing:

$$ct = \frac{h^2 - c^2t^2}{2ct}$$

$$t = \frac{\sqrt{3}h}{3c} = \frac{h}{595} \qquad (4)$$

The reciprocal of which gives the lower frequency limit f_{min}

$$f_{\min} = \frac{595}{h} \qquad (5)$$

At the distance between transducers of

$$d = ct = c\left(\frac{\sqrt{3}h}{3c}\right) = 0.577h \qquad (6)$$

which is the optimum spacing between transducers for a given minimum room dimension h.

For reflections from the end walls of the room along its longest dimension (L), the length of the pulse must be shorter than the difference between the time it takes for the first reflection to return to the microphone (L/c) and the time it takes for the direct sound to reach the microphone (d/c).

Hence $$t \le \frac{L-d}{c} \quad \cong \quad d < L - ct \qquad (7)$$

Now reflections from the far wall only become a limitation when the minimum distance of Equation (7) is equal to, or less than that of Equation (3). Setting the two equal

$$L = 2ct \qquad (8)$$

and substituting t from Equation (4) we get

$$L = \frac{2}{3}\sqrt{3}h = 1.15h \qquad (9)$$

Hence the length of the room must be at least 15% longer than the smallest dimension in order for Equations 4-6 to be valid.

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However, with reflections from the end walls setting the limits, the pulse length must be (from Equation 8.)

$$t = \frac{L}{2c} = \frac{L}{688} \qquad (10)$$

with an optimum distance between transducers (combining Equations 3. and 8.)

$$d = \frac{L}{2} \qquad (11)$$

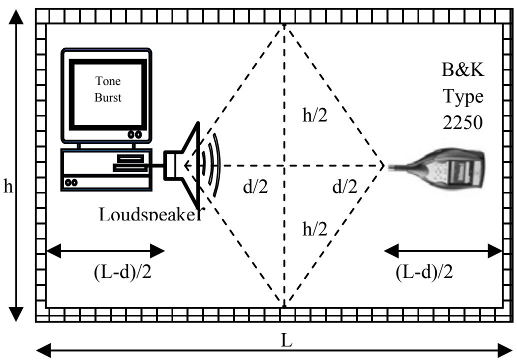

Fig. 3. The geometry environment

2. Begin with a relatively short tone burst about 3 ms at the wished frequency and observe the received waveform on the B&K Type 2250. See Fig. 4.

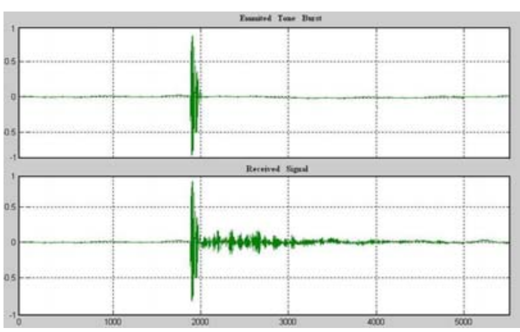

Figure 4. Emitted Tone Burst and Received Signal

At the same time, the size of the loudspeaker must be considered in determining the far field. The microphone should be placed at a distance at least equal to the largest dimension of the loudspeaker. Unfortunately, due to practical restrictions on room size, these criteria are often ignored, thus leading to non reproducible measurements. Certain standards, of course, also call for fixed distances.

3. At a given angle between the loudspeaker and the barrier, we set a distance d/2 between the loudspeaker and the B&K type 2250. Note that the total distance for the wave is d, see fig. 6. The short tone burst is emitted again and the B&K type 2250 receives the direct and reflected signals, see fig 5. Note the point of the first reflections and increase the duration of the tone burst. If the tone burst is too long, the received signal will have overlaps.

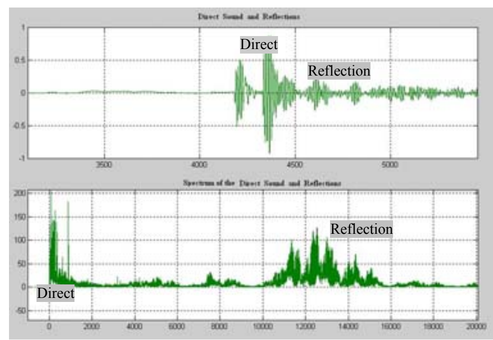

Fig. 5. The Direct and Reflect Sound

4. With direct and reflected signals, the Sound Power Level (L_w) is calculated and compared for a same way: incident angle and frequency, in octave bands. Sound intensity may be used when measuring sound absorption in situ.

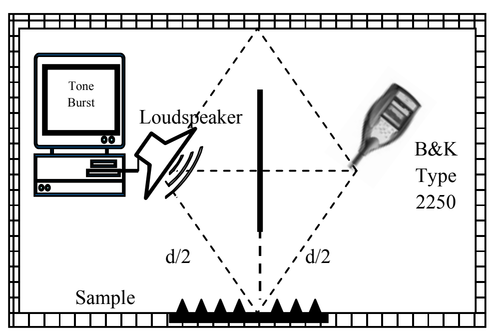

Fig. 6. The geometry environment with angles

A tone burst contains not only the frequency of the sine wave contained in the burst but also a band of harmonic frequencies originated by the sine wave frequency. These frequencies arise due to the square wave by which the sine signal is gated.

Advantages: It is not necessary to have a reverberation chamber to accomplish the test; samples of different material can be measured in situ with different angles.

Disadvantage: The tone Burst Method is truly effective beginning at 1000 Hz, consequently it is somewhat limited to test low frequencies.

3. Experiment and Results

The sound power level of a source in decibels, is given by

$$L_w = 10\log_{10}(\frac{W}{W_0}) \quad dB \qquad (12)$$

Where W is the power of the source in watts and W_0 is the reference power in watts.

The reflection factor R is related to the wall impedance Z by:

$$R = \frac{P_r}{P_i} = \frac{Z\cos\vartheta - Z_0}{Z\cos\vartheta + Z_0} \qquad (13)$$

$Z_o=\rho_o c$ is the characteristic impedance of air. The wall impedance Z is defined as the ratio of sound pressure to the normal component of particle velocity, both determined at the wall [1].

The absorption coefficient, is given by

$$\alpha = \frac{|\rho_i|^2 - |\rho_r|^2}{|\rho_i|^2} = 1 - |R|^2 \qquad (14)$$

And the specific impedance

$$\xi = \frac{1}{\cos\vartheta}\frac{1+R}{1-R} \qquad (15)$$

For example for a frequency of 2 KHz with an angle of 45°, the power W measurement in the B&K type 2250 was 3.16 watts, can be corroborated with the Power Spectral Density of the signal

(16)

We can use the following data: the reflection factor $R=0.31$ (Equations 12. and 13.), the specific impedance $\zeta=2.68$ (Equation 15.), the absorption coefficient $\alpha=1\text{-}0.31=0.69$ (Equation 14.) and the *NRC= 0.4725.*

The absorption coefficients measured in octave bands are:

Hz	α_0
125	0.04
250	0.30
500	0.42
1000	0.48
2000	0.69
4000	0.69

Table 1. Absorption coefficients in octave bands.

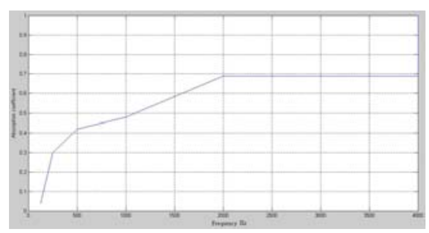

Fig. 7. Absorption coefficients in octave bands

This method was corroborated using the Bell Acoustic Panel and the result was similar to the technical specifications of the material (*α= 0.75)* for the data shown in the example.

4. Conclusions

The egg carton has a good absorption coefficient from 2 KHz on. For frequencies lower than 2 KHz it has poor absorption properties. It is important to point out that the test has no significance below 1 KHz, but the absorption measured at that frequency is bad enough to disregard this material.

Along with it, the egg carton does not have reflection properties, so it cannot be used for acoustic purposes.

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In memory of Eng. Fernando von Reichenbach.

Vertical Non-linear Vibrations of the Automobiles

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Abstract: - It is known that the vibrations are an important source of noise and discomfort. In our paper we purpose a non-linear model with two degrees of freedom for the vertical vibrations of the automobiles. The influence of the road is considered to be a harmonic one. For this model we obtain the equations of motion, we study the equilibrium positions and their stability and, also, the stability of the motion. Finally, we complete discuss a numerical application.

Key-Words: - non-linear, vibrations, equilibrium, motion, stability, viscous damping

1 Introduction

The automobiles' vibrations have a very great importance for the passengers' comfort, for the durability of the car and for the degree of the noise felt by the automobile's occupants.

In our paper we purpose to study a non-linear twoo degrees of freedom model for the automobile's vibrations in a vertical plane.

2 Mathematical model

Let us consider an automobile schematized as two bodies of masses m_1 and m_2 which oscillate in a vertical plan. Between the bodies 1 and 2 there exist a non-linear spring and a visco-elastic damper, and the body 1 is linked to the ground by a non-linear spring and a visco-elastic damper (Fig. 1).

For the non-linear springs we assume that the elastic force that appears in such a spring is given by

$$F_e = ky + \varepsilon y^3 , \quad (1)$$

where y is the elongation of the spring.

Because of the non-uniformity of the road, the ground acted on the automobile with the excitation z which is considered to be a harmonic-type one,

$$z = E \cos \omega t , \quad (2)$$

where E is its amplitude.

3 The equations of motion

Denoting by z_1 and z_2 the displacements of the two masses, by $\dot{z}_1$ and $\dot{z}_2$ their velocities, then the elastic and damping forces that appear in the system (Fig. 2) have the expressions:

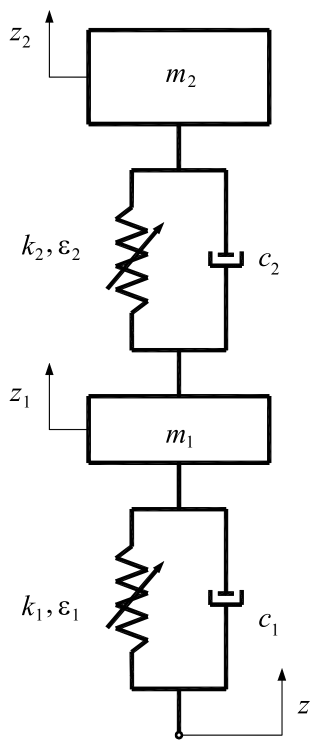

Fig. 1. Mathematical model

$$F_{e01} = k_1(z_1 - z) + \varepsilon_1(z_1 - z)^3 , \quad (3)$$

$$F_{e02} = k_2(z_2 - z_1) + \varepsilon_2(z_2 - z_1)^3 , \quad (4)$$

$$F_{d01} = c_1(\dot{z}_1 - \dot{z}), \quad (5)$$

$$F_{d12} = c_2(\dot{z}_2 - \dot{z}_1). \quad (6)$$

Isolating the two bodies, one obtains the equations of motion

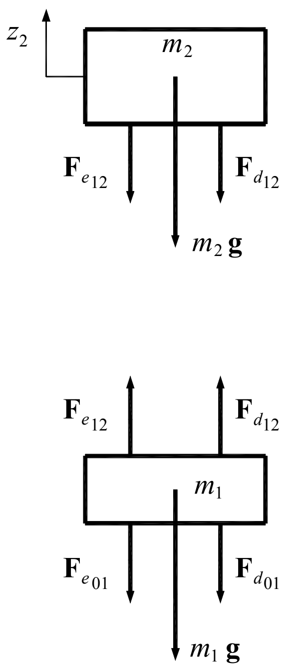

Fig. 2. The isolation of the bodies.

$$m_1\ddot{z}_1 = -k_1(z_1 - z) - \varepsilon_1(z_1 - z)^3 - c_1(\dot{z}_1 - \dot{z}) - m_1 g + k_2(z_2 - z_1)^3 + \varepsilon_2(z_2 - z_1)^3 + c_2(\dot{z}_2 - \dot{z}_1),$$

(7a)

$$m_2\ddot{z}_2 = -k_2(z_2 - z_1)^3 - \varepsilon_2(z_2 - z_1)^3 - c_2(\dot{z}_2 - \dot{z}_1) - m_2 g. \tag{7b}$$

Denoting $\xi_1 = z_1$, $\xi_2 = z_2$, $\xi_3 = \dot{z}_1$, $\xi_4 = \dot{z}_2$, it results the following system of four ordinary non-linear first order differential equations

$$\dot{\xi}_1 = \xi_3, \tag{8a}$$

$$\dot{\xi}_2 = \xi_4, \tag{8b}$$

$$\dot{\xi}_3 = -\frac{k_1(\xi_1 - z) + \varepsilon_1(\xi_1 - z)^3}{m_1} + \frac{k_2(\xi_2 - \xi_1) + \varepsilon_2(\xi_2 - \xi_1)^3}{m_1} - \frac{c_1}{m_1}(\xi_3 - \dot{z}) - g + \frac{c_2}{m_1}(\xi_4 - \xi_3), \tag{8c}$$

$$\dot{\xi}_4 = -\frac{k_2(\xi_2 - \xi_1) + \varepsilon_2(\xi_2 - \xi_1)^3}{m_2} - \frac{c_2}{m_2}(\xi_4 - \xi_3) - g. \tag{8d}$$

4 The equilibrium positions in the absence of the external excitation

In this case $z = 0$ and the system (8) transforms in

$$\dot{\xi}_1 = \xi_3, \tag{9a}$$

$$\dot{\xi}_2 = \xi_4, \tag{9b}$$

$$\dot{\xi}_3 = -\frac{k_1\xi_1 + \varepsilon_1\xi_1^3}{m_1} + \frac{k_2(\xi_2 - \xi_1) + \varepsilon_2(\xi_2 - \xi_1)^3}{m_1} - \frac{c_1}{m_1}(\xi_3 - \dot{z}) - g + \frac{c_2}{m_1}(\xi_4 - \xi_3), \tag{9c}$$

$$\dot{\xi}_4 = -\frac{k_2(\xi_2 - \xi_1) + \varepsilon_2(\xi_2 - \xi_1)^3}{m_2} - \frac{c_2}{m_2}(\xi_4 - \xi_3) - g. \tag{9d}$$

The equilibrium positions are at the intersections of the nullclines; therefore we shall equate to zero the right-hand terms in the relations (9). It follows immediately that $\xi_3^{eq} = 0$, $\xi_4^{eq} = 0$ and, multiplying the third and the fourth expression (9) and summing, one gets the equation

$$\varepsilon_1\xi_1^3 + k_1\xi_1 + (m_1 + m_2)g = 0. \tag{10}$$

Making now $\xi_1 \mapsto -\xi_1$, it results the equation

$$\varepsilon_1\xi_1^3 + k_1\xi_1 - (m_1 + m_2)g = 0. \tag{11}$$

If $\varepsilon_1 > 0$ then the equation (10) has exactly one negative real root and therefore there exists only one equilibrium position ξ_1^{eq}. If $\varepsilon_1 < 0$ then the equation (10) has a positive real root and two negative real roots. The equilibrium position for ξ_1 is unique determined if and only if $\varepsilon_1 > 0$.

Recalling the fourth equation (9) and denoting $\xi_2 - \xi_1 = u$, one obtains the equation

$$\varepsilon_2 u^3 + k_2 u + m_2 g = 0 \tag{12}$$

and making $u \mapsto -u$, it results the equation

$$\varepsilon_2 u^3 + k_2 u - m_2 g = 0. \tag{13}$$

Proceeding in an analogous way, we deduce that the equilibrium position for ξ_2 is unique if and only if $\varepsilon_2 > 0$.

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Obviously, the equilibrium position is also unique for $\varepsilon_1 = 0$ and $\varepsilon_2 = 0$, in the linear case.

Further on we shall consider that $\varepsilon_1 > 0$ and $\varepsilon_2 > 0$.

5 The stability of the equilibrium

Let us denote by $f_k(\xi_1, \xi_2, \xi_3, \xi_4)$ the expressions of the right-hand terms in the relations (9) and by $j_{kl} = \frac{\partial f_k}{\partial \xi_l}$, $k, l = \overline{1,4}$, the corresponding partial derivatives. Keeping into account that the all partial derivatives j_{kl}j, $k, l = \overline{1,4}$, are zero, excepting j_{13}, j_{24}, j_{31}, j_{32}, j_{33}, j_{34}, j_{41}, j_{42}, j_{43}, and j_{44}, it results the characteristic equation

$$\begin{vmatrix} -\lambda & 0 & 1 & 0 \\ 0 & -\lambda & 0 & 1 \\ j_{31} & j_{32} & j_{33} - \lambda & j_{34} \\ j_{41} & j_{42} & j_{43} & j_{44} - \lambda \end{vmatrix} = 0 \tag{14}$$

or, equivalently,

$$\left(j_{31} + j_{33}\lambda - \lambda^2\right)\left(j_{42} + j_{44}\lambda - \lambda^2\right) - \\ - j_{32}j_{41} - j_{41}j_{34}\lambda = 0, \tag{15}$$

wherefrom

$$\lambda^4 - \left(j_{33} + j_{44}\right)\lambda^3 - \left(j_{31}j_{42} - j_{33}j_{44}\right)\lambda^2 + \\ + \left(j_{33}j_{42} + j_{44}j_{31} - j_{41}j_{34}\right)\lambda + j_{31}j_{42} - j_{32}j_{41} = 0. \tag{16}$$

Denoting

$$b_0 = 1 > 0, \tag{17}$$

$$b_1 = -\left(j_{33} + j_{44}\right) = \frac{c_1}{m_1} + \frac{c_2}{m_2} > 0, \tag{18}$$

$$b_2 = -\left(j_{31} + j_{42} - j_{33}j_{44}\right) = \frac{k_1 + 3\varepsilon_1\xi_1^2}{m_1} + \\ + \frac{k_2 + 3\varepsilon_2\left(\xi_2 - \xi_1\right)^2}{m_1} + \\ + \frac{k_2 + 3\varepsilon_2\left(\xi_2 - \xi_1\right)^2}{m_1} + \frac{c_1c_2}{m_1m_2} > 0, \tag{19}$$

$$b_3 = j_{33}j_{42} + j_{44}j_{31} - j_{41}j_{34} = \\ = \frac{c_1}{m_1}\frac{k_2 + 3\varepsilon_2\left(\xi_2 - \xi_1\right)^2}{m_2} + \\ + \frac{c_2}{m_2}\frac{k_1 + 3\varepsilon_1\xi_1^2}{m_1} > 0, \tag{20}$$

$$b_4 = j_{31}j_{42} - j_{42}j_{31} = \frac{k_1 + 3\varepsilon_1\xi_1^2}{m_1} \times \\ \times \frac{k_2 + 3\varepsilon_2\left(\xi_2 - \xi_1\right)^2}{m_2} > 0, \tag{21}$$

it results that the stability can be studied with the aid of the Routh–Hurwitz criterion, respectively if are fulfilled the following conditions

$$b_i > 0,\ i = \overline{1,4}, \tag{22}$$

$$\begin{vmatrix} b_1 & b_0 \\ b_3 & b_2 \end{vmatrix} = b_1b_2 - b_0b_3 > 0, \tag{23}$$

$$\begin{vmatrix} b_1 & b_0 & 0 \\ b_3 & b_2 & b_1 \\ 0 & b_4 & b_3 \end{vmatrix} = b_1b_2b_3 - b_1^2b_4 - b_0b_3^2 > 0, \tag{24}$$

$$\begin{vmatrix} b_1 & b_0 & 0 & 0 \\ b_3 & b_2 & b_1 & b_0 \\ 0 & b_4 & b_3 & b_2 \\ 0 & 0 & 0 & b_4 \end{vmatrix} = b_4\left(b_1b_2b_3 - b_1^2b_4 - b_0b_3^2\right) > 0. \tag{25}$$

It is easy to verify that these relations hold true and therefore the equilibrium is stable.

6 The stability of the motion

Let us recall back the system (8) and let us consider that we give the deviations $\xi_i \mapsto \xi_i + \eta_i$, $i = \overline{1,4}$, to the system's solution ξ_i, $i = \overline{1,4}$. It results the system in deviations

$$\dot{\eta}_1 = \eta_3, \tag{26a}$$

$$\dot{\eta}_2 = \eta_4, \tag{26b}$$

$$\dot{\xi}_3 + \dot{\eta}_3 = -\frac{k_1\left(\xi_1 + \eta_1 - z\right)}{m_1} - \\ - \frac{\varepsilon_1\left(\xi_1 + \eta_1 - z\right)^3}{m_1} + \\ + \frac{k_2\left(\xi_2 - \xi_1 + \eta_2 - \eta_1\right)}{m_1} + \\ + \frac{\varepsilon_2\left(\xi_2 - \xi_1 + \eta_2 - \eta_1\right)^3}{m_1} - \\ - \frac{c_1}{m_1}\left(\xi_3 + \eta_3 - z\right) + \\ + \frac{c_2}{m_1}\left(\xi_4 - \xi_3 + \eta_4 - \eta_3\right) - g, \tag{26c}$$

$$\dot{\xi}_4 + \dot{\eta}_4 = -\frac{k_2(\xi_2 - \xi_1 + \eta_2 - \eta_1)}{m_2} - \frac{\varepsilon_2(\xi_2 - \xi_1 + \eta_2 - \eta_1)^3}{m_2} - \frac{c_2}{m_2}(\xi_4 - \xi_3 + \eta_4 - \eta_3) - g. \quad (26d)$$

Keeping into account that ξ_i, $i = \overline{1,4}$, are the solutions of the system (8) and keeping only the linear terms in η_i, $i = \overline{1,4}$, the system (26) becomes

$$\dot{\eta}_1 = \eta_3, \quad (26a)$$

$$\dot{\eta}_2 = \eta_4, \quad (26b)$$

$$\dot{\eta}_3 = -\frac{k_1\eta_1}{m_1} - \frac{3\varepsilon_1(\xi_1 - z)^2\eta_1}{m_1} + \frac{k_2(\eta_2 - \eta_1)}{m_1} + \frac{3\varepsilon_2(\xi_2 - \xi_1)^2(\eta_2 - \eta_1)}{m_1} - \frac{c_1}{m_1}\eta_3 + \frac{c_2}{m_1}(\eta_4 - \eta_3), \quad (26c)$$

$$\dot{\eta}_4 = -\frac{k_2(\eta_2 - \eta_1)}{m_2} - \frac{3\varepsilon_2(\xi_2 - \xi_1)^2(\eta_2 - \eta_1)}{m_2} - \frac{c_2}{m_2}(\eta_4 - \eta_3). \quad (26d)$$

From this point the discussion is similar to that from the paragraph 5.

7 Numerical application

Let us consider the case defined by the following numerical parameters $m_1 = 100\,\text{kg}$, $m_2 = 1200\,\text{kg}$, $k_1 = 1.5\times10^6\ \text{N/m}$, $k_2 = 7.5\times10^4\ \text{N/m}$, $\varepsilon_1 = 20\,\text{N/m}^3$, $\varepsilon_2 = 200\,\text{N/m}^3$, $c_1 = 10^3\ \text{Ns/m}^3$, $c_2 = 10^5\ \text{Ns/m}^3$, $\omega = 2\,\text{s}^{-1}$, $g = 10\,\text{m/s}$, $E = 0.05\,\text{m}$.

The equilibrium position is obtained from the equations

$$20z_1^3 + 1.5\times10^6 z_1 + 13000, \quad (27)$$

$$200(z_2 - z_1)^3 + 7.5\times10^4 \times (z_2 - z_1) + 12000 = 0. \quad (28)$$

Applying the Lobacevski–Graeffe method, result the values $z_1 = -0.00866\,\text{m}$, $z_2 = -0.16865\,\text{m}$.

Choosing as initial values $z_1^0 = -0.0025\,\text{m}$, $z_2^0 = -0.05\,\text{m}$, $\dot{z}_1^0 = 0\,\text{m/s}$, $\dot{z}_2^0 = 0\,\text{m/s}$, and considering that the excitation has non-zero values only for $0 \le t \le 2\,\text{s}$, we captured the time history for different variables in the next figures.

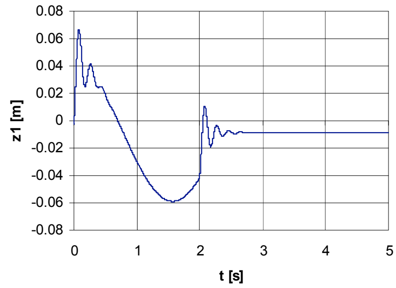

Fig. 3. Time history of z_1 for $0 \le t \le 5\,\text{s}$.

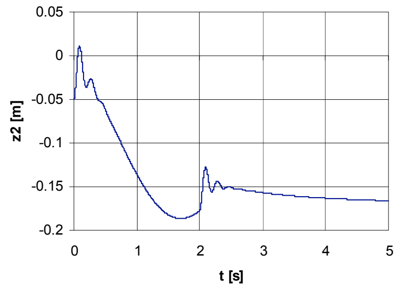

Fig. 4. Time history of z_2 for $0 \le t \le 5\,\text{s}$.

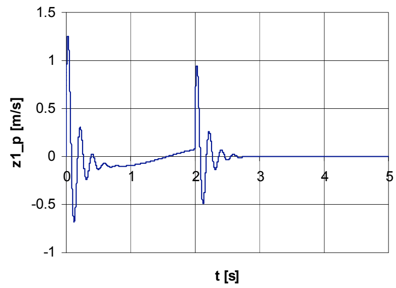

Fig. 5. Time history of $\dot{z}_1$ for $0 \le t \le 5\,\text{s}$.

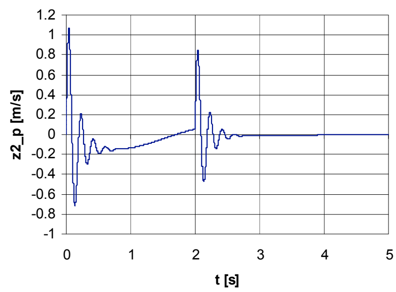

Fig. 6. Time history of $\dot{z}_2$ for $0 \le t \le 5\,\text{s}$.

8 Conclusions

In our paper we described a non-linear model for the study of the vertical vibrations of an automobile. We obtained the differential equations of motions, we studied the equilibrium positions and we proved that the equilibrium position is unique if and only if ε_1 and ε_2 are positive values. The stability of the motion can be studied analytical only in very particular cases, the general case being a numerical study. Finally, we consider a numerical application with the non-zero excitation only for a period of time and for this application we obtained that the motion is stable.

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Using the Root Proportion to Design an *Oud*

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Abstract: Oud is a plucked pear shaped instrument. It is the most popular instrument in the Middle Eastern music. The European lute originates from the Arabic instrument known as the *ŪD*. The neck of *oud* has not frets. The most ordinary string combination is five pairs of strings tuned in unison and a single bass string, although up to thirteen strings may be found. Another typical feature of the *oud* is its head, with the tuning pegs bent back at an angle to the neck. On the other hand, the root proportion is a sequence of irrational numbers (√2, √3, √4 and √5), each of which possesses its own individual characteristics. These have been used in designing musical instruments and we used √2 to design body outline of *oud*. The rational underlying this study was to use root proportion in designing an *oud.* Computer Aided Three-dimensional Interactive Application (CATIA) multi-platform CAD/CAM/CAE commercial software was used to draw the mentioned designs.

Keywords: Lute, *Oud*, Root Proportion, Musical Instrument Design, CATIA Software

1 Introduction

The singular importance of the lute as a key musical instrument of the renaissance is attested to not only by the enormous wealth of music it engendered, but also by the poets and writers. For all twentieth century lute makers, the sources of information about the old lutes are limited; paintings, the surviving lutes, the music and a handful of contemporary tutors. Paintings and drawings are only sometimes accurate, but used with care; they have provided considerable information about stringing, shapes, sizes, materials and chronology. By considering in surviving paintings, we can understand that during the history, lute makers have used different proportions and calculations to design new forms of lutes such as: Hans Frei, Giovanni Hieber, Matteo Buechenberg, Jacobus Henricus Goldt, etc.

In this paper, we present a new method in designing *Oud* by using the root proportion. The rest of the paper is organized as follows. The representation of *Oud*, root proportion and CATIA software marshally will be given in sections 2, 3 and 4. And section 5 describes our methodology to designing an *Oud* by using the root proportion.

2 Oud

2.1 History

Lute (Arabic ūd; Persian Barbat; Greek Outi; Fr. luth; Ger. laute; It. lauto, liuto, leuto; Sp. Laŭd) is a plucked-string, pear shaped wooden instrument of Eastern origin. It flourished throughout Europe from medieval times to the 18th century. The European lute originates from the Arabic instrument famous as the *ŪD*. The principle meaning of this noun is not wood, as generally supposed, but flexible stick. The Arabic lute was introduced into Europe by Moors during their conquest and occupation of Spain (711-1492). The oriental lute was and is played with a plectrum and at first the same method was applied in Europe. Pictorial evidence depicts Moorish *ŪD* players and the 9th and 10th century reports inform of visits of famous players such as *Ziryab* to the court of the Andalusian emir *Abd al Rahman II* (822-52).

According to *Farabi*, the Oud was invented by *Lamech*, the sixth grandson of *Adam*. The myth notifies that *Lamech* hung corpse of his son from a tree. The first oud was inspired by the shape of his son's bleached skeleton. The oldest pictorial evidence of a lute dates back to the *Uruk* time in Southern Mesopotamia, Iraq – *Nasiriyah* city at the present time – over 5000 years ago on a cylindrical seal found by Dr. *Dominique Collon* and nowadays housed at the British Museum. The picture shows a woman crouching with her instrument upon a boat, playing right-handed. This instrument comes into view many times throughout Mesopotamian history and again in ancient Egypt from the 18th dynasty onwards in long- and short-neck varieties. One may observe such examples at the Metropolitan Museums of New York, Philadelphia, Cleveland, and the British Museum on clay tablets and papyrus paper. This instrument and its close family member have been a part of the music of each of the ancient civilizations that have been in the Mediterranean and the Middle East area, including the *Sumerians, Acadians, Persians, Babylonians, Assyrians, Armenians, Greeks, Egyptians,* and *Romans*. The *Oud* applied in the Arab world is slightly different to that found in Turkey, Armenia and Greece. Different tunings are applied and the Turkish-style *Oud* has a brighter tone than its Arab counterpart.

2.2 Structure

The neck of *Oud* is made of light wood, with a veneer of hardwood (usually ebony) and it does not have fret. This lets the players to play more expressive slides and vibrato and also allow them to the microtones of the *maqam* system. This progress is almost recent, as *Ouds* still had frets in AD 1100, and they gradually lose them by AD 1300. The *Oud*'s peg box is bent backwards at a 45-90° angle from the neck of the instrument (figure 1), probably to help hold the low-tension strings firmly against the nut, which is not traditionally glued in place; it is only hold in place by strings pressure. The tuning pegs are simple pegs of hardwood, somewhat tapered, that are held in place by friction in holes drilled through the peg box. The sound box of *Oud* is assembled from wooden staves of hardwood (maple, cherry, ebony, rosewood or other tone woods) named ribs; attached edge to edge with glue to form a deep rounded body for the instrument (figure 1). The soundboard or belly is a teardrop-shaped thin flat plate of resonant wood, like spruce or pine. In all Ouds the soundboard has single or sometimes triple adorned sound holes under the strings, named rose or sound hole (figure 1). The bridge is joined to the soundboard; it does not have a separate saddle but has holes bored into it to which the strings attach directly (figure 1). The most usual string combination is five pairs of strings tuned in unison and a single bass string. The Strings were historically made of gut or sometimes in combination with metal, and are still made of gut or a synthetic substitute, with metal windings on the lower-pitched strings. Modern producers make both gut and nylon strings, and both are in common use. Gut is more authentic, though it is also more susceptible to irregularity and pitch instability due to changes in humidity. Nylon, less authentic, offers greater tuning stability but is, of course, anachronistic.

Figure 1: *Oud* made by Mr. Ahanali Jahandideh with this new method.

3 Root Proportion

The root proportion is a sequence of irrational numbers (√2, √3, √4 and √5), each of which possesses its own individual characteristics. Figure 2 shows the simple geometric generation of the root rectangles (√2, √3, √4 and √5) from the original unity of the square. We have already met the value of √2, as produced by the diagonal of a square; by dropping this diagonal down and retaining a short side of one, our new rectangle will have ratio of √2 (1.4142). The diagonal of this rectangle will promote a √3 (1.732) rectangle, which in turn promotes a √4 (2) rectangle (the double square), whose diagonal will give us a √5 (2.236) rectangle in the same way, and so on. These have been used in designing musical instruments and we used √2 to design the body outline of Lute.

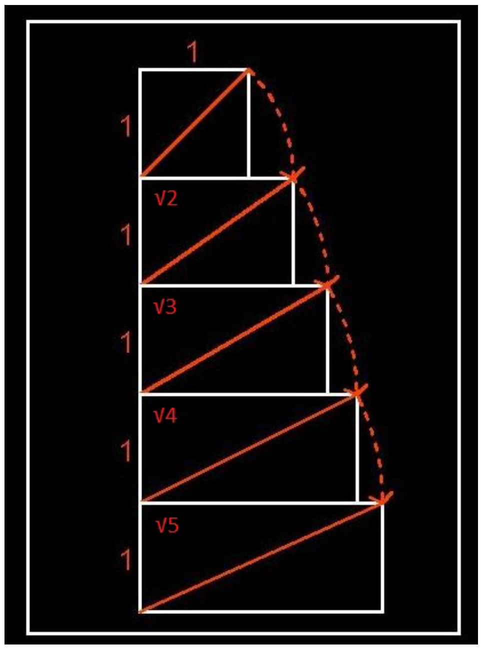

Figure 2

4 CATIA Software

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite extended by the French company Dassault Systems and marketed worldwide by IBM. It has been written in the C++ programming language.

The software was produced in the late 1970s and early 1980s to extend Dassault's Mirage fighter jet, and then was implemented in the aerospace, automotive, shipbuilding, and other industries.

5 Methodology

Root proportion has been used in designing of musical instruments but it has not been used in designing *Oud*. Here, we design an *Oud* by applying Root proportion in all its parts for the first time. Our design was drawn with CATIA software, although it can also be drawn by simple design tools such as ruler and compass.

5.1 System definition

We began by defining length A as 72cm. We divided A by √2 repeatedly to generate some useful ratios, as shown in Figure 3.

A=72cm………………………....total length of lute (sound box and neck without nut)

A/√2=B………………………......length of sound box

B/√2=C…………..……………..….width of sound box

C/√2=D…………………head of sound box upper end of big sound hole

D/√2=E………..……..length of bridge; also half sound box width

E/√2=F…………………………….....length of fingerboard

F/√2=G…………………………..distance behind bridge

G/√2=H…......length of where sound box linked to neck

H/√2=I……………..………………………width of nut

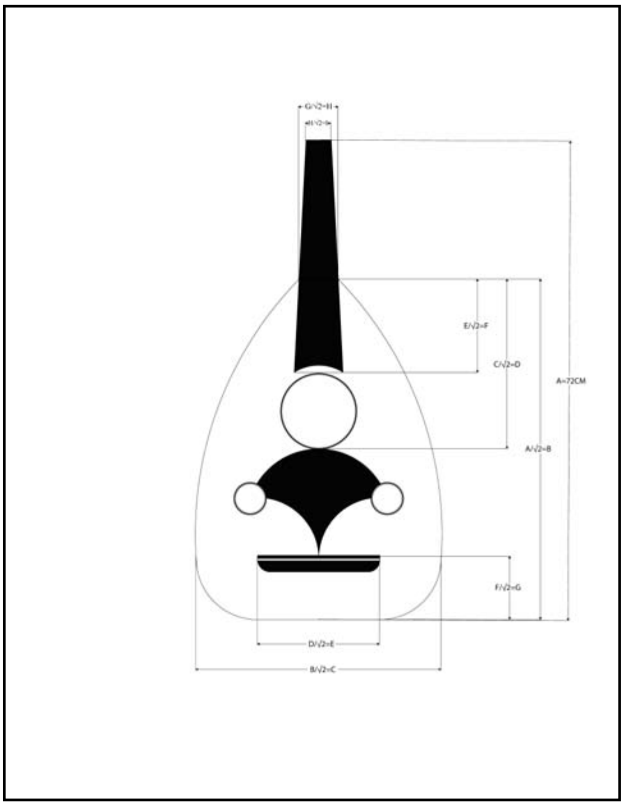

Figure 3

5.2 Designing Method

In Figure 4, we have begun to design by drawing line **ab** with length equal to **A**. then using the distance **G**, we located point **c**. Line **de** with length equal to **C** was drawn perpendicular to line **ab** (**ce**=**dc=C/2**), and centered on point **c**. A circle with radii **E**/2 was drawn with center at point **c**. This circle intersects line **de** to define points **f** and **g**; again from these points, two circles were drawn with the same radii (**E**/2). We have drawn lines **af** and **ag.**

By using the distance **B**, we located point **i**; and also by using the distance **F** we located point **j**. From point **j**, we drew line **kl** perpendicular to line **ab** (**kj=lj=C**) and from point **i**, line **mn** was drawn perpendicular to line **ab** (**mi=ni=H/2**).

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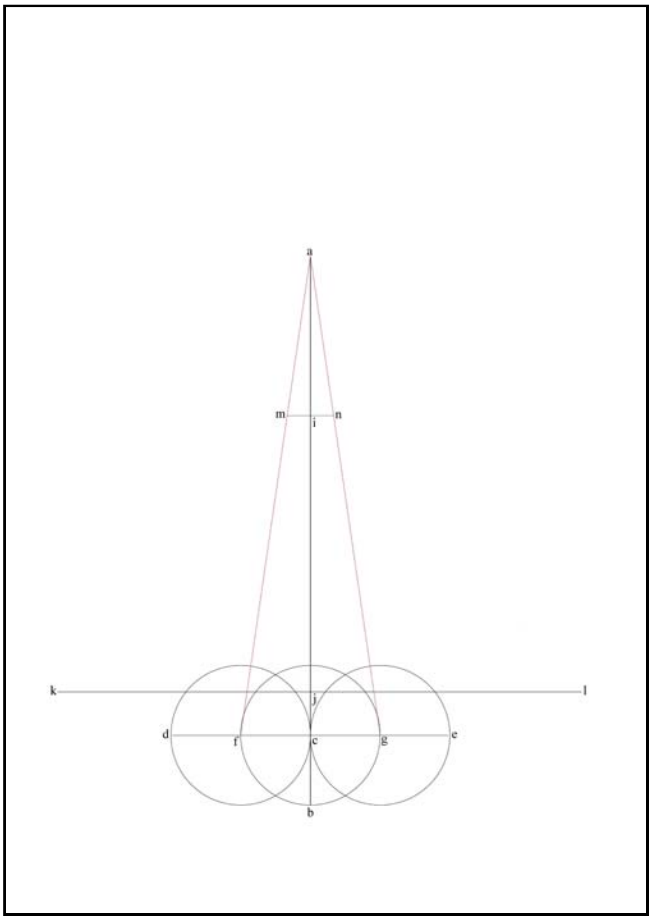

Figure 4

In Figure 5, we have drawn arcs **md** and **ne** with radii **lm=kn** centered at points **l** and **k** which meet point **d** and **e**.

From point **a**, we drew line **op** perpendicular to line **ab** with length equal to **I** (**oa=pa=I/2**).

A circle with center at point **c** intersects line **ab** to define point **q**. from point **q** a circle was drawn with radius=**qf**. This circle intersects line **ab** to define point **r**, center of big sound hole.

By using the distance **C** we located point **s,** from which a circle was drawn with radius=**sf**. This circle intersects line **ab** to define point **t**. Line **rt** is the radius of big sound hole.

By meeting circles with centers at points **s** and **f**, point **u** is defined, and by meeting circles with centers at points **s** and **g**, point **v** is defined, small sound holes centers. By meeting line **af** and circle with center at point f, point **w** is defined and also by meeting line **ag** and circle with center at point g, point **x** is defined. Two circles with radii **uw**=**xv** were drawn with centers at points **u** and **v**, small sound holes.

We drew lines **om** and **pn**, then drew lines **my** and **nz** perpendicular to line **mn** with length equal to **F** and drew arc **yz,** with radii **ry=rz** centered at point **r.**

We drew line **y′z′** passing through two circles with centers at points **f** and **g** to complete the body outline.

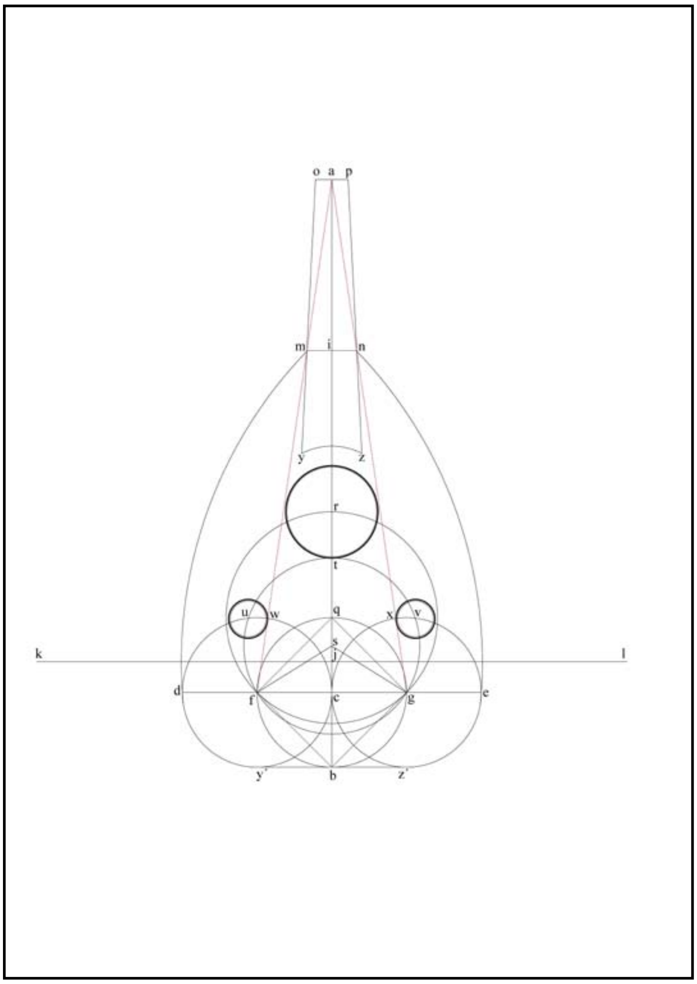

Figure 5

6 Conclusion

The new method of designing *Oud* presented in this paper was based on an essential principle and that was keeping origin of the voice and the body of *Oud.* In order to develop the present method, other methods were also studied. The *Oud* has been designed in different ways during the musical instrument designing history. But this new method tried to design an *Oud* with precise formulas, and because of highlighted effect of sound box on the musical instruments voice, we focused on designing sound box and then flourished it in whole parts of *Oud*. We expanded $\sqrt{2}$ (as a root proportion ratio) throughout whole of instrument body. Then, based on the fact that the shape of musical instrument affects the sound, we tried to design a proportionate shape as well as possible. Some complementary acoustical experiments can help us to show the real effect of this new method on voice of *Oud*. Future works will include acoustical experiments on this new method of designing *Oud*.

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Using the Golden Section to Design a Kamanche

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Abstract: The *kamānche* is a Persian bowed string instrument related to the bowed *Rebab*, an earliest spiked fiddle which is ancestor to most modern European and Asian bowed instruments. *Kamanche* is played in many different cultures and areas, such as Iran, Azerbaijan, Armenia, Turkey and etc. It is played vertically with a variable-tension bow in the manner of the European viol. On the other hand, the golden section (also known as Golden mean, divine proportion or ratio) is a ratio defined by the number phi (Φ=1.618033988…). It has been used in designing some musical instruments but for the first time, we used it to design a Persian musical instrument. The rational underlying this study was to use golden section in designing a *Kamanche*. Computer Aided Three-dimensional Interactive Application (CATIA) multi-platform CAD/CAM/CAE commercial software was used to draw the mentioned designs.

Keywords: Kamanche, Spiked Fiddle, Golden Section, Musical Instrument Design, CATIA Software

1 Introduction

The Renaissance was an enormous cultural progress which brought about a period of scientific revolution and artistic alteration, at the dawn of modern European history. It marks the transitional period between the end of the middle Ages and the start of the modern age. The Renaissance is more often thought to have begun in the 14th century in Italy and the 16th century in northern Europe. The Renaissance artists applied the Golden section widely in their paintings and sculptures to attain balance and beauty. Musical instrument designing also did not exempt of this category, and Golden section was applied in designing musical instruments by the greatest luthier of *Cremona*, Stradivarius. Unfortunately it was not applied in traditional instruments. We use Golden section in designing a *Kamanche* as a Persian traditional instrument and hope it will flourish in other traditional instruments. Until now, no designing procedure or acceptable ratios have been proposed for this musical instrument. The rest of the paper is organized as follows. The representation of *Kamanche*, Golden section and CATIA software marshally will be given in Sections 2, 3 and 4. Section 5 describes our methodology to designing a *Kamanche* by using the Golden section.

2 Kamanche

2.1 History

The *Kamanche* or *Kamāncha* is a Persian bowed string instrument related to the bowed *Rebab*, played with a variable-tension bow. The word "*Kamanche*" means "little bow" in Persian (*Kaman*, bow, and *-che*, diminutive). It is extensively used in the musical culture of Iran, Turkey, Azerbaijan, Uzbekistan, Armenia and Turkmenistan, with slight variations in the structure of the instrument.

Kamanche is being seen in celebration and war scenes paintings, from *Mongol* and *Timurid* periods.

Kamanche was one of the most important instruments in the *Safavid* and *Qajar* periods. It was an instrument which was used in celebration scenes of *Safavid* era. A wall fresco at *Chehel Sotoun Palace* in *Isfahan* shows a Kamanche player among a group of court musicians at the royal court. This wall painting depicts a banquet scene of *Shah Abbas II* in honor of *Nader Mohammad Khan* emir of Turkistan in 1646 (Figure 1). Also, another wall painting at *Hasht Behesh* Palace in *Isfahan* shows a woman playing the *Kamanche* (Figure 2).

A *Tasnif* – a vocal piece played in the modal system of Persian classical music – has been remained from the *Zand* period which is related to *Lotf Ali Khan Zand* (the last king of this dynasty), sang with *Kamanche* and *Ney*.

Eugene Flandin, an Italian-born artist who lived in Paris, was sent to Iran on a mission in 1840 to collect information about Iran's political situation. He talked about *kamanche* in his observation from *Fat'h Ali Shah* – second *Qajar* king of Persia – court; and described it a kind of *Violin* called *Kamanche*.

There were so many groups of jiggers called '*Dásteh*' in *Zand* and *Qajar* periods which some of them were courted and the others non-courted. The most famous of this *Dastehs* were master *Zohreh* and master *Mina Dasteh* in *Fath Ali Shah* monarchy. *Zohreh* and *Mina* were two famous singer and player women in this period which used *Kamanche* as one of the most important instruments in their *Dasteh*; although from the era of *Lotf Ali Khan*, the last king of the *Zand* dynasty, these *Dastehs* decreased but *Kamanche* stand up as one of the most important instruments in these groups. All these explanations revealed importance of *Kamanche* in *Persian* music history but from the end of *Mozafaridin shah* monarchy, the importance of *kamanche* decreased by coming violin to Iran. In last decades, by efforts of *Ali Asghar Bahari*, *kamanche* revived among Persian instruments.

Figure 1: Kamanche player among a group of court musicians at the royal court. This wall painting depicts reception of Nader Mohammed Khan _King of Turkistan_ by Shah Abbas II from the *Chehel Stoun* palace in Isfahan, Iran, 1646.

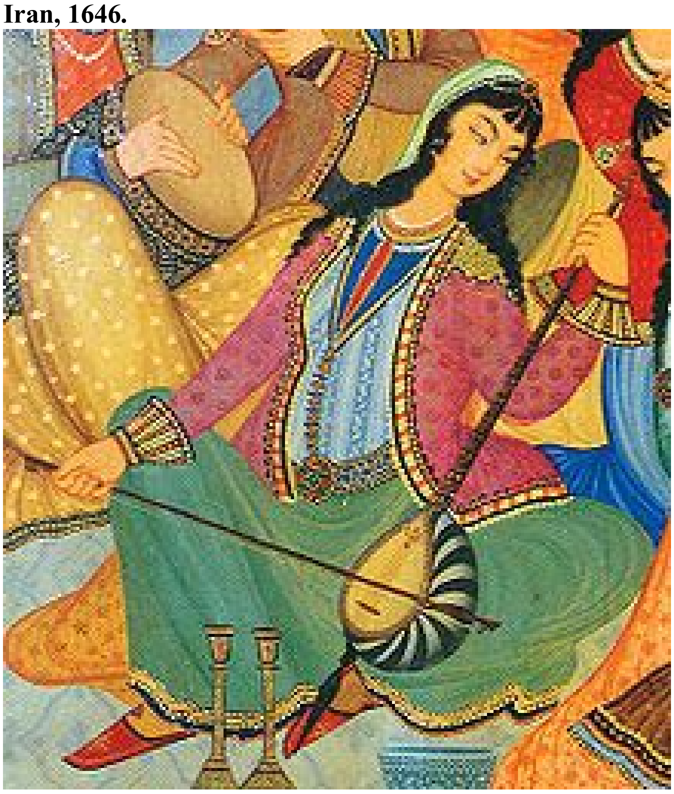

Figure 2: Woman playing the *Kamanche* in a wall painting from the *Hasht Behesht* Palace in Isfahan, Iran, 1669.

2.2 Structure

The *kamanche* has a long neck including fingerboard which *kamanche* maker shapes it as a truncated inverse cone for easy bow moving in down section, peg box in both side of which four pegs are placed, and finial (Figure 3). Its body also has a lower spheroid chamber made from gourd or coconut shell or wooden staves such as blackberry, blackberry root, walnut, pear, maple, cherry or sourcherry – depending upon the geographic region where *Kamanche* maker lived – as a sound box, which is usually covered on the playing side with skin

from a lamb, goat, deer or fish (Figure 3). At the bottom of the instrument protrudes a sort of spike to support the *kamanche* while it is being played (Figure 3). Therefore in English the instrument is sometimes named the *spiked fiddle*. It is played while sitting down and it is held like a viol. The end-pin can rest on the knee or thigh while seated in a chair. The *kamanches* appearing in antique Persian paintings have three strings. It is suspected that the fourth string was added in the early twentieth century as the result of the introduction of the European violin to Persia.
Kamanche is usually tuned like ordinary violin (G, D, A, E) but it may alter depending on Persian music *Dastgah*s and the region of the country where it is played.

Figure 3: ***Kamanche*** **made by Mr. Ahanali Jahandideh wit h this new method.**

3 Golden section
3.1 History

The number $\Phi = \frac{1+\sqrt{5}}{2} = 1.61803398\ldots$ is named the golden ratio. It is also famous as, golden mean, golden section, divine proportion or divine ratio. The term golden section appears to first have been applied by *Martin Ohm* in his textbook *Die Reine Elementar Mathematik* in the 1835. The first one who applies this term in English is *James Sulley* in his article on aesthetics in the 9th edition of the *Encyclopedia Britannica* in 1875. It seems that the symbol "Φ" was first applied by *Mark Barr* at the beginning of the 20th century in honor of the Greek sculptor Phidias, who as a number of art historians declared, made wide application of the golden ratio in his works.

It can be supposed that the golden section has perhaps been discovered and rediscovered during the history, which make clear why it goes under a number of names. Early user of Phi such as: *Phidias* (500-432 BC), a Greek sculptor and mathematician, deliberated phi and used it to the design of the Parthenon. *Plato* (428-347 BC), in his views on natural science and cosmology considered the golden section to be the key to the physics of the cosmos. *Elucild* (365-300 BC), in his book *Elements*, referred to separating a line at the point of phi as "separating a line in the extreme and mean ratio". This later gave rise to application of the term mean in the golden mean. He also related this number to the construction of a pentagram.

Leonardo Fibonacci born in Italy in 1175 AD, discovered the properties of the series the Fibonacci sequence, but it's not definitive that he even understood its relationship to phi and the golden mean. His most notable contribution to mathematics was a work known as *liber abaci*, which became an influence to the Europeans for Arabic decimal system of counting over Roman numerals.

3.2 Golden Section in Music

Golden section emerges many times in music; the great classical composers like Mozart had a consciousness of the Golden Ratio and applied it to compose some of his well-known sonatas. Also Bartók, Debussy, Schubert, J.S. Bach and Satie applied the golden section in their composition. Surprisingly, musical scales are based on Fibonacci numbers and musical frequencies are based on Fibonacci ratios. Golden ratio has been applied in designing some musical instruments, for example Stradivarius applied the golden ratio in his violin, or Baginsky used the golden section in his method of constructing violins.

3.3 Geometry of Golden section

A line segment is divided into two sections such that the ratio of the original segment to the larger section is equal to the ratio of the larger section to the smaller section. If **c** is the original segment, **b** is the larger section, and **a** is the smaller section, then $c=a+b$ and $c/b=b/a$. Thus, **b** is the geometric mean of **a** and **c**; the ratio is well-known as the Divine Proportion.

4 CATIA Software

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite extended by the French company Dassault Systems and marketed worldwide by IBM. It has been written in the C++ programming language.

The software was produced in the late 1970s and early 1980s to extend Dassault's Mirage fighter jet, and then was implemented in the aerospace, automotive, shipbuilding, and other industries.

5 Methodology

Golden section has been used in designing of violin and other musical instruments but it has not been used in Persian instrument designing. For the first time, we used this ratio in designing an Iranian instrument. This ratio was used in the whole of instrument body and a *kamanche* was made by using obtained plans. Because of highlighted effect of sound box on the musical instrument's voice, we designed *kamanche* sound box by using Golden Section. Our design was drawn with CATIA software, although it can be drawn by simple design tools such as ruler and compass.

5.1 System Definition

We began by defining length **A** as 50cm – conventional length among Persian *Kamanche* makers. We divided **A** by Φ=1.618 repeatedly to generate some useful ratios, as shown in figure 4.

50 "total length of neck" ...…...………..…….. A=50cm

50÷1.618=30.9 "fingerboard length"…………..…..A/Φ=B

30.9÷1.618=19.09 "depth of sound box"………..B/Φ=C

19.09÷1.618=11.79 "peg box; also width of skin"………………………………………….. C/Φ=D

11.79÷1.618=7.29 "Finial; also skin behind bridge"……………………………………….. D/Φ=E

7.29÷1.618=4.5 "skin in front of bridge"……...…..E/Φ=F

30.9+4.5=35.4 "resonance length or distance between bridge and pawl"…………………………..………..F+A

35.4÷1.618=21.8 "width of sound box"........ (B+F)/Φ=G

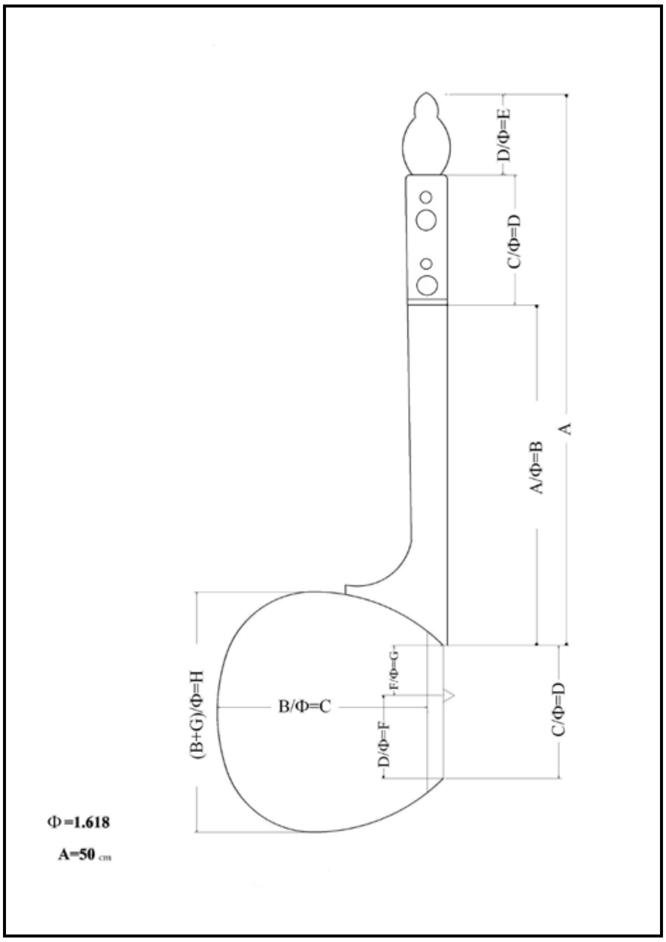

Figure 4

5.2 Designing Method

In figure 5, we have begun to design the cross-section of the sound box by drawing line **ab** with length equal to **C.** Then, using the distance **D** we located point **c.** Line **de** with length equal to **G** was drawn perpendicular to line **ab**, and centered on point **c**. In figure 6, we have located points **f** and **h** on line **de** using **G**/Φ. Two circles with radii **eh=df** were drawn with centers at points **f** and **h**. These circles intersect line **de** to define points **m** and **n**. Also, at the intersection of these circles with line **ab**, point **g** is defined. In figure 7, we have drawn arcs **st, tj** and **sj**, with radii **en=dm** centered at points **g**, **m**, and **n**. From point **b** we drew line **op** perpendicular to line **ab** to complete the outline of the sound box.

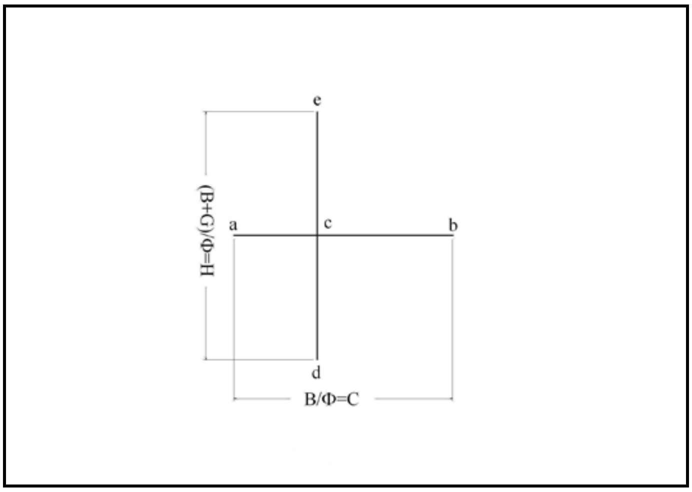

Figure 5

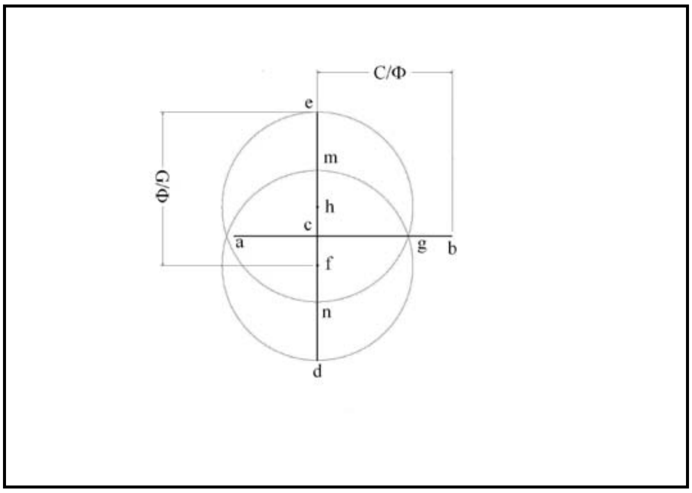

Figure 6

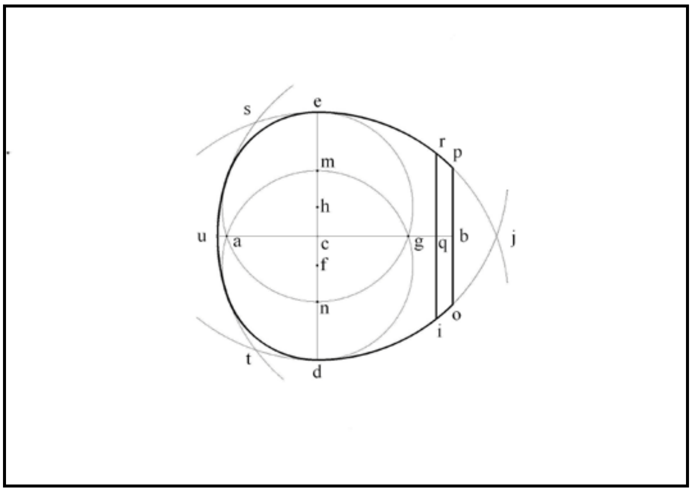

Figure 7

6 Conclusion

The new method of designing *Kamanche* presented in this paper was based on an essential principle and that was keeping origin of the voice and the body of *Kamanche*. In order to develop the present method, other traditional methods were also studied. The traditional methods in designing *Kamanche* were based on empirical methods and have not employed exact calculations. But this new method tried to design a *Kamanche* with precise formulas, and because of highlighted effect of sound box on the musical instrument's voice, we focused on designing sound box and then flourished it in whole parts of *Kamanche*. In fact, the traditional methods give their place to this novel method with more prestigious discipline with keeping them original and making a step toward more comfort. In our opinion, the made instrument has a warm voice. In comparison with traditional shape, our made instrument have gotten a more proportionate shape. Until now, no designing procedure or acceptable ratios have been proposed for this Iranian musical instrument. In addition, we expanded the Golden ratio throughout the whole instrument body. Then, based on the fact that the shape of musical instrument affects the sound, we tried to design a proportionate shape as well as possible. Some complementary acoustical experiments can help us to show the real effect of this new method on voice of *Kamanche*. Future works will include acoustical experiments on this Golden *Kamanche*.

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Vibro-Acoustics of Violins based on a Multi-Physic Approach

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Abstract: The paper attempts to give a contribution to the dynamic analysis of musical instruments through application of a multidisciplinary approach oriented to the study of mechanical, structural, vibratory and acoustical phenomena. The systematic organization of the multidisciplinary study proposed by MUSICOS and some preliminary results related to bowed instruments, with particular reference to violins, are discussed.

Key-Words: Vibration, Acoustics, Dynamics, Musical Instruments, Violins, Multi-physics, Modeling.

1 Introduction

Acoustic musical instruments address various, significant and interlaced mechanical and physical phenomena. Stringed and bowed instruments show interesting peculiarities: the geometry and the vibratory propagation of instruments belonging to these families are very complicated to study by means classical numerical models. From one side the fluid-structure interactions are very exciting to be focused through multi-physic approaches and, from another side, dynamic, vibratory and mechanical features strongly influence the acoustic performance and the sound propagation.

The systematic organization of multidisciplinary theoretical and experimental approaches of design and testing of musical instruments is proposed by MUSICOS Centre of research of the University of Genoa (Italy), following the logic synthesized in Fig. 1.

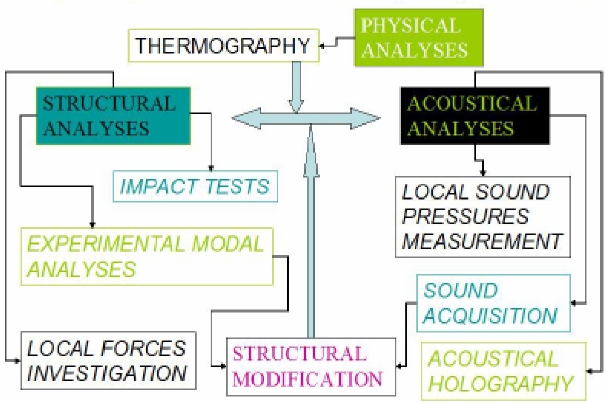

Fig. 1: Integrated approach to scientific design

Structural investigations involve, in particular, numerical and experimental modal analyses both of single parts and the whole instrument. The dynamic response under forcing functions require the detection of local forces exchanged in specific contact area. In the case of violins the monitoring of the actual force generated in the contact between bridge and soundboard is very important. It is consequence to played strings and must take into account the external mechanical constraints imposed to the instrument by the musician.

Acoustical investigations involve local sound pressures measurements, sound acquisition and acoustic holography in the space around the instrument.

Fitting of structural and acoustical analyses suggests structural modification approaches: further physical investigations (i.e. concerning the environment or the thermal behaviour of the instrument under test) complete the integrated approach.

2 Problem Formulation

The violins family is particularly suitable to apply the proposed multidisciplinary approach.

Different modeling and simulation codes are involved and simulated results are compared to experimental tests implemented on specific instruments.

The approach based on COMSOL multi-physics software is, in particular, discussed. It plays a significant role within the proposed integrated approach of study. Specific experiences concern, from one side, the structural and vibratory modelling of elements of the violin (front, back, bass bar, tailpiece and soundboard) and, from another side, the interaction air-structure defining the acoustic performance of the whole instrument. Some preliminary models have been successfully implemented and the corresponding results are discussed hereafter.

3 Problem Solution

The force analysis inside a violin is a fundamental topic of interest to correlate vibration and acoustic performances of the instrument. Two different families of mechanical forces must be analyzed: "internal" and "external" forces. "Internal" forces are typically related to the mounting phases of the instrument: classical examples concern the forces generated by the bass bar, glued under the soundboard, by the sound post forced between soundboard and back, induced between the corner blocks and ribs (Fig. 1) and forces generated at the base of the neck. These are structural forces, influencing not only the mechanical features of the instrument but also its stiffness and damping: they have been analyzed, studied and optimized implementing 3D dynamic models.

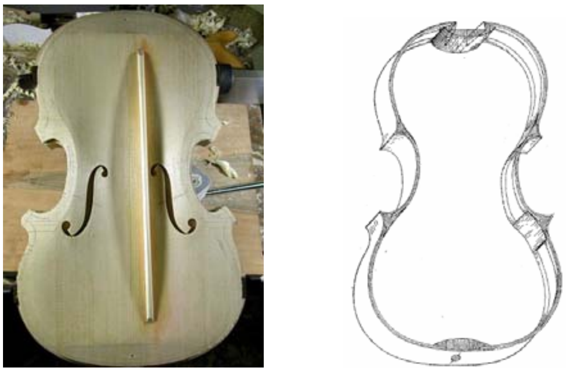

Fig. 2: Places of "internal" forces.

Forces exchanged between elements not rigidly interconnected are classified as "external" forces: they are typically generated during the playing phases. The bow in contact on the strings generates forces on the instrument in addition to the static ones (Fig. 3). Other forces are exchanged between mobile elements (tuning forces from string to bridge, static and dynamic forces between bridge and soundboard). Their static and dynamic theoretical evaluation requires very complicated models and the accuracy of the corresponding results is often not completely acceptable. On the contrary experimental tests are often not taken into account by manufacturers, preferring to estimate the maximum values of the exchanged forces and limit their knowledge to information deduced by empirical references or by simplified tests executable during the instrument assembly phases.

Fig. 3: Places of "external" forces.

4 Mechanical and Structural Models

First step of the multi-physic analysis concerns the implementation of geometrical and dynamic models of single parts of the violin, describing the mutual actions generated under simulated vibrations of the strings.
Original bi-dimensional and three-dimensional have been implemented: some examples of results, concerning the harmonic plate and the bridge, are synthetically described.

4.1 Bridge

As well known, the bridge is the interface between strings and soundboard: its role is fundamental for the vibration propagation and has been studied in detail by various researchers. A 3D model of a classical bridge is defined: the action of the string has been simulated considering the actual motion of the bow on the string, in particular taking into account vibrations tilted with respect to x-y plane (Fig. 4).

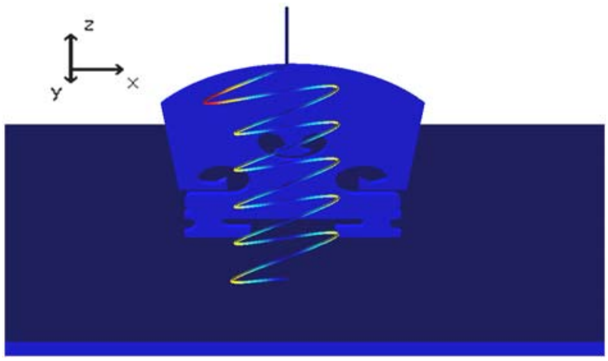

Fig. 4: Excitation on the bridge.

The consequent motion of the bridge is shown in Fig. 5. Two images make evident the effect of fulcrum generated by one of the two feet: this effect is magnified by the sound post, able to increase the stiffness under the feet.

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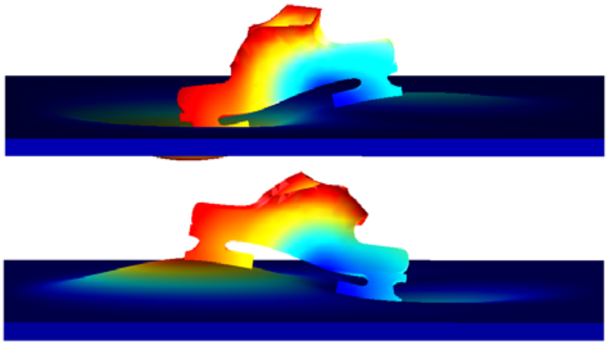

Fig. 5: Dynamics of the bridge.

4.2 Soundboard

In order to detect the level of accuracy of the dynamic analyses based on COMSOL code, and before to model more complicated structures the classical approach identifying the modal shape of an harmonic plate based on the definition of Chladny's figures, has been simulated (Fig. 6). The method, developed also experimentally, consists on the application of a sinusoidal force on a predefined vibrating structure: changing the frequency the mode shapes are detected by an optical approach, searching deformation profiles.

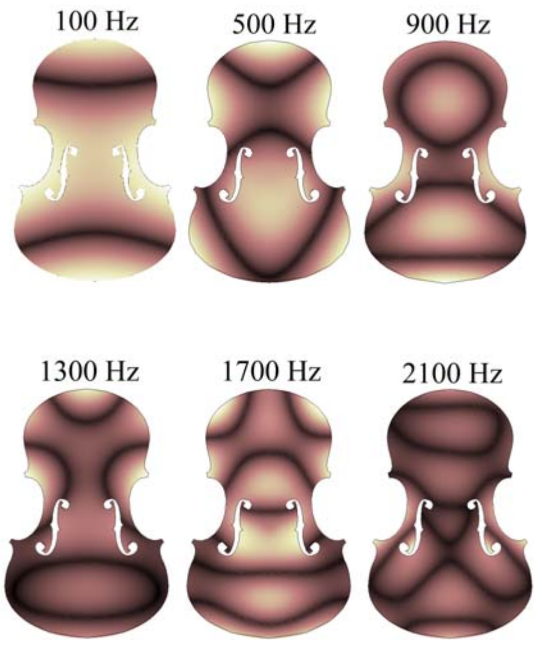

Fig.6: Chladny's figures (100-2100 Hz range).

The good results of this test have supported the soundboard modeling, Bass bar and sound post are considered. The bass bar is pre-deformed and glued to the harmonic plate. The sound post is forced between soundboard and back and generates a static deformation of these surfaces.
The effect of the modeling in shown in Fig. 7.

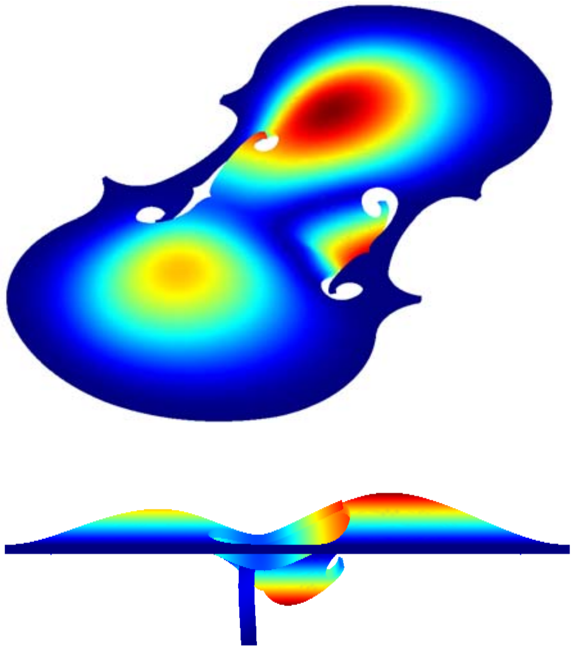

Fig. 7: Soundboard modeling (2 views).

4.3 Complete violin

Starting from the modeling of single elements, the whole geometry of the violin has been performed. Fig. 8 shows a preliminary result: improvements are, at the moment, in progress. All fundamental elements are described, assembling the previously described elementary models in order to reproduce a real instrument with more fidelity.

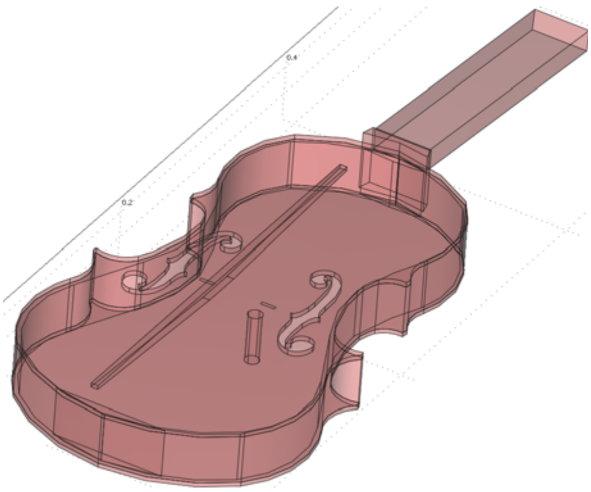

Fig. 8: Model of the whole violin.

Numerical modal analyses based on this model perform good results: Fig. 9 collects examples of results at 310 and 510 Hz. External constraints are applied in order to simulate the contact areas between instrument and musician.

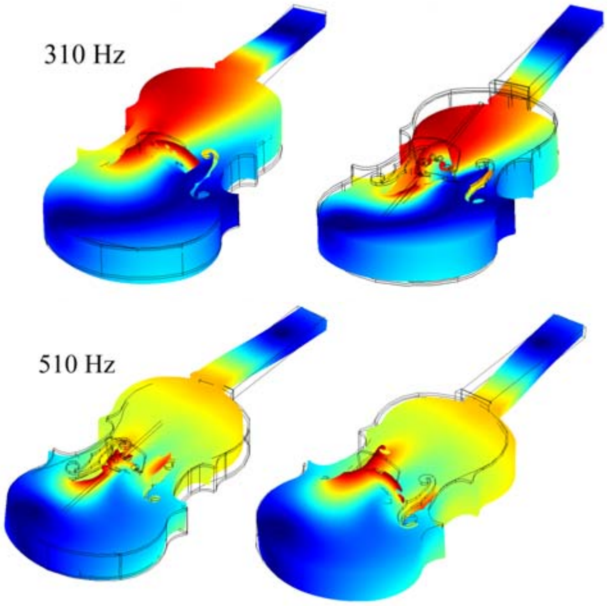

Fig. 9: Modal shapes.

4.4 Acoustic preliminary experiences

Starting from the structural analysis an approach of correlation with acoustic performances has been implemented. The source is the motion of one string, considered as a vibrating wire. The mechanical action is generated on the body of the violin through the feet of the bridge: acoustic pressure as function of the frequency (related to the sound propagation in air) is modeled and applied in correspondence of the contact areas of the bridge feet (Fig. 10).

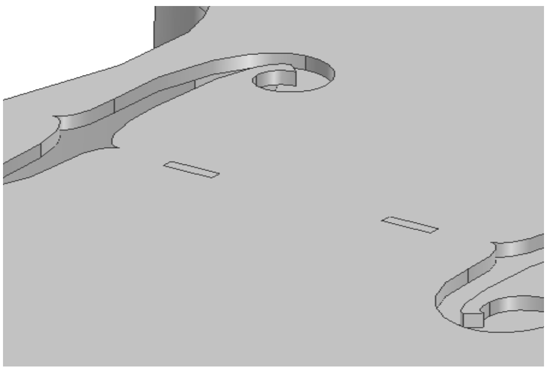

Fig. 10: Detail of the contact areas between feet and soundboard.

Then, properties related to materials can be modified: in particular density, Young's modulus and Poisson coefficients. Models of fluid-structure interaction proposed in literature are implemented into the code. Fig. 11 shows the result of an acoustic analysis performed considering the acoustic propagation around the violin.

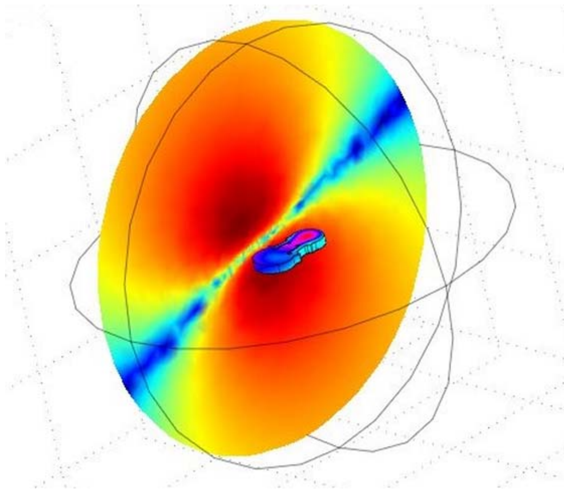

Fig. 11: Acoustic analysis.

5 Conclusions

A multi-physic model based on structural and acoustical parameters influencing the performance of a violin has been implemented. It can be applied to analyse other stringed and bowed musical instruments. Further development will be oriented to improve more detailed models, with particular reference to fluid-structure interaction.

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The Fourier Transform of some distributions from $\mathcal{D}'(\mathrm{R})$ and $\mathcal{D}'(\mathrm{R}^2)$ with applications in mechanics

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Abstract: In this paper, the Fourier images of some function type distributions from $\mathcal{D}'(\mathbf{R})$ and $\mathcal{D}'(\mathbf{R}^2)$ are obtained. These distributions are useful at the study of the vibrations of the elastic rods and of the thin plane plates, as well as in acoustics. The Dirac sequences of one and two variables are deduced on the basis of the obtained formulas.

Key–Words: Fourier Transform; Fourier Acoustics.

1 Introduction

The method of the Fourier Transform in distributions represents an efficient mathematic tool in the study of some measures from physics-mathematics, in acoustics, acoustics microscopy [10], [11], as well as in deducing of the solutions of some measures from techniques represented by functions which do not always have Fourier Transform.

These excepted cases are studied in a unitary manner using Fourier Transform in the distributions space.

According to [3], [5], if $\varphi \in \mathcal{D}(\mathbf{R}^n)$ is a test-function from the space of infinite differentiable functions with compact supports $\mathcal{D}$, and $f \in \mathcal{D}'(\mathbf{R}^n)$ is a distribution, then its Fourier Transform $\hat{f}(\xi) = F[f](\xi)$ is defined by the relation:

$$(\hat{f}, \hat{\varphi}) = (2\pi)^n (f, \varphi),$$

where

$$\hat{\varphi}(\xi) = F[\varphi](\xi) = \int_{\mathbf{R}^n} \varphi(x) \exp(i(\xi, x)) dx,$$

$$(\xi, x) = \xi_1 x_1 + \ldots + \xi_n x_n$$

the inverse Fourier Transform F^{-1} acts by the formula:

$$(F^{-1}(\hat{f}), \varphi) = \frac{1}{(2\pi)^n} (\hat{f}, \hat{\varphi}).$$

The following formulas hold:

$$F[\delta](\xi) = 1,\ F[1](\xi) = (2\pi)^n \delta(\xi)$$

$$F^{-1}[F[f]] = f,\ F[F^{-1}[\hat{f}]] = \hat{f},\ f \in \mathcal{D}'(\mathbf{R}^n)$$

where $\delta \in \mathcal{D}'(\mathbf{R}^n)$ represents the Dirac distribution concentrated at the origin.

In this way one can compute the Fourier images of some function type distributions which in a classical manner does not exist.

2 General results

Let us consider the function $f, g : \mathbf{R} \to \mathbf{R}$, where

$$\begin{aligned} f(x) &= \frac{1}{\sqrt{2\pi ct}} \cos \frac{x^2}{4ct}, \\ g(x) &= \frac{1}{\sqrt{2\pi ct}} \sin \frac{x^2}{4ct}, \end{aligned} \qquad c > 0,\ t > 0 \qquad (2.1)$$

These functions are involved in the study of transversale vibrations of the elastic rods [9], [7] where the parameter $t > 0$ represents the time.

The functions f, g are even functions and integrable on $\mathbf{R}$. Since they are local integrable, its defined function type distributions from $\mathcal{D}'(\mathbf{R}^n)$. Taking into account [4], we have:

$$\begin{aligned} &\int_0^\infty \sin\left(ax^2 + \frac{b^2}{a}\right) \cos 2bx dx = \\ &= \int_0^\infty \cos\left(ax^2 + \frac{b^2}{a}\right) \cos 2bx dx = \\ &= \frac{1}{2}\sqrt{\frac{\pi}{2a}},\ a > 0,\ b \in \mathbf{R}, \end{aligned} \qquad (2.2)$$

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$$\int_0^\infty \sin\left(ax^2\right)\cos 2bx dx = = \frac{1}{2}\sqrt{\frac{\pi}{2a}}\left(\cos\frac{b^2}{a} - \sin\frac{b^2}{a}\right) = = \frac{1}{2}\sqrt{\frac{\pi}{2a}}\cos\left(\frac{b^2}{a}+\frac{\pi}{4}\right)\ a>0,\ b>0 \tag{2.3}$$

$$\int_0^\infty \cos\left(ax^2\right)\cos 2bx dx = = \frac{1}{2}\sqrt{\frac{\pi}{2a}}\left(\cos\frac{b^2}{a} + \sin\frac{b^2}{a}\right), a>0, b>0 \tag{2.4}$$

From (2.2), for $b = 0$, we obtain:

$$\int_0^\infty \sin\left(ax^2\right)dx = \int_0^\infty \cos(ax^2)dx = = \frac{1}{2}\sqrt{\frac{\pi}{2a}},\ a>0 \tag{2.5}$$

which represent the Fresnel Integrals.

2.1 Fourier Images of the functions defined in (2.1)

The following relations hold:

$$F\left[\frac{1}{\sqrt{2\pi ct}}\cos\frac{x^2}{4ct}\right](\xi) = \cos(ct\xi^2)+\sin(ct\xi^2) = = \sqrt{2}\cos\left(ct\xi^2-\frac{\pi}{4}\right),\ c>0,\ t>0,\ \xi>0 \tag{2.6}$$

$$F\left[\frac{1}{\sqrt{2\pi ct}}\sin\frac{x^2}{4ct}\right](\xi) = \cos(ct\xi^2)-\sin(ct\xi^2) = = \sqrt{2}\cos\left(ct\xi^2+\frac{\pi}{4}\right),\ c>0,\ t>0,\ \xi>0. \tag{2.7}$$

Proof. Applying the definition of the Fourier Transform for functions, we have:

$$F\left[\frac{1}{\sqrt{2\pi ct}}\cos\frac{x^2}{4ct}\right](\xi) =$$

$$= \frac{1}{\sqrt{2\pi ct}}\int_{\mathbf{R}} e^{i\xi x}\cos\frac{x^2}{4ct}dx =$$

$$= \frac{1}{\sqrt{2\pi ct}}\int_{\mathbf{R}} \cos\frac{x^2}{4ct}dx\cos\xi x dx +$$

$$+ \frac{1}{\sqrt{2\pi ct}}\int_{\mathbf{R}} \cos\frac{x^2}{4ct}\sin\xi x dx$$

$$F\left[\frac{1}{\sqrt{2\pi ct}}\cos\frac{x^2}{4ct}\right](\xi) =$$

$$= \frac{1}{\sqrt{2\pi ct}}\int_0^\infty \cos\frac{x^2}{4ct}\cos\xi x dx.$$

($\cos\frac{x^2}{4ct}$ being an even function). According to (2.4) it results (2.6). In the same manner we have:

$$F\left[\frac{1}{\sqrt{2\pi ct}}\sin\frac{x^2}{4ct}\right](\xi) =$$

$$= \frac{1}{\sqrt{2\pi ct}}\int_{\mathbf{R}} e^{i\xi x}\sin\frac{x^2}{4ct}dx =$$

$$= \frac{2}{\sqrt{2\pi ct}}\int_0^\infty \sin\frac{x^2}{4ct}\cos\xi x dx$$

and taking into account (2.3) we obtain (2.7).

Consequences. From (2.6) and (2.7) we obtain the Dirac sequences:

$$\lim_{t\to+0}\frac{1}{\sqrt{2\pi ct}}\cos\frac{x^2}{4ct} = \delta(x),\ x\in\mathbf{R},\ c>0 \tag{2.8}$$

$$\lim_{t\to+0}\frac{1}{\sqrt{2\pi ct}}\sin\frac{x^2}{4ct} = \delta(x),\ x\in\mathbf{R},\ c>0 \tag{2.9}$$

Indeed, computing the limits in $\mathcal{D}'(\mathbf{R})$, we have:

$$\lim_{t\to+0}F\left[\frac{1}{\sqrt{2\pi ct}}\cos\frac{x^2}{4ct}\right](\xi) =$$

$$= F\left[\lim_{t\to+0}\frac{1}{\sqrt{2\pi ct}}\cos\frac{x^2}{4ct}\right](\xi)$$

$$= \lim_{t\to+0}[\cos(ct\xi^2)+\sin(ct\xi^2)] = 1 = F[\delta(x)](\xi)$$

and we obtain (2.8).

Similarly one can obtain (2.9).

Using (2.8) and (2.9) we obtain a new Dirac sequence:

$$\lim_{t\to+0}\frac{1}{2\sqrt{2\pi ct}}\left(\cos\frac{x^2}{4ct}+\sin\frac{x^2}{4ct}\right) = \delta(x) \tag{2.10}$$

and

$$\lim_{t\to+0}\frac{1}{\sqrt{2\pi ct}}\left(\cos\frac{x^2}{4ct}-\sin\frac{x^2}{4ct}\right) = 0 \tag{2.11}$$

which is true in distributions sense.

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2.2 Fresnel Integrals in R^2

Let us consider $f, g : \mathbf{R}^2 \to \mathbf{R}$, where

$$\begin{aligned} f(x,y) &= \sin a(x^2+y^2), \\ g(x,y) &= \cos a(x^2+y^2),\ a>0. \end{aligned} \tag{2.12}$$

We remark that these functions are local integrable, and generate function type distributions from $\mathcal{D}'(\mathbf{R}^2)$.

The functions defined by (2.12) are involved in the study of the transversale vibrations of the infinite thin plane plates [7].

Concerning the integrals:

$$\begin{aligned} I_1 &= \iint_{\mathbf{R}^2} \sin a(x^2+y^2)dxdy, \\ I_2 &= \iint_{\mathbf{R}^2} \cos a(x^2+y^2)dxdy \end{aligned} \tag{2.13}$$

these are divergent. Denoting by

$$\omega_h(x,y) = \{(x,y) \in \mathbf{R}^2, x^2+y^2 \le h^2\}$$

the disk with radius h centrated at the origin and using polar coordinates, we obtain:

$$\begin{aligned} I_1 &= \lim_{h\to\infty} \iint_{\omega_h} \sin a(x^2+y^2)dxdy = \\ &= \lim_{h\to\infty} \int_0^h \int_0^{2\pi} \sin(ah^2)hdhd\theta = \\ &= \frac{\pi}{a} \lim_{h\to\infty} (1-\cos(ah^2)) \end{aligned}$$

$$\begin{aligned} I_2 &= \lim_{h\to\infty} \iint_{\omega_h} \cos a(x^2+y^2)dxdy = \\ &= \lim_{h\to\infty} \int_0^h \int_0^{2\pi} \cos(ah^2)hdhd\theta = \\ &= \frac{\pi}{a} \lim_{h\to\infty} \sin(ah^2). \end{aligned}$$

Since the limits don't exist it results that these two integrals are divergent.

From this reason we define the Cauchy principal values of the integrals I_1 and I_2

$$\begin{aligned} \text{p.v. } I_1 &= \lim_{\substack{A\to\infty \\ B\to\infty}} \iint_{D_{A,B}} \sin a(x^2+y^2)dxdy \\ \text{p.v. } I_2 &= \lim_{\substack{A\to\infty \\ B\to\infty}} \iint_{D_{A,B}} \cos a(x^2+y^2)dxdy \end{aligned} \tag{2.14}$$

where $D_{A,B}$ represents the rectangular domain $[-A, A] \times [-B, B]$. Taking into account (2.5) we have:

$$\begin{aligned} \text{p.v. } I_1 &= 4\left(\int_0^\infty \sin(ax^2)dx \int_0^\infty \cos(ay^2)dy + \right. \\ &\left. + \int_0^\infty \cos(ax^2)dx \cdot \int_0^\infty \sin(ay^2)dy\right) = \frac{\pi}{a} \\ \text{p.v. } I_2 &= 4\left(\int_0^\infty \cos(ax^2)dx \int_0^\infty \cos(ay^2)dy - \right. \\ &\left. - \int_0^\infty \sin(ax^2)dx \cdot \int_0^\infty \sin(ay^2)dy\right) = 0 \end{aligned} \tag{2.15}$$

Consequently the integrals I_1 and I_2 are convergent in the Cauchy principal value meaning $p.v.I_1$ and $p.v.I_2$ are called Fresnel Integrals in $\mathbf{R}^2$.

2.3 The Fourier Images of function type distributions defined in (2.12)

The following formulas hold:

$$\begin{aligned} &F[\sin a(x^2+y^2)](\xi_1,\xi_2) = \\ &= \frac{\pi}{a} \cos \frac{\xi_1^2+\xi_2^2}{4a},\ a>0,\ \xi_1,\xi_2>0 \\ &F[\cos a(x^2+y^2)](\xi_1,\xi_2) = \\ &= \frac{\pi}{a} \sin \frac{\xi_1^2+\xi_2^2}{4a},\ a>0,\ \xi_1,\xi_2>0 \end{aligned} \tag{2.16}$$

Proof. Denoting by F_x, F_y the Fourier Transforms with respect to the variables $x \in \mathbf{R}$ and $y \in \mathbf{R}$ respectively, we have:

$$\begin{aligned} &F[\sin a(x^2+y^2)](\xi_1,\xi_2) = \\ &= F_x[\sin(ax^2)](\xi_1) F_y[\cos(ay^2)](\xi_2) + \\ &+ F_x[\cos(ax^2)](\xi_1) F_y[\sin(ay^2)](\xi_2). \end{aligned}$$

Taking into account (2.6) and (2.7) we obtain:

$$\begin{aligned} &F[\sin a(x^2+y^2)](\xi_1,\xi_2) = \\ &= \frac{\pi}{2a}\left[\left(\cos\frac{\xi_1^2}{4a} - \sin\frac{\xi_1^2}{4a}\right)\left(\cos\frac{\xi_2^2}{4a} + \sin\frac{\xi_2^2}{4a}\right) + \right. \\ &\left. + \left(\cos\frac{\xi_1^2}{4a} + \sin\frac{\xi_1^2}{4a}\right)\left(\cos\frac{\xi_2^2}{4a} - \sin\frac{\xi_2^2}{4a}\right)\right] = \\ &= \frac{\pi}{a}\cos\frac{\xi_1^2+\xi_2^2}{4a},\ \xi_1>0,\ \xi_2>0. \end{aligned}$$

In the same manner:

$$\begin{aligned} &F[\cos a(x^2+y^2)](\xi_1,\xi_2) = \\ &= F_x[\cos(ax^2)(\xi_1) F_y[\cos(ay^2)](\xi_2) - \\ &- F_x[\sin(ax^2)](\xi_1) F_y[\sin(ay^2)](\xi_2). \end{aligned}$$

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Taking into account (2.6) and (2.7) we obtain:

$$F[\cos a(x^2+y^2)](\xi_1,\xi_2) =$$
$$= \frac{\pi}{2a}\left[\left(\cos\frac{\xi_1^2}{4a}+\sin\frac{\xi_1^2}{4a}\right)\left(\cos\frac{\xi_2^2}{4a}+\sin\frac{\xi_2^2}{4a}\right)-\right.$$
$$\left.-\left(\cos\frac{\xi_1^2}{4a}-\sin\frac{\xi_1^2}{4a}\right)\left(\cos\frac{\xi_2^2}{4a}-\sin\frac{\xi_2^2}{4a}\right)\right]=$$
$$=\frac{\pi}{a}\sin\frac{\xi_1^2+\xi_2^2}{4a},\ \xi_1>0,\ \xi_2>0.$$

Particularly, considering $a=\frac{1}{4ct}$, $c>0$, $t>0$, relations (2.16) becomes:

$$F\left[\frac{1}{4\pi ct}\sin\left(\frac{x^2+y^2}{4ct}\right)\right](\xi_1,\xi_2)=$$
$$=\cos ct(\xi_1^2+\xi_2^2),\ \xi_1,\xi_2>0,\ c>0,\ t>0$$
$$F\left[\frac{1}{4\pi ct}\cos\left(\frac{x^2+y^2}{4ct}\right)\right](\xi_1,\xi_2)=\sin ct(\xi_1^2+\xi_2^2).$$

Considering the convergence in the distributions sense in $\mathbf{R}^2$, from the obtained results we have:

$$\lim_{t\to+0}F\left[\frac{1}{4\pi ct}\sin\left(\frac{x^2+y^2}{4ct}\right)\right](\xi_1,\xi_2)=$$
$$=F\left[\lim_{t\to+0}\frac{1}{4\pi ct}\sin\left(\frac{x^2+y^2}{4ct}\right)\right](\xi_1,\xi_2)=1=$$
$$=F[\delta(x,y)](\xi_1,\xi_2).$$

It means that:

$$\lim_{t\to+0}\frac{1}{4\pi ct}\sin\frac{x^2+y^2}{4ct}=\delta(x,y),\ c>0. \quad (2.17)$$

Consequently, the sequence of local integrable functions

$$f_t(x,y)=\frac{1}{4\pi ct}\sin\frac{x^2+y^2}{4ct},$$

depending on the parameter $t>0$, converges in distributions sense to Dirac distribution $\delta(x,y)\in\mathcal{D}'(\mathbf{R}^2)$ centrated at the origin.

We have, we well

$$\lim_{t\to+0}F\left[\frac{1}{4\pi ct}\cos\frac{x^2+y^2}{4ct}\right](\xi_1,\xi_2)=$$
$$=F\left[\lim_{t\to+0}\frac{1}{4\pi ct}\cos\frac{x^2+y^2}{4ct}\right](\xi_1,\xi_2)=0$$

and we have:

$$\lim_{t\to+0}\frac{1}{4\pi ct}\cos\frac{x^2+y^2}{4ct}=0,\ c>0. \quad (2.18)$$

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The Effect of the Acoustics of Sound Control Rooms on the Perceived Acoustics of a Live Concert Hall Recording

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Abstract: - Live recordings of music and speech in concert halls have acoustical properties, such as reverberation, definition, clarity and spaciousness. Sound engineers play back these recordings through loudspeakers in sound control rooms for audio CD or film. The acoustical properties of these rooms influence the perceived acoustics of the live recording. To find the practical impact of a sound control room on the acoustical parameter values of a concert hall, combinations of concert hall impulse responses and sound control room impulse responses have been investigated using convolution techniques. It can be concluded that the ITU-recommendations used for sound control room design are sufficient for reverberation and speech intelligibility judgement of concert hall recordings. Clarity judgement needs a very high decay rate, while judgement of spaciousness can only be done by headphone.

Key-Words: Sound control, Sound studio, Control room, Room acoustics, Concert hall, Recording, Playback, Convolution, Head and torso simulator, HATS

1 Introduction

From experience and an earlier investigation [1] it is clear that a recorded reverberation time can only be heard in a room having a reverberation time shorter than the one in which the recording was made. The smallest details and the finest nuances with regard to colouring, definition and stereo image can only be judged and criticized when there is little acoustical influence from the playback acoustics on the recorded acoustics. However, usually the listening or playback room in combination with the used sound system affects the recorded acoustics. This happens in class rooms, congress halls, cinemas and even in sound control rooms.

The impact of the control room acoustics on live recorded acoustics has been investigated, using the acoustic measurement program DIRAC. To this end the convolution function has been applied to binaural impulse responses of six control rooms, a symphonic concert hall, a chamber music hall and a professional headphone. The impact on reverberation, speech intelligibility, clarity and inter-aural cross-correlation has been investigated. From the results, a first step is made to judge the quality of a sound control room using this new approach, starting from the JND (Just Noticeable Difference) as allowable error.

2 Procedure

Starting from a set of 6 binaural control room impulse responses, 1 binaural headphone impulse response and 4 binaural concert hall impulse responses, 28 pairs of impulse responses are defined. From each pair ($\boldsymbol{h_1}$, $\boldsymbol{h_2}$) the first is considered as a concert hall impulse response and the other as a control room impulse response. Each pair ($\boldsymbol{h_1}$, $\boldsymbol{h_2}$) is convolved (see Section 4) to obtain the impulse response $\boldsymbol{h_{12}}$, heard when playing back the recorded concert hall impulse response in the sound control room. $\boldsymbol{h_{12}}$, thus representing $\boldsymbol{h_1}$ affected by $\boldsymbol{h_2}$, is then compared to $\boldsymbol{h_1}$, with respect to the reverberation time T_{30}, the clarity C_{80}, the modulation transfer index MTI and the inter-aural cross-correlation coefficient IACC [2,3].

3 Room acoustic parameters

Many room acoustic parameters are derived from the room's impulse responses. Examples of such parameters are the reverberation time, which is related to the energy decay rate, the clarity, the definition and the centre time, which are related to early to late energy ratios, the speech intelligibility, which is related to the energy modulation transfer characteristics of the impulse response and the latereral energy fraction, the late lateral sound energy and the inter-aural cross-correlation, which are related to the lateral impulse response measurements.

Four of them have been investigated, being the reverberation time T_{30}, the clarity C_{80}, the modulation transfer index MTI and the inter-aural cross-correlation. The JND-values of these parameters are presented in table 1.

3.1 Reverberation time T

The reverberation time T is calculated from the squared impulse response by backwards integration [4] through the following relation:

$$L(t) = 10\lg \frac{\int_t^{\infty} p^2(t)dt}{\int_0^{\infty} p^2(t)dt} \quad [dB] \qquad (1)$$

where L(t) is the equivalent of the logarithmic decay of the squared pressure. For this investigation the T_{30} with its evaluation decay range from -5 dB to -35 dB is used to determine T.

3.2 Clarity C_{80}

The parameter C_{80} [5] is an early to late arriving sound energy ratio intended to relate to conditions for music and is calculated from the impulse response using the following relation:

$$C_{80} = 10\lg \frac{\int_0^{80ms} p^2(t)dt}{\int_{80ms}^{\infty} p^2(t)dt} \quad [dB] \qquad (2)$$

3.3 Modulation Transfer Index

The Modulation Transfer Function m(F) [6] describes to what extent the modulation m is transferred from source to receiver, as a function of the modulation frequency F, which ranges from 0.63 to 12.5 Hz. The m(F) is calculated from the squared impulse response using the folowing relation:

$$m(F) = \frac{\int_{-\infty}^{\infty} p^2(t)\cdot e^{-j2\pi Ft}dt}{\int_{-\infty}^{\infty} p^2(t)dt} \quad [-] \qquad (3)$$

The m(F) values for 14 modulation frequencies are averaged, resulting in the so called modulation transmission index MTI [7], given by:

$$MTI(F) = \frac{\sum_{n=1}^{14} m(F_n)}{14} \quad [-] \qquad (4)$$

3.4 Inter-aural cross-correlation coefficient IACC

Although the IACC is still subject to discussion and research, the parameter IACC [8] is used to measure the "spatial impression" and is calculated from the impulse response using the following relation:

$$IACF_{t_1,t_2}(\tau) = \frac{\int_{t_1}^{t_2} p_l(t)\cdot p_r(t+\tau)dt}{\sqrt{\int_{t_1}^{t_2} p_l^2(t)dt \int_{t}^{t_2} p_r^2(t)dt}} \quad [-] \qquad (5)$$

where $p_1(t)$ is the impulse response measured at the left ear and $p_r(t)$ is the impulse response measured at the right ear of the HATS. The inter-aural cross-correlation coefficient IACC is given by:

$$IACC_{t_1,t_2} = |\,IACF_{t_1,t_2}(\tau)\,|_{max} \quad \text{for } -1\text{ms} < \tau < +1\text{ms} \qquad (6)$$

For this investigation only the interval between $t_1 = 0$ and $t_2 = 80$ ms (early reflections) is used.

Table 1. *JND (Just Noticeable Difference).*

T_{30}	C_{80}	MTI	IACC
10 %	1 dB	0.1	0.075

4 Impulse responses and measurements

4.1 Measurement conditions

All measurements, both the single channel and the dual channel, were performed using a HATS or an artificial head [9]. The decay range (INR) [10] for all measured impulse responses had a minimum exceeding 52 dB for all octave bands used.

4.1.1 Large and small concert hall

Impulse response measurements were performed in the large and small concert hall of "The Frits Philips Muziekcentrum Eindhoven" with a volume of approx. 14,400 m^3, an unoccupied stage floor and $T_{empty} \approx 2$ s for the large hall and a volume of approx. 4000 m^3, an unoccupied stage floor and $T_{empty} \approx 1.5$ s for the small (chamber music) hall. Figures 1 en 2 give an impression of the halls and the schematic floorplans with the source position S as indicated, placed on the major axis of the hall, and the microphone positions R1 and R2, where R1 is placed at approx. 5 m from the source, equal to the critical distance, and R2 is placed at approx. 18 m (diffuse field). More specifications of both concert halls are presented in table 2, using the total average over both microphones (ears) of the HATS, the 500 and 1000 Hz octave bands and the receiver positions R1 and R2. The INR for all measured symphonic and chamber music hall impulse responses had an average of 60 dB for all used octave bands, with a minimum exceeding 54 dB.

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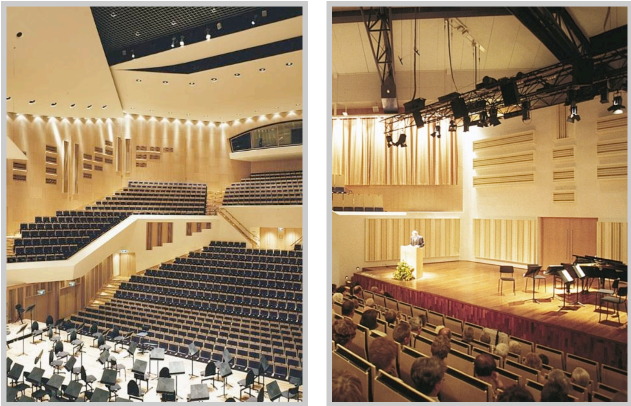
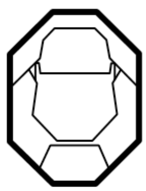


Fig 1. *Measured symphonic and chamber music hall.*

Table 2. *Concert hall specifications.*

Hall type	Symphonic music	Chamber music
Floor plan (10 m)		
Volume	14400	4000
Number of Seats	1250	385
Stage area [m²]	200	70
T_{avg} [s]	2.0	1.5
$C80_{avg}$ [dB]	1.1	2.7
MTI [-]	0.51	0.57
IACC [-]	0.58	0.44

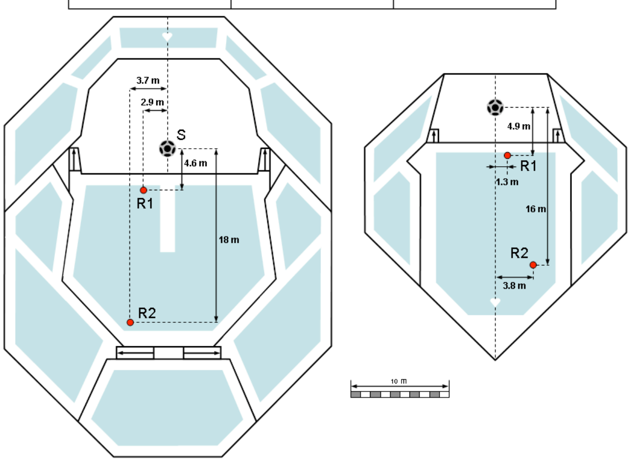


Fig 2. *Sound source S and microphone R positions.*

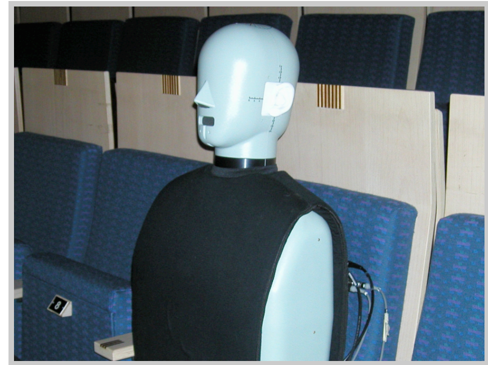


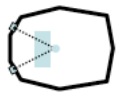
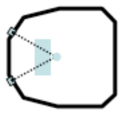
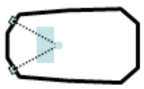
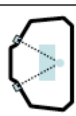
Fig 3. *Concert hall measurement using a Head and Torso Simulator (HATS).*

4.1.2 Control rooms

The control rooms under test are all Dutch control rooms and qualified as very good by the sound engineers as well as the designers. For the sake of privacy the measured control rooms are marked from CR1 to CR6. The control rooms were measured extensively with microphone positions placed on a grid consisting of 15 measurement positions [11]. Based on these measurements several important room acoustical parameters were computed. The results of the reverberation time measurements revealed that in the lower frequencies all control rooms under test met the generally used ITU recommendation [12]. In the higher frequencies only control room CR2 met this criterion. Specifications of all control rooms under test are presented in table 3. The control room impulse response measurements were performed at the sound engineer position, known as the 'sweet spot', the focal point between the main (wall mounted) loudspeakers. Control room CR5 was only suitable for near field monitoring. The INR for all measured control room impulse responses had an average of 57 dB for all used octave bands, with a minimum exceeding 52 dB.

Fig 4. *Sweet spot measurement using a Head and Torso Simulator (HATS) or an artificial head.*

Table 3. *Control room specifications.*

Control room	Floor plan (5m)	Floor area m^2	Vol. m^3	T_{avg} s
CR 1		33	103	0.32
CR 2		33	98	0.22
CR 3		35	100	0.20
CR 4		40	120	0.19
CR 5		25	75	0.14
CR 6		25	75	0.14

4.1.2 Headphone

To complete the set of impulse responses a pure free field measurement was performed using the HATS and a high quality headphone as shown in figure 5. The minimum INR for the measured impulse response reached a value of 88 dB for both the 500 Hz and the 1 kHz octave band.

Fig 5. *Headphone transfer measurement using a HATS.*

4.2 Measurement equipment

The measurement equipment consisted of the following components:

- *Head And Torso Simulator:* used in concert halls and control rooms. (B&K - Type 4128C);
- *artificial head:* used in control rooms (Sennheiser - MZK 2002)
- *microphones:* used with artificial head (Sennheiser - MKE 2002)
- *power amplifier:* used in concert halls (Acoustics Engineering - Amphion);
- *sound source:* omnidirectional, used in concert halls. (B&K - Type 4292);
- *sound device:* USB audio device (Acoustics Engineering - Triton);
- *headphone:* used as a reference source; (Philips: SBC HP890)
- *measurement software:* DIRAC (B&K - Type 7841)

5 Convolution

The convolution ***y*** of signal ***s*** and system impulse response ***h*** is written and defined as:

$$y(t) = s(t) * h(t) \tag{7}$$

or

$$y(t) = (s * h)(t) = \int_{-\infty}^{\infty} s(t) \cdot h(t-\tau)\, d\tau \tag{8}$$

In words: the convolution is defined as the integral of the product of two functions ***s*** and ***h*** after one is reversed and shifted. From a room acoustical point of view ***s(t)*** is a piece of music that is recorded in a concert hall and played back in a sound control room, ***h(t)*** the impulse response of the control room and ***y(t)*** the convolved sound as it is heard in that control room. When the control (listening) room is reverberant, smoothing of the sound occurs. The room acoustics in the music recording that we want to judge will be affected by the acoustics of the sound control (listening) room. With a double convolution by which an impulse response from the concert hall is convolved with a dry recording of music and afterward the result is convolved with the impulse response of a sound control room, it is possible to hear how a recording, made in the concert hall, sounds when played back in the control room. The result is a more or less smoothed sound signal. By using a pure impulse (Dirac delta function) instead of a normal sound signal to be convolved with both room impulse responses (eq 9 and 10) we can examine what the control room does with the concert hall concerning the values for the room acoustic parameters (eq 11). Therefore it is possible to derive a 'room in room' acoustic parameter value from the more or less smoothed impulse response. Mathematically:

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$$h(t) * \delta(t) = \delta(t) * h(t) = h(t) \qquad (9)$$

Where:
h(t) = room impulse response
δ(t) = Dirac delta function (ideal impulse)

$$h_{12}(t) = \delta(t) * h_1(t) * h_2(t) = h_1(t) * h_2(t) \qquad (10)$$

Where:
$h_{12}(t)$ = 'total' impulse response room1 room2
$h_1(t)$ = impulse response room 1
$h_2(t)$ = impulse response room 2

Substituting equation (10) into equation (7) results in:

$$y_{12}(t) = s(t) * h_{12}(t) \qquad (11)$$

Where:
$y_{12}(t)$ = convolution of a random sound signal with the 'total' impulse response
s(t) = random sound signal

6 Measurement results

In Figure 6 through 13 the results of the convolutions are depicted as an average over the 500 and 1000 Hz octave band. Each graph shows the difference between 2 values of a parameter, one calculated from h_{12}, the convolution of the concert hall with the control room and one from h_1, the impulse response of the concert hall. On the x-as the control rooms CR1 to CR6 are given in order of the decay rate. The differences are calculated for four acoustical parameters: T_{30}, C_{80}, MTI and IACC.

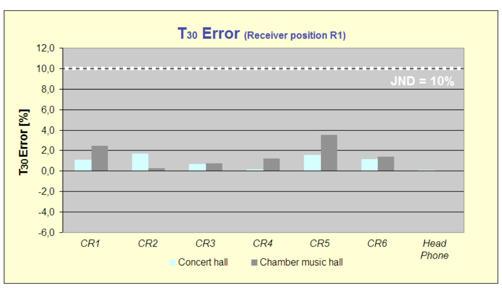

Fig 6. *Percentual difference between $T_{h_{12}}$ and T_{h_1} (T_{30} error) measured at (hall) position R1*

.

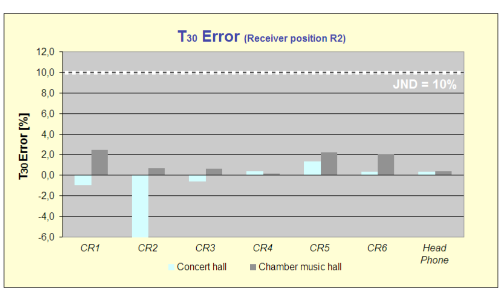

Fig 7. *Percentual difference between $T_{h_{12}}$ and T_{h_1} (T_{30} error) measured at (hall) position R2.*

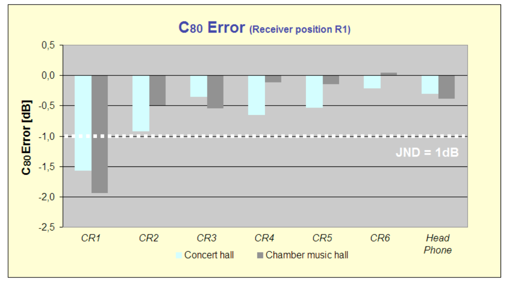

Fig 8. *Difference between $C_{80}h_{12}$ and $C_{80}h_1$ (C_{80} error) measured at (hall) position R1.*

.

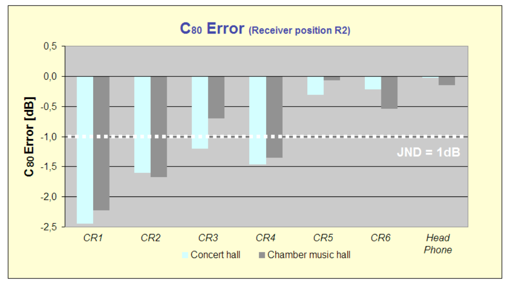

Fig 9. *Difference between $C_{80}h_{12}$ and $C_{80}h_1$ (C_{80} error) measured at (hall) position R2.*

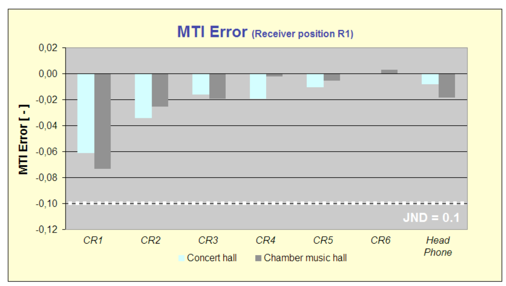

Fig 10. *Difference between $MTI_{h_{12}}$ and MTI_{h_1} (MTI error) measured at (hall) position R1.*

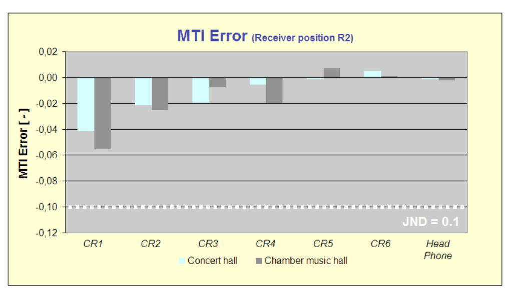

Fig 11. *Difference between $MTI_{h_{12}}$ and MTI_{h_1} (MTI error) measured at (hall) position R2.*

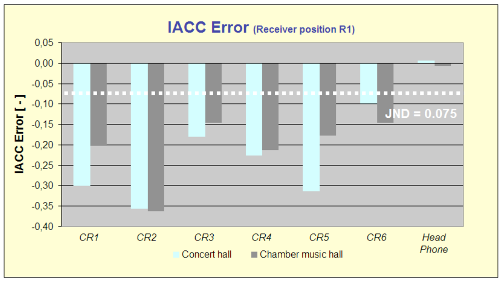

Fig 12. *Difference between $IACC_{h_{12}}$ and $IACC_{h_1}$ (IACC error) measured at (hall) position R1.*

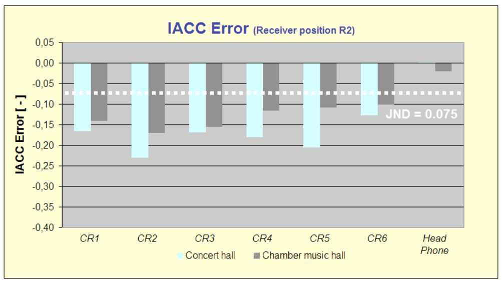

Fig 13. *Difference between $IACC_{h_{12}}$ and $IACC_{h_1}$ (IACC error) measured at (hall) position R2.*

7 Conclusion

Starting with six qualified good, more or less standardised sound control rooms, two concert halls and the Just Noticeable Difference of four calculated room acoustic (ISO/IEC) parameters it can be concluded:

- ∞ The ITU-recommendations for sound control room design are adequate for evaluation of reverberation in concert hall recordings.
- ∞ When it is important to asses the details of sound definition of a concert hall recording, you need a control room with a very high decay rate. Only the control rooms with a reverberation time below 0.15 s can be used.
- ∞ The ITU-recommendations for sound control room design are adequate for evaluation of speech intelligibility in concert hall recordings.
- ∞ An accurate judgement of spaciousness of a binaural concert hall recording apparently requires the use of headphones. This requires further investigation.

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THE CLARINET OF THE 20TH CENTURY IN *MARCH* FOR SOLO CLARINET ADAPTATION AFTER MARȚIAN NEGREA

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Abstract: This study is a monograph containing data about the composer, the literary subject of the work, formal, stylistic and interpretive coordinates, and the analysis of its musical expressivity.
Keywords: Formal coordinates, programmatic motivation, hermeneutic characteristics.

Introduction:

A prominent figure of the twentieth century in Romania, composer Martian Negrea was born in Vorumloc, Sibiu County, in 1893. He started his musical studies with Professor Dobo at the Hungarian Roman Catholic High School in Odorhei (1909-1910), and continued them at the Andreian Pedagogical Seminar in Sibiu (1910-1914) with Timotei Popovici (vocal music and church chanting) and Franz Žižka (violin). He went to Vienna (1913) to study cello with Friedrich Buxbaum, then to the Music Academy in Budapest (1917-1918) where he studied with Zoltan Kodaly (harmony), Viktor Herzfeld (counterpoint) and Pongracz Cacsoh (music pedagogy). He attended the Akademie für Musik und darstellende Kunst in Vienna (1918-1921) under the guidance of Eusebius Mandicevski (harmony, counterpoint, fugue), Eugene Thomas (theory and solfeggio), Franz Schmidt (composition, orchestration), then took private lessons with Rudolf Bella (counterpoint), Franz Schalk and Ferdinand Lowe (conducting), Joseph Saphier (piano), Max Graf (aesthetics) and Witz Worwil (singing). Thus, his personality filtered the influences of several cultural centres of great tradition, combining German Neo-Romanticism with French Impressionism, while his knowledge and thorough study of folklore found its musical expression in many orchestral and chamber works on themes of Romanian folkloric origins.

Tratatul de forme muzicale, Tratatul de armonie, *Teoria instrumentelor muzicale*. Totodată, este autorul unei monografii, intitulată *Un compozitor român ardelean din secolul al XVII-lea: Ioan Caioni (1629-1687).*

After 1921, M. Negrea becomes a professor at the Conservatoire in Cluj, then artistic director of the *Gheorghe Dima* Philharmonic Orchestra (1927-1940). During the Second World War in 1941, he teaches harmony at the Conservatoire in Bucharest, where he stays on until 1970. After retirement, he dies in 1973 in Bucharest.

Aiming at improving teaching, he wrote *A Treatise on Counterpoint and the Fugue*, *A Treatise on Music Forms*, *A Treatise on Harmony*, and *The Theory of Musical Instruments*. He is also the author of a monograph entitled *A Romanian Composer of the Seventeenth Century in Transylvania: Ioan Caioni (1629-1687)*.

Besides his teaching activity, he composed two rhapsodies, a fantasy and symphonic suites, "*Tales from Grui*", "*Spring Symphony*", "*Concerto for Orchestra*" and other works, film music for *Across the Apuseni [Western] Mountains*, the opera *Marin the Fisherman*, *The Oratorio of the Fatherland*, a symphony poem called *The Recruit*, a *Requiem*, and choral music.

In the field of chamber music, he composed works for piano, harp, art songs, a *String Quartet* op. 17 (1949), the *Suite for Clarinet and Piano* op. 27 (1960).

Martian Negrea is an eternal seeker. In his chamber works we discover a lyrical soul, which expresses itself through a spontaneous, sensitive, sometimes colourful music, other times meditative, strewn with pastoral elements influenced by the Transylvanian environment in which he lived and was originally formed.

His style evolved from his initial Romantic tendencies towards a modalism of folk origins and even towards dodecaphonism.

Attracted by the exceptional personality of Transylvanian philosopher and poet Lucian Blaga[1], as

1 Lucian Blaga (Lancram, 1895-1961, Cluj - Napoca), philosopher, poet, playwright, translator, journalist, university professor and diplomat, obtained his Ph.D. in philosophy in Vienna. Since he did not join the Communist Party, he was dismissed from his department, and his poems were printed posthumously. M. Negrea's idea of composing art songs on poems by Blaga was an acknowledgement of his worth.

well as by Viennese culture (as both artists studied there roughly at the same time), the composer expressed his appreciation by first adapting to music a cycle of *Eight Songs for Voice and Piano op. 9* (on poems by Lucian Blaga, Veronica Micle and folklore) composed in 1955 despite the obstacles raised by the regime, and later, in 1969, he wrote *10 Songs on Verses*[2] *by Lucian Blaga*, after his poems began to be published again.

The tenth song was also written for solo flute. The existence of programmatic indications facilitates the understanding of the primary source of inspiration.

1. Problem formulation

The poem "March" is part of the volume *Poems of Light* by Lucian Blaga, written in 1919 and dedicated to Cornelia Brediceanu, his future wife. "*These are not poems and it is not light that masters them. They are slices of soul, sincerely captured at all times and conveyed with superior musicality in verses which, broken as they may be, meander according to the very movements of the soul. This elastic form makes it possible to convey even the most delicate nuances of thought and the finest urges of sentiment*."[3]

The poem depicts the beginning of spring through existential metaphors, transposed into free verse, conveying the sadness of nature shivering with cold in the absence of light, as a metaphor of the poet's loneliness, bereaved of his beloved, whom he compares with light.

March (1919)

Out of a tangled flock of clouds
the wind spins
long threads of rain.
Fickle snowflakes
would land on the mud,
but as they loathe it -
they rise again
and fly to find
a nest of branches.
It's windy and it's cold -
and the buds
too greedy for light
now muffle
their ears in their collars.

(Lucian Blaga, *Poems of Light*, 1962, Tineretului Publishing House)

March for solo clarinet was rewritten by the composer Martian Negrea in collaboration with clarinettist Aurelian Octav Popa so that it might be performed at the *Prague Spring International Music Competition* in 1959, where the competitor won the first prize. Martian's Negrea inspired style and his musical imagination, as well as the technique and masterful interpretation of the great clarinettist, who advised him on some specific technical and performing characteristics, resulted in this musical gem, which enjoyed great success.

2. Problem solution

The work is an excellent study for solo improvisation. Its programmatic support facilitates the understanding of the semiotic sphere of work. The metaphors, the concepts suggested by the title and the poetic text become musical events. The development of the primary ideas occurs freely and unexpectedly, in impromptu style, enhancing the charm of the structure. Although he was very familiar with the compositional techniques of the twentieth century, the composer did not abandon the classical musical notation. Thus the score contains precise indications: the notation of metre, tempo, pitch and duration complies with the classical system. This small-scale work begins in simple triple metre, 3/4, in *Larghetto*, while other metric units are added by and by – 4/4 and 2/4 (bars 19, 31-33). The tempo accelerates towards the end (*accelerando poco a poco*), in the Coda, but it slows again (*poco ritenuto*) and the work ends in the initial tempo. The interpreter must adopt the *parlando rubato* style, derived from the oral style.

The diversity of expression results on the one hand from the variety of manners of developing the motifs, through antitheses of melodic origins especially between rhythmic pulsation units, the order of their appearance being chosen by the composer. On the other hand, the interpreter plays a decisive part in achieving that diversity through dynamic windings between the vigorous climaxes and the moments of elegant delicacy, through subtle constructions in which the suppleness of nature and metaphorical meanings evolve in arabesques akin to Impressionist outlines, through the alternation of the melodic substance with the agglomerations of cadenzas, performed with ease. The composer has imagined-, and the performer highlights-, the rows of dualities in which the logic of the score must produce a continuity of the arch of becoming, a feature characteristic of nature and of the music which depicts it. The images do not appear in the order that they have in the poetry, but seem to be first captured in their entirety, as in a cinematographic

[2] Poems: *Fiorul [The Thrill], Visătorul [The Dreamer], Primăvara [Spring], Sus [High Up], Linişte [Quiet], Stelelor [To the Stars], Melancolie [Melancholy], Mugurii [The Buds], Stalactita [The Stalactite], Martie [March]* written by Lucian Blaga in the volume *Poems of Light*, printed in 1919.
[3] Nicolae Iorga – *Neamul Românesc [The Romanian People]*, periodical, 1 May 1919.

film, and then individualised, brought to the fore at random, in an order other than the written one.

The most widely used musical ideas are motif 1 (bar 1/1-1/3 first quaver) and motif 2 (bar 2/1-2/3 first quaver). The melodic and rhythmic constructions combine several dualities that occur throughout the work, in different proportions:

- Melodic cell M1 opposes motif M2;
- The rhythm of M1 (minim - quaver) in contrast with the rapid rhythm in M2 (demisemiquavers - dotted quarter);
- Crusic rhythm in M1 as against anacrusis in M2;
- The cell made of neighbouring sounds as against the motif made of neighbouring sounds and leaps; or the difference between the bichordic scale and the heptatonic mode (A - B - H# - D - Eflat - E - G#; mode 96[4] is obtained: 1-2-2-1-1-4-1);
- The smallest interval (the semitone) as against the range which exceeds the octave (augmented ninth);
- A straight melodic outline in M1 as against the sinuosity of the arabesque in motif M2;
- The calm *cantabile* cell in M1 opposed to the aggressiveness and impatience of motif M2.

Example: motifs 1-5: 8/1:

M1: bar 1:

M2: bar 2:

M3: bar 3 beats 2 and 3:

M4: bar 5 beat 3:

[4] Vieru, Anatol. *O carte a modurilor. Catalogul structurilor modale* [*A Book of Modes. The Catalogue of Modal Structures*]– Editura Muzicală, Bucharest, 1980.

M5: bar 8:

The composer chose the technique of the variations on a theme for the rich possibilities of development that it offers, because it allows for the permanent renewal of the original thematic patterns. We have singled out the theme and five variational segments. Just like the complete work, the inner sections are short, but not equal:

Segment A: a....av1.....av2....av3....av4....av5

Bars:...........1....4/3.....10......18......25......35-40

The 40 bars of the study develop the five motif entities:

1. By inverting the melodic cell of the semitone with asymmetric rhythm, marked as M1, the composer obtains a major seventh (very frequently used), and other times he uses a minor ninth (perceived as one semitone over the octave, in bars 3/3-4/2) and a diminished eleventh (perceived as one semitone over the tenth, in bars 27/3-28/1) instead of the original figure. An example of the variations on motif one:

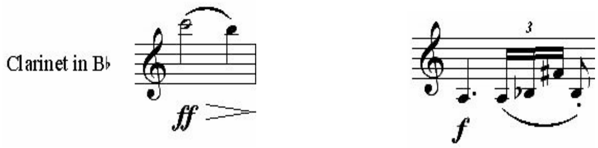
In one instance he brings together two such cells, adding a grace note (bars 3/3-4/3), but the grace note can leap (bar 10).

Here is motif 1 in the two hypostases presented above:

The figure also appears with diminished rhythm (bars 7/3 last quaver - 8/1 first demisemiquaver, 11/3 last semiquaver - 12/1 first quaver; 19/3 last demisemiquaver - 20 / 1 first quaver).

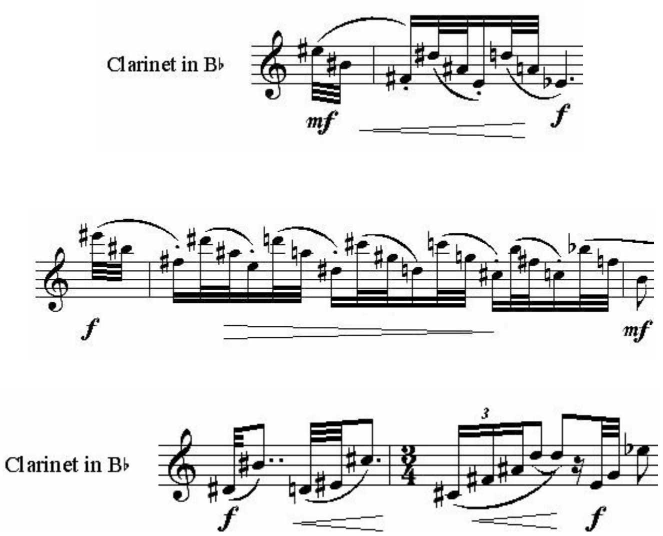
Example: Diminutions of motif 1, bars 7/3-8/1,19/3-20/1:

The inversed interval appears in bar 18; in bar 25, the second sound gets a grace made of a semiquaver triplet. The significance of this cell must be sought for in the key-metaphor conveyed by poem, "sadness" ("cold", lack of "light".)
Example: Motif 1 inversed and developed rhythmically (bars 18, 25):

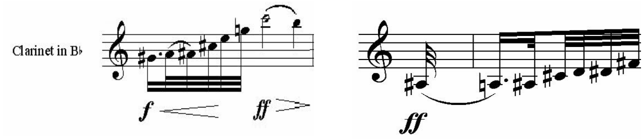


2. The arpeggio in motif 3, on the same stretch of major seventh or its equivalent, diminished octave and even ninth (the original cell inverted; bar 6/1 last quaver - 6/2 first quaver, 12/2-12/3, 16/1, 16/2, 16/3-17/1, 27/2-27/3, 30/3, 34/1-34/2) is widely used. Example: Motif 3, augmented seventh and then ninth (bars 12/2-12/3, 30/3):

The formula also appears in an inverted version (bars 6/1) or placed in a chain of descending sequences (bars 6/3-7/3, 15/3-16), with widened range and progressively more dynamic (bars 33-34). Example: Inversion, chain of sequences (6/3-7/3, 15/3-17/1): Example: Range widening and progressive rhythmic boosting (bars 33-34):



In other instances it contains a fluctuating number of inner steps (bars 17 / 3, 23 / 2, 33 / 2, 34 / 3, 36 / 1.) Example: Expansions of motif 3 (bars 17/3, 23/1):



The dissonant sonority which it produces cumulates tension. The musical structure suggests a short motion, for instance that of the clouds, of the wind, a change of direction in the motion of snowflakes, or the buds which "muffle their ears in their collars".
3. The motif that comes after the semitone cell, marked as M2, is formed of arabesques with ever-modified structures (bars2/1-2/3, 5/1-5/2, 11/1-11/3, 26/1-26/3, 29/1-29/2); it is also altered through inversion (bars 31-32). It is synonymous with other metaphors in the text which suggest wider movements: "rain", "the wind spins", "long threads of rain", "fickle snowflakes" and "they rise again and fly". Example: Hypostases of M2 (bar 29/2):

4. The melodic pattern whose intervals move in zigzag, gradually expanding the inner intervals, M4 will also be altered by sequencing and expansion (bars 14/3-15/2, 29/2-31/1, 32/2-34/1). It produces latent harmonies, which build the auditory perception of a tense harmonic march and convey the sensation of motion as well.
5. The motif which develops chromatically, on adjacent steps, ascending up to the third, originates in the initial cell, the semitone, and is a possible variant to it. But the specific development that it undergoes prompts us to consider it an independent motif, marked as M5 (bars 8/1). It is developed by exceptional divisions (13/3), by iteration (17/1-17/2), by sequencing (19/1-22/1), and by combinations with other motifs (31-32/1). Through its internal oscillation between the minor and major third, this motif builds latent consonant harmonies. Example: motif 5, latent harmonies and modal and metric oscillations (19/1-22/1):

Although there is no second melodic line anywhere, as the clarinet is not a harmonic instrument by design, we detect a tendency to build two planes of sound through the wide gap between the registers, which leaves the impression that the parts (voices) are layered. At other times a dialogue is established between the registers (bars 8 -9, 12-13-14, 21-22, 27-28, 29 / 2, 31-32). This pattern recurs often, its inner structures modified. Its significance is related to the idea of "budding" expressed by the "buds" and "nest of branches", but the journey becomes painful, even strained (*espressivo molto e dolente*, bars 19-21).

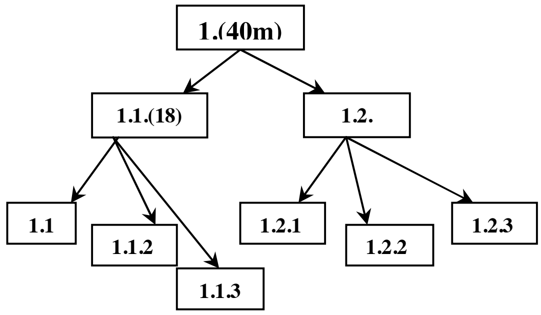
The logical continuity of the musical discourse, maintaining the impression of improvisation in the *parlando rubato* style, and the naturalness in the flow of the musical phrase are the most difficult features for the clarinettist. The interpreter must imagine a dynamic hierarchy of the phrases, designed so as to gradually build the four major dynamic curves: the first one leading to bar 15, the second to bar 18, the third to the low register in bar 23 and the last to the top high register of the instrument in bar 31. Example: The culmination in bars 29-32:

Conclusions:

In this study, the metaphorical meaning generated by the title requires a lot of imagination in conceiving the sounds proper, especially since the instrument is able to convey a wide range of meanings. It is ideal for each interpreter to master and use these instrumental tools. Thus, he can choose matte or buoyant, soft or strident sonorities, shrill or deep, rich in overtones. The way he conducts the flow of sound can convey agitation or calmness, impatience or peace, according to the pressure of the emission, the quality of the instrument and of the reed, the clarinettist's skill and interest, to the states of mind he experiences and conveys.

The same passage can be performed in different ways, with varied sounds and can generate a new perception every time (for instance M2 in bar 2, repeated in bars 5, 11, 23, 25, 29; or arpeggio M3, bar 3 / 2, repeated: 6 / 1, 6/3-7/1, 12 / 2, 15/1-15/2, 15/3-16/3, 22 / 2, 23/2-24/1, 25 / 2 27 / 2, 27/3-28/3, 30/1-30/3, 33/1-34/3, 35/3-36/1, 36/3-37/1, 37/3-38 / 1, 39/3-40/1). There are moments in which the sonority has to be changed abruptly, with an astonishing effect (*forte - piano*, bars 3, 18-19). It takes probing, trying out numerous types of emission and sound level, a precise identification of breathing caesuras and as accurate and elegant a performance as possible.

The Grid of the Syntactic Tree of *March* for Solo Clarinet
Composer: Martian Negrea



The Semantic Character

Psychological					Religious			Moral				Philosophical			
Intimate	**Dramatic**	**Subtle**	**Comic**	**Angelic**	**Funeral**	**Mystical**	**Religious**	**Sober**	**Ironic**	**Pure**	**Generous**	**Transcendental**	**Dreamy**	**Pesimistic**	**Evolutive**
m1-C		m1-I	m1-I	m1-I	m1-I	m1-I	m1-I	m1-P	M1-P	m1-I	m1-I	m1-I	m1-I	m1C	m1 C
m2-C		m2.I	m2-I	m2-I	m2-I	m2-I	m2-I	m2-I	M2-P	m2-I	m2-I	m2-I	m2-I		m2-C
m3-C	m3-I	.						m3-I	M3-I				m3-C		
m4-C			m4.I	m4.I	m4-I	m4-I	m4-I	m4-I				m4-P	m4-P	m4-P	
m5-C	m5-C	m5-C	m5-I	m5-I	m5-P	m5-I	m5-I	m5-I				m5-I	m5-P	m5-I	

C – Certain **P – Possible** **I – Impossible**

M1

M2

M3

M4

M5

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The Modal-Harmonic Algorithm. Pattern and Transformation

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Abstract: The present study is an attempt to demonstrate and stress upon the complexity characterizing the way in which Anatol Vieru – a representative composer for the Romanian musical vanguard – through the organization of the initial available sound material resources on principles of horizontal and/or vertical symmetry (typical to non-gravitational harmony), manages to create in *Symphony no. 5 "Peste varfuri"*, a cycle of 48 Variations reunited under the form of an original *chaconne* – a true model of the genre, starting from a **modal-harmonic algorithm** with polychordal structure – with double functionality: that of **an unique generative source** of the sound matter and also, of a ***perpetuum*** obsessively extended throughout the entire variational cycle.

Key-Words: variation, *chaconne*, modal-harmonic algorithm, Vieru, "the Sieve of Eratosthenes", scordatura

Anatol Vieru' *Symphony no. 5*, lyrics by Mihai Eminescu is, undoubtedly, a **visionary** work. It's composition truly meant an act of courage for that time (1985), as it implemented an original modal concept – where the gravitational and the consonance became operational once more, after the outrageous vanguardist prohibitions –, and also used the chorus throughout the four parts of the symphony, which was an extremely rare, even hazardous phenomenon, after such experiences of the two predecessors, Beethoven and Mahler.

Following this idea, the main risk would have been linked to the fact that such symphonic approach may easily shift towards "oratory"; however this did not occur in Vieru's case, as the composer knew how to convey to the chorus the organicity of a **constitutive group**, perfectly integrated in the orchestral whole.

1 The Modal – Harmonic Algorithm

To begin with, we must note that the entire construction of the *Symphony* is centered on a modal-harmonic algorithm defined by the fusion of the two traditional chord entities – the Major and the Minor – following an ordering principle inspired by "the Sieve of Eratosthenes".

Thus, the correspondence that Vieru [1] established between the sequence of prime numbers and the cycle of fifths is the following:

- for **minor chords:** 2 = **F**; 3 = **C** etc… up to 37 = **B flat**/(enharmonic) **A sharp**;
- for **major chords**: 41 = **F**; 43 = **C**; 47 = **G** etc… up to 89 = **B flat**/(enharmonic) **A sharp**.

As a basic strategy, a rule is applied according to which **the ordinal number** of a quarter note must be decomposed into prime factors, *the greatest prime factor* turning into the determinant element of a certain chord. In order to be more explicit, a demonstration [2] of the author referring to quarter notes 98, 99 and 100 in the bar 25 of Part I is shown below:

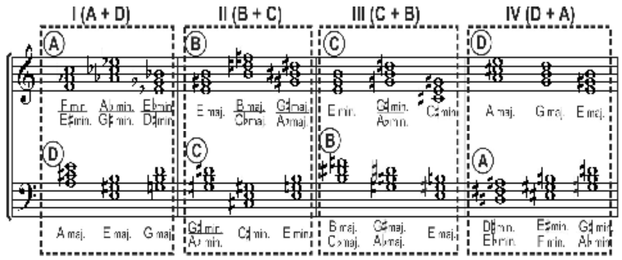
98 = 2×7^2, the greatest prime factor is 7 = **D**
99 = $3^3 \times 11$, the greatest prime factor is 11 = **A**
100 = $2^2 \times 5^2$, the greatest prime factor is 5 = **G**

Our study holds considerations on **Part III** of Anatol Vieru's *Symphony*, more appropriate in order to point out how this type of sound organization becomes an active principle in generating a **variational hypercycle** that follows the structuring pattern of the ***chaconne***.

The modal-harmonic algorithm of this particular section of the symphony receives a special function, with a **double meaning** in the global dramaturgy of the work: on the one hand, the unique **generative source** of the sound matter, and, on the other hand the ***perpetuum*** obsessively extended to a 48-variation cycle under the form of an original *Chaconne*.

This harmonic incipit has a configuration essentially consisting of cumulative organization (union) – with intersections and differences in distinct degrees – of a finite class of **major** and **minor** chords filtered through "the Sieve of Eratosthenes" and brought into polychordal simultaneity (structures made up of layers permanently opposing the two states) based on principles of horizontal and/or vertical symmetry.

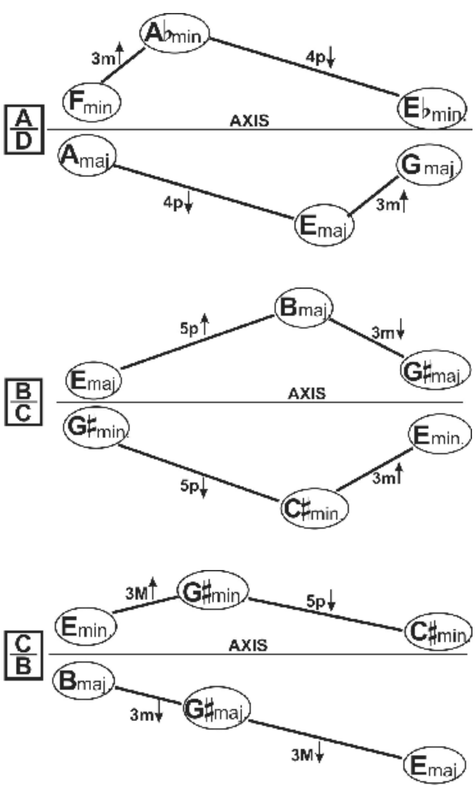
Fig. 1 Modal-harmonic matrix, modules I-IV, bars 1-4



Paradoxically, even though the dual genesis of the polychords points to the consonant-triadic bi-stratification while their juxtaposition indicates "traditional" relations of second, third and fourth/fifth, the harmonic resultant does not validate a tonal-functional connotation (see Fig. 2).

The phenomenon is due to the non-gravitational harmony which generates the relation/integration of the chord entities on the fifths scale (**A** major+**F** minor=7Q, see Fig. 3) with the help of sufficiently large intervals but also, at the same time, a significant dissonant potential – note the axial oppositions of different chord components through augmented fourth and/or diminished octave (Fig. 3).

Fig. 2 The symmetric disposition within the four harmonic modules



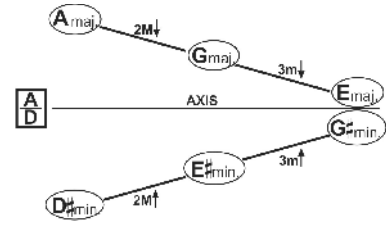
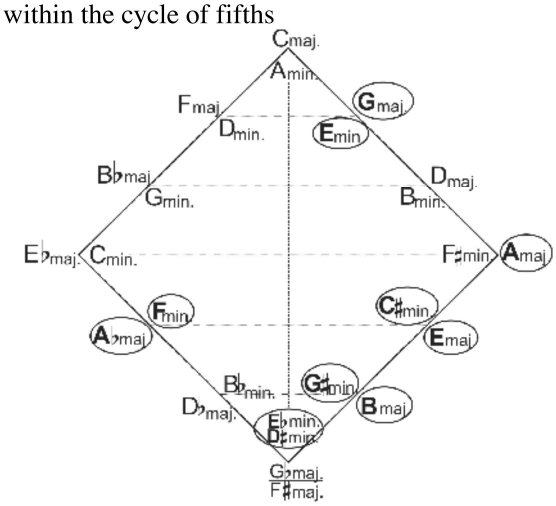


Fig. 3 The position of the harmonic structures within the cycle of fifths



Without further detailing the polychordal structure of the generating module of the *Chaconne*, we must stress upon the fact that these complex harmonic aggregates still lack the roughness or the harshness of heterogeneous constructions, which does not mean they do not hold a very important semantic tension (particularly in this section of the symphony). However, by masterfully cultivating relationships of **harmonic scordatura** (to offer a single explanation for the given phenomenon), Vieru's modal combinatorics creates the sound image of deeply interiorized feelings, totally "consonant" with the lyricism retrieved from the verses of Mihai Eminescu's poem *Dintre sute de catarge* (*From Among Hundreds of Masts*).

To support the last statement, in order to end these first observations on modal structure of the *Chaconne*, mention should be made that the generating base of the entire harmonic specter relies on a symmetric construction of **palindromic type** (Fig. 4) which results in a corresponding number of submodes (Fig. 5), as shown below – if decomposed for each polychord:

Fig. 4 The palindrome-modal structure

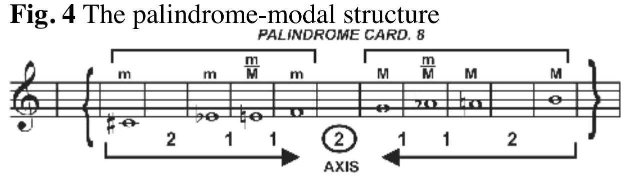
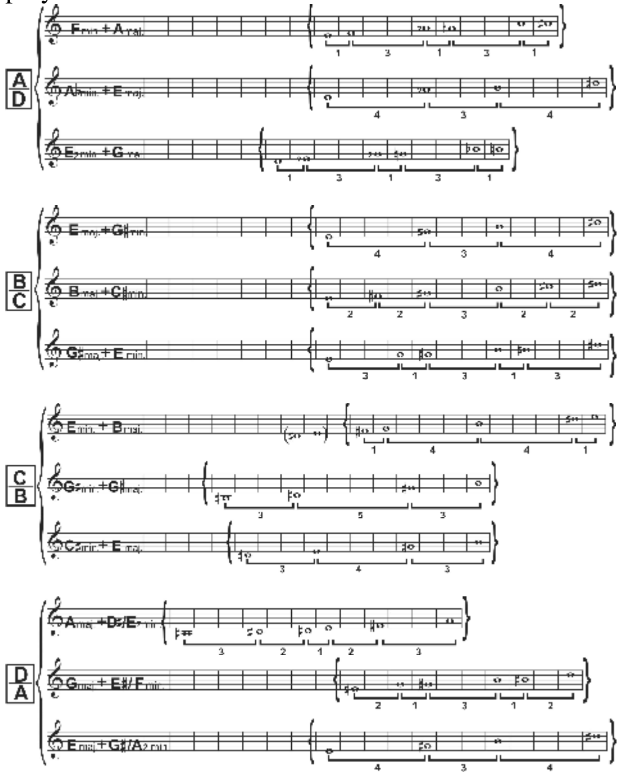


Fig. 5 Palindrome submodes equivalent to the 12 polychords



2 Variational chronology

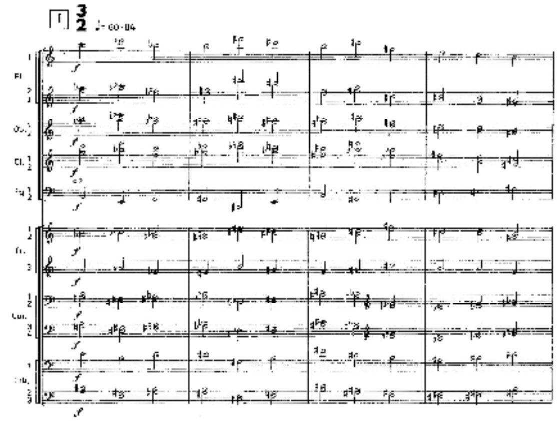
The exposure of the Theme in the *Chaconne* (which really is an isorhythmic harmonic module similar to classic chorus) coincides with **Variation I**. The sound matter is embedded in a strictly-determined temporal structure, having four bars in 3/2 time – a pattern that will reappear 48 times (the total number of variations) not once swerving from the original duration.

In accordance with the classic principle of *basso ostinato* variations, Anatol Vieru's *Chaccone* preserves the two characteristic temporal levels: that of the **the constant** – associated with the non-evolving-repetitive phenomenon *(ostinato*) and that of **the variable** – associated with the evolving-transformational phenomenon.

Another connection with the above-mentioned classical principle is drawing the attention on a complementary *chaconne* bass from the harmonic mass by means of symmetry with the help of a *descant* – a trait that can be observed in every every rendering of the original module.

Beyond the initial theme algorithm, what individualizes Vieru's compositional concept is the range of instances (which could be referred to as "stylistic licenses" in connection with the Bachian model) to approach the **two** levels.

Fig. 6 – Theme -Var. I, p. 48 [3], bars 1-4



Thus, **the state of the constant** is preserved throughout the musical work both as a display of the original harmonic module and also as dissolution of the temporal level into disparate harmonic units (or treated in a punctualist manner by short values, interpolated by rests). Along the same line, **the state of the variable** is focused on temporality as concerns the rhythmic parameter (while the meter and the tempo remain constant) and on the arpeggiated figuration, following the line of the intonational parameter.

In an apparently paradoxical way, there is an **intersection point** of the constant with the variable, signifying a **fusion** of the two levels. Concretely speaking, the harmonic matrix, under the form of an isorhythmic block, **will dissolve itself in horizontality**, on exclusively figurative sound areas as shown throughout this analysis.

A first group belonging to the variational macrocycle consists in the display of the theme module for woodwind and brass instruments sections – corresponding to **Variation I** – and in its repetition just for brass players in **Variations II** and **III** (p. 49, bars 5-12). We could speak about a **triple exposition**, as this option is justified by the necessity to impregnate the whole sound environment of the Third Part with the ethos derived from the perpetuation of the available harmonic resources – structured in accordance with a major-minor dualism.

The second group belongs to **Variations IV-VII** (pp. 50-51, bars 13-28), revealing for the first time a picture of the two levels (the constant and the variable) synchronized, where the string instruments create a highly suggestive image, thoroughly exploited by the orchestral apparatus and by the mixed chorus alike.

In fact we are dealing with a type of **arpeggiated figuration** with double sense of the melodic gradient (*ascensio-descensio*) – this rhetorical option having an onomatopoeic effect derived from the very phonetic instrumentalism enclosed in poetic text.

Variation VIII (p. 52, bars 29-32) has an unique character imprinted by the appearance of the chorus which will take over the arpeggiated figurative level with the beginning verses of Eminescu's poem. This protagonist is introduced to the *Chaconne*'s sonorous landscape with a remarkably discrete sonority reduced to a single layer of the harmonic module.

Fig. 7 – Var. VIII, p. 52, bars 29-32

Variation IX (p. 52, bars 33-36) already brings consistency to the harmonic structure by completing it with the second layer, entrusted to the woodwinds.

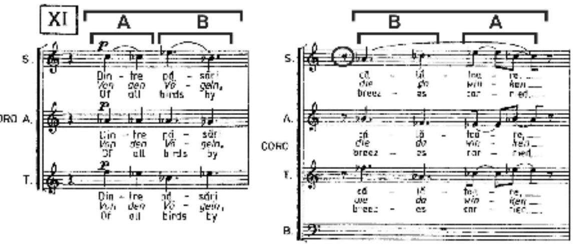
While the first three variational groups have in common the rhythmic unit of the theme module playing the role of a temporal reference, **Var. X** (pp. 52-53, bars 37-40, where a temporary removal of the chorus is noted) initiates the dissolution of the originally-compact structure which is achieved by abbreviating and dispersing the components belonging to the harmonic module with the help of interpolated rests. This is the moment where the entire **level of the constant** itself undergoes a **transformational application**.

Variation XI (p. 53, bars 41-44) is edifying as concerns the rhythmic organization based on the principle of **bilateral symmetry** of palindromic type.

The procedure is applied either on micro-temporal segments (as it happens in Fig. 8) or on larger structures (as is the case, for instance, in **Var. XIX**).

The excerpt from **Var. XI** shows a palindrome structure of type **AB/BA**, with an eighth rest axis within which the unveiling of a phenomenon characteristic for the entire temporal conception of the *Chaconne* can be noticed under the form of a binary-ternary juxtaposition with significant contribution to the frequent generation of *hemiola* structures.

Fig. 8 – Var. XI, p. 53, bars 41-42 (chorus)



As we may notice, the rhythmic unit **A** has a binary character and the rhythmic unit **B** is organized by ternary values, while it suggests an exceptional division of duplet in proportion of 2:3. Based on this alternation, we observe the occurrence of asymmetrical, vertical-isorhythmic, isochronal or complementary chains, fitting the syllabic structure of the verse where the rests act like real *caesura* elements in the delimitation of incisions.

If we marked the real metric controlling the rhythmic groups derived from the desymmetrization of the temporal flow, then the more or less dissimulated action of a horizontal, alternatively-symmetrical polymeter would be clearly revealed.

Starting with **Variation XIII** (bar 50), the same perpetuation pattern of the theme module through the dispersive character initiated in **Variation X** can be seen.

Throughout **Var. XIII-XVI** (pp. 54-57, bars 49-64), the *ostinato* level (the level of the constant) is maintained by woodwinds – dispersive, quasi-punctualist manner that in **Variation X** is sustained by chordophones.

This background reveals an emancipation of the harmonic figuration which (given the elimination of the chorus) develops a superior level of agglomeration under the form of a sixteenth note continuum written for chordophones.

Consequently, **Var. XIII – XVI** mark another chapter of the cycle which stands out because of the transparency noticed in the bi-stratification of the levels (quasi-punctualism *versus* sound continuum).

Stepping forward, the segment covered by **Var. XVII-XX** (pp. 57-60, bars 65-80) promotes the exclusive chorus development occasionally accompanied by short *pizzicato* interventions played by strings, maracas *tremolo* and onomatopoeic effects produced with the help of the "wind machine".

Exclusivity also acts at the level of isorhythmic writing whose purpose is that of providing unity and consistency to the collective character in the variational approach. Thus, the analogy between

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the syllabic structure of the verse and the rhythmic structure of the figurative arpeggiated model, on the one hand, and also the disjunctive juxtaposition of the incisions – with the help of interpolated rests, on the other hand, are preserved.

Unlike other moments, **Var. XVII** and **XVIII** stimulate a change in the fluidity of the melodic thread up to a densification noticeable on the rhythmic level (achieved through sixteenth note contribution).

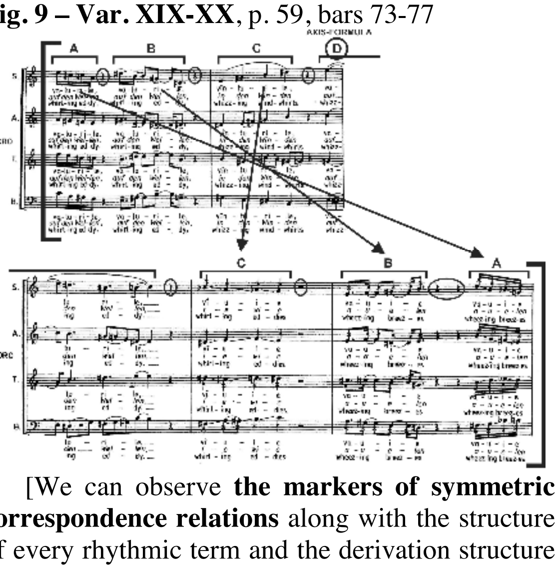
Contrastingly, **Var. XIX-XX** bring forward the desymmetrization phenomenon by employing the earlier-mentioned dual groups of binary/ternary type, the entire procedure culminating with a broken melodic flux caused by the dispersion of the rhythmic order with the help of rests.

Furthermore, **Variation XIX** – which presents an extension of the palindrome at the level of symmetrical juxtaposition of seven rhythmic formulae (in the following succession: A B C **D** C B A – where D is the axis-formula) – is representative for the symmetry concept widely extended throughout the opus.

Regarding the configuration of the sound matter, a special remark must be made as concerns the new figurative instance extracted from the matrix structure, the *descant* type of detachment in the part of the soprano sustaining the proliferation of a melodic profile through the *ascensio-descensio* complementarity.

Another sound mark of the mentioned group sends to the timbre range and consists of special emission techniques which imply whispering, murmuring and the *quasi-parlando* sound.

Fig. 9 – Var. XIX-XX, p. 59, bars 73-77



[We can observe **the markers of symmetric correspondence relations** along with the structure of every rhythmic term and the derivation structure achieved by the augmentation of some formulae (3-beat quadruplet – **B**) and then the binary / exceptionally-ternary (quadruplet) alternation and the **axis-formula**.]

Variation XXI (p. 60, bars 81-84) reaches an abyssal threshold, a rupture in the variational chronology now marked by the occurrence of a space swallowed by **rest**.

The exclusiveness of the moment not only induces a contrasting effect but also an anticipative one as well, because on the background of maximal rarefaction, the new grouping formed of **Var. XXII-XXV** (pp. 61-62, bars 85-100) revives the incipient level of the *Chaconne* through the exposition of harmonic/thematic choral in accordance with the initial bi-stratification.

Starting from **Variation XXVI** a new apotheotic moment of the cycle is prepared through the engagement of three timbral compartments: woodwinds, chorus and strings.

Thus, **Var. XXVI, XXVII** and **XXVIII** (pp. 62-63, bars 101-112) preserve the temporal level of the constant by unfolding the harmonic choral now divided between woodwinds and strings. The intervention of the chorus on this background is marked by the well-known figurative arpeggiated formulations, at first isorhythmic yet presenting a polyphonic-imitative nuance (**Var. XXVI-XXVII**), then varied through syncope chains, while preserving the imitative tendency (**Var. XXVIII**).

Making its debut with a polyrhythmic canonic *stretto*, **Variation XXVIII** introduces, at the same time, a new stage of the arpeggio figuration as phenomenon linked to harmonic block dissolution, the woodwinds moving gradually through the rarefied, isorhythmic phase towards the densely-figurative one, in an attempt to take over the flexuous waving dynamics of the previously-announced level from the chorus – the next variation (**var. XXIX**, pp. 63-64, bars 113-116) symbolizes the culminating point of the movement from verticality to horizontality.

Var. XXX-XXXII (pp. 64-66, bars 117-128) assumes once more the role of progressive isorhythmic restriction in the movement up to a new threshold of rarefaction (half notes intercalated with corresponding rests), **Var. XXXII** having the value of yet another anticipative moment for a long presence of the harmonic continuum stage which will persist throughout **Var. XXXIII-XLVIII**.

The last 15 Variations (**XXXIII-XLVIII**, pp. 66-74, bars 129-192) bring the chorus into the spotlight again, along with the obsessive invocation – *vânturile, valurile* – by reactivating the movement from the explicit pronunciation of the words to their dissolution into phonemes with onomatopoeic character.

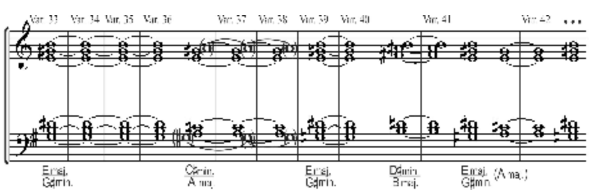
We find ourselves in another spiral of variational evolution, with a debut in the rarefaction zone, materialized under the form of a long harmonic pedal spanning along **Var. XXXIII-XXXVIII,** with a single change of chord, in **Var. XXXVI**.

In this context, the last variational group initiates yet another **spatial-temporal continuum** of harmonic essence, individualized now by the **polyphonic attacks**.

This harmonic stasis slightly syncopated (rhythmed) through the dispersive distribution of the sound impulses over the choral apparatus forms the sonorous magma available for future transformations. At this point, the choir only emits vowels, entering thus in resonance with the amorphous, yet unarticulated state of the sonority.

Up to **Variation XLI** (inclusively), the harmonic blocks, delimited as temporal incisions of variable extension (length) are defined as a succession of **three harmonic structures**:

Fig. 10 – Harmonic scheme, **Var. XXXIII-XLII**



- The first one is a structure containing two chordal layers – G sharp minor + E major – extended from **Var. XXXIII** to **Var. XXXVI**, with a come-back to **Var. XXXIX**, **XLI**
- The second structure is the juxtaposition result of A major + D sharp minor, which generates, overall, a major chord with major seventh, covering **Var. XXXVI-XXXVIII**
- The third structure is basically a transposition of the second one – B major + D sharp minor (or B major with major seventh) – and can be noticed in **Var. XL** only.

The last group, containing **Var. XLII-XLVIII**, has a particular aspect, conferred by the original manner in which the fusion of the horizontal with the vertical occurs, the figurative, arpeggiated melodic line being accompanied through repeated attacks by the entire choral apparatus.

In this case also, the harmonic movement can be reduced to three structures, alternated by the principle of **scordatura** and associated to tighter and tighter temporal incisions.

Each incision has a double determination: a harmonic one and a rhythmical one, the principle of rhythmic alternation consisting of the juxtaposition of two basic segments – 5/4 and 8/4, respectively – these surfaces presenting a correspondence with *Fibonacci's Numbers*, where the segment of five quarter notes has, in its turn, an inner structure of 2 + 3 (see Fig. 11).

The asymmetry derives from the indivisible structure of standard values for each segment individually, which generates a temporal area of bichronal type (characterized by only two different pulsations – the quarter note and the half note).

Mention must be made, in the end of our study, that the discussed approach is not singular in Anatol Vieru's work. On the contrary, it belongs to a triad formed by *Symphonies IV*, *V* and *VI*, *Symphony no. VI-"Exodus"* presenting even an unusual *Tangociaccona*.

If we take into consideration other creations of the same type, we can appreciate the fact that ***basso ostinato*** **variations** in general and the *chaccone* in particular mark a relevant sequence in Anatol Vieru's compositional concept, which rightfully allows it to aspire to the condition of a true **model of the genre**.

Fig. 11

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The Functional Tonal Musical System and its Mathematical Acoustical Basis

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Abstract: - the tonal musical system is based on a clear acoustic foundation – the component sounds follow each other in the order of a perfect fifth; the chords that sustain these tonal functions are built on a mathematical base (Fibonacci series).

Key-Words: - harmony, acoustics, mathematics.

1. The Functional Tonal Musical System and its Mathematical Acoustical Basis

Approaching such an interdisciplinary subject, the most logical starting point would be by first defining the fields in which the theoretical proof will manifest itself with music on the one hand and physics/mathematics on the other. In order not to unnecessarily lengthen this study we start by enunciating in a simple and clear manner-instead of certain definition that would enviably take us into other areas (aesthetics, philosophy, etc.)-that music is an art but physics and mathematics are sciences. Music and mathematics/physics are two distinct areas in human activities that tend not to intersect because of a very simple rationale: human nature and its extraordinary complexity is built on two fundamental ideals: 1) the sensory element of emotions and feelings by which the human being communicates with its surroundings and other human beings, as well as enriching its own existence by developing important feelings, approaches, and emotional states; 2) the rational element, calculus, intellectual speculation, the element that gave lift to human beings to rise to the top of the biological pyramid, the element by which knows and governs in both the micro as well as the macro, everything that surrounds human beings.

The two areas that will remain in our discussion (artistic-music and scientific-physics and mathematics) will provoke two fundamental human components representing, ideally, the sensory and the rational elements.

Complex existence, yet still indivisible, man cannot separate these two components which, in spite of their apparent incompatibility, will inevitably coexist; in other words, the coexistence of subjectivity and objectivity, of strict individualism versus collective being, which further implies an abstract average of everything that humans do, feel, think, act, etcetera. One might say that the way Homo Sapiens knew how to combine these two fundamental elements (in a different manner!) and that savoire faire or "life sciences," is the capacity of going through biological existence at a level reclaimed by its own special status in the biological world.

This essential aspect will be followed not only at the level of daily existence, but also on a higher level in the lofty manifestations of human spirit and feelings (sciences and arts). A propos our original subject, we could quote the famous scientist H. von Helmholz, "I always felt attracted by the mysterious connection between math and music-the application of the most abstract and logical science at the level of sound, the physical and physiological basis of music, the most immaterial art, the most vapor and tender, the one that makes us experience the most incalculable feelings hard to define."[1]

The aforementioned quote can represent a departure point for our theoretical journey.

[1] Paraphrasing Urmă, Dem., *Acustică şi muzică,* Editura ştiinţifică şi enciclopedică Bucureşti, 1982, pag. 5.

If we avoid to define music (Helmholz already did it admirably) and consider music simply as an "art"[1], our study of the meaning of tonality requires explanation: "By tonality – largely speaking – one understands the phenomena of gravitation and convergence of sounds, in a musical composition, towards an audio center called tonic."[2] The same author (in the same book at page 282) then makes the important remark: "The tonality is a specific concept of creation, elaborated and emulated by the high musical art" (authors note the west European music after the sixteenth century).

Attempting a short historical overview of the genesis of tonality, one needs to account for the work involving the ancient medieval Gregorian modes and the diatonic heptatonic modes present in the area of official catholic music as well as secular music. The music based on the aforementioned modal structures utilized these modes not only as musical scales, as simple musical audio "materials" but also established the element of audio melodic functionalism separated into two large steps: the finale (vox finalis) and the ténor.[3]

The Renaissance era brought forth a spectacular development of secular music, which inherently implied the renouncement of the influence of the Catholic Church, namely it's artistic obligation. The melody followed a more expressive path, unrestricted, and evolving polyphonic elements into a more simple line, in the shape of vertical blocks, yielding more and more clear harmony. Even though the basis will remain modal, the harmonic function will start to include more of a vertical nature alongside it's melodic aspect. A new type of functionalism arrived, namely the chordal functionalism, where the function's quality will be given not by the melodic line but by the chord's harmonic function.[4] The consequences are clear: harmonic functionalism will no longer be tied to only one solution, but will have at its disposal any number of solutions (see footnote 4) and the sounding result will be realized with a three or four note chord and not on one lonely pitch. The harmonic essence of the tonal phenomena is in the result itself; Constantin Rîpă confirms: "Tonality can only be thought of as harmonic."[5] The father of the functional tonal harmonic system, Jean Philippe Rameau, found himself to be "blinded" by this way of musical thought. Rameau was unable to find an alternative, being completely opposed to other types of musical cultures (for example, more traditional ones, strictly monophonic). „Music divided into harmony and melody, but we will demonstrate that the latter is rather an element of the former and that the knowledge of harmony is enough for a complete understanding of all the properties of music".[6]

From the above affirmations and confirmed by the quoted opinions mentioned, the result is the foundation of the principle of functionalism, and within the function itself we will find the chord.

What is functionalism? An essential component in the "equation of tonality," it is the element that defines the tonality and the key. It can be easily defined in this way: a chord on a certain scale degree of a tonal scale has a well established role as part of the tonal mechanism. From where did the establishment of the tonal functionalism begin, who chose the tonal scale, and who "invented" tonality?

There is only one answer: the common practice spread throughout a large period of time, a period in which tonal scales were selected out of the medieval modes and the three tonal functions were born. A more specific explanation can be found in acoustics.

Starting from heptatonic diatonic material, one can imagine five theoretical possibilities of building the

[1] Although there could be different points of view! We could talk about Igor Stravinsky's opinion "Music is an act of human mind which puts order in the world of sound" (paraphrasing Giuleanu, Victor, *Pricipii fundamentale în teoria muzicii, Editura Muzicală, Bucureşti, 1975, pag. 14) which rather sends the music in a scientific zone rather than the artistic.*

[2] Giuleanu, Victor, *Principii fundamentale în teoria muzicii, Editura Muzicală, Bucureşti, 1975, pag. 284*

[3] As far as the authentic modes are concerned: protus, deuterus, tritus and tetrardus, these scale degrees, I and V (paraphrasing Rîpă, Constantin, *Teoria superioară a muzicii, vol. I – Sisteme tonale*, Editura Media Muzica, Cluj Napoca, 2001, pag. 170-171).

[4] In this manner, different functions of the melody will be able to propose different harmonic functions of, for example, the heptatonic mode; the harmonic chords will each support different functions, in this case, I when it is root, VI when it is third, IV when it is the fifth scale degree, or II when it is the seventh. As a melodic pitch, it can also appear on each of the other harmonic underpinnings (VII, V, or III)!

[5] Rîpă, Constantin, *Teoria superioară a muzicii, vol I – Sisteme tonale*, Editura Media Muzica, Cluj Napoca, 2001, pag. 200.

[6] Rameau, Jean-Phillipe, *Treatise on Harmony*, translated by Philip Gosset, Dover Publication, Inc., New York, 1971, pag. 3.

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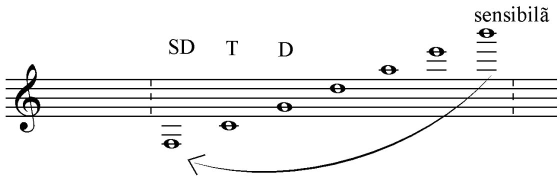
tonal scale which contain the functional trinity of tonality: subdominant – tonic – dominant. A demonstration will be done by starting with the succession of the seven diatonic pitches, each a perfect fifth apart, the so-called natural order of sounds.[1] These pitches, presented in this order of fifths, will represent "the ascending system of perfect fifths, the source of Pitagora's scale."[2]

Fig. 1[3]



Theoretically speaking, there are five ways of building a tonality which has the three functions of: SD – T – D; these would be:

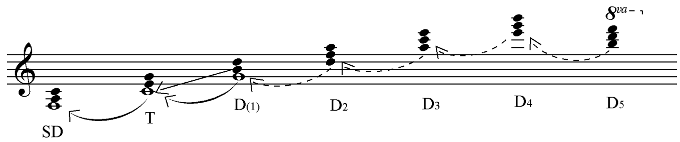
Table 1

	SD	T	D
1	fa	do	sol
2	do	sol	re
3	sol	re	la
4	re	la	mi
5	la	mi	si

The question arises: how did we get from two melodic functions (vox finalis and ténor) to three tonal harmonic functions. The answer seems to be rather simple and it explains the role of each chord of the three scale degrees (also known as the principle scale degrees): IV, I, V.

Acoustically, the seven natural pitches generate each other. The starting point is Fa (F), which generates Do[5], which in turn generates Sol, etcetera. On first impression, Fa (the fourth scale degree) is the most important. But with a more profound analysis we come to the conclusion that Do is actually the main character; it is flanked by Fa and Sol, which apply pressure from two different directions. Fa, by generating Do, will attract it. The same relationship will be born out of the Do-Sol relationship. The balance of the tonic Do will rest amidst the mutual annihilation of the two opposed forces that act upon it.

Fig. 2



In order to obtain "Tonal Functionalism," it is necessary to build the chords on their respective steps so that the three functions, subdominant (fourth scale degree chord), tonic (first scale degree chord), and dominant (fifth scale degree chord) will gain the necessary harmonic cohesiveness. In the major tonality, the three chords are major.

Starting from an acoustic premise – the pitch which is found a perfect fifth higher was generated by its preceding pitch and is dependent on it, having the tendency of pulling back to the generating element – the tonic chord is attracted by the subdominant chord[4] and the dominant chord[5] by the tonic chord. So far as this relationship (D – T) is concerned, one can notice the fact of the dominant as a scale degree and by being a chord and not just a mere pitch; it contains the leading tone of the key (the chord's third, seventh scale degree) which, at a half-step distance from the tonic, is strongly attracted to the tonic and will resolve melodically, Si – Do. One should also take into consideration the substantial force of the dominant, which is not alone, having a potential of at least five chords, with each chord built on the second, fourth, third, and seventh scale degrees, being a possible dominant for the chord residing on the preceding step (in the order of fifths!).

It is very interesting to note that in spite of the entire chordal system getting farther away from the tonic center, it still remains strictly "closed" (!) by the powerful relationship established between the furthermost acoustic elements from the Tonic, VII (Leading tone), and I (tonic!) with which establishes a

[1] In the natural harmonic sequence, the perfect fifth is the first interval that separates two distinct sounds (between the second and third harmonic) because the octave (created between the first and second harmonic) does not produce anything but the fundamental sound (the first harmonic) in a higher register (an octave higher – the second harmonic).

[2] According to Urmă, Dem., *Acustică şi muzică*. Editura ştiinţifică şi enciclopedică, Bucureşti, 1982, fig. 63, pag. 130.

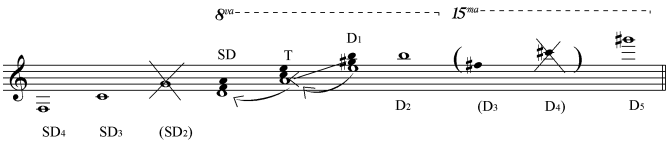
[3] For examples, we will use the diatonic material of the C Major/A Minor scale (depending on case).

[4] Hence the "depressive" character of this functional movement, which contains the destructive seed of tonality and "threatening" the supremacy of the tonic.

[5] Placed a perfect fifth above the tonic, the dominant has an "extroversive" character in contrast with the subdominant, by "dominating" the tonic from a perfect fifth up and creating a resolution into itself.

strong communication, the half-step (this time, a subjective element, strictly musical, as opposed to the objective acoustic relationship of the perfect fifth.) The leading tone in minor scales, "suggested" yet missed (all of them!) by the medieval system is an essential element in the functional tonal system. Originally from the Aeolian mode but bearing in mind the functional tonal model of the Major (Do Major, former Do Ionian), the making of the minor key had to accept an essential and absolutely necessary modification: the alteration of a raised half-step on the seventh scale degree, thus obtaining the necessary leading tone to make the fifth scale degree chord (dominant) major.

Fig. 3



As seen from figure 3, the presentation of the material of the La harmonic minor scale (with raised leading tone) leads to the five potential chords for dominant (supported by D2 and…D5, the leading tone) but also leads to the depressive quality of the subdominant (supported by SD3 and SD4, SD2 being replaced by D5!). It is no accident that the musical ethos expressed by the minor key supports rather tense, expressive, less balanced, and depressed musical areas; this aspect will be preferred by the acoustical build of this type of key (with a subdominant potential more powerful than the major key, found in a superior, dominant zone).[1]

Finally, we have objective acoustical support on which the musical concept called "tonality" is based, the acoustic element that explains the functional aspect and the interdependence of the tonal functional relationships.

A propos, the fact that in our tonal system, the relationships between functions (represented by the principle chords or their secondary substitutes) will be fundamentally different on the basis of the acoustics (the relationship of the fifth). The main dependence of the tone found a fifth above the preceding one will make it possible for the tone found a fifth above to have a privileged relationship, qualified as authentic, based on the interval of the fifth down (V – I), as opposed to the opposite less convincing plagal relationship (IV – I, perfect fifth up).

The relationships between chordal functions will in fact create the musical discourse, being essential in the configuration of the tonal schematic of the sound.[2] "The term (author's note harmonic relationships) implies not only the fact that a chord is followed by another but also that the succession is controlled and orderly".[3] Starting from the musical sense of each function, the tonal harmony will decide, logically, the paths between the functions, the favorable corridors, the mandatory articulations (cadential formulas) and the seldom taken more difficult paths. At the very foundation of this impressive monument, a climax of musical thought will be the acoustic element as a principle decisive factor.

The functional tonal system (as it was affirmed many times and was confirmed not only by composer's practice but also by numerous scholars' opinions) has as a basis the concept/idea of chord. In a traditional tonal conception (but also in the modal-renaissance arena) the chord is a sound formed of at least three different pitches, disposed, in the root position a third apart from each other. In making a reference to the musical role of this audio "product" called a chord, Marțian Negrea offers an interesting opinion: "…the sound has a force that activates in two directions: one horizontal that produces the scale and the melody, and the other vertical that produces the chord, and thusly, the harmony."[4] This noted scholar quotes the words of Arnold Schoenberg, which, in his Treaty of Harmony, ed. III, pag. 26, second paragraph, declares the following: "If the scale is an imitation of the sound in a horizontal form, the chord is an imitation of the sound in a vertical form" and then "the scale is analysis and the chord is the synthesis of the sound."[5]

Trying to classify these types of chords (of three notes) we can say that the triads formed in a given key will be differentiated "by the intervals from which they are made of, in their sound quality." There are four types of triads, classified according to the nature of the

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[1] The labeling of the minor key as "sad" and the major key as "optimistic and exuberant" must be avoided due to the fact that most major historical composers knew how to surpass, when necessary, these objective acoustic barriers, creating very tense major areas or calm, elegiac, contemplative minor areas, which even sometimes did not lack in humor or joy.

[2] By logically extending this concept, the relationships of the third and second will also be authentic (third down, second up) or plagal (third up, second down).

[3] Piston, Walter, Harmony revised and expanded by Mark DeVoto, London, Victor Gollancz Ltd., 1987, pag. 20.

[4] Negrea, Marțian, *Tratat de armonie*, Editura Muzicală, București, 1958, pag. 8-9.

[5] Negrea, Marțian, *Tratat de armonie*, Editura Muzicală, București, 1958, pag. 9.

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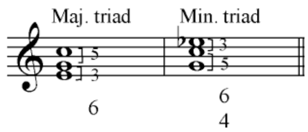
intervals formed between the fundamental and the other two notes."[1] These four types of triads[2] did not all appear at once in general musical practice. Moreover, the types used[3] in the archaic forms of polyphony appeared in first and/or second inversion.[4] The intervals of such chords can lead our thoughts towards Fibonacci's series[5], based on component numbers in this series, the major chords (in first inversion) and minor chords (in second inversion) will be formed.

Fig. 4

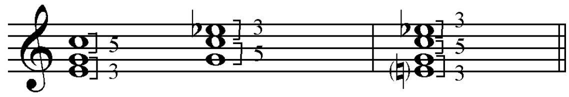


Based on this predicament, one can observe the coherent organization of the main chords from the tonal system, based on this numeric series.

Fig. 5

From the above example, one can make a logical deduction that the organization of these vertical structures (the chords, to name them tonally[6]) will be executed mostly by using the numerical elements from the Fibonacci series. In the case of the great composer Béla Bartók, we are certain to find a basis in the Fibonacci series within which Bartók created his musical system. This Fibonacci basis influenced the organization of his tonal chordal structure, building a language which has the modal underpinning coexist with a logical implication of traditional tonal elements, adopted together into the new musical requirements found in modal thinking. The nucleus of his famous $\boldsymbol{\alpha}^7$ chord comes from superimposing a major chord on top of a minor chord.

Fig. 6



In looking back to "traditional functional tonality" (the type that dominated western European art music from the XVI to the XIX centuries) one can say that the basic elements that define it – functionalism, harmonic relationships, chords – establish close relationships with the scientific areas of physics (acoustics) and mathematics, sciences that either validate (the acoustics) or from which they borrow elements of organization (mathematics). Hugo Riemann's opinion "takes from the tradition of physics (Jacques Handschin), and goes through to Rameau the concept that the tonality is fundamental in acoustics.[8] We took liberty in using the expression "traditional functional tonality" (it could also be called "functional harmony") because the term tonality, invented by F. J. Fétis in 1844[9] does not cover other systems which can have connections with the traditional tonal system. "The diversity of the historical and ethical conditions generated many ‹‹kinds of tonalities››.[10]
It is not the author's intentions to open up a Pandora's box by entering this territory. It is only the wish to point out the fact that the term of tonality can be used for many other systems and it's definition (at least when it is referred to the European musical thinking of the Baroque, Classical, and Romantic eras) can be different in the views of different well known

[1] Piston, Walter, *Harmony revised and expanded* by Mark DeVoto, London, Victor Gollancz Ltd., 1987, pag. 13.

[2] Major, minor, diminished, and augmented.

[3] The major and minor triads.

[4] Chordal mixtures found in old forms of the gymelus or the faux-bourdon.

[5] The "measuring" unit 1=1 half-step; thus, second = M2 (major second), third = m3 (minor third), fifth = P4 (perfect fourth).

[6] There can be other different types of chords, utilized in modern and contemporary music, which imply different constructions and different sonorities.

[7] Named by the musicologist Ernö Lendvai, the one that "deciphered" for the first time the mechanism of the Bartókian language.

[8] Dahlhaus, Carl, *La tonalité armonique Étude des origines*, traduit de l'allemand par Anne-Emmanuelle Cenlemans, Pierre Mardaga, éditeur Liège 1993, pag. 9.

[9] According to Carl Dahlhaus, this will define it as "a collection of necessary relationships, successive or simultaneous notes of a scale," see Dahlhaus, Carl, *La tonalité armonique Étude des origines*, traduit de l'allemand par Anne-Emmanuelle Cenlemans, Pierre Mardaga, éditeur Liège 1993, pag. 7.

[10] Dahlhaus, Carl, *La tonalité armonique Étude des origines*, traduit de l'allemand par Anne-Emmanuelle Cenlemans, Pierre Mardaga, éditeur Liège 1993, pag. 7.

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musicologists that analyze the same phenomenon (see Fétis-Reimann).
The short conclusions that we wish to draw point to the "natural" element that the tonal system implies. Having acoustic support and using sound material (chords), the tonal system will constitute the logic of a numeric series (Fibonacci) which implies specific proportions (golden section). The tonality will justify its "naturalness" being able to articulate a clear expression, logical yet sensitive. Not by accident, tonality will prolong its existence in the twentieth and twenty-first centuries[1] in symphonic music, chamber music, opera, or choral as well as the areas of jazz and pop. Even though tonality is not any longer the "unique" musical system that is used, it continues to have major importance in the context of the music of today. It is thought that these acoustic-mathematical foundations are not foreign to the impact which tonality has had on music, and thus, on human psyche. This problem stays open; it is the duty of new musicological research to point out new connections that musical art in general and the tonal system in particular have in common with the realm of science.

2. Conclusion

The functional tonal musical system proves to be built and to function based on an acoustic foundation (the natural order of sound). The chords that create the tonal functions have at the very foundation numeric proportions deducted from the Fibonacci series.

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[11] Urmă, Dem, *Acustică şi muzică,* Editura ştiinţifică şi enciclopedică, Bucureşti, 1982.

[1] The tonal system can be found (partially, together with other systems as neomodal, atonal, dodecaphonic etc.) in the modern and contemporary periods in the closed „formula" to Romantic period of the nineteenth century (Rachmaninov, Elgar) or new „formulas", neotonal (Prokofiev, Hindemith, Richard Strauss) or in different other musics (jazz, pop etc.).

Mathematical models for analysing diatonic modes

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Abstract: - The study herein aims to present two mathematical models for analysing heptachordic diatonic modes. We chose to approach the issue through a structuralist method, the first mathematical model being based on permuting some structures inside the octavian structures as this fact in itself allows a better visualisation of the characteristics of the modes; while the second model is based on juxtaposing tetrachords so that the final result is analogous to the one that is achieved if the first analytical model is applied.

Key-Words: - modality, structure, mathematical model, non- retrogradable, recurrence, mathematical formula

1 Diatonic modes

The ideas we are going to point out are somewhat correspondent to those defining real music, case in which the intervals of every mode bear a function and are hierachized in terms of certain criteria and are perceived as manifesting certain attractions and affinities among them. Therefore, we will talk only about models analysis. The tones and semitones from any melodic structure have never been equal. We set the limit at diatonic tones only, be them Greek, Gregorian, Folk or Acoustic as they are composed of two elements, tones and semitones that we may represent in letters or two numbers: (T, st) or (2, 1).

2 Two models for analysis

Any mode may be reduced to a scheme. This was possible only in European music, once the octave pitch has been mathematized. As the octave has no more than fine tones and two semitones, we may define a set made of seven elements as follows: $A = \{st_1, st_2, T_1, T_2, T_3, T_4, T_5\}$. By permuting the elements within this set there may result a multiple number of permutations incurred by the formula:

(1) $P_n = n!$,

meaning,

(2) $P_7 = 7!$,

which means a total number of 5040 structures. The result is irrelevant as in modes the way that tone are arrangement among them is not important. However, if one takes into account the distribution of tones and semitones within the limits of an octave, one may notice several situations determined by the number of tones in between semitones as well as by the way that this substructure is translated inside the larger one (we are in fact dealing with a cyclic structure). In fact, the mere positioning of the semitones if compared to that of the tones, simplifies a to a great extend the way such an issue needs to be approached.

The second analytical model considers the tetrachordic structures, their typology, the combinations as well as the way they are juxtaposed.

3 Solutions

We need to find the solutions offered by each analytical model one at the time.

3.1 The first mathematical model

The first mathematical model is based on the idea of not adjoining semitones but on creating some structures made of three, four, five and six elements, and on the cyclic permutation of there structures. Thus, the following substructures may result: (*st T st*), (*st T T st*), (*st T T T st*) şi (*st T T T T st*).

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3.1.1 Substructure (*st T st*)
We therefore take into account the first case in which we separate the semitones from a single tone. Thus, we obtain the structure (*st T st*) whose movement from left to right generates five corresponding structures to some diatonic modes that have already been theorized in music practice:

Fig.1
(*st T st*) T T T T – *Acoustic 4*

T (*st T st*) T T T – *Acoustic 3 (Hystrian)*

T T (*st T st*) T T – *acoustic 2 (Major Melodic)*

T T T (*st T st*) T – *Acoustic 1 (Lydian - Mixolydian)*

T T T T (*st T st*) – *Acoustic 7*

We may note the fact that the first with the last structure, the second with the fourth, are of recurrent type while the third in non-retrogradable. We point out this fact as if sung descending it is identical, structurally speaking, to the recurrent mode that is sung ascending.

3.1.2 Substructure (*st T T st*)
We hereby present the following substructure that generates, through the same procedure, four modal structures and which is characterized by the fact that the great number of elements from its composition determines a lesser number of transpositions:

Fig.2
(*st T T st*) T T T - *Locrian*

T (*st T T st*) T T – *Aeolian (Minor)*

T T (*st T T st*) T - *Mixolydian*

T T T (*st T T st*) - *Lydian*

The first structure with the last and the second with the third are recurrent strucures and the parity frame does not allow non-retrogradable strucures.

3.1.3 Substructure (*st T T T st*)
As noted in the previous case, the number of resulted structures is reduced to three :

Fig.3
(*st T T T st*) T T – *Phrygian*

T (*st T T T st*) T – *Dorian*

T T (*st T T T st*) – *Ionian (major)*

The Phrygian as well as the Ionian and recurrent strucures while the Dorian is a non-retrogradable one.

3.1.4 Substructure (*st T T T T st*)
The last substructure that we intend to present generates only two structures, both recurrent:

Fig.4
(*st T T T T st*) T – *Acoustic 6 (Dorian - Phrygian)*

T (*st T T T T st*) – *Acoustic 5 (Minor melodic)*

We thus note the presence of a total number of heptachordic structures of diatonic nature.

3.2 The second mathematical model
Musical practice is familiar with nine types of tetrachords that will be merely pointed out without theorizing them: Major, Major modified, Harmonic, Minor, Phrygic, Lydic, Lydic modified, Exotic and Diminished. From these, those that are made up of augmented intervals are no longer taken into account. We therefore intend to analyze five tetrachords: Major, Minor, Phrygic, Lydic, and Diminished. Each tetrachord is to be noted with the greek letters α, β, γ, δ, ε.

The first three are based on a structure made up of two tones and one semitone. They result from the cyclic permutation of the three elements. Their diagram shall be described as following:

Fig.5
α = (***T T st***)

β = (***T st T***)

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γ = (***st T T***)

The following structures either do not contain any semitones in their composition, or contain two semitones without their being adjoined. It therefore results:

Fig.6
δ = (***T T T***)

ε = (***st T st***)

3.2.1 Juxtaposing tetrachords through tone

In case tetrachords are juxtaposed through tone, the formula that needs to be applied in order to find out the total number of results is:

$$(3) \quad A_n^k = \frac{n!}{(n-k)!}$$

to which one may also add number five which constitutes the number of arrangements presupposed by the repetition of elements, a number that is equal to the cardinal number of the set. The result is as follows:

$$(4) \quad A_5^2 = \frac{5!}{(5-2)!} + 5 = 25$$

The total of the results are presented in the table depicted above emphasizing on the arrangements presupposing the repetition of elements:

Table 1

αTα	βTα	γTα	δTα	εTα
αTβ	**βTβ**	γTβ	δTβ	εTβ
αTγ	βTγ	**γTγ**	δTγ	εTγ
αTδ	βTδ	γTδ	**δTδ**	εTδ
αTε	βTε	γTε	δTε	**εTε**

For the total of results we would need to subtract those combinations exceeding the limits of the perfect octave by modifying the established number of tones and semitones or by using scales that are of no practical use.

The first column brings three octavian modes as the others go past the limits of the perfect octave:

Fig.7
αTα - *Ionian (Major)*

αTβ - *Mixolydian*

αTγ - *Acoustic 2 (Major Melodic)*

αTδ - *8+*

αTε - *8-*

The second column is similar:

Fig.8
βTα - *Acoustic 5 (Minor Melodic)*

βTβ - *Dorian*

βTγ - *Aeolian (Minor Natural)*

βTδ - *8+*

βTε - *8-*

The third column brings two familiar structures, the second and the third. The first is of no practical use while the fourth and the fifth go past the limits of the perfect octave:

Fig.9
γTα - of no practical use

γTβ – *Acoustic 6 (Dorian - Phrygian)*

γTγ - *Phrygian*

γTδ - *8+*

γTε – 8-

The fourth column brings only one familiar structure, three of augmented octave and even one of double augmentation.

Fig.10
δTα - *8+*

δTβ - *8+*

δTγ - *8+*

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δTδ - *8++*

δTε - *Acoustic 7*

Finally, the last column brings a result that is similar but is reversed:

Fig.11
εTα - *8-*

εTβ - *8-*

εTγ - *8-*

εTδ - *Acoustic 4*

εTε - *8--*

A general outlook on the issue would lead us to the conclusion that from those twenty five structures presented initially, only ten are standing. The other fourtheen are unravelled by the situation in which tetrachords are juxtaposed through semitone.

3.2.2. Juxtaposing tetrachords through semitone

In case tetrachords are juxtaposed through semitone, the results are similar to the previous one but only to a certain extend. The calculus formula is identical and the table is configured in the same way, the only different lying in the fact the the tone is substituted by semitone:

Table 2

αstα	βstα	γstα	δstα	εstα
αstβ	**βstβ**	γstβ	δstβ	εstβ
αstγ	βstγ	**γstγ**	δstγ	εstγ
αstδ	βstδ	γstδ	**δstδ**	εstδ
αstε	βstε	γstε	δstε	**εstε**

The results may be displayed much quicker when first viewing the table. Thus, one may note that the first column and the fifth disappear from our analysis due to semitone adjoining. We note only four valid structures, two from the fourth row and second and third column and two from the fourth column. All the other structures are not valid as they neither fit into the limits imposed by the perfect octave, nor do they bring adjoining semitones. The new structures are presented below in corresponding order:

Fig.12
βstδ - *Acoustic 3 (hystrian)*

γstδ - *Locrian*

δstα - *Lydian*

δstβ – *Acoustic 1*

Thus, the second mathematical model also detects a total of fourteen diatonic heptachordic structures.

4 Conclusions

When referring to the first mathematical model, we note the fact that we avoided two structures: (*st st*) and (*st T T T T T st*), meaning that in which we avoid the juxtaposition of semitones and that in which the semitones were exposed to extremities being therefore divided in five tones. Taking all these into account, not to mention the fact that permuting the tones, as well as semitones, among them, is not a relevant fact for music, the formula for obtaining all possible modes becomes:

$$(5)\quad P_7 - \sum_{k=1}^{k=6} k(2P_5 - 1)\text{, where } k \in \boldsymbol{N}$$

the result is 21, much closer to what we all know. Yet, if we subtract the six structures obtained as a result of the cyclic permutation of the structure (*st st*), as well as the only structure with semitones in extremities, we get exactly the result we need. We get the very same result by applying the second model and by taking into account the very same assumptions.

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The Music Space

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Abstract: Music is traditionally considered as a temporal art. At the same time, a musical work supposes *organisation, unity, continuity.* These are attributes of spatiality. By consequence, we are talking in music about a special kind of space – not surfaces or volumes, but a metaphorical one, which we call here *the virtual musical space.* It is important not only to admit its presence among the musical language elements, but especially to comprehend its structure, and its influence in the modern forms of art.

Key-Words: music space, virtual space, psychological space, acoustics, temporal-spatial.

1 What is Music?

"Succession of musical moving forms" (Eduard Hanslick) [1].

Why humankind did create *a special space* for the music?
Why the antiques joined arithmetic to music?
Actually, why the music has *a form*?
Why the main groups of instruments in the orchestra are situated to be better *heard* rather than *looked*?
… These are only a few questions to which we try to find here an answer.

The same as all human productions, Music supposes *organizing, unity* as well as *continuity.* All these features are related to *the spatiality* of music. We therefore agree that music supposes *time*, *virtual moving* as well as *space.*
There are three 'partners' in the art of sounds:
- *The composer*
- *The performer*
- *The listener*

To these, we add:
- *Time* – controlled and determined,

and
- *Space* – consisting in: the acoustic, the virtual and the psychological forms. [2]

Although the humankind did not perceive the *music space* right from the beginning, it was all the time there, enclosed in the artistic phenomenon.

1.1 The Acoustic Space

Along the history, people tried to adapt music to special environments; and all the same, they created proper places to serve music. Such was the relationship between the religious music and the cathedral or church; such used to be the relationship between the ancient Greek *tragedy* and the *amphitheatre*.

It is important that the right music should be performed into the right space. The music effect upon the listeners grows if this condition is accomplished.

1.2 The Virtual Space in Music

We consider the *virtual space* to be the largest as well as the richest sphere of the musical space. We could define it as *the composer's artistic imagination, his entire subjective musical world.*

The virtual space in music includes the technical part – the main specific language of each composer –, and the aesthetic part – his own sensibility. Only a part of this sensibility is going to be perceived by the listener. The sonata form, the tonal functional system, the pentatonic scales are parts of the technical virtual space; the same are the specific approaches of Bartók, Skriabin, Messiaen *etc.*

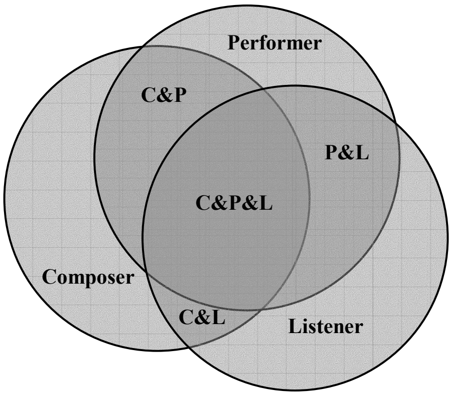
The further atmosphere of, let's say, Bartók's *Music for strings, percussion and celesta* assigns a singular, unmistakable virtual space. Or, the *ethos* in the 4th movement of the *Symphony No. 4* by Brahms – the musical 'cathedral', synthesis of *passacaglia*, *classical variations* and *sonata form*. The same is the *Quartet op. 133 Grosse Fuge* by Beethoven.

1.3 The Psychological Space in Music

We consider this one to be the sphere of both the *performer* and the *listener.* Both the performer and the listener are not able to find out and comprehend all detail of the composer's mind; at the same time, the composer could not discover the entire sphere of emotions that his music is able to create. There are distinct spaces, connected, but not identical. In other words, it's the difference between the *intention* and the *effect.* See the figure below.

In the mean time, the acoustical space – the church or the cathedral *i.e.* – has an indisputable effect upon the human spirit. A *mass*, for instance, will be more impressive if we are listening to it in a specific religious establishment rather than no matter where.

The musical phenomenon supposes a partnership between the composer, the performer and the listener.



Each of them has his own imagination, sensibility, comprehending.

In the mean time, between the two of them there is a familiar sphere of understanding and communication.

Finally, there is also a smaller zone where the three of them are communicating to each other without difficulties.

---

2 The Virtual Space in Music

Considering the circumstances of the present essay, we are choosing to expose a few more details regarding the virtual sphere of the music space. The principal reason is that this form of space is the largest as well as the oldest in the history of music, even it wasn't all the time consciously realised by the composers, the performers and listeners.

When we listen to music, or when we perform it, consciously or not, we have not the *pure time* feeling; we feel some kind of *spatial time*. We mean by that a metaphoric succession of moving acoustical objects, related to each other, and also to the entire work. Therefore, the listener, as well as the performer has to remember all the time each previous moment of the musical work in order to comprehend the present, the next one and the whole work. We are talking here about *succession* and *simultaneity* at the same time – both of them results of the musician's imagination.

We therefore consider *the virtual space in music* as a small part of the infinite sphere of the human spirit. It's that particular form of *space* which makes us to consider the melody as a winding line; to explain the musical syntaxes (polyphony, homophony, heterophony etc.) as *vertical* forms of organizing the music; to talk about *higher* or *lower* sounds, and so on.

Pure acoustical time means one or several sounds accidentally uttered. At the moment when two or more sounds are intentionally produced, a musical *relationship* occurs. In this case each sound is *related* to the precedent and to the next. This phenomenon creates the *virtual space.* As the aesthetician Rudolf Arnheim used to say, "*the time* pure an simple is creating *succession*, not *order*." [3]

Order, unity, continuity are spatial attributes. They are not related to the notion of time. By consequence, when we are talking about: tonality, modal and serial systems, musical theme (including *leit-motif*) generating the musical form and genre, all kind of musical syntaxes (including *symphony*), we refer to *the musical virtual space.* The same are the general aesthetic and mathematic aspects and methods like: symmetry-asymmetry, unity-diversity relations, variation forms, all sorts of structural proportions, the *climax* in music *etc.*

According to the composer Anatol Vieru, "Man cannot perceive the time or the space as an outsider; it is very difficult even to separate time by space: everything which exists in time, requests spatiality, and all space demands temporal existence." [4].

Let's take, for instance, three important elements of the musical language: the form, the genre and the symphony [5]. The three of them could be comprehensible as spatial parts of the music.

The musical form and genre are aesthetical categories whose elements could acquire sense only related to the whole. By consequence, it's necessary to hear the entire musical work in order to have a complete image of the creation – structure, content, sense, expression – and be able to make your own considerations towards them. Sonata form is one of the best examples of spatial representation in music. The relative symmetry between the Exposition and the Recapitulation could be perceived by the elementary memory of the listener. In their turn, the composer and the performer have in mind a literal or/and diagram representation of the sonata form like:

A B A or

The term of *symphony* is very often used, but rarely explained. "The symphony in music could be compared to the dramaturgy in theatre" – sais Alexandru Leahu. [6]. By attaching the symphony to the dramaturgy, the author reveals the spatiality of the

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first one.

The musical virtual space is a dynamic one, as Gisèle Brelet specifies:
"The virtual space is not given by simultaneity, but by a succession of moments in a multitude of directions. Let's consider the hearing plunging into obscurity, independently by the sight: what remains of the space is just the multitude of directions our sense of hearing is made for, where the space cannot be detached by the time." [7]

3 Possible effects of the Music Space

Let's take, for instance the *polytopes* of Iannis Xenakis, or Jean Michel Jarre's multimedia shows.

In 1972, Iannis Xenakis was commissioned to produce a multimedia "polytope" – as he termed his work – placed in an ancient site, in the heart of Paris. The Baths of Cluny, near Sorbonne, were built by the Romans, and the palace above them has become a prime example of medieval architecture. The idea of installing lights and sounds right in the vaults of the baths was designed to help Parisians connect with their past. This project succeeded beyond the organizers wildest dreams. *Polytope de Cluny* opened in October 1972 as part of the year's *Festival d'Automne*. The "spectacle" consisted of a 24-minute eight-channel tape containing electro acoustic music, several hundred flashbulbs placed on scaffolding throughout the underground chambers and able to be individually triggered to create vivid patterns of light, and three lasers of different colours that could be projected throughout the vault by means of a network of adjustable mirrors. [8]

On 3rd June this year, Jean Michel Jarre is going to perform in Bucharest a new-called spectacle "all-in-one-show". He is another multimedia representative author, considered to be one of the pioneers especially in using multimedia effects. Some of his well-known creations are: *Oxygene, Paris-Ville-en-concert, Aero etc.* In his shows, the synthesizers meet the digital technology, design, choreography, traditional instruments and voices and so on.[9]

We know already that the crowd can be manipulated by all sorts of ways and means. Art is one of them. The question is what sort of effect can we obtain – a good or a bad one? There are more and more frequent situations when the psychological pressure in association with acoustic and visual aggression can produce disastrous effects, going till general hysteria.

The musical space, by its three forms – *acoustic, virtual* and *psychological* – could be considered as a part of the specific language in the art of sounds. Is it important to study this special and specific 'territory'? If it is so, why should we do it? Even they are not yet confirmed values, the new forms of art include the three types of the musical space. Among them, there are:

- *Surround* audition, which represents one of the results nowadays.
- *3D movies* can now be seen in thousands of new generation 3D theatres all around the world. It supposes, of course, an important acoustical part.
- *The Second Life* program, Internet's largest 3D virtual world community, supposes all sorts of sound simulations as well.
- *Multimedia* continues to be one of the most spectacular forms of artistic syncretism, including text, audio, still images, animation, video, and interactivity content forms.

All these and a lot of other traditional artistic forms include music by its peculiar part – the music space.

We are living now in the era of information technology, which is involved in almost entire our existence. In this respect, the art of sounds does not make an exception; and the musical space became a main 'character' in this huge human 'story'. Many new activity fields did appear during the last fifty years or so. Among them, *the sound engineer, the acoustician architect, record producer, professional audio application coordinator, audio restoration engineer etc. etc.* For all these professions there are necessary acknowledges of electronics, physics, architecture, building structure, engineering, and above all, *music* and specially *music space*.

Unfortunately, the Romanian artistic education – especially on the university level – does not include this sort of specialities yet. Around the world, the sound engineers for instance, are professional graduated from more and more specialised institutes, universities, schools. In Romania this part of the cultural activity, even in media domain, is covered by (sometimes) talented and passionate people, but not completely trained for that. We are building all sort of public halls – large and small, for all sorts of destinations, including music performances of all kind – without professional preoccupation regarding the acoustics. Even the new built churches do not have – some of them – the best acoustic qualities, required by their destination.

4 Professional Education Forms

As we mentioned above, there is nowadays a large preoccupation towards the sound technology all over the world. An example consists in the *SAE Institutes – Practical Creative Media Education*, with many residences in Europe, USA, Asia, Australia, Middle East, Africa. *SAE* (*School of Audio Engineering*) is a large worldwide private college for audio engineering

and digital film training, with practical training courses and academic degree programmes. In Europe, there are *SAE Institutes* in Austria, Belgium, Germany, Greece, Italy, Netherlands, Slovenia, Spain, Sweden, Switzerland, UK – impressive aria, but far from the Eastern Europe! [10]
In France there are preoccupations towards the educational forms in the sound technology as well. *École nationale supérieure Louis-Lumière* – the National Film, Photography & Sound Engineering School – dedicated to providing pre-professional training for the audio-visual industries. *ENS Louis Lumière* offers theoretical, practical as well as technical and artistic education and training for those wishing to go into the various branches of the audio-visual industry. Run under the auspices of the Ministry of Education, it offers a state-funded course at postgraduate level leading to a nationally-recognised diploma equivalent to an M. Phil. [11]

Conservatoire National Supérieur de Musique et de Danse de Paris includes the department named *Formation supérieure aux métiers du son / High Training in Sound Technology*. [12]

The Audio Engineering Society is a professional society dedicated to audio technology. Founded in the United States in 1948, the *AES* has grown to become an international organization that unites audio engineers, creative artists, scientists and students worldwide by promoting advances in audio and disseminating new knowledge and research. [13]

And so on…

The international preoccupations of the kind are interested to train the youth for professional manipulating the most sophisticated audio-video techniques. By tradition, the Eastern Europe seems to be not so interested in this activity, although here the newest technologies are running as well as abroad. Could be helpful at least organizing master courses on this theme, or/and scholarship at the international institutes for young musicians interested. Training professional people in these directions and founding specialized forms of education seems to be an important and urgent target in Romania at least.

5 Conclusion

As final argument, we are convinced that nowadays, the specific cultural activities force us to consider the musical space as an important part of the art of sounds; more than that, we need to use it in the professional education, in order to limit, to reduce the dilettantism, the *kitsch,* and all sorts of errors of the kind.

The professional forms of education towards the sound technology – including the musical space with all its aspects – should reduce, for instance, the real danger caused by the *DJ* 'species' to the minds, sensibilities, even physical health of the young people.

Nowadays, more and more complex audio-video performances are organized in the most diverse locations: ancient amphitheatres, archaeological sites, public parks or squares, stadiums etc. An important part of the large teams who are making everything working is represented by the professionals in sound technology. Manipulating the sound in a very large location, destined to be heard by thousand and thousand people is not an easy activity; more than that: it could become dangerous if, for instance, the frequencies and intensities become out of control.

According to all the above arguments, a malicious mind could remark: *So, the Music is a spatial art?!*
Well, if we consider the space to be a visual expression of surfaces or volumes – no, Music is not a spatial art, like picture, sculpture or architecture! But if we agree that the notion of *space* supposes a concrete as well as an abstract meaning – yes, Music is a *temporal-spatial* art!

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Several representative musical manuscripts in Byzantine and psaltic notation in the Rare books section at Central University Library in Iasi

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Abstract: Within the Rare books section of the Central University Library Mihai Eminescu (BCUME) of Iaşi, there are around 70 musical manuscripts in psaltic and in Byzantine neumatic notation written between the 10th to 20th centuries. They are an important musical documentary resource as they illustrate almost all the stages of Byzantine notation: ecphonetic, medio-Byzantine, neo-Byzantine and Chrysantic. The present paper aims at briefly presenting the basic features of the above mentioned notations, as they can be seen in four valuable manuscripts at the BCUME: Ms. 160, call number IV 39 "Lecționarul evanghelic of Iaşi / The Iaşi Gospel Lectionary"- 9th – 11th century, Ms. IV 34 "Stikhirarion" – 13th century, Ms. I 26 "Anthologion of Iaşi", 1545, and Ms. III 87, „Stikhirarion or Doxastarion" by Petru Lampadarie translated by Ghelasie Basarabeanu in 1840.

Key words: byzantine musical notation, manuscript, lectionary, anthologhion, stikhirarion, doxastarion

1 Introduction

Byzantium fell under Ottoman occupation more than five hundred years ago, but the cultural, religious and artistic echoes of the great empire still reach us through the centuries, vibrating under the wonderful cathedral domes, in miracle-working icons or in the chants specific to the Orthodox rite, incessantly going on in churches.

Musical notation is one of the main reasons that allowed Byzantine chanting to continue ever since the Middle Ages to our days. Ingeniously devised at the end of the Ancient Age by using the accents in Ancient Greek – at that time a language of wide circulation – and of the directing signs of protopsalts, this neumatic notation has gone through several evolutionary stages, starting with the Ecphonetic stage (centuries 7th to 13th). The next stage – paleo-Byzantine (centuries 9th to 12th) – presents itself as a superior stage to the Ecphonetic one, which can be described as more rudimentary, as it did not define the meaning of the notation signs. The medio-Byzantine notation evolved into the last stage of Byzantine semiography, known as neo-Byzantine, starting with the Fall of Constantinople (1453), while at the beginning of the 19th century (1814) it was replaced by the current psaltic notation, as instituted by the three reformers: Hrisant of Madyt, Protopsalt Grigorie and Hurmuz Hartofilax.

In the Romanian principalities, continuous chanting of Byzantine music within the Liturgy caused the above mentioned notations to be used, as can be seen from research done on the great funds of Byzantine musical and psaltic manuscripts in our country: the Library of the Academy, the Central University Library *Mihai Eminescu* of Iaşi (BCUME), the National Library of Romania.

In this year (2010), when 150 years from the foundation of the *Al. I. Cuza University* are celebrated, and from the creation of what was previously the Music and Declamation School, we consider that a brief presentation of the most important Byzantine and psaltic manuscripts in BCUME is welcome, and they are proof that the spirit of Byzantium still lives on the territory of Romania, where it has been treasured and is still held in great respect through the important manuscripts that are representative for all stages of Byzantine notation.

The Central University Library *Mihai Eminescu* of Iaşi (BCUME), a prestigious cultural institution created in 1853 as the Library of the Royal Academy, the oldest higher education institution in Iaşi, was founded and endowed with books by Prince Vasile Lupu in 1640. When the first university was founded in Romania (1860), the previous institution named the Michaelian Library became the University Library, a name that has been in use ever since, albeit various interruptions. Among the documents in the Rare manuscripts section within the Library, about 70 are musical manuscripts in Byzantine and psaltic neumatic notation, dating from the 10th to 20th centuries, as standing proof of the Orthodox religious and musical culture on the territory of Romania.

2 Presentation of topic

The manuscripts at BCUME of Iaşi are part of a very important fund for research in Byzantinology, as they illustrate almost every stage of Byzantine notation: Ecphonetic, medio-Byzantine, neo-Byzantine and modern (Chrysantic); the only type missing are documents in the paleo-Byzantine neumatic notation.

3 Argumentation for the topic

The Old manuscript section of the BCUME keeps the oldest musical document in Romania, written in Greek, most likely in one of the Imperial courts in late 10th century or early 11th Byzantium. The codex, known as *Lecționarul evanghelic de la Iaşi / The Iaşi Gospel Lectionary* (inventory number Ms. 160, call-number IV-34), consists of rudiments of musical notation known as Ecphonetic notation within the evangelical pericopes. They are the first stage in the Byzantine notation, used in manuscripts starting with 6th century up to the 14th century with the aim of indicating the melodic line of the lithurgy recitative used in the solemn rendition of the Biblical texts. It is rooted in prosodic accents of ancient Greek drama attributed to Aritophanes of Byzantium [1].

The Ecphonetic notation system consists of red signs written above, below or in between the words of the text of the Liturgy. The signs that are used come in different shapes: as simple, double, straight, slanting, zig-zagging lines, curves, groups of three dots, all of them being written on the manuscript in groups of twos with a golden cross at the end of the phrase. Carsten Hoeg claims that each group of signs may indicate a short melody or melodic formula, and that there are fourteen melodic formulas in a pericope [2]. Starting from the shape of the signs, Egon Wellesz shows that this suggests the musical line of the recitative without specifically explaining the interval represented by each sign [3]. On studying the document *Lecționarul evanghelic de la Iaşi / The Iaşi Gospel Lectionary* (Ms. 160, call number IV-34) and taking into account the opinion of the above quoted musicologists, the Romanian paleographist Grigorie Panțiru succeeded in offering a new, more plausible explanation to the groups of Ecphonetic signs known as incidences. In his opinion, each such incidences represents a fixed sound, related to the basic sound of the recitative Below, we present a fragment from the Monday Gospel pericope in the Holy Week, as transcribed by Grigore Panțiru [4] (fig. 1):

Fig. 1

The suggested interpretation of the meaning of the Ecphonetic signs was favourably received by various Byzantinologists; other researchers, such as Gheorghe Ciobanu, Miloş Velimirovici and Egon Wellesz did not, however, agree to the solutions suggested by Grigore Panțiru.

The manuscript named *Lecționar / Lectionary,* about one thousand years old (10th – 11th century), has roused the interest of musicologists and paleographists; one of them, Sandra Martani (Italia), has studied the manuscript and has recently published two papers in the journal CSBI [5].

As a final remark on Ecphonetic notation, we should mention that Iaşi (at the Museum of Romania Literature within the Pogor Memorial House) holds another *Evangeliarion*, Ms. 7030, probably written in the 12nd / 13th century, which is the only one existing in other cultural centres in Romania. It can therefore be said that Iaşi stores important documents where the Ecphonetic notation is used. The *Evangeliarion*, Ms. 7030, contains the same rudimentary musical symbols which, as we have stated in a previous study in the journal ”Acta Musicae Byzantinae” [6], can be interpreted accordig to the method suggested by the great paleographist Grigore Panțiru, his method thus proving its validity. His activity is worth mentioning at the anniversary of the University of Iaşi, not only for his achievements in Byzantinology, but also for his activity as a professor at the Pedagogical Seminar within the ”Al. I. Cuza” University of Iaşi between 1931 and 1945, as well as for his activity as a conductor of a female students’ choir between 1935 and 1945 [7].

Related to the musical echoes of Byzantium to the modern age, other musical documents in medio-Byzantine notation can be

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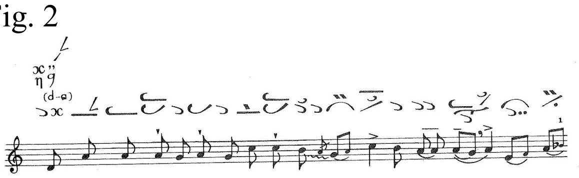
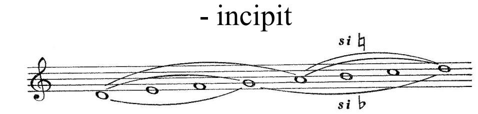
found in the Rare Books section within the BCUME, where a very important manuscript (call number Ms. IV-39) is kept; it is known to specialists as the Stikhirarion due to its musical content; it is also mentioned in the catalogue issued by the researcher Nicu Moldoveanu. There is only one other manuscript of this kind in Romania, also named *Stikhirarion*, in medio-Byzantine notation, Ms. gr. 953, at the Library of the Academy in Bucharest [8]. Medio-Byzantine notation evolved from the paleo-Byzantine, the main progress consisting of: the precise explanation of the significance of all diastematic signs (somata and pneumata), the introduction of martyria which had a role in checking up on the accuracy of melodic intonation, the validation of the Echoi, the introduction of the cheironomic signs and their classification into three large rhythmic, dynamic and expressive groups. Grigore Panțiru was among the first Romanian researchers to emphasize the importance of the Ms. IV-39 and to study the notation it contains. A part of the chants in this manuscript has been transcribed and published by the Romanian paleographist in his capital work *Notația și ehurile muzicii bizantine / The notation and the Echoi of Byzantine music*, which offers ”anyone interested the opportunity to read and transcribe such texts.” [9] We present here the incipit of the first stichera of 26th of October *Veselește-te întru Domnul cetatea Tesalonic / Rejoice unto the Lord, City of Thessaloniki* (fig. 2), as transcribed by G. Panțiru [10], in order to illustrate the melodic simplicity of the Byzantine chanting of 13th century and the modal configuration of the scale of the first authentic echos:

Fig. 2



Stichera *Rejoice unto the Lord, City of Thessaloniki* - incipit



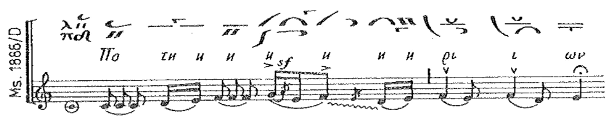
The scale of the first bzyantine authentic echos

There are several manuscripts in neo-Byzantine (Koukouzelian) notation of varying dates at the BCUME. The oldest manuscript containing this notation, *The Anthologion of Hieromonk Antonie* (Ms. call number I 26), was written in 1545 at the Putna Monastery near Suceava, where a school ran in which Byzantine arts were taught and performed: calligraphy, painting, miniature, and music. This important centre for learning and creation was founded at the initiative of the Moldavian Prince Stephen the Great (1457 – 1504); the school was founded towards the final part of his reign, and reached its peak in the first three decades of the following century, then gradually falling into oblivion towards the end of the 16th century. We should show here that the Romanian researchers Gheorghe Ciobanu, Marin Ionescu și Titus Moisescu discovered ten more manuscripts from the musical school at Putna beside Ms. I 26 of Iași, which were spread in many important libraries in Romania and abroad. Another interesting discovery – a twelfth manuscript from Putna – was made by Gabriela Ocneanu, Traian Ocneanu and Archimandrite Clement Haralam [11].

The Koukouzelian notation used in Ms. I 26 is consistent with the general features of Byzantine notation: (1) the use of the interval signs *somata* and *pnevmata;* (2) of the approximately 40 cheironomic signs used during this stage of the Byzantine notation, only 32 appear in Ms. I 26, also used in the incomplete *Propedia* to be found at the beginning of the manuscript; (3) martyria are comparatively seldom marked; (4) apechemata only appear in a few pieces. The chants in the *Antologhion of Iași* belong to the Byzantine composers of the period, Ioan Cucuzel, Ioan Cladas, Kukumas, Gherasim, as well as to the main representatives of the musical school of Putna: Evstatie Protopsaltul and Dometian Vlahu, whose compositions can be found in most of the manuscripts from the Putna school [12]. Some of the chants belonging to these two important Romanian composers, such as *The Hymn to Saint John the New of Suceava (*by Evstatie) or *The Chalice of Salvation* (by Dometian Vlahu) have represented a source of inspiration for contemporary Romanian composers (Viorel Munteanu – *The Voices of Putna*, or Miriam Marbé – *The Time Found Again*). Here are the incipits of these Byzantine hymns:

Fig. 3

The Hymn to Saint John the New of Suceava – incipit [13]



The Chalice of Salvation – incipit, Ms. I 26, f. 127 [14]

Other important manuscripts in Koukouzelian notation copied during the 17th century are Ms. III 86, Ms. III 96 [15], Ms. I 22 [16]. A large number of Greek musical manuscripts from the 18th century can be found, but only few in the Romanian language. Here are some of the Greek manuscripts: Ms. gr. III 85, ms. 88, Ms. III 87, Ms. gr. 89, Ms. I 24, Ms. III 93, Ms. III 95 [17]. A smaller number of manuscripts in Koukouzelian notation dating from the beginning of the 19th century are in store at the BCUME: Ms. III 94, Ms. III 95, Ms. IV-40, Ms. IV 71, Ms. IV 93 [18]. Towards the end of the period when neo-Byzantine notation was used (18th century and the beginning of the 19th century), dissenting opinions appeared: some musicians considered that the cheironomice signs should be improved and enriched, while others considered that they should be simplified, as in their exisiting form they made reading difficult, sometimes making chanting almost impossible. The latter tendency gained ground so, finally the Chrysantic reform emerged and was approved by the Patriarchy in Constantinople in 1814. For this reason, Romanian paleography considers that there is a period of transition from the Koukouzelian notation to the Chrysantic notation.

Modern notation, also known as Chrysantic after the name of the main representative of the reform that took place in 1814, Hrysant of Madyt, retained the most important interval signs from the neo-Byzantine notation, *somata* and *pnevmata* (under the name of simple vocalic signs) and the combined signs, and reduced the rhythmic signs to four and the cheironomic signs to five; the latter were re-named *consonant* signs. The Chrysantic reform also resulted in a simplified and unified structure of cadences and of the formulas of intoning the voices. The entire repertoire of the previous period was transcribed according to ”the new system” by its promotors, Hrisant of Madyt, Grigorie the Protopsalt and Hurmuz Hartofilax.

In the Romanian Principalities, the new notation came in use as soon as it was approved by the Patriarchy of Constantinople; in 1817 a school of psaltic music was opened at the the church St Nicholas Şelari in Bucharest, where the Greek singer Petru Efesiu taught. His best pupils were Hieromonk Macarie and Anton Pann, who eventually became founders of the modern Romanian psaltic music. The former published in 1823 in Vienna a group of three books, *Theoritikon, Anastasimatar and Catavasier*, which are essential and indispensable to learn the new notation and to apply church chanting according to the new semiography. The latter, Anton Pann, was also a man of letters, folklore researcher, composer, psalm singer, pedagogue and editor, a complex personality who contributed greatly to the promotion of the new repertoire by publishing in his own printing shop the main books necessary for the church chanting.

Most of the manuscripts at BCUME are written in the new notation. Here are some of them: Ms. II 31, *Canoanele Musichiei / The Musical Canons of Ghelasie Basarabeanul, Anastasimatar and Catavasier* (1866), Ms. III 78, *Stikhirarion or Doxastarion*, by Petru Lampadarie, translated by Ghelasie Basarabeanul and others (1840), Ms. II-157, *Idioms and Praises of the Holy Week,* by Protopsalt Constantin, Ms. III 84, *Chants for the Ceasurile împărăteşti*, Ms. III 15, *Romanian – Greek Antologhion* (1828), Ms. III 36 *Antologhion* in Greek (1830-1842) [19] etc.

We shall lay emphasis on Ms. III 78 mentioned above, since its puts forward a Romanian personality who is less known, Ghelasie Basarabeanu, protopsalt, who was active as psalm reader, transcriber and calligrapher, composer at Curtea de Argeş. As a teacher of music at the Seminar, he transcribed all the books of the church repertoaire in the new system and created new musical versions that were at the same inspired and accessible. Unfortunately, since he was a monk, he failed to obtain the support to print his work during his lifetime. Ghelasie's work remained in manuscript form and only few made their way to the public arena, published in several anthologies; the manuscripts he and his pupils copied and transcribed were discovered only recently. As a result of these discoveries, his personality has been rightfully restored to public recognition – the Byzantinologist Sebastian Barbu Bucur and Priest Ion Isăroiu published four volumes in both semiographies – linear and psaltic – comprising his creation in its most representative elements. His editors legitimately consider Ghelasie to be ”a classic of Romanian music of Byzantine tradition in the former half of the 19th century, along with Hieromonk Macarie and Anton Pann” [20].

Below we present the incipit of a Stichera by Ghelasie Basarabeanu (in 4th plagal voice) [21]:

Fig. 4

4 Conclusions

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Among the approximately 70 musical manuscripts of the Rare Books section within the BCUME, there are invaluable unique manuscripts of national and international importance.

The notations used in these manuscripts prove the continuity of Byzantine music on the territory of Romania and the constant concern for the preservation of Byzantine and psaltic monody in the Orthodox church, especially the Romanian church.

Beside the manuscripts written in Greek in Moldavia during the 19th and the 20th centuries, other manuscripts were produced in the Romanian language in which the modern Chrysantic notation was used. This notation corresponds to a period in which the emerging national music schools became prominent. The main unifying characteristic of the 19th century musical schools of psaltic music is that they actually have the same source, from the period of the states' organization to the end of the Middle Ages. A common set of features can be said to describe the modern music of all Orthodox churches.

Our hope is that the data in the present paper have shed light on a part of the musical treasure stored at BCUME and have restored to the current arena issues related to Byzantine music and its specific notation from the 11th century to the 19th century.

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Chromatic Patterns of Sounds Waves in Java Applets
Coloured Sounds

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Abstract: – The paper herein presents a way in which sound waves are chromatically represented in Java language. It realizes a direct correspondence between visible frequencies of the light and frequencies of sound waves via a sound wave frequency range transformation into a linear scale. Java written software was developed for converting sound wave intensities in colour saturation coefficients. The application allows further development in order to generate a colour visual interpretation of the musical atmosphere and also to develop the performer's creativity. The article addresses the reality in a sensitive manner creating in an undifferentiated manner bridges between face colours and the artistic sensitivity of the human hearing.

Key-Words: - RGB light, Java Applets, sounds waves, music, education

1 Introduction

The sinusoidal time-dependent processes of natural systems are easier to be understood in an interactive way. Most physics systems, including sound and light, seem to have a wave-like behaviour. While light is a transverse electromagnetic wave with an approximately linear scale in the visible region, the sound is an elastic longitudinal wave with a logarithmic frequency scale. In order to point out the main elements concerning the elastic waves, the computer generation of the light spectrum and the possible correspondence between them, a package of applets embedded in a structure of HTML pages were developed. These applets aim at intuitively revealing the following aspects: the sinusoidal behaviour of a sound wave and the possible association of a corresponding colour to each sound frequency; the principle of obtaining a resulting colour mixture derived from the composition of two sounds, composition of perpendicular oscillations; broadcasting the longitudinal and transversal elastic waves; a visual pattern simulation derived from the composition of elastic waves; stationary waves – Column of air and Vibrating string

2 Theoretical Aspects

Some theoretical aspects regarding the equation, which describe the physics phenomena and which are implemented in applications, will be briefly presented. The main issues taken into account are the natural light spectrum and its RGB computer simulation, the sinusoidal time dependent representation of a wave and the possible correspondence between a sound and a color.([1], [2])..

2.1 RGB generation of natural light spectrum

There are illustrated in Figure 1 the absorption spectra of the four human visual pigments, which display maxima in the expected red, green, and blue regions of the visible light spectrum. When all three types of cone cells are stimulated equally, the light is perceived as being achromatic or white ([3]).

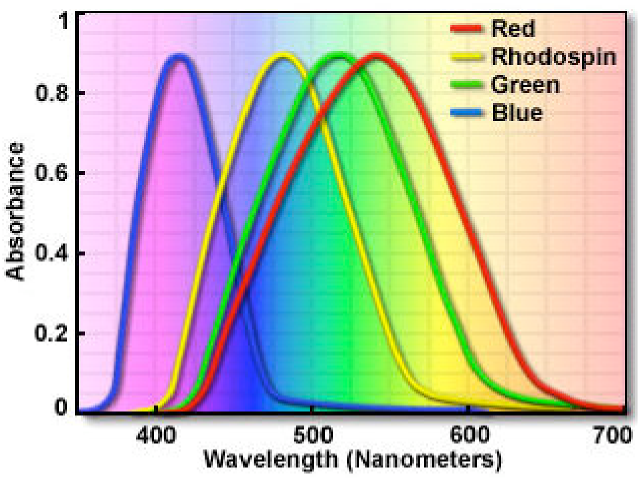

Fig.1 Absorption Spectra of Human Visual Pigments

For example, noon sunlight appears as white light to humans, because it contains approximately equal

amounts of red, green, and blue light. Human perception on colours is dependent on the interaction of all receptor cells with the light, and this combination results in nearly tri-chromic stimulation.
There are shifts in colour sensitivity with variations in light levels, so that blue colours look relatively brighter in dim light and red colours look brighter in bright light. The cone response sensitivities at each wavelength shown as a proportion of the *peak response,* which is set equal to 1.0 on a linear vertical scale, is called *Linear Normalized Cone Sensitivities* ([4]). This produces the three similar (but not identical) curves shown in figure 2. This representation is in some respects misleading, because it distorts the functional relationships between light wavelength (energy), cone sensitivity and colour perception. However, the comparison with the absorption curves of the photo-pigments above identifies some obvious differences between the shape and peak sensitivity of the photo-pigment and cone fundamentals. Overall, human eye spectral sensitivity is split into two parts: a short wavelength sensitivity narrow peak centred on "blue violet" (445 nm), and a long wavelength sensitivity broad band centred on about "yellow green" (~560 nm), with a trough of minimum sensitivity in "middle blue" (475 to 485 nm).

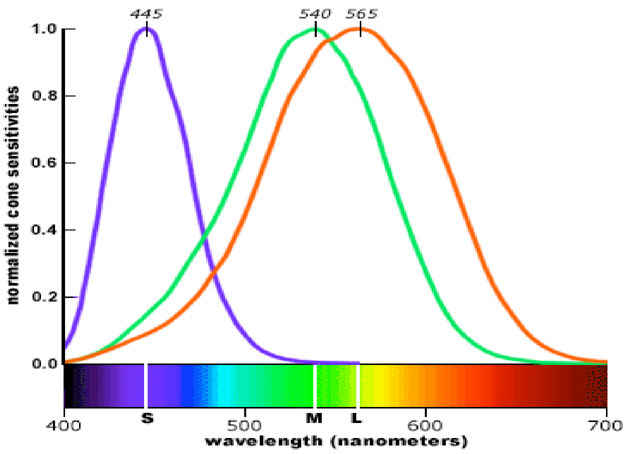

Fig. 2 Normalized Cone Sensitivity Functions

2.2 Free oscillations

Some physics laws such as: the equation of displacement, the equation of velocity and the equation of acceleration are represented by the following mathematical equations [5]: (1), (2), (3), (4) and (5)

$$y = A * \sin(\omega t + \varphi) \quad (1)$$

$$v = \omega A * \cos(\omega t + \varphi) \quad (2)$$

$$a = -\omega^2 A * \sin(\omega t + \varphi) \quad (3)$$

$$\omega = \sqrt{(\omega_0^2 - \beta^2)} \quad (4)$$

$$A = A_0 e^{-\beta t} \quad (5)$$

where

- y is the displacement;
- ν is the frequency;
- ω is the angular frequency;
- β is the dumping (attenuation) factor;
- A is the amplitude of the oscillation.

2.3 Composition of parallel oscillations

Two independent oscillations and the resulting compound motion of these are represented by the equations (6), (7), (8).

a) The equations for the two independent oscillations:

$$y_1 = A_1 * \sin(\omega t_1) \quad (6)$$

$$y_2 = A_2 * \sin(\omega_2 t + \Delta\varphi) \quad (7)$$

b) The equation for the resulting compound motion:

$$y = A_1 * \sin(\omega_1 t) + A_2 * \sin(\omega_2 t + \Delta\varphi) \quad (8)$$

2.4 Mechanical waves

A mechanical wave is a disturbance that propagates through space and time, in an elastic medium (which on deformation is capable of producing elastic restoring forces), usually with transfer of energy.
The harmonic plane wave that propagates on a certain direction OX is described by the equation of propagation (9).

$$\xi(x,t) = A * \cos(\omega t - kx) \quad (9)$$

where:

- ξ is the displacement of the particles of the medium the wave travels in;
- ω is the angular frequency;
- k is the wave number.

If the vector displacement is perpendicular to the direction the wave travels, the wave is called transversal and if it is parallel to this direction, the wave is called longitudinal.

2.5 Composition of waves

In order to simulate the composition of mechanical plane waves a number of four waves were taken into account, a longitudinal and a transversal wave for each of the two main directions - vertical and horizontal. For each of these waves the frequency and the amplitude can be modified.

2.6 Stationary (standing) waves

A standing wave, also known as a stationary wave, is a wave that remains in a constant position. This phenomenon can arise in a stationary medium as a result of the interference between two waves travelling in opposite directions. In this case, for waves of equal

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amplitude travelling in opposing directions, there is on average no net propagation of energy.
The effect is a series of nodes (zero displacement) and anti-nodes (maximum displacement) at fixed points along the transmission line. Such a standing wave may be formed when a wave is transmitted towards one end of a transmission line and is reflected from the other end. Two waves with the same frequency, wavelength and amplitude travelling to opposite directions will interfere and produce a standing wave or stationary wave. The equation of a standing wave is represented as follows (10).

$$\xi(x,t) = 2 * A * \cos\left(\frac{2\pi x}{\lambda} + \frac{\pi}{2}\right) * \sin(\omega t - \varphi) \qquad (10)$$

3 "Coloured Sounds" application

"*Coloured Sounds*" application is written in Java and reveals a chromatic representation suggestion of sounds by associating a corresponding light frequency to each elementary sound frequency. Furthermore, the intensity of the sound is revealed in the application by a properly adapted value of the colour saturation.

3.1 Simulation of RGB generation of natural light spectrum

For the generation of the natural light spectrum, the proposed functions for the three components (RGB) are presented in Figure 3, functions which lead to the spectrum shown in Figure 5.

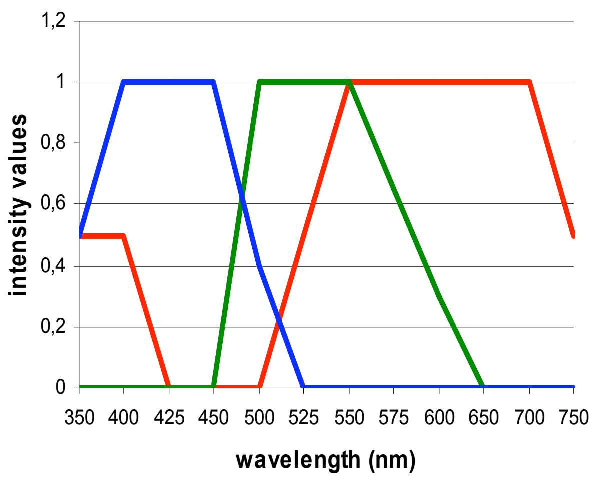

Fig.3 Linear functions for simulating the RGB generation of the natural light.

These functions were defined in a java **public class Light** (Fig.4) [6], as *Light.color* (int. *wavelength*), function which returns the appropriate colour associated to the value of the wavelength argument.

```
public class Light {

public Color color (int wl){
Color color=new Color(R(wl), G(wl), B(wl));
return color; }

public int R(int wl){        int r=255;
if (wl>750)             r=0;
else if (wl>700)        r=(int)(255*(800-wl)/100);
else if (wl>550)        r=255;
else if (wl>500)        r=(int)(255*(wl-500)/50);
else if (wl>425)        r=0;
else if (wl>400)        r=(int)(255*(425-wl)/50);
else if (wl>350)        r=(int)(255/2);
else                    r=0;
return r;    }

public int G(int wl){        int g=255;
if (wl>650)             g=0;
else if (wl>550)        g=(int)(255*(650-wl)/100);
else if (wl>500)        g=255;
else if (wl>450)        g=(int)(255*(wl-450)/ 50);
else                    g=0;
return g;   }

public int B(int wl){        int b=255;
if (wl>525)             b=0;
else if (wl>450)        b=(int)(255*(525-wl)/75);
else if (wl>400)        b=255;
else if (wl>350)        b=(int)(255*(wl-300)/100);
else                    b=0;
return b;    }}.
```

Fig.4. Java-source code for **public class Light**

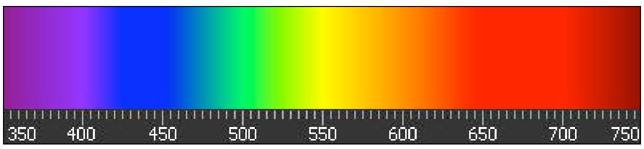

Fig. 5 Light spectrum obtained with the linear RGB functions.

3.2. "The colour of the sound" application

The application presents the time-dependent representation of a sinusoidal oscillation (sound source) allowing adjustments to be made for the frequency and the amplitude. In the lower region of the application panel (see fig.6) the background of a defined window changes its colour according to the frequency and amplitude of the sound. The frequency spectrum of sound waves has a logarithmic scale between the extreme values 20 Hz – 20 kHz while the visible spectrum of light is bounded by the highest wavelength value of 750 nm for red and the lowest wavelength value of 350 nm for violet. By transforming the sound frequencies scale into a linear one, a direct correspondence between the two frequency spectra was established so that the high wavelength light colours (red, orange, yellow) were associated to low frequency sounds and low wavelength light colours (green, blue, violet) were associated to high frequency sounds.

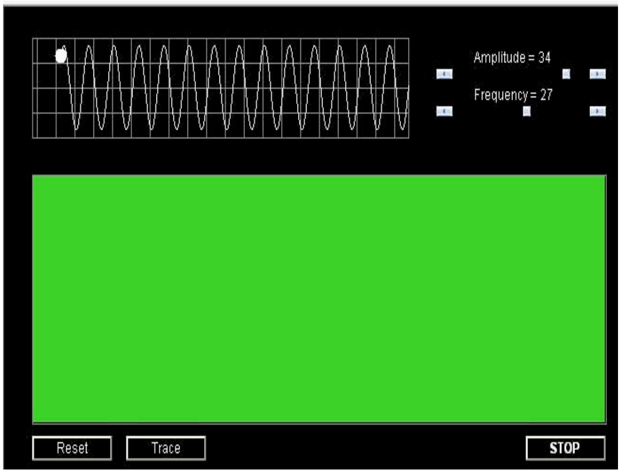

Fig.6 “The colour of the sound” application

The application has the following three buttons: “Reset”, “Trace” and “Stop/Start”. By activating the “Trace” option, the time-dependent movement of a sound source is recorded, simulating the wave broadcasting. The “Reset” option allows actualizing the starting moment for trace registering. The frequency and amplitude of the simulation may be changed at any time using the two sliders placed in the upper right side of the applet.

3.3 “Mixture of two Sounds” applications

“*Mixture of two Sounds*” application is created to the purpose of visualising the resulting colour mixture derived from the composition of two sounds (Fig.7). Mention should be made that combining two sounds does not result in a simple overlapping of the two corresponding colours but in a constructive/destructive composing process both for the intensity and the chromatic range. In figure 5, four strips are visible in the designated colour panel.

The two external strips stand for the colours associated with the elementary sounds while the two inner strips reveal the resulting composed colours which partly cover the previous with a transparency coefficient “*alpha*”, calculated to be proportional with the two elementary amplitudes and frequencies.

Equation (11) reveals the way the transparency coefficient “alpha” is computed:

$$alpha = |(A_1 + A_2) \cdot \cos(k \cdot \pi \cdot t \cdot (\nu_1 - \nu_2))|\,| \qquad (11)$$

where:

- A_1, A_2 – represent the amplitudes of the sounds;
- ν_1, ν_2 – represent the frequencies of the sounds;

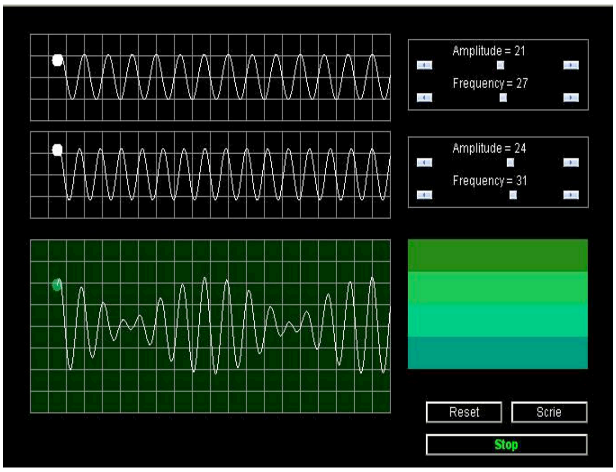

Fig. 7 “Mixture of two Sounds” application

The amplitude and the frequency for each of the two oscillations can be modified using the corresponding sliders.

3.4 “Mechanical Waves” application

The panel shown in figure 8 is built for the *Mechanical Waves* application. This application simulates the propagation of a longitudinal and a transversal elastic wave offering the possibility to modify the amplitude and the frequency (angular frequency) for each wave. Using a Checkbox one may reverse the direction of propagation transforming a progressive wave into a regressive one. A window was included in the screen of the applet. In this window, the particles of the medium wherein the wave travels can be freely reshaped (using the "ZOOM" option) and the interactions between them are simulated using connecting springs which are distorted during the wave propagation.

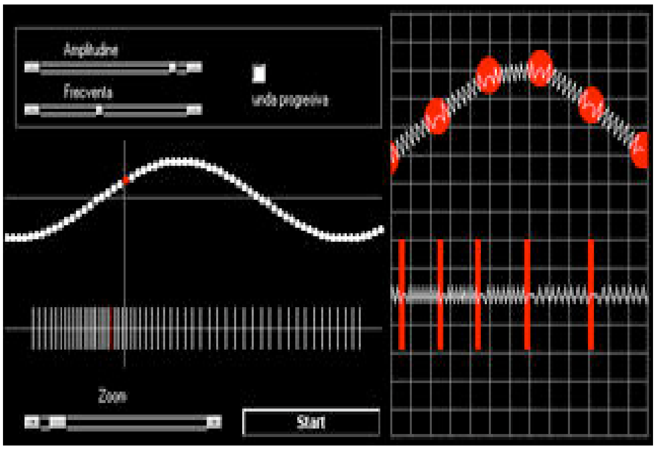

Fig. 8 Mechanical Waves application

The frequency and amplitude of the wave can be modified by choosing the desired position on the scroll bar. Selecting the Checkbox it is possible to reverse the direction of propagation transforming a progressive wave into a regressive one.

3.5 "Composition of Waves" application

The panel standing for *Composition of Waves* application is the one presented in figure 9.

The application allows the visualization of the particles of the medium the wave travels in (using the "ZOOM" option) and the apparent motion of the medium as a visual pattern derived from the composition of elastic waves. In order to be presented in a suggestive way, the medium fragments were coloured according to the oscillation direction and the value of the wave vector.

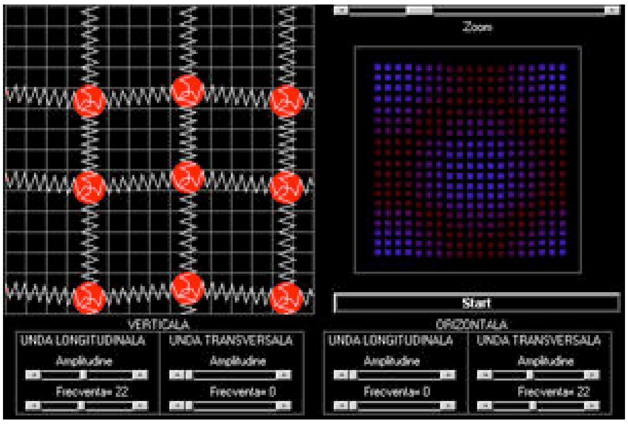

Fig. 9 Composition of Waves application

In the window included in the left side of the applet, the motion of the particles of the medium wherein the superposition of waves travels is simulated. By choosing the desired position on the scroll bar (using the "ZOOM" option) the particles of the medium change their size. The frequency and amplitude of each wave can be modified using the scroll bars „*Amplitude*" and „*Frequency*".

3.6 "Stationary Waves" application

The page shown in figure 10 is built for the *Stationary waves* application.

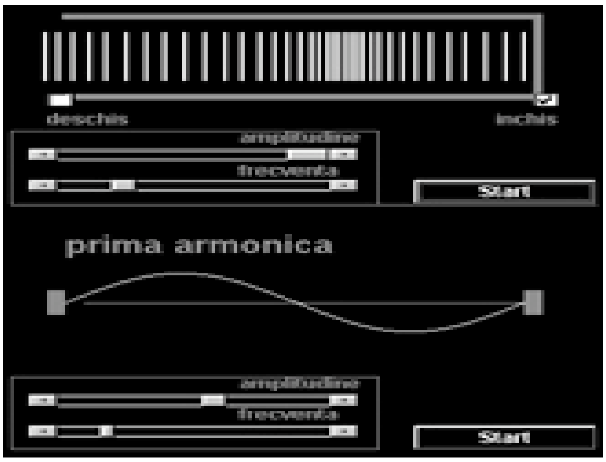

Fig. 10 Stationary Waves application

The application shows both Column of air and Vibrating string case. Increasing the frequency leads to different oscillation modes. Consecutively a standing wave is created, allowing harmonics to be identified. The column of air can be regarded as with a closed or opened end on both sides using the appropriate Checkbox.

4 Conclusion

The present paper can be further developed using a Fourier decomposition of musical signals and combining their corresponding colours in a characteristic visual image. Thus, a visual picture of musical compositions can be achieved. This picture can still be used in creating a psychologically comfortable atmosphere, as a desired effect of a visual image on the human body, ranging up to a physical therapy through music and colours. Of course, the desired effects are to be further investigated. The idea developed in this paper may have important educational valences by stimulating the interest for sounds and colours and by widening the reality perception area. On the other hand, the application developed in this manner can be successfully used in the e-Learning and distance Learning systems for the benefit of pupils and students. Being a Java based application it can be also easily integrated in web pages.

The idea of using applets as a teaching tool, both in face-to-face and online learning, is quite extended. The content of the lecture does not change, but the methods intend to improve the students' attitude towards active learning [7]. The best option is to use graphical and interactive tools in two ways. On one hand, these tools help the teacher in the classroom; while on the other hand, the students can work and experiment making their own examples, outside the classroom [8].

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The Modal Palindrome – A Structural Matrix and A Generative Mechanism

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Abstract: - Generative symmetry is a fundamental issue of the musical language. This paper investigates the polysemy of the palindrome-modal systems, aiming to evidence their matrical-structural and generative-syntactic potential values. The foundation of our argument consists in some representative works by composers Anatol Vieru and Mircea Chiriac, whose conceptual strategies focus on interdeterminism and the fusion of sonorous elements within the macrotemporal binome: syntagmatic-paradigmatic.

Key-Words: - symmetry, palindrome, matrix, mode, generative syntax, geometric harmony, Chiriac, Vieru

The word **palindrome** comes from Greek, where 'palin' means 'again' and 'dromos' means 'path'. Originated in the School of Alexandria, having the Greek poet Sotades of Keroneea (Thrace, 3rd century B.C.) as a hypothetical author, the palindrome is introduced as a formulation built around a **centre of symmetry** – a mirroring process which reflects the principle of identity (irreversibility) according to which: 'left-right' = 'right-left'. Let us mention, in this sense, the famous Latin palindrome SATOR AREPO TENET OPERA ROTAS, whose symmetry axis is represented by the letter N in the middle of the palindromic word TENET.

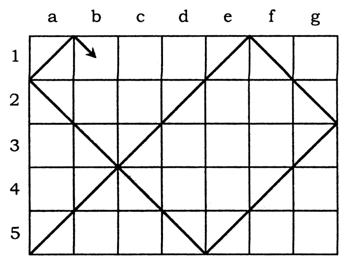
To generalise, let us demonstrate that "any palindrome **x** having an even length **2n** can be conceived as the result of the concatenation of its prefix having the length **n** with the mirror image of this prefix. If the palindrome **x** has the odd length **2n+1** and **y** is the prefix of **n** length of palindrome **x**, then we get **x** = **ycy''**, where **y''** is the mirror image of **y**, and **c** is the term of rank **n+1** of **x** " [3]. Hence there is a relation of determination between the palindromic structure and the mirroring principle, their common denominator being the phenomenon of **symmetry**.

Another organic (natural) connection occurs between palindromes and **periodicity**, and one of the best areas of manifestation is music, specifically modal structures base on **strings**.

Composer Anatol Vieru [5] developed and applied, to his own works, a compositional algorithm based on the string of prime numbers (the *Sieve of Eratosthenes*). Investigating the chronogenesis of the musical opus, Vieru notes that the product of prime numbers is capable of generating palindromes (called 'non-retrogradable blocks' by Messiaen – rhythmic aggregates that read the same by recurrence: {5,3,2,7,2,3,5}).

As grounds for demonstration, let us take the product of 5 and 7, which can be expressed by means of a rectangle having the dimensions 5 and 7, respectively:

Fig. 1



Drawing successive diagonals from one corner of the rectangle and 'ricocheting' off every side, we notice that all 35 cells of the rectangle can be intersected in one line. For instance, the line starting in **a5** will have the following direction: (a5,b4,c3,d2,e1), (f1,g2), (g3,f4,e5), (d5,c4,b3,a2), (a1), (b1,c2,d3,e4,f5), (g5), (g4,f3,e2,d1), (c1,b2,a3), (a4,b5), (c5,d4,e3,f2,g1). Thus, for the itinerary between **a5** and **g1** the string of cycle lengths is 52341514325, a palindromic sequence where the sum of the terms is 35. Moreover, we notice that the structure of this palindrome includes the structures {5,5,5,5,5,5,5} and {7,7,7,7,7}.

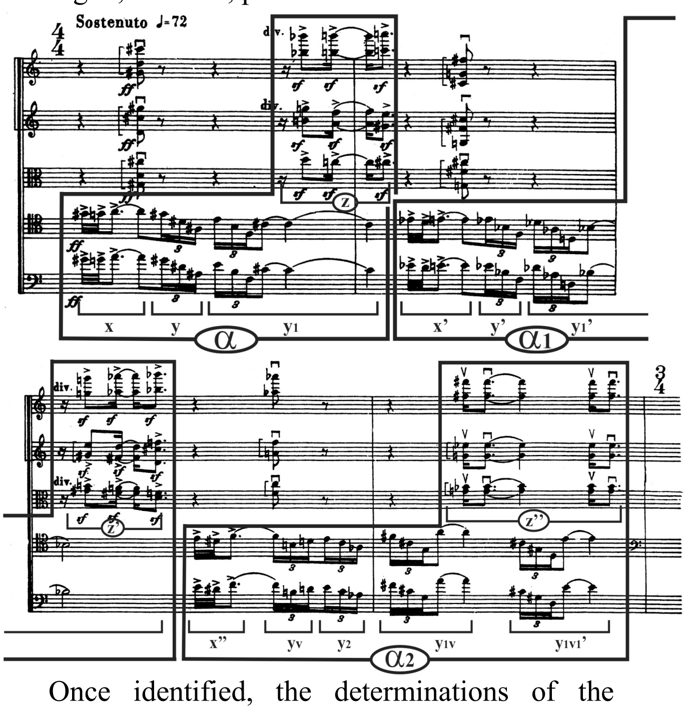
On the same grounds, Anatol Vieru analyses the palindromes obtained by multiplying 5 by 7 by 4; 7 by 11, and so on, elaborating generative matrices (genuine rhythm studies) which he makes use of in his works *Soroc* (*Deadline*), *Odă tăcerii* (*Ode to Silence*) or *Cvartetul de coarde nr. 6* (*The String Quartet n° 6*).

Starting from the generative prerogatives of the palindrome-modal matrices, the composer Mircea Chiriac succeeds in clearing up globally an entire symphonic opus, all the three parts of the *Concerto for orchestra* being circumscribed to this strategic concept.

Part I is prefaced by a short **Introduction** (bars 1-13) which displays a **matrix-structure** able to manage the entire musical evolution.

The pith of the introductory step is concentrated in a complex **theme** (see Fig. 2) of binary morphology **(a+b)** which explores exhaustively the resources of the **generative symmetry**. In this context, segment **a** (bars 1-4) develops the principles of the **translation symmetry** into a **cellular-motivic algorithm of the sequential type** generated by the complementarity of the melodic-harmonic levels under the incidence of the relations existing between the microstructures **x**, **y**, **z** within the **α module**. Although the cellular binomial {**x**+**y**} sustains a ***proposta*** that suggests the occurrence of a quasi-autonomous formulation, the **responsive** (harmonic) complement **z** amplifies triadically the **α** thematic module rendering it (through integration) structurally and semantically relevant to a full extent.

Fig. 2, bars 1-4, p. 3/PG



Once identified, the determinations of the expositional incipit converge towards this **triply-sequential** grid:

α = {x + (y+y1) + z} +

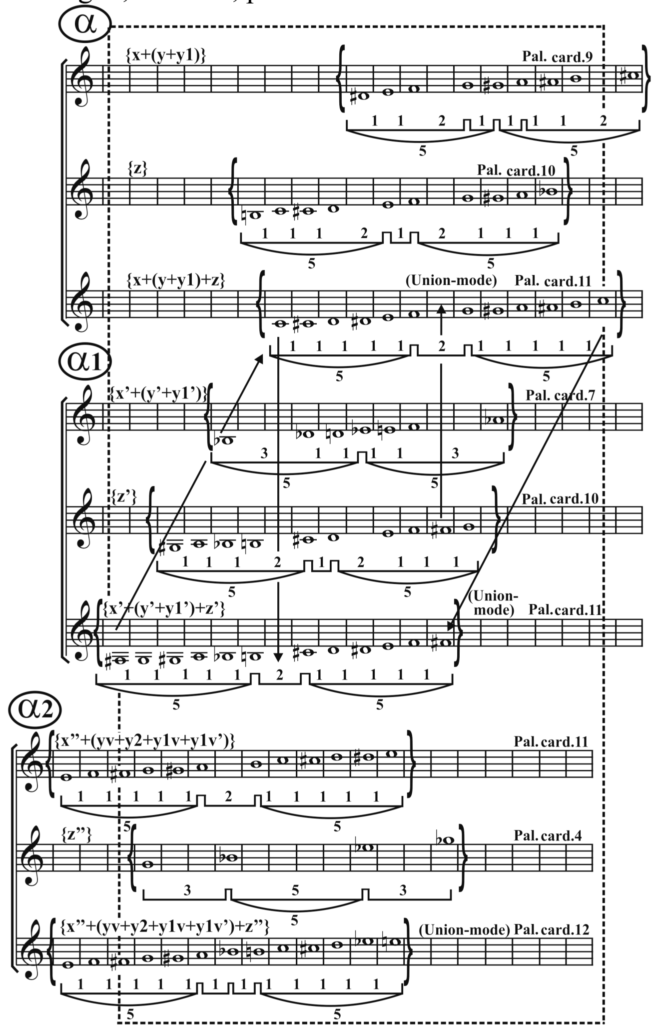
α1 = {x' + (y'+y1') + z'} +

α2 = {x'' + (yv+y2+y1v+y1v') + z''}

If the principles of the **translation symmetry** have governed the articulation of the morphological and syntactic levels, the modal system of the first thematic segment is owed to the **mirror symmetry** which generates **palindromic** structures with axis-sound or with axis-interval (see Fig. 3).

As can be observed, the sonorous material of the thematic matrix is organised in an **organic corpus** of intonational systems located symmetrically around some axes, palindrome-modal entities corresponding to the three sequential modules: **α**, **α1** and **α2**.

Fig. 3, bars 1-4, p. 3/PG



One first observation refers to the **tetrachordal-chromatic** basis of each system, where the conjunction/disjunction by means of the **fourth** – an interval produced by the configuration of the melodic line itself (the **y** cell with its derivatives) – becomes a generalised **congruence frame**. A second observation pertains to the maximum **density *modulo 12*** – a modal-chromatic integral unusually positioned at the very beginning of the *Concerto*.

Corroborating these two general references, we discover that the **translation symmetry** of the melodic level (accurately reflected into the relation of the union-modes **α**, **α1** and **α2**) is systematically doubled by the non-retrogradable **bilateral symmetry** of each structure.

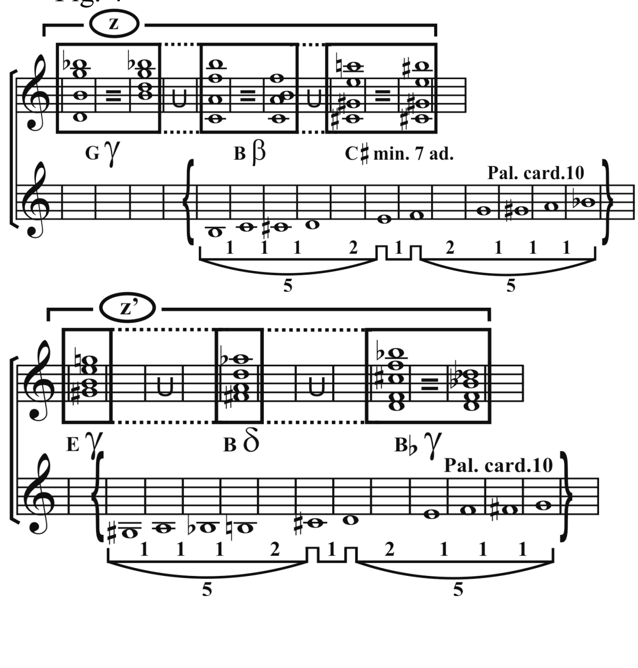
The modules **α**+**α1** have an identical modal structure: {1,1,1,1,1/2/1,1,1,1,1} – palindrome of cardinality 11, resulting from the union of the sub-modes: {**x**+(**y**+**y2**)}U{**z**}, and: {**x'**+(**y'**+**y1'**)}U{**z'**}, respectively. They form around the tritonic axis **C-F#**, thus establishing a relation of complementarity ***modulo 12*** (see the vertical arrows that indicate the sounds-symmetrical difference).

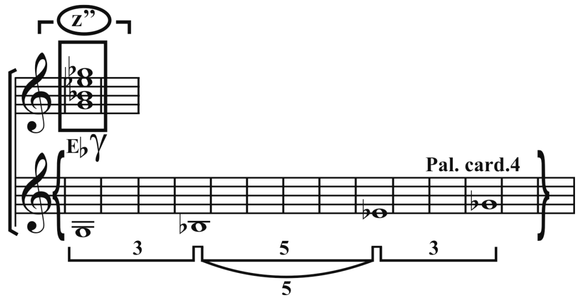
In exchange, the module **α2** (the second sequence, amplified) possesses a reversal of levels, in that the palindrome of cardinality 11 {1,1,1,1,1/2/1,1,1,1,1} is attributed to the submode {**x''**+(**yv**+**y2**+**y1v**+**y1v'**)}, while the submode {**z''**} is reduced to a palindrome of cardinality 4 (a type **α**, segment **γ** geometric structure). Evidently, the union of the two sub-motivic entities engages the **total chromatic**.

In this context of generalised symmetry, it is appropriate to develop a few considerations on the **modal-harmonic** structure of the cellular triad {**z**→**z'**→**z''**}.

As underlined in the beginning of our analysis, this significantly contrasting sub-motivic entity occurs in a **responsive** manner, justifying its adherence to the thematic matrix (induced by the conjunction of the cells **x**+**y**) by the **complementary-harmonic** function.

Fig. 4



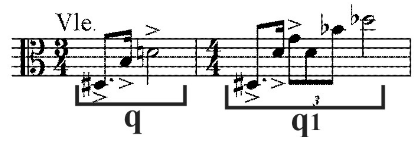


Contrary to the minimal appearances induced by the reductive path of the descant, the harmonic complex of the **z** cells reflects the symmetrical arrangement [2] on structures of chordal layers **α** [4]– **β**, **γ** and **δ** segments –, materialised either in the palindrome-submodes of cardinality 10 having reversed extremes: {1,1,1,2/1/2,1,1,1} – for the cells {**z**→**z'**}, or in the palindrome-submode of cardinality 4 having identical extremes: {3/5/3} – for cell **z''** (see Fig. 4).

The rigour of the thematic construction in Introduction directs all the advancing processes in **Part I**, moulded in the form of classical **sonata**.

From this perspective, the **Exposition** (bars 14-50) begins with a theme derived from the first segment of the Introduction.

Fig. 5



T1 distinguishes itself by a particular significance. When we assert this we have in view the relevance of the concision and the austerity of expression due to the incisive motif **q** (structure **α**, segment **γ**), on the one hand, and especially the perfect analogy with the **leitmotif** of the ***Patricide*** (*Laius*) in George Enescu's opera, ***Œdipe***. Both here and there, the geometric structure of segment **γ** predisposes to a certain 'rhetoric of ambiguity' due to the 'contradictory' interval of diminished octave (8-). This remarkable expression of the strained expectation face to the unpredictable and/or the imminence (considering it, obviously, in connection with the semantics of the Enescian leitmotif) is potentiated by Mircea Chiriac by juxtaposing conjointly two **α** microstructures, segments **B γ** and **G γ** [1].

The modal synthesis of **T1** – the motifs **q-q1** – points out the consistency in applying the principles of **generative symmetry** launched (strategically) in the original sector, as the detailed structure of the axial branches (upper layer-lower layer) – related to the sonorous substance deduced from the process of **virtual union** – demonstrates

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that the two cellular-thematic microstructures belong to the reference modes **1:2** (**B γ**) and **2:1** (**G γ**), respectively.

Fig. 6

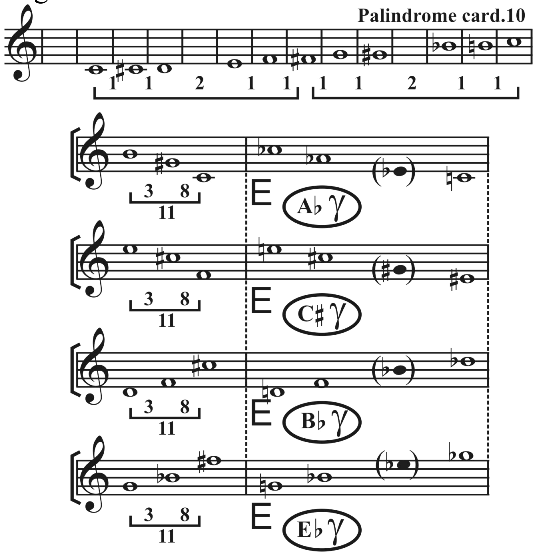
However, the generative mechanism induced by the palindromic matrix acts strategically on the syntagmatic axis establishing macro-temporal correspondences. By analogy, the geometric-harmonic latencies mentioned in Part I are multiply hypostatised in a polyphonic-imitational agglomeration which marks the beginning and the development of Part III.

Thus, the segment between bars 6-12 offers in the first stage one of the most edifying examples of cellular-motivic processing of a pre-serial nature, as the composer – in keeping with the modal algorithm based on **palindromic symmetry** – creates a true 'mosaic' of microstructural **permutations** potentiated polyphonically by imitational *stretto*.

Fig. 7, bars 11-12, p. 18/PG

Designed horizontally (in arpeggio), these entities, which are generically dissipated in the quasi-totality of Part III of the *Concerto*, are partitions of the **α** chord, more precisely, **γ** segments whose union leads to a modal palindrome of cardinality 10.

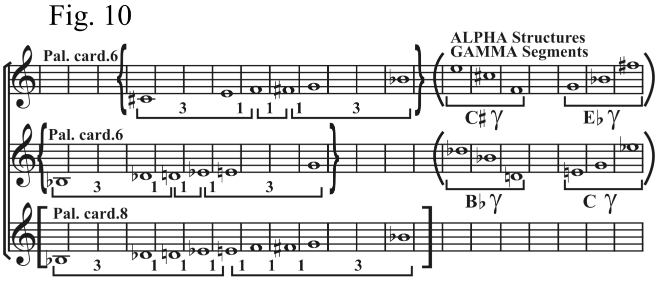
Fig. 8



The observation of a similar context (bars 25-30) highlights the **organic connection** between these microcellular units and the modal matrix of the theme (the **β/z+z'** motif), and the material of the juxtaposed segments unites in a modal palindrome (of modal palindromes) of cardinality 8 (see the intersection of the two submodes, the density of each being 6). It is equally important to note that the instance of variational labour to which we are referring holds a **multiple syntactic functionality**, in this case being a counterpoint of the theme in the Chorus.

Fig. 9, bars 25, p. 20/PG

Fig. 10



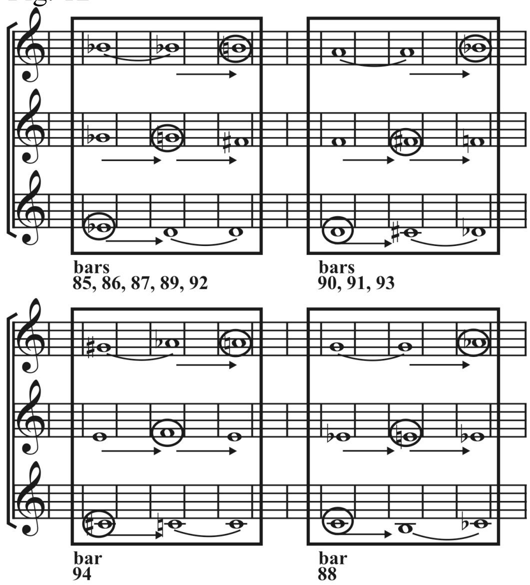
The modal-palindromic morphogenesis is polysemous and dissipative, and the harmonic paradigm merely confirms the level of complexity attained by the generative symmetry.

To make things clearer, we shall go back to Part I of the *Concerto* where **T2** is engaged in an *ostinato* based on the **quadruple symmetrical translation** of a **harmonic scordatura-module** of **panchromatic** extension.

Fig. 11, bars 85-94, pp. 9-10/PG

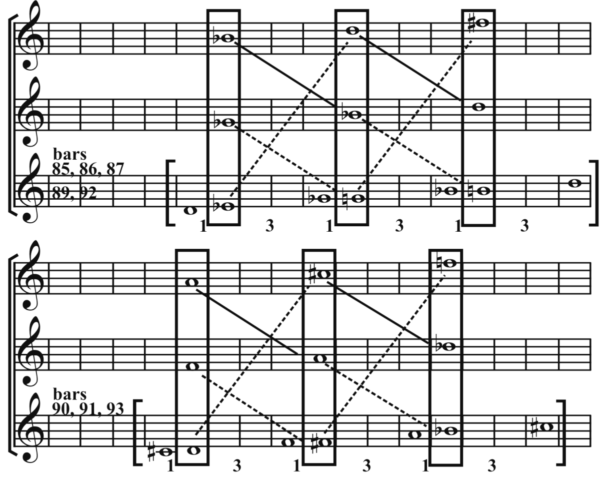
In the context, each harmonic module consists of three distinct minor chords whose fundamentals are located at an interval of 3M/6m. The juxtaposition of the chords reflects the application of the **scordatura** based on a combination of semitone 'glide' (↑/↓) and common sounds (see Fig. 12+13). The intermodular connection of the minor triads generates oppositions of 8- (sometimes expressed by 7M), and chronology conforms to the constant grid: root position, 2nd inversion, 1st inversion.

Fig. 12



Consequently, each scordatura module exhausts the sonorous availabilities of the octaval symmetrical system 1:3, the union (intersection) of the four harmonic sequences clarifying the reference set *modulo12*. Besides, a similar spread of the panchromatic environment also results from the virtual union of the four sections of chordal fundamentals (4 x 3 = 12).

Fig. 13



Legend:
1. The dotted line - ST shifts ↑↓ 2. The continuous line - common sounds
SCORDATURAS

The issue approached above enters the realm of the applied research of modal systems organised according to principles of symmetry, complementarity and transposition. The examples analysed highlight the palindrome structures as a double-articulated generative matrix: syntagmatic and paradigmatic.

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Beneficial Subliminal Music: Binaural Beats, Hemi-Sync and Metamusic

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Abstract: - The present study describes the usage of subliminal music set to incur beneficial effects on the human mind and body through the Binaural Beats and the Hemi-Sync technologies. The Binaural Beats technology was discovered in 1839 by the German physicist Heinrich Wilhelm Dove (1803–1879) and tested on the encephalograph by the American biophysicist Gerald Oster (1918-1993) in 1973 at Mount Sinai School of Medicine in New York. The Binaural Beats uses are carried out by blending them into music or other sounds. This procedure represents a recent discovery in the music therapy field as well as a new brain training technique studied and tested in many research centers and universities.

Key-Words: - subliminal music, Binaural Beats, Hemi-Sync, Metamusic, Frequency-Following Response, brain waves, cerebral hemisphere

1 Introduction

„The greatest illusion is that mankind has limitation." Robert Monroe

The present study describes the usage of subliminal music set to incur beneficial effects on the human mind and body through the Binaural Beats technology and Hemi-Sync technology. A large number of scientific studies focusing on the phenomenon of subliminal perception in the second half of the 20th century have revealed the negative effects of subliminal messages hidden in the musical discourse. Results based on scientific data have shown that „information acquired subliminally will be integrated subconsciously and unconsciously, subliminal programming thus becoming an instrument used to influence and alter behaviors." [1] Due to recent developments, subliminal music may presently be used to improve people's health.

2 The influence of vibrations on the human body. The phenomenon of resonance

We can hear not only by means of the auditory analyzer, but also by means of the neuro-cerebral system: „it is obvious that the auditory system can act solely via connection to the nervous system. The human body is like a resounding instrument."[2] Both musicians and music therapists, Steven Halpern and Louis M. Savary have put forward the idea that" if on one hand our body cells and our senses may be looked at as vibration transformers, on the other hand the whole body is an instrument that releases its own vibrations and sounds. Some such as breathing rhythm and heart beats are audible, whereas others are more subtle and more profound and seem to escape us. Were we endowed with the appropriate auditory apparatus we could <<hear>> our own harmony." [3] The human body captures the vibrations, then internally transforms them into emotions and responds through its own vibrations, its own music. Menuhin stated that „there is sound right in the middle of the vibrations' cycle. I am very sure that music helps us stay in touch with all the vibrations in the world. When the lowest sounds of a big church organ are heard, we can feel the vibrations in the whole body: also the violin which releases sounds up to the seventh octave has a similar impact on us" [4]. The human body responds to a sound with another sound due to the resonance phenomenon. While the science phenomenon of resonance has been known for a long time, its impact on health has just recently been studied. In 1665, The Dutch physicist and mathematician Christiaan Huygens (who is also the scientist who developed the undulatory theory of light) noticed that two pendulums located one next to the other on the same wall show a tendency to synchronize their oscillatory motion, getting the same rhythm by a mutual transfer of energy [5]. In fact, the two pendulums mutually synchronize their own frequency. Similarly, sounding a tuning fork which emits a sound wave with a constant frequency of 440Hz, will determine another sounding fork to start vibrating spontaneously in response to the sound waves released by the former. Resonance has an impact on the whole universe and manifests itself at sound, electromagnetic, nuclear and gravitational levels. If we carefully listen to the effect that a speaker has upon some glasses positioned in its vicinity, apart from the music from the speaker we will perceive some other sounds emitted by the glasses that have started resonating with the vibrations from the sound source. Upon trying various types of music we will notice that vibrations bear different impact on the glasses. The same is true when the human body is in contact with sound vibrations, in cases such as being in a concert hall, or producing sounds ourselves. Not all sound sources have a positive impact on health: for instance, atonal contemporary music creates a physical and mental state of discomfort in the body by the multitude of dissonances, and so do hard rock and heavy metal music, as well as the noise in the surrounding environment. Doctor of alternative medicine Masaru Emoto (b. 1943) made it possible to visualize the effects of vibrations generated by music, words, and feelings based on research results related to wave fluctuation measurement in water. Frozen water crystals previously subjected to vibrations were photographed in special conditions and showed that due to resonance, the transmitted vibrations had changed the water's crystallographic structure to a great extent. In Masaru's opinion, this structural modification is valid in the case of water contained by the human body as well, taking into account that water in the human body amounts to a huge ratio (90% at birth, 70% in adulthood and 50% in old age). The classic music „that we exposed the water to resulted in well-formed crystals with distinct characteristics. In contrast, the water exposed to violent heavy metal music resulted in fragmented and malformed crystals at best." [6] The picture gallery authored by Emoto comprises harmonious images of crystals created using pieces by composers Bach, Vivaldi, Mozart, Beethoven, and Tchaikovsky.

3 Frequency-Following Response (FFR) and Binaural Beats history

The resonance phenomenon accounts for brain waves-related occurrences. Even though by nature people are characterized by a specific combination of different brain waves, research shows that related individuals exhibit a cerebral synchronization of as much as 90%. These findings have created opportunities for assessing phenomena such as empathy, telepathy, and couple affection. As well, it has been found that when brain was subjected to visual, sound or electric impulse, it had a natural tendency to synchronize itself with the transmitted impulse. The phenomenon was called Frequency-Following Response (FFR). For example, when the cerebral activity induced stress in the body and the subject was exposed to a different frequency stimulus corresponding to a state of relaxation, the brain would modify its activity due to resonance with the induced pattern. These investigations were the starting point that led to the discovery of frequencies called Binaural Beats. The technology was uncovered in 1839 by the German physicist Heinrich Wilhelm Dove (1803–1879) and tested on the encephalograph by the American biophysicist Gerald Oster (1918-1993) in 1973 at Mount Sinai School of Medicine in New York.

4 The biological effects of the Binaural Beats on brain waves

The Binaural Beats phenomenon occurs when two sounds of different frequencies are released in a headset each in one ear and the brain makes the frequency difference between the two sounds. The brain processes the two different sounds of 1000Hz maximum frequency and creates the sense of a third sound called Binaural Beats. This sound must not exceed 30Hz so that the brain may be stimulated in a positive way only, thus inducing the desired cerebral wavelength. The audible sound wave frequency ranges between 30 and 15000 vibrations per second. Given the fact that humans do not perceive infrasound-ranging sound waves less than 30Hz, this special technique comes in necessary to „trick" the ears. Electronics and the computer science applied to music make it possible to use these frequencies via some special sound waves. Depending on the stimulus frequency, a certain cerebral wave corresponding to a certain state of the body is induced. To conclude, Binaural Beats are in fact a subliminal aural message because they cannot be captured by the human ear and are perceived unconsciously at brain level.

For example, if a sound of 510Hz frequency is released in the right ear and another of 500Hz is simultaneously released in the left ear, the difference of 10Hz will be perceived and decoded by the brain which in turn will be stimulated as a reaction to the new sound generated by this innovative technique. Binaural Beats are brain's auditory responses

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coming from the superior oval nucleus of each cerebral hemisphere. (Fig.1)

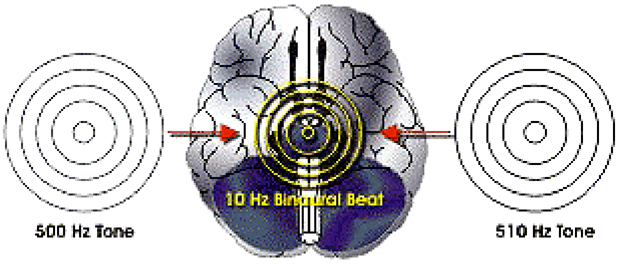

Fig.1 Graphic representation of the Binaural Beat wave

„In the case of binaural beats, the brain acts like a mixer. These impulses encourage mental training. In ancient cultures monoaural beats were used to induce a state of trance in the brain using rhythmic drum sounds and other instruments that generate such waves, a specific example being the Zulu and the South American rituals." [8]

The brain is in a permanent flow of electric and chemical activity, releasing electric impulses called brain waves: Delta, Theta, Alpha, Beta, and Gamma whose combinations determine an individual's different states of conscience. In order to understand the underlying principles in beneficial subliminal music it is necessary to understand our brain waves activity. The states of conscience are associated with brain waves frequency patterns illustrated by the electroencephalograph. These waves frequency calculated in Hz varies depending on the individual's state of conscience. The brain waves used in the binaural technology have been categorized into four frequency bands which correspond to the four frequency patterns reflecting different brain activities. Delta waves ranging between 0.5Hz and 4Hz correspond to deep physical and mental relaxation of deep, dreamless sleep. They also define the clinic condition of unconsciousness and are produced in either self-degeneration or self-healing processes. Theta waves which are located between 4Hz and 8Hz accompany deep meditation and REM dream-type sleep. They also associate with artistic, creative processes as well as with eager study habits. Children, more than adults, are by nature in the Theta stage, therefore learning and retaining information is much easier for them. Alpha waves have a frequency ranging between 8Hz and 14Hz and characterize the vivid yet relaxed state of conscience, calm and receptive mind, and are typical of meditation. Beta waves ranging between 14Hz and 30Hz underlie our fundamental activities related to survival and are associated with brain's alert intellectual activity. The EEG signal dominant frequency establishes the brain's state: if, for instance, the Alpha wave amplitude is higher than the others', the brain is in the Alpha state. If Beta waves are predominant and a 10Hz stimulus corresponding to Alpha waves is induced, the cerebral activity will change and get synchronized with the frequency to which it was exposed, thus changing the individual's mood. When leading the cerebral cells to a certain „emission" state is desired, it is necessary to apply a frequency corresponding to their „wavelength" at that moment, after which the frequency will be increased or decreased so that the brain may be in continuous resonance with the induced stimulus until the desired state is reached. The cerebral synchronization occurs naturally on a day-to-day basis but only incidentally and on short term periods. The majority of people in modern society use the vigil state of their brains, leading to Beta wave predominance. This wave frequency is typical of analytic thinking as well as permanent tension, concern and anxiety, based on which most of the cerebral wave transformers attempt to convert Beta waves in Alpha ones.

5 Applications of Binaural Beats and their biological effects

The easiest methods of brain stimulation are put into practice using auditory and visual subliminal stimuli. Many companies have applied the Binaural Beats technology in creating the so-called Mind Machines which induce the desired state in the brain thus yielding similar effects to yoga meditation, autogenous training, but in a much shorter time and through easier techniques.

Fig.2 Reson-8

One such device is Reson-8 (Fig.2), a miniature Binaural Beats generator that synchronizes the cerebral hemispheres to the Alpha, Theta or Delta wavelengths. Reson-8 is equipped with a microprocessor containing eight audio programs on different frequencies: three programs for inducing

Alpha waves, three for Theta waves, and two programs for Delta waves. The use of the device is very simple, requiring mere program listening using a headset. Reson-8 was created to improve the learning processes, to help cure insomnia and headache, addiction to medicine, drugs, alcohol, or smoking, and to support excessive weight loss. Ronald Montplaisir from Saint Louis, State of Missouri (USA) shared his experience using Reson-8 wave generator „to help me learn to create more endorphins so I could quit taking morphine. I have a rare bone disease (Erdheim-Chester). [...] I searched the Internet and found the brain wave generator. I set up a 10 voice profile and used it for 4 months almost non stop day and night. Next month I stopped taking Zoloft and 13 months later I was completely off pain killers. From time to time the pain rises up and I use the generator for a few days. [...] My case is very well documented and I would be happy to discuss it. This technology is quite remarkable." [9] Rod Paille from Mount Carmel, State of Illinois (USA) stated that „for years I have been suffering from cycles of insomnia, sometimes sleeping only 4 hours a night for days in a row. As owner of a health food store I have access to all herbal products for sleep. These would help sometimes but only for a while. [...] When I tried the brain wave generator I was able to design some presets that have worked extremely well for me. I fall asleep easily and if I wake up usually a few minutes with the tape is all it takes. My insomnia has decreased by at least 90%. I am greatly impressed!" [10]

The subliminal cell phone is one of the Samsung Company's notable achievements, apart from cell phones capable of fingerprint recognition or movement detection. Samsung SCH-S350 promoters state that this cell phone can induce Alpha waves in order to increase mental vividness and focus. The Alpha waves are released by a cell phone-integrated MP3 player.

6 The Monroe Institute: Hemi-Sync sound technology and Metamusic

The Binaural Beats phenomenon was also researched by Robert Monroe at the research centre bearing his name The Monroe Institute (TMI), founded in 1974 and aimed at the human potential development. In his experiments, Monroe proved that certain sounds can be mixed to the outcome that they modify the cerebral activity, triggering a change in the individual's mood from deep relaxation or sleep to expanded consciousness states. The technology studied and developed by Monroe based on the Binaural Beats phenomenon was called Hemi-Sync. Robert Allan Monroe (1915-1995) was an American engineer, business person, inventor, a pioneer in investigating the human consciousness, a radio station producer and director, and was also known as a radio, TV and cinema music composer. In 1956 he created a research and development department to study the effect of various sound patterns on human consciousness. He initiated experiments of methods and techniques aimed at learning processes acceleration, including the possibility of learning while sleeping. Furthermore, Monroe worked in close connection with physicists, biochemists, doctors, psychiatrists and psychologists to add more perspective to his initial findings. His preliminary studies were published in his first book „Journeys Out of the Body" (1971) available in 8 languages. His research led to remarkable discoveries on the nature of human consciousness. In 1975 Monroe patented the scientifically-based and clinically proven audio technology called Hemi-Sync. Monroe's research initiated a whole mind-focused audio products industry that have since benefited millions of people. Monroe Institute's programs are coupled with Metamusic CDs to benefit and entertain the listener which do not contain subliminal messages. Metamusic combines Hemi-Sync technologies with different types of music, from classic to New Age music.

6.1 Metamusic examples

Examples of metamusic audio materials released by The Monroe Institute: „Einstein's Dream" is aimed at intensifying mental abilities using the Mozart Effect [11]. It addresses the spirit and the intellect, stimulating focus and imagination. It is also meant to help patients suffering from Attention-Deficit Hyperactivity Disorder (ADHD), dyslexia and other learning challenges. The CD includes Albert Einstein's favorite pieces, i.e. Mozart's thaumaturgic Sonata for Two Pianos in D major, K. 448 to which the Hemi-Sync sound technology was added in order to facilitate the desired cerebral synchronization. „Portraits" use Hemi-Sync sound technology to balance and focus the brain and includes music by Bach, Mozart and Beethoven in recognition of their genius. The CD is exploring the imaginary possibility for the three composers to create using the presently available technology and puts forward a reevaluation of the existent audio material. „Baroque Garden" contains pieces composed by Bach, Vivaldi, Corelli and Albinoni combined with the Hemi-Sync technique in order to create a suitable environment for concentration and creativity. The music on this CD is interpreted by Arcangelos Chamber Ensemble and produced by Richard Lawrence and Joshua Leeds. For instance, the first entry on the CD is the second part Largo in Vivaldi's Concerto for Oboe and Violin, RV 548. Comparing the original to the recording, it may be noticed that the musical form's integrity in the original composition has been maintained, although some modifications are present as follows: the three instruments in the original piece - oboe, violin, and harpsichord have been reduced to two - a violin and a flute that replaces the oboe, the harpsichord was eliminated; the recorded version is a simplification of the soloist melody line obtained by eliminating the melody ornaments and theme variations; the violin's figurative accompanying performance in arpeggios is rendered pizzicato. All these alterations were performed for the recording to accomplish the CD's declared vision of a „Baroque Garden". The audio material rearranged by Richard Lawrence does not infringe on the beauty of the original composition: it offers a new perspective to which value was added by means of interpretational accuracy.

7 Richard Lawrence and the Advanced Brain Technologies (ABT) Music

Richard Owen Lawrence (1946-2005) was musical director of the Arcangelos Chamber Ensemble and Advanced Brain Technologies (ABT) Music and member of The Listening Program Product Development Team. Born in Troon, Scotland, Lawrence was a violinist, composer, orchestrator, producer and sound engineer and combined his artistic talent to his sound engineering skills. At 12 years of age he won the Edinburgh Music Festival trophy and went on to study the violin at The Royal Scottish Academy of Music in Glasgow. He studied under the Amadeus Quartet's guidance, was a member of the BBC Orchestra in Bristol and of other orchestras and chamber music ensembles in Europe, Canada and America thus completing a vast repertoire. He produced audio recordings for ABT aimed at focus development, learning, thinking, motivation, productivity, inspiration, and relaxation support. Similar to other metamusic recordings, is a series of CDs containing reorchestrated classic music whose parts have been reconnected in order to increase the targeted aim's effectiveness. For instance, „Music to Relax" is focused on mental relaxation, rest and rejuvenation, muscular hyperactivity decrease, and reflective ability improvement and contains the following musical pieces: 01. Bach - Arioso from Concerto for harpsichord, strings and basso continuo No. 5 in F minor, BWV 1056; 02. Beethoven - Adagio from Piano Concerto No. 5 in E flat Major („Emperor"), Op. 73; 03. Chopin - Largo from Sonata No. 3 in B minor, Op. 58, CT. 203; 04. Corelli - Adagio from Concerto Grosso in G minor („Christmas Concerto"), Op. 6, No. 8; 05. Schubert - Andante from Piano Trio No. 1 in B flat Major, D. 898; 06. Bach - Air from Orchestral Suite No. 3 in D Major, BWV 1068; 07. Bach - Adagio from Concerto for 2 harpsichords, strings, and basso continuo in C Minor, BWV 1060; 08. Vivaldi - Largo from Concerto for violin, strings and basso continuo in A minor Op. 3, No. 6, RV 356; 09. Schumann - Träumerei from Kinderszenen for piano, Op. 15/7; 10. Bach - Arioso from Concerto for harpsichord, strings and basso continuo No. 5, in F minor, BWV 1056. The musical pieces have been selected based on his research and experience as a violinist on one hand and his studies spanning over 20 years to determine the impact of music on the psyche and the human body, on the other hand. In producing the CDs, Lawrence's personal experience was supported by other researchers' findings studying the phenomenon, including the Bulgarian psychiatric physician Georgi Lozanov (n.1926) who studied the effects of baroque slow musical movements on learning and memorization processes, the English composer Cyril Scott (1879–1970) who wrote extensively about several composers' music effects and influence on the social life of the time, the French doctor Alfred Tomatis (1920–2001) who researched the effects of music on the auditory function and cerebral processes, doctor John Diamond (b. 1934) who looked at the effects of music on interpreters and orchestra directors. The ABT project accomplishment was for Lawrence an alternative to the contemporary world' noise. „All of us, children and adults, are bombarded every day by noises and sounds that have deleterious effects on our nervous systems and well-being. Even when we consider our houses to be quiet, there is often a hum from the lights, refrigerator, and other electrical appliances. We have to work hard to <<tune out>> extraneous sounds in order to focus on conversations, our studies, or the task at hand. One practical solution to this modern problem is to create healthy sound to mask the irritating environmental noise pollution." [12]

8 Conclusion

The cerebral hemispheres synchronization technology Binaural Beats was applied by Monroe as Hemi-Sync sound technology by means of mixing cerebral wave frequencies with music, nature sounds, and verbal guidance to the result of something more than music – Metamusic. This acoustic alchemy put into practice has yielded significant results in the exploration of expanded consciousness states, creative capability development, learning processes acceleration, learning disabilities, focus and concentration, wellness, pain relief, anxiety and depression amelioration, as well as in improved sleep, hypnosis induction, meditation and relaxation.

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Music as A Dramaturgical Component of The Opera *Elektra* by Richard Strauss

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Abstract: - By briefly analysing the motifs, we noticed the importance of the process of variation and development undergone by all the sound entities by means of traditional devices consisting of motif expansion or narrowing, segmentation, sequence accumulation underlying the main plot elements and the particularities of the actual evolution of the characters' dramatic art.

Key-Words: - Tragedy, revenge, *Elektra*, semantics, metamorphoses, description, illustration, development

Elektra is a tragedy created in the first half of the 20th century a time when issues related to European symphonism dominated the thinking of opera creators and authors such as Paul Dukas *(Arianne et Barbe-Bleue*) or Alban Berg (*Wozzeck*, *Lulu*), whose genre works had gone beyond a mere sequence of freely developing sound episodes, which were undoubtedly heading towards the clear-cut constructions of instrumental music. It may be divided into two distinct parts, depending on the tonal and dramaturgical clarifications, although both the modulation between the tonalities – D minor and C major –, and the characters evolving in their discourse together with their pertaining motifs, belong to both parts. A difference may be perceived in the dramatic stature of the main characters. The first part emphasizes the evolution of the heroes – Elektra, Chrysothemis, Klytemnestra – towards a climax, when the protagonist reveals the bare and painful truth to her mother: Klytemnestra will be murdered to avenge her father's death, which would bring peace to the whole palace. The second part sees the disappearance of Klytemnestra from the discourse and the occurrence of Orestes, who participates in the progress of the plot together with the other protagonists.

At the general sound level, an expressive and architectural equilibrium is required, based on the alternation between several moments of dramatic tension, of build-up, consisting of "tonally suspended harmonic sequences up to sonorities reaching the atonality limit" [1], and different moments of calm, of harmonic clarity, of cantability, reminding us of Wagner's *ariosos*. We note the extremely expressive, consonant and richly melodic pages, which follow the extended chromatic moments, in which the vocal line comes close to *Sprechgesang*: "Agamemnon's invocation (reference 35^{+12} m.), Chrysothemis' dream of freedom and fulfillment through love of a family (reference 75), Orestes' recognition (reference 148a)" [2].

The musical semantics of *Elektra* may be analyzed considering 3 levels of subordination of the means of expression: sound symbolism *Elektra* through the occurrence of motifs, phrases, themes, designating characters, feelings; the descriptive level, illustrating the plot; the developing level [3].

1 The Symbolic Role of Motifs

In this musical work, the motifs are distinguished by their cyclic nature, their leitmotif function and symbolic role. We will proceed hereafter to analyze the occurrence of motifs having a symbolic role and their original transformation into close sound structures.

The character of Elektra is symbolized by two typologies of motifs. We will refer here to the occurrence of several similar rhythmic-melodic entities (α, α_1, α_2), which suggest the psychological struggle related to "the image of avenging her father" [4].

The first occurrence of the motif α is orchestral, played by the strings, characterized by their anacrustic structure, 3/4 ternary rhythm and meter, and arpeggio melodic configuration. We note the emphasis placed on the sound F^2 (six beats), suggesting Elektra's intention to avenge her father.

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(m. 1-3)

Fig. 1

The motif α_1 relies on a harmonic ambiguity, on which an ascending chromatic line is superimposed, combining gradual progress and interval skips, which include major second (A flat^1 - B natural^1) and diminished third (B natural – D flat), emphasizing the protagonist's pain and tension. (reference 1^{+6} ms.)

Fig. 2

The motif α_2 is different as concerns its timbre and expression, it occurs in the score of the woodwinds and it is characterized by an ascending arpeggio progress and especially by a harmonic clarification – B flat major, suggesting Elektra's heroism. (reference 17)

Fig. 3

The second category of configuration contrasting motifs represents "the main character's off-balance"[5] (β, γ, x).

The above-mentioned rhythmic-melodic entities (β, γ) are revealed during the introduction by the orchestra, more precisely by the wind instruments. The chromatic harmony, dotted rhythm associated with interval skip, extensive nuance (*ff*) correspond to the composer's staging directions in the music score ("Elektra springt zurück wie ein Tier in seinen Schlupfwinkel den einen Arm vor dem Gesicht"), pointing out the abnormal reactions – Just like an animal hiding in its den, Elektra leaps backward hiding her face in her arm. (reference 1^{+3} m. - β, γ)

Fig. 4

We may also note that the sound expression of the x cell corresponds to Elektra's memory of her father's grandiose image as a king. "So kommst du wieder, setzest Fuß vor Fuß, die beiden Augen weit offen, und ein königlicher Reif von Purpur ist um deine Stirn" (And thus you return, placing one foot in front of the other, with your two eyes wide open and a purple crown on your head …).

This is the only rhythmic-melodic entity developed in soft dynamics (*p*) and it occurs in the orchestra's low-pitch register, distinguishing itself through the repetition of the D natural sound in *marcatto* by means of the prevailing rhythmic formula (the fourth connected to four sixteenths), which confers special expressiveness. (reference 43^{-4} ms.)

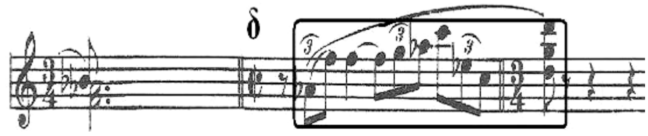
Fig. 5

The motifs related to the image of the other characters are either remote variations of Elektra's musical symbol (δ, Σ – Chrysothemis; y – Orestes) [6], or contrasting rhythmic-melodic configurations with a secondary role.

The first occurrence of the motif designating Chrysothemis is embodied by the oboe, progressing in piano, supported by a melody whose gradual unwinding is combined with the interval skip, in a rhythmic triplet formula. The motif's delicate sound expressiveness reveals Chrysothemis fearing for Elektra, who risks imprisonment.

Elektra notices her anxiety and asks her: "Was hebst du die Hände?" (Why do you raise your hands?) (reference 66^{+2} ms.)

Fig. 6



Chrysothemis' frailty and worry are also pointed out by the second occurrence of the motif (ε), which, on a sonorous level, is characterized by a richly

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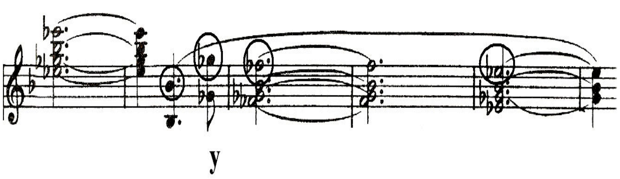
chromatic arpeggio melodic line within the unwinding of a single measure, the fixed rhythmic formula (two sixteenths followed by an eighth - anapest) and Elektra's ironic comments of Aegisth's deeds – "der tapfre Meuchel mörder" (the mighty murderer). (reference 69)

Fig. 7

While the occurrences designating Chrysothemis have an ornamental and chromatic melodic line, reminding us of Elektra's first appearances, the y cell symbolizing Orestes distinguishes itself through a descending sound unwinding in the E flat minor tonality, the expressive timbre of the woodwinds and the ascending interval skip suggesting aspiration – common constituents of the leitmotif α, symbolizing revenge –, contribute to the creation of Orestes' solemn image, a vision which is virtually the orchestra extension of the dramatic *arioso* uttered by Chrysothemis. (reference $23a^{-4}$ m)

Fig. 8



The melody of the opera comprises two cyclical themes, which represent sequences of motifs derived from within a phrase:

a. the image of Elektra seen by the servants
b. the symbol of the children's love for Agamemnon

The change in the courtiers' attitude towards Elektra, from reproof to compassion, is suggested at the level of the relation between the melody (sonority filled with chromatic elements), the chromatic harmony and the text uttered by the maid:

"Sind sie dir nicht hart genug mit ihr?" (Don't you find they're too hard on her?) (reference 15 + 4 ms.)

Fig. 9

Unlike the other motifs or themes we have mentioned, we are surprised by the diatonic harmony and cantability of theme *b*, exposed at the level of the strings. Played in *pp*, at low pace, by combining the triplet with the dotted rhythm, this idea develops in a seven measure-interval, under the form of an orchestral comment of soft words, expressing the sadness of the characters' solitude - "Ich will dich sehn, laß mich heute nicht allein! Nur so wie gestern, wie ein Schatten dort im Maurwinkel zig dich deinem Kind!" (I want to see you, don't leave me alone today! Like a shadow, show yourself to your daughter, in a corner of the wall! (reference 45^{+8} ms.).

Fig. 10

2 The Symphonic Role of the Motifs

We notice the metamorphosis, at a semantic and sonorous level, of the symbolic motifs in the evolution of the opera dramaturgy.

2.1 The transformations of the leitmotif α, connected to the vision of avenging the father

The rhythmic, melodic and harmonic (C 5) transformation of the initial motif (α 1) – occurs when the protagonist is in a state of imbalance, imagining a possible dance of revenge around her father's tomb. (reference 58)

Fig. 11

The joy of having found her two brothers is rendered, at the sonorous level, by means of the *waltz* inflections, revealing the heroine's sudden transformation, from toughness to delicacy.

The rising scale shift (B flat^1 – E flat^2), α_v from the melody is only a variation through segmentation and a reversal of the incipit specific to the initial motif α (D^2-A^1). Hence, the nuance of the psychological experience related to the vision of avenging the father turns into the joy of finding the beloved brother whom the heroine calls:

"Orestes! Orestes!" (reference 148a)

Another instance of the initial motif (α_3) can be found in the vocal line of Aegisth who, feeling that his end is near, cries: "Helft! Mörder! Helft dem Herren!" (Help! They are killing me! Help your master!) (reference $213a^{+2}$ m.)

However, the emotional intensity of the acoustic moment is rendered by resorting to Elektra's leitmotif, transformed from a rhythmical and melodic perspective (α4), representing the protagonist's reply to Aegisth's question:

"Hört mich niemand? Agamemnon hört dich!" (Does anybody hear me? Agamemnon hears you!). Meanwhile, Aegisth dies, but not before showing, for the last time, his face at the window: "Noch einmal erscheint Aegisth Gesicht am Fenster" (Aegisth shows its face at the window once more). (reference $216a^{+3}$ m.)

In the general joy at the end, the orchestra returns to segments of the transformed motif of avenge – above them we hear Elektra's meditation on love and death. We note the transformation of the motif α, from the symbol of revenge to the symbol of love and death: "Ai! Liebe tötet! Aber keiner fährt dahin und hat die Liebe nicht gekannt!" (Ah! Murdered love! And still, no one dies without having experienced love!)

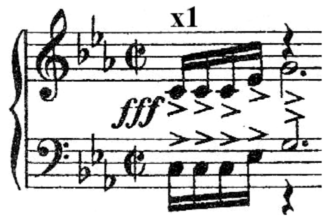
2.2 Metamorphosis of the rhythmical and melodic entities suggesting Elektra's lack of balance

The motif β appears again in the part dedicated to Klytemnestra, this time subjected to rhythmical and melodic variations (βv). We may notice that the variation of the motif coincides with the characters' psychological transfer, so Elektra's lack of balance can be found in her mother's attitude: "Ein jäder Dämon läßt von uns" (All demons should leave us alone) (reference 199^{+2} m.)

Fig. 12

If, during Elektra's monologue, the cell x was rendered in *piano*, the ample dynamics (*ff*) and in the *molto vivace* tempo, its return in a varied hypostasis (x_1), in the C minor tonality, corresponds to an extremely tragic moment. In her anxiety, Klytemnestra asks Elektra: "Who should die in order to be able to sleep in peace?" In restlessness, her daughter replies: "Was bluten muβ? Dein eigenes Genick ..." (Who should bleed? Your throat...) (reference 230^{-4}m.)

Fig. 13



2.3 Metamorphosis of the cell *Y* symbolizing Orestes

The rhythmical and melodic entity *Y* will return in the orchestra, in an augmented instance (*Yv*), where the chorale writing and the chromatic harmony suggest the character's solemnity, enforced by the words he utters: "Ich und noch einer, der mit mir ist, wir haben einen Auftrag an die Frau" (I and the person accompanying me have a message for the queen). (reference $126a^{-3}$ m.)

Fig. 14

2.4 Transformation of the cyclical theme *a* – Elektra as seen from the courtiers' perspective

We note the circular nature of this sonorous idea in the unwinding of the music score, but with different symbols. We observe the shift that occurs from Elektra's ambiguous image in the courtiers' eyes to the protagonist's attempt to impose herself on Chrysothemis, forcing her to participate in the consummation of the avenge: "Nicht Schwester, nicht / Spricht nicht ein solches Wort in diesem Haus / Der führt kein Weg hinaus als der / Ich laß dich nicht..." (No, my sister, / Do not utter such a word in this house / There is no other choice for you but this one / I will not let you ...) (reference $89a^{+4}$ m.)

Fig. 15

2.5 Metamorphoses of the cyclical idea *b* – symbol of the children's love for Agamemnon

The rhythmical and melodic variation of theme *b* occurs in relation to the transformation at the poetic level (*b1*). The symbol of the children's love for Agamemnon will turn into Chrysothemis' dissatisfaction with Elektra's ambition and anger: "Wärst nicht du, sie ließen uns hinaus, so ließen sie uns ja heraus aus diesem Kerker, Schwester" (If it had not been for you, they would have let us get out of this prison, sister! (reference 82^{+2} m.)

Fig. 16

At a structural level, we noticed, in relation to the progress of the moments, that each section and subsection brings about new rhythmical, melodic or motif related elements, as well as ingenious procedures for the variation and processing of the previous material. The second part reveals itself as an echo of the first, by resuming the motifs in a transformed state, without actually performing a reprise.

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Neural Correlates of Music Perception and Cognition

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Abstract: The complexity of mental operations relative to music perception and cognition provides a unique field of research for the neuropsychological approaches, the most up-to-date studies revealing a vast neural activity involved in music processing. The present paper aims to draw up a synthesis on the neural correlate of music processing, based on a series of clinical studies or on neuroimaging data. The paper discusses aspects referring to neural substrate corresponding to the perception of sound pitch and duration, as well as to intonation, rhythm and metric relations of sounds. Results have shown that music processing involves a vast network of cortical and sub-cortical structures, belonging to both brain hemispheres.

Key-words: neural correlates, brain structures, music perception, music cognition, pitch relations, time relations

1 Introduction

The neuropsychological mechanisms for processing music have long fascinated neuropsychologists. However, it was during the last 10 years that the intensive and systematic study of this area of knowledge highlighted some important discoveries, due also to the evolution of the investigation techniques of the human brain, as well as to acoustic phenomena.

The way a music piece is perceived triggers an intense cerebral activity, involving several cortical or sub-cortical structures, depending on a series of physical, musical or neuropsychological factors.

In contact with the human auditory faculties, the physical properties of the sounds are transformed into physiological faculties, the latter being theorized in the artistic area by means of four elements pertaining to the musical language, as follows: the frequency of waves can be perceived as pitch; the duration of the waves is related to time; the amplitude is perceived as intensity; the spectral shape of the sound is perceived as timbre.

Pitch, time, intensity and timbre, despite simultaneously intervening in the perception of a musical piece, are separately studied at a theoretical level from a musical as well as from a neuropsychological point of view, since processing supposes different mental tasks and activates specific cortical areas.

Most studies carried out by neuropsychologists focused on processing the pitch and time relations of sounds, given the methodological opportunities that these two musical elements offer in carrying out the research studies. This is why the present paper focuses especially on the neuropsychological perspective of pitch and time relations.

2 The Perception of Pitch and Pitch Relations

Pitch is a quality of sounds that allows placing them on a conventional scale, from the lowest to the highest. There is a bi-univocal correspondence between the height of the sound and the sound frequency that produced it, the latter being measured in hertz [1].

The sound waves propagate and amplify at the level of the inner ear, by vibrating the basilar membrane, and then going, through the auditory nerves, to the auditory cortex (cortical areas 41 and 42, on the superior side of the temporal lobe) of both hemispheres [2].

The neural correlates of pitch reveal a tonotopic map at the level of auditory cortex, meaning that neurons typically respond to a restricted range of frequencies and are physically ordered within a brain area by the frequency to which each neuron is most sensitive. The low frequency sounds are represented in the rostrolateral side of the primary auditory cortex, and the high frequency ones are processed in the caudo-medial auditory regions [3].

The individual sounds are processed, according to their frequencies, in both cerebral hemispheres, by the primary auditory cortex (area 41, Brodmann), but the pitch relations between the sounds are analyzed at the level of the right secondary auditory cortex (areas 42 and 22, Brodmann). Electroencephalographic studies proved that, when the listeners are trying to identify the contour (defined by the pitch directions), the right superior temporal gyrus plays a critical role. Moreover, when the interval information is required (defined by the frequency ratios between successive notes), both the right and left temporal structures are involved [4].

The musical structures that result from adjoining intervals are called melodic sequences. When formed of random intervals, they are processed by the same area responsible with pitch contour, that is, the right superior temporal gyrus [5].

When the listener is trying to identify the tonality of a specific melodic fragment during music perception, he is performing complex metal tasks that involve not only the primary and secondary auditory cortex, but also the frontal areas related to important cognitive functions. Research [6] has discovered that the task of finding the tonality activates the prefrontal cortex, an area with major roles in maintaining the map of the pitch information so that the modulation of the melody (moving from one key to another) would not alter the listener's ability to remember the melodic pattern. More than that, inside the prefrontal cortex, the perception of two different keys is analyzed in two separate regions.

Using magneto-encephalographic measures, a recent Japanese study [7] has identified the cortical areas responsible for the detection of the tonality mismatch based on pitch analysis. The subjects (non-musicians) had to listen to 26 melodies composed in six different keys, each of them lasting for approximately 8 seconds. Two seconds after each melody, subjects were presented with a new sound that was either consonant with the tonality of the song, or dissonant (for example, natural A does not belong to C flat tonality). The task was to asses the consonance/dissonance of each end-note. The results have found that there is a significantly different cortical activity corresponding to the two types of situations, in the way that the magneto-encephalographic response is stronger in the case of the dissonant end-notes. Besides that, the cortical activity showed a dynamic change in the right hemisphere from the auditory cortex in the supratemporal plane at about 310 miliseconds to a posteroinferior region in the superior temporal sulcus, proving that this area is involved in the detection of the tonality mismatch.

Another frequently performed task by musicians is to differentiate the mode, by comparing major and minor tonalities. The neural correlates of processing minor mode melodies increased activity in the limbic structures, namely left parahippocampal gyrus, bilateral ventral anterior cingulated and left medial prefrontal cortex [8]. Also, anterior cingulated gyrus, as seen in a previous study [10], is functionally involved in a variety of cognitive and emotional tasks, such as error monitoring, conflict solving and pain perception.

One of the most popular psychological aspects related to tonality processing is the emotional effect, so that minor keys are associated with sadness. Functional magnetic resonance imaging studies [11, 12] found that the minor mode melodies were evaluated as sadder than major melodies and they caused stronger activation of the limbic structures. Moreover, the emotional state is enhanced in the absence of cognitive requirements.

In music, the pitch relations of the sounds can be presented sequentially, as they appear in melodies, or simultaneously, in chords. The relations between chords form a specific musical syntax, and the term is not accidentally chosen, considering the studies [13, 14, 15, 16] that identified neuro-functional similarities between the spoken language and the musical language. The neural correlate of chord processing is the bilateral inferior frontal cortex. Or, in the left hemisphere, this area (also called Broca area) represents the motor centre of speech. After sending the information to motor area 4, the Broca area will coordinate the contraction of the muscles involved in pronunciation. Broca discovered the motor center of speech in 1864 and this is the earliest cortical localization [2]. The difference between harmonic and speech processing is that the neural correlate of chords analysis is bilateral whereas the verbal language activates only the left hemisphere.

Interestingly, when the harmonic display deviates from the western classical music principles and breaks the harmonic expectancies by introducing dissonant chords, it generates specific tension within the listener's mind. This tension amplifies the concentration of attention and creates the sensation of an internal conflict that needs to be solved. Keeping the dissonance for a long time is associated with strong emotional reactions. Some physiological studies also proved the correlation between the perception of dissonance and skin conductibility [17].

In the attempt of identifying the neuro-psychological mechanisms related to consonance and dissonance, one research [18] presented the subjects with a melody accompanied with more and more dissonant chords. They were asked to assess the situations in terms of pleasant and unpleasant emotional responses. By examining the cerebral blood flow, researchers found that dissonance is associated with increased activity in the right parahippocampal gyrus, whereas consonance activates the right orbito-frontal cortex and cingulated gyrus. It is also important to remind that the cingulated gyrus, through its connections with amygdala, performs significant functions in emotional processing. Further studies [12, 15, 19] confirmed the role of the amygdala in mediating the emotional responses generated by dissonant chords.

Other neuro-psychological studies focused on the differences between musicians and non-musicians regarding harmony processing. The results showed a right dominance tendency for non-musicians in chord perception. In contrast, musicians tend to use mostly the left hemisphere when judging harmony [20], this fact being more obvious in the case of women.

Also, researches conducted on children and adults ongoing musical training [21, 15] confirm more and more activation of the left hemisphere correlated to the increasing musical experience.

3 The Perception of Time and Time Relations

Time perception is a fundamental psychological dimension, considering the fact that all human activities include a temporal organization, at a simple or complex level.

The neuro-psychological approach of time perception follows two theoretical paradigms [22]. The first conception is widely spread in the musical field and it is of a beat-based timer. On this account, the mental-neural representation of the duration of an interval involves entrainment of neural machinery to the beats defined by endpoints of the interval to be timed. Apprehension of an interval is achieved by setting up a timing circuit that produces pulses which continue in time with the beats defined by endpoints. The second conception is of an interval-baser timer, where the duration is stored in a form that can be used to assess or produce another interval starting at some arbitrary time.

The author [22] has shown that the two timing techniques are equally efficient in measuring given durations. Moreover, in their professional activity, musicians tend to combine the beat-based timer with the interval-based timer.

The mental processing of time in music requires sensory-cognitive tasks of various difficulties, from detecting the differences between two durations or pauses, to identifying the beat of a complex rhythmic sequence. In this context, there are two fundamental concepts that serve the neuro-psychological approaches of time processing: rhythm and meter.

From the musical point of view, rhythm is generally considered an organized structure of durations [1]. Analyzing rhythm outside the context of the other musical elements (intensity, pitch and timbre) is somehow artificial. Even so, the duration remains the most important quality in rhythm structures.

One of the fundamental aspects of rhythm is symmetry, illustrated by the existence of an energetic force that makes any rhythmical structure fit into a certain pattern [23]. Musically and psychologically, when we listen to a rhythm, we feel the need of a periodicity whose pulses would create some kind of stability. This periodicity can be determined by accentuating certain sounds. Therefore, musicians introduced the concept of meter, defined as a periodical alternation of accents. So, the combination of different durations and pauses creates the rhythm, and the periodicity of accents creates the meter [1].

At the behavioral level the metrical pulses are marked, sometimes involuntarily, by moving our head, arms, feet or the entire body, and these movements help us understand and memorize the rhythm of a musical piece. The more symmetrical durations are, the more obvious metrical pulses become. If the rhythmic structure is asymmetrical, our capacity of detecting the meter decreases [24, 25].

The detection of a regular pulse in an auditory signal is considered a fundamental human trait that can also be seen in newborn infants [26]. Therefore, by measuring the electrical activity of the brain during rhythm perception, researchers found that newborn babies develop expectation for the onset of rhythmic cycles (the downbeat), even when it is not marked by stress or other distinguishing spectral features. Omitting the downbeat elicits brain activity associated with violating sensory expectations. Thus, up-to-date research strongly supports the view that the beat perception is innate.

Other studies proved that the beat perception occurs even in the absence of external accents [27]. Researchers talk about internally generated-stresses that appear when people are listening to unstressed periodic sequences. An isochronous series of tones of identical frequency and intensity is often heard as stressed, and strong pulses alternate with weak pulses, usually in 1:2 patterns, but sometimes in 1:3 or other patterns [25].

In an earlier study [28], researchers suggested the hypothesis that the right hemisphere would be responsible for meter processing and the left hemisphere is activated in rhythm perception. The idea came from the observation that subjects tend to move their left hand according to the beat and their right hand in rhythm production. These results were later confirmed by two clinical studies where lesions on the right temporal cortex determined the incapacity to keep the beat of rhythmic fragments [29, 30].

The supremacy of the left hemisphere in beat perception and production was also certified through neuroimaging studies [31] that explained this dominance by revealing the mathematical nature of time relations in music.

Recently, researchers have identified a significant difference between musicians and non-musicians in rhythm perception and production [32]. According to this, both categories have a common cortical area situated in the right frontal lobe, responsible for rhythm perception. Nevertheless, non-musicians tend to use mostly the right hemisphere, while musicians rely on the left perisylvian cortices (left frontal operculum, superior temporal gyrus, inferior parietal lobule) when processing rhythm. Because these brain structures are also involved in speech processing, we can speculate about the relationship between rhythmic perception and language development.

People spontaneously coordinate periodic motor activity with complex musical rhythms, a phenomenon defined by neuro-psychologists as generalized synchrony [25]. Most of the listeners are usually able to coordinate periodic tapping with complex rhythmic patterns. The tempo fluctuations do not disturb the capacity of keeping the beat. However, the level of syncopation is a good predictor of pulse finding difficulty.

When listening to a rhythmic melody, people usually feel a strong need for motor action. This dynamism of music rhythms is used today in various situations. In the military, marches are used to stimulate walking, and rhythmic songs were introduced in the American factories in order to improve working resistance [33]. This is why the presence of generalized synchrony can be a scientific proof for the ancient link between music and movement.

Functional neuro-imaging studies have found that the perception of rhythmic structures, even when the subjects stood perfectly still, triggers the activation of motor areas of the brain [34, 35]. This discovery has received a lot of attention from neuropsychologists [27, 4, 36, 24, 37, 32, 38, 39]. Thus, it is known that spontaneous movements following rhythm perception can be the result of the activity triggered into motor brain regions such as the supplementary motor area [24, 38], the basal ganglions [27, 36, 39] and the cerebellum [38]. The supplementary motor area extends on the medial frontal lobe and its main function is to identify the purpose of movements, to establish the movement program and to organize the motor sequence [2]. In addition, this brain area is well-connected to the basal nuclei, whose function is to control, to automate and to select the routine movements, in order to spare the energy used by the frontal lobe in focusing attention [9].

Beside its role in regulating motor behavior, the cerebellum is also an important timing structure. Clinical studies have revealed difficulties of patients with cerebellum lesions in differentiating durations of sounds [9].

Imaging studies performed on healthy subjects discovered that, when the rhythmic structure is simpler and can easily be included into a metrical pattern, it activates mostly the supplementary motor area and the basal nuclei [24]. Furthermore, musicians tend to use the cerebellum and the basal nuclei in a higher degree than the supplementary motor area, when rhythm processing. In addition, the connections between the auditory regions and the motor areas are stronger in people with long-term musical training.

In the end, the neural correlates of rhythm and meter, as musical elements of time perception, activate brain structures involved in motor behavior, bridging music and dance, from a neuro-psychological point of view.

4 Conclusion

Pitch and time processing require complex sensory and cognitive tasks that activate the human brain in a wide structural and functional area.

As shown before, the neural correlates of pitch perception involve mainly the auditory cortex. Moreover, depending on the complexity of the mental task related to pitch perception and cognition, people can also activate frontal regions.

Time processing involves motor areas of the brain proving the ancient link between rhythm and movement.

Musical training can have an important effect on the neural substrate of music processing. Musicians, in contrast with non-musicians, tend to use mostly the left hemisphere in music perception and cognition.

The intense mental stimulation determined by music perception raises new research directions. One further idea is drawn from the effects that long-term musical training may have on brain development. Also, another interesting research area can focus on the possibility to transfer musical skills to other domains of human knowledge and activity.

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Conceptions of learning and teaching in music education as voiced by pre-service student teachers

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Abstract: The article presents the findings of a small-scale study investigating the student's conceptions and approaches to learning within the space of a pre-service teacher education program in music education. The data was generated in the academic year 2009/2010 in a Romanian institution of higher education in an exploratory attempt to understand how students position themselves in reference to the competences and skills proposed to them through the curriculum of their bachelor degree in Music and Level 1 in the National Curriculum for pre-service teacher education. Approaches to learning and individual estimations of the time-resources invested in studying different subjects in the curriculum are studied in relation to their quantitative estimations of the importance various competencies carry for their development as musicians and music teachers.

Key-Words: conceptions, approaches, learning, music, education, student teachers

1 Introduction

The discourses in politics – albeit confined to the education activity or not - are generally abundantly filled with imperatives framing teaching and teacher education as an important key for developing educational systems capable of formulating practical responses to the demands of an ever-changing social and economical 'outside' (of school) world. The teacher education scene becomes, thus, a space where multiple discourses and conceptions of teaching meet: performance-based curricula embedding governmental conceptions of education and teaching, teacher-mentors' experiential conceptions of teaching, faculty members' views of knowledge, learning and teaching along with student-teachers more or less naïve conceptions of teaching – all enter the 'melting pot' of teaching and learning. The multi-voicedness of the practical discourse of education is an idea often explored in the research literature. Studying the relationship between conceptions of teaching and approaches to teaching, Lam and Kember [1] reviewed relevant studies investigating these two constructs and found that when attempting to systematize approaches to teaching, a difficulty occurs: despite the fact there is a vast literature on the topic, the construct lacks careful operationalization when being used in the school teaching literature [idem]. The term has connotations of both the philosophy of teaching that guides teachers to make sense of their planning and pedagogical action and the how of implementation. Separating between the *why* (the intention behind the action or succession of actions) and the *how* (the way actions are being carried out), the two researchers found that the only case where there is a significant correlation between the two is the one of the higher education teachers. In the case of secondary education teachers, the two researchers found that where there is limited contextual influence on the way they teach, as happens in higher education, the approaches to teaching follow logically from teacher's conceptions of teaching, whereas very strong contextual influences, such as external examination syllabi or school policies and specified curricula [2], can lead to a complete divorce between conceptions and approaches [1].

On another stream of research, investigating opinions of music teacher educators and pre-service music teacher students on the standards for music education in US, Forsythe et al.[3] observed that while research literature focuses on measurement and content of the qualities and competences associated with effective music teaching [4] or exploring perceptions and conceptions of pre-service and in-service teachers concerning various dimensions of teacher effectiveness [5], little attention has been paid to understanding how practitioners and students in music teacher education programs work with the conceptions of learning and teaching embedded in the available standards and

competencies for music teacher education. That is whilst studies recognize that teacher attitudes are an important aspect of bringing about change in learners [3]
As actions, actors and artifacts in the educational context voice distinct discourses on conceptions of learning and teaching, one can enquire whether they simply *co-exist* (as Halldén [6] put it) in the learning activity or just as well – and most often do –*collide*. Whether is conflicts and collisions between discourses and conceptions of teaching and learning or mere co-existence of distinct understandings and beliefs about it that lead to mediation and emergence of new ones that are embedding prevailing approaches to learning and education, remains an issue where research is still much needed.

2 Problem Formulation

Hardly spaces of undisturbed co-existence for all discursive instances' conceptions of teaching, the teacher education programs need to acknowledge and validate the importance of each and propose resourceful approaches to learning for student teachers. The research literature says little about the relationship between different conceptions of teaching and learning emerging in the formative space of teacher education. The author of this paper argues that explorations of the learning activity in spaces where multiple conceptions of learning and teaching are voiced are absolutely necessary for understanding the way in which student teachers' conceptions and approaches to learning and teaching may shift from naïve to 'scientifically accurate' [7]ones, and further more – understanding how these shifts in conceptions of participants to the learning activity come to shape the very 'world' (the learning settings) they act in. The aim here is to provoke explorations of the learning activity by analyzing the manner in which the students – participants to a pre-service music teacher education - position themselves in relation to the requirements, contents and competences proposed to them in the curriculum for music and music education. The analysis is thought of as part of a longitudinal study aiming at understanding how conceptions of learning and teaching in music education may shift throughout the duration of the bachelor degree program.

2.1 Method

The data was generated by means of inviting students taking the pre-service teacher education in Music Education and simultaneously pursuing a curriculum for a bachelor degree in Music Interpretation (Instrumental and Canto) or Music Pedagogy (including majors in Composition, Musicology, Pedagogy of Music, Religious Music) to respond to a survey based on three instruments collecting their written, quantitative estimations of the degree of importance they invest (when considering their professional development in the role of *musician and music teacher*) the competencies and skills listed in the syllabuses of the various disciplines they study in the first year at the university. A list of 60 cognitive, technical and professional as well as attitudinal and ethical attributes, competences and skills drawn from the curricular documents describing the course of study for the first year – bachelor degree - was presented to the participants to the study who were pursuing the teacher education course simultaneously to their bachelor degree in either Music Pedagogy (including majors in Composition, Musicology, Pedagogy of Music, Religious Music) or Music Interpretation (Instruments or Canto).
All participants to the study were asked to estimate on a 5 point Likert scale extending from 'little or no importance' (1) to 'maximum level of importance' (5) the value of *importance* they attach to the different attributes, competences and skills forming the profile of the musician and music teacher as conceived by the curriculum makers – members of the faculty making decisions based on disciplinary and contents specific requirements and national requirements and standards for music education and teacher education. Also – in an attempt to replicate the findings of Forsythe et al [3] researching along the lines of the "nature-nurture" debate (i.e., teachers are "born" not "made") – students were asked to estimate on the same 5 point Likert scale the degree of *confidence* they have in acquiring the specified attributes and competencies within the time-span of the year of study. The students estimates on these curricular elements were studied in relation to their estimates of *time spent* (average per week) for meeting the requirements of different areas of study pursued in the first year at the university, as well as with their responses to a survey asking them to express their level of agreement/ disagreement with a number of 30 statements describing ways of reasoning, acting and positioning towards learning. This last survey is and adaptation to the Romanian language of Entwistle and Peterson's 2004 ASSIST instrument measuring conceptions of learning. Entwistle [8] studied the relationship between students' understandings of learning and their approaches to learning and proposed a shift from the notion of 'concept' to the

one of 'conception' of learning in an attempt to capture within the new term the variety of meanings, the flexibility of meaning making processes and the affective component attached to the notion of *learning*. Conceptions can develop from naïve, experiential forms to more 'scientifically accurate' [7], can co-exist and are contextually related [6]. In this paper the same type of shift (from *concept* to *conception*) is proposed with reference to the notions of ‘learning’ and 'teaching'.

In its English language original version, the ASSIST instrument is composed of three sections: (A) statements concerning conceptions of learning (a sections upon which authors [8] comment on its incompletion); (B) a revised form of *ASI* (Approaches to Studying Inventory, [9]) containing 52 statements and often employed separately from the other two parts of the ASSIST instrument, under the name of ASI Revised or RASI [10] to measure deep, superficial and strategic approaches to learning; (C) this section of the inventory requires students to indicate their preferences for different types of teaching approaches.

For this study a version of ASSIST has been used after translation into Romanian and validation (December, 2007) of the instrument with Romanian subjects (*n*=53 first year students at the university undertaking a course of study in teaching). The instrument in its Romanian version maintains the original three parts structure comprising 30 statements (12 statements from the original English version were dropped; the remaining 30 were after Alpha Cronbach indicating values for internal consistency of each factor higher than 0.7: deep learning (AC 0,7234), strategic learning (0,8210), superficial learning (0,7360)). In the Romanian version of the instrument used in this study the three factors are: a) *deep learning approach:* indicates the respondent’s tendency towards an approach to learning focusing on seeking the meanings of what is learned, on seeking connections between the different aspects of learning, actively seeking arguments to sustain proposed ideas (by oneself or the others), an interest for ideas and monitoring the efficiency of actions pursued in the space of the learning activity; *the strategic learning approach*: indicates the respondent’s orientation towards an approach to learning focusing on a tendency to organize the learning, to manage the time resources, a focus on academic results and performance and a high responsiveness to learning contexts where individual assessment is stressed upon; *the superficial learning approach:* indicates the respondent’s focus on memorizing the learning contents (without making connections or significantly link the memorized sequences of contents memorized), the absence of developmental goals correlated to the learning on long term, confinement to the prescriptions of the syllabus and the teachers requirements and fear of failure.

2.1.1 Selection of participants to the study

The participants to the study were student teachers undertaking a course of study in music teaching simultaneously to their bachelor degree in either music interpretation (instrumental or canto) or music pedagogy (including composition, pedagogy, musicology and religious music). Students responded to an open invitation to take part in a study aiming at exploring how conceptions of learning and teaching are being shaped in the course of the bachelor degree in music education. Thus, 52 surveys were distributed to first year students and to master students who completed a bachelor program in music and the level one of pre-service teacher education national curriculum (pursued simultaneously to the bachelor degree). All students in attendance on the day the questionnaire was distributed and who were willing to participate completed the questionnaire (n = 52). Only 36 of the returned questionnaires were filled completely and thus made the object of further analysis. Demographics were summarized descriptively and data comprising of participants’ rating responses were analyzed using SPSS statistical analysis software. Responses on the 1–5 scale were averaged for each item, resulting in mean ratings that were then ranked from highest to lowest for importance and degree of confidence in acquisition of attributes, competences and skills. Numeric estimations of time expected and time spent for studying were divided on a 5 point interval from the lowest to the highest estimate within the group of reference. In addition, independent t-tests were computed to compare mean ratings of first year students and graduates on the importance, confidence in learning, approaches to studying and time estimates.

3 Findings

The group of 36 participants to the study was formed of 23 female and 13 male respondents, majoring in music pedagogy (8), interpretation-instrumental (19) or canto (9), most of them (26) listing high school as the latest course of study they are graduates of, whereas the other 10 specified being graduates of a bachelor course of study in something other than music.

Descriptive statistics of the responses show that when considering *their development as musicians* all listed attributes, competences and skills participants were presented with received rather high ratings. The range of the ratings respondents attached to the importance of each of the 60 common items grouped in 18 relevant categories of attributes and competences they assessed, showed mean values from 3.27 to 4.53; standard deviations were lower on the highest rated items than on the lowest rated items. The lowest ranked were the cognitive competences related to the contents of psychology of education – a compulsory course in the national curriculum for pre-service teacher education program. Respondents ranked competencies like '*the capacity to analyze psychological and pedagogical aspects of an educational setting'* lowest in their estimations of what constitutes important acquisitions for them as musicians. The category ranked highest was that of cognitive and instrumental competences associated to piano general knowledge (e.g. '*correct execution of basic instrumental skills*'). These results are not necessarily surprising as the competence listed lowest in the hierarchy of prioritized acquisitions in the profile of developing as a musician are competences most likely interpreted as more relevant for another role – that of a person who is employed or engaged in education; likewise, the competences ranked highest are confined to the general representations of what constitutes a musician's profile of competence.

When looking at rankings of what constitutes important acquisitions for respondents thinking of themselves in the role of music teachers, results show again mean values ranging from 3.84 to 4.67 for all 18 categories of competences and attributes analyzed; standard deviations were lower on the highest rated items than on the lowest rated items in the case of these ratings as well. Respondents ranked competencies like '*advanced knowledge on MIDI computer programs*' (computer skills) lowest in their estimations of what constitutes important acquisitions for them as music teachers. The category of competences ranked highest was that of technical competences related to the psychology of education(e.g. '*the capacity to develop creative strategies for stimulating pupils' motivation for learning* ').

In explaining these ratings, studying the correlations between students' approaches to study and their estimations of the importance each attribute or competence proposed in the program of study carried plays for their development as musicians and/or teachers of music proved beneficial. In studying how students prioritize the various competences and attributes whilst within the space of reflecting on their development as musicians and the relationship between their ratings and the scores on the ASSIST scale indicating how they position themselves in their approaches to study, results show medium (Pearson Correlation higher than 0.3 and lower than 0.5) positive correlations, significant at the 0.01 and 0.05 levels (2-tailed) between the *deep approach* to study and students' ratings on cognitive and instrumental psychological competences (e.g. '*communication skills for the educational environment'*), cognitive and attitudinal attributes associated to learning the history of music (e.g. '*capacity to understand and operate selections of artistic products based on stylistic, esthetic and ethical criteria*') as well as strong (Pearson Correlation higher than 0.5) positive correlations of the *strategic approach* to study and students' ratings of the instrumental, cognitive and attitudinal pedagogical competences and attributes. Also, it is important to observe that between the deep approach to study and the strategic approach to study there is a strong positive correlation (CP of .561, correlation significant at the .01 level (2-tailed)) showing a tendency for the two approaches to co-exist in the conceptions of learning relevant for this group of participants to the study. The *superficial approach* to study showed negative medium correlations with estimates of importance attached by respondents to cognitive competences in theory of music (e.g. '*critical, logical thinking skills based on demonstrative, argumentative approaches to musical knowledge*'), cognitive and instrumental history competences, as well as to cognitive and technical competences in foreign modern languages (e.g. *'basic knowledge on the musical culture of other people*'). A strong negative correlation (CP of .513, correlation significant at .01 level (2-tailed)) was noticed between this approach to study and students' estimates of importance attached to the cognitive competences in general knowledge of piano (e.g. '*making connections between the theoretical and practical musical aspects of knowledge in counterpoint, harmonies, musical forms, history of music*'). These results were somewhat predictable as the competences and skills the *surface approach* to study negatively correlates to are comprehensive, significance seeking, critical thinking oriented statement that are contradicting to the tendency of approaching learning as memorizing delivered curricular products in the shape of textual information already structured as required during examinations.

Things are just as interesting when considering students manner of rating the importance the same set of competences, attributes and skills attached to the program of study they pursue hold in relation to their reasoning of what constitutes important aspects of being a teacher of music. In this case, results indicate medium positive correlations of the *strategic and deep approaches* to study and students estimates of the importance instrumental competencies in the field of psychology of education, as well as cognitive and attitudinal attributes associated to history and theory of music; instrumental competences in harmonies were also positively correlated (CP of .064) with the deep approach to study (correlations were considered relevant at the .01 and .05 levels (2-tailed)). The *superficial approach* to study showed negative strong correlations with estimates of importance attached by respondents to instrumental competences in psychology, harmonies and history of music, to cognitive competences in history and theory of music, harmonies, general piano knowledge and foreign modern languages (correlations were considered relevant at the .01 and .05 levels (2-tailed)).

Somewhat expected, the deep and strategic approaches to study showed positive strong correlations with students estimates of their *confidence* in their capacity to acquire various competences and attributes related to their development as musicians and teachers of music; relevant in this respect are the results showing correlations between the deep and strategic approaches to study and the levels of confidence expressed by students in relation to acquiring competences and skills related to the fields of psychology, theory and history of music, harmonies and pedagogy (all correlations considered ranged from values of .446 to .655 and were significant at the levels of .01 and .05 (2-tailed).

Students were also asked to estimate the time (average number of hours per week) dedicated to studying, when considering the different subjects they have listed in the curriculum. A list of the subjects was presented in the inventory and students were required to express numerically their estimates of time invested in studying (estimates should have included the time spent in classes associated with each subject). Analyzing the resulting data in relation to the students' approaches to study showed interesting, somewhat surprising correlations (CP .339, significant at .05 level (2-tailed)) between the *superficial approach* to study and students' estimates of the time invested in studying for acquiring skills and competences associated to Pedagogy. Explaining this week positive correlation requires mentioning that the invitation to take part in the study was made to first year students taking the simultaneously to pursuing a bachelor degree in music. The stage in the teacher education program where the students participating in this study were at the time of their responses was that of studying the discipline of Pedagogy in the national curriculum for pre-service teacher education and the person asking them to take part in the study was their Pedagogy teacher. This may explain why the scores in superficial approaches to study – indicating a general tendency to confinement to the prescriptions of the syllabus and the teachers requirements and fear of failure – tend to go together with students declarative estimates of time allocated to of studying the subject they anticipated the researcher to pay more attention to.

Independent *t*-tests computed on approaches to study, importance attached to competences when thinking of developing as musicians and when thinking of developing as teachers of music as well as on the levels of confidence expressed in relation to respondents' belief in acquiring each competence and attribute listed showed *significant* differences between male and female participants to the study between some of the listed variables, such as the importance attached to attitudinal attributes in the profiles of the musician and of the music teacher. For the first, female participants to the study rated attitudinal attributes associated to studying the history of music (e.g. ''*capacity to understand and operate selections of artistic products based on stylistic, esthetic and ethical criteria*') in reflection to developing as musicians at 4.565, whereas male participants at 3.769 ($p< .05$); the same category of attributes were associated an estimative level of importance in the profile of the music teacher of 4.695 by female participants and of 3.769 ($p< .05$) by male respondents.

Studied between the groups divided by the field of study the participants are *majoring* in, an interesting observation occurs as it becomes noticeable that in scoring on the *superficial approach* to studying, respondents majoring in *canto* tend to score higher on this dimension (mean 2.88, SD 1.53); the higher standard deviation than in the case of the group of students majoring in *instruments* (mean 1.631, SD 1.065) shows a greater dispersion of the scores around the mean value for the canto respondents' scores in superficial approaches to study ($p< .05$).

The *level of studies completed* prior to admission to the university showed no significant differences in relation to the mentioned variables. However, a small additional group of 5 graduate students accepted to take the survey and in relation to the respondents statuses ('freshmen' vs. 'graduates') results indicate significant differences between groups in relation to their approaches to study, positioning the graduates as more inclined to high scoring in deep approaches (mean 4.2, SD .836) and strategic approaches (mean 5, SD .00) to studying than the freshmen are ($p< .05$).

4 Conclusion

This study indicates that most competences, skills and attitudinal attributes proposed to students in a higher education curriculum in music and music education in Romania are invested by the beneficiaries of the program – the students – with above average degrees of importance for their development. The students differentiate between what constitute the priorities of their profile of acquisition when reflecting on their development as musicians as opposed to music educators. In the differences they make an important predictor could be considered the manner in which they approach studying, as deep, strategic and superficial approaches to studying seem to significantly correlate with the importance they attach to the various categories of competences proposed to them in the study programs. Also, the level of confidence expressed by students regarding acquisition of these competences within the program of study was found to be significantly correlated to the approaches to study. Participants to the study provided responses significantly different according to their sex category in relation to the importance attitudinal attributes hold for their development as teacher educators. Also, students majoring in canto scored higher on superficial approaches to learning than those majoring in instrument-interpretation.

The results generated by 'freshmen' participating in this study are lower on the dimensions of deeper and strategic approaches to learning than those of 'graduates' taking part in this study.

Although the small number of participants to the study restricts any attempt of generalization of findings, some of the results generated indicate that an increase in the value students attach to deep and strategic approaches to learning throughout the bachelor degree can be expected. Further investigations should thus focus on what aspects of the curriculum facilitate such outcomes. Also, further explorations of the manners in which students' priorities and approaches to learning and developing as musicians and music educators shift throughout the bachelor degree are in order, as part of a longitudinal study for which these results could stand for a point to start at.

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Trio for violin, double bass and piano (1991) by Ghenadie Ciobanu - an original musical interpretation of some events recorded in the Holy Scripture

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Abstract: During his stay in the Holy Land Ghenadie Ciobanu had the opportunity to visit a lot of places connected with the events described in the Bible what inspired him to create a musical work full of profound significances - *Trio for violin, double bass and piano*. For Gh. Ciobanu's creation is characteristic the value of the semantic criterion and that of the content. This appears to be very complex and profound, determined by the philosophical – cultural synthesis of the precursory historical periods, by a specific approach of the musical culture of different peoples (Indian, Chinese and of course Romanian etc) and their integration in the palette of images of contemporaneity. All these specific peculiarities define the unrepeatable aspect of Gh. Ciobanu's creation and are strongly manifested in his *Trio*.

Key-Words: Gh. Ciobanu, Trio, musical language, musical form, opposition, numerical symbols.

The present work appeared owing to the composer's wish to speak about those impressions, feelings and absolutely specific sensations created by his journey to Jerusalem. During his stay in the Holy Land Ghenadie Ciobanu had the opportunity to visit a lot of places connected with the events described in the Bible what inspired him to create a musical work full of profound significances.

The *Trio* consists of two movements: *Indicium* and *An Almost Biblical Journey on a Little Donkey*. Both from the program of the movements and from their first audition one have the impression that they are parts of two different worlds. But taking in consideration the composer's account about this work and after a more profound analysis we can say that there is a close connection between the two movements of the *Trio* both at the level of idea and its realization. The composer said: "In the *Trio* I tried to express in a symbolic plan the unity and, at the same time, the border line between the New and the Old Testament, to convey through musical means the course of two periods of time - a real and concrete time and a period that has nothing to do with history, philosophical one." The names of the movements correspond very well to the content and character of the music according to the author's own vision. Movement I designates the Old Testament, looked upon in general lines, abstractly. Movement II deals with a historical period that is closer to us, it even conveys a definite event - the escape of the Holy Family to Egypt. According to this program, Movement I seem to be, in some way, more abstract, more indefinable like the sense of the word *indicium* (in the dictionary it has the following meanings: declaration, confession, proof, sign, confirmation, reflection.). Here predominates an atmosphere of a slow course of cosmic time. The musical means used by the composer are intended to create a sensation of space, profoundness, to bring back to the listener's imagination some far off periods of time and events that are nearly razed from memory. But we can notice here a description of something transcendental that, in Gh.Ciobanu's opinion, is in this case, Time and Cosmic Space.

Movement II, on the contrary, brings us back to the "terrestrial dimension". We accompany the Holy Family in their journey towards Egypt and all the musical means are purposefully used to convey definite events and to create pregnant images.

The *Indicium* consists of seven episodes that are organized in a concentric form.

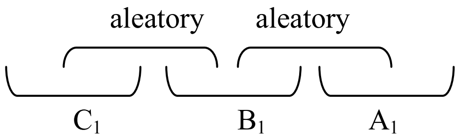
$$A\ B\ C\ D\ C_1\ B_1\ A_1$$

Determining the bounds of the form we, in the first place, took in consideration the obvious change of the texture. Thus, sections A and A_1 are monodic, B and B_1 contain polyphonic elements, C and C_1 are variants of a homophonic structure, but controlled aleatory is used in section D.

A specific feature of the musical language of this movement is the metro-rhythmic aspect. Unlike the well-defined structure of the movement the metre is unstable, variable and some episodes are, in fact, non-metrical (A, D). The use of polymetrical and polyrhythmical principles (section C) should be specially mentioned here.

Another peculiarity of the composition of this part is the variant principle. It is, first of all, manifested in the framework of episodes B and B1 that, in fact, represent a cycle that has variants (three in B and three more in B_1). This principle is noticed at the cycle level, due to the fact that not a single re-entry (except the exact re-entries from section D) of the musical material is done exactly what confers the music an uninterrupted course.

In the re-entry sections (especially) we notice the use of the technique named by V. Holopova *thematic cohesion*, but the composer uses it not at the level of motifs or themes but at the sections level. That is why extrapolating the term suggested by V. Holpova it would be more correct to speak about a cohesion of the sound blocks. An element from the preceding section continues its existence during the following one superposing itself on the rest of the material. In this way, a special continuity of discourse is realized and there is an impression of a slow and unnoticed course of time.



The *Indicium* starts with an improvising monody with a lot of chromatisms and varied rhythmic figures performed by the violin and double bass (episode A). The melodic line, starting from **B flat**, outlines a sinusoid or two oppositely directed angles that have as reference points the same **B flat**. The melody is carried on in a range of three octaves through non-rectilinear activity that contains big leaps (example 1).

The next section contains two different “thematic” elements: a cluster that is formed gradually by overlapping sounds in the piano part and a melodic line set forth in the strings as if continuing the one from the preceding episode. The unusual way of “attacking” the cluster removes the sensation of dissonant sonority and creates a very specific sound effect (example 2).

The statics and soft character of the sonorities from episode B are interrupted by the harsh clusters staccato performed by the piano (section C). This episode is perceived more like a replication or bridge that takes us to the central section of the *Indicium* (section D). All the three instruments merge into a dense aleatoric texture formed from three melodic lines that rotate in a very narrow range. The uncontinuous aleatoric activity is interrupted by the *col legno* double bass beats in order to be resumed precisely three times (example 3). Then the discourse is interrupted by a violin declarative phrase after which the activity continues, but with same changes). The episode ends with **B seventh** played by the strings 20 times in succession. From here the musical narration seems to retreat but, thanks to the transformed re-entries, we realize that it does continue. All the three episodes to follow will have changes, often essential ones, compared to their expositions.

In this way C_1 that coincides with the golden section is perceived more like a continuation or development of the discourse begun in C. If in C the composer outlines just a single sonorous plan (a very short one) in C_1 we see the presence of two spheres: an accordic one played by the piano (unchanged compared to C) and the other one melodic-played by the strings (example 4). Each sphere is very well individualized and outlined. We see a concentration of poles in this episode: polyphony, polymetry and polyrhythm. Towards the end of the section the metric precision is gradually removed (in the string part), the discourse is disorganized and becomes an aleatoric one. A third layer is added to those two present in B in the re-entry of the next episode: aleatoric figures on the violin, as if “left” from C_1.

The last part of the form can be called re-entry only to a certain extent of conventionality. The thematic material from A is not repeated here, but it is the general atmosphere that is reproduced: again a monody played by string instruments. The violin is preoccupied with recovering and reaffirming the sound **B flat**, from which everything started and with which we expect the Indicium to end. But after so many “modulations” in other spheres, after conquering some other “centres” the discourse cannot simply return to the starting point (one can’t step twice in the same flowing water). Sound **C** produced by the double bass seems to confer a new quality to section B, a quality acquired on the way. But, at the same time, it can mean a new beginning as well, a possibility of continuing the musical narration (example 5).

As a result of a close analysis we have determined that the sound **B flat** has the function of a gravitational center in the Indicium and most of the episodes are centered around it. In some episodes local centres appear by this central sound. Thus, in section A the discourse is organized around the sounds **B flat** and **F**, in section D it oscillates among **B flat**, **F** and **D flat**, but in A_1 beside B flat is sounding **C** as well.

If in the *Indicium* the composer was preoccupied with the creation of space in Movement II *A nearly biblical journey on a little donkey* he brings the musical action to earth. The listener becomes witness of a real musical journey, in spite of the fact, as the author admits that it was not so important to reproduce the concrete event but rather to convey the impressions and

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personal feelings experienced during his journey through biblical places.

In Movement I of the cycle, the form had the main constructive function, the model (pattern) under the conditions of a very free metre, is somehow “unorganized”. In Movement II the composer resorts to the same principle, but “oppositely directed”. It is the metre and rhythm that comes out here as organizing elements of the discourse, all the musical material is strictly metric, the form is free and open. For creating the form the composer uses a principle that is more characteristic of cinematography – a frequent change of “frames”, of images (that seems to be natural when it comes to a journey, even if it is imaginary). *The journey* has a number of episodes that differ by character and colouring, with thematic material and organizing principles that are new every time. Towards the end of the form (in the last episode but one) there appears, as a matter of fact, a re-entry, but it is strongly extended and transformed having in common with the first section only the characteristic rhythmic figure. The last of the eight episodes, both by the character of the musical material and due to the presence of the only re-entry before it, is perceived as a general coda of the cycle (we’ll come back with more details later), a fact that permits us to treat the form as a seven-part form:

A B C D E F A_1 coda

A pregnant folkloric line is evident in Movement II: Some folkloric elements (the improvising character of the monody, the tone quarters) were present in the Indicium too but, in fact, in a latent form. Here they became more “palpable”. The author approaches folklore introducing in the discourse some characteristic folkloric sings such as the *aksak* rhythm and specific intonations of folk Jewish music.

In Movement II we notice elements of instrumental theatre. The individualized instruments in their treatment become real characters.

A special role in the *Journey* rests on the piano. After the balanced use of instruments in Movement I, here the piano appears in the foreground, becoming the main character of the action. It is the change of structure in the piano part and the appearance of a new sound image that is realized the division of the musical discourse, into episodes each presenting a new impression from the journey. And only in the coda the piano retreats offering the strings the possibility “of commenting” the things that had happened.

Something new, in comparison with Movement I, is the use of human voices that recite some verses from the Bible.

Movement II of the cycle includes a number of episodes based on different thematic material, creating a mosaic image. Every section of the form contains a key-element around which the musical discourse is concentrated. This key-element is frequently present in the piano part.

In this way, a very pregnant musical image appears in A that is due to the use of the *aksak* rhythm (example 6). The key-element from episode B is represented by a rhythmic dotted formula with trill (example 7). The next section (C) is again very illustrative through the melodic-rhythmic figures in the piano part (example 8). Episode D demonstrates a certain mechanical character, unique in part II that, due to the active movement and quick rhythm, is associated with a fugue or gallop. Section E introduces an evident contrast by sounding human voices that recite the biblical text (Matthew 2-13, 14). Episode F seems to illustrate the moment of the night (according to the witnesses from the Holy Scripture) when the Holy Family escape from Bethlehem. The melody from the strings part seems to convey the attention and precaution of the fugitives motion while the Jewish motifs from the piano part witness the nostalgia and sadness of separation from the native land (example 9). Section A_1 cannot be named reprise in the direct sense of the word because it is much better developed than A (taking in consideration both the form and means of expression). The musical material appears here much more consistent than at the beginning of the movement where it was confined to just one rhythmic-melodic figure. A new thematic element is added to it, it contains an accentuated repetition (27 times) of the accord. **B - F sharp - A flat** that produces an effect very similar to the end of episode D from Movement I (where the septima b-a is repeated 20 times). The coda is emphasized through an original sonorous realization (at the cycle level), being entirely maintained in *pizzicato* in the strings.

Some peculiarities of the musical language from the Trio at the cycle level:

Taking in consideration the specific features of the movements we can state that Movement I has a more improvising character, is less pregnant from the point of view of the thematic material. On the contrary, Movement II differs through a more individualized and varied thematism. We discover here a concentration of musical images. In this way, the composition of this cycle is approaching, to some extent, the structure of **bipartite constituent-contrasting forms**.

An important conceptual principle that involves the use of some specific technical proceedings is the **principle of distance reprise**. In the Trio the composer often makes use of variants of the same repeated sonorous blocks that are continued some time later after introducing new musical material. We could compare this phenomenon to reminiscent arches if the conceptual evolution of the discourse were not obvious: the material taken over is always modified. In this context, can be mentioned the variable mini-cycle from sections B and B_1 from Movement I (part I), the conceptual transformation of the discourse from episode C an C_1, Movement I, and especially the beginning and A_1 from Movement II. Unintentionally, there appears an association with the human destiny: nothing is repeated exactly in the same way but every time in a different way, at another level, under other circumstances, from other experiences. The program of the work connected "in some way" with the Bible, permits us to draw a parallel with the Holy Scripture where certain events that were once predicted come true some time later.

We can point out the presence of some leitintervals and leitintonations at the cycle level. The composer uses the seventh and nona and their variant - the second. As leitintervals of the entire cycle can be treated the rhythmic – melodic figures formed of three sounds placed at distance from the fourth and fifth (perfect, increased, diminished) the extreme points of which constitute the seventh, octave or nona (examples 1, 8).

An integrating element of the work is the **coda** of the second movement as well which, as it was mentioned before, is perceived more as a coda or a *post- scriptum* of the entire cycle (example 10). At the level of the second movement, the somehow abstract and indefinite character of the coda (and especially the interval of the increased fifth **C – G sharp** that ends the *Journey*) could be treated as an expectation or prediction of the event that was to come true 33 years later – Christ's coming to Jerusalem on Palm Sunday (also riding a donkey). Through the timbre of the strings the coda forms an arc with the beginning of the work. In a conceptual thematic plan it could create some conformity between the first man who committed a sin (at the beginning of the Old Testament) and the one who will bring him salvation (in the New Testament).On the other hand, the coda of the second part corresponds to the end of part I (through the strings timbre). In this sense, we could say that there is a parallel between the end of an Eon and the approach of the end of the millennium, the witnesses of which we are all at present.

The complementarity, opposition and as a result the remarking of the unity is obvious both at the cycle level and that of the elementary constituents of the musical discourse. We'll analyze the work of this principle at the cycle level.

At the cycle level we see both an opposition of the order-disorder type and complementarism which is manifested in the very character of the parts.

Movement I	**Movement II**
Principle of undeclared order:	Principle of declared order:
unorganized metro rhythm, closed form;	strictly organized metro rhythm, open form;
arbitrary, accidental, aspect: use of aleatory;	adaptation to the public: use of genre signs, intonations and folkloric rhythms.
non-evolutionary principle: thematic repeats, variating aspect of development;	evolutionary principle: succession of different thematic episodes;
passive energetic type: slow tempo, thematism of character improvising, less expressive compared to the one from Movement II	active energetic type: a quicker tempo, thematism of dynamic, impulsive character, pregnant thematic material.

Therefore Movement I can be specified as having its character that is more irrational, instable, passive while Movement II demonstrates a rational, active and impulsive character. Uniting these two movements in a cycle the composer realizes dialectically the unity of the opposites.

The analysis of numerical symbols in the Trio offers us very interesting results. We have noticed that in this work Gh.Ciobanu uses preponderantly the numerical symbols 2, 3 and 7 (the latter is often represented by different variants of the combination of the first two: 2+2+3; 2+3+2; 3+2+2) that show compositional levels.

Digit 2, at the cycle level, could symbolize the two books of the Holy Scripture. This symbol manifests itself through: two movements, two timbre groups (piano and strings), two instruments that begin and end the work. In Movement I digit 2 is realized through 2 elements in episode B, a 20 time-repetition of the 2 sound-interval at the end of D (the moment of the golden section), two gravitation centers in A_1.

Digit 3, at the cycle level, could symbolize the family (the Holy Trinity or Christ's heavenly family in Movement I and his earthly family in Movement II) and manifests itself through three instruments, through melodic-rhythmic figures consisting of three sounds. In Movement I the symbolism of digit 3 is conveyed through three variants, in B and B_1, the repetition of the aleatoric fragment from D, through three melodic lines in C_1, three sonorous layers in B_1. At the level of section B, we can see that the first three sounds, both in the piano cluster and from the violin melody in all three variants, remain unchanged.

Digits 2 and 3 "work" together in more rhythmic formulas from Movement II.

The numerical archetype manifests itself at architectonic level. In this way, we find the seven-part form structure of both movements: $ABCDC_1B_1A_1$ in Movement I and ABCDEF**A** + coda in Movement II.

Digit 7 symbolizes the unity between 3 and 4, that is between the terrestrial, dimension, material (4) and celestial one – spiritual (3).

Finally we would like to mention that for Gh. Ciobanu's creation is characteristic the value of the semantic criterion and that of the content. This appears to be very complex and profound, determined by the philosophical – cultural synthesis of the precursory historical periods, by a specific approach of the musical culture of different peoples (Indian, Chinese and of course Romanian etc.) and their integration in the palette of images of contemporaneity. All these specific peculiarities define the unrepeatable aspect of Gh. Ciobanu's creation.

Fig. 1

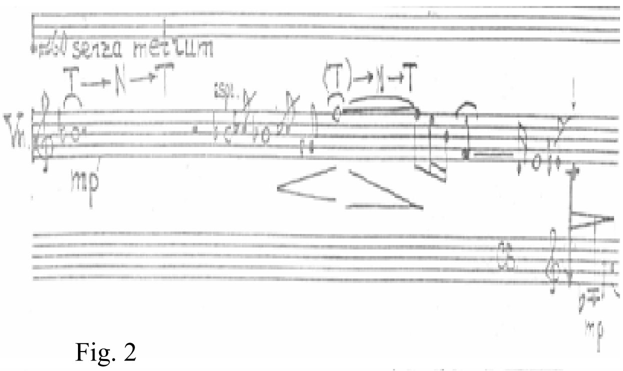

Fig. 2

Fig. 3

Fig. 4

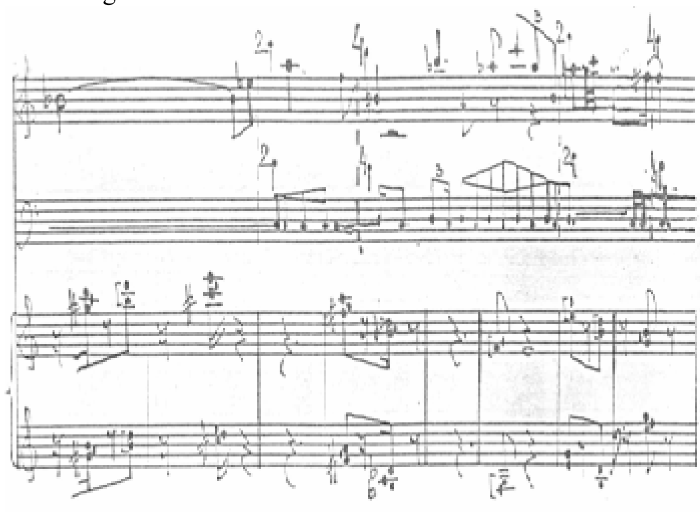

Fig. 7

Fig. 5

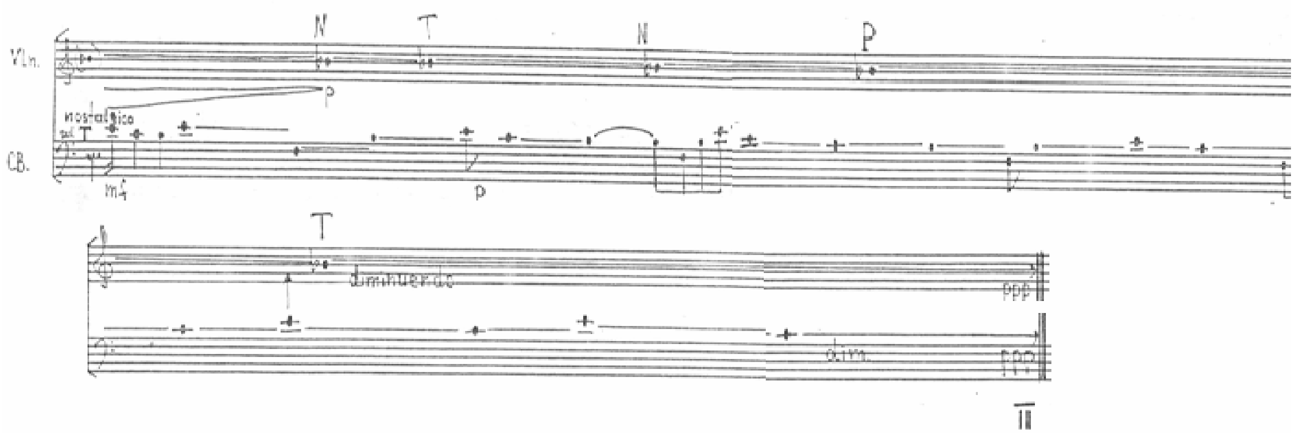

Fig. 6

Fig. 8

Fig. 9

One Modal Pattern, Three Compositional Entailments

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Abstract: - Frescos for solo violin (1976) draws a 'boundary' between my early years as a composer and everything that ensued until *Seven Intersections of A Feeling and A Season* (1988). Starting with the *Frescos*, I devised a coherent musical grammar which nourished, fully or partially, all my succeeding works. The grammar in question is represented by a non-octaval proportional intervallic mode and its derivatives. The mode belongs to a family of modes (*Miorita – The Ewe Lamb*, the *Fibonacci* modes) which has become emblematic in the Romanian contemporary musical output due to its rigorous theoretical support, on the one hand, and to the remarkable creative applications provided by some very important composers (Anatol Vieru, Wilhelm Berger, Aurel Stroe and others), on the other hand.

Keywords: - mode, proportion, symmetry, reflection, translation, palindrome, circular permutation, intersection (Mathematics)

1 Introduction

The proportional intervallic mode (MP) represents the intonational projection of the string of numbers [1, 2, 3, 5, 6, 7, 9, 10, 11] on which the semitone unit is applied in one direction (ascending or descending). In the structure of the string there are three triplets made up of consecutive numbers, between which there is an empty slot (the missing consecutive number):

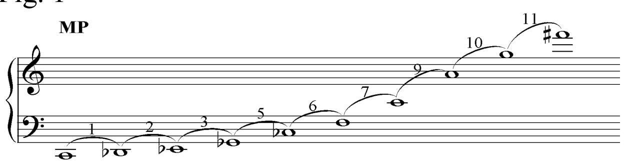
1, 2, 3, (4), 5, 6, 7,(8), 9, 10, 11

If it went on using the same algorithm (…13, 14, 15, 17, 18, 19 etc.), the string would return to the original intervallic structure by subtracting the module 12 (octave):

13-12 = **1**, 14-12 = **2**, 15-12 = **3**, 17-12 = **5**, etc.

Consequently, we are dealing with a closed modal structure composed of nine intervals (ten sounds, actually eight – in absolute values – since two of them are repeated)

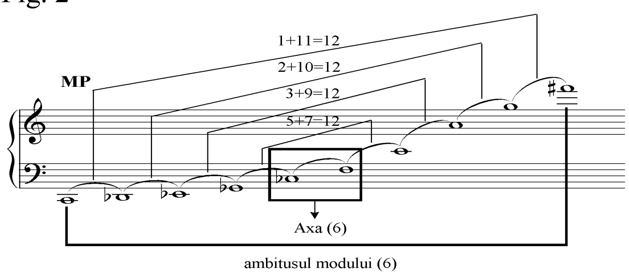
Fig. 1



This structure has some quite interesting properties:

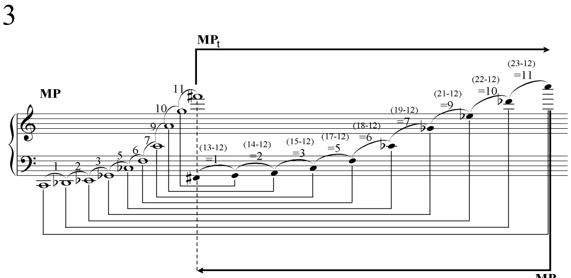
- **firstly**, it is a symmetrical structure: the axis – tritone (augmented fourth – diminished fifth) divides the mode into two equal sections whose intervals are symmetrically complementary. The ambitus of the mode represents the equivalent of the axis interval.

Fig. 2



- **secondly**: if we were to continue the modal structure according to the algorithm of the extended string of numbers, to which we would apply subtraction by 12 (octave), we would come up, on the one hand, with the transposition (*translation*) to semi-octave (augmented fourth or diminished fifth) and, on the other hand, with the reversed recurrence (*reflection*), by means of complementary intervals, of the initial modal structure (MP) namely its derivatives (MP_t şi MP_r).

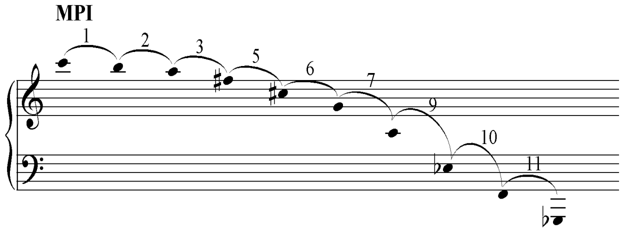
Fig. 3



All these aforesaid render the MP structure palindromic and, at the same time, make it a mode of limited transposition (six transpositions);

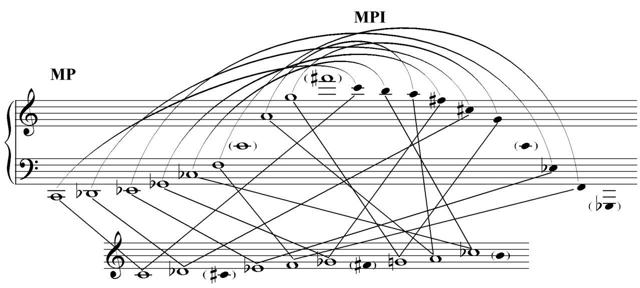
- **thirdly**: the change of direction in mode construction – its inversion (*reflection symmetry* with axis – sound) – generates the derivative MPI whose formal properties stated above remain identical but whose ethos is 'reversed' by changing the direction of the intervals and the relations between them:

Fig. 4



- and, finally, **fourthly**, a striking coincidence: although radically opposed from an intonational viewpoint, the two modal instances (MP and its derivative MPI) possess **exactly the same sonorous material**, exactly the same ten sounds (actually eight, in absolute values, since the same two are repeated). Naturally, in order to confirm this identity it is necessary to resort to enharmony.

Fig. 5



The situation above proves once more that the musical structure is built fundamentally on relations and only formally on absolute values (sounds).

I mentioned earlier that between the basic mode (MP) and its reversed derivative (MPI) there is a 'reversal' of the intonational direction . It occurs both partially (on sections) as well as globally. The MP contains two major harmonic structures which can be extended to two corresponding spectral-acoustic polarities: one with the fundamental B (C flat), the other with the fundamental F. In the case of the MPI, the two structures are – through *reflection* – minor, with the fundamentals F sharp and C, respectively.

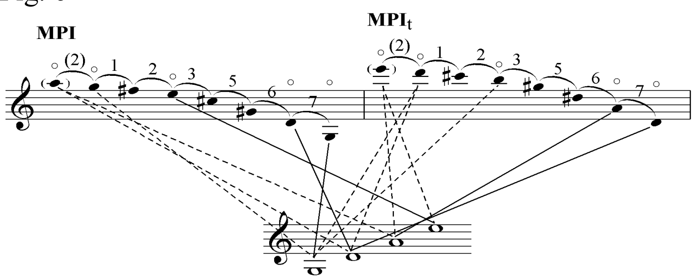
All the above-mentioned properties characteristic of the MP mode offer it and its derivatives specific qualities of an expressive nature, but also a remarkable structural unity, qualities that I have tried to exploit in almost all the works written since 1976.

2 The MPI – *Frescos*

The work *Frescos* for solo violin (1976) is the first consistent application of the MP structure through its 'minor' derivative MPI. The title offers a plastic suggestion en rapport with the two contrasting sonorous structures on whose alternation music is developed. The ***A*** structure, 'ascetic' from a rhythmic and intonational viewpoint, is meant to render the hieratic character of the old church frescos. The ***B*** structure cultivates a fickle and agile rhythmic-intonational pattern whose inner geometry suggests the mouldings and the decorative strips on the houses and the carpets from Bukovina.

The modal structure MPI is present in two transpository instances; the reason for their choice lies in the fact that the sounds G, D1, A1 şi E2 that they contain are found in the standard violin strings, which allows for the timbral exploitation of the free strings, but also of the natural flageolets.

Fig. 6



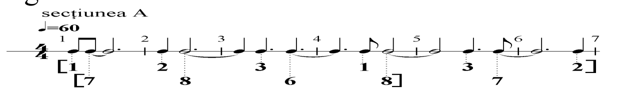
The occurrence of the two modal instances is reduced to partial structures (sections) of the basic mode. Occasionally, there is a sound 'attached' to the pitch of the mode, which comes from its straight form (the MP). The central section of the work (B var.1, bars 68-89) synthesizes the intonational material through the union of MPI and MPI_t.

The contrast between the A sections and the B sections occurs mainly because of the use of two reversed rhythmical operations.

The former – for the A sections – is a multiplying operation: the unit (the eighth) is multiplied alternatively by the items in the string [1, 2, 3, 6, 7, 8] grouped into two triplets: the 'small' numbers (1, 2, 3) and the 'big' numbers (6, 7, 8). These last ones derive from the 'small' numbers to which 5 is added: $1+5=6$, $2+5=7$, $3+5=8$.

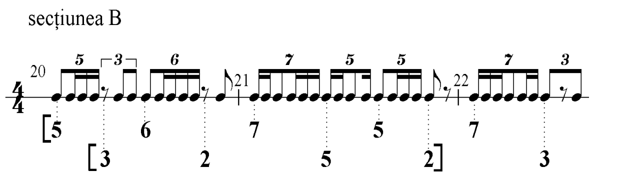
It is obvious that I have resorted to the same string of numbers which generates the intonational grammar [1, 2, 3, 5, 6, 7] as concerns the rhythmical organisation as well. This results in a rhythmical structure made up alternatively of 'short' durations and 'long' durations. The succession of the 'short' durations is determined by a *symmetrical* algorithm with period 6: [1, 2, 3, 1, 3, 2 etc.], and the succession of the 'long' durations – by an equally symmetrical algorithm with period 4: [7, 8, 6, 8 etc].

Fig. 7



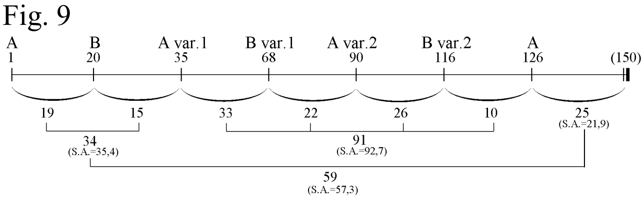
The latter operation – for the B sections – is, by contrast, de-multiplying: the unit (the crotchet) is divided alternatively by the items of the string of numbers [2, 3, 5, 6, 7] which is again grouped into two triplets: the small' numbers (2, 3, 5) and the 'big' numbers (5, 6, 7) – where 5 is now the conjunction. This results in a rhythmical structure made up alternatively of 'long' divisions (3) and 'short' divisions (6 , 7), where the value 5 is the medium value (*the symmetry axis*). The algorithm of this succession is again *symmetrical*: [5, 6, 7, 5, 7, 6 etc.] (period 6) and [3, 2, 5, 2 etc.] (period 4) respectively.

Fig. 8



The diagram of the work illustrated in Fig.9 denotes the existence of symmetry as well as the filiation with the the ratios of *the Golden Section*.

Fig. 9



Frescos for solo violin is my first creative experience where the rigorousness and the constructivist spirit prevailed over intuition. The work was one of the seven pieces for solo violin to be selected as finalists in the composition section of *Henryk Wieniawski* International Competition in Poznan, Poland, 1977.

3 The MP - *Sinus*

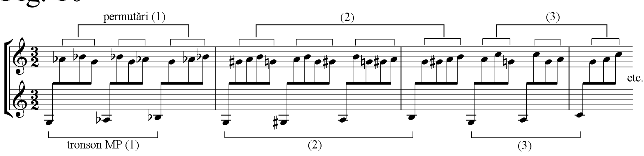
Sinus – for solo clarinet (1982) is a 'case study', in fact an exercise of technical rigorousness in extremis. Hence its uniqueness in the present analytical context.

The exercise aims at assessing the motivity of a modal mechanism, none other than the MP – the proportional intervallic mode. The starting point is the trichord stage of the MP mode built on G1 (F1 effect for clarinet in B flat). The evolutionary process is based on the operation of adding successively one new interval to the already existing ones. The maximum extension attained is eight sounds (seven intervals) and an ambitus of double augmented octave (G1, G3 sharp).

The motivity of the modal sub-structures (sections) depicted above is activated by the operation of **circular permutation** – the double application of *translation* and *rotation*. The directions of the permutations can be ascending (sub-structures 1-7, 10, 15, 21), descending (sub-structures 11, 16 and 17) or, alternatively, ascending-descending (sub-structures 8, 9, 12-14, 18-20).

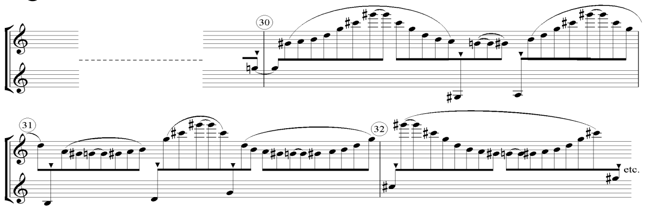
The figurative syntactic structure is constantly dissociated on two levels one octave apart, which provide it with the attributes of a latent polyphony.

Fig. 10



The composition of the permutational pattern remains stable as long as the elements of the modal sub-structure go in one direction only (either descending or ascending). Hence the continuity of the rhythmic-intonational periodicity of the melodic relief set in a constant pulsatory environment. However, once the directions start alternating (bar 9, the final time – modal section 8), the melodic arch enters a state of 'arrhythmia' stressed also by syncopations, which will occur more and more frequently on increasingly larger areas, culminating with bars 30-32 (modal section 20) – the climax of the work.

Fig. 11



In a constant unit value (the half note) to which a variable division is applied – depending on the number of sounds of the MP section – there results a pulsatory density (Δ^p) proportionally variable. However, the general direction of the pulsatory structure is progressive accelerando.

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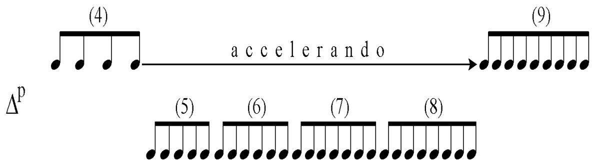
Fig. 12



The peak of maximum density is reached in the segment corresponding to bars 30-32, a replica of section 20. Henceforth, the melodic continuum breaks up into fragments, the sonorous interventions become more and more sporadic, more disjoint, the rests grow stronger, the music fades.

Despite a largely mechanical 'recipe' of construction, *Sinus* – for solo clarinet conveys to the audience quite a dramatic touch. Perhaps this also happens as a result of the title's association with the the musical pattern and, even more, with the visualisation of this pattern, which offers an oscilloscopic image.

4 The MPO – *Seven Intersections of A Feeling and A Season*

Seven Intersections of A Feeling and A Season – trio for flute, oboe and bassoon (1988) open a new stage in the structuring of the intonational musical grammar. The starting point was the same string of numbers whose properties and sonorous consequences we spoke of earlier. The idea of re-composing the grammatical structure or, better still, of finding an alternative grammatical structure to the MP (and its derivatives) was given to me by Anatol Vieru's observations on the diatonic-chromatic relation in his *Book of Modes* [1].

Here is what Vieru writes when referring to diatony: "The process of formation of diatony takes place in the order of the fifths. (…) We call a perfectly diatonic modal structure any modal structure that can be arranged in a single continuous string of fifths. (…) To measure the diatony of a mode means to compare it with the string of perfect fifths."

As concerns chromaticism, it is again Anatol Vieru who adds: "We shall proceed analogically: let us call chromaticism a connected string of semitones. (…) Let us call a perfectly chromatic structure any modal structure that can be positioned in a single string of semitones. (…) To measure the chromaticism of a modal structure is to compare this structure to the scale of semitones, in the same way that we tackled diatony and the scale of fifths."

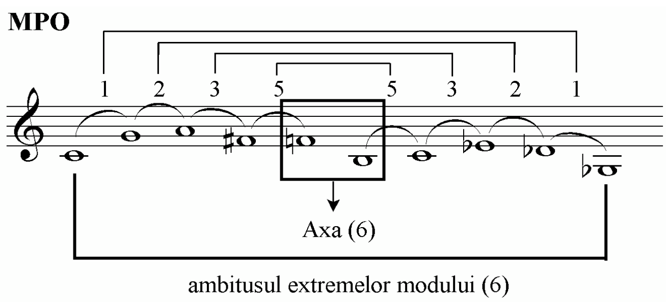
Vieru's observations and their developments in chapter 4 (*Transposition*) of the above-mentioned book, have made me go back to the MP structure. This time, though, the intervallic unit applied to the string of numbers [1, 2, 3, 5, 6, 7, 9, 10, 11] was no longer the semitone – the constant CRO (according to Vieru) – but its reciprocal, the perfect fifth – the constant DIA (ibid.).

Given the large intervals that resulted from the multiplication of the perfect fifth by the elements of the string of numbers, certain intervallic restrictions (of the octave and its multiples) and enharmonies were required. At the same time, I chose the 'small' intervals, up to and including the perfect fifth, which determined in some cases the operation of intervallic reversal (complementarity) as well. Under the new circumstances, it became obvious that, although the modal construction still went in one direction (ascending or descending), through the 'devices' and intervallic 'adjustments' that I resorted to, the intonational structure of the mode would adopt an oscillating conduct, sometimes upward, sometimes downward. In other words, although the new grammatical structure preserves essentially its scalar origin, the position of the elements in the sonorous environment fluctuates. From now on I will refer to the new grammatical structure as MPO, where the initials stand for 'Oscillating Proportional Mode'.

The properties of the new structure are congruous with those of the MP structure, as follows:

- the MPO is also a perfectly *symmetrical* structure. The axis – tritone (augmented fourth – diminished fifth) divides the mode into two equal, recurring sections whose intervals are bilaterally symmetrical. The ambitus of the extremes of the mode is the equivalent of the axis interval.

Fig. 13



the ambitus of the extremes of the mode (6)

- the recurrence of MPO generates again MPO, which render the structure *palindromic*, and, at the same time, qualify it as a mode of limited transposition (six transpositions):

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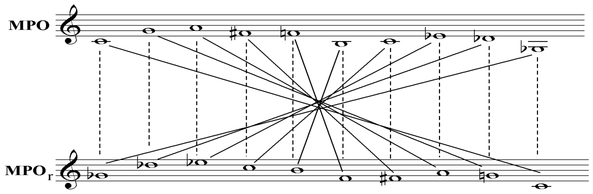
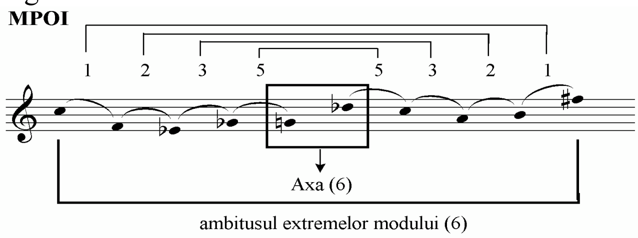
Fig. 14



- just like in the case of the MP, the change of direction in the construction of the MPO – from ascending to descending – produces the reversed derivative MPOI whose formal properties stated above remain identical, despite the essential change of ethos:

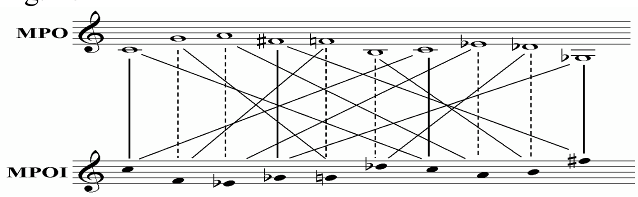
Fig. 15



the ambitus of the extremes of the mode (6)

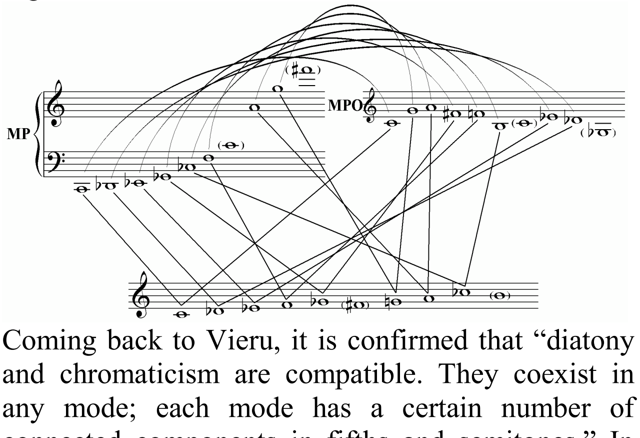
- finally, the same coincidence in the case of the MP occurs in the case of the MPO: the reverse variant (MPOI) possesses **exactly the same sonorous material** present in the case of the straight variant:

Fig. 16



- moreover, the same ten sounds (actually eight, in absolute values, since two are repeated) are present in the case of the MP (with its derivatives) as well as in the case of the MPO (with its derivatives):

Fig. 17



Coming back to Vieru, it is confirmed that "diatony and chromaticism are compatible. They coexist in any mode; each mode has a certain number of connected components in fifths and semitones." In our case, the compatibility between the two constructions – the former based on the constant CRO, the other on the constant DIA – extends until the **identity of content**. The formal differences which place the structures MP and MPO – as structures 'in time' – on quite distinct positions with regard to ethos, remain defining.

The title *Seven Intersections of A Feeling and A Season* represents a metaphorical extrapolation of the homonymous mathematical operation which, starting with this work, I have applied somewhat consistently on the MP and especially the MPO structures, either by making them interact with each other or with themselves, or by 'sifting' them through the sieve with a mesh of perfect fifths.

By applying the operation of intersection, the common elements of the (modal) sets are kept, whereas the separate elements are removed. This results in a different structure each time, partial by comparison with the original structure, and in a new time placing as well. Each intersected structure can be converted into a simpler or more complex morphological phrase (cell, motif, figure, etc.), fit to its size and expressiveness. All of them, either together or selected – according to one's imagination or liking – can be moulded into syntactic structures (monody, homophony, monody accompanied chordally or figuratively, polyphony or heterophony) having varied densities – from pointillism to texture.

The work consists of two parts, the former having five structures, the latter – three. The two parts are played in attacca, and the element which joins and divides them at the same time is the fifth structure flanked by two general rests. Each structure has its own distinctly-shaped personality that make it interact even beyond the relations of successiveness.

The first structure, *Rubato*, having an introductory role, denotes a bucolic character; mode fragments (MPO) alternate in the flute and the oboe. The rhythmics in proportional notation (controlled randomness) is attached to a circular permutational process *(translation, rotation).*

Fig. 18

The second structure, *Ruvido,* (letter **A** in the score sheet), is a heterophony obtained by dephasing the three 'voices' of the whole. Each element of the MPO mode built on *B* becomes the unison of the heterophony through successive addition. The

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sonorous density rises progressively with the completion of the mode (the area coincides with the *Golden Section* of the structure) and then slowly falls again, through the dissolution of the mode.

The third structure (letter **B** in the score sheet) is a cadenza reserved for the bassoon, conceived on three contrasting levels: the first – hymnic, with Byzantine resonances (*una corda, uguale*), the second – *giusto* (*marcato*) and the third – melismatic (*quasi vibrato lento e ampio*).

Fig. 19

The three levels face each other in an improbable alternation; toward the end of the cadence, the hymnic level yields in favour of the other two; the last occurrence, that of the second level, is progressively distorted from *giusto* to *rubato* and invested with the role of transition to

The fourth structure (letter **C** in the score sheet). This structure comes to continue the cadential ending of the bassoon which it transforms into a figurative accompaniment for an ample monody that will pass from the oboe to the flute and from the *rubato* rhythmic conduct to the *misurato*. Both the monody (flute) as well as the accompaniment (oboe, bassoon) gain density, progressively, toward the end of the structure. To this is added the use of repetition and sequencing (*translation*), apparently in a free and uneven manner; their rhetoric sharpens the sonorous tension that will be released at the end of the structure through the four overtones in forte (*ruvido*) of the flute. The four structure is also the amplest of the eight, and the *symmetry axis* of the work is located at the passage between the *rubato* and the *misurato* (*uguale*) – letter **D** in the score sheet, approximately 5'30''. The general rest that precedes the fifth structure is where the *Golden Section* of the work lies (approximate ratio 6'50''/ 4'10'') – letter **E** in the score sheet.

The fifth structure plays a transitive part. It resumes the technical-constructive elements of the introduction (the first structure), which it amplifies and strengthens in all three instruments. After the unisonal climax (*ff*, *marcato*) located according to the *symmetry axis* of the structure, there occurs a process of dissolution of the second section of the MPO, achieved by its descending sequencing, more and more fragmented, simultaneously with the rhythmic rarefication, in proportional notation.

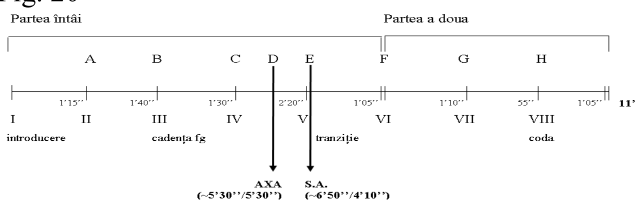
The sixth structure, *Giocoso*, (letter **F** in the score sheet), is circumscribed syntactically to the accompanied monody. The accompaniment of a figurative nature is attributed to the flute and the oboe. Each of the two figures possesses a *symmetrical* pattern repeated obstinately under the circumstances of an inner intonational variability, has a monochronic rhythmic conduct (sextolet semiquavers), and evolve in the instrument's acute register. In contrast with the quasi-continuous figurative level, the bassoon's monody is a recitativo structured in a discontinuous, apparently improvisational manner, whose components originate – as a result of a transformational process – from the *giusto* level of the cadenza (the third structure of the work). Characterologically speaking, they interpolate among the aesthetic categories of the comic, the tragic and the grotesque; it is a *Till Eulenspiegelish* anamorphosis.

The seventh structure, *l'istesso tempo* (letter **G** in the score sheet) is in the same register of expression. This time, however, the polarity is reversed. The monody distributed to the flute has a quasi-continuous conduct, and the figurative accompaniment assigned to the oboe and the bassoon is achieved in a pointillist fashion.

The eighth structure, the final one, in the form of a coda (letter **H** in the score sheet), resumes the 'hymnic' and 'melismatic' levels of the bassoon's cadenza (third structure of the work), this time assigned to the flute and the oboe, respectively.

The diagram of the work:

Fig. 20



Seven Intersections of A Feeling and A Season – trio for flute, oboe and bassoon, was first 'introduced' to the audience at the tenth edition of the *Romanian Music Festival* of Iasi, May 1998, performed by Trio *Syrinx*. That same year, the work was awarded the Prize of the Romanian Composers and Musicologists' Union, under the plain title *Trio for flute, oboe and bassoon*.

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D.I.M.A. on-line multimedia resources for Music Education

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Abstract: On-line multimedia resources in music teaching can offer a wide scale of tools leading to the shift of the teaching process from one closed and rigid, teacher-oriented to an inciting and interactive educational process centered on learners. Multimedia is defined as media made up of various contents, including both visual support (photographs of scores, videos) and texts that one may access interactively. As teaching support, multimedia has an increasingly role for providing education. The research made by the specialists of the Romanian Music Academy "Gheorghe Dima" aims to explore the possibilities and the most efficient ways of adapting the online multimedia resources to music education's specific requirements. This is achieved through the development and monitoring of an interactive pilot application called D.I.M.A. (direct impact multimedia application), functioning as an online terminological anthology, useful for information gathering and study. This article will provide theoretical insights into the on-line musical instruction process. D.I.M.A. shall be implemented on an e-learning platform.

Keywords: multimedia, on-line, anthology, education, music.

1 Introduction

The education through media contributes to the development of each individual's personality and integration into the contemporary society, the impact of these changes being summarized by Folkestad (2005). The efficacy of multimedia in the training field results from its fundaments: interactivity and the possibility of using different environments; it is a form of modern virtual reality being situated at the contents and creative inventions crossroads in multimedia. The maximum potential of using the new technologies in education is achieved through training systems Web based „with and for internet" (Fourmentraux, 2005). Exploring the adaptation of online learning is currently a mandatory task in the music education, within the framework of the applications for consumer digital media. Comparing with traditional text and data, multimedia objects are typically larger in size and include images, video, audio and some other visualization components.

Education issues have changed profoundly, the alternative to an insufficient and pricy knowledge being the discovery of some efficient teaching methods through which the students could attend actively to their own formation and not only passively receive learning experiences (Young, 2003).

2 ICT in musical education

The ICT (information and technological communication by electronic means) represent the core of progress in all areas. The phenomenon has been deeply involved in the education structures. Today there are programs facilitating the implementation of basic musical knowledge which will be used to elaborate other programs of learning process diversification.

New opportunities will arise through information and communication technology in education. Even if one will meet difficulties in using at highest capacity the technology, benefits will be felt by all persons involved in the process (Crow, 2006).

There are various musical fields where ICT is applied, e.g.: musical composition, sound generation researches developed within the last 40 years (materialized by the synthesizer and audio processors production, musical interfaces created with the aim of recording performing gestures through sound production modules), music listening and understanding which will interpose between acoustics, musical structure, cognition and emotion.

Obviously, the teacher should get familiar with all the possibilities and opportunities that ICT holds as a compensatory and/or supporting tool and must be able to determine the students' needs. In terms of ICT as a music teaching tool, teachers must strive to achieve an appropriate blend of musical activities, concepts and technology with

technological tools being used correctly and appropriately in order to enhance the music and not diminish it.
There are many ways technology can help teachers to meet their instructional goals. These include:
• Programs designed to help students develop their musicianship or improve their knowledge and skills in reading notation;
• Simultaneous appearance of sound and notation;
• Means for improving there improvisation skills;
• Programs which focus on teaching music notation or performing aural tests involving recognition and dictation of rhythm patterns, melody patterns, musical intervals, chord sequences and harmonic progressions;
• Notation and sequencing programs which assist students in composing activities;
• CD-ROMs focusing on music history and listening activities;
• The pace of lessons can be uniform and appropriate. For example, musical excerpts can be located and/ or replayed quickly;
• Virtual instruments allow experimentation through changes in tempo, modality, voice and transpositions.
Most importantly, these new technologies hold the key to improved musical learning. Placing the tools of technology into pupils' hands will guide them to active music making. Studies indicate that when students become active participants in learning, they gain confidence, learn more effectively and are drawn to further study (Hamel 2004). Music technology help pupils to learn to become more appreciative on music as an art, it gives the opportunity to link their musical experiences outside the classroom to the learning process inside, thus becoming active participants in the joy of music-making. Using music technology inside the classroom can offer alternative ways of learning to children who may experience difficulties with more conventional approaches (Cox 2006).
Using music technology effectively can enable pupils to work more effectively at their own pace and according to their individual abilities as well as limiting any performance anxiety by focusing on learning and not on peer competition.
The evolution of musical technologies was prompted by the ICT development, as well as by the evolution of research in other areas of activity.

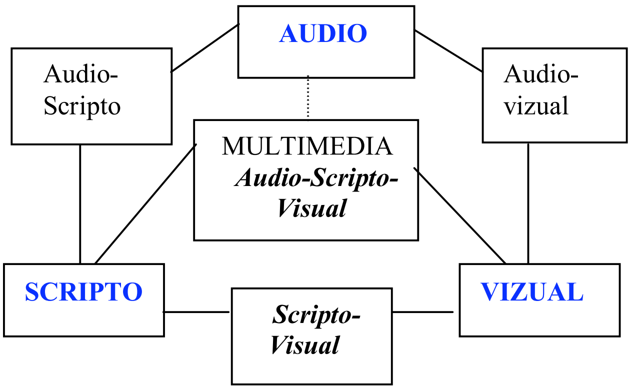
2.1 Educational platform

The e-learning platforms provide specific instruments of implementation to the education institutions, with courses and other multimedia materials in electronic format, by applying a complex synchronous and asynchronous communication system.
The elaboration of an e-learning platform devoted to music education is a requirement that must observe cognitive ergonomic demands to ensure the highest level of efficiency. The cognitive ergonomics are a branch of economy, emphasizing the analysis of the cognitive processes (making decisions, planning, etc) needed for the equipment and apparatus operation of modern informatics. Cognitive ergonomics concentrate on the increase in performance of cognitive tasks through actions like: user-oriented organizing within man-machine interaction (HCI-Human Computer Interaction) and instruction achievement and task re-organizing to intensify the degree of cognitive loading, etc.

2.2 The multimedia resources

Multimedia is the result of combining three innovations developed within the last century: telecommunication, audiovisual means and computer science; it refers to the integration within a unitary document of texts, static or animated images, sounds, and radio sequences on electronic support. (Fig. 1)

Fig. 1. Multimedia – various media of information Retrieval



Multimedia (multi - more; media - media, means) refers to the capacity of a system to communicate (present) simultaneously the information by way of several presentation media, such as text, graphics, photographers, animation, sound, video clips, etc. Although images are carrying the biggest information bulk among all the communication means, the sound is the more expressive and subtle way of transmitting a specific message. Having really access to the human hart, the sound has the quality of inducing, in the most direct, rapid and efficient manner, a large sphere of feelings, unlike images and texts that are firstly and mainly filtered by the brain.

Animations can be used for conveying a more dynamic and attractive aspect to the students through the visual impact generated in the receiver during the communication process. The course participant can control the order, coherence, duration and multitude of data received via the transmission channel- the TV screen-, a process that subsequently influence the perception and vision on the subject in hand.

The opening towards multimedia does not reject the classical education; on the contrary, by multimedia is promoted the communication side of media, Internet being the new exponent of the mass-media.

The multimedia technologies are designated as the totality of creating, storing, retrieving, spreading and utilizing modalities of documents composed of multiple media, such as texts, graphics, static images, animation, sound and video objects.

Associating graphical elements and the discourse has a double role: besides transmitting concrete information it induces a special approach to the discussed subject.

Multimedia offers the advantage of various forms of messages integration. Each multimedia element uses specific files with well-defined characteristics. Before selecting a type of file, it is recommended to find out what computer type is disposal at concerned group. A multimedia application includes various kinds of information, giving the appearance of movement, directed on basis of a script established according to the message to be transmitted.

Interactive multimedia is constantly growing, and is also starting to have a major role in our lives. As we are going towards a digital world, people communicate interacting with a multimedia interface. A system in which the items of information are connected and can be presented together is called an interactive multimedia system.

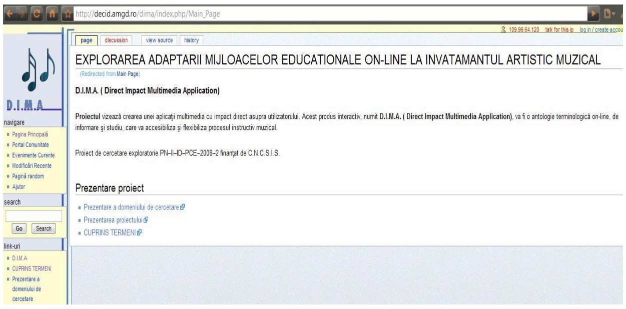
The opportunities for creating combinations of sound and image for multimedia projects stimulate the learning interest. (Kumpalaien 1998, Koutsonsnos 2005)

A multimedia system comprises a multimedia engine, a database and a human-machine interface. The multimedia engine may be adapted to access multimedia files from a number of multimedia data sources for playback on one or more different multimedia output devices. The database has to record information relating to the multimedia files stored from those data sources. The multimedia file information from these sources will be compiled in a commonly accessible format. The human-machine interface will provide a graphical interface to the information stored on the database for playback of corresponding multimedia files from the multiple multimedia data sources.

3 D.I.M.A. (Direct Impact Multimedia Application)

D.I.M.A. was conceived as an exploratory project, organized in the “Gheorghe Dima” Music Academy from Cluj Napoca, Romania, which aims to explore the possibilities and to establish the most efficient ways of adapting the on-line educational means to the music education.

Fig. 2 The project’s screen



DIMA is a multimedia anthology of terminology consisting of more than 1000 musical creations focusing on the Romanian creation and performing. The Core of musical examples will be a fund for all education, study degree and research levels.

An anthology of musical terminology interactively connected to information on the cultural and historical context, with links to other sites. The anthology will be made on the basis of a Romanian bibliography (works in the field, courses, didactic books, dictionaries, lexicons)

The DIMA project was elaborated by means of MediaWiki, a free wiki software package, PHP written initially for Wikipedia use. Currently, it is used in several non-profit Wikimedia Foundation projects, and in many other wikis.

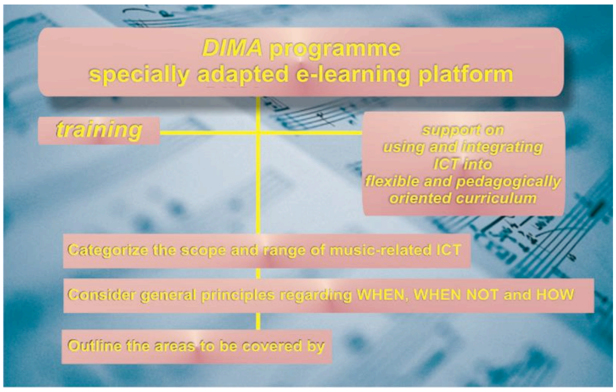
Application basic facilities:

- Navigation
- Search
- Changes follow-up
- Editing
- Formatting
- Add, delete, page (sub page) modification
- Link, video, audio recordings addition
- Safety

D.I.M.A. will be implemented on an e-learning platform, thus requiring a serious interdisciplinary approach, prospectively benefiting the educational system.

Starting with the objective of musical education which aims to develop the performing abilities (vocal and instrumental), the perception of music, the use of elements of musical language, the cultivation of the sensitivity and musical creativity, we foresee the using of alternative environments of learning that have a meaningful component defined by new technologies (Nedelcuț, Plăian 2010). The purpose of the application is to create an easy access database where each term/concept/notion would be associated with multimedia content (texts, images, sounds), thus stimulating the interest in learning.

Fig. 3 Platform facilities



The program's basic fund will cover certain domains.

Table 1. Domains covered by D.I.M.A. application

Domain of performing disciplines	
Key instruments	Sheet music
String instruments	Landmarks of the study
Wind instruments	technical solutions
Religious music	Performing examples
Domain of historical - humanistic discipline	
History of music	Personalities of the worldwide music
Esthetic	Panorama of the 20^{th} century music
Stylistics	Romanian composers
Musicology	Romanian folk traditions
Applied music disciplines	
Theory of music	Systematizations on stylistic stages
Harmony	Examples
Counterpoint	Reference sources
Sheet music reading	
Folklore	

Additionally, D.I.M.A. will also contain:

- an on-line tutorial for improving basic computer skills,
- an introductory tutorial to musical writing

a virtual index with Romanian publications on the covered domains (books and articles in the music realm) related to the project's work plan (objectives and activities)

D.I.M.A. will provide the musician with the information on a given subject from numerous analytical angles. The user of the anthology will be able to access information in different forms: audio, text and images. The novelty of this project consists in the analytical - musicological approach of the registered terms, presenting terminology from different perspectives:

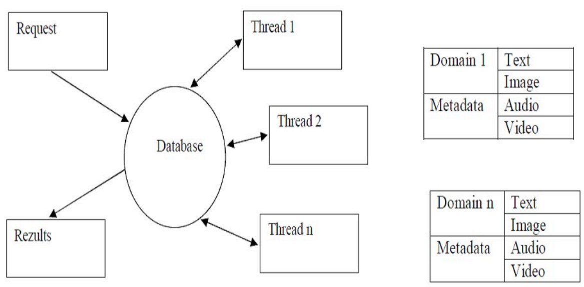
- the history and evolution of the term;
- the reference of the term to be performed on various instruments and in different stylistic stages;
- bibliographical references and selective auditions;
- interactive, practical applications of the term;
- the term in the context of the 20th century Romanian music creations based on the musical patrimony of the „Gh. Dima" Music Academy.
- The idea behind this approach is to secure resources that can help pupils to understand the cultural and historical contexts of musical styles and genres in an interactive way (Hamel 2004)
- The activities in all areas should be closely connected with the training activity by:
- incorporating the learning opportunities into the working processes;
- extending the focus from single- learning to team- learning , as an organization;
- establishing a curriculum containing subjects directly connected with the tasks of a certain moment;
- sharing the information resources with other partners within the training process.

3.1 System architecture

Project approach is a key to the successful completion of each project. The D.I.M.A. is split up into individual phases, each with its own tasks and deliverables. Each phase provides functionality and payback for the beneficiary. Several steps are necessary to ensure the solution is developed in the most effective, and efficient way according to the main objectives.

The task of a multimedia database server is to build up a system that can manage huge collections of

multimedia data efficiently. Figure 4 depicts the overall request processing of the database server.
Fig. 4 Multithreaded database engine architecture



The database is organized according to the domains specified by the users to support multiple media types (text, video, audio and imagery) and operations upon those media. File retrieval and playback are also supported for all media types.
Currently, the server in our system supports the following operations: analyzing the multimedia data and retrieving the useful features; processing content-based retrieval for images and videos; listing the contents of a media type.

3.2 Students Feedback

The D.I.M.A. application was tested during the information/instruction process by a group of *Gheorghe Dima* Music Academy students included in distance learning programs. The content is an open source, as the teachers and students may upload now or in the future new articles or musical examples.
Students were given pre- and post-questionnaires for evaluating the application at its current e-learning platform implementation stage; the students' feedback referring to the intervention upon the product quality suggested the undertaking of the following beneficial actions:

- on-line availability of educational and information resources;
- informal feedback at the sections' end to make possible the evaluation of the understanding level of information at the beginning of a new chapter;
- the use of on-line multimedia resources is decisive to the teaching methods improvement;
- ICTs are extremely useful to the learning process;
- these type of resources can be used to the creativity process development;
- DIMA applications allow students to freely use a large variety of learning technologies (video, educational and music soft, etc.)

Students were also involved in creating educational content. It must be said that such an implementation requires a lot of effort but offers plenty of advantages, such as:

- acquisition of teamwork abilities;
- the development of competitive spirit.

By this research we intend to supply a pertinent theoretical framework concerning the registered data methodology, which will guide the development of this interdisciplinary domain.
The original elements of this research are referring to an intensified technological approach to the cultural heritage (performance, theoretical concepts and Romanian creations) by discerning the critical aspects needed to design the specific multimedia application – an interactive instrument that will facilitate digital access to the use of scientific and cultural resources. Another opportunity is to create a sound-image combination for multimedia projects in order to stimulate the learning interest.

4 Conclusions

Multimedia is an exciting technology that gives technical communicators a broad range of tools for information designing. Considerations such as: content and organization, style, installation and distribution, legal, and cultural issues bring new challenges for technical communicators.
D.I.M.A. will represent a significant resource which, after implementation, will prove its usefulness and efficiency. The goal of the researchers involved in this program is to promote the educational process through modern technology.
In this context, the applications of IT in the educational system represent a dynamic, fully extended field, a central point of interest for both schools and commercial societies active on the education market. In this context, the need for creating standards which should allow inter-operability through transfer and use of educational materials in different systems requires immediate attention.

Acknowledgement
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ON THE RELATIONSHIP BETWEEN MUSIC AND 20TH CENTURY ABSTRACT MATHEMATICS

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Abstract: - We will analyze the relationship between music and abstract mathematics by taking into consideration the statement that „since Boole, mathematics is understood as the creation and study of abstract patterns and structures" [3], statement which belongs to Edward Nelson, professor at the Department of Mathematics of Princeton University.

Key-Words: - mathematical models in music, axiomatic mathematics, generating motif

1 Introduction

At present, mathematics has two major branches, namely abstract mathematics and applied mathematics. The nucleus lies in abstract mathematics which, just like music, draws its substance from the unseen. In abstract mathematics, "meaning is found in the beauty and depth of the abstract patterns, in unsuspected relationships between structures that previously seemed unrelated, in the fierce struggle to bring order to seemingly insurmountable complexity". Thus, while dealing with mathematics, one may have the impression that one is creating art. For example, the pair specific to the field of mathematics, namely the theorem followed by the proof, can be seen as the theme followed by its development, as is the case with music. Moreover, when it comes to complex proofs, with a multitude of notions, correlations and intermediate stages, symphonism seems like an appropriate term.

From this perspective, the shift from mathematics to music becomes smooth, and, in addition, sometimes necessarily, for through music one can access the infinite worlds from within the living soul. To this we can also add the joy of finding in music, most of the times, deeply motivated order and unity, structure, explicit or implicit coherence.

A fascinating case is that of axiomatic mathematics, where one starts every time from a nucleus made up of primary elements and axioms. The theory which develops from hereon emphasizes the latencies that one may infer and sometimes the distance between the initial and the obtained information is amazing. Let us take the example of topology: one starts from a couple of elements of set theory and gets to the description of some extremely refined structures. All flowers can be described as differential varieties and their topology is indeed interesting. In the theory of stability and of catastrophes, one has whole families of varieties which can be considered as a variant of a single one. This situation makes us think about the varied hypostases that a musical motif can embrace throughout a musical creation, especially in the case of the opuses that illustrate the cyclic principle. If we take into account the fact that mathematics can also be considered "a general method for the investigation of structural aspects" [2], musical analysis becomes an abstract mathematics process.

2 Problem Formulation

The relationship between music and mathematics is supported not only by the mere presence of some mathematical notions, which can be more or less complex, but also by the coherent processing of musical data, capitalizing on, and at times even transfiguring the possibilities of the initial material, as it happens in axiomatic mathematics. It is worth mentioning the fact that the musical opuses where we are seeking the influence of mathematical thought are only those opuses in which the approach reveals profound musical thought, serving the ethos, and thus conferring value, in line with the nature of the initial material, because in mathematics one works with the basics at the level of increasingly refined syntheses and processing.

3 Problem Solution

We will proceed by discussing a couple of musical opuses where we can find substance similarities between the composition and the method of axiomatic mathematics.

3.1 Introduction

We will commence with the case of Johann Sebastian Bach. In his fugues, the substance of the subject, of the countersubject, of some episodes, is profoundly worked, and thus, we can compare the subject of the fugue with the enunciation of the theorem, and the development of the fugue with the proof. Mathematicians will not look for specific notions in Bach's work- they will simply enjoy the way musical ideas flow, develop and reveal themselves, according to a superior order, inherent to the cantor -organist, acknowledging the substance similarities between mathematics and music.

The Inventions for the wind and percussion quintet, written by the Romanian composer Liviu Glodeanu (1938-1978) abound with musical meaning and are characterized by mathematic rigour, starting from a musical mode which resembles an aphorism: x_C= (C, D, E-flat, E, G), influenced by the distilled and stylized Romanian folklore. Although for some this opus can be viewed as mathematics in musical terms, if we look closely, we notice that the composition is very well founded from a musical perspective. In this sense we mention *Inventions 3 and 4*, which can be interpreted as music rendered via mathematical ideas, as well as mathematics in musical terms. In *Invention 3*, the rhythm is overlapped by its recurrence. This procedure immediately sends us to the calculation of the sum of the first n natural numbers, or, if we generalize, to the calculation of the sum of the first n terms of an arithmetic progression, for the used rhythm is 1123456789 (expressed in eighths):

$$S=\sum_{k=1}^{n} k$$

$$S=\sum_{k=1}^{n}(n+1-k)$$

$$S=\frac{1}{2}\left(S+S\right)$$

$$S=\sum_{k=1}^{n}\frac{1}{2}(k+n+1-k)$$

$$S=\frac{1}{2}\sum_{k=1}^{n}(n+1)$$

$$S=\frac{1}{2}n\cdot\left(n+1\right)$$

As concerns *Invention 4*, this has overlaps of pedals built by using transpositions of the reversed recurrence of the initial mode. If we consider that y_C= (C, E-flat, E, F, G), we can identify the following associations:

Flute…….y_G
Oboe…….y_F
Clarinet….y_E
Horn……..$y_{E\text{-flat}}$
Bassoon….y_C

We may notice that the indices are elements from y_C. "Rhythmic characters" (Fig. 1) appear successively in each pedal – these are rhythms that gain individuality and expressivity via circular permutations (basic mathematic procedure), thus becoming "characters".

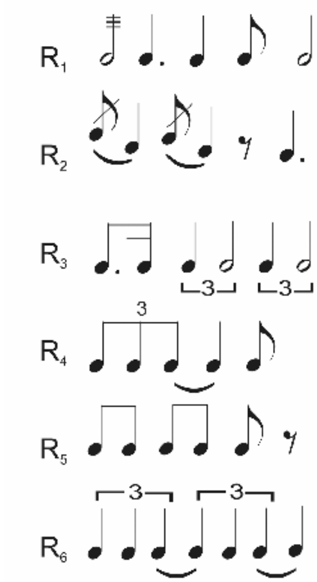

Fig. 1. The "rhythmic characters"

R_3 and R_6 are related and therefore one can substitute the other. The general picture is similar to the operation table of the five elements' group. We have:

Flute…………R_2 R_3 R_4 R_5 R_1
Oboe…………R_6 R_4 R_5 R_1 R_2
Clarinet………R_4 R_5 R_1 R_2 R_6
Horn…………R_5 R_1 R_2 R_3 R_4
Basson……….R_1 R_2 R_3 R_4 R_5

For ($\mathbf{Z}_5$, +), we have

+	$\hat{0}$	$\hat{1}$	$\hat{2}$	$\hat{3}$	$\hat{4}$
$\hat{0}$	$\hat{0}$	$\hat{1}$	$\hat{2}$	$\hat{3}$	$\hat{4}$
$\hat{1}$	$\hat{1}$	$\hat{2}$	$\hat{3}$	$\hat{4}$	$\hat{0}$
$\hat{2}$	$\hat{2}$	$\hat{3}$	$\hat{4}$	$\hat{0}$	$\hat{1}$
$\hat{3}$	$\hat{3}$	$\hat{4}$	$\hat{0}$	$\hat{1}$	$\hat{2}$
$\hat{4}$	$\hat{4}$	$\hat{0}$	$\hat{1}$	$\hat{2}$	$\hat{3}$

3.2 Key case

An extremely interesting example is *The Rite of Spring*, by Igor Stravinski. This music is programmatic, free of abstraction tendencies and is not subject to any external constraints – every time we hear it, it gives us a feeling of organic unit, of stable structure, similar to that of nature. As concerns the composer himself, it is worth mentioning "his sovereign instinct, his confidence in the infallibility of his own hearing, his sense of formal proportions"[4]. If the note by note analysis confirms the unity and coherence present at auditions, it results that The Rite of Spring, written predominantly based on inspiration, is an argument in favour of the strong connection between music and abstract mathematics – and this connection refers to the very substance and essence of the two fields, and not to their secondary aspects.

In the book entitled *Reading the Rite of Spring*, Roman Vlad states that "the Rite was born from a three sounds seed which spreads and organically integrates into the four, five, six, seven, eight sound structures, until it covers the entire space of the twelve sounds of the total chromatic". The generating cell is $\mathbf{c}_{\text{D-flat}}$ = (D-flat, B-flat, E-flat) (Fig.2).

The notation resembles that of a vector, and the permutation of the components leads to another vector element.

Fig. 2. The generating cell, $\mathbf{c}_{\text{D-flat}}$

We will analyze only a part of *The Augurs of Spring*. *Dances of the Young Girls*, according to parts, and we will focus on the manifestations of the generating cell, in its explicit or implicit form; thus, coherence and unity will become increasingly persuasive.

Part 13 The ostinato relies on a set of sounds (F-flat, A-flat, C-flat, E-flat, G, B-flat D-flat) that is complementary to the set (A, F-sharp, C, D, F). Roman Vlad noticed that "A had been the first tonal pole of the Introduction, F-sharp had been the pedal held by the bass clarinet, and the C-F-D nucleus involves the initial motif from its first occurrence"[4], with the mention that C-F-D is the recurrence of the inversion of the initial motif.

Part 15 From hereon, we may notice the use of anticipation. Anticipation is aimed at conferring unity, being a preparation process, and, at the same time, a procedure used in mathematical proofs, where data processing prepares the way for additional stages, necessary during the course of the proof and in which the first action becomes motivated. Apart from its thematic function, the descending chromatic motif, with the ambitus of a third or of a perfect fourth, anticipates the chromatic scales at part 17 and the chromatic figures at part 30. The chromatic scale can be inferred by using a variant of the initial cell. We will prove this point by using Roman Vlad's ideas. We consider S_1 = (D-flat, B-flat, E-flat, C, F, D, G, E, A, F-sharp, B, G-sharp), obtained via successive transpositions of the initial cell (Fig. 3).

Fig. 3. S_1

We may notice a fractal construction repetition. By permuting sounds 1 with 6 and 7 with 12 in S_1, we obtain S_2 = (D, B-flat, E-flat, C, F, D-flat, G-sharp, E, A, F-sharp, B, G) (Fig. 4).

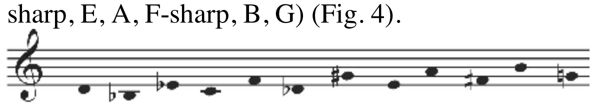

Fig. 4. S_2

Thus, we have a variant of the initial cell, **c'**. By considering the number of semitones, we associate an ordered set (-3, 5) to **c** and (-4, 5) to **c'**. We obtain two related melody cells which can be included in a family, just like in the catastrophe theory. For example, the perfect fourth can become augmented, and thus, we obtain S_3 = (D, B-flat, E, F-sharp, C, A-flat, G, E-flat, A, B, F, C-sharp) (Fig. 5)

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Fig. 5. S_3

The modified cell is of the type (-4, 6) and in S_3 alternates with the recurrence of its inversion. If we continue the procedure, we obtain S_4= (E-flat, B-flat, F, C, G, D, A, E, B, F-sharp, C-sharp, G-sharp) with a type (-5, 7) generating cell (Fig. 6).

Fig. 6. S_4

The last series we need is S_5= (E, A-sharp, F, B, F-sharp, C, G, C-sharp, D, A, D-sharp), with a generating cell of the type (-6, 7) (Fig. 7).

Fig. 7. S_5

We may notice the occurrence of two melody levels, each of them representing a chromatic scale and thus the proof is concluded.

Part 16 The defining elements for this part are: 1. the pedal on C, 2. the melodic or harmonic fifths (from contrabass, cello and clarinet), and 3. the variations relying on the minor tetrachord (C, B-flat, A, G) of the flutes and of the 1st violin. All these elements result from the exclusive processing of c. Thus, if we consider the scale associated to the first four sounds in S_1, we obtain a minor tetrachord (B-flat, C, D-flat, E-flat). This can be an argument in favor of the occurrence of the C pedal, sound which becomes necessary in order to complete the minor tetrachord, together with the cell c. The contrabass and cello suites of fifths and especially the clarinet fifths result from the permutation of S_1, permutation which is in line with the structure of S_1. The permutation is (3 2 5 4 7 6 9 8 11 10 1 12) and we thus obtain the suite of fifths, covering the entire total chromatic. We may notice that the harmonic intervals used as backing are also fifths, in harmony with the modal-archaic ethos of the work and with the economy of means specific to axiomatic mathematics.

Part 19 We notice the minor tetrachord (B-flat, A-flat, G, F) and its thematic role. It is worth mentioning that any minor tetrachord can be included in the mode (2, 1) and Allen Forte states that "over 90% of this composition can be directly correlated with a matrix of whole tones and alternative semitones" [1].

Part 21 comprises a highly inspired processing of the minor tetrachord, for all the appoggiaturas also belong to the set of sounds specific to the tetrachord. This makes us think about the exhaustive processing activities that occur as part of the mathematical proof. A variant of this procedure, which makes use of appoggiaturas, is also present in part 29.

Part 25 is where the proper theme starts, at the horns. The consequent, rendered by the big flute, also comprises a natural integration of the interval of the fifth. The backing is made up of pedal overlaps from which result harmonic fourths. The oscillation (G, A) from the second violin will be included in the minor tetrachord (G, A, B-flat, C) and the unison will become, through the division of the partition, a mixture of fourths.

In **part 28**, the first flute plays a melody which synthesizes the initial cell (reversed recurrence variant), the antecedent and the consequent of the theme. It is worth mentioning that the theme makes use of elements from a minor tetrachord, completed to a perfect fifth, in our case the set {A-flat} reunited with the set {B-flat, C, D-flat, E-flat}. The brass and cellos will render a variant of the theme, based explicitly on the minor tetrachord. We juxtapose the two themes (Fig. 8) in order to show that the first is a "permutated and blossomed form" of the second: thus, we can consider that one of them is a "perturbation" of the other, using a term specific to algebraic topology.

Fig. 8. The two themes

As concerns the brass theme, Stravinski, in authentic axiomatic spirit, makes the theme explicit, by using the B-flat major for the violas, tonality in which can be included the tetrachord of the theme. Moreover, the second violin anticipates, from the beginning of the part, the B-flat minor tonality, via a tritone tetrachord built on a G-flat, and its motivation becomes clear with the presentation of the theme. The brass mixtures imply four overlapped hypostases of the theme. We have the

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theme in a minor, tritone, Phrygian and major context. We consider that all these arguments are sufficient to prove the unity and coherence of the composition, faithful to the principles of abstract mathematics.

4 Conclusion

The supreme example of reality, built with a single nucleus as a starting point, is that of Creation. Peter Russell, mathematician and physician at Cambridge University, states that "the substrate of the whole Universe is an intelligent, conscious, creative, bearer of living information energy. The mystics call it Light". Thus, the example of a musical creation, in harmony with the principle of axiomatic mathematics, makes us meditate upon the fact that all things come from the Light; the attempt to understand this musical creation is also motivated by the hope that, throughout the analysis process, we will receive some answers about Creation, Creation which has its origins in God.

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Interdisciplinary Didactical Strategies of the Musical Education from Integrated Education Perspective, in Early Ages

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Abstract: The need for musical education in early ages (school and kindergarten), alongside the other education disciplines, from integrated interdisciplinary perspective, is a contemporary need, because it brings a significant contribution at the children’s personality shaping, it brings a plus of efficientness of the educational act. Even from preschool period of time is better that the instruction to be done from the perspective of recognizing the fact that not even one discipline constitutes a close domain, as well of the request to extend and deepens the connections between disciplines. This can be done through interdisciplinary correlation of the activities unfolded in kindergarten and in school, giving them a plus of efficiency. The correlation of the acquired knowledge in different education disciplines constitutes a connection of the specific knowledge of different domains, of whose purpose leads to a unitary system of knowledge, to the general view on world. The selection of the education content is a problem of great didactic responsibility. It has to operate in such way to completely cover the volume, the structure and the nature of the scientific, moral, aesthetic and physical values which make the object of children’s informing and forming in accordance with their psycho-physical possibilities.

Key words: musical education, interdisciplinarity, integrated education, early ages

The aesthetic education constitutes an essential component of the education, because through this step it is intended the shaping of the sensibility and receptivity of human being towards the non-pragmatic aspects, alternative of existence. The aesthetic represents another form, a superior and particular one, of structuring the objective world and the imaginary. Through aesthetic education, man accedes to another form of organization, of existence’s transfiguration, outrunning the routines of intellectual – rational and utilitarianism order. In the well-known hierarchy of needs, elaborated by Abraham Maslow, the needs satisfaction of aesthetic order, placed in the top of the pyramid, defines, in an essential measure, the humanity and the spirituality: the whole man is so the educated one under aesthetic aspect as well. The aesthetic education of formal order is done in particular methods, through disciplines specific to those seven arts. Among these, in the compulsory education a special attention is given to the *musical education*, started from the pre-school period of time and continued through the whole school line.

A problem, insufficiently treated or neglected till present, in the psycho pedagogic research assembly is that of the musical education in early ages, when so called *sensorial acquisitions* are done, respective the first perceptions and representations of musical – auditory order, the foundation of a consistent musical education realisation in the following periods of schooling. This phase is also called *the prenotation phase* or that of auditory-sensorial acquisitions, since the using of the specific musical symbols is not possible. Otherwise, the research of the musical acquisitions of children in this period of time, represent a step of great difficulty and complexity, which can be done with maturity and responsibility only through some seriously researches, from interdisciplinary perspective.

The simple correlations between the disciplines which are studied in kindergartens and school’s are not sufficient and in concordance with the new types of contents generated by the contemporary evolution, by the movement of the products in the cultural – scientific and professional – applied domains. In the pre-collegiate education are already established three levels of entering of the interdisciplinary in the didactic and extra didactic process conceiving and unfolding. *The first* is reserved to those who conceive the curriculum (plans, programs, textbooks), *the second* to those who carry on the proper activities (educators, teachers, professors), but who promotes the disciplinary connexions according with the personal preparation, and *the third*, in non-formal plan (extra school) when whose involved have more approaching freedom.

Another aspect is the way in which it interferes through compulsory correlations establishment scheduled by the curriculum and imposed by the teaching's logic and disciplinary, systematic and elaborated connections divulging a *bi* or *polydisciplinar* vision, in which common elements for more domains must be detected, where the work is done in teams. According with the elaboration way, *the interdiscipliarity* can be centred on the reach and *multidisciplinary* culture of the teacher (at the optional disciplines), or realised in teams of specialist from different domains, but approached in class, in the common program. *The transdisciplinary activities* carry on a general theme foundation, from more *curricular areas* perspective, to build a more complete image of the *theme*, by reaching the objectives of all *areas*, in integrated context. The reality forms through a global step, the boundaries between the disciplines being eliminated, the activity being centred on groups or person, with transfer possibilities of the information in an interactive way (for example the realization of a theme can combine the drawing, the music, the dance, the writing, the reading, the mathematics, the practical abilities and the environmental knowledge).

The **interdisciplinarity** concept in the sense of *circuit* between disciplines has formed even from antiquity, both in the Greek schools and in the Romanian one. It was transmitted in the medieval education under the form of groups of related disciplines which give freedom in thinking (but separately studied). The *"Trivium"* assembly is made of grammar, rhetoric and dialectics, and *"Qvadrivium"* was made of arithmetic, geometry, astronomy and music. The idea was continued by Francis Bacon and Comenius, and then assumed till the XIX-th century, being used in the establishment of the groups of proposed domains to be studied in schools and universities. In the present period of time can be noticed a structure of the teaching plans on *"curricular areas"* established on related disciplines principle, in the idea of amplification of the connections between these. The interdisciplinarity's promotion at the didactic and extra didactic processes levels must consider the common objectives of more disciplines, educational finalities, the assimilation of those three types of learning (formal, non formal and informal) requiring a multiplication of the disciplinary connections, realised with common methods and ways.

Even from the preschool period of time it is better that the instruction to be done from the perspective of recognizing the fact that not even a discipline constitutes a close domain, as well from the perspective of the demand to extend and deepen the connections between disciplines. This can be done through the interdisciplinary correlation of the activities carried on kindergarten and schools, giving them a plus of efficiency. The correlation of the acquired knowledge in different education disciplines constitutes a connection of the specific knowledge of different domains, of whose purpose leads to a unitary system of knowledge, to the general view on world. The selection of the education's content is a problem of great didactic responsibility. It has to operate in such way to completely cover the volume, the structure and the nature of the scientific, moral, aesthetic and physical values which FAC OBIECTUL of children's informing and forming in accordance with their psycho-physical possibilities.

The appropriation of some information form other domains in the benefit of a subject – problem from a private discipline represents **associated interdisciplinarity**; This approach consists in the unfolding of an activity (*music*) by using some acquired knowledge during the *Romanian language class* – poems, stories, words and expressions, *mathematics* – numbers, numerators, physical training – marching steps, running, lateral walking, arms' movements, *the environmental knowledge* – animals and birds' behaviour, seasons' aspects, that help at the awareness and memorizing some songs' texts, the adding of the movement elements at musical games. The cultivation of some interdisciplinary objectives through some objects specifications of intracurricular and intercurricular education represents **integrated interdisciplinarity**. It is realized through the activities' conceiving and unfolding with the participation of more disciplines: in the first part takes place the activity of *communication, science, practical abilities* or *drawing*, after that it continues with *musical education*, by learning a song or repeating a seized repertoire, but with a content in concordance with the seized theme in the first stage of the lesson. In this context, we propose to determine common objectives and contents between disciplines that are studied in the preschool and primary education, especially from this integrated interdisciplinary perspective.

Activities from the **language and communication** domains (story, memorization, stage version, reading, writing, learning a foreign language) need the practising of diction, the rhythmical syllabifying of a poem's verses, the imitation of characters' voice met in stories, exercises for speaking deficiencies' correction (s, ş, r, z, l), the fluent utterance, the vocabulary's enrichment. All these can be done with musical intonation and through the rehearsal of some songs with common text or content (stories, poems or reading after images). Foreign languages have of a musical repertoire thematically rich, folkloric predominant, repertoire that can be approached to help to enrich the vocabulary and the pronunciation specific to the studied language. The communicative – functional model requires the integrated development of reception capacities and of oral expression, as well of reception and expression capacities of the written message, and the pre alphabet period of time can be stimulated as well through auditions.

The disciplines from the curricular area science pursue the stimulation and the development of psychical processes of cognition (the analyses, the synthesis, the abstractization, and the voluntary attention), the education of some thinking qualities (independence, rapidity, flexibility, originality, and observation), the adequate use of specific language. **Mathematic activities** must be integrated and interactive conceived, individualized on groups of children, to develop mathematic calculus capacities, of some ideas and experiences representation, to lead to the development of some logical reasoning of time and space understanding, to increase the interest and motivation for this discipline's study and appliance in varied contexts. Many songs contain in their texts mathematic notions (multitude, group, number, increasing and decreasing numerators) or elements of **environment's cognition** (plants, animals, insects, meteorological phenomena, seasons, cosmic bodies). Intoned during these lessons with an abstract content, relaxes the atmosphere, give good mood and contribute to the need of child's informing, to the development of the observation, elaboration, understanding of the surrounding environment and to the formation of a positive attitude toward the medium.

For the specific activities of **education for society (moral – civic and religious)** there is a repertoire of songs and games which contain in texts *history, religion, geography, and social behaviour, concern for health and hygiene* elements. Through their specific it is followed the formation of some positive behaviour, cognition of the historical past, to cherish and respect the Romanian people, family, community, personal and collective things, religion and rejoicings.

Practical abilities prepare the child for work through the shaping of an entire complex of manual working abilities. Through these the tactile – kinaesthetic sense is developed, different working techniques are assimilated, techniques that are employable in other activities, it is done with different materials collages, ornaments, with common themes taken over from the other disciplines, the cooperation spirit forms, the working standards assumes, the practical, household, aesthetic sense. The music can positively influence, through the creation of a pleasant atmosphere, stimulative, for the volition's education to finalize the started thing; it is recommended that at the activity's end to be repeated a song that was prior studied, connected to the unfolded activity, or when an independent working activity must be done, auditions can stimulate positive states of spirit.

The plastic – artistic education helps children to find the relation between image and sound. For the imagination's stimulation, for a given theme, can be intoned songs with that content, or one can work on an adequate musical background (drawing, painting, MODELAJ). The audition increases the impressive level and motivates the conceiving of works. The inverted connection done during the musical education classes, where children are asked to imagine through forms and colours what they hear. At this discipline visual perceptions develop in the same time with the specific notion's assimilation about the plane, spatial form, colour – non colour and practical resolving in drawing, painting, MODELAJ. Plastic, imaginative compositions will develop the communication through artistic language, stimulating the sensibility, the taste for beauty.

Physical training is needed for the harmonious physical development, forming the self control on posture, force, will, character, vigour and body's resistance to effort. Through sportive information children will be motivated toward practical – sportive activities according with their physical possibilities. Musical games with movement can be fully turned account, as a support for the realization of: gymnastics elements, accurate space orientation, personal body scheme's awareness, breathing exercises. These kinds of elements can be as well found in songs, but also one can refer to musical auditions (march, folk dances, waltz).

From I-II grades, themes from the musical repertoire must be in concordance with the other discipline's contents, imposed by the curriculum and textbooks, and in the preschool stage we meet the same aspect, when themes must be close to the medium where children develop, to the level of their knowledge and interests; they will have as inspirational sources aspects from the following domains: literature, science, social life, nature, events (religious and lay feasts), the life and work of personalities from culture or social – political life. Themes can have a monthly schedule, being weekly projected in under themes. The unitary thinking of the program and the contents in kindergarten imposes the realization of a timetable which can allow the interdisciplinary and integrated approach.

For the musical education's efficiencyness in early ages I have undertaken some experiments which aim at the interpretative capacities' development, the music reception and the formation of a musical's culture. Evaluation matrixes have been established for two out of the four frame objectives and then referred to lessons realization, parallel with the *witness group* (control one) and the *experimental group*, the groups being numerical equivalent (twenty children with the same musical education level). The witness group has beneficiated of mono disciplinary activity, mixed type (learning and repeating), and the experimental group has participated to a learning activity, centred upon one way of musical education – song, game, audition, interdisciplinary integrated conceived, in combination with another activity (communication, science, plastic – artistic education, physics). The experiments have been done in the Kindergarten with prolonged program no 8, Barlad and in "George Tutoveanu" School with I-VIII classes, from the same city, from 2002 till 2004. From realized experiments we have ascertained an improvement of children's musical evolution, till 70 – 90% on the co-ordinates: rhythm, hearing, voice, memory, imagination, using types of activities centred on one musical component (song, game, audition) as well the improvement of the cognition specific to the associated discipline (with the same percentage). In the preschool and small school age, musical education is thought as an activity articulated from two components: learning and repeating. But this structure does not offer the sufficient time for none of them, children not being able to memorize not even the melodic line, nor the text or the game's tasks. Because the movement elements can be easily performed, there is the tendency to resolve only these ones and the attention toward song to be insufficient, the learning proportion being between 30% and 50%. In the same percentage, the operational objective at the other activities have been realized, mono disciplinary carried on. That is why, we propose the song's learning and consolidation variant also through game elements in the same activity, giving the occasion for seriously learning of the song, but as well for relaxation through movement, in the same time, in association with other disciplines in with the didactical projection is for the interdisciplinary activities, associated or integrated (as seen in tables no 1, 2, 3 and 4)

The organized frame of the musical activities, in which children catch and interpret music, according with their possibilities of understanding and giving back, bring them in a conscious way to its beauties, shapes them, harmonizes them, balances them, helping them to integrate in society, perceiving it as a functional universe. Continuously developing its elements of expression, music has reached the high level of manifestation of the human's sense and thinking, whose capacity of emotional life's reflection has influenced the mankind, contributing together with the other domains of the culture to the human's universe cognition and its transformation. In this context, has established that musical education fulfils three functions. *The cognitive function* consists in the fact that music is a specific way to communicate thoughts and ideas through artistic images, with a powerful emotional character. *The social – instructive function* is demonstrated through the fact that develops believes and gives models to follow, speaking to all children. *The aesthetic function* arise from the capacity to cultivate the aesthetic taste and to contribute to the spiritual life's enrichment, bringing them joy and satisfaction. Starting with the 2004-2005 school year, the curriculum for the I-II grades anticipates the organization of activities in integrated way, and starting with the 2008-2009 school year a new curriculum has been conceived in an integrated vision for the preschool education as well.

We have the belief of the need on a musical education in school and kindergarten, alongside with the other disciplines, from the integrated interdisciplinary perspective, because it brings an important contribution to the children's personalities shaping, being part of the activities' group which main purpose is the aesthetic education realization, id est, the skills and capacities' cultivation to know the reality, learning on the artistic emotions' path to admire the beauty, to adopt a civilised and sensitive attitude in relations with others. In children's musical education (preschoolers and scholars) we have to take into account what is normal and natural in their psychology, namely the fact that in their life music interweaves with game. In independent games, the child sings from his own initiative and improvises small rhythmical or melodic motives, which integrates them in an organic way in the game. So, musical activities must comprise varied forms, combined with games, to maintain vivid children's interest and to cultivate their pleasure to sing. The artistic taste starts as well from the game, but, gradually, it separates, crystallizing in the aesthetic pleasure to sing nicely, to create or to listening music. Starting with the simplest creations, children must be orientated toward the understanding of the music's idea content and an active participation to the live, sensitive fulfilment of the musical phenomenon and through this benefiting of an energizing environment for the other disciplines and activities.

The present sonorous world, with well-known aspects, which corrupt the musical taste, imposes a reviewing, a consolidation and a viable reorientation of the musical's education as a position in the syllabus, by including some other artistic disciplines – dance, theatre, and visual arts, for a more complete vision on beauty. But all these can not be accomplished if the musical qualification of the educators, teachers and professors it is not seriously and modern done, especially through the artistic interdisciplinarity's promotion. The love and the respect toward music and beauty are built in the first years, from the preschool age, and children must benefit of these. An increased preoccupation is imposed for the knowledge of the fundamental instructive-aesthetic competences, such as: the formation of the aesthetic taste and that of the selection and appreciation capacities, of the interest for aesthetic quality of the human's existence, of the skill of beauty's inclusion in the sense of children's creation's inducement.

I

No	Rated competences	Evaluation tools		
		Practical exam		The analysis of the individual behaviour
		Group	Individual	
1.	Vocal singing	˅	˅	˅
2.	Musical game with movement elements and instrumental accompaniment.	˅	˅	˅

Table 1. The evaluation matrix of the interpretative capacities
Done during the learning lesson of a song or musical game (the eldest age group and the Ist grade)

No of children - 20	Rated competences	The witness group (control)				Learning percentage (FB+B)	The experimental group				Learning percentage (FB+B)
Epithets		FB	B	S	I		FB	B	S	I	
The eldest age group - a	1	4	6	6	4	50%	7	8	5	–	75%
	2	5	5	6	4	50%	8	8	4	–	80%
I Class – b	1	4	5	7	4	45%	7	10	3	–	85%
	2	5	5	6	4	50%	8	10	2	–	90%

II

No	Rated competences	Evaluation tools		
		Practical exam		The analysis of the individual behaviour
		Group	Individual	
1.	The recognition of the interpretation's method	˅	˅	˅
2.	The determination of the musical repertoire's characteristics.	˅	˅	˅

Table 3. The evaluation matrix of the music's reception and The formation of a musical culture (preparatory group and IInd grade)

No of children - 20	Rated competences	The witness group (control)				Learning percentage (FB+B)	The experimental group				Learning percentage (FB+B)
Epithets		FB	B	S	I		FB	B	S	I	
Preparatory group - a	1	3	5	6	6	40%	5	8	7	–	65%
	2	1	7	7	5	40%	6	9	5	–	75%
IInd grade – b	1	2	5	7	6	35%	7	8	5	–	85%
	2	3	3	8	6	30%	8	9	3	–	95%

Table 4. Results

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Reflections on the opera *La Deuxième Aventure (céleste) de Monsieur Antipyrine*

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Abstract: Dadaism is a concept based on the rejection of all the classical, social and intellectual rules of conventional wisdom. Music is by contrast a highly structured discipline. How then to reconcile Dadaism with music? In particular how to write an opera based on a Dadaist play? The author has done so, and he argues that the solution is to retain a Dadaist substrate but to overlay the rigours of musical composition, and finally in the Dadaist spirit, to allow liberties to the conductor and performers. The result can be a liberating experience for the composer.

Keywords: Dada, Dadaism, Tristan Tzara, Monsieur Antipyrine, avant-garde, opera

In a time of synthesis, when the phenomenon of Dadaism seems to be, in musical terms, merely a shadow of the past, it may seem a daring move to write an opera based on the play by Tristan Tzara (Samyro / Samuel Rosenstock) *La Deuxième Aventure (celeste) de Monsieur Antipyrine.*

If the phenomenon of Dadaism is more or less well-known in literature because of artists like Hugo Ball, Hans Arp, Marcel Janco and later Andre Breton, Luis Aragon, Picabia and others, the question is whether in music we can speak of a pure Dadaist phenomenon.

Hence, another question: how can one proceed to the writing of an opera on a Dadaist text? What kind of musical techniques and means may a composer adopt in the face of such a provocation?

Making a summary of the musical techniques through which we approach the Dadaist concept, we can mention in the first instance aleatoricism: the creation of art by chance.

Although the Dada Manifesto of 1918 proclaims**:**

„Tout produit du dégoût susceptible de devenir une négation de la famille, est dada; proteste aux poings de tout son être en action destructive: dada; connaissance de tous les moyens rejetés jusqu'à présent par le sexe pudique du compromis commode et de la politesse: dada; abolition de la logique, danse de impuissants de la création: dada… abolition de la mémoire: dada; abolition de l'archéologie: dada… hurlement des couleurs crispées, entrelacement des contraires et de toutes les contradictions, de grotesques, des inconséquences: LA VIE."

"Every product of disgust capable of becoming a negation of the family, is Dada; protest with fists with all one's being in destructive action: Dada; knowledge of all the means hitherto rejected by modest sex, by convenient compromise and by politeness: Dada; abolition of logic, dance of the powerless of creation: Dada ... abolition of memory: Dada; abolition of archaeology: dada ... howling of clenched colours, interlacing of opposites and of all contradictions, grotesques, inconsistencies: LIFE." - excerpt from the *Dada manifesto.* [4] (Tzara, 1918)

We propose to reverse and to ignore all traditional academic precepts. Though even in the original play, there slip some poetic images which foretell how the poet's creation will later become perceived as classic:

„je connais un chifre à genoux qui n'est pas un
poème brosse
jouant
aux bouches des coquillages
mais l'adresse d'un artist français
et une composition de staccato noir
de balcon végétal métronome sur un clin d'oeil
médicament pour les vagues pulmonaires dans un
sac"

"I know a cipher on his knees which is not a brush
poem
playing
in the mouths of shells
but the address of a French artist
and a composition of black staccato
of metronome plant balcony on a wink
medicine for the pulmonary waves in a bag "

(the first reply of Madame Antipyrine).

Dadaism is spoken of as a cosmopolitan phenomenon, forgetting, advisedly or not, the fact that Dadaism can firstly be considered to be of Romanian origin:

„The first avant-garde manifestation of Dadaism, marked by a programmatic desolemnised lyricism, in a language which challenged word order / syntactic standards, made its appearance in Romania from 1912 to 1915, as the fruit of the ludic collaboration between the young poets, Ion Vinea (Giurgiu, Romania, 17 April 1895 – 6 July 1964, Bucharest, Romania) and Tristan Tzara (Moineşti, Romania, 16 April 1896 – 24 December 1963, Paris, France)". [2] (Tatomirescu, 2009)

Much has been said about the avant-garde. From the beginning, the representatives of Dadaism expressed their aversion to Cubism, to Italian Futurism and to German Expressionism, which prepared the ground for avant-gardism. Thus Dadaism may basically be regarded as a reaction against an avant-garde which already existed but no longer corresponded to the moment:

"The birth of avant-garde - or at least one of its key moments - is achieved, not incidentally, in a country free from war, in Zurich (1916-1918). Here there gather refugees of every kind, deserters, the lost, plotters, anarchists and nihilists, bohemians, pacifists, from all over Europe. They are people who have refused to fight in the trenches and have found shelter here. They belong to several traditions, cultures, radically different schools." [3] (Tănase, 2008)

"The reason that the art, poetry, music, theatrical performance of the avant-garde are often so difficult to understand is not necessarily the intrinsic hermetism of the work, but the fact that it ignores or attacks the rules that prevailed within the artistic percepţion of those accustomed to contemplate and try to understand art." [1] (Grigorescu, 2003)

Although we can understand that Dadaism proclaimed absolute freedom, the atmosphere which emanates from this piece of Tristan Tzara is one of psychic constriction and closure. In comparison with Tzara's previous piece (*La premiere adventure de Monsieur Antipyrine*), which was more comic and airy, it seems to be headed towards nothingness and strangeness. In this sense, the end of the work uses a Romanian folkloric song which speaks of the fact that the only hope in the face of death is love.

The song is named *"Nu-i lumină nicări"* (There is no light anywhere). (Fig.1)

The author started in the Dadaist sense with the end of the work, because this song at the end collects like an Amazonian river all the preceding musical ideas.

The musical ideas in the work are inspired in part by children's songs. (Fig.2)

and likewise by unorthodox Romanian carols such as *"Vine hulpe de la munte"* (The fox comes from the mountains). (Fig.3)

To this we may add a continued opposition between stasis and change. Dominant is the rhythmic element, which was for the author most precisely apposite to reflect the valency of the text.

In the spirit of Dadaism, the composer of the opera gives the liberty to the conductor and the stage director of free orchestral moments in which the musicians can freely choose any element from the score.

The opera can stay in the form in which it was written, like the rolling of a snowball, to the horizon of hope. In this sense the composer, although inspired by the pessimism and the apparent absence of sense of the text, imagines the end as a liberation from existential anguish. (Fig.4)

We have already mentioned aleatoricism. Although the text has a Dadaist substrate, the musical construction is relatively rigorous, at least in its melodic and rhythmic aspect. The aleatoric moments of the score are reserved for the points of climax. (Fig.5)

The score is not without dialogue between the soloists and the orchestra. The rhythmic and timbral *ostinatos* as well as the timbral melody, together with the *sprechsgesang*, are often present. One distinctive moment is the reply of Mademoiselle Pause which, musically speaking, is the only moment of the opera in which melisma appears. (Fig.6)

We remark likewise the presence of recitations approaching the classical style, (Fig.7)

as well as moments of *solo tutti*, (Fig.8) or canon. (Fig.9)

It is not possible to encapsulate an opera in a paper such as this. But the provocation of Dadaism brought to the author a breath of fresh air in his way of seeing life and the world. At the same time, the creation of this opera put him face to face with some of the vital problems which an artist must confront: sense, trajectory, limits, adventure, the roots of language and meaning.

To find a concluding remark: the author opened the score at random and discovered the serendipitous phrase "On allume car je suis toujours possible".

Perhaps we may translate this as "one enlightens for I am still possible". (Fig.10)

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Fig. 1

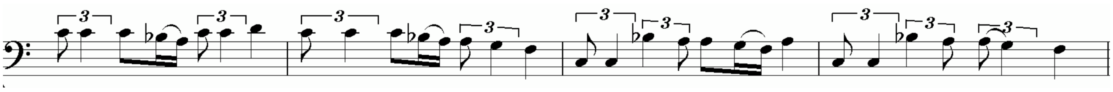


Fig. 2

Fig. 3

Fig. 4


493
Fl.
Ob.
C. A.
Cl.
Bsn.
C Hn.
C Tpt.
Tba.
T.-t.
Mrcs.
W.Ch.
Glock.
Mar.
Vib.
C. D.
lor - sque nous nous ré-jou-i-ssons sur les al - ti-tudes a-ris-to-cra-ti-ques nous man-geons des mous - ta-ches d`an - ti-lope cri ons_ au feu
Vln. I
Vln. II
Vla.
Vc.
Cb.

Fig. 5

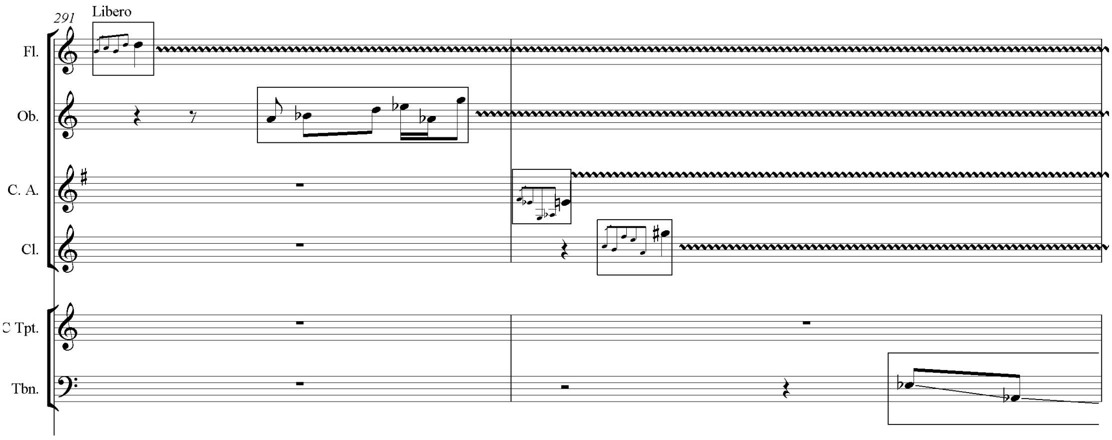


Fig. 6

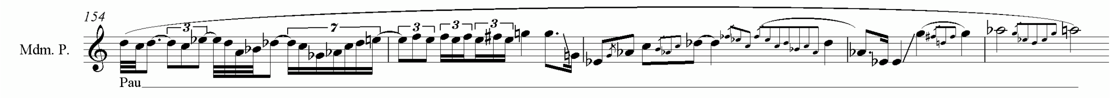


Fig. 7

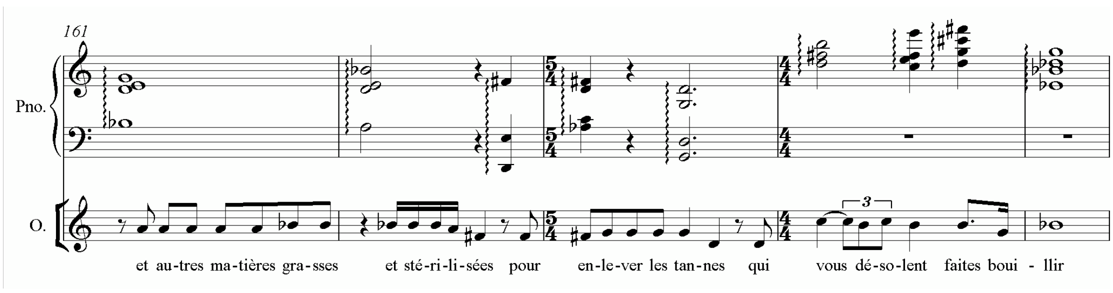


Fig. 8

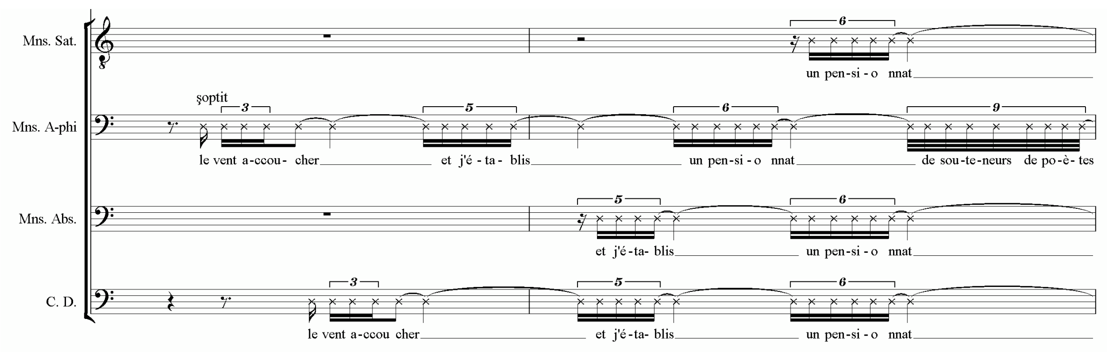
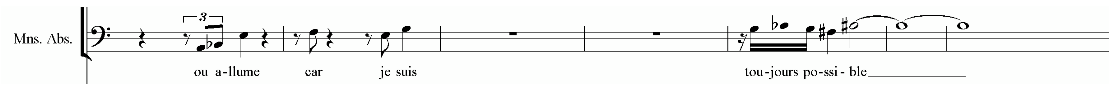


Fig. 9

Fig. 10



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Genesis of the Chords

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Abstract: The verticality process in music realm started in the 10th century is materialized in the 14th century by the bring into use of the chords. Since that time, the music world has been continuously operating with this notion, even though it required a research study designed to elucidate this phenomenon. The chords formation was achieved within the framework of the principles similar to those designated to the generation of all music phenomena: the consonantal, symmetric and sectio-aurea principles.

Key-words: verticality, organum, chord, consonance, symmetry, sectio-aurea, polyphony.

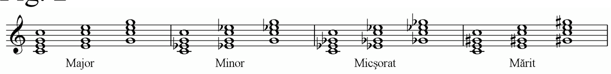
1 Introduction

One of the greatest enigma of the Western-European countries music of the 2nd millennium AC is the genesis of the chords. The matter is about the four chords of three sounds (two overleaped thirds) usually designated as triads: major, minor, descending, ascending, and of their inversions (the sixth chord and the fourth-sixth chord).

Fig. 1

In fact, during the music utilization process they become four sounds by repeating one of the three sounds, thus achieving the framing into an octave.

Fig. 2



It is not known why the musicology did not approach the matter of elucidating this “secret”, even though the impression that it is known does persist yet. Some explanations of physical nature (e.g. the upper harmonics) seem to be sufficient, and will be resumed in this study.

Accordingly, the matter is about the musical birth of these chords during the music evolutionary process, from monody to harmony (polyphony).

2 Consonance accumulation

The first musical culture that deliberately used these triads was the Renaissance (the 14th-16th centuries). Noticeably, within the 14th century there were composers (Guillaume de Machaut, Philippe de Vitry, etc.), who created music using chords with such a structure by a permanent vertical reference of sounds to melodies overleaped polyphonically; thus, it was legiferated their way of succession by the consonance-dissonance ratio.

The subject to come into question is when and who made this “discovery”, or more precisely how these chords were formed?

This puzzle should be elucidated by an insight into the earlier stage of the Western- European ecclesiastic music.

But how earlier?

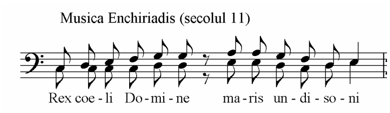
Well, previously to the production of the first verticality “ rebounding “, i.e. when singers and choristers exasperated by the monotony of the monodic Gregorian singing have spontaneously discovered during the singing process the possibility of the solemn voices “to slip” towards a lower fifth , or fourth, and to sing concomitantly the same melody. Perhaps, at the beginning it seemed strange to them (there were probably some bans on this matter), but in the end this phenomenon was settled (as a counterbalance to the sobriety of the Gregorian melody singing submitted for centuries to a continuous pressure to simplicity).

The occurrence of this „incident” approximates to the beginning of the 10th century and extends until the 13th century; it is designated as Ars Antiqua. Presumably, this initiative was taken by certain religious schools (e.g. St Martial and St Victor monasteries, continued by Nôtre Damme), and subsequently disseminated; however, there is the possibility of a polygenesis phenomenon (in several Western- European countries).

Nowadays, this „product” is designated as organum.

Fig. 3

Fig. 4

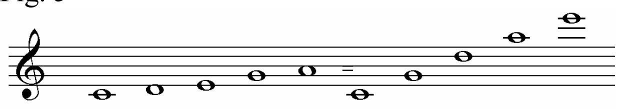


Consequently, the intervallic ratio of the melodic parallelism is the fifth and its inversion, the fourth. Certainly, the two intervals are not equivalent, but anyhow they are complementary within the octave. From here result their quasi-equality (as halves of an octave) and interchangeability as steadiness.

Why the fifth and the fourth?

The explanation for the occurrence (and presence) of these verticality intervals consists in the consonantal principle, an ancestor of the ancient oligochordic and pentatonic modes.

Fig. 5



Where from did the human kind take over this principle?

It is known from the physical principle of resonance, where the fifth and the fourth follow the consonantal intervals next to the octave, adopted by the first tuning up of the antique string instruments (lyre, guitar, etc.), or by the wind instruments.

It must be emphasized that these first intervals- the fifth and its complement the fourth – were the first verticalities.

Besides, the onset of the verticality process determined its dissemination throughout the Western Europe (the Catholic cult).

In contrast to the findings concerning the introduction of the fifth and the fourth verticality the way of the thirds and the sixth consonance's setting up was somewhat more difficult. It would be tempting to believe that this phenomenon took place by the gymel structure integration, a polyphonic form appeared in England during the 12th century. But an insight into the European continental music (France, Italy, Germany), especially the Léonin's and Pérotin's creation- considered to be prodigious musicians of the Ars Antiqua- reveals that the gymel was not assimilated. The basic form remained the organum characterized by a remarkable blooming. However, this flourishing state has developed only at the linear polyphonic level by voice's melodic garnishing, especially of the leading tenor's melody. Within this period, no concern for verticality did exist, the fundamental sound being totally neglected (Chailley, 1960).

In this polyphonic context, the third and the sixth consonance was quasi-conscientiously "insinuated", especially when the cadence was required. Here is a cadence example from the 13th century:

Fig. 6 

But the G-B third is not conceived as a G-B ratio; it comes from the melodic flow of each voice.

Certainly, a consistent contribution to this phenomenon was brought by the discantus technique; its combination with the organum generated an enriched slanting and contrary movement.

Fig. 7

These movements were greatly favorable to the expression of the thirds and the sixths. This phenomenon will be consistently revealed within the motetus technique, which will be the final stage of the 13th century organum evolution.

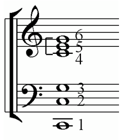
Consequently, the Ars Antiqua music is the receptacle for chords conceiving that will be building stones for more than 600 years.

Nevertheless, the leap towards the awareness of these vertical formations will be achieved in the 14th century by the contribution of composers endowed with genius, who synthesized the four triad forms.

3 Principles of triads formation

As the musical genesis of these triads can be detected this way, the second question is awaiting: why exactly these overlapping forms have been imposed (with fifth, fourth, and thirds), and no other intervals including the second (mainly the augmented second present in the ancient oligochordic and pentatonic formations) remains to be elucidated by musicologists.

The answer to this question is not offered by the Ars Antiqua praxis process; it should be found among other coordinates of the human musical spirit. The first answer is given by the Renaissance theoreticians (Zarlino, 1558) followed by the Baroc ones (Rameau, 1722), who "enjoyed" finding a "scientific" explanation to this matter after having discovered the hidden presence of the major triad inside the upper harmonics.

Fig. 8 

It was considered that this finding was explainable for the complete genesis of harmony.

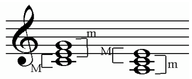
Nevertheless, even though for the major chord the sound resonance logic is accepted (the consonantal principle), for the other three chords the upper harmonic offer explanations only by a lot of numeric "speculations". One can conclude that the consonantal principle has consumed its explanatory resources.

According to our previous viewpoint, the explanation for triads steadiness should be searched inside the nature of the genetically structured human mind, where are reflected fundamental principles of the geometrical ratios from the macro and microcosmic universe.

The matter is about the principle of symmetry and, of the sectio-aurea proportion (the golden section).

Similarly to the vivid manifestation of these principles inside the melodic genesis of the ancient oligochordic and pentatonic systems (Szalay, 1968), they will be also present in the harmonic verticality at thousand years distance (about 40.000 years).

Thus, according to the principle of symmetry we discover the converse symmetry between the major and minor chords (augmented-diminished third/ diminished-augmented third), with augmented third as axis.

Fig. 9 

Regarding the diminished chord the principle of symmetry operates in a simply way; it is a symmetry of two conjunct diminished thirds (with axis sound).

Fig. 10 

The augmented chord is formed on the basis of the same rationale, i.e. two conjunct augmented thirds (with axis sound).

Fig. 11 

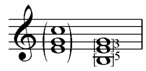
A certain surprise is offered by the chords inversion: the sixth chords and the fourth sixth chords.

Alongside the major sixth chord the third principle comes on stage: the golden section (sectio aurea). By analyzing the sixth chord structure, it can be seen that it is made up a diminished third having 3 semitones and a perfect fourth with five semitones.

Fig. 12 

This ratio leads us to the sectio aurea proportion, according to Fibonacci's numbers. Not dependent on chance, among the most spectacular forms of harmony appears the faux-bourdon in the 14th century that from the sound viewpoint means a succession of sixth chords.

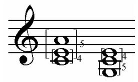
Surprisingly, by a (symmetric) inversion of this sixth chord can be obtained the minor fourth sixth chord (with diminished fourth and third – 5,3 ratio).

Fig. 13 

Hence, a sectio aurea ratio. This converse pair will offer (to B. Bartók) in the 20th century the idea of the bitertiary chord (major-minor) by the vertical overlapping of the two symmetrical structures,

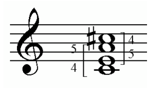
Fig. 14 

legitimating the synthesis of the two modes of the major-minor tonalities, and establishing the chord (and the principle) non-octaviant by the E – E flat diminished octave. (Rîpă, 2001). The other pair, the minor sixth chord and the major fourth sixth chord, maintains the geometry of symmetry but their structure augmented third and perfect fourth- are no more fitted to the golden section ratio.

Fig. 15 

I

By the two structures overlapping results again a new complex non-octaviant bitertiary complex , but with augmented octave (C – C#):

Fig. 16 

The diminished sixth chord comprises the same symmetry in direct stage but as a double ratio of 3/6

Fig. 17

This sixth chord seems to derive directly from the ancient antihematonic pentatonic formation 2 (Rîpă, 2001)

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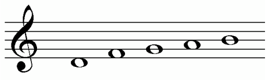
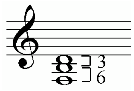
Fig. 18



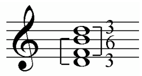
The diminished fourth sixth chord is the converse symmetry of the sixth chord with axis on D note.

Fig. 19



By overleaping we can obtain a symmetry with augmented fourth axis

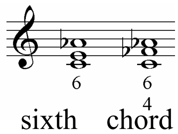
Fig. 20



enclosed in the octave, because the augmented fourth is the quantitative half of an octave (six semitones), whilst the two thirds (3+3) constitute the other half; thus, they amount to twelve semitones.

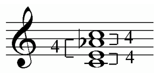
In a somewhat similar way is presented the augmented chord on the basis of the same symmetry of the formation in direct state; without warning, it keeps the equality ratio (symmetry) of the augmented thirds both within the sixth chord and fourth sixth chord, through the augmented third enarmony with the diminished fourth.

Fig. 21



The sixth chord and fourth sixth chord overleaping will fill the octave frame by the total of twelve semitones of the three major thirds (4+4+4), with major thirds axis or diminished fourth.

Fig. 22



The analysis of the third - fourth chord formations (the sixth chords and the fourth sixth chords), revealed that they are not mere inversion of the chord in direct state (according to all treaties of the theory of music) but structures with autonomous "personality" through which they enhance the harmony musical expression.

Consequently, during the process of the harmonic concept formation (vertical) did operate the same structural principles, similarly to the melodic process (linear): the consonantal, symmetry and sectio aurea principles.

4 Conclusions

The musicology of all times went about in search of scientific explanations of acoustic and mathematical nature for the musical phenomena. Nevertheless, it was the inorganic, mainly the organic chemistry that over the latest centuries dealt with the matter microstructure organization, rendering evident the specific ways of molecular "arrangement" of the leaving and non-living nature reflected within the human artistic and scientific mind.

Accordingly, in the case of harmony the construction "stones" derived from the inner structure of the human conscience, as well.

At the beginning of the 14th century, Guillaume de Machaut, Philippe de Vitry, Marchetto di Padua, Pietro Casella, Giovanini da Cascia, Jacopo da Bologna, Francesco Landino, synthesized the chord types existing under budding form in their mind owing to their musical education in the spirit of Ars Antiqua polyphony from the polyphonic linearity of Léonin's and Pérotin's creations.

The introduction of a brand new vertical composition technique exceeding the simple polyphonisation of melodies by using the imitation as developing procedure required o new vertical order that stabilized the chords; their succession ensured the functioning of the basic principle of the future polyphony (Renaissance polyphony), i.e. the consonance-dissonance ratio. Thus, the consonance pillars become the two chords with perfect fifth, major and minor, whilst the diminished and augmented chord together with the melodic notes (transgression, compensation, anticipation, delay) were the dissonant notes.

The improvement of this technique style will take three centuries reaching its apogee in Palestrina's creation, developing later towards Monteverdi's and Gesualdo's chromatic notes.

The Renaissance ending and the evolution towards the Baroque era determined the tri-sound "interdependence" by the so-called functionalism, creating a new language for another 300 years (the 17th and the 19th centuries), until the 20th century when Schönberg declares their ineffectiveness.

In conclusion, after a century of the chords „exit" from the history of music stage we succeed to near the understanding of their reason of formation.

Acknowledgement
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The relationship between sound/sonority and time/temporality in the structuring of the modern musical form

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Abstract: - This article presents some of the laws of sound matter in temporal organization, which I have discovered in European musical works of the early 20th century – the modern period. The research is novel through a demonstration of new principles of formal structuring, determined by the features of sound systems: tonal, modal, atonal. Alongside tonal functionality – a generally accepted law, now extended to post-romantic works, we propose intervallic functionality and the functionality of colour (of the complex sound).

Key words: **-** tonal, modal, atonal, functionality, form, structure

1 Introduction

In the first two decades of the 20th century, a parallel or simultaneous emancipation of every coordinate of the musical language is taking place, one that reaches beyond the limits of structure and expressiveness. The melodic turns into an integrating cyclic concept and into vertically-extended hyperthemes; rhythm becomes an organizing principle of the other sound features, gradually setting up the supremacy of pulse; the harmonic creates colour and temporal forms, polyphony evolves into linearism, but also towards textures with global effects; timbre steps into the foreground by becoming *Klangfarbenmelodie*, while traditionally-established forms move away from the language and mentality that had generated them and become generalized means of expression. It's a time of excess and experiments that will inspire all directions of musical evolution right down to today. Through its complexity, this age allows a peek inside the entire universe of musical forms, as they define styles, but also as an autonomous field in the phenomenology of musical art.

Right at the beginning of this period, Hugo Riemann recognizes form as a logics-based **organic structure** connected to the ontology and dialectics specific for the art of sounds. His concept develops two levels of sound correlation – one is essentially musical and demonstrates the role of **tonal functionality** in the crystallization of formal principles, while the other interferes with the grammar of ordinary language, where it examines the connection and evolution of semantic units (cells, motifs, phrases, periods), according to rules of discourse [1].

Starting from the duality of the levels of formal analysis, achieved through the dissociation of the structuring from the discursive process – which in Riemann's theory were, however, organically integrated -, subsequent concepts of the '20s and after will tend to stress the absolute importance of each field, as a consequence of the experimental phenomena in the world of musical composition and other philosophic and aesthetic mutations. By absorbing further ideas from the psychology of form (gestaltism), musical phenomenology dwells on perception, on living the musical phenomenon as it unfolds, generalizing the dynamic, kinetic and temporal character of sound art, while the methods of structuralist analysis consider sonority to be an atemporal system (especially in the doctrinarian structuralism that applies Saussure's linguistics) and concentrates on formalizing the layers of internal cohesion.

As a consequence, the theory of form acquired the dichotomy between form and structure. "The form in music – remarks Hermann Erpf – is experiencing a structure by hearing it (…) Two consequences ensue: 1. Structures come up in the sound relationships that one doesn't hear, they cannot be actually heard – so they do not become form (…) 2. Form is realized only by the auditory subject, with structures as the premises that enable this experience. Sometimes structure is more or less than form. Form is always a premise and a part of the artistic experience" [2].

2 Problem Formulation

Contemporary thought goes through a new wave of integration of musical sonority and temporality. This is because the orientation of the theory of art towards "the genesis of forms", towards that internal mechanism of production and transformation based on "diachronic structuralism" [3], the effort to discover the „internal determinism of the «biological» movement of the sound organism", reflecting "the capacity of any form to structure itself" [4], starts from the concept of **function-functionality.**

At a maximum level of abstraction, any structure is a function [5]; if applied to the musical universe, this judgment leads to the observation that every **system** of sound organization (tonal, modal, dodecaphonic) is/has a propagating, directional and centrist function, which is manifest in the "relationships of contiguity and connection between the units of meaning" [6], that is, on the temporal level.

In other words, the laws governing the internal dynamics of every system of sounds become form-creating functions. This is why it was not only the seductive parallel with the phenomenon of determining musical forms through harmonic-tonal functionality – a law of composition proved many decades ago by German musicology – that prompted me to formulate another couple of implied connections between the fields of sound and time: **intervallic functionality,** an active principle in structuring the musical form and **the functionality of colour** (of the complex sound), an active principle in structuring the musical form.

Before analyzing the nature of every function in musical language, an observation is due: given the age of culmination in the evolution of all musical parameters, the laws of sound determinism do not come up in a pure state; they combine and overlap, but one of them usually becomes the fundamental law of formal construction, marking the stylistic affiliation of the work. If there is mutual neutralisation of these active principles, the temporal development becomes emancipated but does not spawn any new musical architectures; it unfolds according to traditional patterns. This is how we have come to formulate the fourth direction in structuring form: **traditional musical forms, models that in time convey structure to the new language.**

3 Demonstration

3.1 Tonal-harmonic functionality, an active principle in structuring the musical form

It is a well-known fact that at least for the past couple of centuries, tonal harmonic functionality has determined the internal structure of musical composition. Influenced in the romantic age by non-musical factors and the wish for self-expression, harmony develops, diversifies and differentiates its artistic capabilities through means long debated in the theory of music. However, the fundamental relationship of tonal determinism, D – T, continues to mark form, conveying chronology to the temporal development. Unlike the multiple ramification of harmonic paths, one can notice, moreover, a tendency of integration of all chord relationships with a functional or expressive role, however far apart, into the basic tonality. The concepts of mono-tonality and tonal regions, put into theory by A. Schönberg, constitute the structural base for cyclical forms. In this way, the configuration process of the genre as a macro-form, concentrating on a central idea which is developed, amplified, metamorphosed und underlined by confrontation with secondary ideas, is intimately related to the phenomenon of mono-tonality, which paradoxically cumulates the dynamics of harmonic transformations and a relativisation of tonal gravity, capable under different circumstances of destroying the system. The works we have in mind are the A. Schönberg's sextet *Transfigured Night*, the Symphonic Poem *Pelleas and Melisande*, *Quartet for strings no. 1 op. 7*, *Chamber Symphony op. 9*, but also works by Gustav Mahler, such as *Symphony No. 6*.

On the other hand, the integration of modal relations within the complex of tonal functionality and the so-called tonal-modal system is responsible for all the extension phenomena in traditional dramaturgy, by generating thematic mosaics, splitting sections (dissociating them) and leading to an interpenetration of traditional formal principles, resulting in unprecedented architectural complexities. We are particularly thinking of G. Mahler's *Symphony No. 9* and G. Enescu's symphonies no. 2 and 3. It clearly follows that the music marked by the German classic-romantic tradition cannot have its thematic component – usually the object of formal analysis – dissociated from the systematic concept of harmonic sonority.

3.2 Intervallic functionality, an active principle in structuring the musical form

First of all, this principle proves to be the formulation of a composition law in the modal music of Claude Debussy and those works by I. Stravinski and B. Bartók influenced by the French school. This stylistic area is dominated by a melodic-harmonic functionality with particular sound coordinations: the primacy of melody over harmony, the instability and variability of modal sonority, the modal structure arising on the tonal level of the opus.

Second of all, intervallic functionality can be applied to the atonal music of the second Viennese school, where the intonational cell as grouping of intervals is not only a unit of the temporal discourse, but above all, structurally-marked sonority.

By joining modal and atonal compositions within the application area of the same mode of analysis, we wish to underline that neomodalism and free dodecaphony share some fundamental features, although they have often led to clearly different results. Beginning with the final conquest of the chromatic totality – the space for sound construction and/or consistent reference – the two systems develop by geometric ordering of this referential framework, based on the functionality and expressiveness of the melodic and harmonic interval. Although the componistic sonorities and strategies in modal works also include the gravitational harmonic phenomenon (which explains, for instance, the transformation of the modal intervallic structure at the tonal level of the opus), the distance principle, materialising through complementarity, transposition and symmetry, is the common law of both sound organisation systems and of their temporal projection. As a consequence, the principle of cellular variation will dominate the level of musical form – as grouping of intervals, the cell is both a unit of the temporal discourse (particularly in the modal, where the melodic determines the harmonic) and/or structurally-marked sonority (especially in free dodecaphony, where horizontality and verticality are equal).

3.3 The functionality of the sound colour (of the complex sound), an active principle in structuring the musical form

Despite structural coherence at the intonational level and the application of the laws of proportionality and simmetry, the auditory perception of form in the avantgarde compositions of the modern period (in the modal-impressionist, modal-abstractionist, atonal-expressionist and atonal-abstractionist styles) relies on general reference points concerning the sound relief. Moreover, we can state that this period witnesses the first steps towards a shift away from the intonational reference, dominant for almost three centuries, and closer to the complex sound – equally pitch, intensity and colour. Through the increased contribution of timbre, the suggestion of space is augmented – colour amplifies depth -, thus generating new relations of time differentiation, such as: dense-rarified, opaque-bright, compact-sprayed, etc. The so-called space music, which appears in the following decades in works by E. Varèse, P. Boulez, C. Stockhausen, Y. Xenakis, starts from Cl. Debussy's „sonorous" conquests and from geometrizing the intonational field of Webern's serialism.

Let's go over the factors that led to this tranformation in musical thought:

- overcoming tonal functionality and treating harmonic complexes and some plurivocal segments by means of their sound quality (**colour – a result of intonational combinations)**

- the ongoing timbral differentiation in romantic music, from H. Berlioz to R. Strauss, both by the multiplication of pure timbres and by colour mixes, gradually leading to the structuring of timbral functionality (**klangfarbenmelodie)**.

- the increasing freedom of the sound from the temperate system, through the discovery or invention of microtonal intonational systems, through a widening range of percussion intruments (tunable and not tunable), by experimenting new „instruments", as a consequence of bruitist manifestations, through pitch relativization techniques (*sprechgesang*) in the body of traditional work (**the emancipation of noise).**

In the first two decades of the 20^{th} century, neomodal and atonal music transforms the concept of sound by means of musical writing, notation and established sources: the two layers of sonority, the intonational and the strictly colourist, enter into a natural association, mutually strengthening their effects. In this way, the construction of form has a

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double reference: towards the sound texture – the quality of sound that results from instrumentation, orchestration, registers and dynamics [7].

3.4 The traditional musical forms – models for the long-term restructuring of the new language of sound

If until now we tried to explain how the modern form was structured based on laws of sound determinism that were, in their turn, derived from the active principles of neomodal and atonal systems, our next intention will be to present a few aspects of a certain type of componistic thinking that developed in the first two decades, but remained significant throughout the past century; according to it, the two building blocks of the opus – sonority and temporality - are relatively autonomous.

Here as well, everything started with the disintegration of the tonal system. The evolution of harmony from its dynamic, process-related function, creating melody and form, to its colouring function with semantic and aesthetic contributions to the sound whole resulted, among other things, in the **emancipation of the melodic** [8].

We see three main directions in which the rhythmic-melodic level steers away from the general harmonic context:

- the post-romantic development of concrete and diverse themes, capable of sustaining the explicit level of the musical language; through an extension of the cyclic principle, these were furthered in atonal music to the level of hyper-themes;
- bringing temporal architectures and preclassical genres back to life as part of the tendency to re-appropriate the pure musical form. This was done by means of a composition technique dominated by counterpoint linearity and a figural "motor-driven" development;
- the primacy of rhythm in folklore-inspired compositions (but not only), imposed by various means and nuanced dosages until its final establishment as a main element in the construction of form with I. Straviski.

Under the circumstances of unprecedented language complexity by all parameters, the emancipated horizontality of the musical space requires centering the composition process on established models, that is, when capitalizing on the dynamic aspects of the new sound structures is not on the agenda.

As far as the application of this principle is concerned, we had in mind the way patterns of classical form develop in A. Schönberg and A. Berg's atonal music and in the neomodal music of M. Ravel, B. Bartók and G. Enescu.

4 Conclusion

Although exemplified with works from the first two decades of the 20th century, the active principles I have formulated explain processes of formal construction in general, and anticipate in their succession the evolution of componistic thought in the last hundred years: from tonal-harmonic functionalism to modal-intervallic and/or cellular-dodecaphonic coordination and then to timbre colourist and rhythmically temporal determination. The new laws of musical determinism – **intervallic functionality** and the **functionality of colour** (of the complex sound) – together with **the structural role of rhythm** will come into prominence as composition principles and references for analysis in all music to follow, thereby confirming in retrospect Cl. Debussy's visionary assertion: „music is colour and rhythmed time".

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[5] „function represents the mode by which structure exists" (Gheorghe Firca, *Structuri și funcții în armonia modală [Structures and Functions in Modal Harmony]*. Bucharest, Editura muzicala, 1988, p.85); "a modal structure is a function, as opposed to a mode, which is a set" (Solomon Marcus, op. quote,. p. 259).

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[8] The primacy of the melodic concept is also related to the aesthetics of plastic art and music that developed in the first decades of the century, as well as to E.Kurth's theory *Energitism ,* and with *Art nouveau*-type practices, which in their musical transposition declare the value and seraphic beauty of the „lineary arabesque" (See Gh. Firca, *Structuri și funcții în armonia modală [Structures and Functions in Modal Harmony]*, Bucharest, Editura Muzicală, 1988, p. 83).

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Baroque Reflections in *Ludus Tonalis* by Paul Hindemith

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Abstract: - The originality and constructive complexity of the cycle *The Well-Tempered Clavier* by Johann Sebastian Bach generated a series of valuable replies in the 20^{th} century. Among these, one of the most ingenious and inspiring is *Ludus Tonalis* by Paul Hindemith. This paper aims at highlighting the main aspects that reveal, on the one hand, the correlation of Hindemith's work with the Bachian model, and, on the other hand, the transformation of some compositional elements in the spirit of the new school of thought of the 20^{th} century.

Key-Words: prelude, fugue, exposition, imitation, writing, polyphony

1 Introduction

In 1722, Johann Sebastian Bach named his first volume of preludes and fugues ***The Well-Tempered Clavier*** or, according to the notations in the original manuscript [1], "Preludes and fugues in all the major and minor keys for the profit and use of musical youth desirous of learning and especially for the pastime of those already skilled in this study." 200 years later, the rediscovery of the polyphonic art generated some original replies to this work, among which that of Paul Hindemith, ***Ludus Tonalis*** (*Play of Tones* or *Tonal Game*), subtitled *Kontrapunktische, tonal und Klaviertechnische Übungen* (Counterpoint, tonal and technical studies for the piano), that retains the didactical intentions of the Bachian model, bringing about at the same time ingenious changes to the previous formal and technical concepts.

This study proposes to analyze the main elements of correlation between the two cycles, through the perspective of the tradition-innovation duality.

2 The Concept of Tonal System

The cycle of preludes and fugues *Ludus Tonalis*, Paul Hindemith's last composition for piano, is a work with obvious didactic intentions that, on the one hand, represents the direct application of a new tonal system, and, on the other hand, demonstrates a different side of the neo-baroque aesthetics, through the employment of the most diverse counterpoint techniques and the innovations brought to the fugue form, a representative form for the Baroque Age.

Unlike *The Well-Tempered Clavier* by Johann Sebastian Bach or *24 Preludes and Fugues* by Dmitri Shostakovich, the *Ludus Tonalis* cycle is not structured according to the tonal principle of successive fifths; the relations of tonal similarity are entirely new, reflecting the revolutionary tonal principles presented by the composer in the work *Unterweisung in Tonsatz* (The Craft of Musical Composition) [2].

The result of the harmonic ensemble is a melodic series the sounds of which form the tonal centres of the preludes and fugues in the *Ludus Tonalis* cycle.

Fig. 1

Although the traditional tonal system, anticipated by *The Well-Tempered Clavier*, is different from the Hindemithian system, a fundamental element of correlation can be established: the relation to the tempered system, which makes Hindemith's model a modern variant of the Bachian one.

The prelude-fugue groups alternate according to the order of the degree of similarity between the sounds of the series and the "tonic": 1^{st} degree – 4^{th}, 5^{th}, 6^{th}, 2^{nd} degree – 2^{nd} and 7^{th}, 3^{rd} degree – augmented 4^{th} and diminished 5^{th}. At the same, Hindemith suspends Bach's concept of major-minor, as well as modulation; the tonality thus becomes a purely external element.

3 Prelude-Interlude

Unlike the Bachian preludes, the interludes are musical moments that retain characteristics of some genres quite distinct from the baroque preludes that accompanied the organ or clavier fugues, rather influenced by secular genres: pastoral (interlude I), scherzo (interlude III), march (interlude VI), waltz (interlude XI), with mono-, bi- or tristrophic structures. Moreover, an element of novelty is the architectonic symmetry given by the correspondence between the *Prelude* and the *Postlude*, the latter representing the inverted and recurring variation of the first.

2.1 Writing

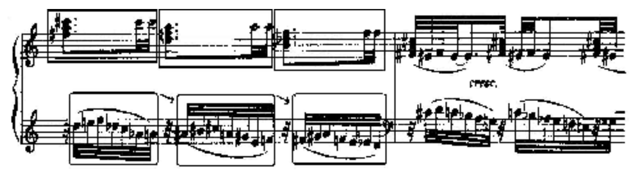
Some preludes are similar to the Bachian preludes through their rhythmic-melodic construction: interlude IV corresponds to the Prelude in D minor in *The Well-Tempered Clavier*, the common element being represented by the repetitive figural constructions based on which the sound discourse is developed.

Fig. 2a - **J. S. Bach** - *W. Kl.* [3] I, *Prelude 6* in D minor, the first 2 systems

Fig. 2b - **Paul Hindemith** - *Ludus Tonalis* [4], *Interlude IV*

Various polyphonic procedures are used, the moments of polyphonic syntax alternating with the homophonic ones. Hindemith renews procedures and techniques, which he adapts to the new sound context, gives the development of the discourse a marked baroque character and at the same time achieves amazing correspondences with the Bachian preludes in *The Well-Tempered Clavier*. Among these one can identify **latent polyphony, double counterpoint, sequencing**.

Fig. 3 - Paul Hindemith - *Ludus Tonalis*, *Interlude I*, p. 7, systems 3-4, descending sequencing

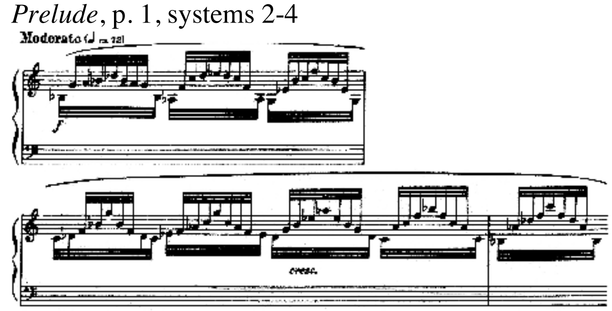


In the absence of a tonal focus, the transposition of the model on various phases is recorded at the level of a single voice; the others hold a line independent of sequencing, sometimes unremitting (see the last example), against the traditional baroque procedure, where all voices were subjected to sequential repetitivity.

The most significant element of congruency between the two works resides in the complementarity of the voices in the polyphonic writing, chiefly used by Bach, but also by Hindemith in most of the interludes.

Fig. 4a - J. S. Bach - *W. Kl.* I, *Prelude 1*, system 1

Fig. 4b - Paul Hindemith - *Ludus Tonalis*, *Prelude*, p. 1, systems 2-4



This rhythmic-melodic fluency becomes in Hindemith the nucleus of some moments with motor character, less frequent in the Bachian preludes, a characteristic similar to one of the main fundamental features of the modern sound language, which individualizes the rhythmic factor, with the tendency of dominance in relation to the other language elements (see Interlude 1 p. 8 the last system, Interlude no. 8 p. 38 the first system).

4 The Fugue Form

In the 12 three-voice fugues of the Hindemithian cycle the composer defines the

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concept of fugue reconfigured in the new mosaic-like sound context of the 20th century, achieved through the combination of the baroque traditional constructive techniques with the innovative principles of personal thought. Each fugue begins in the tonality of the previous piece and ends in the tonality of the following interlude (or in a different tonality, very similar to the latter), following the order of series 1, the circle of tonalities ending with the tonic of the *C* series.

Although Hindemith uses a novel sound material, reflected in the original harmonic constructions, the architectonic structure of the fugues is perfectly elaborated, equal to the perfection of the Bachian fugues. The three main moments of the baroque form can be found in Hindemith's fugues, each of these sections undergoing modifications, according to the polyphonic procedures that are used, as well as to the type of fugue which is approached: simple, double, canonic, with exposition in *stretto*, mirror, recurrent.

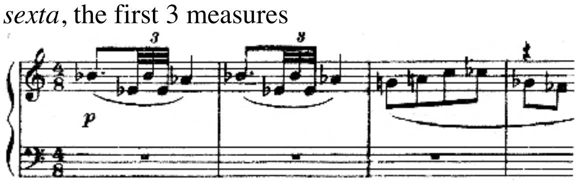
4.1 Exposition

4.1.1 The fugue theme is as diverse in all its aspects as the innovative Hindemithian language.

a. Melodic Aspects

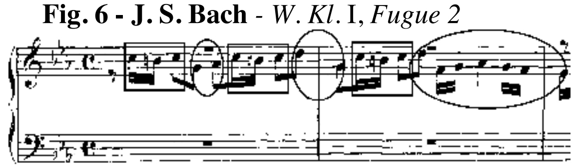
If in the Bachian fugue one can identify the diatonic-chromatic predominance in the organization of the thematic articulation, the combinations of the gradual movement with the melodic leap and the dramatic implications of the latter (reaching the climax, fractioning the theme in contrasting modules, etc.), in the case of the fugues in *Ludus Tonalis* one can no longer speak of the consonant-dissonant duality, as the intervallic variety of the theme is based on the unexpected succession of ascending and descending leaps (often placed in a ninth or tenth in less than three beats), as well as the intrusion of the repetitive, symmetrical melodic formulas that direct expressivity towards the rhythmic area, (also see *Ludus Tonalis*, *Fuga nona*)

Fig. 5 - Paul Hindemith - *Ludus Tonalis*, *Fuga sexta*, the first 3 measures



Similar structures based on repetitions of the same melodic model can also be found in the Bachian fugue themes, but they are used especially at the level of pure melodic expressivity.

Fig. 6 - J. S. Bach - *W. Kl.* I, *Fugue 2*



Another element related to the rhythmic aspect is represented by the beginning sound of the theme, which, in the Bachian fugue, due to the strict rules of imitative polyphony, was restricted to the two functions of tonality – tonic and dominant. Hindemith proves to be conservative in regard to the tonal implications of this aspect, most of the fugues observing the traditional rule. However, as in the case of *The Well-Tempered Clavier* [5], two exceptions can be discovered, demonstrated in reaching the T or D sound through an intermediary element or group of elements (in *Fuga quarta* and *Fuga quinta*).

Fig. 7 - Paul Hindemith - *Ludus Tonalis*, *Fuga quinta in E*

b. Rhythmic and Metric Aspects

Hindemith makes full use of the rhythmic side in his fugues, thus becoming a significant exponent of the new sound thought of the 20th century, which rediscovered the expressive values of the rhythm. In this regard, the baroque spirit is renewed through the use of a variety of rhythmic formulas, often interrupted by pauses which unexpectedly fragmentarize the discourse, as well as presenting some unusual measures (5/8 in Fuga II *secunda in G*). Nevertheless, analyzing the 12 fugue themes, one observes a double emphasis of the rhythm: on the one hand, an assertion of the freedom to combine formulas, with simple or multiple divisions, normal or exceptional, with accents or groupings of the values that shift the metric pulsation,

Fig. 8a - Paul Hindemith - *Ludus Tonalis*, *Fuga octava*, m. 1-2

and, on the other hand, an assimilation of some configurations similar to the Bachian fugues, characterized by great values (halves, quarters) and/or by theme delineation in contrasting motivic units.

Fig. 8b - Paul Hindemith - *Ludus Tonalis*, *Fuga quarta*, m. 1-2

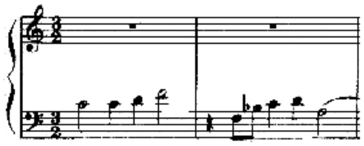


Fig. 8c - J. S. Bach - *W. Kl.* I, *Fugue 22*, m.1-2

4.1.2 The Imitative Principle

The imitative principle as a fundamental element in the construction of the fugue form, clearly determined in the interval between subject and response, manifests in *Ludus Tonalis* the same tradition-innovation duality previously emphasized in the expositive segment, as well as in the developing part; moreover, one can delineate an evolutionary trajectory of the transformation of the Bachian principle, from imitation in the fifth (in five of the 12 Hindemithian fugues), to the perfectly ascending fourth [6], up to the third [7]. The equivalence established by Hindemith between the perfect fifth and fourth, thus achieving an emancipation of the traditional technique, is illustrated in their simultaneous use in the expositions of the *fugues secunda* and *sexta*.

Fig. 9 - Paul Hindemith - *Ludus Tonalis*, *Fuga secunda*, exposition

As to the exceptional modalities of manifestation of the imitative principle in the expositive sector, there can also be found fugues with two or three subjects (*fuga prima*, *fuga sexta*) and a fugue with exposition in *stretto* (*fuga duodecima*), the composer showing perfect knowledge of the baroque polyphonic techniques. In *The Well-Tempered Clavier* there exist three fugues with two subjects, a fugue with three subjects (II/14) and one with exposition in *stretto* (*W.Kl.* II/3), the polyphonic complexity of such constructions exceeding the initial didactic purpose of the work, the two typologies being subsequently developed in *Kunst der Fuge* and *Orgelwerke*. In *Ludus Tonalis* Hindemith follows the same line of clarity and relative accessibility, the approach of these agglomerated polyphonic structures representing constructive replies to the baroque model.

4.2 The developing sector

What makes *Ludus Tonalis* a modern reply to *The Well-Tempered Clavier* is the variety of procedures of thematic treatment used in the central section of the form.

The thematic sections bring in the Bachian cycle numerous elements of theme variation, from the tonal and harmonic ones to the most complex melodic aspects (inverted, augmented or diminished) to polyphonic variations (double or multiple counterpoint). The transposition of these modalities to give complexity to the monothematism in the Hindemithian language will eliminate the tonal-harmonic aspects, diversifying up to a maximum the counterpoint artifices operated with the theme, as well as its melodic aspects. Next to the mentioned variants, Paul Hindemith will also use recurrence, the reversal of recurrence and the intensification of the theme, in various mixtures.

Fuga tertia is the most elaborate in this regard, as its theme appears in all the four fundamental aspects of a melodic structure in the traditional counterpoint: direct, inverted, recurrent and the inversion of the recurrence.

Fig. 10 - Paul Hindemith - *Ludus Tonalis*, *Fuga tertia*, p. 13 systems 5, 6, p. 14, system 1

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4.3 Final Section

In the last articulation of the form, with the role to reaffirm the initial tonality, Hindemith demonstrates a faithful observance of the Bachian model, given the tonal stream of his sound thought (a personal tonalism though), even using some functional artifices employed in *The Well-Tempered Clavier* and adapted to his own tonal system. Thus, while in Bach one identifies the subdominant-tonic relation, maintaining the fifth relation between theme and response, in *Ludus Tonalis* one finds in the final section of *Fuga octava* an augmentation of the principle up to the blurring of the initial centre due to its placement in a chain of ascending fifths: G-D-A.

Fig. 11 - Paul Hindemith - *Ludus Tonalis*, *Fuga octava*, p. 38, systems 1-2

4.4 Exceptional fugues

A special role within the *Ludus Tonalis* cycle is played by some particular types of fugue that, because of the polyphonic complexity, have no correspondent in *The Well-Tempered Clavier* cycle, but which were approached by Bach in his elaborate polyphonic works (*Kunst der Fuge* and *Musikalisches Opfer*):

- **the canonic fugue** used in *Fuga undecima*;
- **the mirror fugue** in *Fuga decima*, a fluent variant of the Bachian model; the form has as axis of symmetry the cadence in unison on the sound of the dominant (*lab*) at the end of the central section

5 Conclusions

Paul Hindemith's work *Ludus Tonalis* represents, through its complexity and practical value in the study of counterpoint, the most important and at the same time the most original work written in the aftermath of Johann Sebastian Bach's masterpieces. The cycle of preludes and fugues simultaneously provides a synthesis of the polyphonic science and proposes the new concepts of tonal treatment specific to the 20th century. Hindemith's art is inevitably compared to Bach's due to the complex intertwining of voices endowed with their own vitality, accomplished not only as a result of a well-acquired technique, but also as an internal necessity.

References:

[1] „Das Wohltemperirte Clavier oder Praeludia und Fugen durch alle Tone und Semitonia sowohl tertiam majorem oder Ut Re Mi anlangend, als auch tertiam minorem oder Re Mi Fa betreffend. Zum Nutzen und Gebrauch der Lehrbegierigen Musicalischen Jugend als auch derer in diesen studio schon habil seyendern besondern Zeit Vertreib auf gesetzet und ver fertigen von Johann Sebastian Bach p.t. Hochfürstl. Anhalt. Cöthenischen Capell-Meistern und Directore derer Cammer-Musiquen. Anno 1722." Introducere la reeditarea variantei Breitkopf und Härtel din anul 1947 realizată de J.W. Edewards, Ann Harbor, Michigan, U.S. A. Surce http://www.dlib.indiana.edu/variations/scores/abt8726/large/index.htm.

[2]Staring from the acoustic phenomenon of the natural resonance, Hindemith "populates" the space of an octave with sounds that do not belong to the series of harmonics with a single generating centre, still through the function invested into the first six harmonics, one by one, each of them becomes fundamental, the second, the fourth and the fifth harmonic making up a chromatic scale, that he considers one of the most ingenious inventions of the human spirit, specific to the keyboard instruments, with equally tempered vibrations.

[3] For the examples from *The Well-Tempered Clavier* we shall use the abbreviation of the original title, accompanied by the corresponding number from book I or II and the registration number of the work

[4] The examples are extracted from the score, Edition Verlag Music, Moscow, 1964.

[5] There are two exceptions: the supertonic in *W. Kl.* II/21 and the sensitive in *W.Kl.* II/13.

[6]. Hegemonic in Hindemith's work, the fourth in one of the intervals that fits the first relating degree, along with the perfect fifth.

[7]. According to the same principle of the tonal relationship, present in the *tertia* and *quarta* fugues.

Links between mathematical models and musical texture in Xenakis's Achorripsis

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Abstract: Exploring the transitional field between a mathematical model and the resulting musical texture is a path to enhance the listening experience and stimulate the creative imagination. In the case of Xenakis Achorripsis, issues as the considered parametrization of the sound, the characteristics of the 'stochastic texture', the way that specific numerical choices in the frame of the stochastic models affect the musical texture in detail, are examined to highlight the trajectory from the mathematical model to the musical result and lead to a better understanding of the composer's creative procedure. Matlab codes for the calculations needed in the construction of the work are offered for further research.

Key-Words: - algorithmic composition, stochastic music

1 Definition of sound units in Xenakis's stochastic works

One of the fundamental procedures of Xenakis's compositional work is the *definition of sound units.* Those sound units are represented by 4-dimensional vectors of the form (c,h,g,u), where c: timbre (instruments family), h: pitch, g: intensity (dynamics) and u: duration.

This choice is an important aspect of the structural concept of Xenakis's works for many reasons: the physical - scientific approach of music as a sound phenomenon (through an approximation of the physical reality), the parametrization of musical sound as a set of elementary properties (connected to Xenakis's concept of creation 'ex nihilo'), the non-temporal character of this parametrization (like a momentary "fingerprint" of a sound, considered as an instantaneous occurence) – creator of a notion of 'sound grains' evoluting in time (continuously or discontinuously), are some of those reasons and approaches that could (or perhaps should) affect the listening experience of his music.

2 The stochastic texture

Stochastic music was for Xenakis the solution to the impass where serialism was driven. The idea was to replace the interdependence of the sonic elements in the polyphonic texture of serial music, where he found that complexity was preventing the discernation of the voice – leading, with sound masses of totally independent sonic elements, where the statistical mean of movement is the basic structural tool, offered for macroscopic perception.

Most important characteristics of the stochastic musical texture are the non-symmetry of the structure, the non-causality due to not operating with any of the known rules of linear combinations and superpositions, the effect of a sonic mass made of independent elements, whose behaviour is controlled with the notion of probability and perceived from a statistical point of view. The non-symmetry, the non-causality and the statistical character are more relevant to the 'natural' behaviour (Xenakis often referred to the rain, to the crowds, to cicadas e.t.c.) – a fact based also on the latest scientific results.

3 Over the sonification in Achorripsis

GENERAL ORGANISATION

3.1 Timbre

Defined timbral classes:
I) *Flute*: Piccolo, Eb Clarinet, Bass Clarinet
II) *Oboe*: Oboe, Bassoon, Contrabassoon
III) *String glissando*: Violin, Cello, Double Bass
IV) *Percussion:* Xylophone, Wood Blocks, Bass Drum
V) String pizz.: Violin, Cello, Double Bass
VI) *Brass:* 2 Trumpets, Trombone
VI) *String arco:* Violin, Cello, Double Bass

3.2 Density

Clouds of sounds

Suppose we have a given set of punctual sounds defined in an intensity/height space occurring in a time interval. This group of several randomly distributed notes forms a "note cloud".

There are two main characteristics of a cloud of notes: density and pitch.

Cloud density

There can be an arbitrary number of clouds, each with its own density (μ), in a composition. We can choose the value μ_0 as an average value for the density of clouds.

The density is measured in number of notes per second.

Given the mean surface density of this cloud, the Poisson distribution law provides the probability of having a certain density in a certain region of the intensity/height space:

$$P_\mu = \frac{{\mu_0}^{\mu}}{\mu!} e^{-\mu_0}$$

where μ_0 is the mean density and μ is a certain density.

Explanation of the construction of the density matrix of Acorripsis

In "Achorripsis", the structure of the work is based on a matrix, whose rows represent the timbral classes and whose columns are duration fragments in the time field. The steps of the construction of this matrix are:

(a) A priori decision of the total duration of the musical work (7 minutes)

(b) Definition of column length: 15 sec. (~ 6.5 measures in which the time signature is 2/2 with half note = MM 52.) This leads to a matrix with 28 (= 7 min./15 sec.) columns. Multiplied with the number of defined timbral classes (7), this leads to a matrix with 196 (=28*7) cells.

(c) A priori choice of a value of average density for the global structure ($\mu_0 = 0.60$)

(d) Application of the Poisson distribution law for integer values of μ (in "Achorripsis" it is μ = 0 : 4, because for μ = 5 the probability gets zero). This provides the possibility of zero, single, double, triple and quadruple "events", which must be multiplied by the number of cells (196) to calculate the number of events in each category.

(e) Distributing the calculated numbers of events for each category (zero, simple, double, triple, quadruple) in the 28 cells. This requires another application of the Poisson distribution law, using the mean of "presence" of this specific category in the global structure, calculated from the first application of the Poisson distribution - i.e. for the simple event in "Achorripsis" we get $P_1 = 65$ from the first Poisson, hence the mean presence of the single event in the 28 columns is 65/28 cells = 2.32. The second application of the Poisson law, for $\mu_0 = 2.32$, provides the number of columns where there are 0,1,2,3,4,5,6 ocurrences of the single event respectively. Observe: 3 columns with 0 single events, 6 with 1, 8 with 2, 5 with 3, 3 with 4, 2 with 5, 1 column with 6 single events.

This is repeated respectively for the other categories of events.

(g) Definition of the mean number δ of sound ocurrences in a simple event. Xenakis's choice for "Achorripsis":

λ = 5 sounds/measure 26MM for the single event. The numbers in the cages of Achorripsis's matrix are calculated appropriately according to this mean number.

3.3 Duration

The time (metric) is considered to be a straight line, on which the variations of other components are marked using points. The distance between two points represents the duration.

We consider a set of points on a given segment. The question is: given a set of points on a segment, which is the maximum number of segments of a given length?

The note length is determined by a random generation process which obeys the following exponential distribution:

$$P_x = \delta \cdot e^{-\delta x} dx$$

where δ is the linear density of points and x is the length of a random segment.

This probabilistic formula gives the probabilities for all the possible lengths when we know the position of a set of points randomly positioned.

One can observe that a larger value will produce on average shorter notes and a smaller density will produce longer notes.

To obtain the probability that the outcome is between two values (say l_0 and l_1), the density function must be integrated, in this case giving:

$$P(x) = \int_{l_0}^{l_1} \delta \cdot e^{-\delta x} dx$$

The value of δ obviously affects both the density of the section and the duration of the events, which is only natural, as the duration of the sound events (time interval between successive ocurrences) is an interpretation of the density.

In the example of "Achorripsis", time intervals between successive events, calculated with the exponential distribution using the appropriate δ are divided in five classes (in augmenting succession):

(a) <= 12/52 sec (division of the measure in 10 quintuplet eighth notes)

(b) <= 15/52 sec (division of the measure in 8 eighth notes)

(c) <=20/52 sec (division of the measure in 6 triplet quarter notes)

(d) <= 30/52 sec (division of the measure in 4 quarter notes)

(e) <= 60/52 sec (division of the measure in 2 half notes)

'Duration.m' is a matlab code for the calculation of durations, given the value of δ:

```
function duration()
x = 0:.1:1;
dx=0.0805;
%for the first column of Achorripsis matrix,
delta = 3.5;
%change the value of delta appropriately;
delta=3.5;
deltax=0:.45:3.5;
for i=1:10
column3(i)=exp(-(delta*x(i)));
column4(i)=delta*column3(i);
column5(i)=column4(i)*dx;
column6(i) = column5(i)* (delta *6.5-1); %the
%number of durations
end
% open the file with write permission
fid = fopen('C:\duration.txt', 'w');
for i=1:10
fprintf(fid, '%6.2f %12.8f %12.8f %12.8f
%12.8f %12.8f\r\n', x(i), deltax(i), column3(i),
column4(i), column5(i), column6(i));
end
fclose(fid);

% view the contents of the file
%type ('duration.txt')
```

For δ = 2.5 (cell I – κ' of Acorripsis matrix), the duration matrix is:

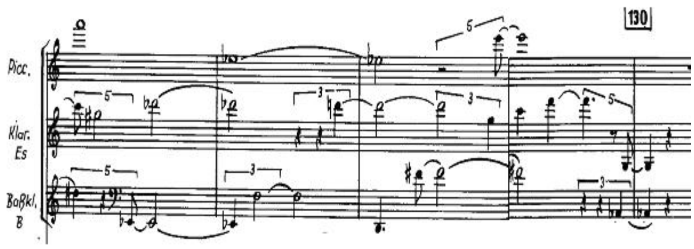
duration - Σημειωματάριο

Αρχείο Επεξεργασία Μορφή Προβολή Βοήθεια

0.00	0.00000000	1.00000000	2.50000000	0.20125000	3.06906250
0.10	0.25000000	0.77880078	1.94700196	0.15673366	2.39018828
0.20	0.50000000	0.60653066	1.51632665	0.12206430	1.86148050
0.30	0.75000000	0.47236655	1.18091638	0.09506377	1.44972247
0.40	1.00000000	0.36787944	0.91969860	0.07403574	1.12904500
0.50	1.25000000	0.28650480	0.71626199	0.05765909	0.87930113
0.60	1.50000000	0.22313016	0.55782540	0.04490494	0.68480041
0.70	1.75000000	0.17377394	0.43443486	0.03497201	0.53332309
0.80	2.00000000	0.13533528	0.33833821	0.02723623	0.41535244
0.90	2.25000000	0.10539922	0.26349806	0.02121159	0.32347681

The last column returns the number of notes in every duration category (these numbers are used rounded to the closest integer). Compare the sum of those numbers in this matrix with the next two matrices: it is the smaller of all three duration matrices presented (due to the lowest value of density δ).

An excerpt of this section of the score (only the timbral class I):



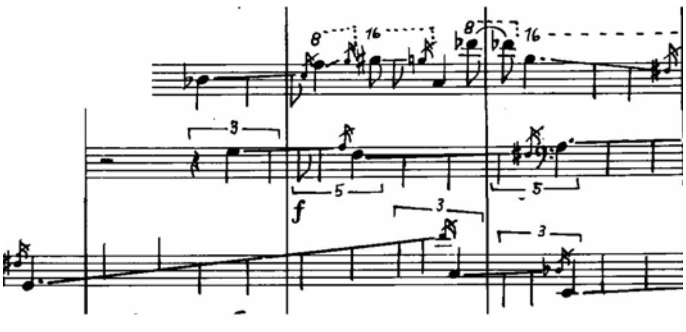
Duration matrix for δ = 4.5 (cell III – Iζ' of Achorripsis matrix). Observe the exponential distribution of the numbers notes in the considered categories of durations; the majority of notes seems clearly concentrated in the categories of smaller durations, as the value of δ increases:

duration - Σημειωματάριο

Αρχείο Επεξεργασία Μορφή Προβολή Βοήθεια

0.00	0.00000000	1.00000000	4.50000000	0.36225000	10.23356250
0.10	0.45000000	0.63762815	2.86932668	0.23098080	6.52520754
0.20	0.90000000	0.40656966	1.82956347	0.14727986	4.16065602
0.30	1.35000000	0.25924026	1.16658117	0.09390978	2.65295141
0.40	1.80000000	0.16529889	0.74384500	0.05987952	1.69159650
0.50	2.25000000	0.10539922	0.47429651	0.03818087	1.07860955
0.60	2.70000000	0.06720551	0.30242481	0.02434520	0.68775181
0.70	3.15000000	0.04285213	0.19283457	0.01552318	0.43852992
0.80	3.60000000	0.02732372	0.12295675	0.00989802	0.27961902
0.90	4.05000000	0.01742237	0.07840069	0.00631126	0.17829296

An excerpt of the score at the cell III – Ιζ' :



Duration matrix for δ = 20 (cell II – κε' of Achorripsis matrix) :

duration - Σημειωματάριο

Αρχείο Επεξεργασία Μορφή Προβολή Βοήθεια

0.00	0.00000000	1.00000000	20.00000000	1.61000000	207.69000000
0.10	2.00000000	0.13533528	2.70670566	0.21788981	28.10778498
0.20	4.00000000	0.01831564	0.36631278	0.02948818	3.80397504
0.30	6.00000000	0.00247875	0.04957504	0.00399079	0.51481204
0.40	8.00000000	0.00033546	0.00670925	0.00054009	0.06967223
0.50	10.00000000	0.00004540	0.00090800	0.00007309	0.00942911
0.60	12.00000000	0.00000614	0.00012288	0.00000989	0.00127609
0.70	14.00000000	0.00000083	0.00001663	0.00000134	0.00017270
0.80	16.00000000	0.00000011	0.00000225	0.00000018	0.00002337
0.90	18.00000000	0.00000002	0.00000030	0.00000002	0.00000316

There can be clearly noticed an impressive increase of the sum of notes (241, where the sum of the same column was 12 in the first duration matrix with δ = 2.5), as also of the number of small durations (208 durations <= eight of quintuplet, where in the first matrix the respective value was 3). Notice the dense presence of small durations in this excerpt of the score at the cell II – κε':

3.4 Pitch

The second main characteristic of a note cloud is its pitch. The pitches of the notes in the cloud are determined by a starting pitch along with the intervals between each pair.
The intervals are determined according to the following linear probability distribution:

$$\Theta(\gamma)d\gamma = \frac{2}{a}\left(1 - \frac{\gamma}{a}\right)d\gamma$$

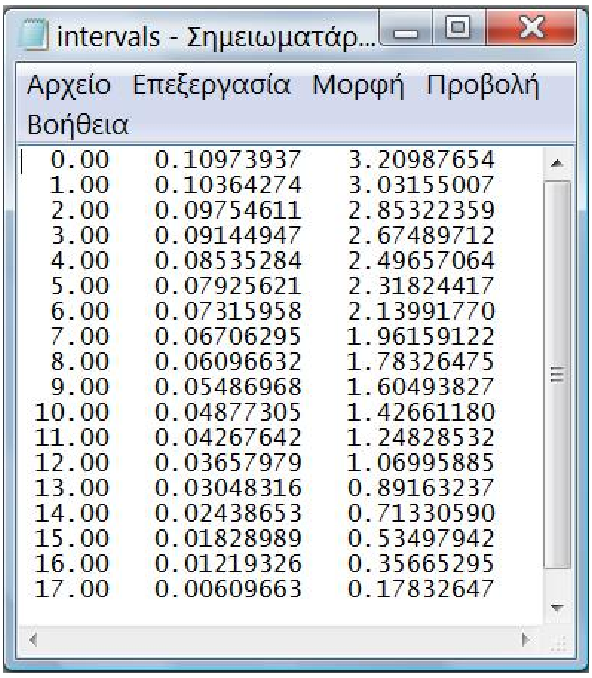
where a is the maximum interval value specified by the composer.
This law gives the probability that one segment (interval of intensity, melodic, etc) s, which is interior in a segment of length a, to have a length between γ and $\gamma + d\gamma$ for $0 \leq \gamma \leq a$.

One can notice the use of an additional simple random variable equivalent to the flipping of a coin. This is used to determine whether the interval is rising or falling.
The maximum interval limit helps reduce the production of sequences that are unnatural sounding or difficult to play.
interval.m is a matlab code for the calculation of pitch changes in 'Achorripsis':

```
function intervals()
%v = 0:1:18;
%alfa=3.88;
delta = 3.5; %changing every 6.5 measures in Achorripsis
a = 18;% approx.80/4.5 (80 semitones divided in unities of 4.5 semitones)
dj = 80/(80+1); %80 semitones
for j=1:18
P(j) = (2/a) * (1-(j-1)/a)*dj;
L(j)=P(j)*delta*6.5;
end
% open the file with write permission
fid = fopen('C: \intervals.txt', 'w');
for j=1:18
```

```
fprintf(fid, '%6.2f %12.8f %12.8f\r\n', j-1, P(j),
L(j));
end
fclose(fid);
```

Pitch matrix for δ = 4.5 (cell III – Iζ'). The last column of this matrix is the probability multiplied to 6.5 * δ, in order to distribute the calculated probabilities of each category of intervals to the desired number of events (controled by δ), in the space of 6.5 measures of every cell.



intervals - Σημειωματάρ...

Αρχείο Επεξεργασία Μορφή Προβολή Βοήθεια

0.00	0.10973937	3.20987654
1.00	0.10364274	3.03155007
2.00	0.09754611	2.85322359
3.00	0.09144947	2.67489712
4.00	0.08535284	2.49657064
5.00	0.07925621	2.31824417
6.00	0.07315958	2.13991770
7.00	0.06706295	1.96159122
8.00	0.06096632	1.78326475
9.00	0.05486968	1.60493827
10.00	0.04877305	1.42661180
11.00	0.04267642	1.24828532
12.00	0.03657979	1.06995885
13.00	0.03048316	0.89163237
14.00	0.02438653	0.71330590
15.00	0.01828989	0.53497942
16.00	0.01219326	0.35665295
17.00	0.00609663	0.17832647

Score excerpt of cell III – Iζ':

The lines linking successive pitches give a general idea of the distribution of intervals: Bb – E: category j=1, E – F: category j = 2, F – D: category j = 3, D – G#: category j = 7, G# - A: category j = 8, A – C: category j = 5, C – Db: category j = 11, Db – G: category j = 1.

The category j =1 manifests in this excerpt a greater frequency (which is justified by the predicted frequency value).

3.5 Speed

Xenakis considers a categorisation of sound to granular v.s. continuous sounds. Granular sounds are not evoluting in time, in contrast to continuous, whose evolution can be of less or more complexity (continuous sounds are a much bigger set than granular ones, which actually could be considered as a particular case of continuous sounds of a very small duration.) Among these continuous sounds, the ones considered here are the glissandi with a uniform behaviour (speed).

We are going to make an homogenity hypothesis which will lead us to a mathematical formula for the distribution of speeds.

The formula for the speeds is determined according to the following normal distribution formula:

$$f(v) = \frac{1}{a\sqrt{2\pi}} \cdot e^{-\frac{v^2}{2a^2}}$$

where a is the aggregate temperature. The name of this parameter comes from the kinetic gas theory. From a statistic point of view, the above formula defines the standard deviation.

The function $f(v)$ gives the probability of the occurrence of the v speed, the constant which defines the "temperature" of this sound atmosphere.

Speed.m is a matlab code for the calculation of the speed matrix, using the appropriate value of δ according to the cell of interest:

```
function speed()
v = 0:1:10;
alfa=3.88;
for i=1:10
lambda1(i)=v(i)/alfa;
delta = 6.5; %this is the value of density delta,
varying in each cell of the row III (string glissandi)
fi(i)=erf(lambda1(i));
end

for i=1:9
Plambda(i)=fi(i+1)-fi(i);
column5(i)=Plambda(i)*delta*6.5;%Here I
substituted 29 (which was 6.5 * delta for delta = 4.5,
but now
column6(1) = (v(1)+v(2))/2; %here I added the
average of the first 2 which should also be
calculated column6(i)=(v(i)+v(i+1))/2;
end

% open the file with write permission
fid = fopen('C: \speed.txt', 'w');
for i=1:9
fprintf(fid, '%6.2f %12.8f %12.8f %12.8f %12.8f
```

%12.8f\r\n', v(i), lambda1(i), fi(i), Plambda(i), column5(i), column6(i));
end
fclose(fid);

% view the contents of the file
%type speed.txt

For δ = 6.5 (cell III – Iς) the speed matrix comes as follows:

speed - Σημειωματάριο

Αρχείο Επεξεργασία Μορφή Προβολή Βοήθεια

0.00	0.00000000	0.00000000	0.28450639	12.02039500	0.50000000
1.00	0.25773196	0.28450639	0.24947730	10.54041612	1.50000000
2.00	0.51546392	0.53398370	0.19182622	8.10465777	2.50000000
3.00	0.77319588	0.72580991	0.12933635	5.46446062	3.50000000
4.00	1.03092784	0.85514626	0.07646551	3.23066793	4.50000000
5.00	1.28865979	0.93161177	0.03964046	1.67480941	5.50000000
6.00	1.54639175	0.97125223	0.01801916	0.76130931	6.50000000
7.00	1.80412371	0.98927139	0.00718202	0.30344027	7.50000000
8.00	2.06185567	0.99645341	0.00250996	0.10604601	8.50000000

For δ = 4.5 (cell IV – Iζ) the speed matrix comes as follows:

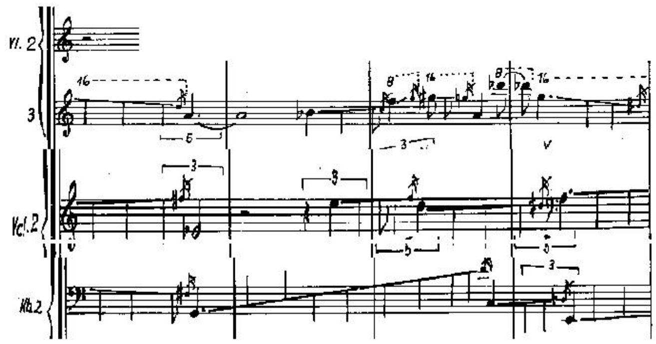
speed - Σημειωματάριο

Αρχείο Επεξεργασία Μορφή Προβολή Βοήθεια

0.00	0.00000000	0.00000000	0.28450639	8.32181192	0.50000000
1.00	0.25773196	0.28450639	0.24947730	7.29721116	1.50000000
2.00	0.51546392	0.53398370	0.19182622	5.61091692	2.50000000
3.00	0.77319588	0.72580991	0.12933635	3.78308812	3.50000000
4.00	1.03092784	0.85514626	0.07646551	2.23661626	4.50000000
5.00	1.28865979	0.93161177	0.03964046	1.15948343	5.50000000
6.00	1.54639175	0.97125223	0.01801916	0.52706029	6.50000000
7.00	1.80412371	0.98927139	0.00718202	0.21007403	7.50000000
8.00	2.06185567	0.99645341	0.00250996	0.07341647	8.50000000

Compare the two following excerpts of the score (the first is for δ = 6.5:

and the second is for smaller δ = 4.5 – observe that there are fewer parts of string div. dedicated to the timbre 'string glissando', hence fewer glissando sounds, a result of the smaller value of density):



4. Conclusion

The parametrization of the sound, as much as the choice of the used mathematical (stochastic) models cause a large impact on the macroscopic formation of the musical result encountered in Achorripsis. In the microstructure, the choice of the numerical values applied in the frame of the used stochastic models reveals enlightening details about the sculpting of the musical texture.

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"Diathlassis", for flute solo: a composition based on an application of the mathematical model of cusp catastrophe

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Abstract: - "Diathlassis" for flute solo is a music composition based on an application of a mathematical model from catastrophe theory: the cusp catastrophe. The initial inspiration for this piece came from the optical phenomenon of refraction (translated in greek: 'diathlassis'). The exploration of the cusp manifold and, particularly, of its characteristic fold, through lines vertical to the plane of the two control variables, is interpeted by a 'refracting melody', due to the mapping of the state variable on the musical parameter of pitch. Timbral experiments and the corresponding notational findings are the result of the mapping of one control variable to the musical timbre.

Key-Words: - catastrophe theory, cusp catastrophe, refraction, algorithmic composition.

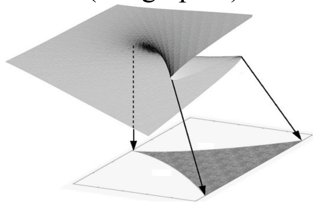
1 Introduction

Physical phenomena as a trigger of artistic inspiration is an idea that has always been present in the history of art. The approach of these phenomena from a scientific aspect has been a widely spread notion among composers during the last decades. "Diathlassis" for solo flute is a music project inspired by the optical phenomenon of 'refraction' (translated in greek: 'diathlassis'), materialised through the application of a mathematical model of catastrophe theory: the cusp catastrophe.
The mapping used in this implementation is the result of an aesthetic evaluation of the expressive potential that appears in the natural (physical) reality of refraction and in the cited mathematical model, a choice made mainly through the filter of artistic intuition.

2 The construction of the work.

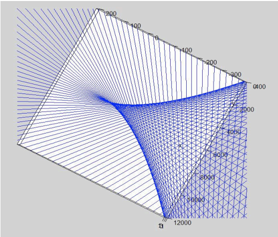
2.1 The cusp catastrophe model

The mathematical formula that decribes the catastrophic manifold of the cusp model is:
$t^3 + Yt + X = 0$ (1),
where X and Y are the control variables and t is the state variable. This manifold is a folded surface, and the fold's projection to the (X,Y)– plane indicates the area of the (X,Y) where more than one – and up to three - equilibrium states are possible: the bifurcation set of the cusp catastrophy model (see graph.1).



Graph.1: the cusp catastrophe manifold and the projection of the cusp to the (X,Y) - plane.

As (X,Y) comes 'inside' the bifurcation set, there are three distinct values of t for which (X,Y,t) belongs to the cusp manifold. On the 'branches' of the bifurcation set these possible distinct values are only two (one simple and one double) and on the cusp point (vertex of the curved triangle) there is only one (triple). The bifurcation set of the cusp catastrophe model is the main area of interest.
The formula (1), for several values of the variable t, leads to a set of equations of straight lines, whose directional coefficients are equal to -1/t. The union of all these straight lines form the catastrophe manifold; their projections on the (X,Y)-plane are the "cusp lines", whose intersections form the bifurcation set (compare graph.2 to the projected bifurcation in graph.1).



Graph.2: The cusp lines intersect to form the bifurcation set.

2.2 The structural link with the optical phenomenon of refraction ("diathlassis").

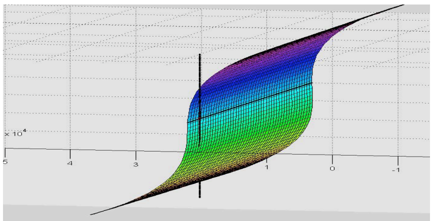
2.2.1 The structural link

The structure of the musical piece "Diathlassis" for solo flute is based on the idea of exploring the cusp manifold's area of interest – the fold - following trajectories vertical to the (X, Y)-plane, passing through one of the branches of the bifurcation set. Every one of these straight lines is interrupted by the 'catastrophic leap' that occurs in the specific position, whose measure varies depending on this position (smaller when closer to the cusp point, bigger as distance from the cusp point increases). The idea of musically exploring the fold of the cusp catastrophe manifold is here associated with following these straight lines vertically to the (X,Y)-plane through a branch of the bifurcation and rendering "melodically" the varying measure of the "gap". Considering the straight lines coming from the formula (1) for specific values of t, the measure of the "catastrophic leap" is also related with their direction coefficients. The two types of straight lines considered can be classified by couples that intersect at a specific point of one edge of the fold. The coordinates of this point simultaneously satisfy the equation (1), as much as the equation:

$4Y^3 + 27X^2 = 0$ (2),

due to the fact that on the enge of the fold the discriminant $D = 4Y^3 + 27X^2$ must be equal to zero.

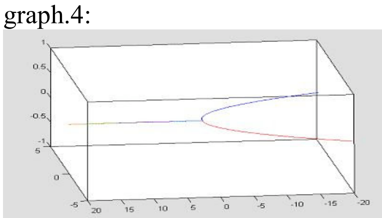
By solving the system of the equations (1) and (2) for a specific value of t one can calculate the coordinates of the corresponding contact point of the two straight lines mentioned above. From this aspect, the measure of the catastrophic discontinuousness is directly related to a direction coefficient, hence an angle, that is interpreted in the musical application as an index of 'melodic refraction'.



Graph 3: The two types of straight lines intersect on the edge of the fold. The straight line coming vertically to the (X,Y)-plane punctures the fold, "measuring" the local discontinuousness.

2.2.2 The "triggering" variable.

A variable t* is used in this mapping as a "trigger", to cause the cited trajectories vertically to the (X,Y)-plane. For t* = 0, by solving the system of the equations (1) and (2) the result is X = 0. Substituting this value of X in (1) leads to the the formula $Y = \pm t^2$ (3). This represents a continuous trajectory with two branches, like shown in the graph.4:



Graph.4: the unique continuous trajectory for t* = 0.

For all t*≠0, the corresponding graphs present discontinuous trajectories, hence a gap that varies, as mentioned, correspondingly to the distance form the cusp point. For every specific value of the trigger t*, a couple of coordinates (X*,Y*) on a branch of the bifurcation set can be calculated by solving the system of the equations (1) and (2). By substituting the found values of X* and Y* to the formula (1), there can be found the second value t*' of t that applies at this edge of the fold. Hence, a straight line coming vertically to the (X,Y) – plane through (X*, Y*, t*) performs a catastrophic leap to the point (X*, Y*, t*') – or vice versa.

3. The mapping to musical parameters.

The work is built in a 4-dimensional space (X, Y, t, t*). The calculations needed were all made in the programming environment of Matlab 7.2 (The Mathworks, Natick, MA)

3.1 The 4-dimensional space of the work.

The triggering variable t* is mapped to the 12-tone. A 12-tone series is used in a macroscopic aspect, creating 12 sections in the piece; every section beginning with the trigger-note.

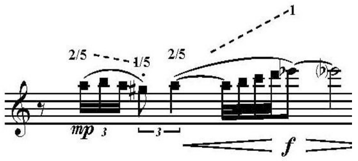
The state variable t of the cusp model is mapped to the musical parameter of pitch. This results to a melodic discontinuousness, correspondingly to the measure of the catastrophic leap calculated in every case.

The first control variable X is associated with the rythmic structeure of the piece. It is used as a factor of rythmic fragmentation.

The second control variable Y is mapped to the timbre, which is considered to evolute continuously from pure air to normal flutistic sound, passing through all the intermendiate stages and from normal sound to an amalgam of normal sound with singing notes, using several stages of dynamical balance between the two combined sounds.

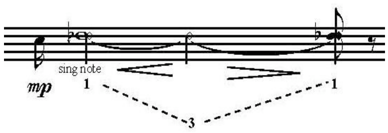
3.2 Issues of musical notation emerging from the specific needs of the parametrization.

As mentioned about the mapping of the control variable Y to the musical parameter of timbre, intermediate stages of aeolian sounds, “aeolian mixes”, considered as a mix of normal sound with air noise, are used in the piece and presented in a scale, gradually transforming from breathy aeolian to normal sound. Upgoing/downgoing/horizontal dashed lines over the notes, when they exist in the score, indicate the gradual increase/decrease/preservation – respectively – of the portion of normal sound in the timbral mix (upgoing line from air tone to normal sound and vice versa).When no line is present, the change is not gradual, it is done non-continuously. The intermediate stages are indicated with: (a) the number 0 for the beathiest aeolian (b) the fractions 1/5, 2/5, 3/5, 4/5, for the next four stages of this timbral scale and (c) the number 1 when reaching normal sound. Aeolian sounds are indicated with rectangular shaped noteheads. (See graph.4)



Graph 4: notation for the “aeolian mixes”.

A similar notation is used to indicate the proportions of normal sound and singing note in the “singing amalgams”: relative dynamics of singing notes in comparison to played note is controlled in three stages; (a) singing is dynamically lower than played note – indicated with the number 1 (b) singing is dynamically equally mixed with played note – indicated with the number 2 (c) singing is louder than played note – indicated with the number 3; dashed lines under the notes (as are also placed the numbers in this case) indicate possible continuous transitions from one stage to another. Singing notes are indicated with diamond shaped noteheads. (See graph 5).



Graph 5: notation for “singing amalgams”

3.3 The effect of the mapping on the resulting musical texture.

For the 11 non-zero values of the triggering variable t* - mapped to the 12-tone – there are resulting eleven corresponding intervals through which the melodic line is respectively refracted.

The table 1 shows the 12 triggers and the corresponding (catastrophic) intervals of refraction. The 12th trigger (fa#) corresponds to t*=0 and leads to a continuous trajectory.

Table 1: Triggers and corresponding intervals.

A modal melody is exposed in the first section of the work, representing the continuous bifurcated trajectory that corresponds to t*=0. The formula (3) defines the evolution of this melody; as t (pitch) is unfolded, Y (timbre) is affected. The result is a continuous melody passing through several timbral situations (see graph.6):

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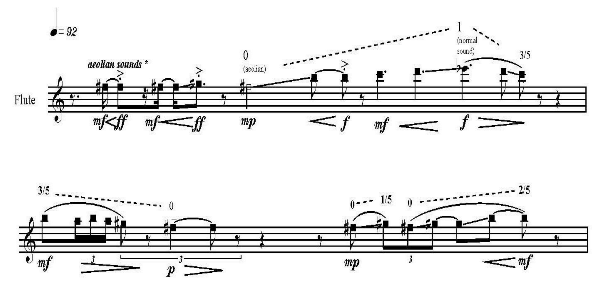
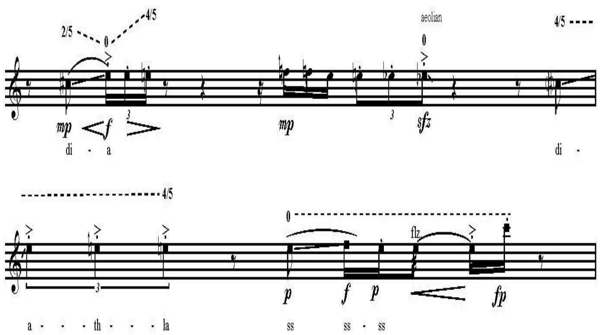


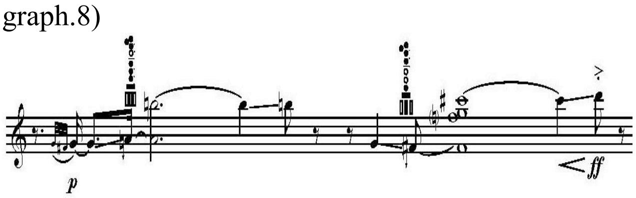
Graph. 6: The beginning of the first section: a continuous melody.

In the next 11 sections, similar melodic lines are refracted to another pitch, advancing by a smaller or bigger interval, according to the measure of the catastrophic leap. In every different case, different manipulations are made to enact the encumbering of the continuous melodic movement that is forced to become discontinuous. Examples of such manipulations: (a) persisting on the ‘obstacle’, using repeated notes, bending notes, fluttertongue, until finally managing to get to the other side of the fold. (See graph. 7)



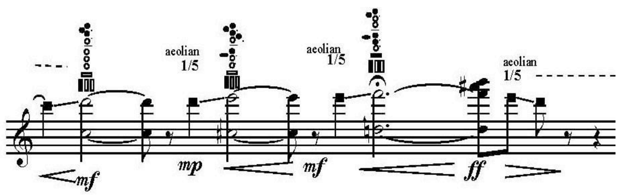
Graph. 7: persisting on an obstacle, until the melody’s forced passage through the discontinuity.

(b) forcing on the ‘dead end’ until the sound dissolves to multiphonics, through which is made the passage to the other side of the fold. (See graph.8)



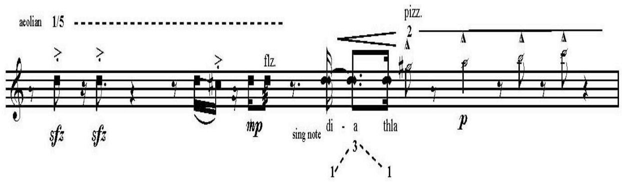
Graph. 8: forcing the discontinuity through multiphonic sounds.

(c) dichotomy of the melody and parallel trajectories on both sides of the fold, using multiphonic sounds. (See graph. 9).



Graph. 9: dichotomy to parallel trajectories.

Every section displays a texture of a uniform character, as the values of X (rythmic factor) and Y (timbre) remain stable, while only t (pitch) evolutes. Every change of rythmic and timbral elements indicates the opening of the next section. (See example of section change in graph.10).



Graph. 10: Texture change (rythmic, timbral) after the discontinuous interval indicates new section beginning.

4 Conclusion

The work “Diathlassis” for solo flute, inspired by the optical phenomenon of refraction, is an application of the cusp catastrophe model. During the process of this composition, the cusp catastrophe model itself has been a second pole of inspiration, through the particularities encountered in the construction of the mapping, a process that lead to timbral experiments, notational findings and, hopefully, interesting expressive strategies. The flutist Katerina Zenz, whose contribution to the refinement of the notation and of the special timbral techniques was trully valuable, made the world premiere of the work in May 2009, in Munich, Germany.

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Performance anxiety in piano playing

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Abstract: - This paper analyzes the performance anxiety of pianists, from the point of view of a teacher and performer. It underlines the idea that this kind of stress is mostly in the performer's mind, in the way he perceives a certain situation. One should try to be prepared at his very best and try to control his thoughts about the situation he is facing. Positive thoughts and self-esteem help you to defeat performance anxiety.

Key-Words: - piano playing, anxiety, coping strategies

1 Introduction

Most pianists or instrumentalists in general have had to deal once or more often with music performance anxiety. This kind of anxiety can occur in many settings, not just on the stage. It appears to be more a consequence of the evaluative nature of the situation, not depending primarily on the presence of an audience. This is a phenomenon which doesn't occur suddenly, but it develops gradually over a longer period of time before an important event, like a piano recital or a piano concert with a well known orchestra.

Thinking about performance anxiety, most people tend to believe that it refers to a negative kind of emotion. But performance anxiety can be divided into two types: positive and negative.

2 Positive performance anxiety

Sang-Hie Lee in "Musician's Performance Anxiety and Coping Strategies" says "Psychologists have labeled a type of heightened state of arousal as a biologically based, motivating force. D L. Hamman's studies showed that musicians with the highest level of formal training were able to use the anxiety factor for positive performance effect. Wolfe similarly learned that professional musicians used the positive anxiety components, such as arousal and intensity, to promote performance rather than letting the negative elements, like apprehension and distractibility, diminish performance quality" (38-39).

Positive performance anxiety derives from the knowledge that something extraordinary might happen between the performer and the audience during the act of performing, where, without any doubt, "making beautiful music" plays the most important role. But there is never a guarantee that this kind of situation with a positive result will really happen. So this is the reason of feeling this type of nervousness, and there is nothing anybody can do to eradicate it. Actually, this positive performance anxiety shouldn't be a subject of worrying, because it tends to improve rather than diminish the quality of one's performance. The energy and excitement it brings upon plays an important role in the degree of inspiration which the musician experiences and puts into their repertoire during the performance, helping also to maintain their concentration on the task for a longer period of time.

3 Negative performance anxiety

Negative performance anxiety is very debilitating for pianists or any kind of performing musician, because very often it may represent the reason why many promising instrumentalists quit a career as a soloist or an orchestra player.

The biggest problem of performance anxiety is that musicians fear that it will have a negative effect on the quality of their performance and on their ability to play the program accurately till the end. And the big concern is that this kind of negative thinking about themselves can only lead to a negative result, which in our case would mean playing under their normal capabilities.

Pianists who suffer from performance anxiety complain about different experiences like: fear, trembling, dry mouth, a rapid heart beat. Other symptoms can be sweating or cold hands, muscle tension, paleness, loss of concentration. And there is a strong belief among musicians that this anxiety will affect their playing in a negative way. You can compare musical performance anxiety to other forms of responses to stress under different circumstances, for example with the stress you feel when you have to go through an academic examination.

When a pianist has to play in public, they have to think about their task. This means that from a cognitive point of view, their thoughts must address to the actual performance. They have to think about tempo, dynamics, phrasing, harmonic changes, rhythmic nuances, different touches and sound colours. They have to adjust their performance to the acoustics of the hall, to adjust their way of playing to a new instrument, which is different from the one they are used to play on every day, they must concentrate on remembering the music and so on.

If you are used to practising in a very concentrated way, it will be easier for you to train the mind to remain focused on the music during a performance, rather than allowing other thoughts to invade your mind. You have to stay concentrated on the sound and on the process of music making. But the fact is that detachment of task-orientated thinking is a characteristic of musical performance anxiety, and this leads to loosing concentration during playing. The most two important problems are that instead of remaining focused on your target, you are preoccupied with exaggerating in your imagination the proportions of what can happen if there are some unwanted mistakes during your playing and you give too much importance to the evaluation of others. Many instrumentalists believe that little errors will destroy their entire recital/concert, or will conduct to the loss of control over the situation, which of course is not true. Pianists should try to understand why those errors occurred and learn something from them. Understanding a mistake can teach performers how to avoid it and what to do in order to play better next time.

Worrying about the reaction of others is also correlated to anxiety. These are normally coupled with very high internal standards and occur very often in individuals with a perfectionist attitude. One possible solution could be that of diminishing the importance of other persons. The problem is that while experiencing performance anxiety, musicians have a distorted view of the power of the audience. They often seem to believe that the evaluation of the people who are listening will affect them. But the fact is that whatever the public might say, if the pianist is self-confident and accepts his playing with all the good parts and the faults, it will not really matter what other people think. Instead of fearing the people who are listening, pianists or instrumentalists in general should try to appreciate the audience, and to start from the idea that the reason why the audience is there is to hear some beautiful pieces, not to look for every little mistake. So performing artists should try to play for their own pleasure, for the fun of making music and offering and sharing emotions with others. It really helps to concentrate on the enjoyable aspect of the process.

Otherwise, the result of these worrying thoughts is that the musician looses his concentration towards the task itself, and this fact will naturally lead to an increase of the risk of errors in one's playing. Performers should try to interpret a rapidly beating heart as a sign of excitement and involvement in the task, because then it would have a positive effect on the performance. They shouldn't think in a negative way. Thoughts about failure during playing in public mean almost always playing worse than you are capable in other situations. Anyone who suffers from performance anxiety should eliminate the imagination of negative possibilities. In any situation, not only when performing in public, there is the possibility of a negative result. But there is also the possibility of a positive result. And since nobody can predict the future, nobody should remain focused on a negative result before it occurs. The best way is to concentrate on the performance and to try to share your music with the public.

4 Coping strategies

There is a variety of coping strategies that can be developed by the anxious performer in order to create some methods which he or she can practice and develop in order to decrease the effects of performance anxiety.The next suggestions for how to deal with performance anxiety are from my own experience.

Negative performance anxiety derives from a sense of insecurity.The less prepared you feel, the more nervous you will be. Not enough practice means anxiety. You have to really prepare, to know your pieces_inside out. You have to give yourself enough time to learn the music properly, not to do it one month before or even less at times. You must be serious about learning and memorising the repertoire from the beginning, not only when there is little time remaining until you have to play in public. From my own experience as a teacher and as a performer, I can say that a musical piece needs time and a lot of practice for you to be self-confident while performing it in front of an audience. The worst possible thing you can do is to memorize it very quickly and then to play it in public or in a competition. From my experience, this is the most direct way if you want to make sure that you will play really bad.

A musical piece must be learned step by step, studying it very slowly, first separately, then with both hands, being aware of the key and trying to understand the

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harmonic structure, the form and the characteristic style of the piece properly. You have to find out where the imitations, sequences and repetitions are, in order to have a certain logical structure to follow during the hours of practice. It is recommended to listen to different recordings and to learn about the composer and the time he lived in. All these will give you the feeling of being in control, of being able to master all musical and technical challenges without any problems.This knowledge will empower you with a sense of control over yourself in stressful situations like public performances. In order to attain this kind of confidence you have to approach studying your repertoire in a relaxed manner, by giving it time, patience and many hours of intense concentration in front of the instrument.. In the end, if you have a real basis to feel confident, then you will not experience that kind of nervousness. The problem is that you may think you feel sure, when in fact there are still some unsolved problems which you are not aware of. But after you have really created the physical and musical basis for successfully performing a piece, you will feel emotionally more secure.

Positive thinking is also a must. You must tell yourself that you have practiced enough and the result will be positive. Negative thinking, messages like: "I am afraid of playing in public", will only increase your state of anxiety.

A good piece of advice is also to be more tolerant to yourself and to accept that everybody makes mistakes. Even the most famous pianists make them, and a missed note or a passage which didn't turn out very well will for sure not ruin their entire performance. It seems that people who tend to be perfectionists also in their normal life experience a greater anxiety performance. The explanation for this would be that being a perfectionist makes you feel more responsible of how you play, you think more deeply about what the audience thinks about your performance as a pianist and you have the impression that everybody expects you to play perfectly. But one must understand that instrumentalists are not robots, and that making mistakes is a part of being human. If you still think you must play perfectly, remind yourself that even famous pianists make little mistakes. And yet, after listening to their performance, I think that only somebody who does not understand music at all could say that they played badly (because of missing a few notes). Most of us, (if not all of us) would agree on the fact that they listened to a great performance of that particular piece, one of a high degree of expressive quality and with communicating sounds.

So the most important thing for any instrumentalist should not be just technical perfection, but making music that says something and touches sensitive cords in people.

Other important recommendations you should take into consideration in order to be better prepared before playing in front of an audience are to be relaxed, to eat healthy food, to sleep well the night before the big event (to go to bed early), to do things that make you feel good about yourself. It is very important not to play for too many hours right before the concert and also a few days before, because otherwise you will be overtired and the chances for you to concentrate at your maximum possibilities will decrease. The last days before the recital, it is recommended to study with a clear head, slowly, focusing more on listening to yourself, making small changes in your interpretation in order to obtain the most expressive performance which could render the composer's ideas in the most appropriate way. At that point all technical aspects should have already been solved, and you should not have any concerns about memorization, technique or increasing tempo, because it would be too late anyway to cope with them.

Some might expect that performance anxiety will decrease with age, because it seems logical that you become more experienced and accustomed with audience and different challenges. But on the other hand, when you experience success, you also feel a greater amount of responsibility which refers to the quality of your performance. You think that the audience has higher expectations on you, and this fact may add some more difficulty to the task."The greater the commitment to music, the greater will be the expectation from self and others regarding performance standard and quality".(Kenny and Osborne, 2006). Anyway, musicians who play more often claim to be gaining a feeling of security because they get more accustomed to the public.

Another suggestion for defeating performance anxiety is to start playing in front of smaller groups of people and then gradually play for bigger and bigger audiences. It is also important to perform pieces you fully understand and also like very much and to start the recital with an easier piece of music. This will give you a sense of security and control, which will help you overcome your anxiety, because this kind of approach will make you be more concerned with the expression of all those musical ideas you like so much rather than with your fear.

5 Conclusion

You have to remind yourself that stress is only in your mind, in the way you interpret a certain situation. Ultimately the way we look at things creates stress, fear or anxiety and not the actual situation. So you should try to control your thoughts about the situation you are facing. If you succeed in having only positive thoughts about the coming event, about yourself, about you being a gifted pianist, then most of your problems are solved.

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Musical and spiritual affinities: Olivier Messiaen and Eduard Terényi

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Abstract: The paper argues that there is a very close connection between E. Terényi and O. Messiaen, implying the mystical, symbolic and stylistic coordinates of their music. The name of O. Messiaen appears in the titles and the subtitles of some of Terényi's organ works: *Chaconne – Hommage à Messiaen* (1978), *In solemnitate corporis Christi* (1993) – in memoriam Messiaen, *Messiaenesques* (1993), or the filiation can be only suggested, as in: *Die Gottestrompeten* (1995), *Dialogues mistiques* (2006), *The Birds* (2007). One of Messiaen's organ plays particulary had an important influence on Terényi's music: *L'Ascension*, the variant for the organ, based on the idea of Christ's resurrection and His glory.

Key-Words: Eduard Terényi, Olivier Messiaen, L'Ascension, organ music, contemporary music, musical style

For half a century, Eduard Terényi (b. 12th of March 1932, Târgu-Mureş), univ. professor, Ph. D. at "Gh. Dima" Music Academy, develops a prodigious and a vast composing activity which is both musicologist and pedagogical and it is permanently marked by the opening towards the new composing tendencies and the musicological conceptualisations. Regarding the creations that are designed for organ, E Terényi is one of the most prolific of the Romanian composers of the twentieth century which have written for this instrument. His organ catalogue includes solo organ plays and organ concertos as well as chamber works where the organ appears in different instrumental combinations or vocal ones.

There is a very close connection between E. Terényi and O. Messiaen (1908-1992), concerning not only the mystical, symbolic and spiritual coordinates of their music but also their fascination for geometric and synthesis harmony [1], for the organ, the *chant d'oiseaux*, the timbre of the percussion instruments, the synaesthesia (associations between music or tones and colours), the cosmic and mystic perspective, the interest for different time dimensions and atemporality, the celebration of love, nature and the Divine, the insertion of the Gregorian plainchants, the repeated rhythmical patterns, the mosaic form, the palindromic structures.

Messiaen himself was the organist at La Trinité Church in Paris for over 6o years and the sacred, instrumental meditation that has mystical reflexes won an important place in the concert music of the twentieth century due to him. In his turn, E. Terényi has had the same purpose: "I wanted to introduce in the concert auditorium, the glorification of God. The interpretation of the sacred music out of the church has a three hundred years tradition, but the transfer of the Christian mediation in the concert halls was O. Messiaen's conquest." [2]

The aiming of the essence leaded E. Terényi, in an existential level, to a steady dialogue with the divine. This aspect is transposed into a musical content since the beginning of its creation and especially in the row of the plays of the organ (or that of the different formations where the organ can be found) through the mystical and the biblical or religious subjects that appear in this hypostasis through the title or their ideate programme. The thematic of the organ plays are diversified: plays that are dedicated to Mary (*Septem dolores*, *Stella aurorae*, *Stabat Mater*), meditations on the birth of the Saviour (*Introitus*, *Semper felice*), the suffering and resurrection of Christ and their significance (*B. A. C. H – composition for organ*, *The Seven Words of the Saviour on the Cross, Stabat Mater*, *In solemnitate corporis Christi*), meditations above the person of Christ and His glory (*In solemitate corporis Christi*, *Epiphania Domini, Chaconne – Hommage à Messiaen*), dialogue with God, mystic experiences (*B.A.C.H – composition for organ*, *Glocken*, *Messiaenesques*, *Dialogues mistiques*, *The Birds*), the vision of the Apocalypse (*Die Gottestrompeten*), the closeness to the silence and the simplicity of the spiritual truths (*Octo felicitatis*). Messiaen was not only one of the most influential composers of the 20th century, he was also one of the most religious musicians in the history of music. Many of his works are mystical description of the essence of the Christianity: *L'Ascension* (1933), *La Nativité de Seigneur* (1936), *Les Corps glorieux (Seven Brief Visions of the Life of the Resurrected)* - 1939, *Quatuor* *pour la fin du Temps* (1941), *Vingt Regards sur l'enfat Jésus* (1944), *Messe de la Pentecôte* (1951) and so on. Messiaen's approach to religion was rather joyous; he didn't write music that was about suffering, on the contrary, he wanted to talk about the most ecstatic aspects of Christianity.

Referring to the musical work *The Concert of the Queen Mab* (of the series of the twelve neo – Baroque concerts) E. Terényi underlines the importance of the duality earth – heaven, the suffering – laudation in his religious music: "The basic suggestion of the musical work is the suffering and the laudation (…) body and soul, earth and heaven, human and the divine. I was preoccupied by the contradictions that are knitted together. This duality characterizes my religious music as well. In the musical works composed for the organ in the eighties, there is already, a special role to the two depictures of Christ: the earthen and the transcendental, spiritual one." [3] The theological motif *Christus Victor* where the cross signifies not only Christ's suffering but also His victory, through a perspective that offers hope and sense to the earthen suffering moment, has also a great significance in Terényi's organ music, in plays like: *The Seven Words of the Saviour on the Cross*, *Stabat Mater*, *In solemnitate corporis Christi*, *Die Gottestrompeten*, *Epiphania Domini*.

E. Terényi celebrates the nature and the Divine in his unique language and among the archetypes that are presented in his organ plays and his entire creation there are a few primary elements that are highlighted and also their metaphorical and mystical meanings: the flight that symbolizes the Holy Spirit and the aspiration of the soul (*The Maestros Bird Symphony*, *Epiphania Domini*), the flow of the water as the live substance that is purified in the presence of its creator (*Epiphania Domini*, *In solemnitate corporis Christi*), the song of the birds (*The Birds*, *Messiaenesques*) and the sublime sonority of the bells of a cosmic cathedral (*Honterus Odae*, *Dialogues mistiques*, *The Birds*, *Epiphania Domini*, *Glocken*), the fire, the continuity and the intensity of the burning, symbolizing the spiritual energy (*Threnody*, *Introitus*, *Cantico del Sol*).

E. Terényi gave me some interviews in the month of February of 2008, when he confessed to a series of aspects that are part of his musical thinking, including the archetypes that he uses: "In many of my plays the motif of the bells comes back, also the motif of the water, the singing of the birds. These are the three great symbols of my life. The flight of the soul and that of the spirit. The bells, the halo of the sounds where you can dive into and the cosmos of the sounds can be found as well. The water, as a support of the life, it is a live substance and a symbol of the purification as well".

The name of Messiaen appears in the titles or the subtitles of some Terényi's organ works: *Chaconne – Hommage à Messiaen* (1978), *In solemnitate corporis Christi* (1993) – in memoriam Messiaen, *Messiaenesques* (1993). In other plays, this filiation is only suggested by the title and the music as well: *Die Gottestrompeten* (1995), *Dialogues mistiques* (2006), *The Birds* (2007). One of Messiaen's organ plays particulary has had an influence on Terényi: *L'Ascension*, composed for the orchestra (1932 - 1933), initially as "four symphonic meditations" (*Quatre Méditations Symphonique*). The variant for the organ was created later, in 1933 – 1934. Every part has a motto based on the idea of Christ's resurrection and His glory and its implications for Christianity:

1. The majesty of Christ demanding its glory of the Father (Father, the hour has come; glorify Thy Son, that the Son may glorify Thee)
2. Serene alleluias of a soul that longs for heaven (We pray you, God, help us dwell in the Kingdom of Heaven)
3. Ecstasies of a soul before the glory of Christ, which is its own glory (Givind thanks to the Father, who has qualified us to share in the inheritance of the saints in light ... raised us up and seated us with Him in the heavenly places, in Christ Jesus)
4. Prayer of Christ ascending towards his Father (Father … I manifested Thy name to the men … and I am no more in the world; and yet they themselves are in the world, and I come to Thee)

The first bar of Messiaen's *L'Ascension* (fig. 1) was quoted by Terényi in his *Chaconne – Hommage à Messiaen* **(**1978) as "an ostinato bass", "a ciacona bass," a modal and harmonical support that has the variations of the *Chaconne* to develop onto it (fig. 2). The comprised tones of Messiaen's motif form a palindrome modal scale (A, B, C, D#, E, F, G#, A, B) which, together with its transpositions, constitutes the sonorous frame of the *Chaconne*. *Chaconne* is a synthesis of the constructivism, aleatorism and graphism that represents the two main tendencies of Terényi's first period of creation. The work has 6 parts, each containing 4 variations and each variation has 3 modules (a, b and c). The order and the number of the parts is not pre-established but it is for the player to choose and he can elude up to five parts. The 3rd part of the *Chaconne* ends the first large section of the musical play and it starts the varied recurrence in the mirror of the first three parts.

In solemnitate corporis Christi (1993) – *in memoriam Messiaen* depicts "a sonorous fresco of the last Supper that precedes the suffering and the death of Christ. It is a commemoration of the scene which the Saviour talks about himself and the mission that He has to fulfil on the earth" (E. Terényi). The first part represents the pattern for the next two parts, it becomes a sort of "theme – personage" in the mind of the author through the preservation of the algorithm of the three segments A, b, c that are characterized through different syntaxes: *A* -

melody,*b* - chords/figurations, *c* – unison/eighths/chords. The first strophe *A* is a melodic line of a neo – Gregorian style that is partially inspired from the *cantus planus* variant of *In solemnitate corporis Christi* from *Cantionale Catholicum*. The stylistic benchmark of the b segment/motif is represented by the third part of *L'Ascension* by O. Messiaen (fig. 3) which, through the title and the *motto* corresponds to the spiritual ideas of the musical work *In solemnitate corporis Christi:* "Ecstasies of a soul before the glory of Christ, which is its own glory".The chorded cell that is chromatically descending is repeated ternary and it signifies the sorrow of Christ (fig. 4). The composer uses it again in 1995 in *Die Gottestrompeten* where it signifies the pouring onto the earth of the fourth cup of the God's anger (fig. 5). The c segment/motif is derived from the b segment/motif: paralel octaves in long rhythmic values – and it has the connotation of the divine voice and the cosmic time (fig. 4). The leitmotif in itself presents in the Terényian creation some variants, in similar contexts that have the same *teophany* meaning, a revelation of the divine in the person of Christ (*In solemnitate corporis Christi*, *Epiphania Domini*), of celebration of God in a cosmical liturgical frame (*Glocken*) or in the middle of the monumental cathedral of the nature (*Stella aurorae*, *The Birds*), Holy Mary's image (*Stella aurorae*, *Glocken*), the dialogue between the artist and God (*Fadrusz Concerto* for organ and orchestra). The b and c motifs are artistic reflections of a mystical feeling and also of the axiological thinking which are paradigms that seem to correspond as an *affectus* to the phrase *mysterium tremendum* that is used by Rudolf Otto in order to define that "answer of the soul in front of the numinous", as "that part of the sacra (…) that is manifested under the form of a specific accompanying feelings" [4].

In Terényi's organ plays *Messiaenesques* (I, II) and *Dialogues mistiques* (I, II, III) the general composing scheme of the character variations is expressed by the author through a mosaic fantasy – design (fig. 6) that "is like stained glass windows in a cathedral" (Terényi) and bears much resemblance to Messiaen's musical form. Each of the geometrical figures represents a melodic, chorded and rhythmical entity that has an improvisatory character and aleatory possibilities as well. The drawing reflects the structuralism vision of the pre-selected paradigmatic elements and, in the same time, it is a generalized graphic representation of the variational micro–montage technique. The geometrical symbols are visual analogies to the musical "drawing" of the sonorous micro-units.

The *Messiaenesques* does not have a theme or a melodic idea in the traditional sense of the term, but a "theme – idea" or a stylistic "theme – bench-mark". The theme – idea appears when, by the imaginary taking of some stylistic elements, of another composer or musical work, the author creates an imaginary replica that is not declared inside the musical work. The connections between the stylistic pattern and its variations cannot be seen by the players, musicologists or the public. "This might be the most extremist variation musical concept, both as an architectural form and also regarding the ideate content" - states the composer. The filiation of the sonorous entities is suggested by the title of the musical work: *Messiaenesques* –illustrating a series of dispersed stylistic suggestions of the music of Oliver Messiaen, namely, melodic lines, rhythms, the dynamics, chords and so on, which are used to create a series of analogies, variations or oppositions. The play on words from the title - by separating the word *Messiaenesque* we get (Olivier) *Messiaen* + (George) *Enescu* - is not an amusement as it may seem as there are some elements taken from the Enescu's style and this musical play mirrors a double stylistic thinking.

Certain harmonic stylemes and the rhapsodic style of some micro – elements (through the rhythmic liberty that allows agogic micro - variations) they remind us of the Enescian thinking and that of Messiaen as well (the *oiseaux* style, the harmonic strata). In addition, the abstract conception of the micro – elements, the lack of fixed themes, and the evolving, organic style of the music is common for all three composers Enescu, Messiaen, Terényi and it is opposed to the Western music configuration in explicit melodic entities that culminated as Pascal Bentoiu remarks, with the rigidity of the Wagnerian musical ideas [5].

In the vision of the composer, this type of musical thinking has an archetypal value that comes in the prolongation of the model of the divine creative thinking: "There is an abstract idea of the leaf, ant, human being and so on. Nevertheless, you will not find in the nature two identical leafs or insects. On the same principle I have my *organic* musical work to rely on".

Fig. 7 is a sample of analyse of the first play from the *Messiaenesques* cycle on the manuscript of the author, by unifying the tones with imaginary lines, and getting different geometrical figures (e. g. 2). For example, the isosceles triangle – is associated with the melodic cell/motif that is characterised through a leap (a generally ascendant one) and the coming back to the basic tone or to one of the tones that is closed to it. The next sign, that is similar to the *rectangle* appears in different forms along the musical play we have analysed so far – as it signifies a figure with latent plans which are the superior oscillations above a pedal tone. It is the symbol of a bird signal, an improvisatory micro – unit in Messiaen's *chant des oiseaux* style [6], and so on.

From 2007 on, the Terényian music goes increasingly towards the mystic states, an aspect, which is strengthened in his organ works as *Dialogues mistiques*

(2006) and *The Birds* (2007). "These two plays- the author confesses in the interview - are about a dialogue with the God. They ask for a different receptivity. This is the type of music that has to be listened in the absolute silence of the church, in the dynamically reduced sonorities by the avoidance of the excessive expressivity of an expressionist type which characterize certain musical works - especially those that belong to the first and the second wave of my creation."

Dialogues mistiques (2006) with the subtitle "three meditations for the organ" has as a basis a variational principle that is similar to that of *Messiaenesque* (1993). The sonorous process is generated by an exterior stylistic complex that is not declared by the composer and it is not suggested by the title. There are stylistic micro – bench-marks that are inspired from the creation of Messiaen, particularly through his organ variant of *L'Ascension*. The artistic filiation comes together with similar mystical revelations on the sacred coordinates. In this respect, the title and the *motto* of the second part of *L'Ascension* confess the same inner imperatives that impulsioned the creation of the musical work: *Serene alleluias of a soul that longs for heaven. Dialogues mistiques* is a prayer and, as a manner of presentation, it is a stylistic and spiritual dialogue with Messiaen's music, on a rich "archetypal palette". In the fig. 8, there are exposed, in a comparative table, a few samples taken from the two musical works (*L'Ascension* and *Dialogues mistiques*), of those sonorous units that are considered by the composer as the archetypes regarding their abstract contour and not the content: "I started from a few moments under the sign of certain musical memories and not of the quotations. I took into consideration the direct hints and not the copying of the contents. The forms are renewed. There is a permanent dialogue between the model (Messiaen's play) and my micro – variations. What is significant here is the fact that all the elements that have already been taken (reminded) represent personal processed feelings and they are not themes with variations but models with remodelling. It is a superior stage in the gradation of the variational forms in the idea that, the variation concept itself can be renewed in this way."

A praise that is given to "the nature", *The Birds* (2007) has as the basis (as the title suggests), the signals of some imaginary birds, *chants d'oiseaux*. There are two variants of the musical work: one for solo organ and another for organ with the percussion. The birds are imaginary and so are their sonorities (fig. 9). The twenty signals present a triple typology: signal – ornamented tone, signal – interval, signal – figuration (arpeggio, scale). These constitute nuclei that are extremely short, which come in an improvisatory order in different repetitive-variational forms, through a composing technique of a montage type: "These signals appear all the time varied although the basic pattern stays the same, with intonation differences – sometimes calmer, sometimes more agitated. Although it is repeated, we listen to it with a great pleasure, without being bored as this permanence of the ostinato creates a big stability, replacing the tonal circle. The ostinato suggests, if we wish, the steadiness of the tonic, the stability through the coming back to a basis structure. The sensibility, our reticence towards the phenomenon of the imponderability explains the tendency of finding fix points of equilibrium to which to come back after each tension state. In a way, we find this continuum flux of the dramaturgic movement in the signals of the birds, the ripple of a spring, the rustle of the leaves spluttered by the wind, whose sounds that are apparently monotonous do not create nervousness – but calm and intimacy".

Although in the first instance the form seems to be free evolving, the writing differences and contrasts allow the detachment of three strophes models, such as: A – ornaments on a tone, the trills, the appoggiaturas (ornaments); B - arpeggio, figurations; C – choral, homophony. In a metaphoric plan, the strophes A and B represent the miracle of the creation and the C strophe (*The Choral*) – the celebration of the Creator.

In conclusion, we can state that Terényi's musical dialogue with Messiaen on different levels, going from quotation to stylistic replicas is manifested under the aegis of everlasting ingenuity and creativity that is anchored in the profound strata of the authenticity and it comes as a result of his spiritual affinity with the French composer, of their related perceptions and the similarity of the artistic credos.

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Fig. 1 (O. Messiaen, the first incipit of the first part of *L'Ascension*)

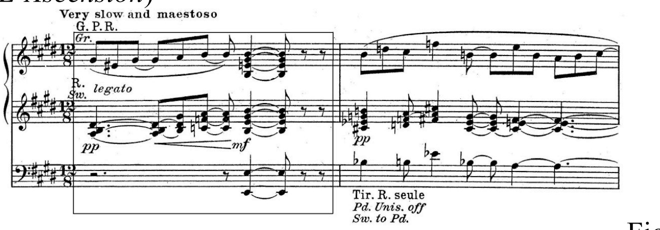

Fig. 2 (E. Terényi, the first part of *Chaconne*)

Fig. 3 (O. Messiaen, the incipit of the third part of *L'Ascension*)

Fig. 4 (E. Terényi: *In solemnitate Corporis Christi*)

Fig. 5 (E. Terényi: *Die Gottestrompeten,* the 4th Bowl)

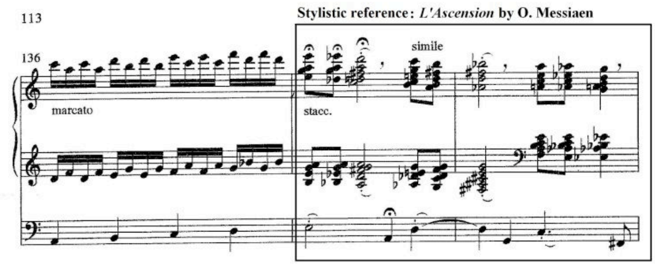

Fig. 6 (E. Terényi: *Messiaenesque*)

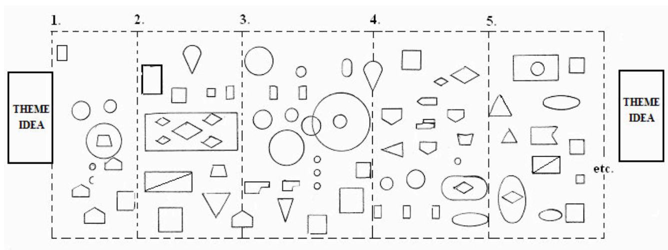

Fig. 7 (E. Terényi: *Messiaenesque*)

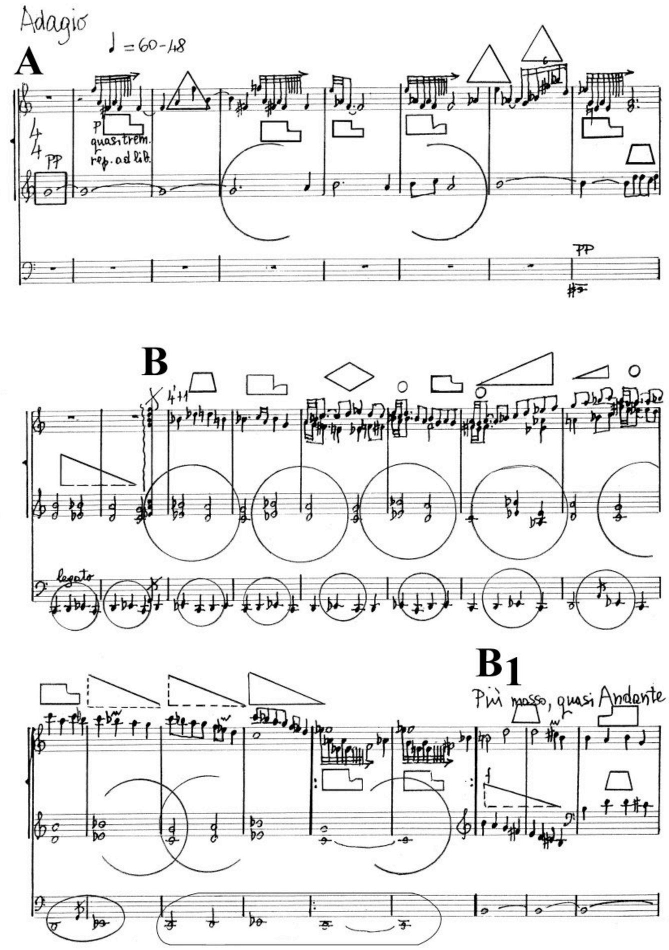

Fig. 8 (Essential elements in *Dialogues mistiques* and their stylistic correspondences with *L'Ascension*)

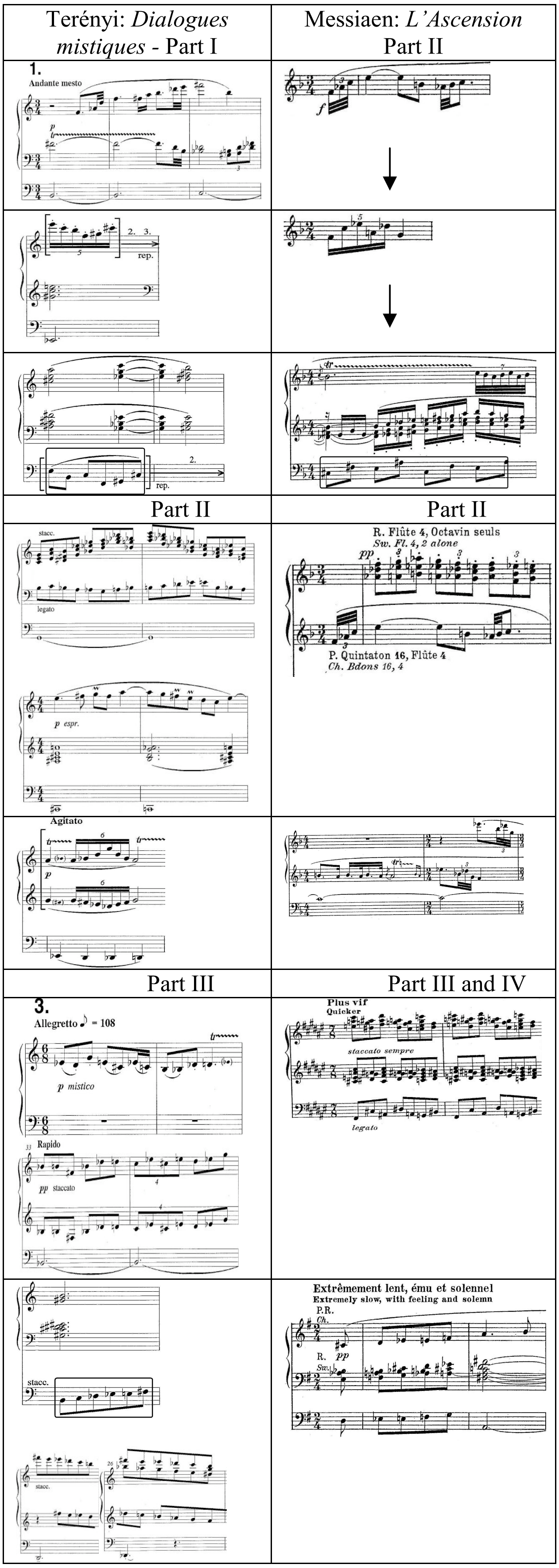

Fig. 9 (E. Terényi: *The Birds*)

Conceiving Music Today: Manifold Compositions, DISSCO and Beyond

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Abstract: - Manifold compositions consist of all actual and potential variants of a work that contains elements of indeterminacy and is generated by a computer reading the same data for each variant. The relationship between manifolds and classes of composition is discussed and a tool (DISSCO) unifying composition and sound synthesis is presented. Deterministic and random processes facilitate by DISSCO are shown to correspond to an implicit worldview and the role of the computer is defined as that of a collaborator complementing the skills of the human composer. It is also shown how musical compositions can be described as complex dynamic systems and two related projects are proposed: a sound “fountain", an ever changing stream of sounds, and a "brewing" piece continuously re-arranging its parts in search of an elusive optimal solution.

Key-Words: - music composition, sound synthesis, stochastic distributions, sieves.

1 Background

The two and half decades that followed the end of the Second World War in 1945 were marked by a period of innovation and consequential ideas unprecedented in music history. In the absence of a common language and in need of finding, in Anton Webern's words, a “substitute for tonality”, major composers of that time proposed radically new ways of creating music and thinking about it: unifying the work through the use of similar proportions applied to all its parameters; using chance as the primary constructive device; employing mathematical tools to realize intricate textures, forms and melodic lines. Seminal publications such as the article "... wie die Zeit vergeht …" by Karlheinz Stockhausen [7], “Penser la musique aujourd’hui” by Pierre Boulez[2], the many writings of John Cage, and the book “Formalized Music” by Iannis Xenakis [10] document personal systems but also offer general, abstract definitions of the most fundamental elements of sound and composition.

Born in the same effervescent period, electro-acoustic music has facilitated and enhanced the search for new ideas, expanded enormously the realm of possible sounds and textures, and helped better understand and exploit acoustic phenomena. It should be also pointed out that even during the more recent period of post-modernist retrenchment (characterized by sociologist Daniel Bell as “living in interstitial time”), technology as applied to music has produced actual advances and has stimulated creative endeavors.

Following is the description of a system using both mathematical tools and computer technology, a system that tries to overcome the present stagnation and points to future developments.

2 Manifold Compositions.

The term, first introduced in 1989 [8], defines all actual and potential variants of a musical work generated by a computer that a) runs a comprehensive program containing elements of indeterminacy and b) reads essentially the same data for each variant. Since each member of the Manifold has a unique character and since an arbitrary number of them can be produced, a variant should not be presented in public more than once.

Members of the manifold (variants of the composition) share the same pitch and rhythmic materials, same textures, and same general formal characteristics but different seeds for the random number generator trigger variations in the output. These variations can range from a slight re-arrangement of the notes in the score or of computer-generated sounds in time, to radical alterations of textures and even of the formal architecture of the piece. Similar to faces in a crowd, the members of the manifold are different while partaking in common features.

There are parallels between the manifold concept and that of an equivalence "class of compositions", a proposition exploited by composers in the 1960s. Discussing such aleatory works, Umberto Eco writes: "They are to be seen as actualization of a series of consequences whose premises are firmly rooted in the original data provided by the author" [3]. In both cases, all conceivable variants are equally valid results of an abstract blueprint and a related process. Although there have been a number of previous attempts at computer-generating variants of the same work - the *ST* pieces of Iannis Xenakis, Lejaren Hiller's *Algorithms*, or Gottfried Michael Keonig's *Ubung für Klavier* - none of them have attempted to mass-produce such variants and they use somewhat different sets of data from run to run.

In the case of manifold compositions, a particular relationship is established between the composer and the computer due to their complementary abilities: while humans are more capable of devising rules and structures, computers are superior at providing speed and random elements. In this context, the computer and the composer establish a true collaboration [9].

Finally, manifold production depends on the availability of comprehensive software that does not require or allow the intervention of the user once it starts running. Such a "black box" set of instructions for the computer is necessary for preserving the integrity of the process. Modifying the output or intervening during the computations would amount to the alteration of the data or of the logic embedded in the software. This model assumes extensive pre-compositional work and promotes an experimental and speculative attitude. Post-production interventions become not only incongruent but also unnecessary especially in the case of a seamless approach to composition and sound synthesis such as that of DISSCO.

3 DISSCO.

A Digital Instrument for Sound Synthesis and Composition, DISSCO [6] represents a unified and comprehensive approach to sound synthesis and composition - unified in the sense that its components share a common formal approach and use similar tools, comprehensive in the sense that they deliver a final product (a musical "event") that does not require further processing. DISSCO is a "black box" that reads in data provided by the user and outputs a finished object.

DISSCO consists of two parts: LASS, a Library for Additive Sound Synthesis, and CMOD, a Composition Module both written in C++. Both components are grounded in the idea that identical or similar operations are required at different time scales when constructing a musical work. The entire piece is conceived as a collection of objects (events) and each object is in turn a collection of lesser objects in a Russian dolls type of arrangement: the piece contains sections, a section includes aggregates of sounds, these are made out of sounds and a sound is a collection of partials. The durations of these event types tend to decrease in an orderly way and even inside a sound, one can distinguish a number of time scales: the duration of a sound itself around 10^0 seconds, "modifiers" such as vibrato (FM) and tremolo (AM) around 10^{-1} second, and the frequency around $10^{-2} – 10^{-3}$ seconds [5]. Choices are made at each of these levels and DISSCO provides a number of possible ways for making such selections.

3.1 Utilities.

As shown before, randomness is an essential part of manifold production. First introduced by Iannis Xenakis in *Pithoprakta* (1955-1956) and detailed in his book [10], ***stochastic distributions*** have become by now a rather common composition tool which provides the "controlled randomness" desired by some musicians. DISSCO has a utility, *Stochos*, that reads in two functions of time (or envelopes as musicians like to call them) defining the dynamic changes of the minimum and maximum values of a range; a third envelope controls the distribution of values within this range at any given moment. A second *Stochos* option stacks up a number of probability envelopes whose values add up to 1 at any point and selects an item corresponding to one of the areas thus identified with the help of a random number.

Such envelopes are defined by specifying *x* and *y* points and the type of segment between y points which can be linear, exponential or spline. Usually, they are normalized and segments are labeled as fixed or as flexible if the distances on the *x* axis can be stretched or compressed in order to accommodate events/sounds of various length. Predefined envelopes are either stored in a library or they can be created on the spot if a certain amount of randomness is desired in the selection of *x* or *y* points - in that case *Stochos* may be called to perform the task. A third option is to evaluate an existing probability distribution function. Traditionally, musicians have preferred to deal with predefined envelopes containing few segments because they tried to avoid involved computations mistakenly believing that complicated shapes have no or little bearing on perception.

A deterministic way of selecting values out of a continuum is provided by ***sieves***. First introduced by Iannis Xenakis [10] and hinted at by Lejaren Hiller [4], sieves are logical filters, part of Set Theory, based on equivalence relations modulo *m*. Combining equivalence classes through Boolean operations (U, ∩, etc.) could produce traditional structures such as the octatonic scale (also a Messiaen mode with limited transpositions) from the simple superposition of two stacks of minor thirds:

$$3_0 \cup 3_1$$

or the major scale through a more involved sequence:

$$(\bar{3}_0 \cap 4_1) \cup (\bar{3}_2 \cap 4_2) \cup (3_0 \cap 4_3) \cup (\bar{3}_1 \cap 4_0) .$$

Sieves may be used as selection tools at other parameters, rhythm being a prime candidate. In a more elaborate example, a rhythmic sieve whose modulo numbers and indices are in a symmetrical relationship

$$3_0 \cap (4_1 \cup 4_3) = \{3, 9, 15, 21...\}$$

will generate a palindrome, a non-retrogradable rhythm repeating after 12 units (3 and 9 are equally distanced from 0 and 12 ≡ 0). Combining deterministic and probabilistic features, weights can be assigned to equivalence classes, a situation leading to even more sophisticated constructs in which more or less importance is given to select individual elements. Weighted sieves can even lead to the approximation of orchestration rules when combined with conditional probability restrictions.

Another feature, ***patterns***, offers a similar blend of determinism and probability. A sequence of predetermined (pitch) intervals is provided by the user; it may be used as such or it may be distorted in a number of ways: by randomly modifying selected intervals, by scrambling their order, etc. At the same time, an origin of the pattern is selected and a range defined. Values within that range corresponding to each equivalence class become available and are assigned a weight. Depending on how strict the selecting procedure is, the result could be either a well defined melody, a pitch class collection typical for tone-row music, a “reservoir of pitches” as in Boulez's domains or anything in between. The same observation made in the case of sieves applies here as well: patterns may be used in connection to any parameter, not only for controlling pitch.

3.2 Event factories.

The C++ class Event produces objects/events of various sizes from piece down to individual sounds. All events have a minimum of three attributes: start time, duration and type. A “parent” event can be described as a “window” or *gestalt* and generates its “children” events in a uniform and consistent way, using the same method for all of them. Three such methods are presently available: Continuum, Sweep, and Discrete. Continuum distributes start times and durations randomly sprinkling them within the parent's duration according to a specified density and children's probabilities of occurrence. Sweep arranges them in sequential order making sure that start times are equal to or greater than the end of the previously assigned child event.

Discrete is the most elaborate method and involves a three-dimensional matrix containing probabilities for each possible combination of start time, duration and type. Such probabilities result from multiplying the weights of a general sieve which determines when events can take place with envelopes the show when each individual type of event has a better chance of occurring and with a probability vector weighing the importance of each type. If the density of the parent is high, DISSCO might not succeed at creating the full number of children in one try and new attempts are allowed until either the operation is successful or the user lowers the density.

4. Other possibilities.

DISSCO is a work in progress and new features are added as needed. Some of them have been already tested in different contexts or are scheduled for implementation in the near future.

Together with stochastic distributions, ***Markov chains*** have become a relatively common tool used in contemporary music to generate sequences of sounds or of higher level events. By designing carefully the transformation matrix, the composer can manipulate the variety embedded in the musical discourse - and thus the information it delivers - and control how fast the process will reach a stationary state (if at all). In another practical application, Markov chains may be instrumental in solving the nagging problem of how to generate only durations that can be transcribed in traditional Western notation. A large matrix that encompasses two or more beats and includes all possible subdivisions of the beat could avoid impossible situations such as having an eight note of a quintuplet at the beginning of the beat followed by a sixteenth. However, the matrix will allow the same combination if the eight note quintuplet is placed at the end of a beat and tied to the first sixteenth of the next.

Related to Markov chains, ***random walks*** have been used extensively by Xenakis in creating the ***arborescences*** present in the works of his middle and late periods and as part of the Dynamic Stochastic Synthesis (GENDY) which engenders directly the air pressure wave.

A more substantial means at the disposal of a present day musician is ***Group Theory***. Introduced by Milton Babbitt in his discussion of tone-row music [1] and applied by Xenakis both as a form-generating device and as a means to control "metabolae" or modulations between sieves (in *Akrata*, *Nomos Alpha* and *Nomos Gamma)* [10], Group Theory should be recognized along with the concept of ***vector space*** as crucial in understanding the fundamental structures of music beyond styles, history or geography.

In *Formalized Music* Xenakis also offers an alternative to aleatory compositions which asks the performers to contribute to the final version of a piece by choosing (improvising) among options offered to them either in matters of detail or with regard to formal aspects of the work. Although only three of his pieces (*Duel*, *Strategie* and *Linaia Agon*) make use of the ***Game Theory***, this approach remains – in our opinion – a potentially powerful ingredient in creating manifolds that involve a dialog between performers and, more generally, between sound sources.

5. World view.

All musical works evince a world view either explicitly or implicitly through their language and formal design. In the best instances, when the composer is aware of this, the choice of a particular system and materials goes beyond a mere aesthetic decision. Although DISSCO could conceivably be used as a neutral tool, it contains strong biases and the manifolds created with it display and enhance these biases.

The world thus created tries to "imitate nature in its mode of operation" - to use John Cage's words. It is a world in which probability plays a major role especially at the level of surface details, but a world that is also anchored in deep structures many of them characterized by symmetries. The play between determinism and indeterminacy, universal laws and chance, or among destiny and free will can also be seen as the interaction between Being (Algebra: sets, groups, etc.) and Becoming (Probability: randomness, distributions, entropy/information, etc.). Using musical terms, one can talk about static or "outside time" structures - scales, meter, textures – and the dynamic, "in-time" realization of a piece (see *Formalized Music* [10]).

On another level, the manifolds point toward the ephemerality of the individual and toward the role of the composer as a *demiourgos* setting in motion a process that acquires a life of its own, independent of its creator. In turn this accomplishes the social-oriented goal of refusing to allow a work of art to become a commodity: each manifold variant ceases to exist at the end of its performance, it can not be sold or kept in a drawer waiting for its market value will increase.

6 … and Beyond.

Two related future projects expand on the scope of manifold compositions.

The first, a sound "fountain", is indebted to an idea Romanian composer Aurel Stroe once shared: a piece that would be performed over a long period of time without interruption, similar to water streams coming out of an artesian fountain. The music should be created continuously, ever changing in its appearance, never the same but restrained by stable constraints. The computing power available today could make it a reality and DISSCO could provide the means for creating a complex and sophisticated work of art unlike the muzak one hears in airports. From time to time live performers could join in predetermined moments of higher density. Decisions made by them could change the initial probabilities and affect the behavior of the computer-collaborator. Instead of discrete variants of a manifold, an evolving composition would develop and transform itself, even in the absence of an audience, over days, weeks and months, like a living organism.

The second project involves a manifold in endless transformation, or a "brewing piece". Presently, in order to generate a manifold variant, choices are made successively until the density (total number of sounds) and the time constraints are satisfied, each selection being final. However, another possibility is for individual choices to influence no only future ones but also to have a retroactive effect on already existing sounds modifying their parameters or even erasing them. This will result in a piece that is continuously metamorphosing, exhibiting only transitory aspects and permanently "brewing". Samples of the process could be taken at arbitrary times and performed; this way versions of the work will come to life only when someone is "looking" - snapshots of particular manifestations of the manifold.

Both projects consider musical compositions a complex dynamic systems whose parts are interrelated and compensate for each other. While the "fountain" channels such influences in one direction following the arrow of time like jets of water, the "brewing" piece can be imagined as an extensive electric power network in which a failure of one component or an increase in demand in another part trigger adjustments in the entire network. In both cases there is no optimum solution while the system is searching for an elusive stable state.

No decisions have been made yet on exactly how to implement these ideas but the design should establish a “buddy system” probably in the form of weighted graph structures linking mostly same level (but not only same level) events. Such events could be considered as objects moving in the multidimensional vector space of sound parameters, random walks or similar probabilistic ways could be used to explore various paths between objects/vertexes while ways in which the creation of new objects and their destruction is controlled are to be defined.

Translating all this into computer code and solving related problems of memory management is not a trivial task since even a modest musical composition contains a few thousand sounds. The effort, however, becomes its own reward: investigating new ways of conceiving music today.

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On the Improvement of Statistical Traffic Noise Prediction Tools

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Abstract: - In this paper the authors propose a new expression to perform a traffic noise prediction by the collection of the acoustical energy sent to the receiver. The equivalent level, in fact, depends on the acoustical energy emitted by each passing vehicle, which can be directly related to its speed by some experimental relations. The main advantage of this procedure is that no measurements in situ are required in order to estimate the global noise level, with a consequent gain in easiness and time respect to other expression present in literature.

Key-Words: - Noise Control, Traffic Noise, Vehicles Flow, Predictive Models.

1 Introduction

Urban environments are often subject to heavy acoustical noise annoyance because of the presence of transportation infrastructures and industrial and commercial settlements. Quality of life is thus affected by a continuous exposure to acoustical noise [1-4]. In particular, International Standards define different thresholds to be considered depending on the purposes of the area under investigation.

The European Directive 2002/49/EC of 25 June 2002 relating to the assessment and management of environmental noise [5] defines the basic principles of a harmonised European noise policy, following the publication of the European Commission Green Paper on the Future Noise Policy in 1996 (COM(96)540). Community noise ordinances have been promulgated by local and by national authorities in many countries, establishing noise zones and noise limits and defining the responsible bodies and obligations to reduce noise.

In this scenario, road vehicular traffic is a very relevant noise sources, since, car is probably the most used mean of transportation in the urban framework. For this reason, in the last decades, many efforts have been spent in the development of models able to predict traffic noise (for a review see [6]). Usually these kind of models are developed taking into account mainly traffic flow, both of light and heavy vehicles, and distance between carriage and receiver. In addition, other parameters should be taken into account, for example roads maintenance, kind of vehicles and weather features, which are related to the specific country in which the model has been developed. A Traffic Noise Model (TNM) is helpful especially in the design of new road infrastructures, in order to evaluate the acoustical impact and to avoid post-construction mitigation actions that often present a great cost. On the other hand, a predictive tool, i.e. a TNM, can be used when the noise impact have to be evaluated on an existing road network, so that the measurement campaign can be minimized and experimental data can be used only for the tuning of the model parameters.

In this paper, the idea is to overcome the need of experimental data, developing a statistical model which can be used without any parameter tuning, i.e. a kind of "parameter free" model. In this way, one can avoid the noise measurement campaign, in spite of collecting only easy to obtain road info, resulting in a strong save of time and resources.

2 Traffic Noise Models

In [6] the authors gave a detailed review of the most used TNMs, underlining the main shortcomings of a statistical approach which do not consider the intrinsic random feature of traffic phenomenon. In this section, the models used in the comparison with our proposal are briefly reported, starting from the **"Burgess"** model [7], applied for the first time in Sydney in Australia, which is one of the first model that consider the equivalent noise level L_{eq}. This is given by the following formula:

$$L_{eq} = 55.5 + 10.2Log(Q) + 0.3P - 19.3Log(d) \quad (1)$$

where Q is the vehicles volume (in number of vehicles per hour), P is the percentage of heavy vehicles and d is the distance from observation point to center of the traffic lane (in meters).

Another model is called "**Griffiths and Langdon"** method [8] and it proposes the evaluation of equivalent level starting from percentile levels as follow:

$$L_{eq} = L_{50} + 0.018(L_{10} - L_{90})^2 \quad (2)$$

where the statistical percentile indicator have the expression:

$$\begin{aligned} L_{10} &= 61 + 8.4Log(Q) + 0.15P - 11.5Log(d) \\ L_{50} &= 44.8 + 10.8Log(Q) + 0.12P - 9.6Log(d) \quad (3) \\ L_{90} &= 39.1 + 10.5Log(Q) + 0.06P - 9.3Log(d) \end{aligned}$$

Q, P and d have the same meaning of previous formula.

The **"RLS 90"** (*"Richtlinien für den Lärmschutz an Straben"*) model, instead, is the German standard TNM, included in the Guideline for Noise Protection on Streets [9], and it is an improvement of the old German standard RLS 81 [10]. The model requires, as input, data regarding the average hourly traffic flow, separated into motorcycles, heavy and light vehicles, the average speed for each group, the dimension, geometry and type of the road and of any natural and artificial obstacles. It includes also corrections due to presence of obstacles, vegetation, air absorption, reflection and diffraction, ground absorption, etc..

The calculation is made starting from an average level $L_{m,E}$ measurable at a distance of 25 m from the centre of the road lane. This $L_{m,E}^{(25)}$ is a function of the amount of vehicles per hour Q and of the percentage of heavy trucks P (weight > 2.8 tons), under idealized conditions (i.e. a speed of 100 km/h, a road gradient below 5% and a special road surface). Analytically $L_{m,E}^{(25)}$ is given by

$$L_{m,E}^{(25)} = 37.3 + 10Log[Q\,(1 + 0.082P)] \quad (4)$$

The next step is to quantify the various deviations from these idealized conditions by means of corrections for the "real speed", the actual road gradient or the actual surface, etc. In particular these correction depends upon whether day (6:00-22:00 h) or night (22:00-6:00 h) is considered. So, for each lane, the mean level in dBA L_m is calculated as:

$$L_m = L_{m,E}^{(25)} + \Delta L \quad (5)$$

where ΔL is a general symbol for the noise level corrections that can be found in [6, 9].

Evaluating the $L_{m,E}^{(25)}$ for each lane as described, one can obtain:

$$L_m = 10Log\left[10^{0.1L_{m,n}} + 10^{0.1L_{m,f}}\right] \quad (6)$$

where n represent the nearer and f the further lane respectively. Finally, the sound pressure level for the street is given by:

$$L_r = L_m + K \quad (7)$$

K is the additional term for the increased effect of traffic light controlled and/or other intersections.

The Italian Research Institute developed a TNM, the **"CNR"** model (*Consiglio Nazionale delle Ricerche*) [11], which have been then improved by Cocchi et al. [12]. This model represents a modification of the German standard RLS 90, adapted to the Italian framework; a relation between the traffic parameters and the mean sound energy level is supposed and the traffic flow is modeled as a linear source placed in the center of the road. So the equivalent sound level in dBA is given by

$$L_{Aeq} = \alpha_{CNR} + 10Log(Q_L + \beta_{CNR}Q_P) - 10Log\left(\frac{d}{d_0}\right) \quad (8)$$

where Q_L and Q_P are the traffic flow in one hour, related to light and heavy vehicles respectively, d_0 is a reference distance of 25 meter and d the distance between the lane center and observation point on the road's edge. The α_{CNR} e β_{CNR} parameters are influenced by characteristics of countries roads and vehicles. In particular α_{CNR} is related to noise emission from the single vehicles and β_{CNR} is the weighting factor that takes into account the greater emission of heavy vehicles (very frequently for Italian roads α_{CNR} = 35.1 dBA and β_{CNR} = 6 are assumed). Formula (8) can be extended with additive corrections related to mean flow velocity, reflections, road's pavement and gradient, etc.. In particular the correction ΔL_V related to mean speed is listed in Table 1.

Tab. 1: Correction related to mean flow speed.

Flow mean speed (Km/h)	ΔL_V (dBA)
30-50	+0
60	+1
70	+2
80	+3
100	+4

The last model used for the comparison has been developed by **Peretti et al.** [13] and it has been tuned on an experimental campaign performed by the author in a medium size city. The calculation is performed according to the following formula:

$$L_{Aeqh} = \alpha_{PER} + 10Log\left[1.5n_m + n_l + 6n_p\right] - 10Log\frac{d}{d_0} \quad (9)$$

where α_{PER} is a constant parameter depending on road typology, n is the number of light and heavy vehicles and motorcycles, d is, again, the distance between the lane center and observation point, d_0 is the reference distance (6,63 m).

It can be easily noticed that the general expression of the equivalent level calculated according to a statistical traffic noise model can be written in a compact formula as follows:

$$\begin{aligned} L_{eq} &= A \cdot LogQ_{eq} + b \cdot Log(d) + C \\ Q_{eq} &= Q\left[1 + \frac{P}{100}(n-1)\right] \end{aligned} \quad (10)$$

The A, b and C coefficients may be derived, for a fixed investigated area, by linear regression methods on many L_{eq} data measured for different traffic flows (Q, P) and distances (d). The acoustical equivalent, n, (defined as the number of light vehicle that generate the same acoustic energy of an heavy one) can be estimated both by regression method or by single vehicle emission measurement.

3 Procedure details and results

The starting point of the procedure here proposed is the relation between equivalent noise level and *SEL*:

$$L_{eq}^{(1h)} = 10Log\frac{1}{3600} + 10Log\left[\sum_{i=1}^{N_L} 10^{\frac{SEL_{L,i}}{10}}\right] \quad (11)$$

where N_L is the hourly flow of light vehicles and $SEL_{L,i}$ is the *SEL* level of *i*-esim car.

If we assume the acoustical energetic content of each transit to be constant (e.g. continuous flow condition, regular volumes, flat speed distribution), then $SEL_{L,i}$ does not depend anymore on the *i* index. Thus, formula (11) can be rewritten as follows:

$$\begin{aligned} L_{eq}^{(1h)} &= -36{,}563 + 10Log\left[N \cdot 10^{\frac{SEL_L}{10}}\right] = \\ &= -36{,}563 + 10Log(N) + SEL_L(r,v) \end{aligned} \quad (12)$$

In order to introduce the flow average speed dependence in the *SEL*, one can start from an experimental study presented in [14], where the power source level as a function of speed is given (see Fig. 1). In particular, we performed the fit of these data with the following expression:

$$L_w(v) = \alpha_L + \beta_L\, Log(v) \quad (13)$$

Let us remind that two different regimes have been considered: cruising/decelerating and accelerating flows. The result obtained by the fit procedure are α_L = 53,6 ± 0,3 dBA and β_L = 26,8 ± 0,2 dBA, for v > 11,5 Km/h in cruising/decelerating regime and for v > 25 Km/h in accelerating regime.

Thus, one can write:

$$SEL(r,v) = 10Log\int_{t_1}^{t_2} 10^{\frac{L_W(v) - 20Log[r(t)] - 11}{10}} dt \quad (14)$$

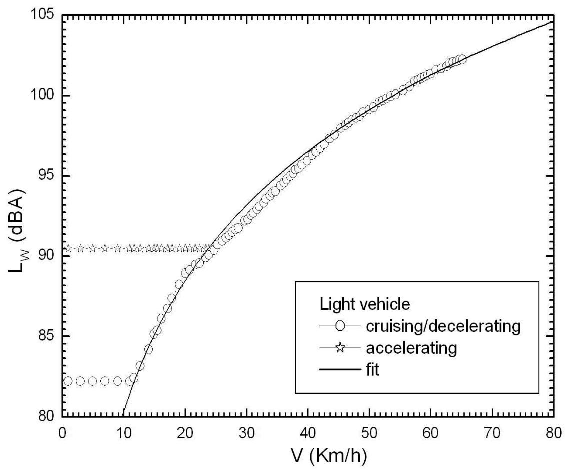

Fig. 1: Experimental diagram of power source $L_W(v)$ for light vehicles with different acceleration regimes.

Since *SEL* represents the area under the curve of sound pressure and since this function is very narrow (with a very fast rise and fall) with respect to the sound pressure level, the *SEL* value evaluated on a $t_2 - t_1 = 1s$ interval does not change evidently with respect to a greater time interval. Moreover, in this interval, a vehicle running for example with an average speed of 70 Km/h (20 m/s), cover a very short distance, thus one is allowed to approximate the distance source-receiver *r* with the constant distance road-receiver *d*.

To exploit this concept, the experimental time history of a single transit is reported (Fig. 2), where the black line (larger one) is the sound pressure level and the blue one (narrow one) is the normalized sound pressure. The red rectangle represents our approximation for the sound pressure function, that is zero outside a ± 0,5 *s* interval around the peak and is constant inside, i.e. vehicle is always at *d* distance. This balance between the underestimation due to the loss of area outside the chosen time interval and the overestimation due to the constant distance source-receiver, makes reasonable our approximation.

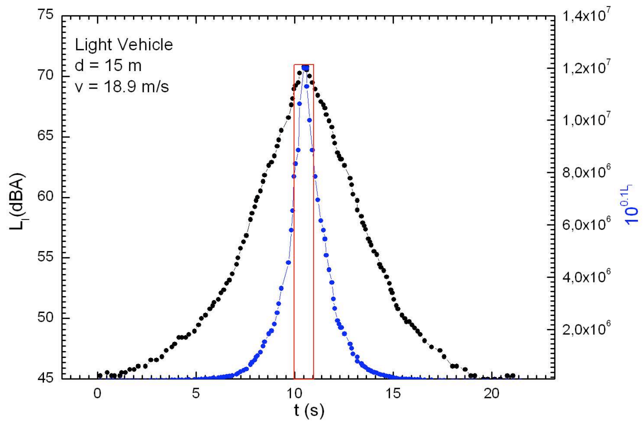

Fig. 2: Experimental time history of sound pressure level (black line) and sound pressure (blue line) for a single transit of a light vehicle

Thus, assuming $t_2 - t_1 = 1s$ and $r(t) \cong d$ formula (14) becomes:

$$SEL = \alpha_L + \beta_L Log(v) - 20Log d - 11 + 10Log(t_2 - t_1) \quad (15)$$

that is:

$$SEL(d,v) = \alpha_L + \beta_L Log(v) - 20Log d - 11 \quad (16)$$

In the end, the final expression is:

$$L_{eq}^{(1h)} = 10Log(N_L) + \alpha_L + \beta_L Log(v) - 20Log(d) - 47{,}563 \quad (17)$$

where the L_{eq} is given in term of number of light vehicles N_L, distance source-receiver *d* and average speed *v*. Let us remind that α_L and β_L coefficients have been evaluated on an experimental basis and the previous calculus has been performed only for light vehicles.

At this point, a comparison between the proposed procedure and other TNMs usually adopted in scientific and civil frameworks can be interesting. The plot of equivalent level calculated according to models presented in Section 2 versus light vehicles flow is reported in Fig. 3. The here proposed procedure (i.e. left oriented triangle, orange line) is in good accordance with the other models both in terms of slope and absolute values. A stable model, in fact, should not diverge for any value of the traffic flow and its slope has to be more or less similar to the general slope of the other curves. Let us remark that, in this plot, the corrective factors of the models, which could strongly influence the behaviour of the prediction in some particular conditions, have been neglected.

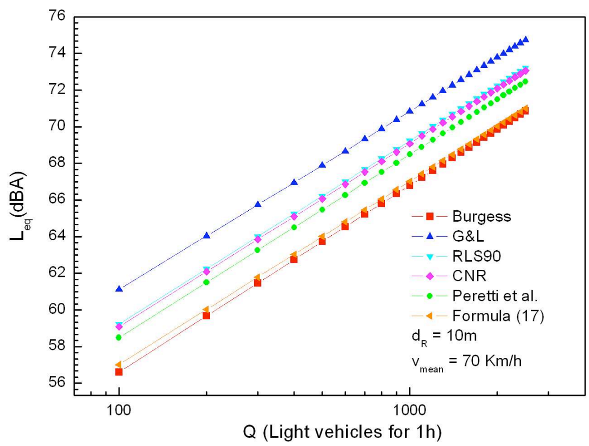

Fig. 3: Comparison between different Traffic Noise Models, with fixed parameters (see legenda).

If one wants to add the presence of other categories of vehicles, it is necessary to add more terms in (11), distinguishing between different typologies. For example, adding heavy vehicles, that generally are considered ones with weight greater than 3,5 ton, the expression (11) becomes:

$$L_{eq}^{(1h)} = 10Log\frac{1}{3600} + 10Log\left[\sum_{i=1}^{N_L} 10^{\frac{SEL_{L,i}}{10}} + \sum_{j=1}^{N_P} 10^{\frac{SEL_{P,j}}{10}}\right] \quad (18)$$

Assuming that the same procedure of light vehicle can be adopted for heavy ones, it can be written:

$$\sum_{i=1}^{N_L} 10^{\frac{SEL_{L,i}}{10}} + \sum_{j=1}^{N_P} 10^{\frac{SEL_{P,j}}{10}} = N_L\, 10^{\frac{SEL_L}{10}} + N_P\, 10^{\frac{SEL_P}{10}} \quad (19)$$

Being generally $SEL_P > SEL_L$, one can write:

$$N_L\, 10^{\frac{SEL_L}{10}} + N_P\, 10^{\frac{SEL_P}{10}} = 10^{\frac{SEL_L}{10}} \left(N_L + n(v)\cdot N_P\right) \quad (20)$$

where we define

$$n(v) = 10^{\frac{\Delta SEL}{10}} = 10^{\frac{SEL_P - SEL_L}{10}} \quad (21)$$

Moreover, in order to estimate the sound power level of heavy vehicles, we performed a fit on experimental data with the following expression:

$$L_{w,P}(v) = \alpha_P + \beta_P\, v \quad (22)$$

Data are shown in Fig. 4, where, again, different regime of acceleration are considered while the fit results are:

$$L_W^{cru}(v) = \begin{cases} 100.6 + 0.089v & for\ \ v > 21 Km/h \\ 102.5 & for\ \ v < 21 Km/h \end{cases}$$

$$L_W^{acc}(v) = \begin{cases} 103.0 + 0.069v & for\ \ v > 20.5 Km/h \\ 104.5 & for\ \ v < 20.5 Km/h \end{cases}$$

$$L_W^{dec}(v) = \begin{cases} 91.0 + 0.20v & for\ \ v > 18 Km/h \\ 94.5 & for\ \ v < 18 Km/h \end{cases}$$

Fit errors are generally bounded between 0.3% and 0.8%.

Thus, we can write:

$$\begin{aligned} SEL_L(d,v) &= \alpha_L + \beta_L Log(v) - 20 Log d - 11 \\ SEL_P(d,v) &= \alpha_P + \beta_P v - 20 Log d - 11 \end{aligned} \quad (23)$$

and:

$$\Delta SEL(v) = \alpha_P + \beta_P v - \alpha_L - \beta_L Log(v) \quad (24)$$

Thus

$$n(v) = 10^{\frac{\alpha_P + \beta_P v - \alpha_L - \beta_L Log(v)}{10}} \quad (25)$$

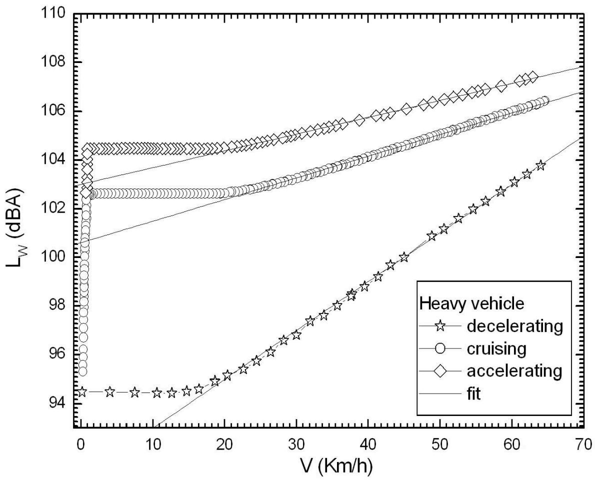

Fig. 4: Experimental diagram of power source $L_W(v)$ for heavy vehicles with different acceleration regimes.

This coefficient has the same meaning of the acoustic equivalent n in the general statistic TNM formula (10). Furthermore, our approach exploits that it is not a constant value to be obtained by linear regression or a-priori assumption, but it depends on average flow speed and traffic typology.

The $n(v)$ function is shown (in cruising state) in Fig. 5, where one can easily notice that, for average speed typical of urban area, i.e. about 40-50 km/h, the acoustic equivalent is bounded between 6 and 4, in a very good agreement with values provided by CNR and Peretti et al. models trough experimental measurements.

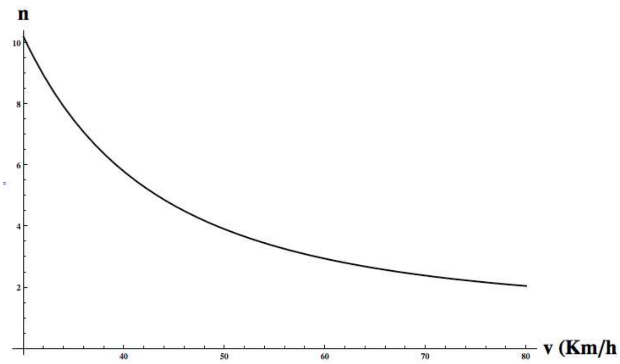

Fig. 5: Acoustic equivalent n versus average flow speed for cruising regime.

Finally we obtain the following expression:

$$\begin{aligned} L_{eq}^{(1h)} &= 10 Log[N_L + n(v) N_P] + \alpha_L + \beta_L Log(v) + \\ &- 20 Log(d) - 47{,}563 \end{aligned} \quad (26)$$

that can be related to formula (10) by the position:

$$Q_{eq}^{1h} = N_L + n(v)N_P \,,$$
$$A = 10 \,,\quad b = -20, \qquad (27)$$
$$C = \alpha_L + \beta_L Log(v) - 47{,}5638 \,.$$

4 Conclusions

In this paper, the authors presented a new procedure to improve traffic noise prediction by means of statistical TNMs, relating the acoustical energy sent to the receiver directly to the number of transiting vehicles (in the chosen time interval on which the L_{eq} is evaluated), to the source-receiver distance and to the average speed of the flow. This is achieved thanks to some experimental relations ([14]) expressing acoustical energy emitted by each passing vehicle to its speed, that have been fitted both for light and heavy vehicles. The results have been used to estimate the source power level, that have been put in the *SEL* formula.

In this way, the prediction of noise coming from vehicular traffic can be performed according to a statistical model (i.e. according to general formula (10)), but this time without the need of experimental data on which the parameters have to be tuned. The procedure, in fact, does not ask for any fit of noise data, in spite of only easy to obtain road info, resulting in a strong save of time and resources.

The results of these procedure have been shown to be in a quite good agreement with the other models both in terms of slope and absolute values.

Moreover the acoustic equivalent *n* of formula (10) has been deduced introducing the presence of heavy vehicle. It has been related to average speed (with a direct dependence from *v*) and to traffic flow typology (with coefficients variation). A good agreement between our theoretical values and other models experimental estimations has been achieved.

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Acoustical Noise Analysis in Road Intersections: a Case Study

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Abstract: - The modelling and the prediction of noise coming from vehicular flows is strongly related with the geometry and the general features of the road, including the presence of conflicting points. In an intersection configuration, in fact, noise cannot be predicted in a standard way, since the traffic slope depends on many random factors, such as priority, signals, traffic lights, driving behaviour, etc.. In this paper, the author focuses on the noise prediction problems related to road intersections and on the analogy between electrical current and vehicular flow. An experimental activity on a case study in the Salerno University campus is presented and the results are compared with simulations made by a predictive software.

Key-Words: - Noise Control, Acoustical Traffic Noise, Road Intersections, Predictive Software.

1 Introduction

In the framework of environmental acoustical noise control, many sources should be considered in an urban area. In the scientific literature one can find both theoretical and experimental studies concerning the control of noise coming from different infrastructures (see for example [1-9]). The Harmonoise and IMAGINE projects (*Improved Methods for the Assessment of the Generic Impact of Noise in the Environment*) [10, 11], funded by the European Community, constitute an attempt to furnish an exhaustive description of the noise calculation, measurement and mapping problems. Moreover, in the Harmonoise project, there is the final and ambitious aim of producing an European common standard criterion for the characterization of noise sources and for the evaluation of their impact on the human being life. This issue is very important because of the possible damages induced by a long exposition to acoustical noise.

Actually, the noise problem is not felt very important for human health by people, with respect, for example, to air pollution or electromagnetic fields. This is probably due to a low perception of the risk and of the possible damages of noise, especially before the problem occurs, i.e. before the noise source is operating. More on this topic can be found in [12], where the authors proposed the definition of an overall Health Quality Index, based on the evaluation and on the monitoring of some physical polluting agents, such as noise, electromagnetic fields, fine dust and other air components, temperature and humidity. This considerations lead to the need of an accurate prediction of noise impact in urban area, both in proximity of operating sources and in the design of a new infrastructure.

In general, literature and law regulation consider vehicular traffic as one of the main noise source in an urban framework, together with railways, industrial areas and airports. Road traffic noise, thus, is a very important element in environmental impact studies, since car is one of the most used transportation mean in Europe. The prediction of noise coming from vehicular traffic is strongly influenced by some "intrinsic" parameters (due to both noise production and propagation processes), such as traffic volume, traffic flow, velocity, road features, etc., and other "specific" parameters (dependent on the particular area of interest), such as kind of vehicles, speed limits, vehicles maintenance duties, law emission thresholds, driving skills, amount and typologies of road intersections, etc.. In last years, many Traffic Noise Models (TNMs) have been developed (for a review see [13]) and the most used ones use an empirical and approximated approach, tuning the model parameters on a particular set of data and neglecting many of the elements listed above. Thus, even if the prediction is quite unstable, these models result to be enough efficient and precise in most of the practical applications. These models, in fact, furnish a good approximation of the equivalent acoustical level (L_{eq}) when the condition of the traffic flow is standard, i.e. continuous flow, regular traffic volume, absence of conflicting points, etc.. This prediction is performed by means of a formula which generally depends on the vehicular flow, usually classified in light vehicles, heavy ones and motorcycles, plus other additive corrections. The general expression of a TNM can be written in a three parameters formula as follow:

$$L_{eq} = A \cdot LogQ\left[1 + \frac{P}{100}(n-1)\right] + b \cdot Log(d) + C \quad (1)$$

where L_{eq} is the acoustic equivalent level (defined later), Q is traffic volume in vehicles per hour, P is the percentage of heavy vehicles, n is the acoustical equivalent and d is the distance from observation point to center of the traffic lane. The A, b and C coefficients may be derived, for a fixed investigated area, by linear regression methods on many L_{eq} data taken at different traffic flows (Q, P) and distances (d). The acoustical equivalent, n, (defined as the number of light vehicle that generate the same acoustic energy of a heavy one) can be estimated both by regression method or by single vehicle emission measurements.

In this paper, the main idea is to focus the noise control problem on the road intersection configurations, where the prediction cannot be performed in simple way. The prediction of noise level is calculated in the CadnaA software framework and then compared to the results of an experimental activity of noise measurements in a case study, by means of noise maps and contour lines. Moreover, the software can be used to model an engineering intervention on the case study, such as the design of a new intersection. In the last section, the introduction of a roundabout is presented as a noise mitigation action.

2 Intersections and flow features

2.1 Intersection typologies

In [14] the authors gave a quite complete description of different road intersections and choice criteria. In this section, the main ideas related to intersection issues will be resumed, in order to introduce the simulation procedure and choices.

"Road intersection" is defined as the area obtained by the convergence in the same point of three or more road branches. The intersections, wherever they are localized, constitute a critical point for a road network because of the crossing of different traffic flows. They are divided into three main categories:

- *Planar Intersection*, subdivided in *linear intersections* (see for example Fig. 1) and *roundabouts*, where the converging roads are coplanar, with consequent interferences between transiting and curving currents.
- *Traffic Light Controlled Intersections*, which are still coplanar crossings, but there is a periodic and alternate stop of the traffic currents. They are used quite exclusively in urban and suburban ambits.
- *Not Planar Intersections*, in which the separation of the different transit currents is obtained through overpasses, while the connection between the two streets is given by one or more exchanging ramps.

The typology of intersection has to be chosen according to specific and regulated choice criteria, resumed in [15, 16, 17]. In particular, the acoustical noise impact on the surrounding environment should be considered in the design phase.

2.2 Flow typologies

Another important feature of the road that have to be considered in the simulation phase is the flow typology. Not always, in fact, vehicles travel at a constant speed (as it is assumed in the principal TNMs). Thus, according to International Standards, one can define four typologies of vehicular flow as follow:

Fluid continuous flow, when all the vehicles travel at an almost steady velocity, with a very narrow variance in the speed distribution.

Pulsed continuous flow: when many vehicles are in a transitory state (i.e. increasing or decreasing their speed) but it is possible to define an average overall velocity, which is stable and repetitive for a sufficiently long period of time.

Pulsed accelerated flow: when a significant portion of vehicles is in accelerating state.

Pulsed decelerated flow: when a significant portion of vehicles is in decelerating state.

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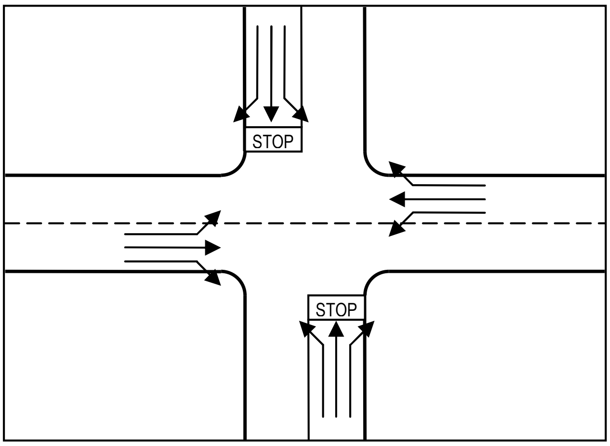

Fig. 1: Example of simple cross intersection with possible directions for each lane.

3 Electric current and vehicular flow analogy

The theoretical model that can be used for studying vehicular flow balance in an intersection has been developed starting from the Kirchhoff's circuit laws in Electrical Engineering. In particular, if one considers the Kirchhoff Current Law (KCL), the analogy between electrical current and vehicles flow can be highlighted. Vehicles entering or exiting the intersection can be considered respectively as entering or exiting currents, where the intersection play the role of the circuit node[1] (junction). Of course, one can easily notice that, in the intersections, vehicles are not allowed to park or to stop, and, consequently no vehicle can enter the intersection without exiting or vice versa. This means that in the intersection a kind of continuity equation related to vehicles density stays, in absence of sources and/or wells.

Standing this analogy, one can affirm that "*the sum of the number of vehicles that enters a given intersection from any road converging in that point, is equal to the sum of the number of vehicles that exits that intersection from any branch*", that is:

$$\sum_n Q_n^{IN} = \sum_n Q_n^{OUT} \qquad (2)$$

For example, if one considers a standard 4 branches intersection as in Fig. 2, where the x_i represents the vehicle flow related to the *i*-esim lane, it can be affirmed that:

$$x_2 + x_4 + x_6 + x_8 = x_1 + x_3 + x_5 + x_7 \qquad (3a)$$

that is:

$$\sum_{n=1}^{4} x_{2n} = \sum_{n=1}^{4} x_{2n-1} \qquad (3b)$$

These considerations do not depend on the kind of intersection chosen, since these equation stays for roundabouts, cross intersections, signal controlled junctions, etc..

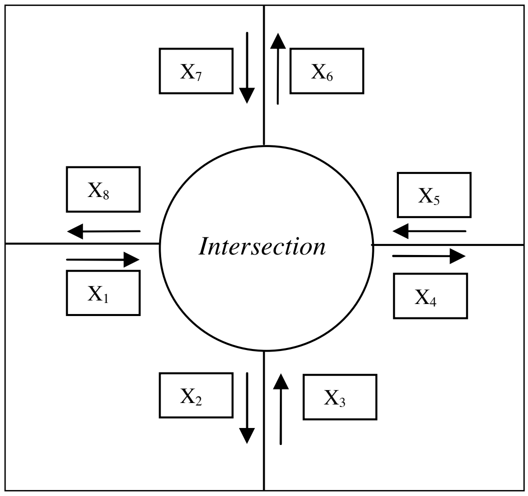

Fig. 2 Generic intersection configuration.

The analogy between circuits and road networks can be helpful in the study of some intersections, such as roundabouts. In this case, in fact, the equation (2) can be used in order to evaluate the flow charge on each sector of the roundabout (see Fig. 3).

If one considers that a vehicle coming from the *i*-esim lane, will not come back on the same direction, i.e. the U-turn is neglected, it can be stated that the *i*-esim sector of the roundabout is covered by all the vehicles coming from the adjacent converging lane, plus a given percentage of vehicles coming from other two converging lanes. These percentages are related to the number of vehicles that converge in the intersection from the other lanes and do not exit before. For example, if one considers the flow y_1 of Fig. 3, the relation is:

$$y_1 = x_1 + \alpha x_7 + \beta x_5 \qquad (4)$$

Of course, no percentage of x_3 flow is considered, since the U-turn is neglected. Moreover,

[1] More in general, the KCL is valid for any closed surface in which the node is placed, since it is related to flux concept.

it is not considered that a vehicle could miss the right exit and could make more than one round. The α and β coefficients can be even measured by operators or induced by statistical considerations and/or historical data.

Starting from this assumption and standing the KCL statement for vehicular flows, one can build the linear system for y_i variables:

$$\begin{cases} y_1 = x_1 + \alpha x_7 + \beta x_5 \\ y_2 = x_3 + (y_1 - x_2) = x_3 - x_2 + x_1 + \alpha x_7 + \beta x_5 \\ y_3 = x_5 + (y_2 - x_4) = x_5 - x_4 + x_3 - x_2 + x_1 + \alpha x_7 + \beta x_5 \\ y_4 = x_7 + (y_3 - x_6) = \\ \quad = x_7 - x_6 + x_5 - x_4 + +x_3 - x_2 + x_1 + \alpha x_7 + \beta x_5 \end{cases} \quad (5)$$

$$y_1 = x_1 + (y_4 - x_8) =$$
$$= x_1 - x_8 + x_7 - x_6 + x_5 - x_4 + x_3 - x_2 + x_1 + \alpha x_7 + \beta x_5$$

From this system, the vehicles volume on each sector of the roundabout can be easily evaluated, once x_i flows and α and β coefficients have been measured or assumed.

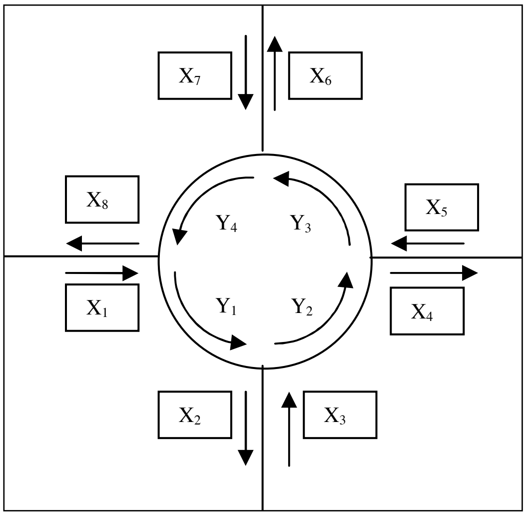

Fig. 3: Roundabout configuration and vehicular flows.

4 Case study analysis and results

In this section, the author presents the noise analysis of a road intersection in Fisciano, Italy, where some peculiarities can be underlined.

The case study here considered is the intersection in Fig. 4, placed at one of the exits of the Salerno University Campus. This intersection is very often congested, especially during lunch time and rush hours, because of the high number of people, in particular workers and students, that live, work or study in that area. The traffic is made both of light (principally cars) and heavy vehicles (buses and trucks), with a moderate number of motorcycles, even in winter time.

Looking at Fig. 4, one can easily notice that vehicles exiting from University have not the priority and, in congested situation, this results very often in a long queue. These vehicles can be considered as a “not continuous” flow.

A measurement campaign has been performed, in order to collect data to be compared with the simulation. The sound data acquisition has been performed by a two channel SINUS Analyzer, SOUNDBOOK (SN 0614), equipped with a pre-amplifier Larson Davis PRM902 (SN 3217), a microphone Larson Davis 2451 (SN 8183) and an acoustical calibrator Larson Davis CAL200 (SN 4874). In addition, a compact digital sound level meter PeakTech 8005 has been used in Point 1 (see Fig. 4c).

The measurement procedure has been carried out in fulfilment to the International regulation, ISO 9613. Once the measurement has been started, the acquisition software is able to detect and record the sound pressure level for each frequency. The experimental activity has been carried out by three operators, in charge of counting the number of vehicles on the roads in proximity of their position (see Fig. 4c), i.e. X_1, X_6, X_7 and X_8, with the nearby turning lanes. In this way, one can evaluate the α and β coefficients and apply the linear system (5) in order to obtain X_2 and X_3. These flows data are fundamental in order to evaluate the noise level with a TNM.

The measured hourly equivalent noise levels can be then compared with the results of a simulation performed by a noise predictive software, i.e., in our case, CadnaA, licensed by DataKustik.

This software is based both on “Angle Scanning” and on the inverse “ray-tracing” principle: area under analysis is divided in many small surfaces in which a receiver is placed at a variable height, in order to build a determined calculation grid. Each receiver releases many rays with a full angle coverage (omni directive) and these rays, eventually after many reflections, intercept the different noise sources. The path length of the single ray describes the attenuation of the sound wave coming from a certain noise emitter. Moreover, it is possible to insert different kind of sources, such as roads, railways, parking lots, geometrical sources, etc.. Noise coming from each source is simulated according to International Standards and to specific predictive model. In [4-7, 14, 16] the simulation performances of this software have been exploited and applied in different cases, with different kind of sources. The results have been also compared with experimental data, showing a quite good agreement in almost all the standard situations.

In the case under study, the simulation is performed according to the French road traffic noise model, recommended by European Community as a standard reference model [18], the *Nouvelle Méthode de Prevision du Bruit* – NMPB. The simulation needs as input many parameters, such as geometry of roads and intersection, traffic flow data together with accelerating or decelerating features (where necessary), heavy vehicles percentage, road pavement, speed limits, road gradient, etc.. Once these parameters have been fixed according to the real case study and the configuration is implemented in CadnaA, the simulation is performed and the calculation is made inside a suitable grid formed by cells. The spatial resolution of the prediction, of course, depends on the size of the cells. Moreover, the height of the receiver is fixed at 1.5 m from the ground, which is the height of the measurement instruments.

In Table 1, the results of measurements and simulation corresponding to one of the measurement sessions are shown, while in Fig. 5, the noise map obtained in CadnaA is reported.

Table 1: Results of measurements and simulation, in Point 1 and Point 2

	L_{eq} exp	L_{eq} sim	L_{90} (background noise)
Point 1	70.3	71.5	50.3
Point 2	70.9	72.5	64.3

It is interesting to notice that this measurement session is related to a traffic jam on the principal road and, if one compares values in Table 1, the measured values are lower than the simulated ones. This is due to the fact that the predictive model, and consequently the software, works in standard conditions, that are fluid continuous, pulsed or accelerated/decelerated flows and average speed. Thus, if the vehicular volume input is given, the software will make these vehicles run with an average speed, resulting in a higher L_w, and thus L_{eq}, with respect to a traffic jam situation where the vehicles are often stopped or run with a very low speed. Moreover, this consideration is confirmed by the fact that L_{90}, which gives an estimation of the background noise, is quite high with respect to normal conditions, being 64,3 dBA.

Fig. 4: Case study: a) Salerno University Campus with; b) Zoom on considered intersection; c) Implementation of the intersection in CadnaA, with measurement points and operators position.

In Point 1, for example, in order to achieve a better agreement between simulations and experimental data, it was necessary to specify, in the simulation, the typology of traffic flow, because the presence of "not continuous" flows results in different equivalent levels with respect to standard conditions. The measurement in Point 1 related to the experimental session reported in Table 1 gave an hourly equivalent level of 70.3 dBA, while the simulation in CadnaA gave 71.5 dBA. This discrepancy is probably due both to the previous consideration (related to the traffic jam situation) and to the intrinsic error in the predictive model, and it was much higher when the traffic flow of X_1 was not set properly ("decelerating" flow because of stop signal and priority).

Besides this comparison, the introduction of a new intersection configuration can be implemented in the CadnaA framework, in order to evaluate the best solution in terms of noise equivalent level impact. In literature [19, 20, 21], the roundabout configuration is suggested as one of the best solution to be adopted, provided that flows and geometry of the intersection are suitable with this solution.

In Fig. 6, the noise map produced by the simulation in CadnaA of the roundabout instead of the actual intersection is presented. The flows have been chosen according to the previous simulation and the roundabout geometry has been designed according to the legislative requirements [26, 27]. In Point 1, the introduction of the roundabout leads to a lowering of the L_{eq} of about 1 dBA, which is consistent with values found in literature.

5 Conclusions

In this paper, the noise control problem in intersections has been exploited in the case study of one of the exits of Salerno University. The analogy between electric current and vehicular flow has been sketched and applied to the case study. The experimental results of a measurement session have been compared with software simulations, in the CadnaA framework. Let us remark that this software has been employed both on the predictive and on the graphical point of view. In fact, a clear and "easy to read" representation of the simulation results can provide a direct feedback of the expected noise coming from a particular configuration.

The CadnaA software has been used also to predict the noise impact of a possible new intersection configuration, i.e. a roundabout, verifying the lowering of noise equivalent level, consistent with literature values.

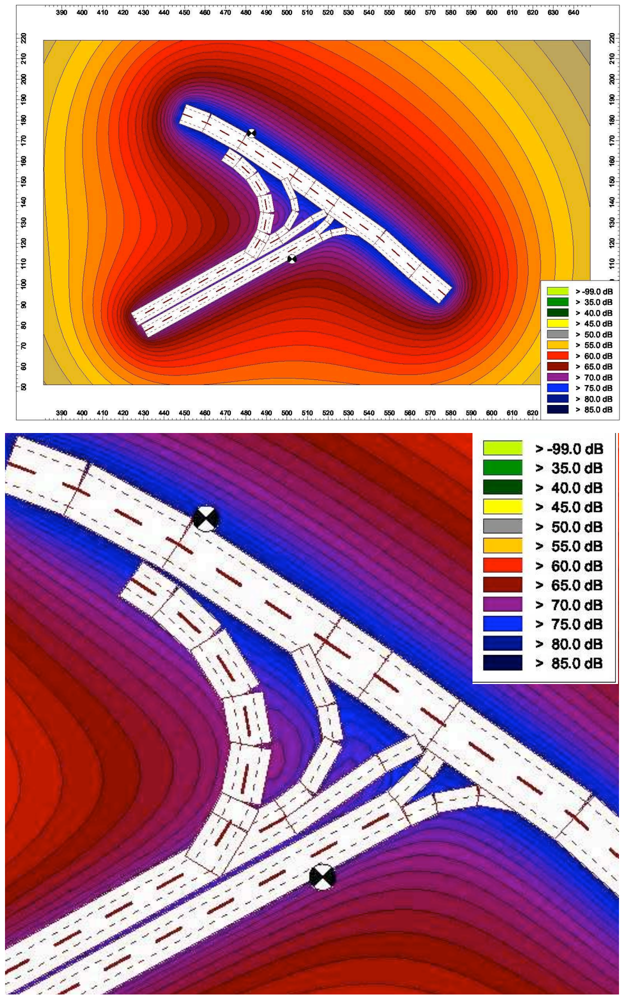

Fig. 5: Actual intersection noise maps

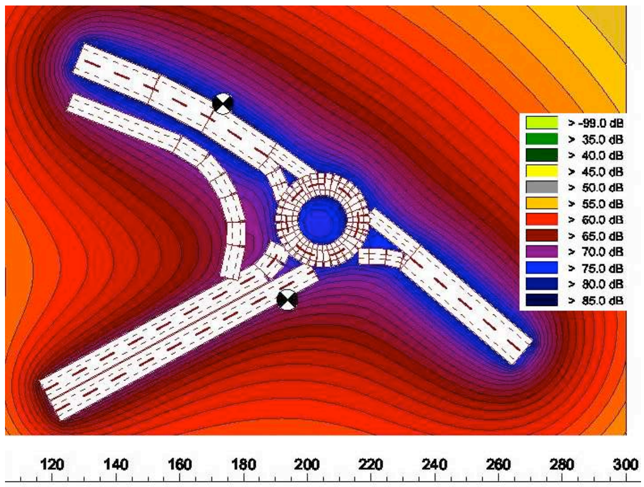

Fig. 6: Roundabout configuration noise map

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Church Acoustics Measurements and Analysis

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Abstract: - The measurement of Reverberation Time (RT) is a quite important estimation of the sound quality in a closed environment. From this measurement, in fact, one can gain information about intelligibility of signals and amount of reflection energy. In particular the liturgical hall of a church is an interesting environment because of its relevant volume and the materials adopted for the interior design. In this paper the authors present an experimental study of a new built church, in which the geometry of two lateral chapels produces interesting acoustical effects. A correction of the RT is proposed in the last part of the paper, by means of absorbing panels insertion. The intervention has been dimensioned, tuned and designed in a predictive software framework.

Key-Words: - Acoustical Field, Church Acoustics, Reverberation Time, Simulation Software.

1 Introduction

In the everyday life, people are continuously inserted in living and working closed environment, which can be acoustically satisfactory or unsatisfactory. Thus, the acousticians are faced mainly with a two-fold problem: on one hand they have to find and to apply the relations between the structural features of a room – such as shape, materials and so on – with the sound field which will occur in it, and on the other hand they have to take into consideration, as far as possible, the interrelations between the objective and measurable sound field parameters and the specific subjective hearing impressions effected by them. This shows that room acoustics is quite different from many other technical disciplines, since the success or failure of an acoustical design has finally to be decided by the collective judgment of all "consumers", i.e. by some sort of average, taken over the comments of individuals with widely varying intellectual, educational and aesthetic backgrounds (unbias).

The prediction of acoustical parameters for the purposes of architectural acoustics is a task currently carried out almost exclusively using computer programs. These give detailed and reliable results but require a three-dimensional (3D) model of the room in question. However, researchers and professionals often welcome the availability of simple prediction formulas because they can provide reference values with little calculation effort and also aid the general understanding of room acoustics.

The success of the Reverberation Time (*RT*) as a relevant acoustical parameter relies not only on its correlation with perceived subjective quality, but also on its being appropriate for a whole space, and, above all, on its predictability with some simple formulas. Actually, one of the most used and simplest one is Sabine formula:

$$RT = k\frac{V}{A} \qquad (1)$$

where k is a constant (0,161 s/m in the metric system), V is the volume of the room (in m^3), A is the equivalent absorption surface (in m^2) given by:

$$A = \sum_i \alpha_i S_i \qquad (2)$$

with α_i and S_i the absorption coefficient and the surface of the i-esim building material.

This formula is useful in many cases, where the theoretical estimation is in good agreement with experimental measurements. In [1] the authors provided a comparison between theoretical values and experimental evaluation of reverberation time, for a new built church. Churches, actually, represent an excellent experimental object of the sound propagation study in a closed space. In these places, in fact, geometry is usually peculiar and many acoustical sources are present: loudspeakers, musical instruments, air conditioners, people talking and moving etc..

In this paper, the authors present a further study on a different church, with a more regular geometry with respect to [1] case study, but with some peculiar responses to an isotropic noise signal. The study has been carried out both by means of an experimental activity and a software simulation, in order to perform a proposal for acoustical sensation improvement.

2 Experimental session description

The site under study is "S. Maria delle Grazie" church, placed in Angri (SA), Italy, and the measurements were performed in February 2009, during day time, from 8 am to 1 pm.

The experimental session has been carried out according to the International Standard (ISO 3382 [2]) regarding measurements of Reverberation Time in a closed environment. At the beginning of the measurements, the operators measured the temperature of the room, according to the cited Standard, founding an inner temperature of 18°C. The measurements have been performed in an empty occupancy condition, in order to best evaluate the Reverberation Time, since the presence of people increases the absorption of sound rays, leading to a decrement of reverberated field.

The hall has an overall volume of about 7000 m^3 and the inner surface is about 4300 m^2. The noise source, which will be described in Section 3, has been placed first on the presbytery of the church (as shown in Fig. 4), and then it has been moved in other positions of the church, as suggested by ISO.

Fig. 1: Pictures of the Church under study

The number and the positions of measurement points have been chosen in order to have a complete mapping of the environment, since this set of data can be used for different purposes. However the choice fulfils the ISO Standard cited above [2], which requires that:

- the positions of microphones must be at least half wave length far from each other, i.e. a minimum distance of about 2 m for the common frequencies range;
- the distance between each position and the nearer reflecting surface, including the floor, must be at least one quarter of wave length, i.e. generally about 1 m;
- the microphones must not be too much close to a source position, in order to avoid a big influence from direct sound. In particular, in [2] a minimum distance, d_{min}, is defined as:

$$d_{\min} = 2\sqrt{\frac{V}{cT}} \tag{3}$$

where V is the volume of the hall, c is an approximated value for the speed of sound and T is an estimation of the foreseen Reverberation Time. In our calculation, we consider $V \cong$ 7000 m^3, $c \cong$ 340 m/s and $T \cong$ 5 s, that result in: $d_{min} \cong$ 4 m.

All these considerations on the position of microphones have been summarized in Tab. 1.

Tab. 1: Summary of the distances in our case study

Relative Position	Theoretical Distance	Chosen value
Microphone-Microphone	$> \lambda/2$	2 m
Microphone-Reflecting surface	$> \lambda/4$	1 m - 1,5 m
Microphone-Floor	$> \lambda/4$	1,5 m
Microphone-Source	$d_{\min} = 2\sqrt{\frac{V}{cT}}$	$d_{min} = 4$ m

Following these criteria, one can choose the measurement points, as reported in Fig. 2. According to the ISO Standard [2], in each position three different measurements of RT have been performed and then the mean value has been calculated.

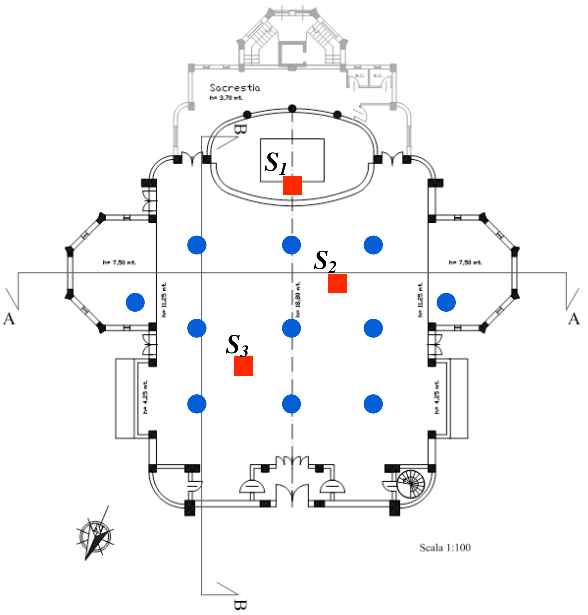

Fig. 2: Church layout with measurement points (blue circles) and source positions (red squares)

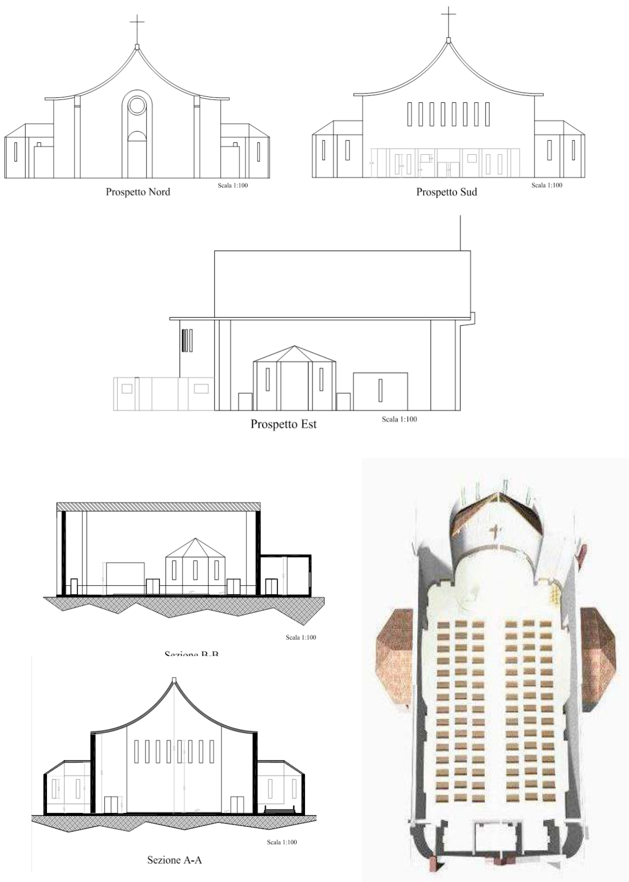

Fig. 3: Different visual angles church designs

The choice of these measurement points, for source position S_1, leads to the possibility to distinguish three different zones:

- *Forward zone*, where the direct acoustic field overtake the delayed one;
- *Intermediate zone*, where the field can be considered "semi delayed";
- *Backward zone*, where the delayed field is almost predominant on the direct one.

3 Measurement details

3.1 Measurement instruments

The sound data acquisition has been performed by a two channel SINUS Analyzer, SOUNDBOOK (Serial Number 0614), equipped with a pre-amplifier Larson Davis PRM902 (Serial Number 3217), a microphone Larson Davis 2451 (Serial Number 8183) and an acoustical calibrator Larson Davis CAL200 (Serial Number 4874).

The microphone has been oriented with an angle of 80° with respect to the noise source, even if in diffuse field conditions, the results are not affected by the orientation.

Once the measurement has started, the software is able to detect and record the sound pressure level for each frequency.

3.2 Noise source

The noise source is used in order to produce a relevant amount of sound energy in the environment in which the measurement of the Reverberation Time must be performed.

According to the ISO Standard on the measurement of the Reverberation Time in a closed environment [2], the noise source can be a peace gun or an isotropic source.

In our case, the chosen source is the OMNI12 Metravib 01dB™ Italia noise source, shown in Fig. 4. This isotropic source is made of 12 speakers embedded in a robust dodecahedron box, which produce an acoustic field very close to the spherical approximation.

The chassis, equipped with wheels, contains the amplification, the power supply system, the noise generator and the mechanical support.

The instrument can be switched on and off with a remote control, so that the noise source can be controlled also without the presence of an operator which could affect the results of measurements.

The major technical features of OMNI12 are:

- Standards: UNI EN ISO 140-3 ISO 3382
- Power: 350 W
- Frequency range: 70Hz – 16KHz

- Sound power level: 108 dB at 1 meter distance (L_W = 119 dB)
- Mechanical support: telescopic adjustable bar
- Speakers: 12 x 5" bi-cone
- Diameter: 50 cm
- Weight: 18 Kg

3.3 Measurement method

The International Standard cited above [2], describes two different methods for the Reverberation Time measurement:

- "interrupted noise" method;
- "integrated response to the impulse" method.

For our measurements, we chose the first method, taking also into account the features of our instruments. In particular we use the following experimental procedure:

1. Start the measurement and recording of data, in order to estimate the background noise level;
2. Switch on the source, by remote control, so that the acoustical field can go in a stationary state;
3. Switch off the source, so that the acoustical field starts its decay;
4. Stop the measurement and data recording.

Fig. 4: Isotropic source and its operating position

4 RT calculus and results

In order to evaluate the RT, the strategy is to calculate it for each frequency, to mediate on the different measurement points, and finally to mediate on the frequencies.

The procedure adopted is widely described in the ISO Standard [2] and in [1]. We only remind that, when the signal is not more than 60 dB higher than the background level, the ISO standard provides a mathematical procedure for the calculation of the RT. The method consists first in the linearization of the decay of the noise signal in a smaller range and then in an extrapolation of the required value directly from the plot. In our case, we choose a 30 dB decay range, from -5 dB to -35 dB, and then extrapolate the Reverberation Time at -65 dB, typically called RT_{30}.

This procedure is well summarized in Fig. 5, for two different frequencies in the same measurement position. The dashed lines represent the average maximum level decreased of 5 dB and 35 dB for each frequency, while the solid lines are the linear regression of the experimental data in the range between the two dashed lines. This leads to an easy estimation of the RT_{30}.

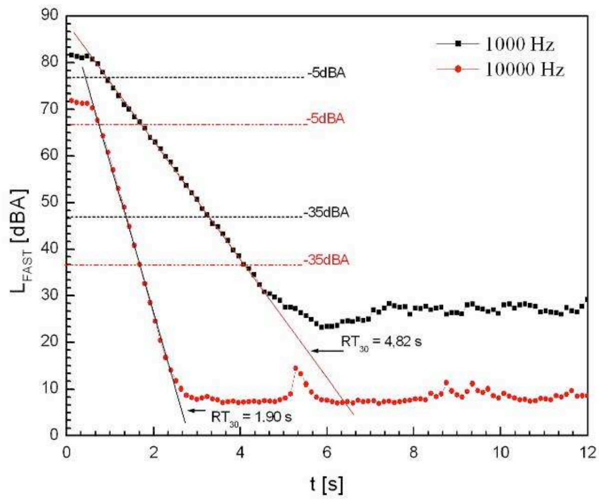

Fig. 5: Example of RT_{30} evaluation according to ISO standard [2] for two different frequencies.

The calculation of the RT_{30} has been performed for each frequency at a fixed measurement point, resulting in a complete set of data for the whole hall.

In Tab. 2 the average values of RT are reported, mediated on the different measurement positions.

Tab. 2: Average RT values for each frequency; value in the last octave has been evaluated with a regression in a 20 s range because of low signal/background ratio.

Frequency [Hz]	RT_{30} [s]
125	4,10
250	5,30
500	7,02
1000	7,75
2000	5,30
4000	3,43
8000	1,88
16000	1,82*

Finally one can evaluate an average Reverberation Time for the environment, mediated on the octaves, and the result is 4,30 s.

In architectural acoustics one cannot define an “optimal value” for Reverberation Time of a hall, since the sensation provided by sound is strongly subjective. In literature one can find suggestions for preferred values of RT, depending on the purpose of the hall, as reported in Fig. 8. It is clear from the plot that our value is not fully suitable with the purpose of the church; in fact the Reverberation Time is too high to ensure a good clearness of signal. This is in agreement with our personal experience during the measurements campaign.

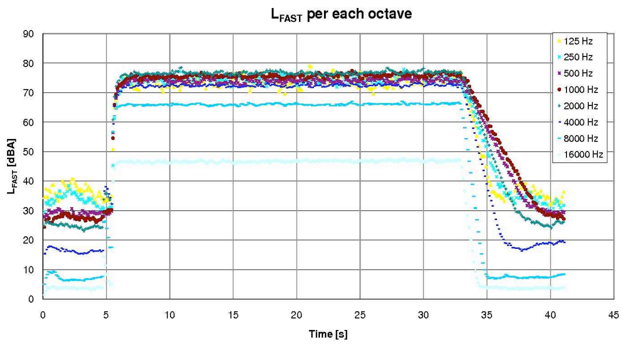

Fig. 6: L_{FAST} signal per each octave in one of the measurement point.

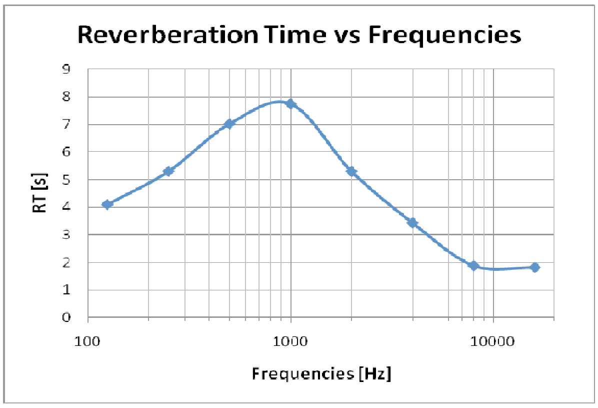

Fig. 7: Average RT values versus Frequency.

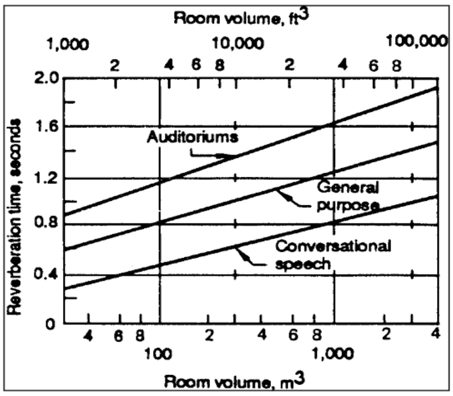

Fig. 8: RT preferred values versus room volume for different purposes [3].

5 Acoustical correction proposal

As it has been shown in the previous paragraph, the hall of the church under analysis has a quite big RT, which can be considered suitable for music and singing but not for speaking. Of course one could think to use a certain number of loudspeakers, in order to improve the direct sound to the receiver, i.e. people participating to ceremonies. This solution, however, does not reduce the presence of reflected sound rays, but sometimes increases the reflection, when a wrong number and/or position of loudspeakers are chosen, so an acoustical correction is still interesting.

The corrective intervention design can be studied by means of software simulation, as the authors showed in [1]. The Autodesk© Ecotect^{tm} software has been used in this phase. It is a building design and environmental analysis tool that give the possibility to simulate and analyze the thermal and acoustical response of a building. Moreover it allows designers to work in 3D and furnish an impressive presentation of the final design and acoustical behaviour of the hall under analysis.

In order to better model the behaviour of sound rays in the church, the real configuration of the church has been fully implemented in the Ecotect software framework. The first step consists in the drawing of the project, together with the definition of the different construction materials, very important in order to model the sound absorption.

Then, the simulation of the source must be performed, by means of supposing an isotropic source placed in a chosen position.

Now different analysis can be performed, such as RT evaluation, reflections study, materials analysis, etc.. The parameter chosen for the analysis of acoustical response in this work is the reverberation time. The software can calculate automatically the RT, once the materials have been specified in terms of absorption coefficients and surfaces. It is important to underline that these coefficients have been modified, since the default values were too much low with respect to reality, especially in the mid low range. The new absorption coefficients, thus, have been chosen according to datasheets of materials and tuning the parameters on the experimental data.

Simulation’s results are reported in Tab. 3.

Before making the proposal for an acoustical correction intervention, let us give some considerations about geometry and building materials of the church.

Tab. 3: Experimental and Theoretical RT values; RT_{THEO2} is obtained with modified absorption coefficients.

Freq. [Hz]	RT_{EXP} [s]	RT_{THEO} [s]	$RT_{THEO\,2}$ [s]
125	4,10	7,2	6
250	5,30	13,2	6,8
500	7,02	17,2	6,8
1000	7,75	12	6
2000	5,30	7	7
4000	3,43	3,8	3,8
8000	1,88	2,2	2,2
16000	1,82*	2	2

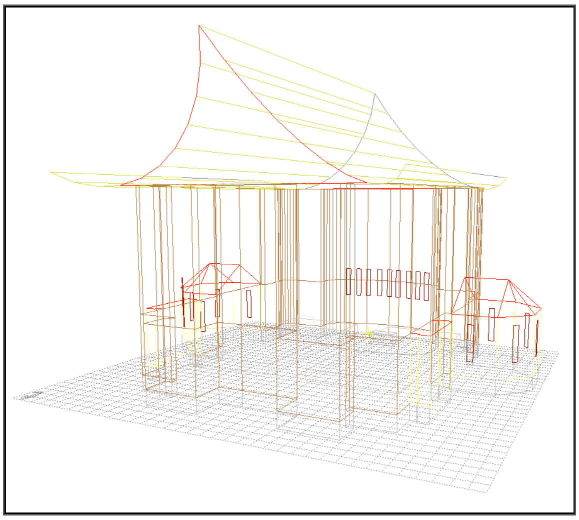

Fig. 9: Screenshot of Church simulated in Ecotect environment. The different colors refer to different building materials.

5.1 Geometrical analysis

Regarding the geometry of the church, a first observation that arises is on the roof. The shape of the roof (see Fig. 3, 9) is not converging, but diverges sound rays. This peculiarity provides two effects: on one hand a bad effect is that direct sound is not converged towards the auditor, while, on the other hand, a good effect is that late reflections (disturbing intelligibility of the signal) are diffused.

In addition, it has to be remarked the presence of two small lateral chapels on the two sides of the church (see Fig. 3 and Fig. 9), with a height much lower than the roof. These two chapels, one devoted to the Eucharistic cult, containing the tabernacle, and the other to the Baptistery, are placed at the end of the transept, and act as a kind of Helmholtz resonator, as it will be shown in this section.

5.2 Materials analysis

Usually churches have a big RT, also because of the presence of relevant surfaces, in terms of dimensions, with low acoustical absorption coefficient. Therefore, this produces a reduction in the equivalent absorption surface values.

In our case, floor and part of the walls are made of marble, resulting in a significant reflecting surface. In addition, the apse has a circular shape and it is made of concrete. The presence of such a surface close to the source, in principle, could lead to a relevant reflection of sound towards the auditor, resulting in a growth of early reflections (see Fig. 10).

Finally we can say that, since the different surfaces don't attenuate significantly sound rays, the reflections present low reduction in the sound pressure. This means that the secondary rays (delayed with respect to the direct sound) that reach the auditor after the time interval in which the brain integrates signals, may cause a disturb in the perception and a loss of clearness of sound. Moreover the high values of RT, especially for medium-low frequencies, are quite fully explained by these considerations.

5.3 RT evaluation and improvement design

The estimation of RT, once the position of the source has been fixed, is performed by the software in the 3D model, producing a bunch of acoustical rays, which interact with environment surfaces, mainly in terms of reflections and absorptions, until their sound pressure level is lowered of a certain quantity fixed by operator (e.g. 40-60 dB). From that point, the ray is considered completely absorbed and it doesn't affect anymore the acoustics of the hall.

The collective behaviour is resumed in the estimation of RT for each frequency, showed in Fig. 11, and, as explained above, it takes into account the geometrical features of the hall and the absorption coefficient of the materials.

The need for an acoustical intervention is thus reasonable, taking into account the considerations given above. This can be performed mainly by means of either modifying the geometry of reflecting surfaces or inserting absorbing materials.

Of course the first method is usually more expensive and invasive, with respect to the second, which, with opportune materials, could also improve the aesthetic of the hall.

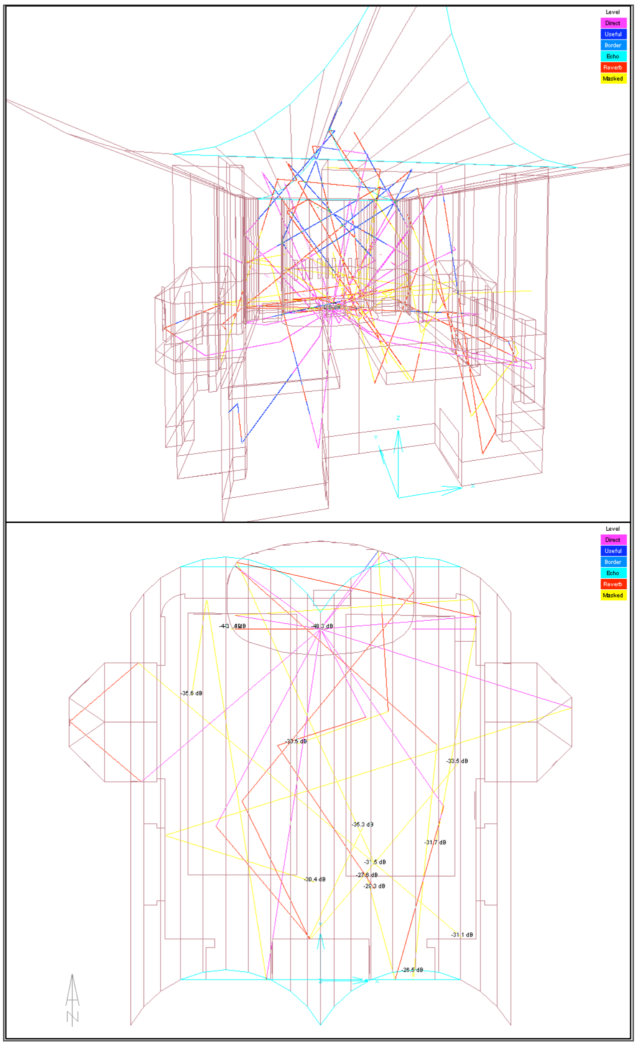

Fig. 10: Screenshots of some acoustical rays generated by a pointlike source placed on the altar. The violet and blue rays represent direct and early reflected sound, while pale blue and red represent late reflections, that affect the clearness of signal. The number in the bottom image are the attenuation due to geometrical divergence and absorption of the surfaces.

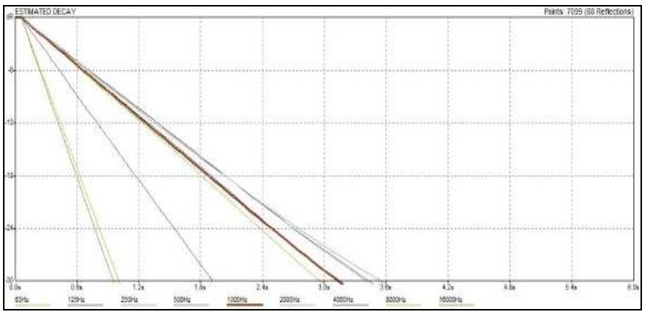

Fig. 11: Simulated signal decrement for each frequency.

This is the reason why, in our simulation, the insertion of absorbing panels is proposed as a RT reduction action. In particular, the chosen material is cork panels, with absorption coefficients per frequency resumed in Tab. 4.

Tab. 4: Absorption coefficients of cork panels for each frequency (octave).

Frequency [Hz]	Absorption coefficients
125	0,4
250	0,34
500	0,4
1000	0,45
2000	0,45
4000	0,5
8000	0,3
16000	0,25

The first scenario proposed is the insertion of these panels in all the lateral surface of the liturgical hall. This design is sketched in Fig. 12, together with the Sound Pressure Level (SPL) decrement versus time. Comparing this plot with Fig. 11, i.e. the slope of SPL without the panels, it is easy to notice that there is a quite significant lowering in the angular coefficients of almost all the frequencies curves.

Following the consideration given in section 5.1, on the geometry of the church, the insertion of absorbing panels only in the two lateral chapels has been simulated. The results are shown in Fig. 13, and it is remarkable that also in this configuration there is a relevant reduction of the signal slope, that decreases quite fast in almost all the frequencies.

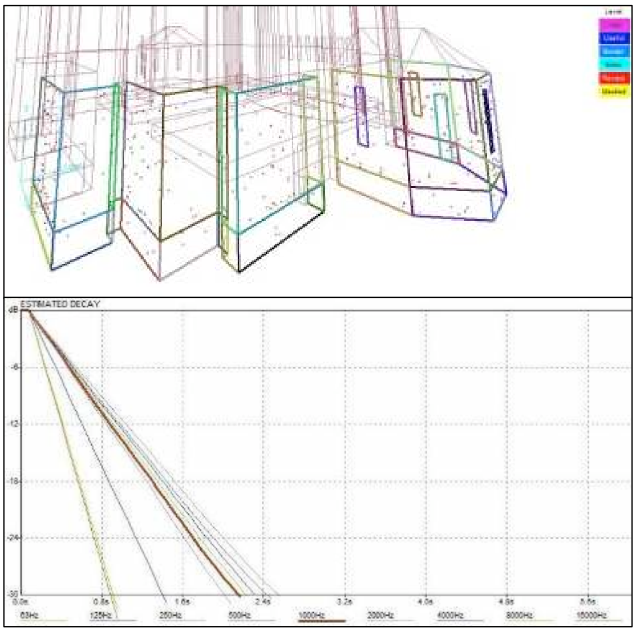

Fig. 12: Simulated signal decrement with the insertion of cork panel all around the lateral surface.

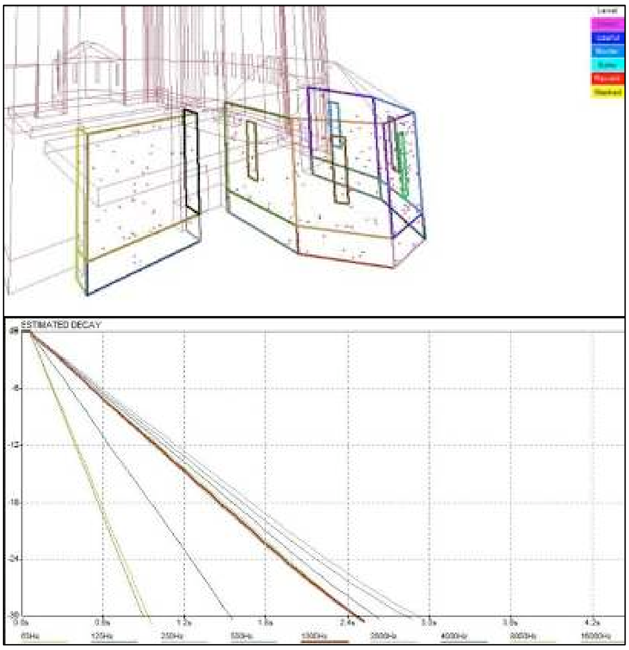

Fig. 13: Simulated signal decrement with the insertion of cork panel only in the two lateral chapels.

This means that probably the two chapels work as a kind of Helmholtz resonator, trapping sound rays in their volume. Acting with absorbing panels in these two region of the church volume, is a cheaper intervention and, at the same time, a very efficient reverberation reduction.

6 Conclusions

The result of an experimental activity in architectural acoustics has been reported in this paper. This work has been conduced first with the Reverberation Time measurements in the studied hall and then with the simulation of the church in a software framework. The RT has been measured following the procedure described in the ISO 3382 Standard [2], with instruments that fulfil the Standard requirements. A quite complete mapping of the hall has been obtained, since the position of the receiver has been changed several times during the experimental campaign.

Thus, the measurement results have been compared with the simulation data obtained for RT, which, after the correction of some default absorption coefficients, are in quite good agreement with the experimental values. Moreover, the software aided the operators also in a better understanding of the opportunity of reverberation reduction, thanks to the possibility to simulate the insertion of new architectural elements, able to improve the absorption, especially of late reflections. The results showed that it is not necessary to act on the entire lateral surface but only on the two chapels placed at the end of the transept, since the RT reduction in this configuration is satisfactory in almost all the frequencies. Furthermore it is important to underline that a greater reduction of RT could cause the degradation of music and singing hearing sensation, which is not desirable, since, in Christian liturgies, songs are part of the ceremony itself. This consideration leads also to the suggestion to move the organ and the chorus from the Baptistery chapel, since the sound produced in that volume, without an opportune amplification system, is not easily distributed in the entire liturgical hall.

Acknowledgements

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On the Determination of the Uncertainty in Environmental Noise Measurements

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Abstract: -In the paper is presented an effective computer code developed for real-time evaluation of confidence intervals associated to equivalent levels measurements in environmental noise measurements. The code has been developed using the application of bootstrap theory [1] and uses as input the equivalent level L_{eq} or the quantile levels L_{qi} data obtained by sound level meter measurement. The code, developed using the Mathematica 4.0 programming language is valid for independent and identically distributed data obtained by environmental noise measurements (i.e. in many cases of traffic noise), allowing to obtain directly, once the confidence level probability is chosen, the upper (sup) and lower (inf) limits of the confidence interval by analyzing the n elements of the data set acquired. In this paper, furthermore, is shown the theoretical basis of the proposed algorithm.

Key-Words: - Environmental Noise Measurements, Leq, Uncertainty, Bootstrap Method.

1 Introduction

It is well known that environmental noise levels can vary over a wide range as a result of the diversity of site conditions and activities occurring during field measurements. Environmental noise very often occurs in the form of randomly fluctuating sound signals. To quantitatively describe this phenomenon, noise indices such as equivalent pressure level L_{eq} and quantile levels L_q are widely used and are expressed in decibels relative to a reference pressure of 20 μPa. In practice when performing a measurement with a sound level meter, the acoustic sound pressure level p(t) is transformed into a discrete set of equivalent levels Lst(t_i) gived by $L_{st}(t_i)$=20 log10 $(p(t_i)_\tau/p_0$, where $(p(t_i)_\tau$ denotes the time average of the absolute value of p(t) in the interval $[t_i, t_i+\tau]$ and p_0 the reference pressure.
Generally, an experiment designed to determine the value of a parameter L_{true} will do this by applying an appropriate transformation to the measured data set D_0. The obtained value for the parameter L_0 for this data set will probably differ from the true one due to the effects of the errors throughout the experiment chain and in the physical phenomenon under study. In most physical experiments there will be a random component affecting the data set so that even repeating it under identical stationary conditions, which can be viewed as re-extracting from the distribution describing the physical measurement D, different data set realizations D_i will be formed.
A number of authors have already made significant contributions in this field. Craven and Kerry [2], for example, recommends the uncertainty budget method for estimating uncertainties in environmental noise measurements. The separate uncertainties associated with each of the variables affecting the measured noise level are added together to derive a combined overall uncertainty. Because of limited time and resources, each component of the overall uncertainty must normally be estimated based on scientific judgment or practical experience rather than be determined from the results of a large set of repeated observations. Craven's approach follows the recommendations of the "Guide to the expression of uncertainty in measurements (GUM ISO Publication 6461-3:1995) which states that uncertainty estimations could be obtained based either on a professional judgment or on real data. Indeed other authors have also adopted this methodology to estimate uncertainties in noise prediction methods.
On the other hand Farrely and Brambilla [1] introduced a methodology to calculate the uncertainty based on bootstrap method. This method was proposed by Bradley Efron in 1979, with the purpose to calculate the standard error of a parameter of a population. In few years, this procedure has had a rapid evolution and now is one of the most used technique of re-sampling of data set.

2 Problem Formulation

Because of the difficulty in the application of the norm ISO IEC 13005 for the determination of the uncertainty in environmental measurements, a different approach has been used by using the bootstrap method.
In the present paper is described the method and the way to applicate it to the measurement of the environmental noise, with the purpose to evaluate of the confidence limits of the measure of specific parameters like the quantile levels, Lq and the sound pressure equivalent levels, Leq.
It needs nevertheless to underline that the method is valid for independent and identically distributed data set, but it

can simply be applied to the treatment of dependent data set.

2.1 The bootstrap method

The bootstrap is used to say with how much accuracy a certain statistic s(x) calculated on data observed represent the corresponding quantity reported to the whole population. The problems of statistic inference involve the respect of some aspects of the distribution function of the probability F of the population under observation, on the base of the empirical distribution function $\hat{F}$. The $\hat{F}$ is an enough statistic of the F; this means that all the informations concerning F contained in x are also contained in $\hat{F}$. The bootstrap is a direct application of such principle, known as *plug-in principle*; the hypothesis is that the data x has been produced through a casual sampling on the base of the distribution F.

In the paper we'll indicate with the symbol $\widehat{\ }$ the quantities obtained by the observed data.

If the champion is formed from k independent data, the idea is to extract from it by using simple sampling with repetition many champions of k observations, to the purpose to find the probability that the measure falls inside a predetermined intervals.

The bootstrap sample is the native sample in which, because of the extraction with repetition, some data are repeated and others, to maintain the same number of observations, are absent. Each of these laces of k observations can contain two or more identical values, with the obvious exclusion of other values that are inside the original sample. They are called bootstrap samples and each of them allows to get an evaluation of the desired statistic.

In order to give a methodology it is possible to state the following steps:

Starting from an observed dataset $x=(x_1, x_2, \ldots, x_k)$, obtained in random way from a population with unknown probability distribution function F, we need to estimate the $\theta=t(F)$ parameter. With this purpose we calculate an assessment of it $\hat{\theta} = s(\mathbf{x})$ on x.

The bootstrap method allows to estimate the standard error of $\hat{\theta}$, in order to obtain information on its accuracy. By using a random sampling with repetition, we extract from x, k data making n bootstrap samples, each of them formed of k elements. In this way we can associate to each element of the observed sample a probability of 1/k to be extract and then the empiric $\hat{F}$ function is a discrete distribution. The random sampling procedure guarantees the independence of data. In these way it is possible to construct a virtual population of n laces of k data.

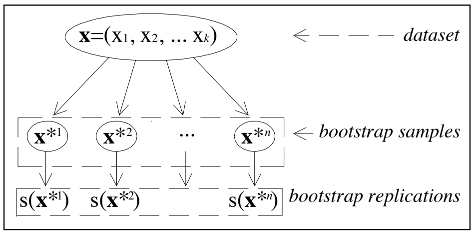

Fig. 1: Scheme of the bootstrap process.

The bootstrap assessment $se_F(\hat{\theta})$ (the standard error of the statistic) is a plug-in value that uses the function of empirical distribution $\hat{F}$ instead of F, that is not known. In particular the bootstrap assessment of $se_F(\hat{\theta})$ is defined as $se_{\hat{F}}(\hat{\theta}*)$. The quantity $se_{\hat{F}}(\hat{\theta}*)$ is defined as the ideal bootstrap value of the standard error of $\hat{\theta}$.

In conclusion after calculating the bootstrap replications of $\hat{\theta}$ (the $\hat{\theta}*$) we calculate the standard error of $\hat{\theta}$ by calculating the empirical standard deviation of the replications of the n bootstrap data set:

$$\hat{s}e_n = \sqrt{\frac{\sum_{b=1}^{n}\left[\hat{\theta}*(b) - \hat{\theta}*(\cdot)\right]^2}{n-1}} \qquad (1)$$

Where

$$\hat{\theta}*(\cdot) = \frac{\sum_{b=1}^{n}\hat{\theta}*(b)}{n} \qquad (2)$$

By increasing the generated bootstrap samplings number n, the empirical standard deviation stabilizes to a limit value:

$$\lim_{n\to\infty}\hat{s}e_n = se_{\hat{F}} = se_{\hat{F}}(\hat{\theta}*) \qquad (3)$$

That represents the bootstrap assessment of $se_F(\hat{\theta})$.

The ideal bootstrap value $se_{\hat{F}}(\hat{\theta}*)$ and its approximation $\hat{s}e_n$ are called many times non parametric bootstrap assessments.

In order to determinate how many bootstrap replications are necessary to consider to obtain an accurate value of the standard error we consider the coefficient of variation of $\hat{s}e_n$ defined by:

$$cv(\hat{s}e_n) = \sqrt{cv(\hat{s}e_\infty)^2 + \frac{E(\hat{\Delta})+2}{4n}} \qquad (4)$$

In which $\hat{\Delta}$ is $\hat{m}_4/\hat{m}_2^2 - 3$ and $\hat{m}_i$ is de i-th moment of the bootstrap distribution of s(x*).

The bias value is defined as the difference between the expected value of the estimator $\hat{\theta} = s(\mathbf{x})$ and the quantity to esteem θ.

$$bias_F = bias_F\left(\hat{\theta},\theta\right) = E_F[s(\mathbf{x})] - t(F) \quad (5)$$

and

$$bias_{\hat{F}} = E_{\hat{F}}[s(\mathbf{x}^*)] - t(\hat{F}) \quad (6)$$

For the calculation is possible to approximate the expected value $E_{\hat{F}}[s(\mathbf{x}^*)]$ with the mean value $\hat{\theta}^*(\cdot)$

$$E_{\hat{F}}[s(\mathbf{x}^*)] = \hat{\theta}^*(\cdot) = \frac{\sum_{b=1}^{n}\hat{\theta}^*(b)}{n} = \frac{\sum_{b=1}^{n} s(\mathbf{x}^{*b})}{n} \quad (7)$$

The bootstrap assessment of the $\hat{bias}_n$ based on the n replications is:

$$\hat{bias}_n = \hat{\theta}^*(\cdot) - t(\hat{F}) \quad (8)$$

In order to give a better approximation of $\hat{bias}_{\hat{F}}$ in this study the re-sampling methods has been adopted [4].

This method can be applied when $\hat{\theta}$ is the plug-in assessment $t(\hat{F})$ of θ=t(F). With this purpose we define a re-sampling vector P*=(P1*, P2*, …, Pk*) with components defined as Pj* = #{xi*=xj}/k with j=1, 2, …, k. A bootstrap replication $\hat{\theta}^* = s(\mathbf{x}^*)$ can be guess as a function of the re-sampling vector P*. once defined the re-sampling vectors it is possible to calculate their mean value:

$$\overline{\mathbf{P}}^* = \frac{\sum_{b=1}^{n}\mathbf{P}^{*b}}{n} \quad (9)$$

The best bootstrap assessment of the bias is:

$$\overline{bias_n} = \hat{\theta}^*(\cdot) - T(\overline{\mathbf{P}}^*) \quad (10)$$

And the corrected estimator is:

$$\overline{\theta} = \hat{\theta} - \hat{bias} \quad (11)$$

In which $\hat{bias}$ can be set equal to $\hat{bias}_n = \hat{\theta}^*(\cdot) - \hat{\theta}$ and then:

$$\overline{\theta} = 2\hat{\theta} - \hat{\theta}^*(\cdot) \quad (12)$$

2.2 The confidence interval

Often the standard error is used to give a confidence interval of the considered θ parameter. Given an estimator and valued the standard error, the confidence interval for θ is:

$$\hat{\theta} \pm z^{(\alpha)} \cdot \hat{s}e \quad (13)$$

In which $z^{(\alpha)}$ is obtained by the normal distribution.

For the confidence interval calculation several method are used like the bootstrap-t, the BCa (Bias Corrected and accelerated), the ABC (Approximate Bootstrap Confidence).

In the developed computer code the bootstrap method has been used. By using this method it is possible to remove the hypothesis of normal distribution of data.

After generating the n bootstrap samplings x1*, x2*, …, xn*, for each one the z*(b) value is calcole as:

$$z^*(b) = \frac{\hat{\theta}^*(b) - \hat{\theta}}{\hat{s}e^*(b)} \quad (14)$$

In which $\hat{s}e^*(b)$ is the assessment of the standard error of $\hat{\theta}^*(b)$ for the bootstrap sample xb*. The α-th percentile of z*(b) is estimate from the value $\hat{t}^{(\alpha)}$ t.c.

$$\left\{z^*(b) \le \hat{t}^{(\alpha)}\right\}/n = \alpha \quad (15)$$

In conclusion the confidence interval obtained from the bootstrap-t method is :

$$\left[\hat{\theta} - t^{(1-\alpha/2)}\hat{s}e, \hat{\theta} + t^{(\alpha/2)}\hat{s}e\left(\hat{\theta}\right)\right] \quad (16)$$

This method is particularly effective when as estimator we choose a position parameter as the mean value, or the median or the percentile levels.

3 The application of the bootstrap method to the environmental noise measuring

More than few difficulties are been found in the application of the norm CEI 13005, with the purpose to express the uncertainty connected to the measurement of environmental noise. First of all it necessary to observe that phonometric measurements are effected mainly in the open space, where environmental conditions are extremely varying in the space and in the time and in frequencies of the acoustic signal. Insofar the uncertainty connected to the attenuation of the sound during the propagation in external environment is not well definable and therefore is not simple to give an assessment of it.

For these reasons a different approach based on the bootstrap method applied to the measured acoustic levels is proposed and a computer code has been developed in Mathematica 4.0 programming language. The code allows the automatic calculation of the uncertainty related to a certain observation period.

The basic consideration is that the environmental noise is made of several independent signals generated by many acoustic sources. Due to the uncorrelated nature of these sources a statistical representation of it is possible. The noise can be considered as a multidimensional aleatory variable. For the acoustical characterization of the phenomenon, once the time constant desired 8slow, fast or Impulse) parameters as continuous equivalent level Leq and percentile levels Lq, referred to a time interval $T = n\tau$,can be used.

$$L_{eq} \cong 10\,\mathrm{Log}\left(\frac{10^{\frac{Lp_1}{10}} + 10^{\frac{Lp_2}{10}} + \ldots + 10^{\frac{Lp_N}{10}}}{N}\right) \qquad (17)$$

The final purpose of the proposed computer code is to calculate to these levels two confidence limits L(p)sup (upper limit) e L(p)inf (lower limit) which delimit a range in which there is a certain probability to have the “true” value Ltrue.

Pointing out with D_0 the measured data set it is possible to evaluate both the Leq and the percentile levels L_{qi} . The value resulting from the measurement is L_0 will be, in general, different from the corresponding L_{true} due to the errors associated to the measurement process. Each D_i data set can be viewed as a realization of the acoustic aleatory phenomenon; for this reason it is possible consider L as a aleatory variable and L_0 as an extracted value from a set of possible data for L. The distribution of L_0-L_i is an assessment of L_{true}-L_i.

If D has a finite variance ad its data are independent, for the central limit theorem, the distribution of their mean value approaches to a normal distribution with the increasing of the number of elements of D_0. This simplify the determination of the confidence limits for Leq by using the standard error. On the other hand the procedure for the Lqi determination in general does not converge rapidly to a normal distribution and, for this reason, it is necessary to apply the a Monte Carlo simulation process in order to generate a number m of data Di sufficient to extrapolate the respective Li.

The sound level meter measure the sound levels (Leq or Lqi), the measured data give the time series D0, from which it is possible to obtain the desired L_0 .The k data of the D_0 series are assumed as assessment of the distribution required from the Monte-Carlo method for the generation of the n data of D_i each one constituted of k elements.(Fig.2)

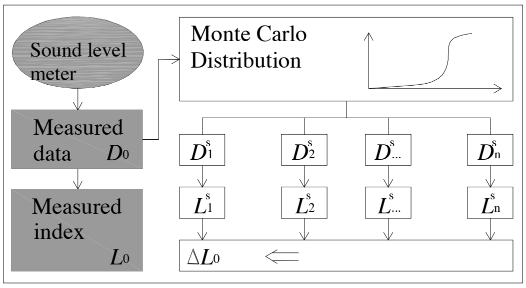

Fig. 2: Scheme of the uncertainty calculation algorithm.

The number n of data set is function of the probability p associated with the confidence interval.

From each data set Di it is possible to obtain Li; finally we obtain a set of n elements, representing the output of the Monte Carlo realizations. In order to determine the the confidence limits of the request index we point the h-th (the greatest or the lowest, $L(p)_{sup}$ or $L(p)_{inf}$) element in the Li data set. The h value is determined from the probability associated to the confidence level:

$$h = \frac{1}{2}\,p \cdot n \qquad (18)$$

Finally the confidence interval amplitude is calculated as

$$DL(p) = L(p)_{sup} - L(p)_{inf}$$

3.1 An application example

The developed computer code read the short equivalent levels Lp valuated on a time interval of 1/8 sec, from an input text data D_0 of k dimension and first calculates the equivalent level Leq and the quantile levels required Lq:

$$L_{eq} = 10Log\left(\frac{1}{k}\sum_{j=1}^{k} 10^{\frac{Lp_j}{10}}\right) \qquad (19)$$

Starting from the D_0 data set with a repeated simple sampling it generates n array (D^S_1, D^S_2, …, D^S_n) each one of k elements and it calculates k Leq, and Lq.

On the basis of bootstrap repetitions of the k Leq and of the k Lq it calculates the mean value and the middle quadratic discard and subsequently the best bias value of the Leq in the following manner: starting from the D_0 data set and from the bootstrapped nxk matris of the short Leq are generate the resampling vectors for the calculation of the Leq corresponding to each string, by using

$$\boldsymbol{L_{eq}} = 10\,\mathrm{Log}\left(\frac{1}{k}\boldsymbol{Vv}\right) \qquad (20)$$

In which **Leq** represents the vector of the n equivalent levels calculated for each string, **V** is the nxk matrix of the resampling vectors and ***v*** is the vector defined in the following manner:

$$v_j = 10^{\frac{Lp_j}{10}} \qquad (21)$$

with L_{pi} the measured values.

The **Leq** best bias is calculated by substracting from the mean values of the vector components of **Leq** the $10\,\mathrm{Log}(\overline{\boldsymbol{V}} \cdot \boldsymbol{v})$ value.

For example we consider a sample of 32 elements obtained from a real environmental measuring made by the Department of Mechanical Engineering of the University of Salerno [6].

dataset = {5.32, 70.15, 71.97, 68.98, 64.38, 67.59, 71.82, 71.87, 62.91, 70.16, 72.88, 70.86, 70.95, 76.79, 72.27, 71.75, 71.71, 74.83, 68.62, 71.88, 72.46, 62.99, 70.74, 69.45, 68.3, 57.08, 68.83, 73.45, 71.88, 73.98, 73.48, 56.65}.

We calculate:

L_{eq} = 71.2 dB

L_5 = 74.8 dB

L_{90} = 63.0 dB

After the code generates 25 bootstrap samplings and from each one it calculates the Leq, L_5 and L_{90} :
{71.51, 70.28, 70.63, 71.09, 71.58, 71.17, 71.74, 70.94, 70.96, 71.41, 70.94, 69.11, 71.68, 70.51, 71.97, 70.89, 71.66, 70.57, 71.47, 71.04, 71.07, 71.75, 71.37, 71.50, 70.46}
l'L5:
{76.79, 72.88, 73.48, 74.83, 74.83, 73.98, 76.79, 76.79, 73.45, 74.83, 74.83, 72.27, 76.79, 73.48, 76.79, 74.83, 74.83, 73.45, 74.83, 76.79, 73.98, 76.79, 74.83, 76.79, 73.48}
e l'L90:
{57.08, 65.32, 64.38, 62.99, 62.91, 62.99, 62.99, 64.38, 64.38, 62.91, 62.99, 62.91, 62.91, 62.99, 67.59, 57.08, 62.99, 62.91, 57.08, 57.08, 65.32, 67.59, 64.38, 62.99, 57.08}.

We obtain:

Index	Mean quadratic discard	Mean value
Leq	0.61	71.09
L_5	1.46	74.93
L_{90}	3.10	62.57

Table 1: Mean quadratic discard s and mean values of the dataset.

and

Index	Bias
Leq	-0.097
L_5	0.106
L_{90}	-0.421

Table 2: Bias of the dataset

For the best bias estimation the re-sampling **Leq** vector and the re-sampling $\overline{V}_j = \frac{1}{n}\sum_{i=1}^{n} V_{ij}$ vector has been calculated:

Leq = {71.9349, 70.6569, 70.8115, 71.2511, 72.2535, 71.4806, 72.0145, 71.1014, 71.582, 71.7017, 71.4216, 69.8209, 72.09, 70.5104, 72.2266, 71.216, 71.8038, 70.9193, 71.615, 71.3561, 71.6832, 71.8916, 71.6655, 71.7849, 70.6484}.

$\overline{\boldsymbol{V}}$ = {0.0375, 0.02, 0.03, 0.03375, 0.03125, 0.035, 0.02, 0.025, 0.035, 0.035, 0.03875, 0.02875, 0.035, 0.0325, 0.04375, 0.03375, 0.03125, 0.02875, 0.0325, 0.065, 0.03375, 0.02875, 0.03125, 0.03125, 0.02625, 0.03125, 0.02875, 0.035, 0.065, 0.02125, 0.025, 0.035}.

The best bootstrap bias is -0.0034.

With the purpose to obtain the confidence limits it is now estimates the probability distribution associated to the generic analyzed parameter L_0 by using the bootstrap-t method as discussed in chapter 3.

In the case of the showed example the confidence intervals are for Leq -2.10 and 1.24; for L_5 -3.42 e 1.58; and for L_{90} -1.9 and 1.9.

4 Conclusion

In this paper is an effective computer code developed for real-time evaluation of confidence intervals associated to equivalent levels measurements in environmental noise measurements presented. The code has been developed using the application of bootstrap theory and uses as input the equivalent level L_{eq} or the quantile levels L_{qi} data obtained by sound level meter measurement. The code, developed using the Mathematica 4.0 programming language, is valid in all cases in which it is necessary to calculate the limits of the confidence interval in a environmental noise measurements data set of independent and identically distributed data.

A numerical example provide to show the obtained results operating on a representative short data set. Of course the code allows to operate automatically on a numerous data set obtained from a long time measurement operation, and allows to give judgment of the quality of the environmental investigation without apply the classical uncertainty theory.

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