

A WEB INTERFACE FOR THE ANALYSIS AND PERFORMANCE OF ALEATORY MUSIC NOTATION

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ABSTRACT

Black and White n.2 is a collection of 120 exercises for keyboard instrument(s) written by the Italian composer Franco Donatoni. Conceived as aleatory music, this composition adopts a non-conventional way to encode the score where some parameters are fixed and others are left to chance. In this work, we will describe a Web-based framework that, after inserting user-defined scores in Donatoni's notation, is able to automatically produce score versions compatible with the composer's constraints and executable by a human player. This application produces modern staff notation and can perform it via the Web Audio API. The goal is on one side to revive the interest towards aleatory music literature, and Donatoni's repertoire in particular, and on the other to investigate the compositional and computational process that originate a given score out of many aleatory variants.

1. INTRODUCTION

In order to define *non-conventional music notation*, often the reference is the so-called Common Western Notation (CWN), namely the archetypical notation system used by composers and performers when they compose, write, and play Western music. In a strict interpretation, all the scores generated in other cultural, historical, geographical contexts far from Western world contain non-conventional music notation: this would be the case of early medieval notation [1] – including *neumes*, still in use for Gregorian chant – or Indian *rāgas*, the melodic modes used in traditional South Asian music genres [2]. In the mentioned cases, scores seem non-conventional to Western non-experts only because they appear far from modern staff notation, but conversely there is broad agreement among practitioners on both notational rules and score-symbol performances.

Narrowing the field to Western culture and contemporary music, non-conventional notation appeared in order to address a range of experimental concerns. For example, during the first decades of the 20th century some innovations were introduced as a consequence of new composition and performance techniques, such as tone clus-

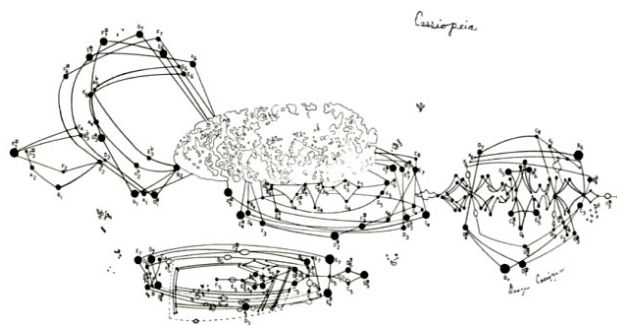


Figure 1: An example of non-conventional score: *Casiopeia* by George Cacioppo.

ters and microtonal composing. In the 1950s and '60s – the golden age for graphic notation – the composers of the New York School (including John Cage, Morton Feldman, Earle Brown, and Christian Wolff) began experimenting with indeterminacy and investigated graphic notation as a way to restrict and reinvent the information provided to performers [3]. Back in 1969, John Cage and Alison Knowles collected an anthology of excerpts from hundreds of notated musical scores [4], often non-conventional as the one shown in Figure 1. Fourty years later, Theresa Sauer – a musicologist who turned to studying graphic design – acknowledged this work by publishing a new collection of notation examples close to the field of visual art [5].

The need for non-conventional notation was triggered not only by the artists' desire to conduct aesthetic experiments or break established rules, but also by a number of practical issues due to the advent of electronic and tape composition: new types of musical instruments – with unprecedented expressive potential concerning timbre, articulation, etc. – required brand new ways to encode scores. The issue of how to properly describe electroacoustic music has been addressed in many works, including [6, 7, 8].

The goal of this paper is to show how the power of Web interfaces can be leveraged to study, exploit and revive specific forms of non-conventional notation, providing support tools oriented to both music analysis and performance. Our case study is focused on *Black and White n.2*, a collection of 120 keyboard pieces written in 1969 by the Italian composer Franco Donatoni [9]. Noticeable example of aleatory composition, its notation recalls the principles of tablature, since the score indicates performance actions

(specifically, instrument fingering) rather than pitches [10], thus leaving ample freedom to choose most music parameters.

This work is structured as follows: Section 2 addresses the problems related to the representation of non-conventional notation on a computer system and in a Web environment, Section 3 focuses on *Black and White n.2* and provides details to decode this aleatory-music score, and Section 4 discusses the Web interface implemented and publicly released as a research result.

This paper can be somehow referred to an earlier work entitled “Automatic Performance of Black and White n.2: The Influence of Emotions Over Aleatoric Music”, which was presented during the 9th International Symposium of Computer Music Modeling and Retrieval held in London in 2009 [11]. That proposal concerned an automatic approach to extract emotion-related parameters from the analysis of a video, and described a computer system capable of mapping such results on the aleatory score of *Black and White n.2*, thus generating a suitable soundtrack. In this work the goals are different and varied, ranging from the rediscovery of Donatoni’s aleatory music repertoire to the comprehension of his notation and the analysis of resulting computer-driven performances.

2. REPRESENTATION OF NON-CONVENTIONAL NOTATION IN COMPUTING

According to some experts, the printed score can be seen as a mediator of meaning. It is possible to identify two approaches to music notation typically followed by players: a *reproductive* approach and an *explorative* one [12]. In the former case, the function of the printed score is that of an explicitly normative document which prescribes how to play; in the latter, the function is an invitation to seek out implicit meaning according to the musicians’ individual judgment. Both the approaches can occur only within a frame of agreed understanding shared with the composer, and this process can be challenging when notation rules are non-conventional, or their interpretation is intentionally left to the performer.

Due to the large variety of notations adopted in contemporary music, the representation of non-conventional scores – concerning both editing and computer-driven performance – is a huge and still open problem in the field of computing.

From the former point of view, namely editing, many music scores are far from CWN conventions and closer to figurative art, and score writers such as Finale, MuseScore or Sibelius – mainly conceived for common notation – are not adequate. In this case, different approaches are available in order to obtain a score in the digital domain: scanning a manuscript version, pushing the behavior of a traditional score editor as far as possible (e.g., by changing the default music font or inserting custom symbols as drawings), adopting a notation style that can be generated and edited through existing software (e.g., by using a graphics editor to combine the common notation produced by available score writers and graphic information entered via a digital drawing tablet), etc.

The other task, related to computer-driven performances of score symbols entered with one of the mentioned approaches, is hard to achieve as well. Narrowing the field to Web platforms, there are a number of experiments of simultaneous visualization and listening of non-conventional scores – for instance, there are dedicated YouTube channels – but often synchronization is hard-coded into the media and consequently these experiences do not offer any possibility of interaction. Conversely, institutions and research centers are more interested in investigating music processes, and the interfaces they design aim to highlight such processes in music notation and make them emerge through user interaction. From this point of view, an early experimentation via Web was conducted by INA-GRM:¹ interactive-listening examples are still available in the section named *Portraits polychromes*, unfortunately most of them require custom browser plugins such as Apple QuickTime and Adobe Shockwave.

A good compromise is offered by W3C-compliant² formats and Web platforms designed both to let untrained users enjoy music and to support music education and musicological investigation. Examples are music-oriented multilayer representation formats, capable to carry symbolic and structural information, multiple notation styles (including non-conventional scores), and audio information. For instance, the IEEE 1599 format is a standard conceived to describe and synchronize the information related to a music piece in all its aspects [13]. A Web player supporting IEEE 1599 documents is available at <http://emipiu.di.unimi.it>. This interface shows how non-conventional scores such as tablatures for lute, Labanotation for ballet, neumes for Gregorian plain chant, and even graphical scores for contemporary music can be linked to transcriptions in modern notation and synchronized with audio content, thus supporting interactive score following [14].

From this overview on available approaches and tools to write, edit, visualize and perform non-conventional notation, it is evident the need to design a context-tailored environment able to support a specific notation, thus releasing a solution customized for a given set of semantic and syntactic rules. This is the approach we will discuss in the next section to revive *Black and White n.2*, an aleatory music composition by Franco Donatoni.

3. AN EXAMPLE OF ALEATORY MUSIC: BLACK AND WHITE N.2

Black and White n.2 is a collection of 120 pieces written by the Italian composer Franco Donatoni. They can be played on any keyboard instrument, including piano, harpsichord, celesta, mute controller, etc. Performances for two and three keyboard instruments are allowed as well. This composition belongs to *aleatory music* – a definition first provided in [15] – since some primary parameters of the composition are not predetermined, rather their values depend on random processes or extemporary decisions made

¹ Institut National de l’Audiovisuel – Groupe de Recherche Musicales, <http://www.inagrm.com>.

² World Wide Web Consortium, <https://www.w3.org>.

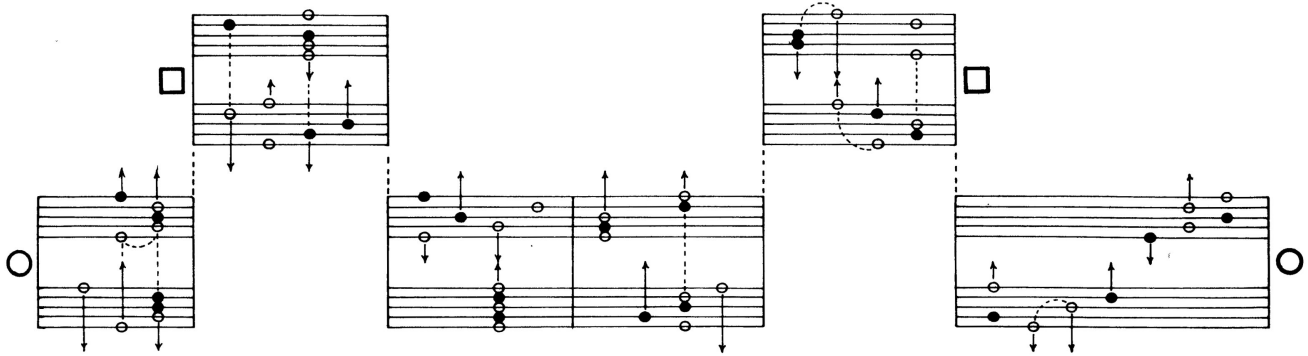


Figure 2: An exercise from the original score of *Black and White n.2*.

by the performer.

In the score preface, the author briefly explains the set of rules to read the score, significantly different from modern staff notation, as shown in Figure 2. First, the two staves usually assigned to standard keyboard notation (i.e. the grand staff) in this case do not carry pitch and rhythm information, but a sort of tablature for piano. Each staff line corresponds to a specific finger, consequently only staff lines (and not spaces) are allowed to host music symbols. For the right hand, the lower line corresponds to the thumb and the upper line to the little finger, and vice versa for the left hand. A note event can be represented as either a white or a black circle: the former indicates that a given finger should play a white key on the keyboard, the latter forces the corresponding finger to press a black key. Therefore, notation is mandatory in specifying which fingers should be used to press keys of a given color.

Conversely, the melodic, rhythmic and harmonic aspects of the composition – the information commonly carried by a traditional score – are left to the performer’s extemporary interpretation. In order to understand the aesthetic and technical purposes of the composition, it is worth recalling the subtitle: “esercizi per le 10 dita”, literally 10-finger exercises.

The instructions a player has to follow, expressed by the author himself in the work’s preface, are:

- The association among symbol positions over lines and fingers is fixed;
- As it regards the color of note symbols, each circle can be either empty or filled, which forces the performer to play either a white or a black key respectively (using the indicated finger, in accordance with the previous rule);
- Each staff system is both preceded and followed by either an empty circle or an empty square. At the beginning of the performance the instrumentalist chooses the association of shapes to dynamics, i.e. if circles should correspond to *ppp* and squares to *fff* or vice versa;
- The concept of chord is associated to the vertical alignment of circles, possibly spanning over the two staves. In the latter case, chords will present the

same dynamics and will be grouped by a vertical dashed line;

- Arrows pointing up or down can be specified chord by chord, thus providing a broad indication about the note range to use: an upward arrow for higher octaves, no arrow for the central region of the keyboard, a downward arrow for lower octaves.
- Dashed slurs provide suggestions about optional *legato* effects.
- Barlines have no specific meaning, since neither time signatures nor rhythmic values are explicitly indicated in the score. Nevertheless, barlines can be seen as a way to embrace a set of chords together, thus providing a sort of structural information.

Since the mentioned set of rules leaves many music parameters to chance or improvisation, for a given score countless score instances and performances are possible. For example, Figure 3 shows a short excerpt from *Black and White n.2* and a number of notated instances that would all meet Donatoni’s requirements.

4. ALEATORY MUSIC OVER THE WEB: BLACK AND BYTE N.2

In order to achieve the goal of reviving Donatoni’s compositional intuitions and notation style, we have designed and implemented a Web interface called *Black and Byte n.2*.

The idea is to provide Web users with an intuitive interface specifically designed to explore notation, create new pieces compliant with Donatoni’s rules, analyze possible score translations into modern notation, and finally play the resulting score. It is worth underlining that Donatoni rejected the idea of a prepared performance, and – in accordance with his ideas – our system has been conceived for analysis and training purposes, with no aesthetic or artistic goal. Nevertheless, our proposal addresses a wide audience, including keyboard performers, scholars in musicology, fans of contemporary music, and experts of music technologies.

In the following the design of *Black and Byte n.2* will be analyzed and discussed in all its aspects. As a result of our efforts, the project has been implemented and released at <http://blackandbyte.lim.di.unimi.it>.

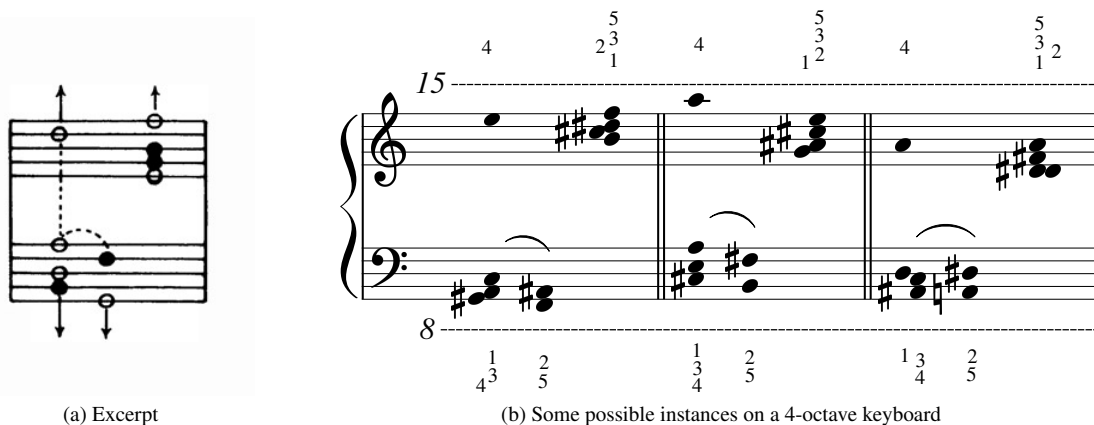


Figure 3: A short excerpt from *Black and White n.2* (a) and some playable variants in modern notation, with the mandatory fingering indicated above and below chords (b).

4.1 Principles of Design

The interface has been designed to take into account the different goals of this work:

1. Supporting Donatoni's notation, in order to rediscover a relevant piece of aleatory music;
2. Allowing the user to extend the original *corpus* of exercises. In our opinion this is perfectly compatible with the composer's original idea, since his creative and artistic work consisted in having established a set of conventions and rules to interpret his custom notation, and not in fixing specific instances of the score;
3. Helping the performer and the scholar in the understanding of the possible translations of the score in terms of modern notation. Since we are dealing with aleatory music, there are virtually endless combinations of pitches that are compatible with a given original fragment;
4. Providing a raw audio feedback to make the user familiarize with the aesthetics of this kind of music.

The layout shown in Figure 4 reflects the mentioned goals. The upper area of the interface contains some metadata (author, title, language) and a drop-down menu to open a multi-language description of rules, a short user guide, and some helpful editing tools. Below, the screen has been divided into two main parts: the upper one to enter Donatoni-style notation, as explained in the next subsection, and the lower one to show the corresponding modern staff notation. By clicking the finalize/reload button between the two sections, a new score instance in the lower area is produced. Finally, a simple media player is displayed at the bottom of the window.

4.2 Data Entry

All the score symbols supported by Donatoni's notation – well exemplified by the excerpt shown in Figure 2 – can be

entered through mouse actions over a double grand staff.³ Clickable positions are quantized with respect to a predefined grid, in accordance with the monospaced original notation.

Upper and lower grand staves contain the note events to be played *ppp* and *fff*; the association of the former and the latter grand staff to music dynamics is left to chance or to performer's decisions. As for Donatoni's exercises, two-hand chords cannot be placed on different grand staves, i.e. only one dynamic level is allowed at any given time.

The main symbols to enter are the black or white circles representing note events, so the simplest mouse action has been assigned to this function: notes are placed through left mouse clicks on grand staves. Left clicks on already existing circles delete previous entries. Any click on a grand staff deletes the simultaneous note events possibly entered on the other. The mouse wheel lets user cycle between black and white note symbols.

Other supported symbols are: i) slurs, drawn by drag-and-drop actions starting on the first event and ending on the last event to tie, ii) up- or down-arrows, entered through left clicks above or below the chord to alter, and iii) additional barlines, placed by left clicks in the area between two consecutive grid positions.

The dashed vertical lines that connect simultaneous chords are automatically placed by the system as soon as two-hand chords are detected. Also the white circles and squares that embed the grand staves are rearranged on the fly on the basis of current entries.

4.3 Algorithmic Computation of Chords

This step can be seen as the automatic process that transforms the original score, entered in the first phase, into modern staff notation. Please note that score symbols are not merely converted from a kind of representation to another (like providing a modern transcription of neumes), but they must be inferred from the application of a set of generative rules. Consequently, the algorithmic computa-

³ Please remember that here the grand staff is used to represent piano tablature instead of common notation.

FRANCO DONATONI
BLACK AND WHITE N. 2

Figure 4: The web interface of *Black and Byte n.2*. The upper part shows a user-defined score encoded through the original notation by Donatoni; the lower part contains a random-generated instance of the score in common notation.

tion of chords requires to satisfy a number of non-trivial explicit and implicit constraints.

As it regards explicit constraints, the score clearly provides the performer with some mandatory indication, for example through instrumental fingering and arrows. Needless to say, not all chords formed by a compliant combination of white and black keys can be performed. Even if in *Black and Byte* the pianist is a computer system, virtually able to play any set of pitches, we decided to produce human-playable score instances. In order to reject unwanted chords, we modeled the hand positions that an averagely skilled pianist can take.

Another example of explicit constraint concerns the keyboard regions for chords, indicated in the score by up- and down-arrows. In this case, the requirements are easier to satisfy, thanks to suitable octave offsets for chords.

Other constraints are implicit and subtler: for example, when both hands have to play in the same region of the keyboard, the system has to detect possible overlaps and crossings and establish what a pianist can reasonably perform.

The process that brings to the choice of a sequence of chords is made of many steps. First, the system is provided with a set of chord models aimed at covering all the com-

binations of pitches that a pianist can easily perform. In order to have flexible but compact data structures, pitches in a chord are encoded in terms of semitone distances from the chord root, whose position is in turn movable in the keyboard. In other words, all the values that define each chord model are relative rather than absolute, and they can be instanced starting from any point of the keyboard. Inside data structures, chord models are clustered based on the number and type of fingers required for their performance.

Please note that the encoded models include not only “traditional” chords such as triads, sevenths and ninths in root position and in their inversions, but also more complex combinations of adjacent/non-adjacent piano keys, tone clusters, etc.

A preliminary selection of candidates is based on finger-related characteristics, that can be retrieved from Donatoni’s notation. The following step consists in verifying if the selected chord model has at least one instance compliant with the white/black key configuration indicated in the score. If one of the mentioned steps fails, as there are no candidates having the required characteristics, a backtracking technique is used to select a new candidate. To adhere to Donatoni’s concept of aleatory music, the choice

of a specific chord model out of many compliant models, as well as the choice of the chord root among many compatible start pitches are left to chance.

From a graphical point of view, it is worth underlining that the production of a syntactically-correct and elegant notation is not easy to achieve. For example, the current clef has to change frequently in order to limit the number of ledger lines. Besides, the output score will typically contain a great number of accidentals, hard to be placed on staff due to note-head overlays and to be correctly shown/hidden in terms of printed and courtesy accidentals. Finally, an important part of the graphical representation is instrumental fingering, shown chord-by-chord either as a verification tool for the algorithm and as an aid to human performance.

4.4 Audio Performance

In order to produce a sound feedback, the Web interface has been equipped with a basic media player, capable of launching a computer-based performance of the score.

For our purposes, audio output is less important than the production of modern notation: in fact, the latter lets the user understand how the composer's ideas can be instanced on different sequences of logic events, an activity that has a high theoretical and musicological valence; conversely, the former is a mere translation of such computed symbols into audio events. Nevertheless, we decided to implement this function in order to give a broad idea of how the exercises from *Black and White n.2* or similar user-defined fragments could sound.

From a technical point of view, two Web-oriented approaches were possible: i) the adoption of the Web Audio API, and ii) the use of the Web MIDI API. At the moment of writing, both solutions are draft under development in the framework of W3C standardization activities.

The Web Audio API provides a powerful and versatile system for controlling audio on the Web, allowing developers to choose audio sources, add effects to audio, create audio visualizations, apply spatial effects (such as panning), etc. [16]. In order to obtain a high-quality output, this approach requires to load instrumental audio samples from the server. Sounds could be synthesized as well, e.g. through additive synthesis techniques, but the audio output would likely sound artificial.

The Web MIDI API specification defines an interface that supports the MIDI protocol, thus enabling Web applications to enumerate and select MIDI input and output devices on the client system and send and receive MIDI messages. The Web MIDI API is intended to enable MIDI applications by providing low-level access to the MIDI devices available on the users' systems [17]. Like in other MIDI-based applications, the resulting sound quality largely depends on the characteristics of the MIDI synth in use.

In addition to a different philosophy (i.e. server-side samples vs. client-side synthesis), an aspect to take into account concerns browser compatibility. As it regards the Web Audio API, most of its features are now available on all major browsers but Microsoft Internet Explorer, be-

ing supported e.g. by Google Chrome, Mozilla Firefox, Opera and Apple Safari in their desktop and mobile versions. Conversely, the Web MIDI API is currently supported only by Google Chrome, even if rumors say that also Mozilla and Microsoft are working on implementations and browser support should be guaranteed within the next year or two.

Moreover, the MIDI approach requires a virtual or physical MIDI chain, formed at least by a software synth installed on the client and equipped with a sound font.

Since cross-platform compatibility from our point of view is highly desirable, our choice fell on the Web Audio API. However, future developments in audio browser technologies could change such a design principle.

5. CONCLUSION

In this paper we addressed the problem of reviving Donatoni's *Black and White n.2* through an interactive Web platform, allowing musically untrained people as well as an expert audience to experiment with a relevant example of aleatory music.

Since at the moment of writing the Web prototype has just been released, an accurate experimentation phase has not been conducted yet, and some research questions are still open. For example: Is this approach effective to achieve the goals mentioned in Section 4.1? Was the interface properly designed to support human performance? Can additional tools be added to improve user experience, such as a step-by-step chord navigator? In the near future we will further investigate these aspects with the help of both untrained and expert users.

Even if we faced problems typical of a given compositional style (i.e. aleatory music) and specific for a given music piece (e.g., the set of rules to infer score instances, keyboard-notation issues, etc.), we think that our general approach and most technical solutions can be generalized to drive the design and implementation of similar platforms.

This activity was carried out in the context of a more general project aiming at the release of free Web tools to support music dissemination, education and analysis. Other applications are available in the Demo section of the LIM official Web site.⁴

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