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Discrete Mathematics and Rechnender Raum (Computing Space)

– Part 1 –

Cellular Structured Space (Rechnender Raum) and Physical Phenomena

– Part 2 –

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Discrete Mathematics and Rechnender Raum (Computing Space)

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Konrad Zuse

Hünfeld

April 1994

Preface

This manuscript summarizes a talk, that Konrad Zuse gave at the DMV/ GAMM workshop "Scientific Computing in der Theoretischen Physik" during March 1994 in Berlin. It also includes an updated version of a previous report. Both deal with "Rechnender Raum", a topic that Konrad Zuse discussed earlier in a book. This work is a unique manifestation of the continuing intellectual freshness of the now 84 year old Konrad Zuse who impresses all those that are in contact with him. Through this publication we are happy to convey this impression to a wider public.

Prof. Dr. P. Deuflhard
(President of the Konrad-Zuse-Zentrum Berlin)

Discrete Mathematics and Rechnender Raum (Computing Space)

– *Part 1* –

Lecture

presented at Scientific Computing in der Theoretischen Physik — workshop organized by the *DMV-Fachgruppe Scientific Computing* in cooperation with the *GAMM-Fachauschuß Scientific Computing*, Freie Universität Berlin, March, 16–18, 1994.

1 Introduction

Discrete mathematics got increasing importance during the last years. There are strong similarities to the theory of *Rechnender Raum (computing space)* which has been initiated by the author 30 years ago. The ideas in Rechnender Raum are based on the theory of *cellular automata*. The final goal of these investigations is to substantiate the notion of the cosmos as a gigantic computer, an idea already being discussed by scientists.

Until now only first steps in this direction have been made – with modest, but significant aspects. Figs. 1, 2a and 2b show some examples of *digital particles* in the Rechnender Raum. Here, arrow configurations are propagating in a two-dimensional cellular automaton. In the theory of cellular automata normally rules are employed that determine the new state of a site, i.e. a crossing point of a grid, as a function of the present state of the neighbouring sites. One can take an active version of these rules, determining an action of each site to its neighbouring sites. The author performed some investigations with different and more complicated arrow configurations at Prof. Volmar's research institute at the University of Braunschweig.

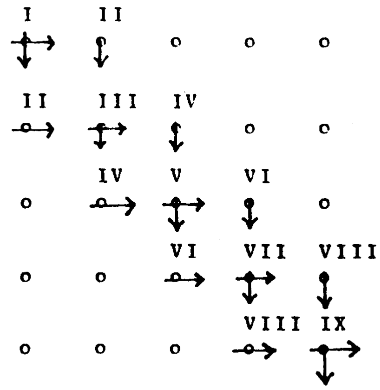

Figure 1: A bipod of two arrows is progressing along the diagonal of a two-dimensional grid, forming a digital particle.

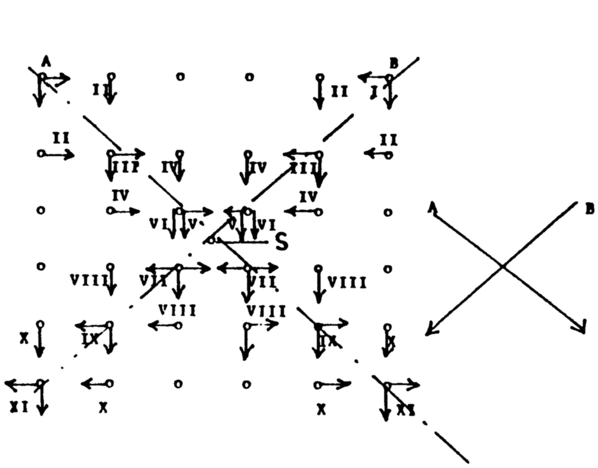

Figure 2a: Two particles are crossing independently without any reaction.

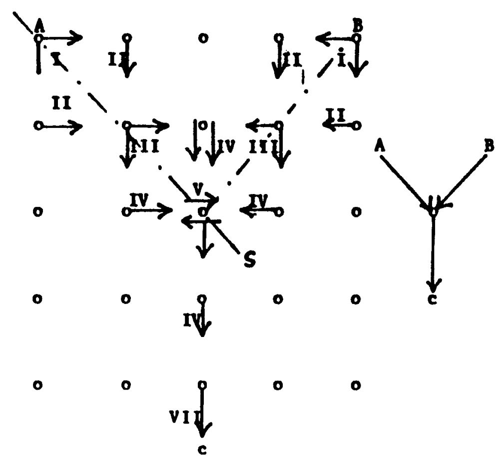

Figure 2b: Two particles are colliding, producing another particle.

Some scientists, for instance Stephen Wolfram [4], investigated the behaviour of cellular automata, especially in one and two dimensions. They found that the complexity of such derivations is rather high.

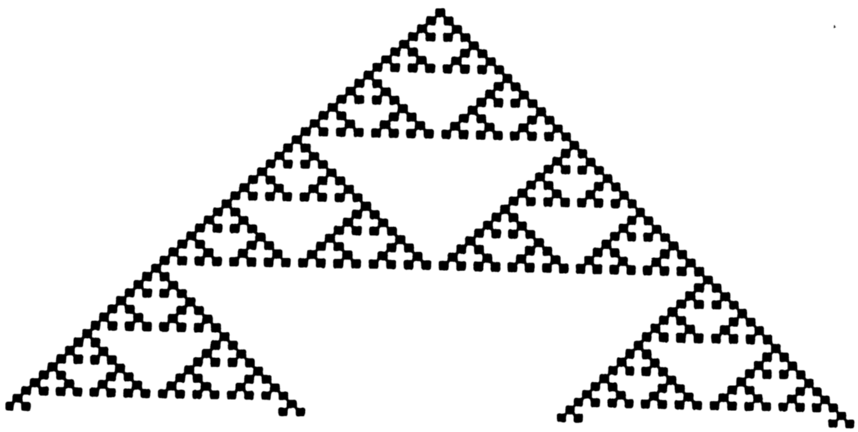

Figure 3: Example of evolution of a one-dimensional cellular automaton with two possible values at each site. Configurations at successive time steps are shown as successive lines. Sites with value 1 are black; those with value 0 are left white. The celluar automaton rule illustrated here, takes the value of a site at a particular time step to be the sum modulo two of the values of its two nearest neighbours on the previous time step. This rule is represented by the polynomial $T(x) = x + x^{-1}$, [4].

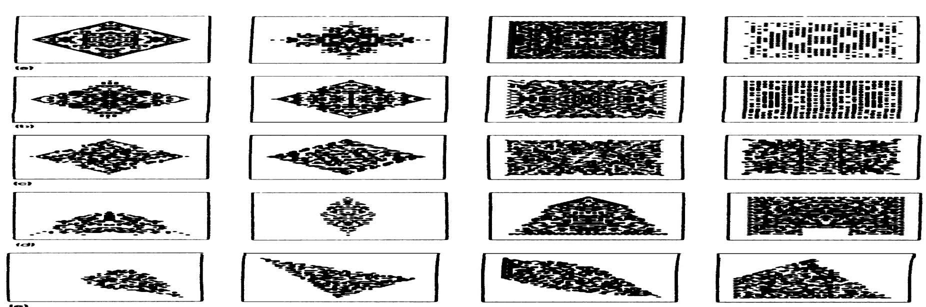

Figure 4: Example of patterns generated by growth from single-site seeds for 24 time steps according to general nine-neighbour square rules with symmetries: (a) all, (b) horizontal and vertical reflection, (c) rotations, (d) vertical reflection, (e) none.

It is not recommendable, even in two dimensional space, to investigate all possible variations of rules and configurations. Therefore only special problems have been investigated. Cellular automata for instance can give useful solutions for lattice gases, corresponding to well-known theories in physics.

Until now it can only be shown that the general idea of the computing cosmos is far from having a solid foundation. Nevertheless, some interesting conclusions that support the concept of the Rechnender Raum are possible.

2 Non-Local Correlation

The problem of non-local correlation can be considered from a new viewpoint: in a cellular automaton a configuration, representing a moving particle, can be placed in different ways on the grid, resulting in different behaviour referring to collisions. A good illustration of this effect is given by the *bishop-principle* in chess (Fig. 5). The bishop related to white squares never can collide with a bishop related to black squares.

A similar effect can be observed in patterns that arise in cellular automata.

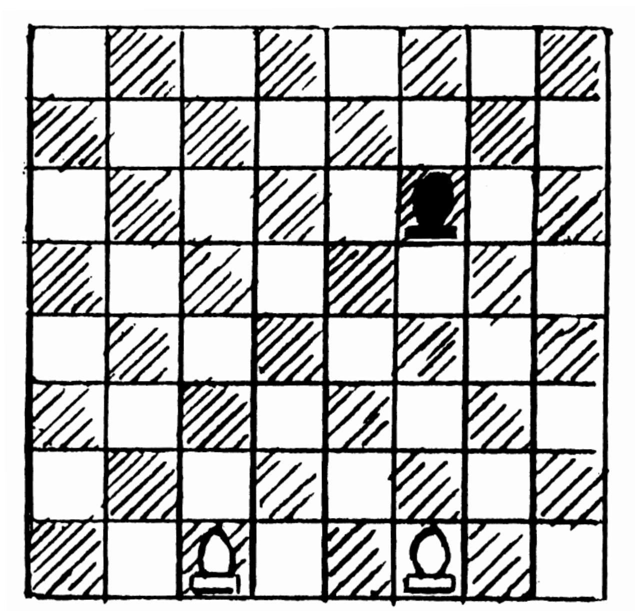

Figure 5: The white bishop related to the white squares never can collide with the black bishop related to the black squares.

This aspect is different from the concept of hidden parameters and may be for instance of some importance for the until now unsolved Einstein-Podolski-Rosen-Paradox.

Instead of hidden parameters it may perhaps be more promising, to look for hidden algorithms, represented by rules of a cellular automaton.

3 Asymmetries and Chirality

Constructing arrow-patterns, moving in a three dimensional grid, you come to a behaviour according to left handed and right handed thread (Fig. 6,7), cf. [6].

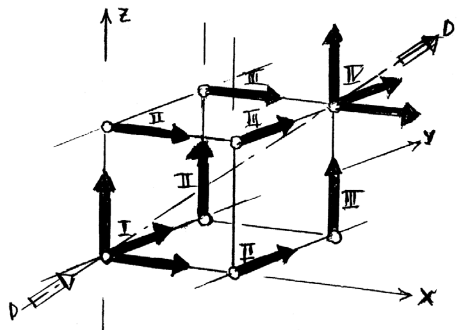

Figure 6: The progression of a tripod rotating clockwise.

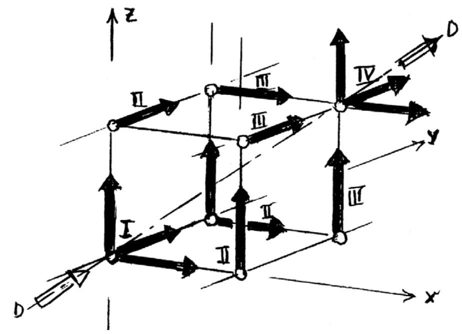

Figure 7: The progression of a tripod rotating counterclockwise.

4 Microstructure of the Cellular Space

In theories of cellular automata often totalistic rules, using for instance the sum of all neighbouring sites, are needed, e.g. in the "life" game. If you try to develop a switching diagram for this purpose, you come to a detailed and rather complicated structure. You cannot solve the addition in one step. You must decide, which spatial dimension should be prefered, i.e. whether the horizontal or the vertical neighbours are considered first. This may lead to new considerations in physics.

5 Microstructure Computability and Theory of Unification

The behaviour of matter depends on the temperature, that means the energy of the particles. We know different aggregate states like solid, fluid and gaseous. The melting process destroys the structure and the configurations (Gestalt) of the solid state. Evaporation also leads to a more disordered state. We can extend this aspect to high energy physics. Simulating such phenomena with computers using the concept of *Rechnender Raum* we may arrive at a new point of view.

In cellular automata there are limits caused by the microstructure of the grid. Phenomena which can be simulated easily in an extended space will show abnormal behaviour on a microscale. The theory of special relativity allows to use the rules of physics even at very high energies. This means that we may work with an interial-system moving nearly with the velocity of light relative to our own system. Using a cellular automaton with a finite distance between grid points, surely there must be limits. But even in the most powerful accelerators until now there are no signs that the standard rules of physics are violated. Nevertheless, we can observe the phenomenon of unification of the so-called coupling constants, for instance concerning the electromagnetical and the weak force.

Physicists are currently developing theories that unify physical laws. As a final goal they look at the grand and complete unification which, from their point of view, would be a final conclusion of physics. The theory of the Rechnender Raum or Computing Cosmos however allows another point of view. The phenomenon of unification shows the limits of our standard physical rules concerning particles with very high energy. This may be more a overcharge of physics than a final triumph. Physicists as Stephen Weinberg and others see clear that going the traditional way will lead to accelerators of ever higher energies, which surmount our economic possibilities. Investigations with a big cellular automaton in the sense of the Rechnender Raum can provide us with new tools, independent of the problem of high energy.

6 Conclusion

The items mentioned above give a general scope of physical problems, which appear in a quite different light when considered from our point of view. As already stated above, until now the theory of Rechnender Raum is investigated only to a small extend. Hard work will be necessary to find step by step useful systems that correspond to the rather complicated laws in physics. Phenomena as a zero-inertial-system, velocities faster than light, the deduction of the physical term of action as a basic switching action in cellular automata and the germ cell idea in comparison with the idea of the big bang will be seen under new aspects.

Until now computer science (Informatik) was only an auxiliary, though important tool for physicists. In future, perhaps this may change. The theory of computing will be integrated in physics, too.

For better understanding, the paper "Cellular Structured Space (Rechnender Raum) and Physical Phenomena" [6] is added in a modified form (several figures are duplicated).

Cellular Structured Space (Rechnender Raum) and Physical Phenomena

– Part 2 –

1 Non-Local Correlation and Asymmetries

The item *Rechnender Raum (Calculating Space)* has been introduced by the author to simulate physical phenomena like the moving of particles in space and their reactions with each other. In the background stands the question, whether the cosmos is a big computer. *Cellular Automata (CA)* offer a good tool for corresponding investigations.

Several steps were made in this direction. An example is the *"life" game* [3]. The behaviour of patterns is studied there, but this has only little relations to physical problems. The author made some investigations with arrow combinations in an orthogonal CA [5]. Figures 1-4 demonstrate some examples. The patterns are formed by arrow combinations. In Fig. 1 a simple arrow moves in its direction through space.

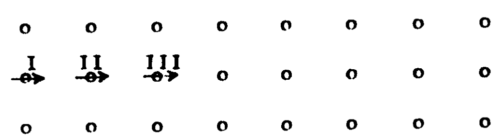

Figure 1: An arrow progressing along a main axis of a grid.

A special law corresponding to Fig. 2 is supposed for arrows crossing at the same grid point.

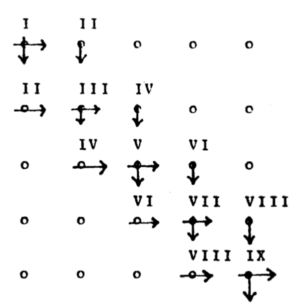

Figure 2: A bipod of two arrows is progressing along the diagonal of a grid, forming a digital particle.

The patterns undergo several phases I, II, ... during the transmission. What happens, if such digital particles are approaching each other ? It may happen that the particles meeting in a point don't collide, but actually pass through each other without an interaction (Fig. 3).

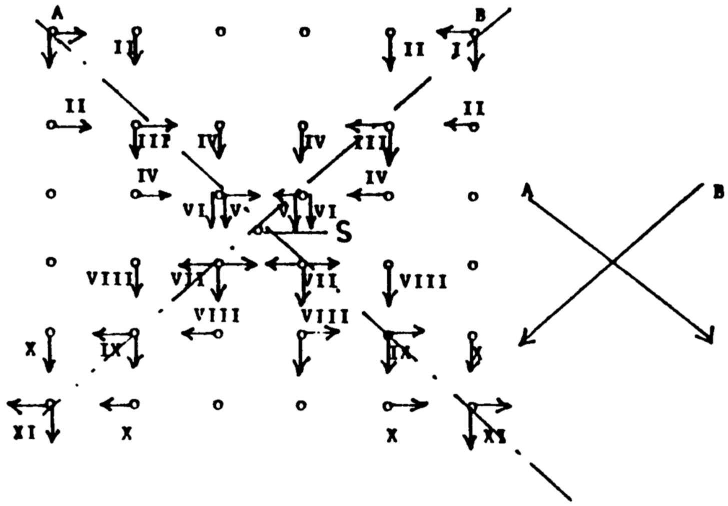

Figure 3: Two particles are crossing independently without reaction.

It may happen as well that they interact, causing an information process. As a result, a new particle could be created, which proceeds in another direction (Fig. 4). If one would demonstrate this effect to a mathematician,

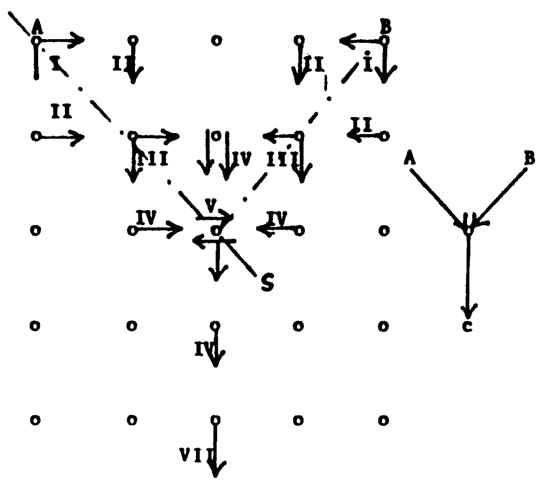

Figure 4: Two particles are colliding and producing another particle.

for instance at a display screen connected to a computer, without telling him that he is watching digital processes, what could he do ? He could only perform measurements and observations and conclude: the particles interact with probability one half. Similar phenomena arise in physics, where the interaction of two quantum mechanical particles is determined by probability laws.

The reason for this different behaviour is demonstrated in Figs. 5 and 6. The two particles A and B react with each other, if the crossing point C is a grid point (Fig. 5), else there is no reaction (Fig. 6). We can divide all grid points in two classes Cl_1 and Cl_2 (Fig. 7). Each diagonal trajectory is assigned to one of the two point classes.

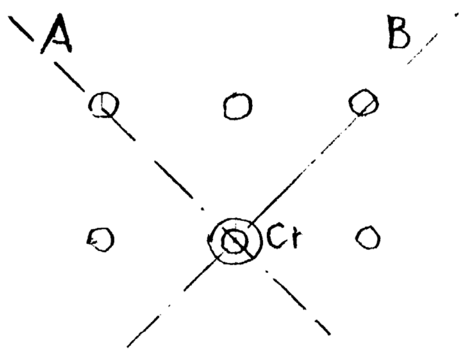

Figure 5: The trajectories of two particles are meeting in a grid point.

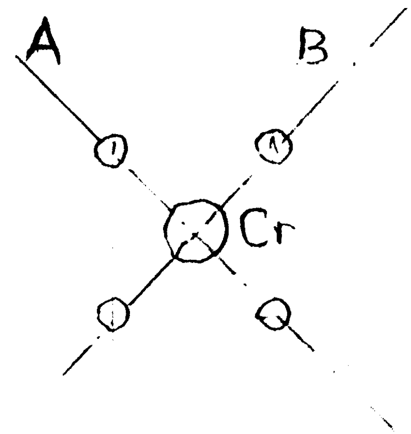

Figure 6: The trajectories of two particles are not meeting in a grid point.

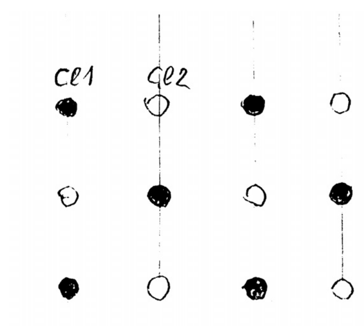

Figure 7: The grid points of a cellular automaton can be divided in two classes.

2 Non-local Correlation

As a result of this view we can state: *space is structured.* But the arrangement of patterns in space is possible in different ways. In a CA, this means that two particles will react only if the intersection point of their trajectories corresponds to a cross-point of the underlying grid.

This assignment is preserved even for long distance. It corresponds to the non-local correlation in physics which is observed in several experiments like the *Einstein–Podolski-Rosen-Paradoxon (EPR-Paradoxon)* [2] or the *Fransen Experiment* [1].

The assignment to different point classes is not the same as the idea of the hidden parameters, which supposes a variation of the pattern of the particle. This is not the case referring to the particle position relative to the grid structure of the automaton. Such problems are discussed very hard by theoretical physicists. Till now no satisfying solution has been found. The hypothesis of *Rechnender Raum*, as discussed above, may provide a new aspect. The so-called *twins* of particles may be produced so that they belong to the same space phase. So, the non-local correlation and the *EPR paradox* easily can be understood.

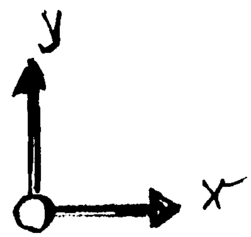

Figure 8a: A bidpod in a two dimensional grid.

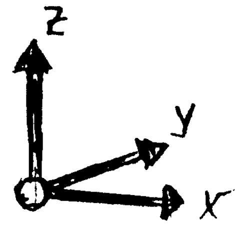

Figure 8b: A tripod in a three dimensional grid.

3 Symmetries in the Space Structure

Going from two dimensions to three, further important phenomena arise. Fig. 8a shows a bipod in two dimensional space corresponding to Fig. 2, Fig. 8b depicts a tripod in three dimensional space. If we try to state the rules of propagation in three dimensional space according to the rule in dimensional space (Fig. 2) we get in a dilemma. As shown in Fig. 9, it is possible to switch the z-component of the tripod as well in the x-direction as

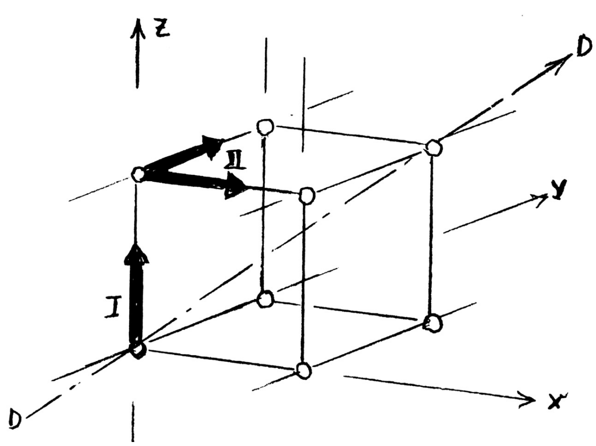

Figure 9: In a three dimensional grid the z-component of a tripod can be promoted in the x- and y-direction.

in the y-direction. The corresponding holds for the x- and the y-component. We have to choose between two possibilities as shown in Fig. 10 and 11.

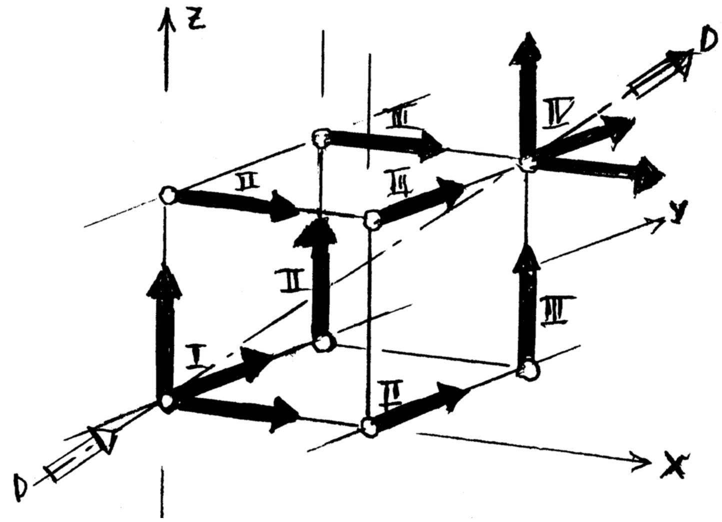

Figure 10: The progression of a tripod rotating clockwise.

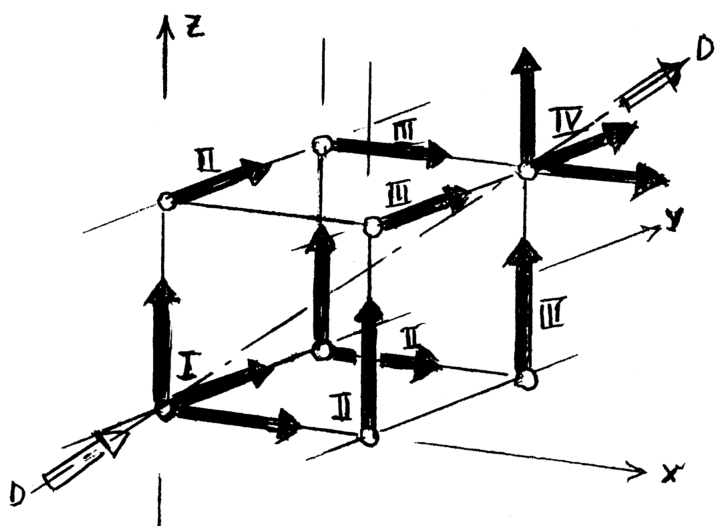

Figure 11: The progression of a tripod rotating counterclockwise.

A tripod xyz is progressing in three phases I, II, and III in the direction of the space diagonal D-D.

Figs. 12 and 13 show the particles projected in the direction of trajectory D-D. So we can recognize left and right in the space.

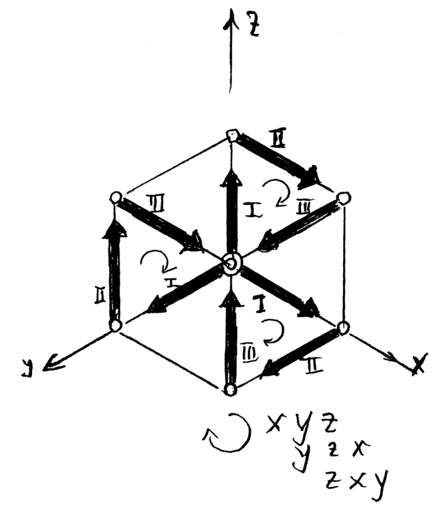

Figure 12: The clockwise rotating tripod seen in the direction of the trajectory.

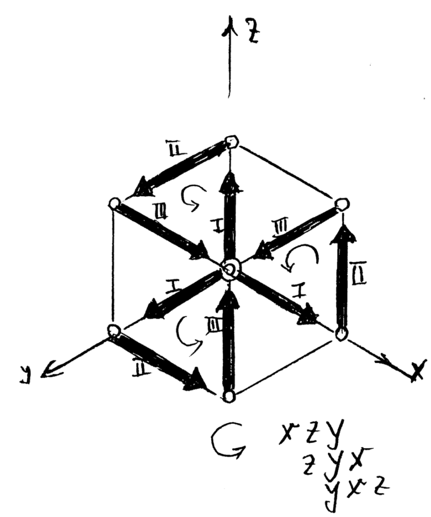

Figure 13: The counterclockwise rotating tripod seen in the direction of the trajectory.

Similar asymmetries are already observed in physical laws. This rotation is not the same as the spin of particles. The different behaviour is a property of the whole space. Contrary to that, we have the choice to assign a positive or a negative spin to particles in the real world. The particles of Figs. 10 to 13 also are positioned relative to different classes of grid points. Surely the possible combinations are more complex.

References

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