Causality and Emergence

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Abstract

This paper tries to show that emergence of any novelty cannot take place without some kind of indeterminism. Determinism and indeterminism both are aspects of reality and they are interconnected. A General Systems Theory has to include indeterminism which apparently exists in most basical systems (e.g. quantum systems) as well as in highly specific systems (human minds and societies).

1 The System

Since the dawning of philosophy, the notion of a "system" has been widely used and was defined in many different ways by different philosophers. The Greek substantive "systema" means as much as "arrangement", or more common, a "whole". All the various definitions and usages of the word "system" have one thing in common: they presume that a system is a (more or less) ordered arrangement of interacting objects, whether these objects are of material or ideal nature.

In his Critique of Pure Reason, Immanuel Kant defines a system as "the unity of manifold cognitions under one idea" [Klaus and Buhr, 1974] According to him, only the (ideal) categories project structure into reality which (without human cognition) is only manifoldness. The materialists on the other hand consider systems as sections of reality, recognizable for the human mind. The German philosopher Herbert Hörz formulated it as follows: "Cognition is possible because, in the universal interaction, objective, relatively isolated, stable systems do exist, whose structures are determined by system laws." [Hörz, 1974]

As this paper is not meant to focus on epistemological questions, I consider the following definition as sufficient for our purposes: *a system is a section of our intuition which is distinguishable from its environment – this means that a border exists – and consists of parts which are interacting with each other*.

2 Determinism and Causality

Another question which is probably as old as philosophy itself is concerning the role chance and necessity play. According to ancient Greek materialism (Demokrit, Leukipp) every event in the world occurs through a necessary cause. This leads us to the term "causality". The principle of causality describes our belief – as human beings – that events in the world occur in an order of cause and effect (*post hoc* and *propter hoc*). This conception which is hardened by our perception and our experience enables us to create models of the world, to form theories which can help us to describe the world and to meet predictions; it is crucial for practising nature sciences at all.

For our purposes, we can define *causality as essential relation between the state of a system at a given "time" t_0 and its state at another "time" t_1*. (The word "time" appears in quotation marks because it does not necessarily correspond to our everyday life conception of time).

In early materialism, the development of nature was strictly determined by one form of cause-effect relation. Contrary to this conception, Aristotle distinguished between four forms of cause [Klaus and Buhr, 1974]:

- *causa materialis* (the material conditions of an event – the substance)
- *causa formalis* (the formal conditions – nature's laws)
- *causa finalis* (the purpose)
- *causa efficiens* (the conditions of the effect)

Strict causality leads us to a deterministic world view, where no degrees of freedom in the development of the world exist. This corresponds to the world view of Newton (*actio est reactio*), Kepler and LaPlace. The whole universe is comparable to a clockwork – what is still needed in this conception is the clock-maker to create the universe and "wind it up". Then he can go to sleep and leave the clockwork by itself.

Despite of its problems, even today this world view is quite common under scientists. In biology it lead to the development of an idea which is known as the Theory of Preformation. It basically postulates that every organism is already preformed with all its parts in the ovum, and from that day on it is only unfolding during the development process. [Klaus and Buhr, 1974] More generally – and projected to the whole history of the universe – it seems to suggest that the whole cosmic development can be seen as the unfolding of those conditions which have been pre-arranged in the big bang and are predetermined since. As everything just happens because of the deterministic laws of nature, there is no place for novelty in such a universe.

3 Problems of the Mechanistic View

Of course, the mechanist/reductionist view raises several problems. The old idea of Heraklit that "the whole is more than the sum of its parts" is neglected. There is no place for the free will of human beings let alone for degrees of freedoms for other systems. It is a static world of the Being without respect to the Becoming that has been proposed by several philosophers (Heraklit, Laotse, Hegel) during all ages.

Nevertheless, the ideas of mechanism were successfully introduced into natural science. From Newton and Gallileo to Einstein, this world view was propagated, and also found its way into biology (Darvinism), psychology (Behaviorism), sociology and other human sciences.

Ludwig von Bertalanffy was one important criticist of this approach. He noticed how mechanistic attitudes had seeped into virtually every area of social behaviour, encouraging doctors to view patients as cases, employers to regard workers as units, advertisers to regard consumers as stimulus-response robots, and television programmers to reduce the public to a set of demographic numbers. [Bertalanffy, 1970]

From the end of the 19^{th} century, a lot of problems arised in reductionist science. The image of a "billard ball universe" in classical physics collapsed, leading to the development of quantum physics. In biology, there were difficulcies in describing the embryo development in a mechanistic way. [Bertalanffy, 1949] Later on, similar problems arised in information science and artificial intelligence research.

Furthermore, the ethic implications of mechanism are problematic because this world view does not leave any space for the free will of human beings. Not only that this is contradictionary to our everyday experience, it also means that our "actions" are determined only by outer circumstances hence none can be held responsible for his/her actions.

4 Emergence of novelty

Emergence can be defined as the appearance of novelty or features at a macro-level that do not exist at the respective micro-level. That means, something new is emerging that cannot be explained sufficiently with deterministic development of the old, or a new macro-level has evolved which cannot be completely described by describing the old parts on the micro-level.

The definition above implies that emergence of novelty cannot be deterministically reduced to the old; otherwise the term novelty would not be appropriate.

The introduction of emergence leads us to a world view which is much more satisfying than the mechanistic approach, as it is more consistent with the world we are experiencing. Aspects as the evolution of matter, of life, of society, and culture can be much more adequately described using the paradigm of novelty.

5 Determinism vs. Indeterminism

Indeterminism is also a very old concept. Epikur was the first philosopher to overcome the strict determinism of the Atomists, when he proposed that the atoms can experience small random (without a cause, i.e. indeterministic) deviations in their trajectories [Bertalanffy, 1949].

Nowadays, mainly two movements in nature science indicate that Indeterminism is probably part of our world as well as determinism is:

- **Quantum physics**
  As long as we are talking about a Quantum system, its development is strictly deterministical and is following the Schrödinger equation [Penrose, 1991]. The reality of the system exists as a superposition of all possible locations and impulses of the system's particles. But as soon as a "measurement" takes place (whatever epistemological meaning this expression has), information is lost. The behaviour of the system changes in an unpredictable way, which allows us to only meet statistical statements.
- **Chaos Theory**
  A non-linear system can get into phases where infinite small variations of parameters can lead to unpredictable variation in future system behaviour. These phases are called Bifurcation points. In these points there are several possibilities for the future phase space trajectory of the system, and it cannot be predicted which possible trajectory will be realized. [Gleick, 1987]

Both theories are (at the first glance) constructions relying on mathematics. But if we believe in the possibility that we can recognize aspects of reality by using our thinking, there is no reason why we should not accept the existence of indeterminism in the world. In both cases the term "indeterminism" – in the sense I am using it - does not mean that everything can happen. Indeterminism occurs only within the boundaries of determinism. This is also the reason why we do not experience indeterministic events at a macroscopic level (e.g. objects that suddenly appear out of nothing).

6 Weak Determinism

Let us imagine a system A and its development along the timeline.

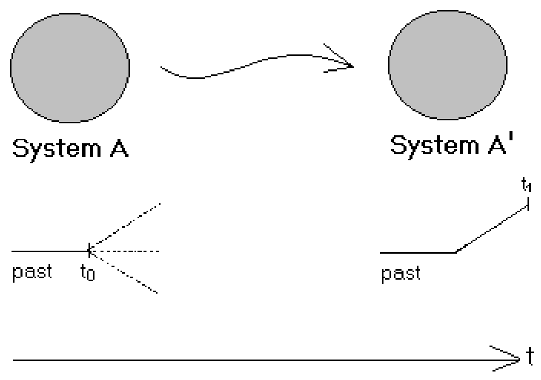

Figure 1

t_0 describes a critical state of the system A, i.e. a state where the system has to meet a decision. There are several ways (degrees of freedom) for the future development of system A, each one with its own probability. It ts possible for us to meet probabilistic statements about the future of A, that means, if we are examining a large number of equivalent systems, we can say statistically, which way most of the systems will behave, but if we look at one single system, it is impossible for us to exactly predict how it will behave.

With simple systems (e.g. physical or chemical), our predictions will be sufficiently enough. But the more complex such a system is (e.g. human minds, societies, the weather), the more difficult it will be to forecast its future behaviour.

The connection between determinism and indeterminism can be depicted as follows:

Causes are necessary, but not sufficient for the emergence of novelty. Determinism confines the possibilities of the future system development. Indeterminism describes the system's degrees of freedom. The development that leads to a critical state of the system can be described deterministically. But at the point of decision (or of Bifurcation) determinism ends.

I think that determinism and indeterminism are both aspects of reality that can be sublated ("*aufgehoben*") in a Hegelian sense into a third one which I, in accordance to Wolfgang Hofkirchner, would prefer to call Weak Determinism ("*schwacher Determinismus*") [Hofkirchner, 2001].

This interpretation is also consistent with Quantum Theory. The development of a quantum system according to the Schrödinger equation is where determinism takes place. The "measurement" corresponds to the point of Bifurcation, where indeterminism comes into play.

7 New Image of Phase Space

Ervin Laszlo was one of the first to apply the Bifurcation metaphor of Chaos Theory to systems. The points where the system has to meet a decision between several possible future trajectories can be compared to the points of Bifurcation in a non-linear iterative equation:

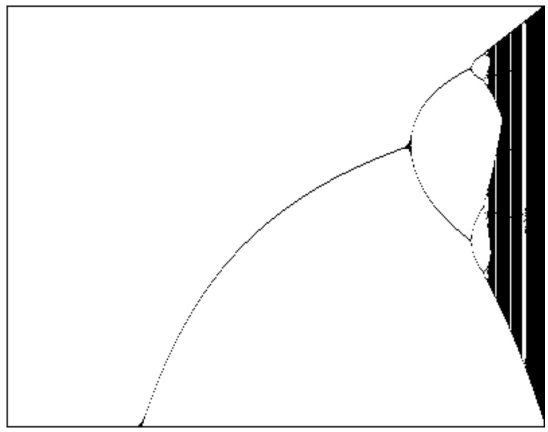

Figure 2

Figure 2 shows a Bifurcation Diagram of the iterative system $x(n+1) = k\ x(n)\ (1–x(n))$. The x axis shows attractors (fixed points) of x for $n\rightarrow\infty$. The parameter k is depicted on the y axis.

Of course, this diagram shows a very simple system with just one parameter (k). For each additional parameter we will need another dimension in phase space, which makes visualization of more complex systems nearly impossible. Furthermore we could have more than two possibilities for the future development of the system in each point of decision (Multi-furcation).

As we came to the conclusion that emergence of novelty exists, we will have to change our picture of phase space. To describe classical systems (e.g. of particles) it is sufficient to use 6 parameters (location and impulse) for each component. When we define novelty as a new attribute that is not reducible on the known parameters of the system, we will have to introduce a new parameter in the moment of emergence. In a mathematical interpretation, the new parameter cannot be seen as a linear combination of the old parameters, so it has to be orthogonal to all basis vectors of the phase space [Kaiser *et al.*, 1985].

As we do not know when (and how many) additional parameters will be required, our picture of a phase space must include a locally different number of dimensions, a space which cannot be thought as statical structure, as its new dimensions only reveal in the development of the system.

"...the very process of emergence will necessarily change the local appearance of phase space, so that the higher level attractors are only created in the process of emergence – leading to the distinction between boundary conditions and constraining conditions." [Andersen *et al.*, 2000]

8 Conclusion and Future Research

As expressed in the above argumentation, I think that several classes of systems show degrees of freedom in their development, real possibilities for the emergence of novelty.

Of course, we know other systems who do not have these possibilities (e.g. classical mechanical systems as a clockwork or a computer). But complex, self-organizing, autopoietic systems as humans and human societies certainly feature such degrees of freedom.

So one interesting topic of research could be the question, which properties are indispensible for a system to possess degrees of freedom. In particular, it should be discussed, whether only self-organizing systems can show degrees of freedoms. If so, can quantum systems be considered "kind of" self-organizing?

Another topic is concerning the sociological implications of this theory. As stated above, systems that can produce novelty necessarily do feature such degrees of freedom. And who could deny that systems like human beings (of course within their social context; a human being is unthinkable without society) have been producing novelty all time since the existence of mankind?

Now the question arises, how individuals and society are interconnected, and how they both influence each other's degrees of freedom. The structuralist approach thinks that all degrees of freedom are on the side of society. In accordance with Christian Fuchs and Wolfgang Hofkirchner, I would propose a picture where on the one side the individuals are influencing society with their personal norms and values. On the other hand they are infuenced by societal norms and values. [Fuchs *et al.*, 2001] Both sides cannot be separated, and both ways of influence are not strictly deterministic. This idea still has to be worked out in detail, and this could also be an issue for future discussions.

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