On Emergence and Wheeler's dream

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Abstract

In this essay we take a quick look at the concept of cellular automata and use it as the link between Wheeler's information-theoretic framework and the concept of emergence in order to identify whether information or material objects (and their interactions) are fundamental.

1 Introduction

Modeling and simulation are disciplines of major importance for science and engineering. There is no science without models, and simulation has nowdays become a very useful tool, sometimes unavoidable, for development of both science and engineering. But, what is in a model?

A natural way to describe a physical system is to propose a model of what we think is happening. During this process we usually retain only the ingredients we believe to be essential in order to capture the behaviour we are interested in. Using an appropriate mathematical machinery, such model can then be expressed in terms of a set of equations whose solution gives the desired answers on the system. The description in terms of equations is very powerful and corresponds to a rather high level of abstraction. For a long time, this methodology has been the only tractable way for scientists to address a problem.

Another approach which has been made possible by the advent of fast computers is to stay at the level of the model. The idea is that all the information is already contained in the model and that a computer simulation will be able to answer any possible question on the system by just running the model for some time. However, the degree of reality of the model depends on the level of description we expect. When we are interested in the global or macroscopic properties of a system, the microscopic details are often not relevant. It is therefore a clear advantage to invent a much simpler microscopic reality, which is more appropriate to our numerical means of investigation. In the framework of Cellular Automata, this last step is usually very intuitive and require little development time.

1.1 What is a Cellular Automaton?

Cellular automata (CA) are dynamical systems which consist of a finite-dimensional lattice, with each site (or cell) containing a finite number of information bits (or states), that evolve in discrete time steps obeying a set of homogeneous local rules which define the systems dynamics, much as is the case for a large class of continuum dynamical systems defined by partial differential equations [**?**].

The main attractive feature of CA is that they provide simple models of complex systems. They exemplify the fact that a collective behaviour can *emerge* out of the sum of many, simply interacting components. Even if the basic and local interactions are perfectly known, it is possible that the global behaviour obeys new laws that are not obviously extrapolated from the individual properties, as if the whole is more than the sum of all parts. This properties makes CA a very interesting approach to model physical systems and in particular to simulate complex and non-equilibrium phenomena. Wolfram has argued that underneath the laws of physics as we know them today it could be that there lies a very simple program from which all the known laws emerges [**?**].

Since some of the most engaging and perplexing natural phenomena are those in which highly-structured collective behavior emerges over time from the interaction of simple subsystems: i.e. large number of H_2O molecules collected in a box will manifest solid, liquid, and gas phases. Thus, we find it necessary to analyze what it is meant by the *emergence* of global behaviour.

2 Emergence

Emergence is generally understood to be a process that leads to the appearance of structure not directly described by the defining constraints and instantaneous forces that control a system. Over time "something new" appears at scales not directly specified by the equations of motion. An emergent feature also cannot be explicitly represented in the initial and boundary conditions.

In his definition of Emergence, Clayton substitutes the doctrine of *Ontological physicalism* by the more neutral doctrine of *Ontological monism* [**?**]:

> Moreover, rather than treating all objects that are not "recognized by physics" as mere aggregates, it suggests viewing them as emergent entities (in a sense to be defined). Thus it might be more accurate to begin with the more neutral doctrine of ontological monism:
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> - *Ontological monism*: Reality is ultimately composed of one basic

> kind of stuff. Yet the concepts of physics are not sufficient to explain all the forms that this stuff takesall the ways it comes to be structured, individuated, and causally efficacious. The one 'stuff' apparently takes forms for which the explanations of physics, and thus the ontology of physics (or 'physicalism' for short), are not adequate. We should not assume that the entities postulated by physics complete the inventory of what exists. Hence emergentists should be monists but do not need to be physicalists in the sense that physics dictates their ontology.

Here we have found a decisive point to decide if Wheeler's dream is attainable. Even as emergence theories presuppose that the project of complete explanatory reduction is finally impossible, the use of the ontological monism doctrine allows us to declare that the universe is fundamentally material, validating the realist thesis that the "Bit" supervenes the "It".

3 Conclusion

Something that exist is defined by its properties, which could be understood as the answers to fundamental questions about the ob ject of our study. Thus, information emerges from our perception of the reality of things. One can argue then that information has to do with pattern recognition. We could then reverse this idea an impose rules (or laws) of interaction of the constituents of a primordial medium, so that the emergent phenomena represent reality.

Like the emergence of complexity in cellular automata, reality could be the result of growing patterns produced by the evolution of an self-evolving, self-regulating computer code. However, there must be a primordial reality in which this information is being encoded.

References

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