Wolfram Model and the Technological Architecture of the Fourth Industrial Revolution

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Abstract
In this essay, we will defend the thesis that the multi-computational paradigm is a natural way of thinking about the fourth industrial revolution. This will be done considering the geometry that emerges as the continuum limit of multiway systems.

1 Introduction

1.1 What is the fourth industrial revolution?

To understand the nature of the people one must be a prince, and to understand the nature of the prince, one must be of the people.

Niccolo Machiavelli

According to the founder of the World Economic Forum, Klaus Schwab [Sch15], the main economic activity of highly developed countries is evolving from the paradigm of the third industrial revolution, characterized by
the automation of specific industries, to the paradigm of the so-called fourth
industrial revolution, where the scope of automation is extended to encompass
the entire society. In this new paradigm, inanimate objects, such as the
kitchen and the car, will communicate with each other. This haunted reality
will be based on a technology known as the Internet of Things, where objects
will be equipped with sensors, processing power, and wireless communication
channels. The money will be completely digital and trading will be based
on so-called blockchain technology, which uses cryptographic techniques to
prevent transaction fraud, such as illegal duplication of money. Technological
applications of quantum weirdness, such as quantum computing and quantum
cryptography, are expected to be used to solve optimization problems
related to automation, improve communications security, verify physical location, etc. Ultimately, this universal automation is expected to reach the
biological sphere through connections between electronic devices and living
being, including humans, e.g., the watch can inject medication and call an
ambulance if it detects that the wearer’s vital signs indicate a heart attack.

1.2 Industrial revolutions and scientific paradigms
All industrial revolutions have been accompanied by a new way of doing
mathematics. In fact, following Stephen Wolfram’s classification of theoretical science paradigms [Wol21], we immediately note that the pre-industrial
world was primarily associated with the structural paradigm, where time is
ignored or imagined as periodic, like in the composition of a finite number
of circular motions in Ptolemaic astronomy.

1.3 First industrial revolution
The development of the classical mechanics in the 1600s by Galileo Galilei,
René Descartes, Gottfried Wilhelm Leibniz, and especially Isaac Newton,
changed the conception of time from a circumference to an infinite line. Here
begins what S. Wolfram calls the mathematical paradigm, where the geometric
machinery is mobilized to include time as another dimension. This shift
in mathematics roughly coincided with the first industrial revolution (late
1700s), where steam engines industrialized textile manufacturing.
1.4 Second industrial revolution

The second industrial revolution, which began in the mid-19th century, was associated with the use of electricity. Like the first industrial revolution, it was intellectually grounded on the mathematical paradigm, but Maxwell’s equations played a role similar to that of Newton’s equations in the previous revolution (at least as proof of concept). The germ of the 3rd paradigm of the theoretical science, the computational one, was already present in the form of a human production line.

1.5 Third industrial revolution

In both the first and second industrial revolutions, the applications of mathematics were mainly to analog systems. As Leibniz would say, nature does not jump. However, in the third industrial revolution, starting in the 1950s, discrete systems were systematically introduced into electronics. The goal was to replace the human production line with an electronic device production line. This led to the automation of various industries, where the role of the worker was to interact with the machine rather than with the objects that the industry is producing.

In the paradigm of the third industrial revolution, time is idealized as a sequential progression of calculations, for example, in an automatic production line, one machine makes a change in matter, another machine makes another change in matter, etc. Wolfram calls this stage of theoretical science, the computational paradigm, where systems are classified into two classes: computationally reducible and computationally irreducible. Systems developed by engineers are designed to be simple enough to be predictable and to keep you in control. Therefore, they are computationally reducible. On the other hand, most of the systems found in nature, and in the field of machine learning, are computationally irreducible, that is, to determine exactly their future, the only way is to execute all the steps in the calculations. Of course, prediction is possible to some extent in computationally irreducible systems, after coarse-graining [IG06] or applying geometric theorems for critical phenomena [Sor06].
1.6 Eve of the fourth industrial revolution

Wolfram [Wol02] and Gerard ’t Hooft [tH16] attempted to reformulate and extend fundamental physics from the mathematical paradigm to the computational paradigm, with success in some toy models. After extensively exploring the cellular automata toy model space, Wolfram [Wol20] expanded his model class by adding a new feature that resembles a discrete version of the many-worlds interpretation of quantum mechanics: the system multi-way. This conceptual change implies a new geometric representation of time, which is no longer a straight line, but a tree. This is the birth of the fourth paradigm of theoretical science, the multi-computational one.

2 Non-thinking automation

Ettore Majorana [MM06] pointed out that nothing prevents the application of the statistical machinery, initially developed for physics, to macroscopic situations, such as the description of sociological phenomena. This idea was developed by Andrei Khrennikov [Khr20] in his social laser theory, where the mathematical apparatus used to describe bosons and fermions is applied to predict collective human behavior to some extent.

Despite the success of Khrennikov’s social laser, the use of analogies with physics to describe sociological and economic phenomena has serious limitations. Indeed, extending the work of his tutor, Karl Popper, in the philosophy of science, George Soros [Sor08] developed a series of conceptual tools to heuristically derive the unpredictability of situations involving a thinking participant, for example, reflexivity theory, human uncertainty principle, fruitful misconceptions, etc.

In the fully automated society proposed by the fourth industrial revolution, inanimate objects will interact in complex real-life situations that are less predictable than interactions among elementary particles, but they will be simple enough to escape the scope of Soros’s limitations for situations involving thinking participants. Hence, the methods of mathematical physics should be relevant for modelling the interactions among these inanimate objects.
3 A society organized as quantum gravity

According to Edward Witten [Wit87], the most fundamental components of physics are spacetime, bosons, and fermions, which are geometrically represented by a pseudo-Riemannian manifold, a principal bundle, and an associated bundle, respectively. In this approach, quantum mechanical features of reality play a secondary role. They only indicate how geometric laws are to be interpreted. For simplicity, in this essay, we will omit bosons and fermions and develop only the applications of the theory of relativity and quantum mechanics.

Leslie Lamport [Lam19] noted that a distributed system, that is, the set of interactions between various inanimate objects, is essentially a discretization of the situation that we encounter in special relativity. The only difference is that the model of clock in relativity is continuous (physical clock), whereas it is more natural to use discrete clocks, known as logical clocks, in distributed systems. A logical clock does not need to progress in a uniform way with respect to a physical clock. The non-uniformity progress of time of some logical clocks relative to the others will be perceived by the observers as gravitational time dilation. Geometrically, the pseudo-Riemannian manifold that is the continuous limit of the distributed system will not be flat. Therefore, the techniques of general relativity will be relevant in this context, because the delay in the calculations seems to be related to the gravitational attraction.

Some of the inanimate objects that interact in the Internet of Things can be activated by quantum effects, for example, a decision-making device can be activated by measuring a quantum state that is entangled with another device. To model distributed systems that contain this type of technology, the only way is to invoke the geometry of quantum mechanics. Thus, the fourth industrial revolutions provide examples of macroscopic systems, modeled by graph theoretical structures from the Wolfram model, in which both quantum mechanics and relativity act at the same time.

4 Conclusions

Industrial revolutions are related to the paradigms of theoretical science, although the coincidence is not perfect in some cases. The third industrial revolution was computational and the fourth is multi-computational. Analo-
gies with physics can be helpful in understanding multi-computational systems, as long as the role of the thinking participant is insignificant. This is likely to be the case of distributed systems involved in the Internet of Things. Both general relativity and quantum mechanics are involved in the distributed systems that the fourth industrial revolutions aim to develop. Therefore, the Wolfram model, as an approach to quantum gravity, can be used as a theoretical tool to think about the technology of the 4th industrial revolution.

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