# A Functional Virtual Reality

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## Abstract

If reality is analog, in the sense that there is an infinitely divisible spacetime, then relativity theory describes a macrocosm that is autonomous, deterministic and obeys locality. If reality is digital, in the sense that spacetime is granular, then quantum theory describes a microcosm with indeterminacy at the level of particle interaction. In an attempt to resolve the apparent contradiction between the words of relativity and quantum physics, we may attempt to answer a fundamental question about the nature of reality: is it analog or digital? I will assume in this paper that reality is fundamentally digital and then based on a modern version of the old doctrine of Cartesian occasionalism I will sketch a model of the world that allows both uncertainty and autonomy within the limits of physical laws. I will then outline an experiment that has the potential of falsifying the model.

## 1. Introduction

If reality is analog in the sense that there is an infinite divisible spacetime, then one way out of the paradoxes of plurality, discussed in more detail in Section 2, is the theory of relativity and its Parmenidean world. Although relativity has had huge experimental success, the metaphysical commitments of this theory are unacceptable to many because the autonomous and at the same time deterministic world that it describes leaves no room for free will, as it will be discussed in more detail Section 5. If reality is digital, in the sense that spacetime is granular, then quantum theory best describes reality. This theory has been also very successful in making predictions and has enjoyed experimental success but, as it will be discussed in Section 6, it predicts non-local phenomena that are incompatible with relativity. The puzzle is then how the observed world that is ruled by certainty and an upper limit in the speed of information propagation emerges from a world that is ruled by probabilities and non-local effects. One way of resolving the contradiction is by deciding first which theory offers a true description of the world and which one is a mere instrument for making predictions. This can be achieved by providing an answer to the following fundamental question: is reality analog or digital? This question is about the foundations of physics and the answer must be within the context of the scientific method. At this point we must first agree that the thesis that reality is both analog and digital in lieu of a final unification of general relativity with quantum physics, and specifically a final solution to the quantization of the former theory, begs the question. That reality is both analog and digital is already the thesis of a realist about both theories as this is what the two most successful theories of physics tell us already about the world if both assumed to be true. This assumption, namely that they are both true, is at the root of the contradiction and the motivation for the analog vs. digital debate. Also, we must agree that the final solution should be given through experimentation and it cannot be solely based on theory, especially abstract mathematics that is based on axiomatic foundations. Thus, we need a theory that can make predictions in the context of analog vs. digital reality that are falsifiable.

Before proceeding, there are a couple of more possibilities to consider: (1) There is no spacetime but only material objects and (2) reality is neither analog nor digital but something else. I will expose a key epistemological contradiction arising from (1) in this paper in Section 4 and refrain from discussing (2) as it does not fit within the bounds of scientific inquiry. I will argue in Section 7 that a modern version of the old doctrine of Cartesian occasionalism can serve as the foundation of a model of an all digital reality. This model allows free will and autonomy of the physical world within the limits of physical laws. Relativity and quantum mechanics are not true descriptions of reality in this model but only useful and accurate instruments for making predictions. I will then try to sketch an experiment in Section 8 that could potentially falsify or corroborate this model. If this model is falsified, then reality is not digital and it is possible that quantum mechanics is not a true description of reality.

The brief historical account of the fundamental issues related to the analog vs. digital debate that follows is not intended by any means to be complete due to space limitations.

## 2. Zeno's Challenge of Naïve Space and Time Notions

The notion of an analog reality has puzzled philosophers and scientists since antiquity. Especially puzzling was the notion that material bodies move in a 3-dimensional space that possesses infinite resolution. Zeno of Elea (c. 450 BCE) was a student of the Eleatic philosopher Parmenides who founded Monism[1]. Zeno attacked common sense perceptions of space, time and motion with a set of paradoxes. The best known paradox attributed to Zeno is that of *dichotomy*. Zeno argued that motion is impossible in an infinitely divisible space because in order to travel a given distance, an object must arrive at the middle of that distance first and just before that, the object must arrive at the middle of the first half interval and so on, *ad infinitum*. The dichotomy paradox has its roots in Zeno's plurality paradox stating that "many things do not exist". Zeno asserted that, "if there are many things, it is necessary that they are as many as they are, and neither more nor less than that. But if they are as many as they are, then they will be limited. If there are many things, the things that are, are unlimited; for there are always others between the things that are, and again other between them. And thus the things that are, are unlimited. Therefore, the proposition "many things exist" leads to a pair of contradicting conclusions." (Kirk et. all, 1983, p. 266)

The mathematical contradictions in Zeno's logical arguments were finally resolved in early 20$^{th}$ century by number theory. That has compelled many, especially physicists, to claim that the physical aspects of the paradoxes regarding the possibility of motion were also resolved. Nothing can be further from the truth[2]. The fact that a finite interval remains finite in a mathematical sense after it is dissected into infinite sub-intervals cannot serve as a proof that motion is possible in an infinite divisible spacetime. Infinite series convergence is only asymptotic and when time is involved, like in kinematics and dynamics, things get much more complicated than just mathematical asymptotic convergence. First, a fundamental question arises: what is time? Second, a more subtle question emerges as one delves deeper into the physics of motion: how is motion and time related? Answers to these questions are required before one considers Zeno's paradoxes resolved. One solution to the paradoxes is offered by the theory of special relativity of Albert Einstein. We will see in Section 5 how relativity theory resolves Zeno's paradoxes and at what price. But before that, it is important to recall how the founders of science tried to tackle this problem. This is not just a historical review but part of the process that leads to potential answers.

## 3. Descartes and the Continuous Recreation of the World

Descartes' (1596 – 1650) mechanical philosophy was based on a model of the universe consisting of corpuscles of matter. He argued that matter was in constant motion and formed a plenum in which no void could exist. Motion occurs due to matter moving in vortices and pushing other matter he argued.

Descartes spent a great deal of effort in his treatise *Mediations* to denounce discrete atomism and the notion of atoms moving in voids. He realized the importance of science foundations that offer a causal explanation of motion and duration in the world, as well as, of the continuous existence of created things. But he found it not possible to offer a causal explanation of motion in a plenum. The reason was that an active cause is required that must be in direct contact with the body in motion and that cause should not be in motion itself, otherwise motion was defined in terms of itself.

Almost 2,000 years after Zeno, Descartes also concluded that it was difficult to find a primitive explanation of motion that does not lead to a circular definition or to a paradox. He thus introduced the concept of *continuous recreation of the world by an immutable God.* In *Meditations* III, Descartes argues (Franco, A., 2001, p. 23):

1. "I existed a little while ago"
2. "I exist now"
3. "A lifespan can be divided into countless parts, each completely independent of the others"
4. "I experience no power" [of creating myself]
   Therefore, "There is some other cause which as it were creates me afresh at this moment – that is which preserves me"

The above argument by Descartes rests on the assumption that instantaneous existence does not imply continuing existence[3]. The argument conclusion further implies that if time is digital, i.e. a collection of instances or nows, then continuing existence requires an intervening cause. In Section 7, I will discuss how Nicholas Malebranche, who was another French Cartesian philosopher, carried Descartes' doctrine of continuous recreation one step further by attributing all real causes to God and I will argue that a modern version of his doctrine of occasionalism can serve as the basis of a model of a digital reality.

## 4. Leibniz and the Impossible Relationism

One possible way out of the analog versus digital debate is to argue that spacetime does not exist independently of material things and their spatiotemporal relations. This was an intriguing argument put forward by Leibniz (1646 – 1716), one of the greatest scientists of all times.

In contrast to the Cartesian view that matter is passive and has extension in space, Leibniz proposed that all there is are pointlike forces that act in such a way as to produce the phenomena in the world. Matter, space and time are the result of such pointlike interactions, which he called *monads*.

Leibniz was against the dualistic concept of matter and force and also against the concept that force somehow arises from interactions of inert matter. Also, Leibniz argued that for motion to be real in a metaphysical sense, it must be grounded on something that is not a mere relation, something absolute and unobservable that serves as its cause (Garber, 1995, pp. 270-352). He argued that Newton's *substantival spacetime*, i.e. the notion that space and time exist independently of material things and their spatiotemporal relations, is not a well-founded phenomenon. Leibniz defined space as the set of all (possible) relations among material things. He further argued that the only well-defined quantities of motion are relative ones like relative position and relative velocity (Roberts, 2003). Thus, Leibniz challenged the Newtonian notion of an absolute and unobservable space, which serves as an arena where all matter interactions take place through forces that are generated by contact, pressure, gravitation, etc. His argument was that such concept is not well founded because it fails empirical verification.

In order to justify motion and interactions, Leibniz tried to identify and define an innate property of matter that would be a measurable cause of all interactions. He thus defined the *living force*, or *vis viva*, as the quantity $mv^2$, which he argued is conserved. But it seems that his choices were limited because the only kimematic quantity other than position that is relative and conforms to a relationist account of the world is velocity. As it turned out, Leibniz's definition of *vis viva* as a real metaphysical property of a substance led to great difficulties. Specifically, velocity is a frame dependent quantity. For a train passenger moving at 100 Km/hour and stationary in the train frame, his measure of vis viva is zero in his rest frame. However, an observer in the ground gets a non-zero measure based on the relative velocity of the train. Can a relative measure serve the purpose of an active force? The answer is no, unless there is some magic involved.

Leibniz tried to offer an alternative to the world of unobservable absolute space and Newtonian forces but run into another level of problems. The main problem was that a living force cannot have many measures and thus there must be at least one measure that is metaphysically real. But how could that be? In a Leibnizian world, there is no preferred reference frame to define such real value. Thus, the efforts of Leibniz to define a quantity that is the cause of motion and interactions that does not depend on absolute space and time failed and together failed the notion of a relational spacetime and of an autonomous world.

## 5. Einstein and the Parmenidean World of Relativity

I briefly discussed some the problems the two of the founders of science stumbled upon in their effort to salvage the autonomy of the world. Descartes could not find a primitive explanation of motion and Leibniz could not find an innate property of matter that could be reference frame independent. After almost 300 years, Albert Einstein came to the rescue. *Relativity*, and in particular Einstein's special relativity, changed the classical view of a world where substances with intrinsic properties, such as a body with extension, move in three-dimensional space where there is objective simultaneity of events. This change however came at a very high price that many philosophers of science are still not convinced it has to be paid. Most physicists accept relativity theory as a very accurate mathematical model in an instrumentalist sense but not its metaphysical commitments. The theory of special relativity in its modern formulation generates many testable predictions that have been verified in laboratories numerous times. So far, none of the predictions made by special relativity have been falsified in a laboratory experiment although scientists have intensely targeted them. So what is the problem?

The problem arises from the fact that relativity commits to a tensless theory of time and existence and to events instead of substances (For a detailed treatment see Esfeld, 2009). This is a drastic departure from the metaphysical commitments of classical physics. According to relativity, simultaneity is only relative to a reference frame and it is not objective. As a result, an event that it is the past of an observer can be in the future of another observer depending on their relative state of motion. Furthermore, everything that exists, in the past, present or future, exists in a 4-dimensional *block universe*. The objects in the block universe are very different from the objects of classical mechanics. The objects of relativity theory have also temporal parts, not just geometric. Their extension is not fixed, as in the case of rigid three-dimensional objects but it is dependent on the reference frame of the observer. In relativity theory, physical objects are continuous sequences of spacetime points, also known as *processes*. According to this radical departure from classical mechanics, motion in a block universe can be defined as a continuous sequence of spacetime points that have similar physical content. Change is a continuous sequence of spacetime points with different physical content.

Let us try to understand the implication of the concepts of motion and change in a block universe. In Zeno's dichotomy paradox discussed in Section 2, an object starts moving along a certain distance in three-dimensional infinitely divisible space, from point S to point E. Zeno argued that this is impossible in infinitely divisible space. However, if we were to merge the notions of space, objects and time, the paradox no longer applies. In this new reality, there is spacetime and its processes. In order to accomplish this, we must consider space and time as a four-dimensional continuum. The consequence is that the concepts of objective "now" and objective "here" are abolished together with the notions of substance. Motion and change are defined as sequences of spacetime points that are already *here* and *there*. In three-dimensional reference frames, these sequences give rise to phenomena such as objects and their motions. Everything that happened in the past or will happen in the future is already there as a continuous collection of spacetime points.

This is the solution to Zeno's paradoxes from the point of view of a block universe: An object in three-dimensional space starts at point S at time $t_1$ and arrives at point E at time $t_2$. Zeno argued that this is impossible to occur in three-dimensional infinitely divisible space with absolute time. Relativity comes in and tells us that the object is part of a continuous collection of spacetime points and also $\{E, t_1\}$ and $\{S, t_2)$, the start and the end, are spacetime points that belong to that sequence. The collection of all the spacetime points defines both the object and its motion. The object starts and finishes its motion in three-dimensional space because this collection of points and associated process are already part of spacetime. It is not a problem if these points are infinite as long as they are part of continuous spacetime. This is the relativity answer to Zeno. Again, the relativity view abolishes the notion that there are three-dimensional objects that move *in* space and replaces it with the notion of processes in spacetime.

To summarize, Einstein's relativity commits to an autonomous eternal world but in this world there is no room for free will. All events already exist as part of this block universe. This is a Parmenidean world, the world Zeno tried to defend with his paradoxes and Relativity theory is its mathematical model.

## 6. Quantum Physics and Spooky Interactions

The picture of the world that relativity offers is somewhat clear in terms of ontological commitments made but this is not the case with quantum physics. There is a plethora of interpretations of quantum theory but the details are not central to the main subject of this paper, mainly the analog vs. digital nature of reality. What is important is to recall that Bell's theorem (Bell, 1987) proves that every quantum theory must violate either counterfactual definiteness or locality.

Counterfactual definiteness is the hypothesis that material objects have existence and possess properties, even if they have not been measured. For example, if one measures the speed of a particle, then one may assume that this measurement is objective. If the speed is measured, then any reference to the position that would have been obtained for a given speed makes sense. Realists about physical theories must adhere to counterfactual definiteness because realism rests on the assumption that material objects have defined properties, whether they are measured or not.

Locality is the hypothesis that an object is influenced only by its immediate surroundings. Newtonian Mechanics did not include this assumption because in that theory gravitational forces act instantaneously and at infinite distances. In relativity theory, there is an upper limit in the speed of propagation of information that happens to be equal to the speed of light in vacuum and as a result this theory conforms to the hypothesis of locality. The problem that arises is that in quantum theory there is the phenomenon of distant entangling, which has been demonstrated experimentally. This phenomenon presents us with a serious problem: action at a distance is not compatible with relativity theory and an upper limit in the speed of information propagation.

Although there are objections to Bell's theorem, the issue of non locality in quantum mechanics is real[4]. Physicists have been forced to take sides due to this phenomenon. Most reject realism and counterfactual definiteness in favor of locality and relativity. This has also been one cause of the plethora of quantum mechanics interpretations. Some of the interpretations reject counterfactual definiteness and some reject locality. However, both the presence of non-locality and the emergence of properties after they are measured are considered spooky interactions by many. It would be a great relief to them if quantum mechanics was falsified. On the other hand, there are those who hope that relativity will be falsified one day in favor of a probabilistic and non-deterministic world. This is the main reason that the analog vs. digital reality debate is an important one. However, this cannot be just a philosophical debate. It must lead to theories that are falsifiable through experimentation. In the next two sections I will sketch a theory and the proposed experiment to falsify it.

## 7. A Model of a Functional Virtual Reality

According to Nicolas Malebranche and other seventeenth-century Cartesian occasionalists, what we actually call causes are really no more than *occasions* on which, in accordance with his own laws, God acts to bring about the effect (Brown, 1995, pp. 43-46). If one were to replace the notion of God in the occasionalism doctrine by the notion of a mechanism, then a modern (or mechanical) occasionalist could assert that what we actually call causes are no more than occasions on which a mechanism acts to bring about the effect. In this modern version of Cartesian occasionalism, time emerges as an ordered progression of instances, or nows, on which the mechanism acts to bring about the effect. At the phenomenal level, time and motion cannot be separated because there is no motion without time and no time without motion, i.e. time and motion are inextricably related, as in relativity theory. Under this model, reality, in the sense of the physical reality we observe, is an effect but also part of the mechanism that creates it. Thus, causality in the observed world is only epiphenomenal, as the assumed mechanism is the real cause of all phenomena.

This is the model of what I call a *functional virtual reality*. It is not a virtual reality or a computer simulation in the traditional sense of these terms. In a functional virtual reality free interactions are allowed within the limitations of the physical laws imposed by a mechanism. Thus, there is some degree of autonomy and some degree of free will but both are constrained within the limits of physical laws. The future can be determined to a high degree of accuracy if the initial conditions are known but since free interactions are allowed, local effects are predictable only after their initial conditions emerge.

One could view spacetime in this model as a kind of a substance that acts as a mechanism and creates reality. This is a different spacetime than that of relativity. It is digital and substantival, in the sense that it exists independently of the events that occur in it. Non-locality is a feature of the mechanism to accomplish its task of bringing about the effects in the functional virtual reality. Here is what is happening according to this model: as one moves towards the macrocosmic level, special and general relativity apply because these are the rules that govern the observed reality as dictated by the mechanism. But as one approaches the particle level, quantum physics apply because this is the level at which the mechanism operates at. In order to observe the mechanism, one would have to probe the Planck scale or below that, something that is impossible with our current technology and energy levels available at particle accelerators. However, even if we were able to reach that level, we may be faced with a reality that will be beyond comprehension or measurement. Thus, we may be forced to find alternative indirect means, of falsifying or corroborating the hypothesis of functional virtual reality. That of course will limit the capability of proving it true but this is how physics works. Physics without falsification through experimentation is an exercise in futility.

## 8. The Experiment

The objective of this experiment will be to falsify or corroborate the functional virtual reality model. The basic premise of the experiment rests on the hypothesis that a mechanism which continuously recreates a functional virtual reality has an upper limit in its processing capability at the local level. At a global level, the limit may be practically infinite due to the distributed nature of the mechanism.  Thus, given the premise, the objective of the experiment will be to observe phenomena where there is a deviation from expected results due to a demand of a higher than possible processing capability of the mechanism. One possible way of achieving this test is by detecting deviations in the output of a nanoscale processor accelerated at very high speeds. The processor may consist of a dense array of billions of nanoscale transistors and it will execute a complex set of instructions. The processor could be made three-dimensional for greater density by utilizing three-dimensional wafer technology. It should be shielded to avoid interference. When this devise will be accelerated at very high speeds for short distances, if there is a limitation in the capability of the hypothesized mechanism to bring about effects, deviations may occur from the expected output. Of course, the processor should be first tested at the same speeds without running any set of instruction in order to check for malfunctioning or presence of noise.

The above was a sketch of a possible experiment for testing the processing capability of a mechanism that continuously recreates a digital functional virtual reality. There can be other similar experimental setups. Again, we are interested in falsification or corroboration of the functional virtual reality hypothesis. Proving this hypothesis true is impossible within this class of experiments.

## 9. Conclusion

In this paper I started by presenting a historical account of the analog vs. digital reality thesis. An analog reality, in the sense of an infinitely divisible space and time, was challenged since the ancient times by Zeno and his paradoxes of motion. Descartes thought that the only possible world with motion and duration is one that is constantly recreated at every instant of time. His followers came up with the doctrine of occasionalism, the hypothesis that all causes are attributed to God. Leibniz failed to salvage the autonomy of a relational world where an independently existing spacetime, is a redundant notion. Einstein came up with relativity, the first accurate theory of physics that describes an autonomous but deterministic and eternal world. Quantum physics came to challenge relativity with spooky interactions and non-local behavior at the particle interaction level. Science has reached a point where for progress to take place just one of the two predominant scientific theories must be considered a true description of reality and then, depending on which, a new program must start that will either show how quantum uncertainty emerges from the certainty of the macrocosm or how, meaning in a physical sense and not just mathematical, the certainty of macrocosm emerges from quantum uncertainty. In this paper I presented a model of a digital reality, which I called a functional virtual reality, and I argued that in this reality relativity is just a tool for making predictions about the phenomena and not a true description of how reality operates. I did that with the aim of falsification in mind. For that purpose I presented the principles of an experimental setup that could possibly lead to the falsification or corroboration of the hypothesis that our world is a functional virtual reality. The aim of the experiment is the testing the processing limits of a hypothetical mechanism that generates this type of digital reality. I am sure that the idea for this experiment needs a lot more refinement to be put in practice but my aim here was to present the principles involved.

## Endnotes

[1] In ancient Greece there were three predominant Presocratic schools of thought: Monism, founded by Xenophanes and his student Parmenides who argued that all that exists is one, immutable, indestructible, indivisible, finite and that there is no void, Pluralism, founded by Empedocles and his student Anaxagoras who argued that all elements in the world are infinitely divisible, indestructible and that there is no void and Discrete Atomism founded by Leucippus and his student Democritus who introduced the notion of an atom and of motion in a void.

[1] Barnes (1982, pp. 231 – 294) offers an extensive analysis of the paradoxes just to conclude that he cannot show that they are unsound because he cannot prove false the fundamental premise of Zeno that 'nothing can perform infinitely many tasks'.

[1] Those who have attacked Descartes' argument for using independent time divisions should not forget that also in classical physics such notions are fundamental.

[1] See (Christian, 2010)

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