Why do we live in a quantum world?

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Anybody who has ever studied quantum mechanics knows that it is a very counterintuitive theory, even though it has been an incredibly successful theory. This paper aims to remove this counterintuitiveness by showing that the laws of quantum mechanics are a natural consequence of classical Newtonian mechanics combined with the digital universe hypothesis of Konrad Zuse and Edward Fredkin. We also present a possible way to test the digital universe hypothesis.

1 Introduction

The late and great physicist Richard Feynman once said, "I think I can safely say that nobody understands quantum mechanics." [5] He said this not because he thought scientists were incapable of understanding how to apply the laws of quantum mechanics to make predictions about experiments, but because quantum mechanics is a very counterintuitive theory; there are many paradoxes associated with quantum mechanics [3] and many ways to interpret quantum mechanics as well [4]. The aim of this paper is to completely remove counterintuitiveness from quantum mechanics by showing that the laws of quantum mechanics are a natural consequence of classical Newtonian mechanics combined with the digital universe hypothesis of Konrad Zuse and Edward Fredkin. We also present a possible way to test the digital universe hypothesis.

2 Digital Universe

The digital universe hypothesis of Zuse and Fredkin is that our universe is in essence a giant (but finite) digital computer and that everything which happens in our universe is the result of a computer program [6, 11]. This is a radical departure from contemporary physics, which is based on the assumption that space-time is continuous, not discrete. As Edward Fredkin said, "From a Digital perspective, contemporary models of fundamental physics are a bit like looking at an animated cartoon while assuming that it is reality; that the images are moving continuously" [6]. So if everything which happens in our universe is the result of a computer program, then Who is the programmer? Digital physics does not address this question.

If the digital universe hypothesis is correct, does this imply that all of contemporary physics is wrong? The answer to this question depends on one's definition of "wrong": If "wrong" means that the equations of contemporary physics do not completely describe our universe, then yes, contemporary physics would be wrong if the digital universe hypothesis is correct. But if "wrong" means that the equations of contemporary physics do not predict the results of experiments done in the real world, then no, contemporary physics would not be wrong, since contemporary physics does a great job of predicting the results of many experiments done in the real world.

3 Classical physics on a computer

The position and momentum of particles play a central role in classical Newtonian mechanics, as we can see from Hamilton's equations,

$$\frac{\partial H}{\partial p_i} = \frac{dx_i}{dt}, \tag{1}$$

$$\frac{\partial H}{\partial x_i} = -\frac{dp_i}{dt}, \tag{2}$$

for $i = 1, 2, 3$, where H is energy, t is time, (x_1, x_2, x_3) is position, and (p_1, p_2, p_3) is momentum. Suppose that our universe is a digital universe which attempts to simulate the laws of Newtonian mechanics as well as it can, given the limitation that it would only have a finite number of bits, n, available to specify both the position and the momentum of each particle. Let A be the number of bits that the computer which generates such a universe allocates to specify the position of a particle, and let B be the number of bits that the computer which generates such a universe allocates to specify the momentum of the same particle. Then the error in position, Δx, would be of the order of magnitude 2^{-A}, and the error in momentum, Δp, would be of the order of magnitude 2^{-B}. So since

$$A + B = n, \tag{3}$$

the product of both errors would yield the constant 2^{-n}. Thus, if we let $\hbar = 2^{-n+1}$, we obtain

$$\Delta x \cdot \Delta p = \hbar/2. \tag{4}$$

If the reader hasn't noticed already, this equality is an exact version of Heisenberg's Uncertainty Principle [11].

Now consider the fact that in 2002, Michael Hall and Marcel Reginatto derived Schrödinger's equation,

$$i\hbar\frac{\partial\psi}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi + V\psi, \quad (5)$$

from equation (4) combined with the assumptions of classical Newtonian mechanics, where m is mass, V is potential energy, and $\psi = \sqrt{p}\exp(is/\hbar)$, where p is the probability density function of position and s is the average momentum potential [8]. Then since Schrödinger's equation is the fundamental equation of quantum mechanics, we have shown that the laws of quantum mechanics are a natural consequence of classical Newtonian mechanics combined with the digital universe hypothesis.

Caveat: Note that equation (5) is only an approximation, since it was derived from the assumption that our universe is digital; nevertheless, it is still a better approximation than Hamilton's equations (1) and (2), since Hamilton's equations do not take into account equation (4), which applies in a digital universe. Hence, for the remainder of this paper, we shall call the combination of classical Newtonian mechanics and the digital universe hypothesis *digital mechanics*.

4 "Shut up and calculate!"

The so-called *measurement problem*, which asks "What is the nature of the mechanism which causes the wave function to collapse?", is the single feature of quantum mechanics that makes it a counterintuitive theory. This problem has inspired many interpretations of quantum mechanics [4]. N. David Mermin summed up its most popular interpretation, the Copenhagen interpretation, as "Shut up and calculate!" [10] This interpretation supposedly solves the measurement problem by ignoring it and pretending that it does not exist. Nevertheless, the measurement problem still *does* exist in quantum mechanics, since Schrödinger's equation does not appear to explain how and why the wave function collapses.

However, in digital mechanics, the phrase "Shut up and calculate!" is the *answer* to the measurement problem: Since everything that happens in digital mechanics is the result of calculations, the calculations themselves are the mechanism which causes the wave function to collapse; therefore, it is appropriate (although not polite) to respond "Shut up and calculate!" to anyone who asks questions about the nature of the wave function collapse in digital mechanics. So we see that digital mechanics effectively removes counterintuitiveness from quantum mechanics by providing a clear and concise answer to the measurement problem. Can the digital mechanics hypothesis be tested? The answer to this question is "possibly, yes". To understand how, we must understand the concept of *quantum computing*.

5 Quantum computing

A quantum computer is any device which makes direct use of distinctively quantum mechanical phenomena, such as superposition and entanglement, to perform computations on data. As of today, nobody has ever built a large-scale quantum computer; however, much is known about the theoretical properties of quantum computers. For example, quantum computers have been shown to be able to efficiently solve certain types of problems, like factoring large integers, which are believed to be very difficult to solve on a digital computer [7].

The *Extended Church-Turing Thesis* is the assertion that any mathematical function that is efficiently computable in the natural world is efficiently computable by a digital computer [2]. Therefore, if a large-scale quantum computer ever gets built and it is impossible to efficiently factor integers on a digital computer, the Extended Church-Turing Thesis would be false. And if large-scale quantum computers are impossible in principle to build, this would mean that quantum mechanics needs to be modified. The quantum computer expert Scott Aaronson summed it up as follows: "Either the Extended Church-Turing Thesis is false, or quantum mechanics must be modified, or the factoring problem is solvable in classical polynomial time. All three possibilities seem like wild, crackpot speculations - but at least one of them is true!" [1]

Some scientists are of the opinion that building a large-scale quantum computer is impossible; in fact, the complexity theorist, Leonid Levin, wrote: "QC of the sort that factors long numbers seems firmly rooted in science fiction. It is a pity that popular accounts do not distinguish it from much more believable ideas, like Quantum Cryptography, Quantum Communications, and the sort of Quantum Computing that deals primarily with locality restrictions, such as fast search of long arrays. It is worth noting that the reasons why QC must fail are by no means clear; they merit thorough investigation. The answer may bring much greater benefits to the understanding of basic physical concepts than any factoring device could ever promise. The present attitude is analogous to, say, Maxwell selling the Daemon of his famous thought experiment as a path to cheaper electricity from heat. If he did, much of insights of today's thermodynamics might be lost or delayed" [9].

Can a large-scale quantum computer that can efficiently factor integers ever be built? According to quantum mechanics, the answer is "yes, in principle". But according to digital mechanics, the answer is "no", assuming that it is impossible to efficiently factor integers on a digital computer. So in principle, there is a way to test digital mechanics, assuming that it is impossible to efficiently factor integers on a digital computer: If one successfully builds a large-scale quantum computer, then the digital mechanics hypothesis is false. And if one does everything possible to build a large-scale quantum computer but is still unsuccessful in building one, then the digital mechanics hypothesis is confirmed, and the laws of quantum mechanics are not fundamental but only an approximation.

6 Conclusion

Digital mechanics, the combination of classical Newtonian mechanics and the digital universe hypothesis, predicts all of the observed phenomena that quantum mechanics predicts. And one can use Occam's Razor to argue that digital mechanics is a much better theory than quantum mechanics, since digital mechanics is much simpler than quantum mechanics. Digital mechanics is also intuitive, since its measurement problem has a clear and concise answer. Furthermore, digital mechanics is falsifiable: If one could successfully build a large-scale quantum computer, then digital mechanics would be false, assuming that it is impossible to efficiently factor large integers on a digital computer (which is generally believed to be true). But so far, nobody has ever built such a computer, although not for lack of trying. Because of this, the author predicts that as more computer engineers attempt to build large-scale quantum computers and fail, scientists will eventually accept digital mechanics as a better theory than quantum mechanics.

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