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NATURE OF COMPUTER SIMULATION

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Since ancient time humans have been modeling the different situations in their heads or on pieces of paper in order to make a decision. Through the evolution of mankind, the models have radically changed. Drawings on the ground turned into maps and now into the digital interactive maps. With the advent of computers, the accuracy of the models began to grow exponentially, and we are not far from the time when the accuracy of the simulation will be equal to reality. Nevertheless, before exploring this trend I should give some definitions.

Computer simulation is the reproduction of the behavior of a system using a computer to simulate the outcomes of a mathematical model associated with said system. Since they allow checking the reliability of chosen mathematical models, computer simulations have become a useful tool for the mathematical modeling of many natural systems in physics (computational physics), astrophysics, climatology, chemistry, biology and manufacturing, human systems in economics, psychology, social science, health care and engineering. Simulation of a system is represented as the running of the system model. It can be used to explore and gain new insights into new technology and to estimate the performance of systems too complex for analytical solutions [1].

In order to trace the trend of computer simulation evolution, it is worth taking a look at the development of gaming engines, because the gaming industry is one of the largest industries in the computer world and a lot of money is invested in its development. A game engine is a software-development environment designed for people to build video games. Usually a game engine is described by the laws of physics and therefore is a form of simulation of the real world. The first games were very simple, for example, one of the first games, created in 1972, was about a ball that bounced off the surface, but even that game had a primitive engine, which had a several mathematical equations in it. Now, sometimes, one cannot see the difference between the game and the real world, because almost all the laws of physics are implemented into gaming engines.

However, in addition to rising power of computer simulation, other avenues have opened up that may have equally important consequences. It is now possible for groups and individuals on modest budgets to solve challenging problems and conduct technologically useful research. Two main factors are responsible for this. First, PCs and workstations now cost only a few thousand dollars and provide significant computing power together with graphics. Second, advances in communications enable researchers in remote locations to have access to the latest ideas, software and experimental data. The accessibility afforded by the Internet makes possible close collaborations between scientists using models that span the range from the macroscopic scale to electronic structure calculations. Therefore, now computer simulation is one of the most powerful tools that found its use in all spheres of science. Computer simulation is used to simulate weather, invent drugs, simulate molecules, chemical reactions, simulate the origin of stars, and even simulate brain work. Despite this, computer simulation has several serious problems, for example, classical computers are bad in exponential scaling, and so when it comes to simulating more than 100 atoms simulation can take enormous amount of time. Also, a classical computer cannot generate absolutely random values so every model is not stochastic in some way.

All these problems can be solved with the help of a quantum computer. In quantum computing, a qubit (short for quantum bit) is a unit of quantum information similar to a classical bit. Where classical bits have a single binary value such as a 0 or 1, a qubit can have both values simultaneously in what's known as a superposition state. When multiple qubits act coherently, they can process multiple options simultaneously. This allows them to process information in a fraction of the time that would be needed even for the fastest nonquantum systems. "Quantum modeling" is the process by which a quantum computer models another quantum system. Due to quantum oddities of various types, classic computers can simulate quantum systems only in a cumbersome and inefficient way. But a quantum computer itself is a quantum system capable of demonstrating the full spectrum of quantum oddities, so it can effectively model other quantum systems. Each of the parts of a simulated quantum system is mapped to a set of qubits in a quantum computer, and the interactions between these parts become a sequence of quantum logical operations. Such modeling can be so accurate that the behavior of the computer will be indistinguishable from the behavior of the system itself. If two systems that process information can effectively model each other, they are logically equivalent. Since the Universe can perform quantum computations, and a quantum computer can simulate the Universe, the Universe and a quantum computer have the same processing power: they are essentially identical [2].

The question of the difference between modeling and reality arose long ago. In the VI century BC in the first lines of "Tao Te Ching", "Books of the Way and Dignity," Lao Tzu described the problem inherent in any description of reality: "The path that can be followed is not the true Path. A name that can be called is not a true name". The original Chinese text "Dao Te Ching" is very compact and can be interpreted in 10,000 ways, but Lao Tzu seems to believe that by giving things names and assigning one or another meaning to words, we introduce artificial differences that cannot encompass the whole fullness of the universe. The philosopher Archie Bam suggested a less literal translation of this statement: "Nature cannot be described completely, because such a description of nature should reproduce the very nature. In other words, the perfect description of the universe would be indistinguishable from the universe itself.

Let's see what happens if we apply Lao Tzu's maxim to a quantum computer that simulates the Universe. As we shall see, the Universe, at least the part of the Universe accessible to us, is finite in space and time. All fragments of the part of the Universe accessible to us, in principle, can be mapped onto a finite number of qubits. Similarly, the physical dynamics of the Universe, consisting of the interactions between these parts, can be mapped onto logical operations with these qubits.

This is not to say that we know exactly how to do this mapping. We know how to map the behavior of elementary particles to qubits and logical operations. In other words, we know how the Standard Model of Particle Physics — a model that describes our world with amazing accuracy — can be displayed in a quantum computer. But we still do not know how the behavior of gravity can be displayed in a quantum computer, for the simple reason that physicists have not yet reached the complete theory of quantum gravity. We still do not know how to model the Universe, but we may soon find out.

In a quantum computer that simulates the Universe, there will be as many qubits as there are in the Universe, and logical operations with these qubits will accurately simulate the dynamics of the Universe. Such a quantum computer would model the behavior of the universe as a whole. Such a quantum computation would constitute a complete description of nature, and therefore it would be indistinguishable from nature itself. So, in essence, we can assume that the Universe performs quantum computations. Similarly, due to the fact that the behavior of elementary particles can be directly reflected on the behavior of qubits interacting through logical operations, the simulation of the Universe by a quantum computer is indistinguishable from the Universe itself.

As a conclusion, I want to say that with a development of a quantum computer, we will be able to simulate the things from a real world such as the human brain that will be indistinguishable from the real one, and therefore, it will have a subjective experience.

References:

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