Simulated reality

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Simulated reality is the hypothesis that reality could be simulated—for example by computer simulation—to a degree indistinguishable from "true" reality. It could contain conscious minds which may or may not be fully aware that they are living inside a simulation.

This is quite different from the current, technologically achievable concept of virtual reality. Virtual reality is easily distinguished from the experience of actuality; participants are never in doubt about the nature of what they experience. Simulated reality, by contrast, would be hard or impossible to separate from "true" reality.

There has been much debate over this topic, ranging from philosophical discourse to practical applications in computing.

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Arguments

Simulation argument

The simulation hypothesis was first published by Hans Moravec.[1][2][3] Later, the philosopher Nick Bostrom developed an expanded argument examining the probability of our reality being a simulacrum.[4] His argument states that at least one of the following statements is very likely to be true:

> 1. Human civilization is unlikely to reach a level of technological maturity capable of producing simulated realities, or such simulations are physically impossible to construct.
> 2. A comparable civilization reaching aforementioned technological status will likely not produce a significant number of simulated realities (one that might push the probable existence of digital entities beyond the probable number of "real" entities in a Universe) for any of a number of reasons, such as, diversion of computational processing power for other tasks, ethical considerations of holding entities captive in simulated realities, etc.
> 3. Any entities with our general set of experiences are almost certainly living in a simulation.

In greater detail, Bostrom is attempting to prove a tripartite disjunction, that at least one of these propositions must be true. His argument rests on the premise that given sufficiently advanced technology, it is possible to represent the populated surface of the Earth without recourse to digital physics; that the qualia experienced by a simulated consciousness is comparable or equivalent to that of a naturally occurring human consciousness; and that one or more levels of simulation within simulations would be feasible given only a modest expenditure of computational resources

in the real world.

If one assumes first that humans will not be destroyed nor destroy themselves before developing such a technology, and, next, that human descendants will have no overriding legal restrictions or moral compunctions against simulating biospheres or their own historical biosphere, then it would be unreasonable to count ourselves among the small minority of genuine organisms who, sooner or later, will be vastly outnumbered by artificial simulations.

Epistemologically, it is not impossible to tell whether we are living in a simulation. For example, Bostrom suggests that a window could *pop up* saying: "You are living in a simulation. Click here for more information." However, imperfections in a simulated environment might be difficult for the native inhabitants to identify, and for purposes of authenticity, even the simulated memory of a blatant revelation might be purged programmatically. Nonetheless, should any evidence come to light, either for or against the skeptical hypothesis, it would radically alter the aforementioned probability.

The simulation argument also has implications for existential risks. If we are living in a simulation, then it's possible that our simulation could get shut down. Many futurists have speculated about how we can avoid this outcome. Ray Kurzweil argues in *The Singularity is Near* that we should be interesting to our simulators, and that bringing about the Singularity is probably the most interesting event that could happen. The philosopher Phil Torres has argued that the simulation argument itself leads to the conclusion that, if we run simulations in the future, then there almost certainly exists a stack of nested simulations, with ours located towards the bottom. Since annihilation is inherited downwards, any terminal event in a simulation "above" ours would be a terminal event for us. If there are many simulations above us, then the risk of an existential catastrophe could be significant.[5]

Relativity of reality

As to the question of whether we are living in a simulated reality or a 'true' one, the answer may be 'indistinguishable', in principle. In a commemorative article dedicated to the 'The World Year of Physics 2005', physicist Bin-Guang Ma proposed the theory of 'Relativity of reality'.[6] Although the notion appears in ancient philosophy: Zhuangzi's 'Butterfly Dream', and analytical psychology.,[7] the above article for the first time explicitly stated the reference-world-dependency of 'Reality' definition. Based on two basic principles, the Physics about simulated reality was discussed.

Computationalism

Computationalism is a philosophy of mind theory stating that cognition is a form of computation. It is relevant to the Simulation hypothesis in that it illustrates how a simulation could contain conscious subjects, as required by a "virtual people" simulation. For example, it is well known that physical systems can be simulated to some degree of accuracy. If computationalism is correct, and if there is no problem in generating artificial consciousness or cognition, it would establish the theoretical possibility of a simulated reality. However, the relationship between cognition and phenomenal qualia of consciousness is disputed. It is possible that consciousness requires a vital substrate that a computer cannot provide, and that simulated people, while behaving appropriately, would be philosophical zombies. This would undermine Nick Bostrom's simulation argument; we cannot be a simulated consciousness, if consciousness, as we know it, cannot be simulated. However, the skeptical hypothesis remains intact, we could still be envatted brains, existing as conscious beings within a simulated environment, even if consciousness cannot be simulated.

Some theorists[8][9] have argued that if the "consciousness-is-computation" version of computationalism and mathematical realism (or radical mathematical Platonism)[10] are true then consciousnesses is computation, which in principle is platform independent, and thus admits of simulation. This argument states that a "Platonic realm" or ultimate ensemble would contain every algorithm, including those which implement consciousness. Hans Moravec has explored the simulation hypothesis and has argued for a kind of mathematical Platonism according to which every object (including e.g. a stone) can be regarded as implementing every possible computation.[1]

Dreaming

A dream could be considered a type of simulation capable of fooling someone who is asleep. As a result, the "dream

hypothesis" cannot be ruled out, although it has been argued that common sense and considerations of simplicity rule against it.[11] One of the first philosophers to question the distinction between reality and dreams was Zhuangzi, a Chinese philosopher from the 4th century BC. He phrased the problem as the well-known "Butterfly Dream," which went as follows:

> Once Zhuangzi dreamt he was a butterfly, a butterfly flitting and fluttering around, happy with himself and doing as he pleased. He didn't know he was Zhuangzi. Suddenly he woke up and there he was, solid and unmistakable Zhuangzi. But he didn't know if he was Zhuangzi who had dreamt he was a butterfly, or a butterfly dreaming he was Zhuangzi. Between Zhuangzi and a butterfly there must be *some* distinction! This is called the Transformation of Things. (2, tr. Burton Watson 1968:49)

The philosophical underpinnings of this argument are also brought up by Descartes, who was one of the first Western philosophers to do so. In *Meditations on First Philosophy*, he states "... there are no certain indications by which we may clearly distinguish wakefulness from sleep",[12] and goes on to conclude that "It is possible that I am dreaming right now and that all of my perceptions are false".[12]

Chalmers (2003) discusses the dream hypothesis, and notes that this comes in two distinct forms:

- that he is *currently* dreaming, in which case many of his beliefs about the world are incorrect;
- that he has *always* been dreaming, in which case the objects he perceives actually exist, albeit in his imagination.[13]

Both the dream argument and the simulation hypothesis can be regarded as skeptical hypotheses; however in raising these doubts, just as Descartes noted that his own thinking led him to be convinced of his own existence, the existence of the argument itself is testament to the possibility of its own truth.

Another state of mind in which some argue an individual's perceptions have no physical basis in the real world is called psychosis though psychosis may have a physical basis in the real world and explanations vary.

Computability of physics

A decisive refutation of any claim that our reality is computer-simulated would be the discovery of some uncomputable physics, because if reality is doing something that no computer can do, it cannot be a computer simulation. (*Computability* generally means computability by a Turing machine. Hypercomputation (super-Turing computation) introduces other possibilities which will be dealt with separately.) In fact, known physics is held to be (Turing) computable,[14] but the statement "physics is computable" needs to be qualified in various ways, as a recent result[15] shows.

Before symbolic computation, a number, thinking particularly of a real number, one with an infinite number of digits, was said to be computable if a Turing machine will continue to spit out digits endlessly, never reaching a "final digit".[16] This runs counter, however, to the idea of simulating physics in real time (or any plausible kind of time). Known physical laws (including those of quantum mechanics) are very much infused with real numbers and continua, and the universe seems to be able to decide their values on a moment-by-moment basis. As Richard Feynman put it:[17]

> "It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time. How can all that be going on in that tiny space? Why should it take an infinite amount of logic to figure out what one tiny piece of space/time is going to do? So I have often made the hypotheses that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities".

The objection could be made that the simulation does not have to run in "real time".[18] It misses an important point, though: the shortfall is not linear; rather it is a matter of performing an infinite number of computational steps in a finite time.[19]

Note that these objections all relate to the idea of reality being *exactly* simulated. Ordinary computer simulations as used by physicists are always approximations.

These objections do not apply if the hypothetical simulation is being run on a hypercomputer, a hypothetical machine more powerful than a Turing machine.[20] Unfortunately, there is no way of working out if computers running a simulation are capable of doing things that computers in the simulation cannot do. The laws of physics inside a simulation and those outside it do not have to be the same, and simulations of different physical laws have been constructed.[21] The problem now is that there is no evidence that can conceivably be produced to show that the universe is *not* any kind of computer, making the simulation hypothesis unfalsifiable and therefore scientifically unacceptable, at least by Popperian standards.[22]

All conventional computers, however, are less than hypercomputational, and the simulated reality hypothesis is usually expressed in terms of conventional computers, i.e. Turing machines.

Roger Penrose, an English mathematical physicist, presents the argument that human consciousness is non-algorithmic, and thus is not capable of being modeled by a conventional Turing machine-type of digital computer. Penrose hypothesizes that quantum mechanics plays an essential role in the understanding of human consciousness. He sees the collapse of the quantum wavefunction as playing an important role in brain function. (See consciousness causes collapse).

CantGoTu environments

In his book *The Fabric of Reality*, David Deutsch discusses how the limits to computability imposed by Gödel's Incompleteness Theorem affect the Virtual Reality rendering process.[23][24] In order to do this, Deutsch invents the notion of a CantGoTu environment (named after Cantor, Gödel, and Turing), using Cantor's diagonal argument to construct an 'impossible' Virtual Reality which a physical VR generator would not be able to generate. The way that this works is to imagine that all VR environments renderable by such a generator can be enumerated, and that we label them VR1, VR2, etc. Slicing time up into discrete chunks we can create an environment which is unlike VR1 in the first timeslice, unlike VR2 in the second timeslice and so on. This environment is not in the list, and so it cannot be generated by the VR generator. Deutsch then goes on to discuss a universal VR generator, which as a physical device would not be able to render all possible environments, but would be able to render those environments which can be rendered by all other physical VR generators. He argues that 'an environment which can be rendered' corresponds to a set of mathematical questions whose answers can be calculated, and discusses various forms of the Turing Principle, which in its initial form refers to the fact that it is possible to build a universal computer which can be programmed to execute any computation that any other machine can do. Attempts to capture the process of virtual reality rendering provides us with a version which states: "It is possible to build a virtual-reality generator, whose repertoire includes every physically possible environment". In other words, a single, buildable physical object can mimic all the behaviours and responses of any other physically possible process or object. This, it is claimed, is what makes reality comprehensible.

Later on in the book, Deutsch goes on to argue for a very strong version of the Turing principle, namely: "It is possible to build a virtual reality generator whose repertoire includes every *physically possible* environment." However, in order to include *every physically possible environment*, the computer would have to be able to include a recursive simulation of the environment containing *itself*. Even so, a computer running a simulation need not have to run every possible physical moment to be plausible to its inhabitants.

Nested simulations

The existence of simulated reality is unprovable in any concrete sense: any "evidence" that is directly observed could be another simulation itself. In other words, there is an infinite regress problem with the argument. Even if we are a simulated reality, there is no way to be sure the beings running the simulation are not themselves a simulation, and the operators of *that* simulation are not a simulation.[25]

"Recursive simulation involves a simulation, or an entity in the simulation, creating another instance of the same simulation, running it and using its results" (Pooch and Sullivan 2000).[26]

Consequences

If we are living in a simulation, then it's possible that our simulation could get shut down. Some futurists have speculated about how we can avoid this outcome. Ray Kurzweil argues in *The Singularity is Near* that we should be interesting to our simulators, and that bringing about the Singularity is probably the most interesting event that could happen. The philosopher Phil Torres has argued that the simulation argument itself leads to the conclusion that, if we run simulations in the future, then there almost certainly exists a stack of nested simulations, with ours located towards the bottom. Since annihilation is inherited downwards, any terminal event in a simulation "above" ours would also be a terminal event for us. If there are many simulations above us, then the risk of an existential catastrophe could be significant.[5]

In fiction

Simulated reality in fiction has been explored by many authors, game designers, and film directors.

See also

- Artificial life
- Artificial reality
- Augmented reality
- Artificial society
- Boltzmann brain
- Computational sociology
- Consensus reality
- Cyberpsychology
- Digital philosophy
- Digital physics
- The Experience Machine
- Holodeck (*Star Trek: The Next Generation*)
- Hyperreality
- Holographic Universe
- Infosphere
- Interactive online characters
- Margolus–Levitin theorem
- Maya (illusion)
- Mind uploading
- Molecular modeling
- Metaverse
- Tipler's "Omega point"
- Omnidirectional treadmill
- Philosophy of information
- Pseudorealism
- *Ready Player One*
- Reality in Buddhism
- *Simulacra and Simulation*
- Simulacrum
- Simulated reality in fiction
- Simulation hypothesis
- Social simulation
- Theory of knowledge
- Virtual economy
- Virtual Reality Addiction
- Virtual worlds
- Zeno's paradoxes

Major contributing thinkers

- Jean Baudrillard
- Nick Bostrom and his simulation argument
- René Descartes (1596–1650) and his Evil Demon, sometimes also called his 'Evil Genius'[27]
- Philip K. Dick for "We Can Remember It for You Wholesale"
- George Berkeley (1685–1753) and his "immaterialism" (later referred to as subjective idealism by others)
- Stanislaw Lem who presented the idea e.g. in "Further reminiscences of Ijon Tichy" (chapter I) part of The Star Diaries
- Plato (424/423 BC – 348/347 BC) and his Allegory of the Cave
- Zeno of Elea
- Zhuangzi (around the 4th century BCE) and his Chinese Butterfly Dream

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3. Moravec, Hans Pigs in Cyberspace (http://www.frc.ri.cmu.edu/%7Ehpm/project.archive/general.articles/1992/CyberPigs.html)
4. Are You Living in a Computer Simulation? (http://www.simulation-argument.com/simulation.html) by Nick Bostrom. July 2002. Accessed *21 December 2006*
5. Why Running Simulations May Mean the End is Near (http://ieet.org/index.php/IEET/more/torres20141103)
6. About Mechanics of Virtual Reality, by Bin-Guang Ma(2005), published in: The General Science Journal, (August 25, 2006). (http://wbabin.net/science/ma.pdf)
7. Warburg, B. (1942). The Relativity of Reality. Reflections on the Limitations of Thought and the Genesis of the Need of Causality: by René Laforgue. Translated by Anne Jouard. New York: Nervous and Mental Disease Monographs, 1940. 92 pp.. Psychoanal Q., 11:562.
8. Bruno Marchal (http://iridia.ulb.ac.be/%7Emarchal/)
9. Russel Standish (http://www.hpcoders.com.au/nothing.html)
10. Hut, P.; Alford, M.; Tegmark, M. (2006). "On Math, Matter and Mind". *Foundations of Physics* **36**: 765–94. arXiv:physics/0510188. Bibcode:2006FoPh...36..765H. doi:10.1007/s10701-006-9048-x.
11. "There is no logical impossibility in the supposition that the whole of life is a dream, in which we ourselves create all the objects that come before us. But although this is not logically impossible, there is no reason whatever to suppose that it is true; and it is, in fact, a less simple hypothesis, viewed as a means of accounting for the facts of our own life, than the common-sense hypothesis that there really are objects independent of us, whose action on us causes our sensations." Bertrand Russell, *The Problems of Philosophy*
12. René Descartes, Meditations on the First Philosophy, from Descartes, The Philosophical Works of Descartes, trans. Elizabeth S. Haldane and G.R.T. Ross (Cambridge: Cambridge University Press, 1911 – reprinted with corrections 1931), Volume I, 145-46.
13. Chalmers, J., The Matrix as Metaphysics (http://consc.net/papers/matrix.html), Department of Philosophy, University of Arizona
14. *PHYSICS, PHILOSOPHY AND QUANTUM TECHNOLOGY* (http://www.qubit.org/people/david/Articles/PPQT.pdf)
15. http://www.nature.com/news/paradox-at-the-heart-of-mathematics-makes-physics-problem-unanswerable-1.18983
16. Alan Turing, *On computable numbers, with an application to the Entscheidungsproblem*, Proceedings of the London Mathematical Society, Series 2, 42 (1936), pp. 230–265. (online version (http://www.abelard.org/turpap2/tp2-ie.asp)). Computable numbers (and Turing machines) were introduced in this paper; the definition of computable numbers uses infinite decimal sequences.
17. Feynman, R. The Character of Physical Law, page 57.
18. Subjective time
19. "But ordinary computing systems, such as Turing Machines (TM), can only take a finite number of states. Even if we combine the internal states of a TM with the content of the machine's tape to increase the number of possible states, the total number of states that a TM can be in is only countably infinite. Moreover, TMs can only follow a countable number of state space trajectories. The same point applies to any ordinary computing system of the kinds used in scientific modelling. So ordinary computational descriptions do not have a cardinality of states and state space trajectories that is sufficient for them to map onto ordinary mathematical descriptions of natural systems. Thus, from the point of view of strict mathematical description, the thesis that everything is a computing system in this second sense cannot be supported"*Computational Modelling vs. Computational Explanation: Is Everything a Turing Machine, and Does It Matter to the Philosophy of Mind?* (http://www.umsl.edu/%7Epiccininig/Is%20Everything%20a%20TM%20and%20Does%20It%20Matter%20Publish%2020.htm)
20. Ord, Toby (2002). "Hypercomputation: computing more than the Turing machine". arXiv:math/0209332. Bibcode:2002math.....9332O.
21. "The Cosmology Machine takes data from billions of observations about the behaviour of stars, gases and the mysterious dark matter throughout the universe and then calculates, at ultra high speeds, how galaxies and solar systems evolved. By testing different theories of cosmic evolution it can simulate virtual universes to test which ideas come closest to explaining the real universe."*Cosmology Machine creates the Universe* (http://www.pparc.ac.uk/Nw/supercomputer.asp)
22. Popper, K. *Science as Falsification* (http://www.stephenjaygould.org/ctrl/popper_falsification.html)

23. Deutsch, David (1998). *The Fabric of Reality: The Science of Parallel Universes—and Its Implications*. Penguin Group US. pp. 105–107. ISBN 9781101550632. "My question about the ultimate limits of virtual reality can he stated like this: what constraints, if any, do the laws of physics impose on the repertoires of virtual-reality generators? ... Known physics provides no way other than free fall, even in principle, of removing an object's weight. ... Stated generally, the problem is this. To override the normal functioning of the sense organs, we must send them images resembling those that would be produced by the environment being simulated. We must also intercept and suppress the images produced by the user's actual environment. But these image manipulations are physical operations, and can be performed only by processes available in the real physical world. Light and sound can be physically absorbed and replaced fairly easily. But as I have said, that is not true of gravity: the laws of physics do not happen to permit it."
24. Note: from the perspective of its inhabitants, a Virtual Reality is a Simulated Reality:
Deutsch, David (1998). *The Fabric of Reality: The Science of Parallel Universes—and Its Implications*. Penguin Group US. pp. 58,179. ISBN 9781101550632. "Reality might consist of one person, presumably you, dreaming a lifetimes experiences. Or it might consist of just you and me. Or just the planet Earth and its inhabitants... [Living] processeses and virtual-reality renderings are, superficial differences aside, the same..."
25. Bostrom, Nick (2009). "The Simulation Argument: Some Explanations" (PDF). "If each first-level ancestor-simulation run by the non-Sims requires more resources (because they contain within themselves additional second-level ancestor-simulations run by the Sims), the non-Sims might well respond by producing fewer first-level ancestor-simulations. Conversely, the cheaper it is for the non-Sims to run a simulation, the more simulations they may run. It is therefore unclear whether the total number of ancestor-simulations would be greater if Sims run ancestor-simulations than if they do not."
26. Pooch, U.W.; Sullivan, F.J. (2000). "Recursive simulation to aid models of decisionmaking". *Simulation Conference* (Winter ed.) **1**. doi:10.1109/WSC.2000.899898. ISBN 0-7803-6579-8.
27. Chalmers, David (2005). "The Matrix as Metaphysics". In C. Grau. *Philosophers Explore the Matrix*. Oxford University Press. pp. 157–158. ISBN 9780195181067. LCCN 2004059977. "Evil Genius Hypothesis: I have a disembodied mind, and an evil genius is feeding me sensory inputs to give the appearance of an external world. This is René Descartes's classical skeptical hypothesis... Dream Hypothesis: I am now and have always been dreaming. Descartes raised the question: how do you know that you are not currently dreaming? Morpheus raises a similar question: 'Have you ever had a dream, Neo, that you were so sure was real. What if you were unable to wake from that dream? How would you know the difference between the dream world and the real world?'... I think this case is analogous to the Evil Genius Hypothesis: it's just that the role of the "evil genius" is played by a part of my own cognitive system! If my dream-generating system simulates all of space-time, we have something like the original Matrix Hypothesis." p.22 (http://consc.net/papers/matrix.pdf)