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The Simulated as the Simulation

Recent Developments in Quantum Simulation and the Socioontological Principle of Computer Art

The idea of quantum simulation, first conceived by Richard Feynman in his influential 1982 lecture "Simulating Physics with Computers"[2], introduced a peculiar shift to the notion of computer simulation. In this paper, I examine how this shift, that is bound to change the way we think about the computer as a medium, mirrors what I call the the socioontological principle of computer art and how, vice versa, the socioontological principle of computer art mirrors the shift in the notion of computer simulation.

Without taking quantum simulation into consideration, computer simulation usually denotes the computation of solutions to, or the 'articulation'[3] of, a mathematical model of "real-world", material processes. A necessary prerequisite to this articulation, as to all human understanding of "real-world", material processes, is a symbolic distance, a non-nidentity between the simulation and the simulated. Whereas purely language-based "description" realizes this symbolic distance as one

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[2] Feynman, Richard P.. "Simulating physics with computers". In: Journal of Theoretical Physics 21 (6), 1982: 467-488. See also Feynman, Richard P.. Lectures on Computation. Addison-Wesley Publishing Company, 1996.

[3] Schweber, Sam; Wächter, Matthias. "Complex Systems, Modelling and Simulation". In: Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics 31 (4), 2000: 583-609.

big leap from the material to the symbolic, in terms of computer simulation we have to distinguish three consecutive steps: formalization (in the form of differential equations), discretization (in the form of difference equations), and mediatization (in the form of binary computation).

Each step realizes a higher level of abstraction, rendering the resulting relationship between the material and the symbolic to be at least as arbitrary as the one invoked by purely language-based description. The simulation, however, is still recognized not only as a valid representation of the simulated (as a description would be), but as a model of the simulated, as a representation that not only points to the real-world processes it represents but that claims to reproduce their functionality.[4]

Bruno Latour suggests that this preservation of functionality can take place because at every step of the process of abstraction "each element belongs to matter by its origin and to form by its destination; it is abstracted from a too-concrete domain before it becomes, at the next stage, too concrete again. We never detect the rupture between things and signs, and we never face the imposition of arbitrary and discrete signs on shapeless and continuous matter."[5]

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[4] The exploration of this assumption's ontological truth is subject of a whole discourse within the history of science. For an extensive overview see Frigg, Roman and Hartmann, Stephan, "Models in Science", The Stanford Encyclopedia of Philosophy (Fall 2012 Edition), Edward N. Zalta (ed.), URL: http://plato.stanford.edu/archives/fall2012/entries/models-science/.

[5] Latour, Bruno. "Circulating Reference: Sampling the Soil in the Amazon Forest". In: *Pandora's Hope: Essays on the Reality of Science Studies*. Cambridge, MA, 1999. Interestingly enough, this is also how contemporary computers work: through levels

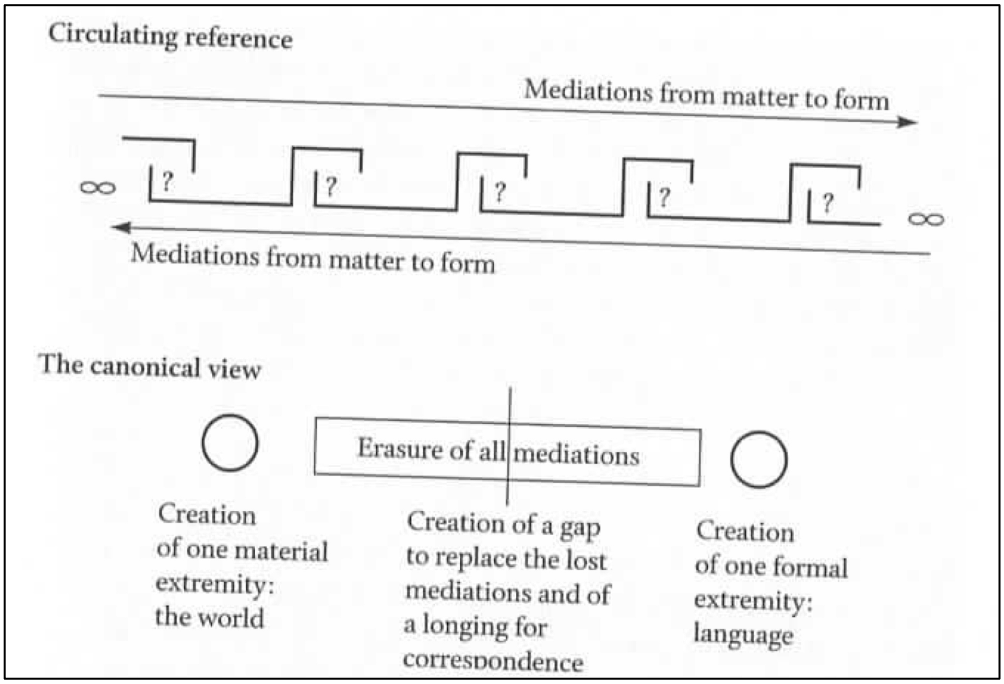

Fig. 1: Bruno Latour, the chain of reference and the canonical view[6]

This oscillation between the material and the symbolic[7] forms what Latour calls a "chain of reference". It is important to keep in mind that this chain of reference does not replace the symbolic distance, it is the symbolic distance. The discreteness of the symbolic operation is kept, the wide gap (of, for instance, a purely language-

of abstraction that each treat the levels below them as "black boxes" of which only certain "public" properties may be considered for further computation.

[6] ibd., 73

[7] Latour famously expands on this idea in his Actor-Network theory that he developed together with Michel Callon and that includes the idea of "translation" as its central concept. See Latour, Bruno. *Science in Action. How to follow scientists and engineers through society.* Cambridge, MA: Harvard University Press, 1987 and Latour, Bruno. *We Have Never Been Modern*. Cambridge, MA: Harvard University Press, 1991.

based description that Latour calls the "canonical view) is just replaced by a number of smaller gaps and those gaps still need to be "jumped" and cannot be "bridged"[8].

For instance, as we measure a "real-world", material process we come up with a series of symbols - in the case of computer simulation most likely numbers - that represent some property in space and time. In itself, this first step - formalization - is a complex achievement already, as it is based on a variety of basic human faculties (for instance the concept of the set[9]). The numbers, however, appear as "raw data"[10] to the next step in the chain of reference. Similarliy, at every step the symbolic is treated as material to the next level of abstraction.

In the light of this realization, let us look more closely at the three steps that can be constructed for computer simulation. In the first step, data gained from the observation of "real-world", material processes is casted into a differential equation. In the second step, this differential equation is treated as the material for a difference equation that usually involves some kind of approximation. In the final step, this difference equation is fed into a universal machine that calculates its results. The existence of an intermediate step, consisting of the "visualization" of "raw data" to

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[8] However, as the symbolic operation exists in the "real", material world, as a faculty of "real", material human beings, this interpretation itself is fueled by the very same symbolic operation it is looking at.

[9] It is no coincidence that all of mathematics can be constucted from set theory.

[10] As Claude Lévi-Strauss discovered that even the mythological antipodes of "raw" and "cooked" translate to well-structured abstract knowledge[10], it should not come as a surprise that "raw data" does not present itself as an antinomy to us. See Lévi-Strauss, Claude. *Mythologiques I : Le Cru et le cuit*. Paris: Plon, 1964.

determine the next step's design, is likeley but we are not concerned with this aspect of the chain of reference in this paper.[11]

Our intuition tells us that this method should be more or less infallible, given a good enough understanding of the "real-world", material processes we would like to simulate. As it turns out, however, the method fails miserably when it is applied to "real-world", material quantum processes. Because quantum mechanics is inherently based on probability, the second step, discretization, becomes impossible even for low complexity quantum processes. Richard Feynman argues that, when it comes to the computer simulation of quantum particles, we face

> a problem about discretizing probability. If you are only going to take k digits it would mean that when the probability is less that 2^{-k} of something happening, you say it doesn't happen at all. In practice we do that. If the probability of something is 10^{-700}, we say it isn't going to happen, and we're not caught out very often. So we could allow ourselves to do that. But the real difficulty is this: If we had many particles, we have R particles, for example, in a system, then we would have to describe the probability of a circumstance by giving the probability to find these particles at points x_1, x_2, ..., x_R at the time t. That would be a description of the probability of the system. And therefore, you'd need a k-digit number for every configuration of the system, for every arrangement of the R values of x. And therefore if there are N points in space, we'd need N^R configurations.[12]

Feynman explains that we will most likely end up with an even higher number

[11] See Latour 1987. Inge Hinterwaldner explores this dimension - in particular regarding the operativity of visualizations - even further in Hinterwaldner, Inge. "Parallel Lines as Tools for Making Turbulence Visible". In: Representations 124 (1), 2013: 1-42

[12] Feynman 1982, 472

of configurations, like N^N, so that "doubling the size of nature" (meaning the part of nature that we are trying to simulate) would lead to an exponential growth in the required computational power.

Hence, the reason for the rupture in the chain of reference, when it comes to quantum processes, is the excessive (usually exponential) complexity of inherently non-deterministic quantum problems within the deterministic computer systems of today. That is why the goal of quantum simulation, as defined by Feynman, is to have "the number of computer elements required to simulate a large physical system [...] only to be proportional to the space-time volume of the physical system"[13] in order to reduce the complexity of such problems to be non-exponential (but, for instance, polynomial). That, however, is only possible if the physical system of the simulation has the same properties as the physical system that is being simulated. This is where Feynman introduces the idea of quantum computing, the idea of a computer performing calculations through basic elements (later called qbits) that make direct use of quantum processes, such as superposition and entanglement.

We will not go further into the technical aspects of quantum computing in the framework of this paper, as the ontological consequences are strikingly evident at this point already: Quantum simulation means not only the simulation of quantum processes, but the simulation of quantum processes with quantum processes. Quantum simulation necessarily requires nothing less than the *simulated* to become

[13] Feynman 1982, 469

the fabric of the *simulation*. Hence, for the notion of computer simulation, what used to be a complex process of negation through abstraction and representation becomes identity, although a curious, not-quite, mediated kind of identity.

This assumption is validated by the fact that, in parallel to the research into quantum computers, or universal quantum simulators, there is a different strand of quantum simulation research that is concerned with experimental quantum simulation or non-universal quantum simulators. This kind of quantum simulator is only useful for the exploration of very specific quantum properties but is easier to realize. As Cirac et. al. put it, in comparison to a full, universal quantum computer, "if we are more modest and only demand our simulator to imitate certain physically interesting systems that cannot be simulated with classical computers, a[n experimental] quantum simulator may be easier to construct, but still would be an important device for the development of science and technology."[14]

To summarize: If we consider the case of quantum simulation, the notion of computer simulation changes, as the chain of reference suddenly becomes an Escher-like staircase, where at the highest level of symbolic abstraction we fall back to the material. In other words, quantum simulation happens at the same time only in the realm of the material and only in the realm of the symbolic.

I argue that in this peculiar double-character we find mirrored precisely what I

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[14] Cirac, J. Ignacio; Zoller, Peter. "Goals and opportunities in quantum simulation". In: Nature Physics 8, 2012: 264-266. See also: Franchini, Fabio et. al.. " Local Convertibility and the Quantum Simulation of Edge States in Many-Body Systems". In: Physical Review X, 4, 041028 (2014).

call the socioontological principle of computer art. Computer art, or media art in general, is inherently concerned with the socioontological reality of technology, with the social effects of the "form" of technology as opposed to the social effects of its "content".

The idea that "form" can have social effects was first developed by Walter Benjamin and is encapsulated in his notion of "Technik". Taken from Benjamin's famous essay "The Author as Producer", the German original term - in comparison to the term "technique" that is usually used in translations - points to the double character of technology use in a work of art. The English edition's translator's note turns out to be quite aware of this fact: "Benjamin uses the word Technik to denote [the] aesthetic technique of a work, but with considerable scientific and manufacturing connotations. Thus it is also close to "technology" – the technical means by which a work is produced, its means of production"[15]. One should add that when Benjamin speaks of the "work" ("Werk") instead of the "artwork" ("Kunstwerk") there is a similar double denotation. "Werk" without the "Kunst" prefix connotates a mechanism (for example a clock) or even a whole factory. Additionally, I would go even further and say that "Technik" not only refers to the work's means of production but to the general relationships of production. As Benjamin puts it: "Namely, instead of asking: what is the relationship of a work of art to the relationships of production of the time? Is it in accord with them, is it

[15] Benjamin, Walter. "Der Autor als Produzent". In: *Gesammelte Schriften II-2.* Frankfurt am Main, 1974: 102.

reactionary or does it it strive to overthrow them, is it revolutionary? - in place of this question, or in any case before asking this question, I would like to propose another. Before I ask: how does a literary work stand in relation to the relationships of production of a period, I would like to ask: how does it stand *in* them?"[16] In other words: “Technik”, in the context of art, is a technique somehow concerned with technology, or, more generally, a practice somehow concerned with the general relationships of production, or finally: a social practice.

This definition of "Technik" is closely related, as Benjamin points out, to the question of form and content: "I could have started from an older but no less sterile debate: what is the relation between form and content"[17]. Throughout the text, Benjamin seems to insinuate that commitment can either be a content-based artistic practice or a form-based artistic practice. The notion of "Technik" thereby gives us a way to grasp the dialectical relation of those two concepts operating in a work of art. Hence, for Benjamin, a politically committed artwork is always formally committed as well: "I want to show you that the political tendency of a work can only be politically correct [sic] if it is also literarily correct. That means that the correct political tendency *includes* a literary tendency"[18]. Hence, "formal" commitment means changing technology through technique, thus changing the relationships of production – which is the goal of every "correct" (that is, for Benjamin at this point of

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[16] ibd., 96

[17] ibd.

[18] ibd., 95

his life, marxist-revolutionary) political tendency. The notion of "Technik" describes this momentum.

Theodor W. Adorno's concept of the logic of art takes this idea of "Technik" even further. For Adorno, art is the "social antithesis to society"[19], both deeply rooted in the fabric of reality and at the same time completely removed from it. In addition to that, however, it has the same kind of relation with rationality:

> The logic of art, a paradox for extra-aesthetic logic, is a syllogism without concept or judgment. It draws consequences from phenomena that have already been spiritually mediated and to this extent made logical. Its logical process transpires in a sphere whose premises and givens are extralogical. The unity that artworks thereby achieve makes them analogous to the logic of experience, however much their technical procedures and their elements and the relation between them may distance them from those of practical empirical reality. The affiliation with mathematics that art established in the age of its dawning emancipation and that today, in the age of the dissolution of its idioms, once again emerges as predominant, marked art's emerging self-consciousness from its dimension of logical consistency. Indeed, on the basis of its formalism, mathematics is itself aconceptual; its signs are not signs of something, and it no more formulates existential judgements then does art; its aesthetic quality has often been noted.[20]

In other words, art is a coherent reflection on the impossibility of coherence, in the realm of material experience, comparable to metamathematics in the realm of the symbolic[21]. By sculpting experience, it builds up coherence from matter and

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[19] Adorno, Theordor W.. *Aesthetic Theory*. Translated by Robert Hullot-Kentor. London, New York, 2004, 8.

[20] ibd., 6

[21] See Cantor, Georg. "Ueber eine elementare Frage der Mannigfaltigkeitslehre". In: Jahresbericht der Deutschen Mathematiker-Vereinigung. Leipzig, Stuttgart,

produces social effects from this coherence. Again, this is the socioontological function of all art. For computer art, however - and this is the important realization - this means that the "matter" coherence is sculpted from is a coherent, symbolic system itself.

Like in quantum simulation, the chain of reference becomes an Escher's staircase, only that we do not fall back to the material but back to he symbolic. This is how the socioontological principle of computer art is mirrored - in the literal sense of the word, as the chain "material-symbolic-material" becomes "symbolic-material-symbolic" - in quantum simulation.

Wiesbaden, 1892 and Gödel, Kurt. "Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme I". In: Monatshefte für Mathematik und Physik 38, 1931.