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The Quantum Turn and the Post-post-digital Future of Computer Art

The idea of quantum simulation, first considered by Richard Feynman in his influential 1982 lecture "Simulating Physics with Computers"[2], introduced a peculiar shift not only in the notion of computer simulation but in the notion of simulation in general. In this paper, I examine what this shift means for the ontology of software and hardware, and how it is bound to change the way we think about the computer as a medium of art.

Computer simulation usually means the computation of solutions to, or the 'articulation'[3] of, a time-based mathematical model of real-world processes. A necessary prerequisite to this process is the creation of a symbolic distance between the simulation and the simulated. Through consecutive steps of abstraction (in the form of differential equations), discretization (in the form of difference equations), and mediatization (in the form of binary computation), this symbolic distance is realized as a chain of reference, where the fabric of the simulation stands in an arbitrary relation to the fabric of the simulated.

The simulation, however, is still recognized as a valid representation of the simulated. Bruno Latour suggests that this is possible because at every step of the process described "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

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[2] Feynman, Richard P.. "Simulating physics with computers". In: Journal of Theoretical Physics 21 (6), 1982: 467-488.

[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.

never face the imposition of arbitrary and discrete signs on shapeless and continuous matter."[4]

For real-world processes that happen on a quantum level, however, this is not a viable approach. Because quantum mechanics is inherently based on probability, the chain of reference fails at the second step (discretization). As Richard Feynman explains, "one way that we could have a computer that simulates a probabilistic theory, something that has a probability in it, would be to calculate the probability and then interpret this number to represent nature."[5] But then 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."[6]

Taking this even further, Feynman explains that we will most likely end up with an even higher number 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

[4] 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 of abstraction that each treat the levels below them as "black boxes" of which only certain "public" properties may be considered for further computation.
[5] Feynman 1982, 471
[6] Feynman 1982, 472

growth in the required computational power.

The reason for the rupture in the chain of reference as we try to simulate a quantum system, as it thus turns out, is the excessive (usually exponential) complexity of inherently non-deterministic quantum problems within the deterministic computer systems of today. Hence, the goal of quantum simulation 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"[7] in order to reduce the complexity of such problems to be polynomial. That, however, is only possible if the physical system of the simulation has the same properties as the physical system of the simulated. This is where Feynman introduces the idea of quantum computing, 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 the fabric of the *simulation*. Hence, for the notion of simulation, what used to be a complex process of negation through representation becomes identity, although a curious, not-quite, mediated kind of identity.

So, what happens to our concept of software and hardware in the light of quantum simulation? In a way, Friedrich Kittler's dogma that "there is no software"[8]

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[7] Feynman 1982, 469

[8] Kittler, Friedrich. "Es gibt keine Software". In: *Draculas Vermächtnis: Technische Schriften*. Leipzig, 1993

comes back to life. Kittler, in his seminal text of the same name, posits that the constraints present in computer hardware translate themselves through whatever number of levels of abstraction into the software dimension. Though Kittler's argument is mainly concerned with Foucauldian power relations inscribed in the hardware, it gains in persuasiveness in the light of quantum computing. Suddenly, we end up in the realm of the *post*-post-digital, where the chain of reference is a circle, the maximum level of abstraction leads right back to the concrete and all black boxes become translucent. The post-post-digital future, as it seems, is a future of a more radical fusion of software and hardware than ever before. Historically, while the liquefaction of hardware with the invention and popularization of programmable logic devices, hardware description languages and related ideas was already a step towards this future, quantum simulation is the pivotal concept for it to become a critical mass.

If we finally consider the computer as a medium of art, Adorno's idea, that somehow art can function as a "social antithesis to society"[9], being both deeply connected to the fabric of reality and at the same time completely removed from it, realizes itself in a peculiar way: quantum superposition as applied dialectics. And while the realization of quantum computing (not to speak of quantum computing in an aesthetic context) may still take some time, computer art increasingly turns to all the peculiar consequences of quantum simulation, as discussed in this paper.

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