Why Determinism is Never a Scientific Concept

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Quantum mechanics requires an ever-increasing energy cost for any attempt to predetermine the future

Let's Play Ball

Imagine a roulette ball at the center of a 1-meter wheel with 64 pockets. How many bits will you need to specify a future move into a specific pocket? Six. If you double the wheel's diameter to 2 meters and the number of pockets to 128, how many bits will you need? Seven. Double it again? Eight bits. How about a wheel as wide as the universe? That one is a very large number, the exact value of which is not the point. Next, how many bits do you need for a sequence of ball positions across the estimated duration of the universe so far? A number that dwarfs the previous one. Finally, what if you decide that the universe endures forever? The number of bits becomes infinite.

Determinism is a concept that ignores information. In physics, the source of this indifference comes naturally because popular smooth continuum maths assumes infinities of information at every point. This deeply built-in assumption makes free information seem like a "natural" viewpoint in physics. After all, the math says so, and everyone assumes "pure" math is never wrong… well, at least not until it is.

Quantum mechanics tells us very loudly that such assumptions do not match the behavior of the obstinately lumpy, always imperfect, infinity-rejecting world of experimentally accessible physics. In that obstinately imperfect world of testable physics, the total future path information available on any one particle in isolation is proportional to its total mass and energy. That is why light particles' wave functions dissipate faster than those of heavy particles. Everything else that determines the future path of the particle comes from the huge information context in which it operates.

Interestingly, the concept of a real-world "exact point" particle encounters the same difficulty. Why? Because it takes infinite bits to specify a position with infinite precision.

Determinism did not originate in classical science. It has been a theme of religion for centuries in Europe and millennia in parts of the world. The particular flavor of determinism that influenced Hilbert came from his Calvinist education, which steeped him in the views of Swiss Reformation leaders such as John Calvin, Huldrych Zwingli, and, my favorite and likely ancestor, Heinrich Bullinger.

Scientific arguments for determinism were never anything more than impossible infinite elaborations of the algorithms that make the classical world possible, enabling atoms but not points, and electron clouds but not electron points. The folks who created them knew nothing about quantum mechanics or relativity, which had yet to emerge.

You may not be thinking, “But Terry, didn’t Einstein prove the need for a block universe by showing that observers in different inertial frames must have intersecting definitions of past and future?” Alas, no, he did not. He neglected a single term that linked each new frame to its past and constrained the space over which it applied. The universe couldn’t care less if your spaceship speeds up to near light speed, since most of the universe for most of the eons after will never know it happened. The speed of light always constrains causality, including the causality defined by new definitions of time and space.

Global Complexity vs. Local Information

Another reasonable question is whether I am confusing the difficulty of predicting the future from an extremely complex set of starting conditions with non-determinism. It’s a great question, but the irony is that I’m talking about the opposite situation: Experiments in which one does everything possible to reduce complexity. My point instead is about data storage in extremely simple situations.

For example, if you send a hydrogen atom into intergalactic space at a slow velocity, determinism requires it to know where it’s headed over the next billion years. If the atom knows that — and especially if it knows that down to which atom on which planet it hits upon arrival — then it requires a truly mind-boggling level of path precision the moment you launch it.

There is no experimental evidence for such pre-existing precision at launch time, since this is exactly the situation for which a rapidly expanding Schrodinger wave equation takes over and endures until a “collapse” event causes the experimentally detectable wave behavior to cease. There are fields devoted to how slow, atomic-scale objects such as neutrons reflect like waves. In such situations, nothing is abstract about Schrodinger waves, including their ability to impart momentum without turning back into particles.

But here’s the real kicker: You can add energy and information to get better targeting.

If you pump incredible levels of momentum energy into the same neutron, that energy behaves like bits of data encoding an increasingly well-defined final target. You may even be able to pick a galactic definition, though you will never get much better than that.

In short, it’s all about bits encoded by energy, not initial state complexity. And, alas, classical Hibert-style continuum maths are utterly and obstinately blind to bits. Someone must fix that, since such incomplete and naïve maths are a terrible way to model reality.

Research and Investment Implications

While one might think that an essay on determinism is a philosophical issue with no research or investment implications, the opposite is true. Quasi-determinism — the belief that the universe is “mostly” classical and “mostly” clock-like up to some hard limit — is an extremely valuable shortcut in all sorts of endeavors. Quasi-determinism is why folks usually don’t need quantum mechanics to optimize an automated production line.

However, absolute determinism is an entirely different matter because it blithely ignores the real physical limits of quasi-determinism. Casual use of absolute determinism in math, computation, and systems design wastes business resources by redirecting costly and often large-scale research down paths that never achieve their promises. They waste precious investments and costly intellectual resources, undermining companies’ and researchers’ ability to recognize and develop new, more physics-based technologies.

The single greatest source of absolute determinism in Western physics was the Calvinist-trained mathematician David Hilbert, who in the late 1800s and early 1900s was wildly successful at promoting infinity-loving "perfect" maths as necessarily superior to results found by experimental physics.

As long as these formalisms stayed close to the quasi-determinism of actual physics — which is to say, close to classical, non-quantum physics — they worked spectacularly well. However, they also contributed profoundly to the impasse that prevented the merger of relativity and quantum mechanics, since a perfectly deterministic universe is identical to a universe in which all events are always observed and thus never quantum.

It's time to move Hilbert's profoundly religious approach back to where it belongs, in religion, and stop letting it block future progress in sciences and technologies. The successful technology investors of the future, both national and private, will be the ones who reject naïve infinity-worshipping maths and refocus on experimentally accessible physics. New, more realistic maths must replace the non-physical, idealistic concepts such as "infinite" differentiability. In short, these new maths must become more algorithmic with well-defined and finite cut-offs. The Taylor series will always be with us in the future of fundamental physics, but the abstract perfection of infinitely long sine waves will not.

References

[1] T. Bollinger, *Why Determinism is Never a Scientific Concept* (LinkedIn copy), 2025-06-17.15:45 EDT Tue. https://www.linkedin.com/pulse/why-determinism-never-scientific-concept-terry-bollinger-xrbye