Four Flavours of Determinism

by Mike Arnautov

When philosophers consider or discuss the world in which we live, 'determinism' usually makes an appearance, even if only to dismiss the possibility of the universe being a deterministic one. The term is generally used as if it were self-explanatory, but it is not. Just limiting ourselves to its application to the physical world (i.e. ignoring 'social determinism', 'genetic determinism', 'theological determinism' and such like), there are at least four distinct ways for the world to be, all of which could be reasonably characterised as deterministic. My purpose is to acquaint the reader with these four versions of physical determinism.[1]

In its most generic form determinism asserts that at any given time the future is 'closed', or, to put it otherwise, that all future events are pre-determined, without specifying how or why they are pre-determined.

The opposite of determinism is often conceived of as indeterminism, which is usually associated with randomness. However, as we shall see, it is a mistake to think that a deterministic universe cannot feature random events. The concept of randomness is itself a deep and complex one, and I do not propose to examine it. For the purposes of this discussion I shall use 'a random event' to mean an event which in principle unpredictable. In other words, I shall use randomness to mean objective (or ontic) randomness, rather than merely the epistemic kind, arising from our ignorance of all relevant factors.

The classical definition of determinism was given in 1814 by the French scientist Pierre-Simon Laplace in his *A Philosophical Essay on Probabilities*:

> We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes.[2]

However, there are problems with this definition.

1. No system can reliably predict its own behaviour in all circumstances because its prediction becomes a part of those same circumstances. It follows that no part of a system can reliably predict the behaviour of the system as a whole. Thus Laplace's demon would have to exist outside the universe.
2. According to Einstein's Relativity, information cannot propagate with a speed exceeding that of light in a vacuum, which makes full knowledge concerning the state of the universe at time T only available retrospectively. As a matter of principle it can be known only when T is in the distant past (or not at all, if the universe is infinite in time or space[3]).

Because of these problems, it is now customary to drop the prediction element. Thus to say that the world is a deterministic one amounts to asserting that the complete state of the universe at time T fixes the state of the universe at any subsequent time.

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1 Determinism should not be confused with fatalism, in which only some key events are pre-determined, while allowing exercise of free will in choosing the path by which such key events come to be.

2 This hypothetical intellect is often referred to as Laplace's demon.

3 Despite the popular belief to the contrary, the Big Bang cosmological hypothesis does not preclude either of these possibilities.

However, this modern reformulation also faces some challenges.

1. What do we mean by 'at time T'? According to Einstein (again!), simultaneity is relative, so two observers in the same location, but moving relative to each other, only share the 'now' of their actual location – their respective 'nows' extend differently into further reaches of the world. The faster they move relative to each other, the more pronounced the difference becomes. This may or may not be a real problem. Einstein's relativity does not preclude us from deriving some notion of 'now' independent of individual observers, for example basing it on the singular event of the Big Bang.
2. Even then we are still left with a further potential problem. Though the matter is not yet entirely settled, it would seem that General Relativity precludes any possibility of foliating spacetime into a stack of separate 'nows'.

Thus classically defined determinism may or may not make sense, but demonstrating its applicability to the actual universe is clearly somewhat problematic. Nevertheless, this is what is typically meant by the unqualified term 'determinism' (or more precisely *causal determinism)*.[4] As must be obvious, it leaves no place for randomness – all events are strictly caused by preceding events.

Closely related to causal determinism is *adequate determinism*, which emerges (in all senses of the word) from the indeterminacy of Quantum Mechanics through purely stochastic mechanisms. While we have no idea whether an atom of Radium will or will not undergo spontaneous fission in any specific time interval, given the vast number of such atoms in a macroscopic piece of Radium[5], we can make a very precise prediction of the proportion of those atoms which will spontaneously split. Through this general mechanism we get an apparently deterministic macroscopic world from the underlying indeterminacy of a sub-microscopic world.

At this stage I fully expect the reader to protest that adequate determinism is misnamed – it is really an inadequate determinism, its deterministic pretensions being based on nothing more than the extreme (and it is extreme!) unlikelihood of departures from an apparently deterministic behaviour. And, yes, it is a point well taken, but here we run into a difficulty with philosophical foundations of probability itself. What exactly does it mean for an event to be so improbable that one would have to wait for periods vastly exceeding the age of the universe for such an event to occur somewhere in it?[6]

As a practical example, in principle there is a vanishingly small, yet non-zero chance of a macroscopic sample of Radium ceasing to be radioactive for a period of time observable to humans. Should such an event be observed, would we just shrug our shoulders and say: "well, it's very unlikely, but not impossible", or would we look for a causal explanation of such a vastly unlikely event? I submit that the latter would be the correct reaction, on the simple ground that the likelihood of our not knowing something relevant, which might explain the observation, is vastly greater than the likelihood of its happening by chance (for no causal reasons).

In short, unlike the classical, causal flavour, adequate determinism of the macroscopic world does not preclude random events in principle, but does so in practice. We can,

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4 We should note here one oddity of this classical definition. It does not entail time reversibility. Future states of the universe may be fixed by its state now, but nothing is said about past states being equally determined. A universe branching backwards in time is perfectly consistent with the above definition. This would, of course, mean a loss of information as different pasts merge into the same present. Since such loss of information is forbidden in Quantum Mechanics and since all our physics theories are time-symmetrical, I shall ignore this wrinkle. It is easily handled by replacing 'all later times' with 'all other times' in the definition of causal determinism.

5 There are approximately 2,661,000,000,000,000,000,000 atoms in a single gram of Radium.

6 Probability and its philosophical interpretations is a complex subject in its own right. I do not propose to address it here.

of course, make the underlying quantum indeterminacy manifest itself in elaborately contrived experimental set-ups by affecting macroscopic states or our measuring devices. However, all such experiments rely on deterministic causal effects to magnify events occurring on the quantum scale.

Turning back to the classically defined causal determinism, there is an interesting complication. Consider a time machine. Not the standard science-fiction type, which allows re-visiting the past (in order to kill your granddad etc . . .), but a much less exciting one, capable of going **only** into the future. Imagine a time machine, which sets out at time T(start), and pops up again at a later time T(stop). It does not in any sense exist in the intervening times. Can such time machines exist? For that matter, are there any natural phenomena which have this property of simply skipping a given time interval? We don't know, but there is no known reason to exclude this possibility.

This has an important consequence for causally deterministic universes: the state of the universe at a time T between the start and stop times is no longer sufficient to fix the state of the universe at all later times. I.e. in the time interval between T(start) and T(stop) a universe permitting such time travel does not conform to the classical definition of determinism. During that time it looks distinctly like an indeterministic universe, even though no actual indeterminacy is involved. This is what is known as a weakly deterministic universe, in which the future is fixed not by the state at some time T, but by the universe's complete (possibly infinite!) past history.

Thus we now have two separate models of classical determinism: *strong causal determinism,* in which the state of the universe at time T does suffice to fix its subsequent history, and *weak causal determinism* in which it is only the whole of the past history that does the trick (or the complete state of the origin of the universe, if the past is finite).

The apparently clear division between determinism and indeterminism suddenly looks rather blurred. One can argue that the apparent indeterminacy of such a universe is still purely epistemic. But one can also argue that, since we can only know about the past by traces it has left in the present, and since forward time-skipping causal influences are by definition unknowable in the time interval they skip, the relevant information is in principle unavailable and hence it is not legitimate to posit its existence: a difference that makes no difference *is* no difference.

Of course, the weak form of causal determinism faces the same Relativity-related difficulties as the strong version. If, as some physicists consider possible, the Big Bang was just an event in an infinite history of the universe, rather than the beginning of time, does the assertion that the whole of the past history of the universe determines its future actually make any sense? This seems at least debatable.

There is, however, another, more radical approach to determinism. Could one define it in a way which would make it immune to challenges by Einstein's Relativity theories? Indeed one could – by stripping determinism to its barest bones, resulting in the 4th version of the concept. *Logical determinism* simply says that all propositions concerning the past, the present and the future are either true or false.

Note an important implication of this definition: logical determinism dispenses with the requirement of causality. It demands all events to be determinate, which makes it a determinism, but unlike the above discussed causal versions of the concept, it does not demand that events be causally determined.[7]

This may sound familiar to readers acquainted with scholastic philosophy. The notion of 'accidental necessity' was invented by scholastics to account for the fact that the

7 This is, of course, why I was careful to qualify both strong and weak flavours of determinism as *causal ones.*

past is unchanging. If something happened in the past than it is necessarily so from then on. But previously it may not have been necessarily so. Thus the necessity of past events is an accidental necessity: every proposition concerning the past is either true or false but may be so accidentally.[8]

Logical determinism gives the future the same status as the past (and the present). In doing so, it becomes compatible with indeterminism. It happily accommodates uncaused events, be they quantum level or macroscopic ones.

Again, this may sound familiar. I have already mentioned Relativity with its multiplicity of 'nows'. Some scientists[9] claim that, as a logical conclusion, if the distinction between the past and the future is relative, then all of time must simply exist – passage of time being but an illusion. This so-called 'block universe' is in fact a logically deterministic universe, which is why it is compatible with Quantum Mechanics and with indeterminism in general. As the result of dispensing with the requirement of causality, logical determinism becomes entirely compatible with non-epistemic randomness.[10]

In a logically deterministic universe it may indeed be determined that a given atom of Radium will undergo spontaneous (i.e. uncaused, according to Quantum Mechanics) fission at a given time T. It's just not **causally** determined. It will happen, but it will happen for no reason. Hence the connection with 'accidental necessity' – which is very appropriate, since logical determinism gives the future exactly the same logical status as the past.

This version of determinism, too, is sometimes rejected as not really qualifying as a 'proper' determinism because it abandons the requirement of strict causation. This objection suggests that in ordinary usage 'determinism' is mostly used to mean *causal* determinism, presumably on the assumption that strict causation is necessary for the future being 'closed' rather than 'open'.

To summarise this brief survey of the four main flavours of determinism – a topic much richer than is usually appreciated – the four versions are:

1. *Adequate determinism*, which emerges statistically from indeterminate 'microbangings' at quantum level.
2. *Strong causal determinism*, which is what is usually meant by the term 'determinism'.
3. *Weak casual determinism*, which permits causal influences to skip into the future, completely bypassing the intervening time interval.
4. *Logical determinism*, which dispenses with the requirement of causality.

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8 The notion of accidental necessity came from scholastics grappling with Aristotle's sea battle example, even though it seems likely that Aristotle was merely pointing out that future events did not fit the simple true/false dichotomy.

9 For example, David Deutsch in his book *The Fabric of Reality*.

10 As an aside, there are two common misunderstandings concerning the block universe. (a) To say the future 'already' exists is just a figure of speech. 'Now' is a slice through the 4D block of the universe's spacetime, so clearly the future and the past do not exist 'now' – unless one imagines a stand-point from some hyper-time. (b) In the block universe, time is not just like a dimension of space. It is measured in units of 'imaginary' length; hence the square of a time interval is a negative number. This makes a considerable difference to the spacetime geometry and thus has very practical consequences predicted by Relativity theories and thoroughly verified by experiments.