The four flavours of determinism and their relationship with probability

(Mike Arnautov, March 2014)

This talk is not about determinism being "true" (whatever that might mean). It is about our conception(s) of determinism and its relationship with probability/chance. My main source are books by Lawrence Sklar – an American philosopher of physics. In particular I draw on his “Space, Time and Spacetime” and “Physics and Chance”. Not that either book is primarily about determinism or probability. The title of the first book is self-explanatory, but the second is really about the tricky and perplexing field of statistical mechanics. However, in setting the scene for his main topic, Sklar summarises very nicely various conceptions of probability and their difficulties. Stanford's on-line encyclopaedia (http://plato.stanford.edu/) is also a useful source on both topics.

To clear one point straight away: I do not know and do not really care whether the universe is or is not "really" a deterministic one. That makes me a "weak compatibilist", which is as close as I care to venture today to the taboo subject of "free will".

And another point: I am not going to talk about pseudo-determinisms such as social determinism, genetic determinism, theological determinism and such like.

But before we venture there, I need to say a few words about another concept widely (and incorrectly) considered to be incompatible with determinism: chance and probability.

Chance in ordinary usage. I am about to toss a coin. What's the chance of it coming up heads? About 50%. I have tossed a coin and covered it with my hand. What's the chance that it's heads? About 50%. I have uncovered the coin – it's heads. What's the chance now? 100%. Last year I tossed a coin and cannot remember the result. What's the chance it was heads? 50%.

In ordinary usage chance really signifies mere lack of information, causing us to envisage a spread of possible outcomes. Generalising this to all events of uncertain outcome leads to the epistemic notion of chance and probability. But it is possible (and in fact QM claims it to be the case) that at least some chance is intrinsic – that for some events, no amount of knowledge would allow us to make a correct prediction.

So the split between subjective (epistemic) and objective (essential, or dispositional) notions of chance and probability. (I leave aside the third “interpretation”, which can be characterised as shut-up-and-calculate.)

Notice, however, that I smuggled in "probability" is if it were a concept transparently following from "chance". It is not. It is a non-trivial abstraction of the empirical notion of frequency of outcomes. Probability is a fairly tricky concept, which for excellent reasons departs from common sense notions. E.g. an event of probability zero is not an impossible event. Ditto an event of probability one is not a certain event. More generally, probability only has meaning in the context of a population. It says nothing about singular events, which are not fitted into a context of a wider population.

Philosophical issues of probability are complex and deep. I do not propose to examine them today. The above should suffice for discussing my main topic. However, for the purposes of this talk I'll ignore epistemic probability altogether because it is trivially obvious that it can be happily accommodated in a deterministic universe, however one might define determinism..

So, what **is** determinism? How does one define it? The term is often used as if its meaning were transparent, but it is not.

There are in fact at least four very distinct flavours of determinism and the point of my talk is to try acquainting you with all four.

The classical definition goes like this: knowing the state of the universe at time T, allows predicting the state of the universe at any later time. There are problems with that definition.

1. No system can reliably predict its own behaviour. Even more so, no part of a system can reliably predict the behaviour of the system as a whole. So re-phrase it: the total state of the universe at time T, fixes the state of the universe at all later times.

2. According to Einstein, information cannot propagate with speed exceeding that of light in 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 only known when T is in the distant past (or not at all, if the universe is infinite). Clearly as a matter of practical principle, such detailed knowledge of the past is impossible.

3. What do we mean by "at time T" anyway? As per Einstein, simultaneity is relative, so for two observers moving relative to each other, "now" means two different things. This may or may not be a problem. If nothing else, Big Bang might give us an objective "now", independent of observers. Though whether time foliates in General Relativity is, I believe an open question.

Thus classically defined determinism may or may not make sense, but demonstrating its applicability to the actual universe is clearly somewhat problematic.

Closely related to such classically defined determinism is "adequate determinism", which emerges (in all senses of the word) from the indeterminacy of QM through purely stochastic mechanisms. While we have no idea whether an atom of U235 will or will not undergo spontaneous fission in in any specific time interval, given the vast number of such atoms in a macroscopic chunk of U235, 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 sub-microscopic world. The result is usually referred to as adequate determinism.

At this stage I fully expect you 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 the universe. Both interpretations of probability (subjective and objective) have problems here because of the lack of a population of equivalent (in some sense) events.

Let me illustrate it on a practical example. In principle there is a non-zero chance of a metre-wide bubble of vacuum spontaneously appearing in this room. Should that happen, 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 bubble is vastly greater than the likelihood of it forming by chance – for no causal reasons.

But let's return to the classically definition of determinism. Consider a time machine. Not the standard SF type, going into the past (in order to kill your granddad etc...), but a much less exciting one, capable of going **only** into the future. There is nothing in the laws of physics to forbid it.

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. It follows that 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.

Can such time machines exist? For that matter, are there any natural phenomena which act like one – by simply skipping a given time interval? We don't know, but there is no reason to exclude this possibility. Thus we have is two separate models of classical determinism: strong determinism in which the state of the universe at time T does suffice to fix its subsequent history, and weak 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).

But there is a curious fact about, a weakly deterministic universe: it is indistinguishable from a nondeterministic universe, unless one has a complete information about its state not nut at some arbitrary time T, but also at **all** past times. This does not amount to objective, non-epistemic indeterminacy, but it does rather blur the line. Is objective probability compatible with weak determinism? One can argue that the answer is clearly no. But one can also argue that since the relevant information is in principle not available, it is not legitimate to posit its existence: a difference that makes no difference is no difference.

Regardless of our understanding of probability, the weak form of classical determinism faces the same Relativity-related difficulties as the strong version. Can one define determinism in a way which would avoid these difficulties? Indeed one can, by stripping determinism to its barest bones. 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, but does not demand them being causally determined.

This may ring a bell: recall the notion of "accidental necessity". It is a concept invented by scholastics to account for the fact that the 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. So the necessity of past events is an accidental necessity: every proposition concerning the past is either true or false. (This comes from grappling with Aristotle's sea battle example.)

Logical determinism gives the future the same status as the past (and the present). In doing so, it becomes compatible with objective indeterminism as well as with the weak/strong classical varieties (which we really ought to call weak/strong causal determinism).

But is it legitimate to give the future the same status as the past? Here's a rather surprising fact about classical causal determinism (weak or strong) which is rarely remarked upon. In a causally deterministic universe it is the past that is open (i.e. history branches **into** the past) rather than the future. (As e.g. in Conway's game of Life.)

Indeed, the only way we know about the past is through the present. If more than one past is fully consistent with the present, would it not be rational to say that there could be a multiplicity of pasts? (Many Worlds version of QM allows branches to merge, provided there is no propagating "sphere of difference" – it says nothing about the possibility that two or more initially different worlds would branch into an identical one, effectively merging as per Leibniz's identity of indiscernibles.)

Going back to logical determinism, some of you may also find it familiar for a different reason. I mentioned Relativity with its multiplicity of "nows". Some scientists claim that as a logical conclusion, in a deterministic universe (of either kind), if the distinction between the past and the future is relative, then all of time must simply exist – time being but an illusion. This is called the block universe.

Two main common misunderstandings concerning the block universe. (1) 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 some hyper-time. (2) In the block universe, time is not just like a dimension of space. It is measured in units of "imaginary" length, so the square of a time interval is a negative number – this makes a considerable difference to the spacetime geometry.

In fact, block universe is a logically deterministic universe, which is why it is compatible with QM (and with indeterminism in general). As the result of dispensing with the requirement of causality, logical determinism becomes entirely compatible with non-epistemic probability (i.e. with what is generally understood as indeterminism). This leads some people to object that the label of "determinism" is therefore inappropriate in this case. However, that pre-supposes on some entirely unclear grounds that causality is indispensable for determinism. In a logically deterministic universe it is indeed determined whether or not a given atom of U235 will undergo spontaneous (i.e. uncaused, according to QM) 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.

And that's the end of my brief survey of the four main flavours of determinism – a topic much richer than is usually appreciated. To summarise, these 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.
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.

- o O o -