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Bold, new quantum cybernetics

Quantum mechanics holds out a promise of doing in a trice the calculations that massive computers would take years to plod through, says S.Ananthanarayanan.

Quantum mechanics is the new worldview that emerged from the crisis that engulfed physics during the early 20^{th} century. Its implications were far from intuitive, yet the accuracy of its results is unparalleled.

The sub-atomic world

In quantum mechanics, or the rules for calculating things at the very small scale, like in the subatomic world, there are two great differences from the rules that apply in our everyday world. One is that certain properties of things, like energy, do not change ‘smoothly’, like a slope, but in ‘steps’, like a staircase. The other difference is that at a given moment, a thing need not be on a particular ‘step’, but is in a ‘combination of all possible states’. The thing settles for a particular ‘step’ only at the moment of measurement, and being found to be on some steps may be more likely than others.

Thus, if two electrons are bouncing off each other, they do not behave like billiard balls, but may ‘scatter’ in a whole lot of directions, of which some may be more likely than others. When we move to more massive objects, the separation between the possible ‘states’ reduces and scattering in the usual ‘billiard ball way’ also becomes overwhelmingly more likely. Till finally, real billiard balls do not behave like electrons at all!

Quantum Computing

This property of a sub-atomic system being in ‘many states at once’ throws up the possibility of a collection of such systems behaving like a stupendously complex machine, because of each system representing not just one set of properties but all values at once. For instance, an electron can exist in one of two possible ‘spin’ states, ‘+1/2’ or ‘-1/2’. Two electrons can then be in 4 possible states and 3 electrons in 8 possible states and so on. The range of possible states increases very fast. With 10 electrons the range is 1024 and with a 100 electrons it is over a million.

This means that a set of a hundred electrons, with each one being in a combination of two states, represents an entity that could simultaneously be in over a million states. With a calculator of just a hundred electrons, then, we could try out calculations with over a million values, all at the same time!

It was the irrepressible R P Feynman of MIT who put forward the idea and David Deutsch, at Cambridge followed up with rigorous theory.

In principle, a string of electrons, or atoms can be acted upon by an agency, like a photon, to alter the state of one or more of the members. The classic AND, NOR and NAND gates can be devised and regular parallel computing can be set up. The difficulty is creating such an ensemble of electrons, to be 'entangled' or to be in the combination of states 'coherently', which is to say that that a disturbance does not move the units of the ensemble into one of the permitted states, instead of being in 'all states at once'. And then to contain and manipulate such an ensemble. And having mastered the hardware of the quantum computer, to program it, with 'photons' that would cause a 'flip of the spin state', for instance, presents the challenge.

Only the very first steps, of computers with just a handful of components, have been taken. But the prospect is of the kind of computing power that cryptography, weather control and space travel demand.