Digital Prediction: Good Results From Sketchy Models

The virtues of digital – as opposed to analog – computation, communication, image processing, ... are well known and widely appreciated. The key advantage is that digital information is quantized, so that you only get it wrong if you make a *big* mistake. So small amounts of uncertainty, error, or noise can be unambiguously, and almost always correctly, compensated. You just interpret the "slightly off" information as representing the nearest acceptable value. If the only possible mistakes are big mistakes, then small mistakes vanish into no mistakes at all.

Still, it came to me as a revelation that the same idea applies in the realm of theories. I was lecturing about the shell model of nuclei, and having a hard time keeping a straight face. The "approximations" that go into that model – quasi-independent, non-relativistic protons and neutrons, an *ad hoc* mean field in which they move, and so forth – are so removed from correct concepts based on QCD and relativistic quantum field theory, that I had to ask myself why these swindles worked. Swindling rubes I understand – but Nature?

Then it struck me that the most impressive, characteristic predictions of the shell model have a digital character. They include predictions for things like the spin, parity, charge and baryon number of low-energy nuclear states. (Or, more generally, the ordering of levels as a function of spin, parity, and ordering of energy levels as a function of those variables.) In quantum mechanics spin is discrete, parity is binary, charge and baryon number are integers – and ordering is intrinsically digital. So a model can be crude and approximate, as the shell model surely is, and yet have a good shot at getting these things exactly right, reliably! *Digital prediction* is a powerful way to get good results from sketchy models.

Once I recognized this principle, I realized that it was a matter of "speaking prose". Physicists – and not only physicists – have been exploiting the idea of digital prediction for a long time, in various special cases. The quark model of hadrons, the *aufbau* account of atoms and the periodic table, and all the simple models of quantum chemistry are built on it. A conscious, and very sophisticated, use of the digital prediction principle is central to Henri Poincare's qualitative theory of differential equations. There, by concentrating on topological features, you can make powerful statements about the solutions of equations, while not knowing exactly what the equations are!

With more of a stretch, we might say that organisms, in biology, use digital prediction when copying and interpreting their genetic and neural codes.

It could be that real progress in economics, or other complex situations, could result from identifying robust, digital variables as targets for prediction.

An important advantage of digital theories – that is, theories that make digital predictions – is that you can tell when they're wrong!