Link Physics in a Nutshell

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May 2005

Link physics is a fundamentally new mathematical approach to physics that owes much to Shannon's fundamentally new mathematical approach to information. Both have taken a familiar *static* concept and reinterpreted it as a *dynamical* concept, i.e. as being not about what *is* but about what *happens*. Let's start with information.

What is information? Common sense says it's what we find in things like newspapers and books and computer memories. Shannon, however, had a rather different take. Instead of asking for a *definition* of information, he asked what it means to *gain* or *lose* information. His simple but profound answer is that gaining means *narrowing* the range of what is *possible*, and losing means *widening* that range. One might object that to know how something is gained or lost doesn't necessarily tell us what that something is. Shannon would respond that we can only know what information *is* by knowing how it *acts* when it is lost and gained, just as we can only know what money is by knowing how it acts when it is earned and spent. Both dollars and bits are what I'll call *dynamical* entities.

When modern mathematical methods were applied to this way of looking at information, an important new science of information emerged,. This wasn't the first time that dynamics has trumped statics; in fact physics as we know it only really got going when, around 1600, *velocity* was added to the concept of *state*. Nor, I believe, will it be the last.

What I am here calling *link physics* is based on a new dynamical concept that is closely related to Shannon's information, but whose subject matter is *connectivity*.

So what is connectivity? What do we mean by a *connection*? Common sense brings to mind strings, bolts, glue, radio signals, gravity, whatever holds things together and keeps them from going their separate ways. Of course there are more abstract kinds of connections, such as that between the past and future, or between poverty and crime, or between algebra and geometry. Indeed, when we start numbering the various ways in which we can say that A is connected to B, we begin to wonder whether there is really a single well-defined concept here at all.

Once again, dynamics comes to the rescue. Rather than searching for the elusive general meaning of the word *connection*, let's take a hint from Shannon and ask what it means to *make* or *break* a connection. As in the case of information, this turns out to be a much easier question.

One broad feature of connectivity fits all of our examples, which is that when we *increase* connectivity, when we *add* connections, then things lose some part of their *independence*. Conversely, when we *break* connection, things become *more independent*. This observation is the starting point for our formal definition of a connection. It is too broad to be the definition itself, however, since a loss or gain of independence doesn't tell us whether we are dealing with one connection or many. What, then, makes an instance of connectivity qualify as a *single* connection?

Consider a situation where this is obvious, such as wiring up an electrical device. Making a connection then means connecting a wire between electrical points A and B on which there are variable voltages x and y. This reduces the range of *joint possibilities* for x and y to just that subset for which x = y. We make an electrical connection when we force a a pair of variable voltages to always have the same value. Breaking a connection allows the voltages on x and y to vary independently. Here are the general rules for x and y in terms that don't involve wires or electricity:

Making the connection between x and y: Narrowing the range of joint possibilities for x and y to that subset for which x = y.

Breaking the connection between x and y: Widening the range of joint possibilities for x and y by adding new joint possibilities in which $x \neq y$.

Clearly there are degrees of being broken, ranging up to that of a *complete* break that makes x and y completely independent, i.e. that allows every joint value of x and y. These definitions are to be understood as idealized abstractions, like points and lines. Our key definition, which closely resembles Shannon's definition of an item of information, and which is the basic idea underlying all of link theory and link physics, is the definition of a *link*.

Link: a dynamical pair consisting of the make and the break of a connection between x and y. We'll refer to the *broken* connection of a link as its *open state* and the *made* connection as its *closed state*.

The closed state of a link is of course determined by its open state, since we can produce the closed state from the open state by simply removing its unequal joint possibilities. This means that a link, even though it involves the widening and the narrowing of a range of possibilities, is not really an item of information, since no new information in the ordinary sense of the word is needed to close it.

Link theory is about sets of links in which some are open and some are closed. Such a set will be called a *link system*. Since an open link always determines the structure of its closure, the basic objects of link theory, then, are *open link systems*. Here is how these are formally defined:

Open link system: a collection of links for which we are given the joint possibilities for all variables. For brevity we'll call these joint possibilities the ***cases*** of the system.

Closing a link reduces the range of cases. We'll also assume that the cases of a closed link, in so far as they refine the cases for the remaining links, lose their *identity* and are only manifest as hidden *multiplicities* for the open cases. When we close all links we are thus left with a single number, which we'll call the *trace* of the system. If we leave one link open, the multiplicity numbers of its cases, divided by the trace, can be arranged in a matrix (missing cases are represented by 0's) which will be called a *d-matrix*.

Link physics begins by identifying a certain sub-class of our d-matrices with von Neumann's so-called density matrices, which he used to represent quantum states. The defining feature of a density matrix is that it is unchanged by reversing rows and columns.[1]

Actually, this is not quite the whole story, since one more step is needed to make our d-matrices fully up to their job.

When we close a link, we remove some of its cases. But what if we should remove more cases than the link has? We would then to end up with a *negative number* of cases. Sounds absurd? But when you spend more dollars than you have, don't you end up with a *negative* number of dollars? Far from being absurd, this is the all too common condition called *debt*. To get link physics we need negative numbers in our d-matrices. To get these we generalize the notion of a link system by bringing in the idea that such a system can go into *case debt,* which will be formalized by allowing both positive and negative cases in our bookkeeping.

Once we have taken this step, the core of quantum mechanics, which includes the Born probability rule and von Neumann's general dynamical rule, drops out of our formalism in a few simple steps (refs). The condition that defines links as quantum and thus leads to these results is simply that they are symmetrical in x and y. But what about other kinds of links? It turns out that if links have a certain simple form of asymmetry, the very same algebraic rules that characterize the quantum core now become the core laws of ordinary "classical" statistical processes. This includes Markov chains and diffusion processes, complete with time's arrow and the non-decrease of entropy. Since there is nothing to prevent a link system from having both quantum and classical links, we can easily use them to represent quantum preparation and measurement, and they are a natural for representing quantum computers. The mystery of EPR begins to look a bit less daunting when we see how its bizarre correlations arise from simple case counting (case debt does play an essential role here).

The big challenge for the future is to explore the behavior of the vast range of processes involving link types that are neither quantum nor classical. What about those that are only slightly off-quantum? Might these explain empirical discoveries in physics that have eluded conventional wisdom?

And what about space and time? Science, including physics, has for the most part taken these to be a priori concepts that are prerequisite for any scientific investigation. The idea of explaining space-time itself would thus seem to be a non-starter. But, as the most familiar domain of connectivity, is not space-time fair game for investigation at a more basic level in a pure theory of connectivity? Might link theory, which is a theory of pure connectivity, not only describe space-time but explain it? And, to take a big leap, might such an explanation solve the problem of uniting quantum mechanics with general relativity? Such are the visions that keep us link theorists going.

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[1] This is not quite true for the complex density matrices of quantum mechanics, which are self-adjoint. However, following Mackey (Mackey: *Mathematical Foundations of Quantum Mexhanics)* , we'll interpret these as real matrices of twice the dimension of the complex matrices, and these real matrices *are* symmetrical in rows and columns.