Space-Time From The View Point Of Dynamical Cellular Networks (DCN) Model Of Quantum Gravity

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This is a review of the DCN model, suggested by Manfred Requardt et. al. in a series of articles [1] - [6]. It was the subject of masters thesis of the second author under the supervision of the first author.

1 General Viewpoint Of The Model About Nature

This new approach, suggests that the nature and the mathematics that describe it, are discrete at and below the planck scale. Also it assumes that the physical world, has several levels and each level has its own structure, laws and effective theories based on these laws. These laws, structures and theories, emerge from the ones of the previous level in a coarse-graining-like manner and so each of them ultimately emerges from the bottom-most level in which there is no space, time, fields and ....

So every physical thing, among them space, is emergent fundamentally from the bottom-most level laws and processes. As for the space, it suggests that each space point has a rich dynamic internal structure.

2 Mathematical And Physical Foundations Of The Theory

The model, postulates that the fundamental level of nature, is a discrete system, a graph, $G(V,E)$, in which there is a kind of information (q) exchange among its vertices, through the edges between them. This evolution or dynamics takes place in discrete evolution steps, called "clock-time", $t = n\tau\,; n \in \mathbb{Z}$ and τ is the elementary clock-time step. Note that t is *not* the physical time.

To describe the dynamics, it assumes that, to each vertex, v_i, and edge, $e_{i,k}$, correspond states $s_i = nq\,; n \in \mathbb{Z}$ and $J_{i,k} = \pm 1, 0$ respectively. The dynamical laws are the followings. Suppose that λ_1 and λ_2 are two critical parameters of the network and the evolution, with the property that $0 < \lambda_1 \leq \lambda_2$:

$$s_i(t+\tau) - s_i(t) = q\sum_k J_{k,i}(t) \;;\; k = \text{All nearest neighbors of vertex } v_i \tag{1}$$

$$J_{i,k}(t+\tau) = 0 \;;\; \text{if } \;|s_i(t) - s_k(t)| > \lambda_2 \tag{2}$$

$$J_{i,k}(t+\tau) = \pm 1 \;;\; \text{if } \; 0 < \pm(s_i(t) - s_k(t)) < \lambda_1 \tag{3}$$

$$J_{i,k}(t+\tau) = J_{i,k}(t) \;;\; \text{if } \; s_i(t) - s_k(t) = 0 \tag{4}$$

$$J_{i,k}(t+\tau) = \begin{cases} \pm 1 & J_{i,k}(t) \neq 0 \\ 0 & J_{i,k}(t) = 0 \end{cases} \;;\; \text{if } \; \lambda_1 \leq \pm(s_i(t) - s_k(t)) \leq \lambda_2 \tag{5}$$

So for example if $J_{k,i}(t) = +1$, a quantum of information, q, will go from s_k to s_i in the next clock-time, $t+\tau$ and so on. These laws let the network go through geometrical phase transitions, specially equation 4 that lets the bonds become inactive or "off", and equation 3 that let them become active or "on" again.

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3 Emergence Of Space

Technically, the main frameworks that are used to emerge the space in this approach are the renormalization group and random graphs.

The model represents a renormalization process, called the Geometric Renormalization (GR), in which we take a graph, find its cliques (maximal complete subgraphs), identify these cliques as meta vertices of a higher level graph and define the meta edges between these meta vertices to exist between two clique, if there is a sufficient overlap between them. This way we construct a new meta graph, over the graph that we started with.

Now suppose that we start with our bottom-most level graph and do this GR iteratively. The idea is that, after applying GR many times (mathematically infinite times), we reach a metric space, which has the structure of a continuum manifold like space-time. This way, we construct the space points, as the vertices of the highest level graph (which is a self similar graph), out of our fundamental graph. This of course needs the correct choice of dynamical laws and graph critical states.

The model also leads to the idea that fields and particles, are probably themselves, torsions and excitations of space and are of the same origin. Another issue is nonlocality which is described by the model in this way: take two points of space that are far apart with respect to the metric of that level. These points may have internal vertices belonging to the bottom-most level, that are nearest neighbors with respect to the fundamental level metric. So despite the fact that these space points are far apart, they are really very near internally. It is like the idea of wormholes in fine structure of the space.

3.1 Time

Unfortunately, the study of time in this framework have not been improved as the study of space. But there are some key clues based on category theory.

References

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