Space from Nonspace: Emergent Spatiality in Dynamic Graphs

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Abstract

We are attempting to construct immersive dynamic realtime visualisations of some modern theories of quantum foam. Physicists claim that graph structures underlie our physical universe, and that the dynamics of these graphs give rise to such phenomena as matter and interaction. The first part of this project has revolved around making embeddings of these graphs into higher dimensional space in order to obtain a locally (nearly)three dimensional form. The next stages will involve finding ways to represent these forms in an immersive and dynamic way in order to make the effects of the dynamics clear.

Roots

There are many streams of thought that lead to the idea that our three dimensional physical world is but an illusion. That we perceive three dimensions and that objects act in that three dimensionality is clear: we have, on the level of our actions and perceptions, something that we call geometry. There are many ways of thinking about space and spatiality, whether analytically or perceptually. Many directions of thought tell us that this is illusion, from ancient traditions through to modern quantum theory. There is a need to explain what it is that lies under our usual perceptions that leads to this geometry. As mathematicians and artists we are unable to deal with the more spiritual directions in our work, however there are several fragments of ideas that try to begin to talk about this idea in a more formal sense. Fifty years ago Wheeler coined the term pregeometry for such ideas.

For out purposes here, let us take the term pregeometry to apply to some system which: 1) has no geometrical terms in its formalism, and 2) shows geometry–like properties in its results. We say that the geometry is emergent or that it is an epiphenomenon of the formalism. In particular we are interested in ways that a metric pregeometry can arise from weighted graphs.

The Project

A series of physicists from Wheeler onwards, have claimed that there is a combinatorial (i.e. graph theoretical) pregeometric structure underlying our universe. Cahill has suggested, based upon the paradigms of particle physics, one possible model[1]. His claim that this structure is pregeometric is based upon Nagel's analysis [2]. The graphs used by Cahill and his collaborators have certain properties which should enhance their pregeometric attributes.

We would like to develop some representation of these models. The main tool that we use is embedding. Technically, an embedding is a one–to–one homomorphism of one structure into another. This means that we map objects in one structure into objects into the second in order that some properties are preserved. A fuzzy embedding is an embedding with a tolerated level of inexactness in the structural mapping(Note that this does not necessarily correspond to ideas of "fuzzy logic."). In our case we embed the nodes of the graph into Euclidean n–dimensional space with the structure of the graph node-to-node distance mapping to Euclidean distance. We attempt to lower the summed errors (i.e. the fuzziness) in this mapping, weighted by the graph-distance closeness (nodes that are closer together are required to have their Euclidean distance more exactly closer to their graph theoretical distance). Closeness is more important that distant-ness. This is known as a relaxation technique in graph visualisation.

The central claim is that the structure of the resulting embedding carries across the structure of the original graph structure. In particular the global distance topology of the graph is represented in the Euclidean space.

Two analyses were then made of the resulting embeddings. The first analysis investigates the distribution of embedded points and their resulting distances from the center of mass. The second investigates the relationship between graph theoretical shortest distance and Euclidean distance between nodes.

The first analysis demonstrates a strong shell structure. In any fuzzy n–sphere, the distribution of the radii from the center of mass, i.e. the center of the sphere, is strongly peaked at the radius of the sphere. Precisely this was observed in the 4– and higher–dimensional embeddings (Figure 1 a)), indicating that we have a structure that is globally a fuzzy 3–sphere. The second analysis (Figure 1 b)) shows a strong and well–structured relationship between the graph shortest path (geodesic) and Euclidean (straight line) distances. The curves follow closely those expected of a 3–sphere.

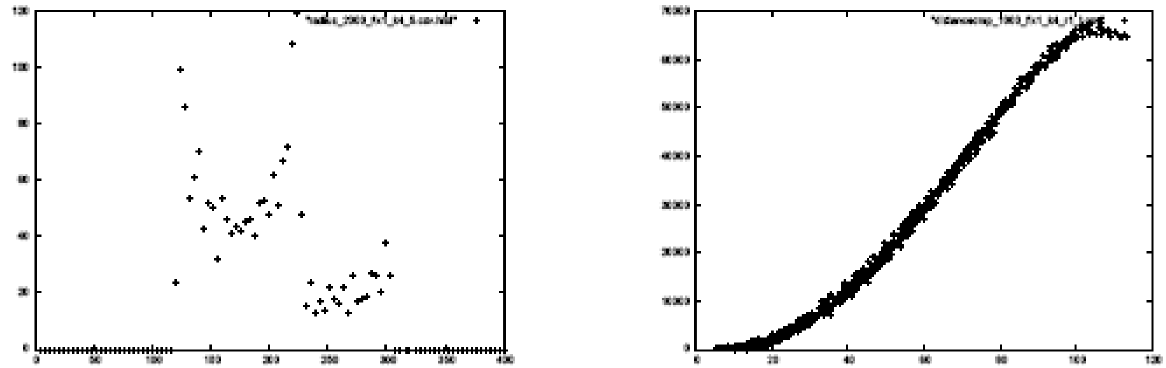

Figure 1: a) *Radius distribution* b) *Euclidean versus geodesic distance*

It remains to find suitable representations of these structures, able to best show the emergent local three dimensionality. Preliminary attempts indicated that this is somewhat problematic, however the above analysis indicates that it must be possible; there is a pregeometry in the graph structures. Once this has been obtained, in a somewhat efficient manner, we anticipate that the representation of the process suggested by Cahill will lead to a relatively intuitive picture of what is happening in this model of physical space.

References

[1] Reg Cahill and Christopher Klinger. Self-referential noise and the synthesis of three-dimensional space. General Relativity and Gravitation, 32(3):529 – 540, 2000.
[2] G. Nagels. Space as a ’bucket of dust’. General Relativity and Gravitation, 17:545–557, 1985.

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