

Smart Nanostructures and Synthetic Quantum Systems*

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Abstract

So far proposed quantum computers use fragile and environmentally sensitive natural quantum systems. Here we explore the notion that synthetic quantum systems suitable for quantum computation may be fabricated from smart nanostructures using topological excitations of a neural-type network that can mimic natural quantum systems. These developments are a technological application of process physics which is a semantic information theory of reality in which space and quantum phenomena are emergent.

Keywords: Process physics, self-referential noise, neural network, synthetic quantum system

1 Introduction

Fundamental discoveries in science have always resulted in accompanying technological developments, not only through the possibilities provided by new phenomena, materials and processes but, perhaps most important of all, through the change in mindset driven by these discoveries. Here I explore new technological possibilities related to the development of, essentially, a quantum theory of gravity; a new theory that unifies the phenomena of space and time with quantum phenomena. This synthesis has arisen not through yet another extension of our current mindset but by the development of a profoundly different way of comprehending and modelling reality at its deepest levels. The follow-on new technology relates to the possibility of synthetic quantum systems and their use in a new class of quantum computers. The characterisation of this class suggests, at this very early stage, that these will be unlike both conventional classical and currently envisaged quantum computers, but will have many characteristics in common with biological neural networks, and may be best suited for artificial intelligence applications. Indeed the realisation that the phenomena of synthetic quantum systems is possible may amount to a discovery also relevant to our understanding of biological neural networks themselves. But first we must review the nature of and the need

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for fundamental changes of the mindset prevailing in the physical sciences. These changes relate to the discovery that we need to comprehend reality as a complex semantic information system which only in part can be approximately modelled by syntactical information systems.

Physics, until recently, has always used syntactical information systems to model reality. These are a development of the Euclideanisation of geometry long ago. Such systems begin with undefined ‘objects’, represented by symbols, together with *a priori* rules of manipulation of these symbols; these rules being a combination of mathematical manipulations together with ‘the laws of physics’ expressed in mathematical notation. This is the game of logic. But logic has only a limited connection to the phenomena of time, for logic is essentially non-process: it is merely symbol manipulation. In physics time has always been modelled by geometry. This non-process model matches the notion of order, but fails to match the notion of past, present and future. For this reason physics has always invoked a metarule to better match this model with the experienced phenomena of time. This metarule involves us imagining a point moving at uniform rate along the geometrical time line. Despite the success of this model, its limitations have led to enormous confusion in physics and elsewhere, particularly when reality and models of reality are not clearly distinguished. For example it is often asserted that time *is* geometrical; it *is* the 4th dimension. The more successful a model is the more likely is this confusion to arise; and also the stronger is the urge to resist an examination of failures of this model.

One consequence of the refusal to examine other models, particularly of time, has been the failure to find a model that unifies the phenomena of space, time and the quantum. As well limitations of self-referential syntactical information systems were discovered by Gödel[1]. The famous incompleteness theorem asserts that there exists truths which are unprovable within such an information system. Chaitin[2] has demonstrated that the unprovable truths arise from a structural randomness in that there is insufficient structure for such truths to be compressed into the axioms of the system. This structural randomness is related to but is outside a non-process syntactical system. This is different from the randomness observed in quantum measurement processes, which is randomness of events in time; nevertheless there are suggestive similarities. The quantum randomness is also beyond the syntactical formalism of the quantum theory; quantum theory is described by entirely deterministic mathematics (which is by its nature is non-process) and the randomness is invoked via the Born metarule. As for the geometrical model of time, these metarules are outside of the syntax, but must not be inconsistent with it.

The analogies between the quantum measurement randomness and the structural randomness associated with self-referential syntax systems has suggested that reality may be a self-referential system subject to intrinsic informational limitations. This has led to the development of the *process physics* modelling of reality [3, 4, 5, 6, 7], see also [8]. This model uses a non-geometric process model for time, but also argues for the importance of relational or semantic information in modelling reality. Semantic information refers to the notion that reality is a purely informational system where the information is internally meaningful. The study of a pure semantic information system is by means of a subtle bootstrap process. The mathematical model for this has the form of a stochastic neural network. Non-stochastic neural networks are well known for their pattern recognition abilities[9]. The stochastic behaviour is related to the limitations of syntactical systems, but also results in the neural network being innovative in that it creates its own patterns. The neural network is self-referential, and the stochastic input, known as self-referential noise (SRN), acts both

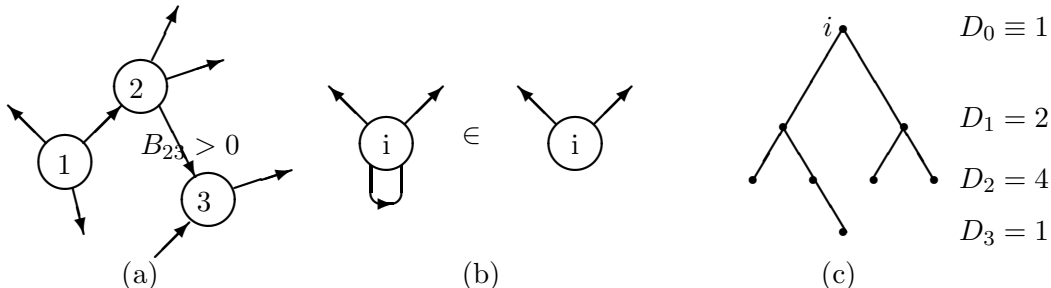


Figure 1: (a) Graphical depiction of the neural network with links $B_{ij} \in \mathcal{R}$ between nodes or pseudo-objects. Arrows indicate sign of B_{ij} . (b) Self-links are internal to a node, so $B_{ii} = 0$. (c) An $N = 8$ spanning tree with $L = 3$. The distance distribution D_k is indicated for node i .

to limit the depth of the self-referencing and also to generate potential order. Such information has the form of self-organising patterns which also generate their own ‘rules of interaction’. Hence the information is ‘content addressable’, rather than is the case in the usual syntactical information modelling where the information is represented by symbols.

In the process physics space and quantum physics are emergent and unified, and time is a distinct non-geometric process. Quantum phenomena are caused by fractal topological defects embedded in and forming a growing three-dimensional fractal process-space. This amounts to the discovery of a quantum gravity model. As discussed in Ref.[7] the emergent physics includes limited causality, quantum field theory, the Born quantum measurement metarule, inertia, time-dilation effects, gravity and the equivalence principle, and black holes, leading in part to an induced Einstein spacetime phenomenology. These are examples of an effective syntactical system being induced by a semantic system.

Here we explore one technological development which essentially follows as an application of the quantum theory of gravity. The key discovery has been that self-referentially limited neural networks display quantum behaviour. It had already been noted by Peruš[10] that the classical theory of non-stochastic neural networks[9] had similarities with deterministic quantum theory, and so this development is perhaps not unexpected, atleast outside physics. This suggests that artificial or synthetic quantum systems (SQS) may be produced by a stochastic self-referentially limited neural network, and later we explore how this might be achieved technologically. This possibility could lead to the development of robust quantum computers. However an even more intriguing insight becomes apparent, namely that the work that inspired the classical theory of biological neural networks may have overlooked the possibility that sufficiently complex biological neural networks may in fact be essentially quantum computers. This possibility has been considered by Kak[11] and others, see works in Pribram[12].

2 Self-Referentially Limited Neural Networks

Here we briefly describe a model for a self-referentially limited neural network and in the following section we describe how such a network results in emergent quantum behaviour, and which,

increasingly, appears to be a unification of space and quantum phenomena. Process physics is a semantic information system and is devoid of *a priori* objects and their laws and so it requires a subtle bootstrap mechanism to set it up. We use a stochastic neural network, Fig.1a, having the structure of real-number valued connections or relational information strengths B_{ij} (considered as forming a square matrix) between pairs of nodes or pseudo-objects i and j . In standard neural networks [9] the network information resides in both link and node variables, with the semantic information residing in attractors of the iterative network. Such systems are also not pure in that there is an assumed underlying and manifest *a priori* structure.

The nodes and their link variables will be revealed to be themselves sub-networks of informational relations. To avoid explicit self-connections $B_{ii} \neq 0$, which are a part of the sub-network content of i , we use antisymmetry $B_{ij} = -B_{ji}$ to conveniently ensure that $B_{ii} = 0$, see Fig.1b.

At this stage we are using a syntactical system with symbols B_{ij} and, later, rules for the changes in the values of these variables. This system is the syntactical seed for the pure semantic system. Then to ensure that the nodes and links are not remnant *a priori* objects the system must generate strongly linked nodes (in the sense that the B_{ij} for these nodes are much larger than the B_{ij} values for non- or weakly-linked nodes) forming a fractal network; then self-consistently the start-up nodes and links may themselves be considered as mere names for sub-networks of relations. For a successful suppression the scheme must display self-organised criticality (SOC)[13] which acts as a filter for the start-up syntax. The designation ‘pure’ refers to the notion that all seeding syntax has been removed. SOC is the process where the emergent behaviour displays universal criticality in that the behaviour is independent of the individual start-up syntax; such a start-up syntax then has no ontological significance.

To generate a fractal structure we must use a non-linear iterative system for the B_{ij} values. These iterations amount to the necessity to introduce a time-like process. Any system possessing *a priori* ‘objects’ can never be fundamental as the explanation of such objects must be outside the system. Hence in process physics the absence of intrinsic undefined objects is linked with the phenomena of time, involving as it does an ordering of ‘states’, the present moment effect, and the distinction between past and present. Conversely in non-process physics the presence of *a priori* objects is related to the use of the non-process geometrical model of time, with this modelling and its geometrical-time metarule being an approximate emergent description from process-time. In this way process physics arrives at a new modelling of time, *process time*, which is much more complex than that introduced by Galileo, developed by Newton, and reaching its high point with Einstein’s spacetime geometrical model.

The stochastic neural network so far has been realised with one particular scheme involving a stochastic non-linear matrix iteration. The matrix inversion B^{-1} then models self-referencing in that it requires all elements of B to compute any one element of B^{-1} . As well there is the additive SRN w_{ij} which limits the self-referential information but, significantly, also acts in such a way that the network is innovative in the sense of generating semantic information, that is information which is internally meaningful. The emergent behaviour is believed to be completely generic in that it is not suggested that reality is a computation, rather it appears that reality is essentially very minimal and having the form of an order-disorder information system.

To be a successful contender for the Theory of Everything (TOE) process physics must ultimately prove the uniqueness conjecture: that the characteristics (but not the contingent details)

of the pure semantic information system are unique. This would involve demonstrating both the effectiveness of the SOC filter and the robustness of the emergent phenomenology, and the complete agreement of the later with observation.

The stochastic neural network is modelled by the iterative process

$$B_{ij} \rightarrow B_{ij} - \alpha(B + B^{-1})_{ij} + w_{ij}, \quad i, j = 1, 2, \dots, 2M; M \rightarrow \infty. \quad (1)$$

where $w_{ij} = -w_{ji}$ are independent random variables for each ij pair and for each iteration, chosen from some probability distribution. Here α is a parameter the precise value of which should not be critical but which influences the self-organisational process. We start the iterator at $B \approx 0$, representing the absence of information. With the noise absent the iterator would converge in a deterministic and reversible manner to a constant matrix. However in the presence of the noise the iterator process is non-reversible and non-deterministic. It is also manifestly non-geometric and non-quantum, and so does not assume any of the standard features of syntax based physics models. The dominant mode is the formation of a randomised and structureless background (in B_{ij}). However this noisy iterator also manifests a self-organising process which results in a growing three-dimensional fractal process-space that competes with this random background - the formation of a ‘bootstrapped universe’. The emergence of order in this system might appear to violate expectations regarding the 2nd Law of Thermodynamics; however because of the SRN the system behaves as an open system and the growth of order arises from selecting implicit order in the SRN. Hence the SRN acts as a source of negentropy, and the need for this can be traced back to Gödel’s incompleteness theorem.

This growing three-dimensional fractal process-space is an example of a Prigogine far-from-equilibrium dissipative structure driven by the SRN. From each iteration the noise term will additively introduce rare large value w_{ij} . These w_{ij} , which define sets of linked nodes, will persist through more iterations than smaller valued w_{ij} and, as well, they become further linked by the iterator to form a three-dimensional process-space with embedded topological defects.

To see this consider a node i involved in one such large w_{ij} ; it will be connected via other large w_{ik} to a number of other nodes and so on, and this whole set of connected nodes forms a connected random graph unit which we call a gebit as it acts as a small piece of geometry formed from random information links and from which the process-space is self-assembled. The gebits compete for new links and undergo mutations. Indeed, as will become clear, process physics is remarkably analogous in its operation to biological systems. The reason for this is becoming clear: both reality and subsystems of reality must use semantic information processing to maintain existence, and symbol manipulating systems are totally unsuited to this need, and in fact totally contrived.

To analyse the connectivity of such gebits assume for simplicity that the large w_{ij} arise with fixed but very small probability p , then the geometry of the gebits is revealed by studying the probability distribution for the structure of the random graph units or gebits minimal spanning trees with D_k nodes at k links from node i ($D_0 \equiv 1$), see Fig.1c, this is given by[14]

$$\mathcal{P}[D, L, N] \propto \frac{p^{D_1}}{D_1! D_2! \dots D_L!} \prod_{i=1}^{L-1} (q^{\sum_{j=0}^{i-1} D_j})^{D_{i+1}} (1 - q^{D_i})^{D_{i+1}}, \quad (2)$$

where $q = 1 - p$, N is the total number of nodes in the gebit and L is the maximum depth from

node i . To find the most likely connection pattern we numerically maximise $\mathcal{P}[D, L, N]$ for fixed N with respect to L and the D_k . The resulting L and $\{D_1, D_2, \dots, D_L\}$ fit very closely to the form $D_k \propto \sin^{d-1}(\pi k/L)$; see Fig.2a for $N = 5000$ and $\text{Log}_{10}p = -6$. The resultant d values for a range of $\text{Log}_{10}p$ and $N = 5000$ are shown in Fig.2b.

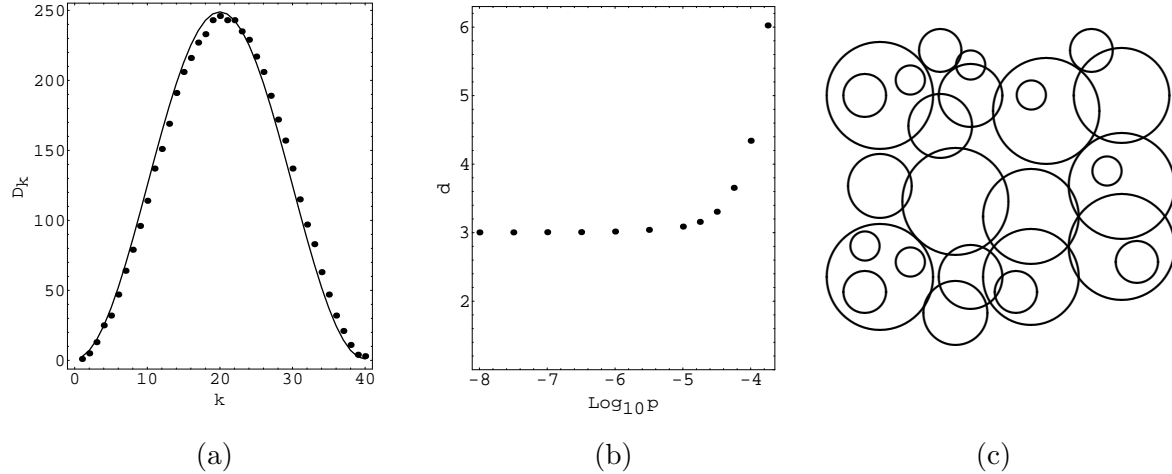


Figure 2: (a) Points show the D_k set and $L = 40$ value found by numerically maximising $\mathcal{P}[D, L, N]$ for $\text{Log}_{10}p = -6$ for fixed $N = 5000$. Curve shows $D_k \propto \sin^{d-1}(\frac{\pi k}{L})$ with best fit $d = 3.16$ and $L = 40$, showing excellent agreement, and indicating embeddability in an S^3 with some topological defects. (b) Dimensionality d of the gebits as a function of the probability p . (c) Graphical depiction of the ‘process space’ at one stage of the iterative process-time showing a quantum-foam structure formed from embeddings and linkings of gebits. The linkage connections have the distribution of a 3D space, but the individual gebit components are closed compact spaces and cannot be embedded in a 3D background space. So the drawing is only suggestive. Nevertheless this figure indicates that process physics generates a cellular information system, where the behaviour is determined at all levels by internal information.

This shows, for p below a critical value, that $d = 3$ indicating that the connected nodes have a natural embedding in a 3D hypersphere S^3 ; call this a base gebit. Above that value of p , the increasing value of d indicates the presence of extra links that, while some conform with the embeddability, are in the main defects with respect to the geometry of the S^3 . These extra links act as topological defects. By themselves these extra links will have the connectivity and embedding geometry of numbers of gebits, but these gebits have a ‘fuzzy’ embedding in the base gebit. This is an indication of fuzzy homotopies (a homotopy is, put simply, an embedding of one space into another).

The base gebits g_1, g_2, \dots arising from the SRN together with their embedded topological defects have another remarkable property: they are ‘sticky’ with respect to the iterator. Consider the larger valued B_{ij} within a given gebit g , they form tree graphs and most tree-graph adjacency matrices are singular ($\det(g_{tree}) = 0$). However the presence of other smaller valued B_{ij} and the general background noise ensures that $\det(g)$ is small but not exactly zero. Then the B matrix has an inverse with large components that act to cross-link the new and existing gebits. If this cross-linking was entirely random then the above analysis could again be used and we would conclude that the base gebits themselves are formed into a 3D hypersphere with embedded topological defects. The nature

of the resulting 3D process-space is suggestively indicated in Fig.2c.

Over ongoing iterations the existing gebits become cross-linked and eventually lose their ability to undergo further linking; they lose their ‘stickiness’ and decay. Hence the emergent space is 3D but is continually undergoing replacement of its component gebits; it is an informational process-space, in sharp distinction to the non-process continuum geometrical spaces that have played a dominant role in modelling physical space. If the noise is ‘turned off’ then this emergent dissipative space will decay and cease to exist. We thus see that the nature of space is deeply related to the logic of the limitations of logic, as implemented here as a self-referentially limited neural network.

3 Emergent Quantum Behaviour

Relative to the iterator the dominant resource is the large valued w_{ij} from the SRN because they form the ‘sticky’ gebits which are self-assembled into the non-flat compact 3D process-space. The accompanying topological defects within these gebits and also the topological defects within the process space require a more subtle description. The key behavioural mode for those defects which are sufficiently large (with respect to the number of component gebits) is that their existence, as identified by their topological properties, will survive the ongoing process of mutation, decay and regeneration; they are topologically self-replicating. Consider the analogy of a closed loop of string containing a knot - if, as the string ages, we replace small sections of the string by new pieces then eventually all of the string will be replaced; however the relational information represented by the knot will remain unaffected as only the topology of the knot is preserved. In the process-space there will be gebits embedded in gebits, and so forth, in topologically non-trivial ways; the topology of these embeddings is all that will be self-replicated in the processing of the dissipative structure.

To analyse and model the life of these topological defects we need to characterise their general behaviour: if sufficiently large (i) they will self-replicate if topologically non-trivial, (ii) we may apply continuum homotopy theory to tell us which embeddings are topologically non-trivial, (iii) defects will only dissipate if embeddings of ‘opposite winding number’ (these classify the topology of the embedding) engage one another, (iv) the embeddings will be in general fractal, and (iv) the embeddings need not be ‘classical’, ie the embeddings will be fuzzy. To track the coarse-grained behaviour of such a system has lead to the development of a new form of quantum field theory: Quantum Homotopic Field Theory (QHFT). This models both the process-space and the topological defects. QHFT has the form of an iterative functional Schrödinger equation for the discrete time-evolution of a wave-functional $\Psi(\dots, \pi_{\alpha\beta}, \dots, t)$

$$\Psi(\dots, \pi_{\alpha\beta}, \dots, t + \Delta t) = \Psi(\dots, \pi_{\alpha\beta}, \dots, t) - iH\Psi(\dots, \pi_{\alpha\beta}, \dots, t)\Delta t + \text{QSD terms}, \quad (3)$$

where the configuration space is that of all possible homotopic mappings; $\pi_{\alpha\beta}$ maps from S_β to S_α with $S_\gamma \in \{S_1, S_2, S_3, \dots\}$ the set of all possible gebits (the topological defects need not be S^3 's). The time step Δt in Eqn.(3) is relative to the scale of the fractal processes being explicitly described, as we are using a configuration space of prescribed gebits. At smaller scales we would need a smaller value of Δt . Clearly this invokes a (finite) renormalisation scheme. Eqn.(3), without the QSD term, would be called a ‘third quantised’ system in conventional terminology. Depending on the ‘peaks’ of Ψ and the connectivity of the resultant dominant mappings such mappings are

to be interpreted as either embeddings or links; Fig.2c then suggests the dominant process-space form within Ψ showing both links and embeddings. The emergent process-space then has the characteristics of a quantum foam. Note that, as indicated in Fig.2c, the original start-up links and nodes are now absent. Contrary to the suggestion in Fig.2c, this process space cannot be embedded in a *finite* dimensional geometric space with the emergent metric preserved, as it is composed of infinitely nested or fractal finite-dimensional closed spaces. The form of the Hamiltonian H can be derived from noting that the emergent network of larger valued B_{ij} behaves analogous to a non-linear elastic system, and that such systems have a skymionic description[15]; see Ref.[7] for discussion.

There are additional Quantum State Diffusion[16] (QSD) terms which are non-linear and stochastic; these QSD terms are ultimately responsible for the emergence of classicality via an objectification process, but in particular they produce wave-function(al) collapses during quantum measurements. The iterative functional Schrödinger system can be given a more familiar functional integral representation for Ψ , if we ignore the QSD terms. Keeping the QSD leads to a functional integral representation for a density matrix formalism, and this amounts to a derivation of the decoherence process which is usually arrived at by invoking the Born measurement metarule. Here we see that ‘decoherence’ arises from the limitations on self-referencing. In the above we have a deterministic and unitary evolution, tracking and preserving topologically encoded information, together with the stochastic QSD terms, whose form protects that information during localisation events, and which also ensures the full matching in QHFT of process-time to real time: an ordering of events, an intrinsic direction or ‘arrow’ of time and a modelling of the contingent present moment effect. So we see that process physics generates a complete theory of quantum measurements involving the non-local, non-linear and stochastic QSD terms. It does this because it generates both the ‘objectification’ process associated with the classical apparatus and the actual process of (partial) wavefunctional collapse as the quantum modes interact with the measuring apparatus. Indeed many of the mysteries of quantum measurement are resolved when it is realised that it is the measuring apparatus itself that actively provokes the collapse, and it does so because the QSD process is most active when the system deviates strongly from its dominant mode, namely the ongoing relaxation of the system to a 3D process-space. This is essentially the process that Penrose[17] suggested; namely that the quantum measurement process is essentially a manifestation of quantum gravity. The demonstration of the validity of the Penrose argument of course could only come about when quantum gravity was *derived* from deeper considerations, and not by some *ad hoc* argument such as the *quantisation* of Einstein’s classical spacetime model. Again we see that there is a direct link between Gödel’s theorem on the limitations of self-referencing syntactical systems and the quantum measurement process.

The mappings $\pi_{\alpha\beta}$ are related to group manifold parameter spaces with the group determined by the dynamical stability of the mappings. This gauge symmetry leads to the flavour symmetry of the standard model. Quantum homotopic mappings or skyrmions behave as fermionic or bosonic modes for appropriate winding numbers; so process physics predicts both fermionic and bosonic quantum modes, but with these associated with topologically encoded information and not with objects or ‘particles’.

4 Quantum Computers and Synthetic Quantum Systems

In previous sections was a description of a fundamental theory of reality that uses a self-referentially limited neural network scenario inspired by the need to implement subsymbolic semantic information processing, resulting, in particular, in a quantum theory of gravity. The neural network manifests complex connectionist patterns that behave as linking and embedded qubits; with some forming topological defects. The latter are essentially the quantum modes that at a higher level have been studied as quantum field theory. Rather than interfering with this emergent quantum mode behaviour the intrinsic noise (the SRN) is a *sine qua non* for its emergence; the SRN is a source of negentropy that refreshes the quantum system. Here I discuss the possible application of this effect to the construction of quantum computers (QC) which use Synthetic Quantum Systems (SQS).

Quantum Computers[18] provide the means for an exponential speed-up effect compared to classical computers, and so offer technological advantages for certain, albeit so far restricted, problems. This speed-up results from the uniquely quantum characteristics of entanglement and the quantum measurement process, both of which now acquire explanation from process physics. This entanglement allows the parallel unitary time evolution, determined by a time-dependent programmed hamiltonian, of superpositions of states, but results in the ‘output’ being encoded in the complexity of the final wavefunction; the encoding is that of the amplitudes of this wavefunction when expanded into some basis set. These individual amplitudes are not all accessible, but via a judicious choice of quantum measurement, determined by the problem being studied, the required information is accessed.

In these early days the construction of simple quantum computers all use naturally occurring quantum systems, such as interacting individual atoms embedded in a silicon lattice. These are both difficult to construct and sensitive to environmental noise. They will play a key role in testing the concepts of quantum computation. The decoherence caused by this environmental noise can be partly compensated by error-correction codes[18]. However as first noted by Kitaev[19, 20] quantum computers that use topological quantum field systems would achieve a fault-tolerance by virtue of the topological excitations being protected from local errors. From process physics we now see that this process is also the key to the very origin of quantum behaviour.

This all suggests that a robust and large scale quantum computer might ultimately be best constructed using a stochastic neural network architecture which exhibits topological quantum field behaviour; a synthetic quantum system (SQS). Such a SQS would essentially manifest synthetic entanglement and synthetic collapse to achieve the apparent advantages of quantum computation, and the inherent robustness would follow from the non-local character of topological modes. Indeed the actual ‘information’ processing would be achieved by the interaction of the topological modes. There are a number of key questions such as (i) is such a SQS indeed possible? (ii) how could such a system could be ‘constructed’? (iii) how could it be programmed? (iv) how is information to be inserted and extracted? I shall not tackle here the fundamental question of whether the phenomenon of a SQS is possible, for to answer that question will require a long and difficult analysis. But assuming the final answer is yes, we shall try here to at least characterise such a system.

We first note that such a synthetic quantum system based quantum computer may be very

different in its area of application compared to the quantum computers being currently considered. This new class of QC would best be considered as being non-symbolic and non-algorithmic; indeed it might best be characterised as a semantic information computer. The property of being non-symbolic follows from the discussions in the previous sections in relation to reality itself, and that information in a SQS QC has an internal or semantic meaning. Semantic information or knowledge, as it might best be described, would be stored in such a QC in the form of non-local topological states which are preserved by the topological character of such states, although more static and primitive information could be preserved in the ‘classical’ structure of the neural network. Such a SQS would be driven by essentially the negentropy effect of thermal noise, with the effective ‘iterator’ of the system selecting special patterns from this noise; this noise essentially acting as a pseudo-SRN. So a SQS QC is essentially a ‘room temperature’ QC which, combined with its topological features, would make such a system inherently robust. The noise also manifests a synthetic wave-functional collapse mechanism, essentially a synthetic-QSD term in the time evolution equation analogous to Eqn.(3). The effect of these collapses is that above a certain threshold the superposition property, namely the Hamiltonian term in Eqn.(3), would be over-ridden by a non-local and non-linear collapse process; it is from this process that the SQS QC would be inherently non-algorithmic, since the collapse is inherently random in character. Of course as in the more ‘conventional’ QC this non-algorithmic ‘measurement’ process may be exploited to extract useful and desired outcomes of the ‘computation’. This directed outcome can only be achieved if the exact character of the ‘measurement’ can be programmed, otherwise the collapse will result in novel and creative outcomes; essentially the generalisation and linking of semantic information already in the QC. For this reason this class of QC may represent a form of artificial intelligence, and may be best suited to generalisation and creativity, rather than just achieving the exponential speed-up for certain analytical problems such as number factoring.

It is unlikely that such a synthetic quantum system computer would be fabricated by conventional ‘directed’ construction technologies either old or new. First such a computer would necessarily have an enormous number of components in order to achieve sufficient complexity and connectedness that topological quantum modes could be emergent. There also needs to be plasticity so that the collapse process can result in permanent changes to the neural network connections, for it must be remembered that the SQS does not operate by means of symbol manipulation, but by the interaction and self-interaction of internal states that arise from actual connectivity patterns within the network. It is also not clear in what manner the SQS would be manifested. Whereas for reality itself the previous sections suggested that connection was sufficient, in the SQS we could also envisage the possibility that the connectivity is manifested by other modes such as pulse timing or signal phasing. For these reasons such a SQS QC would probably be constructed by means of the self-assembly of enormous numbers of active components, with node and linkage elements, whose individual survival depends of their involvement or activity level. That is, the system could be overconnected initially and then SQS status achieved by a thinning out process. To have such an enormous number of components then stipulates that we need very small components and this suggests nanoscale chemical or molecular electronic self-assembly procedures. Indeed the close connection with biological neural networks suggests that we are looking at a nanobiology approach, and that the self-organisation process will be biomimetic.

The programming of such a SQS QC also would have to be achieved by subtle and indirect

means; it is very unlikely that such a system could be programmed by the preparation of the initial connection patterns or indeed by an attempt to predetermine the effective Hamiltonian for any specified task. Rather, like the construction of the SQS, the programming would be achieved by means of plasticity and the biasing of internal interactions; that is via essentially biased self-programming. This is obvious from the role of semantic information in such a SQS; these systems decide how information is represented and manipulated, as the memory process is essentially content addressing. That is, the information is accessed by describing aspects of the required information until the appropriate topological patterns are sufficiently excited and entangled that a collapse process is activated. To bias such self-programming means that the SQS must have essentially complex sensors that import and excite generic pattern excitations, rather than attempt to describe the actual connectivity. Indeed the very operation of such a SQS appears to involve an level of ignorance of its internal operation. If we attempt to directly probe its operation we either observe confused and unintelligible signalling or we cause collapse events that are unrelated to the semantic information embedded in the system. Rather the best we can probably do is exchange information by providing further input and monitoring the consequent output, and proceed in an iterative manner.

5 Non-Symbolic Neural Networks and Consciousness

That a self-referentially limited neural network approach is perhaps capable of providing a deep modelling of reality should not come as a surprise, nor is it in itself mystical or perplexing. With hindsight we can now say how “else could it have been?” Physics for some time has been moving in the direction that reality is somehow related to information, and various ‘informational interpretations’ of quantum theory were advanced; but the information here, as encoded in the wavefunction, was always thought to be about the observer’s knowledge of the state of the system, and in itself may have had no ontological significance. For this reason the early discoveries of quantum theory were quickly interpreted as amounting to limits on the observer’s knowledge of ‘particles’ such as where they are and what momentum they have, but rarely whether such point-like entities actually existed. In this way physicists hung to some of the oldest western science ideas of matter being ‘objects’ in a ‘geometrical space’. Quantum phenomena were telling us a different message, but one which has been ignored for some 75 years. Of course reality cannot be about objects and their laws; that methodology is only suitable for higher level phenomenological descriptions, and its success at these levels has misled us about its suitability at deeper levels.

The nature of reality must be internally meaningful and always self-processing, the stuff of reality continues to exist not because the ‘production process’ is finished, but because these systems are self-perpetuated by this self-processing; at this deepest level there are no prescribed laws or entities. The closest analogy to this idea of ‘internally meaningful’ information is that of the semantic information of the human mind as experienced through our consciousness. The processing of this semantic information is massively parallel and by all accounts non-local. Consciousness involves as well memory, self-modelling and self-referencing and a shifting focus of attention. The recognition of consciousness as a major scientific problem has finally occurred, and the subject is attracting intense debate and speculation. It is suggested here that the difficulty science has had in dealing

with this phenomena is that western science has been entrenched in a *non-process* modelling of reality, and trapped in the inherent limitations of syntax and logic. However process physics is indicating that reality is non-syntax and experiential; all aspects of reality including space itself are ‘occasions of actual experience’, to use Whitehead’s phrasing[21, 22]. Only information and processes that are internally meaningful can play any role in reality; reality is not about symbols and their syntax, although they have pragmatic use for observers.

So process physics reveals reality to be, what is called, panexperiential. To the extent that these processes result in characteristic and describable outcomes we have emergence of non-process syntactical language. But in general the processes correspond to our experiences of time, and match in particular the experience of the ‘present moment’ or the ‘now’; although because of the subtleties of communication in such a system it is not known yet whether the historical records of separated individuals can be uniquely correlated or labelled. This is the problem of establishing simultaneity that Einstein first drew to our attention. In process physics it has not yet been determined whether or not the non-local processes, say those associated with EPR connections, enable the determination or not of an absolute frame of reference and so absolute simultaneity.

The panexperientialism in process physics suggests that at some level of complexity of emergent systems that such systems may be self-aware, not of the individual sub-processes, but of generalised processes at the higher level; because the processes at this level amount to self-modelling and to other characteristics of consciousness. Such experiences cannot occur in a symbol manipulating system.

In process physics we see that one of the key emergent and characterising modes in a semantic information system is quantum behaviour. It is suggested that such a behaviour may also arise in a sufficiently complex synthetic neural network subject to pseudo-SRN, resulting in synthetic quantum systems. Of course one system that may be manifesting such behaviour is that of our brains. Simple neural networks evolved to deal with the processing and identification of various external signals, particularly those essential to the survival of the system. These advantages would result in species of systems with ever larger neural networks, all behaving in the classical mode. But with increasing complexity a new phenomena may have emerged, namely that of the synthetic quantum system, particularly if its ‘semantic information processing’ was considerably enhanced, as now quantum computation theory is suggesting. Hence we are led to the speculative suggestion that ‘mind’ may be emergent synthetic quantum system behaviour. That mind may be connected to quantum behaviour has been considered by many, see Refs.[11, 12, 23]. In particular the enormous number of synapses in the dendritic network[24] has attracted much speculation. Of particular relevance is that the synapses are noisy components. From the viewpoint of synthetic quantum systems this synaptic noise would behave as a pseudo-SRN and so a source of negentropy.

6 Conclusions

We have explored here some novel technological spin-offs that might conceivably arise from the development of the quantum theory of gravity in the new process physics. This process physics views reality as a self-referentially limited neural network system that entails semantic information growth and processing, and it provides an explanation for much if not ultimately all of the funda-

mental problems in physics. In particular process physics provides an explanation for the necessity of quantum phenomena, and suggests that such phenomena may emerge synthetically whenever the conditions are appropriate. These conditions may include those of the noisy neural networks that form in part our brains, and the emergent synthetic quantum system behaviour may in fact be what we term our ‘mind’. But at the technological level emergent synthetic quantum system behaviour may ultimately lead to the development of semantic information or knowledge processing quantum computers which exploit the enhanced processing possible in synthetic quantum systems with synthetic entanglement and a synthetic quantum measurement process. Indeed, because of the similarity of these quantum computers with our biological neural networks and their possible manifestation of synthetic quantum behaviour, this new class of quantum computers may display strong artificial intelligence if not even consciousness. These synthetic quantum system computers may need to be essentially ‘grown’ rather than constructed by laying down fixed structures. To achieve this we would expect to mimic biological neural networks, since by arising naturally they probably represent the simplest manifestation of the required effect. Such a strong AI quantum computer would thus represent a major technological target for the emerging field of nanotechnology, and indeed it would constitute a ‘smart’ nanostructure. While reality demands a fractal structure for the deep reasons discussed in the text, synthetic quantum computers need not be fractal, atleast as regards their manifest structure and operation. Of course being a part of reality they share in the deep underlying fractal system.

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