Conscious Information and Intelligence

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February 14, 2018

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Contents

Abstract

The notions of information and intelligence are discussed in TGD framework. Possible definitions for the information measures of the configuration space spinor field and information gain of conscious experience as well as the information theoretic interpretation of Kähler action are discussed in detail the first sections of the chapter.

1. The key element of the approach is the number theoretic generalization of entanglement entropy. Quantum entanglement between real and p-adic degrees of freedom makes sense if entanglement coefficients are rational or even algebraic numbers. In this case one can define entanglement entropy using the p-adic variant of the logarithm. p-Adic entropy can be also negative, and the states for which the entropy is negative are stable against self measurements (NMP) and define macrotemporally quantum coherent states. The number-theoretic entropy serves as an information measure for cognitive entanglement, and positive entanglement negentropy can be interpreted as a correlate for the experience of understanding. Number theoretic entanglement measures are natural in what might be called the intersection of real and p-adic worlds (partonic 2-surfaces have mathematical representations making sense both p-adically and in real sense) and this leads to a vision about life as something residing in this intersection. The consistency with standard quantum measurement theory leads to the conclusion that negentropic entanglement must correspond to a density matrix proportional to unit matrix. Entanglement matrix proportional to a unitary matrix characterizing quantum computation gives therefore rise to negentropic entanglement.
2. Various measures for the information contents of consciousness are discussed.
   (a) The reduction of entanglement entropy defines a natural measure for conscious information gain in single step of the state of state function reduction process decomposing subsystem to a pair of un-entangled sub-systems. If entanglement is negentropic the entanglement negentropy either increases or the system is stable against state function reduction.
   (b) It seems natural to assume that the information measures are associated with the entire cascade and that they are additive in the sense that information gain is sum over the information gains of the steps of the cascade and that a given step contributes by the sum of the information gains associated with unentangled subsystems which are subject to self measurement in a given step of the cascade.
   (c) One can also assign information measures to the resulting indecomposable systems. For subsystem which is bound state in the normal sense and thus has entropic entanglement, one can consider all possible decomposition of the system to a sub-system and its complement and define the entanglement negentropy as the negative for the minimum value of entropy obtained in this manner. If the system is negentropically entangled one can define entanglement negentropy as the maximum of entanglement negentropy obtained in this manner. This means that one can assign to the final state of state function reduction unique negentropy as the sum of the negative contributions associated with selves which are internally bound state entangled and positive contributions of negentropic selves.
   (d) The information content of the conscious experience associated with self is more interesting practically. Since self defines a statistical ensemble, it is straightforward to define entropies associated with the increments of quantum numbers and zero modes defining non-geometric and geometric qualia. These entropies characterize the fuzziness of the quale and are "negative" information measures. One can also assign to non-decomposable subselves the information measures and they give either positive or negative contribution to the information content of self.
   (e) In principle this allows to define also the net information gain of quantum jump as the difference of the total negentropies of the final and initial states of quantum jump identified as those produced by the state function reduction process. Initial and final state negentropies would characterize spinor fields of WCW ("world of classical worlds").
3. Information theoretic interpretation of the Kähler function is discussed in detail. Quantum classical correspondence suggests that the magnetic part of Kähler action would correspond to information content of negentropic entanglement and electric part to the negative information content of entropic bound state entanglement. Kähler function defined as the negative of the Kähler action can be interpreted as an entropy type measure for the information content of the space-time surface. Without quantum criticality

entropic configurations carrying strong Kähler electric fields would be favored. The proposal is that the quantum criticality of Kähler action possible for the critical value of Kähler coupling strength makes possible large degeneracy of the negentropic extremals carrying large Kähler magnetic action and makes TGD universe maximally interesting and maximizes its intelligence so that even infinite negentropy is possible. Number theoretical criticality would relate to this criticality very closely. The proposal that living matter is near vacuum extremal so that the degeneracy of negentropic configurations is high is discussed.

4. The physical interpretation for the hierarchy of Planck constants would be in terms of a hierarchy of quantum criticalities concretizing the vision about quantum criticality of TGD Universe. TGD Universe would be like a hill at the top of a hill at .... The larger the Planck constant the larger the size scale of the hill. Criticality involves crucially the notion of conformal gauge symmetry. The conformal symmetries correspond to subalgebra of the full algebra isomorphic to it acting as gauge symmetries and with conformal weights coming as n-multiples of those for the full symmetry algebra. $h_{eff} = n \times h$ would label the levels of the hierarchy. This hierarchy would correspond directly to the hierarchy of measurement resolutions and to hierarchy of hyperfinite factors of type II_1 (HFFs). Also now one obtains infinite hierarchies of symmetry breakings and the identification with the hierarchies of inclusions of HFFs is compelling. Hence various hierarchies reflect the same underlying phenomenon.

   The phase transitions reducing criticality would take place spontaneously unlike opposite phase transitions. This vision is especially powerful in biology, where homeostasis could be seen as mechanisms preventing the reduction of criticality but at expense of metabolic energy. The basic goal of living system would be staying at criticality. Eastern philosophies would formulate this fight for staying at criticality using the notions of ego and Karmic cycle. In the phase transition increasing $h_{eff} = n \times h$ part of gauge degrees of freedom assignable to a sub-algebra of the full super-symplectic algebra are transformed to physical ones and this implies better measurement resolution. The new HFF contains the previous one as sub-factor. Evolution understood as increase of h_{eff} forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

Concerning the modelling of conscious intelligence the following aspects are important.

1. Zero energy states -which replace the earlier notion of association sequence inspired by the failure of strict determinism for Kähler action in standard sense - can be seen as memes with M-matrices characterizing the time-like entanglement representing "laws of physics". Negentropic time like entanglement makes possible for fully state function reduced states to represent rules as quantum superposition of state pairs representing instances a→b for a general rule A→B. Also space-like negentropic quantum entanglement is important piece of the story. For fermion Fock states this gives Boolean rules as a special case. Zero energy states represent geometric memories, simulations for time development whereas selves represent subjective memories and conscious experience involves always the comparison of geometric and subjective memories telling whether expectations were realized. Quantum theory of self-organization applies also to the evolution of consciousness understood as self-organization in the ensemble of association sequences/selves and implies Darwinian selection also at the level of selves and conscious experiences.

2. TGD Universe is quantum computer in a very general sense. Negentropic quantum entanglement stabilizes qubits but makes them fuzzy. This leads to a modification of the standard paradigm of quantum computation. Quantum computationalism is shown to reproduce the relevant aspects of computationalism and connectionism without reducing conscious brain to a deterministic machine. Holographic brain is also one of the dominating ideas of neuroscience. TGD based realization of memory allows to reduce hologram idea to its essentials: what matters is that piece of hologram is like a small window giving same information as larger window but in less accurate form. This inspires the concept of neuronal window: each neuron has small window to the perceptive landscape and is typically specialized to detect particular feature in the landscape. Coherent photons emitted by mindlike space-time sheets and propagating along axonal microtubules serving as wave guides, realize neuronal windows quantum physically. Massless extremals allow rather precise definition for the notion of quantum hologram.

A more refined formulation of these ideas is based on the notion of conscious hologram. Many-sheeted space-time is essentially a fractal Feynman diagram with lines thicknened to 4-surfaces. The lines are like wave guides carrying laser beams and vertices are like nodes where these laser beams interfere and generate the points of the hologram. The 3-dimensionality of the ordinary hologram generalizes to stereo consciousness resulting in the fusion of mental images associated with various nodes of the conscious hologram. An essential element is the possibility of negative energy space-time sheets analogous to the past directed lines of the Feynman diagram: negative energy MEs are the crucial element of sensory perception, motor action, and memory.

3. An important element is effective four-dimensionality of brain making possible to understand long term memories, planning and motor activities in a completely new manner. Further important ideas are music metaphor already described and the vision about brain as an associative net. ZEO and the notion of CD (causal diamond) provides justification for the memetic code and relates it to fundamental elementary particles time scales. The codewords of the memetic code consist of sequences of 126 bits and are represented in terms of nerve pulse sequences or membrane oscillations and time varying quark magnetization, is the key essential element of brain as cognitive system. Codewords can be interpreted either as elements of a Boolean algebra or as bits in the binary expansion of an integer in the range $(0, 2^{126})$ so that memetic code makes brain able to assign numbers with qualia. An attractive and testable identification for the memetic codewords is as phonemes of language.

1 Introduction

This chapter is a fusion of two separate parts, the first one devoted to information measures for conscious experience and second summarizing a quantum model for intelligent systems. This reflects in its own way the fact that the development of the related ideas has not been a linear process and has involved many weird twists typical for a mathematical thinking without strong connection with empiria.

The motivation for the recent updating are the developments in basic quantum TGD and in TGD inspired theory of consciousness (I am writing this towards the end of March, 2015). In the following I try to summarize TGD inspired view about information, intelligence and consciousness. Some of the memes of the previous updated version prepared around 2003 have lost the game and new memes - or rather an overall vision about conscious intelligence - has emerged. This is also due to the unification of about decade old ideas related to TGD proper to form single coherent whole.

One of the most notable losers is the hypothesis about the quantum jump replacing p-adic space-time sheet with a real one as a realization of intentional action. The hypothesis was inspired by the idea that p-adic space-time sheets are correlates for both cognition and intentionality. In adelic vision about TGD space-time surfaces are correlates both for the sensory and cognitive aspects and intentional action are assigned state function reduction. Intention is assigned with the sequence of repeated state functions defining self and subselves as mental images of self. Quite generally, p-adic and real aspects integrate to form an adelic view at all levels rather than being thought to be something separate.

The earlier vision identifying evolution at basic as a generation of number theoretic complexity of algebraic extensions of rationals becomes rather concrete in the adelic vision about TGD, and the strong form of holography leads to an elegant unification of real and p-adic physics in terms of number theoretic universality in the intersection of real and p-adic worlds defined by string world sheets and partonic 2-surfaces and serving as the seat of life. This intersection carries also the cognitive and sensory representations and for the parameters characterizing extension take physical meaning.

The new elements relate to the progress in the understanding of the notion of self implied by a generalization of quantum measurement theory based on Zero Energy Ontology (ZEO). In particular, the precise definition of Negentropy Maximization Principle and role of negentropic entanglement (NE) leads to powerful predictions consistent with what is known about biology and consciousness and very relevant for the notion of evolution of conscious intelligence. Also the realization that the hierarchy of Planck constants corresponds to a hierarchy of quantum criticalities

realized in terms of symmetry breakings has strong implications central for understanding evolution and intelligence.

1.1 Magnetic Body As Intentional Agent And Experiencer

The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion-like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism [K7].

The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

Magnetic flux tubes and flux sheets are basic building bricks of the magnetic body and DNA as topological quantum computer hypothesis assumes that DNA nucleotides are connected to cell membrane by flux tubes defining braids playing a key role in topological quantum computation [K8]. Therefore magnetic body is essential for realizing the software of biological intelligence. The essential assumption is that magnetic body carries dark matter consisting of ordinary with a non-standard value of Planck constant. The phase transition changing the value of Planck constant change the size scale of the flux tube and this process together with reconnection of the flux tubes would define mechanisms of bio-catalysis.

Magnetic bodies - or rather their time evolutions connecting two space-like 3-surfaces at the opposite boundaries of causal diamond (CD) in ZEO - are natural space-time correlates for memes and the replication of magnetic bodies completely analogous to what happens in 3-particle vertex makes possible the replication of memes and is assumed to induce biological replication. 4-D character of the quantum self-organization and of the space-time correlates of zero energy states can be seen as an essentially new element allowing to understand how behaviors and function emerge.

1.2 What Is Conscious Intelligence

The following summary tries to give a brief summary about how conscious intelligence could be understood in TGD Universe. The vision about life and conscious information and intelligence as something in the intersection of real and p-adic worlds is certainly the most important aspect in this respect. ZEO (ZEO) and the notion of causal diamond (CD) lead to the modification of quantum measurement theory allowing to define the notion of self and explaining basic aspects of consciousness. The hierarchy of Planck constants as an explanation of dark matter and energy as macroscopic quantum phases even in astrophysical scales and implying that dark matter is a key actor in the drama of life is the third key element.

1.2.1 Zero energy ontology and intelligence

In zero energy ontology (ZEO) physical states are replaced by pairs of positive and negative energy states assigned to the past *resp.* future boundaries of causal diamonds (CDs) defined as pairs of future and past directed light-cones ($\delta M^4_{\pm} \times CP_2$). The net values of all conserved quantum numbers of zero energy states vanish. Zero energy states are interpreted as pairs of initial and

final states of a physical event such as particle scattering so that only events appear in the new ontology.

ZEO combined with the notion of quantum jump resolves several problems. For instance, the troublesome questions about the initial state of the universe and about the values of conserved quantum numbers of the Universe can be avoided since everything is in principle creatable from vacuum. Communication with the geometric past using negative energy signals and time-like entanglement are crucial for the TGD inspired quantum model of memory and both make sense in ZEO. ZEO leads to a precise mathematical characterization of the finite resolution of both quantum measurement and sensory and cognitive representations in terms of inclusions of von Neumann algebras known as hyperfinite factors of type II_1 [K32]. The space-time correlate for the finite resolution is discretization which appears also in the formulation of quantum TGD in terms of the Kähler-Dirac action [K11].

At the imbedding space-level CD is the correlate of self whereas space-time sheets having their ends at the light-like boundaries of CD are the correlates at the level of 4-D space-time. The hierarchy of CDs within CDs corresponds to the hierarchy of selves.

ZEO implies that 3-D objects are replaced by pairs of space-like 3-surfaces at opposite boundaries of CD and holography implies that space-time surfaces replace 3-D objects. Spatiotemporal patterns or actually their quantum superpositions become the basic objects. Behavior and function matter rather than the state of system, say brain, at given moment. This has important implications for the view about morphogenesis in biology and behavior in neuroscience. Self-organization becomes evolution of 4-D rather than 3-D patterns. Identifying magnetic bodies as counterparts of memes, one can even speak about replication of memes inducing that of living matter. Obviously these aspects are central also for understanding of intelligence.

The original interpretation of the space-time correlates of mental images was as mind-like space-time sheets identified as space-time sheets with a finite temporal size. In ZEO all space-time sheets have a finite size and serve as correlates for zero energy states, which could be interpreted as representations of laws of physics as superpositions of pairs of initial and final states given by M-matrix. In state function reduction process these states are reduced to states for which only negentropic time-like entanglement is possible and one might say that the negentropy measures the conscious information associated with the final state of the reduction process. One can interpret negentropic quantum states as memes or morphogenetic fields [K27] [I8].

ZEO based quantum measurement theory leads automatically to the notion of self predicting that self has a finite life-time [K15, K28]. The highly non-trivial prediction is that in death caused by a state function reduction to the opposite boundary of CD self re-incarnates at the opposite boundary of CD as a time-time reversed version: at the level of sub-selves this means replacement of mental image with its time-reversed mental image. The experience flow of subjective time finds a simple explanation and the question why the contents of sensory consciousness is restricted to such a narrow time interval (located near the future boundary of CD) [K31, K1].

The decomposition of contents of consciousness of self to a static part coming from the passive boundary of CD at which state function reduction sequences has no effect and to part coming from the active boundary of CD, which changes and for which the state changes suggest interpretation as an analog of figure-background or experiencer-experienced division. The time reversal would change the roles of figure and background and vase-faces illusion could be an example about time reversal of mental image. Time reversed writing and time-reversed speech [K28] could be also examples about directly experienced time reversal of mental images. This aspect of self-ness is certainly crucial for understanding intelligence: since figure back-ground divisions is what intelligent systems perform routinely. For instance, right and left brain might be specialized to produce time reversed views about same sensory input.

Also first and third person views might correspond to time reversed mental images. In near death experiences person sees himself as an outsider: could this be interpreted as the change of the roles of figure and background interpreted as first and third person perspectives?

1.2.2 Weak form of NMP

The precise form of NMP has chrystallized only gradually. The strong form of NMP states that negentropy gain in state function reduction is maximal. This would fix completely the sub-system complement pair of system for which the reduction takes place and if negentropic entanglement is

present also the final state as negentropically entangled state with density matrix which is projector to subspace which has dimension which can be also higher than $d = 1$. In standard quantum theory one has $n = 1$ and one can argue that the density matrix in practices has only non-degenerate eigenvalues in real context. In TGD framework quantum criticality changes the situation and quantum critical states have the property that $d > 1$ is possible.

It has however turned out that strong form of NMP does not allow genuine morally responsible free will. We would live in best possible world which does not seem to be the case. This leads to the proposal that weak form of NMP is more appropriate formulation. Again NMP would select the sub-system-complement pair which can produce the maximal negentropy gain but the continuation is different.

1. Suppose that $n >$ 1-dimensional projector would produce maximum negentropy gain and would be thus forced by strong form of NMP. The weak form of NMP allows self associated with the CD containing the CD of self as sub-CD to choose also lower-dimensional subspace of sub-space of dimension $n - k$, $0 \leq k < n$.

   For $k = n - 1$ one has ordinary state function reduction destroying NE and isolating the self from the rest of the world. This means free will. Note that self does not itself decide what as it dies and reincarnates: it is self above who decides! One can also understand the quantum correlates of ethics and moral if the generation of NE is what good deed means. The death of self is like picking a fruit from tree and the self picking it decides how much NE is created.

2. If one has fixed base for n-dimensional sub-space (this might be questioned) one the resulting subspaces have dimension in the range $1, ..., n$ and their number is $2^k - 1$: this like putting $n - k$ balls in distinct boxes in all possible manner and the number is given by binomial coefficient: the 0-dimensional final state space is not allowed. This would suggest that the choices are in 1-1 correspondence with the basis of Boolean algebra of k bits. Since the amount of negentropy generated should measure the degree of positive emotional coloring of the choice, it is possible that one has kind of emotional realization of of Boolean logic with one statement thrown away (in set theoretic realization this would be the statement represented by an empty set). Since the p-adic prime appearing in the definition of number theoretic negentropy is a factor of $n-k$, those values of $n-k$ near to n, which correspond to powers of single prime produce largest negentropy gain and would be favored so that powers of prime are favored by selection implied by weak form of NMP.

3. An interesting question is whether this "emotional" realization of logic can be mapped naturally to the realization of Boolean logic by many-fermion states in ZEO (many-fermion state and its counterpart with opposite quantum numbers at opposite boundary of CD in a fixed basis realize the Boolean statement). This realization could be fundamental for understanding the correlates of emotional intelligence at quantum level.

One can represent an objection against the proposed emotional realization of Boolean logic. One is choosing from the discrete set of sub-set of a fixed basis for n-dimensional space. Why not to choose from the continuous set of sub-spaces? This would be the classical option. There is a continuum of choices for $n-k$-dimensional sub-space and the choices are parameterized by complex Grassmannian $G(n, k)$ (appearing in twistor Grassmann approach to scattering amplitudes!) and now one can talk about probabilities only. The probability for a choice of $n-k$-dimensional subspace would be naturally proportional to the volume of Grassmannian $G(n, k)$. The first problem is that this volume is vanishing for $k = 0$ so that the choice with maximal dimension would have zero probability. The second problem is that volume of $G(n, k)$ is proportional to a scale parameter R raised to the dimension $d(k) = k(n - k)$ of $G(n, k)$ and the condition that probabilities for various choices depend on the choice of R. It seems that the classical option cannot make sense and will not be discussed in the sequel.

1.2.3 Boolean mind and fermions

The connection of fermionic Fock space basis with Boolean algebra was one of the first ideas related to the quantum modelling of intelligent systems. The state basis for the fermionic Fock space has a natural interpretation as Boolean algebra (fermion number $=1/0 \leftrightarrow$ yes/no). In this manner

ordinary Boolean algebra is extended to a vector space spanned by fermionic states. Fermion number conservation poses an obvious problem for this scenario in positive energy ontology. ZEO resolves this problem quite generally and zero energy states resulting as an outcome of state function reduction process represent Boolean statements of type A→ B in terms of time-like NE in fermionic degrees of freedom.

The original proposal was to use cognitive fermion pairs instead of fermions with fermion and anti-fermion located at the opposite throats of wormhole contact. In the recent formulation of quantum TGD bosons and their super counterparts correspond to wormhole contacts. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic and whether our logical mind could have something to do with Boolean algebra. For instance, could primary "this is true" experiences correspond to Boolean qualia having increments of fermionic quantum numbers as physical correlates. Boolean truth values could also correspond to spin directions of fermions. In this case fermion number conservation does not pose any constraints and the macroscopic realization replacing single spin as a representative of bit with a magnetized ensemble of fermions, makes the realization robust.

Negentropic entanglement (NE) means that qubits are always fuzzy and the fuzziness depends on the situation. The positive aspect is that the quantum superposition gives rise to an abstraction, rule about pairing of say initial and final states represented as positive and negative energy parts of zero energy state with the pairs of superposition representing the instances of the rule. p-Adic-real entanglement with positive definite number theoretical entanglement entropy in the intersection of real and p-adic worlds could give rise the experience of understanding and makes possible cognitive quantum computation like processes.

A new element is the realization that spinor modes and thus fermions are localized to string world sheets and partonic 2-surfaces by the condition that em charge is well-defined. There are many other reasons for this localization. By strong form of holography these 2-surfaces define kind of space-time genes. The natural assumption is that they are in the intersection of reality and various p-adicities in the sense that the parameters characterizing them belong to an algebraic extension of rationals and are therefore discretized.

This makes possible an elegant correspondence between real and p-adic space-time sheets. They are not mapped to each other directly but obtained by holography from the fundamental 2-surfaces in the intersection by the condition that they are preferred extremals of Kähler action for which the classical Noether charges for a sub-algebra of super-symplectic algebra with conformal weights coming as n-ples of those for the full algebra vanish. No discretization at space-time level is required and problems with the general coordinate invariance (GCI) are avoided. By conformal invariance the parameters in question are general coordinate invariant conformal moduli. The vanishing of classical Noether charges for the sub-algebra of super-symplectic algebra characterizes partially the preferred extremals.

Fermions would reside in the intersection and be number theoretically universal. Indeed, the anticommutations relations are number theoretically universal, even in the case that they involve quantum group phase.

The hierarchy of algebraic extensions of rationals defines the fundamental hierarchy defining also evolutionary hierarchy. The higher the complexity of the extension, the higher the level in the evolutionary hierarchy. p-Adic primes are identified as ramified primes of algebraic extension and the large the p-adic prime the higher the level of cognition. The higher the dimension $n = h_{eff}/h$ of extension, the longer the scale of quantum coherence, and the higher the intelligence of the system. What distinguishes ramified p-adic primes from the others that the prime ideals of of integers of extension define by ramified primes are such that the action of Galois group is trivial. The interpretation is that for ramified primes n space-time sheets co-incide at their ends at boundaries of CD. This would be one manner to interpret quantum criticality and consistent with the adopted interpretation. This brings in n "dark" discrete degrees of freedom which are crucial for intelligence and this is what makes corresponding p-adic primes so special.

Weak NMP supports the generalization of p-adic length scale hypothesis stating that ramified/p-adic primes near but below powers or primes are of special importance. Primes near powers of 2 appear in the original form of p-adic length scale hypothesis and should be central for understanding intelligence in TGD Universe. Finite fields associated with $p = 2, 3, 5$ can be realized as finite geometries representable by Platonic solids. Also other finite fields can be realized as finite geometries realized as regular polygons. This suggests that powers of primes near but below p^k,

$p = 2, 3, 5$ are of special importance. The model of music harmony and genetic code based on icosahedral geometry supports this view: icosahedron corresponds to $p = 5$ finite projective geometry [K22]. Music scales involve both 2-adicity (octave equivalence) and 3-adicity (quint cycle) and the finding that powers of 3 define time scales at which sudden jumps in biological evolution have occurred [I4] support this view. Cyclic group Z_5 defines one particular Galois group with 5 elements and corresponds to angle $2\pi/5$,whose cosine involves $\sqrt{5}$ defining an algebraic extension containing $\sqrt{5}$ and appearing in Golden Mean, which is fundamental in biology.

String world sheets and partonic 2-surfaces would be characterized by $n = h_{eff}/h$ and the ramified primes. Number theory alone does not predict any correlations between them. The generalization of AdS/CFT correspondence to TGD framework realizes quantum classical correspondence and suggests that the p-adic primes identified as ramified primes must divide n. This assumption would mean that even elementary particles would carry surprisingly large number of discrete dark degrees of freedom. For instance, electron would correspond to $n = M_{127} = 2^{127} - 1$ and carry 126 bits of information, and would be ideal for realizing memetic code that I proposed for two decades ago with inspiration coming from Combinatorial Hierarchy [K14]. The secondary p-adic time scale of electron is .1 seconds and corresponds to a fundamental bio-rhythm. The corresponding p-adic length scale corresponds to the size of Earth. Hence - in sharp contrast with standard physics expectations - elementary particles -also quarks - could be crucial for understanding conscious intelligence. Neutrinos correspond to p-adic length scale possibly longer than that associated with Gaussian Mersenne $M_{G,127} = (1+i)^{167}-1$. There are actually 4 Gaussian Mersennes in biologically relevant length scale range 10 nm- 2.5 μ m corresponding to $k = 151, 157, 163, 167$. This number theoretical miracle must have some deep meaning. That Gaussian Mersennes are in question might have some deep meaning. They represent primes of algebraic extension containing i possible for primes $p = 3 \ mod 3$. Do

1.2.4 p-Adic physics as physics of cognition and imagination

The vision about p-adic physics as physics of cognition has gradually established itself as one of the key idea of TGD inspired theory of consciousness. There are several motivations for this idea.

The strongest motivation is the vision about living matter as something residing in the intersection of real and p-adic worlds. One of the earliest motivations was p-adic non-determinism identified tentatively as a space-time correlate for the non-determinism of imagination. p-Adic non-determinism follows from the fact that functions with vanishing derivatives are piecewise constant functions in the p-adic context. More precisely, p-adic pseudo constants depend on the pinary cutoff of their arguments and replace integration constants in p-adic differential equations. In the case of field equations this means roughly that the initial data are replaced with initial data given for a discrete set of time values chosen in such a manner that unique solution of field equations results. Solution can be fixed also in a discrete subset of rational points of the imbedding space. Presumably the uniqueness requirement implies some unique pinary cutoff. Thus the space-time surfaces representing solutions of p-adic field equations are analogous to space-time surfaces consisting of pieces of solutions of the real field equations. p-Adic reality is much like the dream reality consisting of rational fragments glued together in illogical manner or pieces of child's drawing of body containing body parts in more or less chaotic order.

The obvious looking interpretation for the solutions of the p-adic field equations would be as a geometric correlate of imagination. Plans, intentions, expectations, dreams, and cognition in general could have p-adic space-time sheets as their geometric correlates. A deep principle could be involved: incompleteness is characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

The original idea was that p-adic space-time regions can suffer topological phase transitions to real topology and vice versa in quantum jumps replacing space-time surface with a new one is given up as mathematically awkward: quantum jumps between different number fields do not make sense. The new adelic view states that both real and p-adic space-time sheets are obtained by continuation of string world sheets and partonic 2-surfaces to various number fields by strong form of holography.

The idea about p-adic pseudo constants as correlates of imagination is however too nice to be thrown away without trying to find an alternative interpretation consistent with strong form

of holography. Could the following argument allow to save p-adic view about imagination in a mathematically respectable manner?

1. Construction of preferred extremals from data at 2-surfaces is like boundary value problem. Integration constants are replaced with pseudo-constants depending on finite number pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces.

2. Preferred extremal property in real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these 2- surfaces completely independently. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets and partonic 2-surfaces not allowed in real context and realizing imagination.

3. Could imagination be realized as a larger size of the p-adic sectors of WCW? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could the modes of WCW spinor fields for which 2-surfaces are extandable to space-time surfaces only in some p-adic sectors make sense? The real space-time surface for them be somehow degenerate, for instance, consisting of string world sheets only. Could imagination be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real preferred extremals? p-Adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2-surfaces which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

Although p-adic space-time sheets as such are not conscious, p-adic physics would provide a beautiful mathematical realization for the intuitions of Descartes. The formidable challenge is to develop experimental tests for p-adic physics. The basic problem is that we can perceive p-adic reality only as "thoughts" unlike the "real" reality, which represents itself to us as sensory experiences. Thus it would seem that we should be able generalize the physics of sensory experiences to physics of cognitive experiences.

1.2.5 Hierarchy of Planck constants and consciousness

The hierarchy of Planck constants is realized in terms of a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. $CD \times CP_2$ is generalized by gluing singular coverings and factor spaces of both CD and CP_2 together like pages of book along common back, which is 2-D sub-manifold which is M^2 for CD and homologically trivial geodesic sphere S^2 for CP_2 [K10]. The value of the Planck constant characterizes partially given page and arbitrary large values of $\hbar$ are predicted so that macroscopic quantum phases are possible since the fundamental quantum scales scale like $\hbar$. All particles in the vertices of Feynman diagrams have the same value of Planck constant so that particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to $\hbar$ changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory.

Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the causal diamond (pair of future and past directed light-cones in $H = M^4 \times CP_2$). For electron this time scale is .1 second, the fundamental biorhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time

scales coming as h_{eff}/g multiples of this time scale. These two hierarchies could allow to get rid of the notion of self as a primary concept by reducing it to a quantum jump at higher level of hierarchy. Self would in general consists of quantum jumps inside quantum jumps inside... and thus experience the flow of time through sub-quantum jumps.

The hierarchy of Planck constants means the possibility of temporal zooms of the event sequences of the external world making possible "stories" as either zoomed up or zoomed down versions of the actual course of events. This makes possible simulation in the time natural time scales of neuronal activity and is expected to be a key element of conscious intelligence.

The realization that dark matter hierarchy corresponds to a hierarchy of quantum criticalities leads to an understanding of general characteristics of living systems. NMP demands increase of NE and spontaneous increase of h_{eff} can occur in the first state function reduction to the opposite boundary of CD. This however means death of self and self tries to survive as long as possible by gathering NE stored to mental images so that the NE associated with mental images increases. Metabolism makes this gathering of NE possible if metabolites carry NE. Even sensory qualia would involve in the capacitor model transfer negentropic carriers of quantum numbers having interpretation as generalized metabolites so that the primary qualia would characterize metabolites. Nutrients should carry or generate NE. An open question is in what scale NE is present or is generated. In [K33] it is proposed that NE is in scale of Earth.

1.3 The Meanings Of Sensory, Cognitive, Symbolic

With my physicist's background I have used the attributes sensory, cognitive and symbolic somewhat sloppily and the precise meanings of these become only gradually clear. The recent view is that p-adic space-time sheets correspond to cognition and imagination and that their intersections with real space-time sheets in the intersection of real and p-adic worlds define simultaneously both sensory and cognitive representations in algebraic extension of rationals.

These representations are defined in terms of data coming from the rational and algebraic points common to real and partonic 2-surfaces with the algebraic extension in question characterized by the mathematical representation of the partonic 2-surfaces and string world sheets making sense for both real and p-adic 2-surfaces simultaneously. Lowest level corresponds to discrete points of partonic 2-surfaces which string world sheets meet them and their boundaries carrying fermions being. For string world sheets and partonic 2-surfaces discretization is at the level of conformally invariant parameters. A number theoretic variant of quantum field theory is needed in order to have a first principle description of conscious intelligence and intentionality. Strong form of holography defines representations at space-time level.

The classical non-determinism of Kähler action quite generally implies that space-time surfaces define what might be called symbolic representations realizing quantum classical correspondence. This applies irrespective of the number field used and in p-adic context p-adic non-determinism is an additional ingredient. For instance, nerve pulse patterns define symbolic real physics representations of the sensory input but do not give rise to sensory qualia which reside at the level of the primary sensory organs (contrary to the expectations raised by various findings of neuroscience). Sensory experience is always a multiverse experience since sensory qualia have quantum jump increments as quantum correlates, and is thus not reducible to the level of space-time.

1.4 Topics Of The Chapter

The topics of the chapter is as follows.

1. Various candidates for measures for conscious information are discussed. The basic information measure being the reduction of entanglement entropy in state function process for given subsystem as it splits to two parts. NE is also possible and this kind of systems are stable against state function reduction to a pair of unentangled states. It is tempting to characterize self by this entanglement negentropy which is well-defined and positive in the intersection of real and p-adic worlds. Strong form of holography and the appearance of algebraic extensions of rationals whose basic parameters allow information theoretic interpretation allows to assign information measure also with space-time surface as parameters of extension assignable to the string world sheets and partonic 2-surfaces.

2. Frieden's proposal that action principles, including also Maxwell action, could have information theoretic interpretation is discussed in TGD framework in the hope that this would provide additional insights about quantum classical correspondence and living matter. Frieden's prooposal fails in Minkowskian regions but works in Euclidian regions and allows to consider the possibility that entanglement negentropy assignable to Minkowskian regions and fermionic strings equals to the Kähler function apart from a constant factor.

3. The realization of quantum variant of Boolean logic in terms of zero energy fermion states is discussed.

4. The next sections are devoted to the relationship of TGD based visions about brain as computer, hologram, and association machine. Also the connection with the neuro science view about brain is discussed.

5. The notions of meme and morphic field are discussed in TGD framework.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L1].

2 How To Define Measures For The Information Content Of Consciousness?

In this section my aim is to discuss different approaches to the problem how to define the information contents of conscious experience rather than advocating any final truth. Of course, just at this moment the information measures based on entanglement negentropy and associated with self seem to be the most realistic ones to me personally, but during these 37 years of TGD I have learned that it it is better to tolerate all views about the solution of the problem even when their mutual consistency is not obvious.

2.1 Information Measures For Conscious Experience

The concepts of information, information flow and information gain of conscious experience would seem to have a natural place in theories of consciousness. It seems intuitively obvious that WCW spinor fields must contain information. WCW spinor fields have indeed interpretation as both objective realities and Platonic Ideas, the latter interpretation being suggested strongly by the possibility to interpret fermionic Fock state basis as a Boolean algebra of statements about statements. The basic statements are most naturally statements about space-time geometry since fermionic oscillator operators are determined by the second quantized free quantum field theory for the induced spinors [K15].

The condition that em charge is well-defined for the spinor modes led to realization that spinor modes must be restricted to 2-D string world sheets intersecting partonic 2-surfaces at discrete points. The result is consistent with the strong form of holography following from the strong form of GCI and implies that both space-time surfaces and scattering amplitudes can be constructed from the data at these 2-surfaces. This in turn leads to an elegant realization of number theoretic universality. The 2-surface in question are characterized by parameters, which are in some algebraic extension of rationals - all extensions are allowed - and can be therefore continued to the field of real numbers and to the induced extensions of various p-adic numbers fields. The outcome is what one could call adelic physics. Adelic space-time surfaces has a book-like structure with pages labelled by various number fields and glued together along back defined by the 2-surfaces. Same applies at the level of imbedding space and WCW.

Despite the fact that one cannot write formula for the contents of conscious experience, one can define information measures for conscious experience as differences of the information measures associated for the initial and final states of quantum jump identified as those for the state assignable to passive boundary of CD. Note that one can assigned average negentropy also to the the active boundary but it seems that this is potential information rather than actualized information.

The most plausible measure information measure is based on p-adic norm and defined by a generalization of Shannon formula for entropy by replacing 5h3 logarithm of probability with logarithm of p-adic norm of probability and finding the prime for which the resulting negative entropy identifiable as negentropy is maximal. This defies a measure for negentropic entanglement (NE) as number theoretic entropy for the largest power of prime factor dividing the dimension of the final state space resulting in state function reduction. I have discussed this measure already in the introduction and also in [K16] and there is no point repeating the discussion.

State function reduction sequence at fixed boundary of CD defines self. Self dies, when the first reduction to the opposite boundary takes place and re-incarnates as self assignable to the opposite boundary. The first state function reduction to opposite boundary reduction decomposes to a cascade of state function reduction both in zero modes and in quantum fluctuating degrees of freedom ultimately leading to a completely unentangled state decomposing to a product of un-entangled states consisting of bound states and and states for which every decomposition to a pair of subsystems is negentropically entangled. At each step system decomposes to a unique pair of unentangled subsystems. The entanglement probabilities defined by the density matrix for either subsystem characterize the probabilities for the outcomes of the self measurement. Both unentangled subsystems resulting in the first step are again subject to self measurements and the process continues until an unentangled state results.

Consider now the information measures.

1. The reduction of entanglement entropy defines a natural measure for conscious information gain in single step of the state of state function reduction process decomposing subsystem to a pair of un-entangled sub-systems. If entanglement is negentropic the entanglement negentropy either increases or the system is stable against state function reduction.

2. It seems natural to assume that the information measures are associated with the entire cascade and that they are additive in the sense that information gain is sum over the information gains of the steps of the cascade and that a given step contributes by the sum of the information gains associated with unentangled subsystems which are subject to self measurement in a given step of the cascade.

3. One can also assign information measures to the resulting indecomposable systems. For subsystem which is bound state in the normal sense and thus has entropic entanglement, one can consider all possible decomposition of the system to a sub-system and its complement and define the entanglement negentropy as the negative for the minimum value of entropy obtained in this manner. If the system is negentropically entangled one can define entanglement negentropy as the maximum of entanglement negentropy gaine in this manner. This means that one can assign to the final state of state function reduction unique negentropy as the sum of the negative contributions associated with selves which are internally bound state entangled and positive contributions of negentropic selves.

4. The information content of the conscious experience associated with self is more interesting practically. If one assumes that self experiences sub-self as a statistical ensemble of sub-subselves, it is straightforward to define entropies associated with the increments of quantum numbers and zero modes defining non-geometric and geometric qualia. These entropies characterize the fuzziness of the quale and are "negative" information measures. One can also assign to non-decomposable sub-selves the information measures and they give either positive or negative contribution to the information content of self.

5. In principle this allows to define also the net information gain of state function reduction as the difference of the total negentropies of the final and initial states of state function reduction identified as those produced by the state function reduction process. Initial and final state negentropies would characterize spinor fields of WCW ("world of classical worlds"). One can also assign negentropy gain with the life-cycle of self as difference of negentropies of the time reversed self resulting in the first reduction to opposite boundary of CD and self. This negentropy gain can be said to be the saldo of the life of self.

I have considered several forms for NMP starting from a form producing standard quantum measurement theory assuming that density matrix of the subsystem is the universal observable.

The allowance of NE possible for entanglement probabilities in an algebraic extension of rationals was the next step. It was however realized that the condition that the outcome of reduction is eigenstate of the density matrix allows only final states for which the density matrix is projector: unitary 2-particle entanglement corresponds to this kind of situation. Eventually I realized that weak form of NMP is the most plausible option. For strong form of NMP the final state would be essentially unique if the initial state density matrix contains a higher-dimensional projector. Weak form of NMP allows however possible to choose also lower-dimensional subspace of the sub-space giving rise to maximal negentropy gain. This option allows to derive a generalization of p-adic length scale hypothesis. It allows also free will and provides physical correlates for ethics and moral: the basic principles is that the best self can achieve is to increase negentropic resources of the Universe.

Weak form of NMP favor large prime factors in the dimension of the sub-space resulting in state function reduction, which can be any integer $n - k \geq 1$, $k = 1, 2...$ This does not yet imply that the integer $n = h_{eff}/h$ characterizing the super-symplectic subalgebra acting as gauge symmetries contains a large prime as a factor. The condition that the effective string tension associated with elementary particle magnetic flux tube is small is however satisfied if this is the case. For electron this would mean that $p = M_{127} = 2^{127} - 1$ divides n: this suggests that the magnetic flux tube involved carries 126 bits of information. That the fundamental time scale of living matter is .1 seconds and corresponds to the secondary p-adic length scale of electron and size scale of Earth gives additional support for the speculation. This modifies completely the neuroscience based vision about intelligence as emergent phenomenon but is consistent with what is experimentally known: we are not yet able to detect dark matter and in the case of electron the dark contribution to electrons mass is of order $\Delta m/m \sim 10^{-19}$.

In TGD framework negentropy gradients correlate with emotions, which means a somewhat counter intuitive connection between emotions and information gain or loss (consistent however with the fact that peptides are both informational molecules and molecules of emotion [J11]). Note that the binding of information molecules to receptors means the formation larger bound states accompanied by the experience of oneness at molecular level (are analogs spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

2.2 Information Concept At Space-Time Level

Quantum-classical correspondence suggests that the notion of information is well defined also at the space-time level. The non-determinism of Kähler action and p-adic non-determinism plus algebraic information measures suggest a natural approach to the problem of defining the information concept. This approach provides also a new light to the problem of assigning a p-adic prime to a given real space-time sheet.

2.2.1 Can one assign an information measure to a space-time sheet?: the recent view

For years ago I ended up with the idea that space-time surface should somehow code for the preferred primes so that it would be a representations for an integer and considered some naive proposals how this could be realized. Since the ramified primes identifiable as preferred p-adic primes characterize the algebraic extension of rationals - or more precisely, the ideal for algebraic extension - to which the parameters characterizing string world sheets and partonic 2-surfaces belong, they characterize by strong form of holography also the space-time region containing them. In fact, the integer defined by the product of ramified primes characterizes the space-time region.

2.2.2 Can one assign an information measure to a space-time sheet?: the older view

I have included also the older attempts to assign information measure to a space-time sheet. Whether they have any connection with the vision based on ramified primes of algebraic extension, remains an open question. It would however not be too surprising if the character of non-determinism of Kähler action would correlate with the properties of algebraic extension involved. Pseudo-constants belong to the algebraic extension and the dimension of the space associated with given pseudo-constant is the dimension n of extension. If one has m pseudo-constants, the

dimension of corresponding space is n^m, and if p divides n, the dimension is proportional to p^m as p-adic considerations would suggest. The information measure would be naturally number theoretic entropy of system with p^m states with identical probabilities and given by $N = mlog(p)$.

Consider now the earlier argument. In the presence of the classical non-determinism of Kähler action and p-adic non-determinism one can indeed define ensembles, and therefore also probability distributions and entropies. For a given space-time sheet the natural ensemble consists of the deterministic pieces of the space-time sheet regarded as different states of the same system. The probability for the appearance of a given value of observable is of the general form $p_i = m_i/N$, $m_i < N$, where N is the number of deterministic pieces and S_p is always negative, when p divides N.

Obviously the primes dividing N define natural candidates for the information measures but the problem is which criterion selects one of them. There are three options.

1. Require that the information measure corresponds to the prime p for which S_p is smallest. Obviously p must divide N.

2. Define the information as sum

$$I = -\sum_{p|N} S_p \ ,$$

   (here $p|N$ means that p divides N) so that all contributions are positive.

3. Include all primes dividing N or m_i in $p_i = m_i/N$:

$$I = -\sum_{p|N \ or \ p|m_i} S_p \ ,$$

   In this case also negative contributions are present. This defition is actually equivalent with a definition

$$I = -\sum_{p} S_p \ ,$$

   in which the summation appears over all primes. One could say that the information decomposes into different kinds of informations labelled by primes.

   What is interesting is that, the ordinary Shannon entropy S for rational probabilities can be expressed as a sum of all p-adic entropies using the adelic decomposition $|x| = \prod_p |x|_p^{-1}$:

$$S = -\sum_{p} S_p = I \ .$$

   The sum of real and p-adic entropies vanishes. Real dis-information and the p-adic information would compensate each other completely. Whether the adelic formula for information theory might have some deeper interpretation remains open.

2.2.3 Does classical space-time physics represent factorization of integers?

Space-time region represents factorization of integer and p-adic space-time region corresponding to ramified primes define a similar adelic factorization. The reason for the preferred character of the ramified primes is that for them n separate space-time surfaces obtained by the action of Galois group on the parameters of 2-surfaces co-incide at the boundaries of CD (criticality!) so that one obtains analog of bound state [K34]. The different branches correspond to n discrete of freedom, and one can assign to them many-fermion states: at most 1 fermion at single sheet of the covering.

The following represents the older argument for factorization. Quantum-classical correspondence suggests that quantum computation processes might have counterparts at the level of space-time. An especially interesting process of this kind is the factorization of integers to prime factors. The classical cryptography relies on the fact that the factorization of large integers to prime factors

is a very slow process using classical computation: the time needed to factor 100 digit number using modern computer would take more than the recent age of the universe. For quantum computers the factorization is achieved very rapidly using the famous Shor's algorithm. Does the factorization process indeed have a space-time counterpart?

Suppose that one can map the integer N to be factored to a real space-time sheet with N deterministic pieces. If one can measure the powers $p_i^{n_i}$ of primes p_i for which the fractality above the appropriate p-adic length scale looks smoothness in the p-adic topology, it is possible to deduce the factorization of N by direct physical measurements of the p-adic length scales characterizing the representative space-time sheet (say from the resonance frequencies of the radiation associated with the space-time sheet). If only the p-adic topology corresponding to the largest prime p_1 is realized in this manner, one can deduce first it, and repeat the process for N/p_1^n, and so on, until the full factorization is achieved. A possible test is to generate resonant radiation in a wave guide of having length which is an integer multiple of the fundamental p-adic length scale and to see whether frequencies which correspond to the factors of N appear spontaneously.

Seeing the prime factorization might be also possible via a direct sensory perception. Oliver Sacks tells in his book "The man who mistook his wife for a hat" [J16] about twins, John and Michael, who had a mysterious ability to "see" large numbers and their prime factorizations despite the fact that their intelligence quotient was about 60 and they did not have any idea about the notions of integer and prime. For instance, matchbox was dropped from the table and its contents were spread along the floor. Both twins shouted immediately "111!". Then John mumbled "37", Michael repeated it and John said "37" third time. Obviously this was their sensory representation for the decomposition $111 = 3 \times 37$ of number 111 to a product of primes! The explanation of these strange feats suggested in [K28] is a less general idea about physical representation of the factorization. The proposed mechanism could indeed explain prime factorization as a sensory perception involving no algorithmic cognition at all.

2.3 Information Theoretic Interpretation Of Kähler Function

An important stimulus in the development of ideas was the Jan 30, 1999 issue of New Scientist [B6] in which the work of Roy Frieden [B5] about information theoretical interpretation of the variational principles of physics was discussed at popular level. The work of Frieden relies on the concept of Fisher information. One can find a precise definition of the Fisher information in Mathematical Handbooks but this definition does not help too much without any further knowledge about Frieden's work.

Although the article in New Scientist [B6] does not give any mathematical details about Frieden's work, it becomes clear that Fisher's theory as such does not apply to TGD framework. Frieden's basic idea seems however attractive. Indeed, TGD inspired theory of consciousness inspires a hypothesis concerning the information theoretic interpretation of the Kähler function.

Frieden's hypothesis inspired the idea that Kähler function (Kähler action for a preferred extremal) has information theoretic interpretation. At that time I had not realized that Kähler function comes from Euclidian space-time regions whereas Minkowskian regions give an imaginary contribution due to the presence of the metric determinant and identifiable as the counterpart of quantum field theoretic action. This allows to solve the basic problem of the Frieden's approach due to the fact that in Minkowskian realm action is not positive definite. Therefore the information theoretic interpretation of Kähler function might work but Frieden's idea does not have a feasible realization in TGD framework.

2.3.1 Information theoretic interpretation of action in Frieden's theory

Frieden [B5, B6] introduces two kinds of information concepts. Fisher information, usually denoted by I, is defined as the information which can extracted from a physical phenomenon by measurements of a specific type. Information J is defined as the information contained by the phenomenon and in general $J - I \geq 0$ holds true.

The action defining the dynamical equations of a physical theory decomposes into a difference $I - J$, where J is the total information contained by the state and I is the available information. I and J depend on what is measured. Minimization of $I - J$ for position measurement leads to classical Newton's equations.

In classical mechanics J corresponds typically to the integral of potential energy V and I corresponds to the integral of kinetic energy I, in accordance with the decomposition

$$S = \int L dt, \quad L = T - V \ .$$

Maxwell action is obtained by considering position measurement in presence of charge. For Maxwell action

$$S = \int (B^2 - E^2) d^4x \ ,$$

the entire integral of B^2 corresponds to I whereas total (or potential) information J is non-vanishing only provided there is coupling to external currents.

2.3.2 Information theoretic interpretation of Kähler function

The first thing to notice is that without further assumptions the Kähler function of the Universe should be infinite since otherwise the exponent of Kähler action becomes zero. ZEO provides the manner to escape this conclusion: each CD defines it sub-Universe and Kähler function is Khler action for the space-time surface inside CD.

Information theoretic interpretation of Kähler function - albeit not in the sense proposed by Frieden - might make sense in TGD framework. Quantum classical correspondence suggests that Kähler function could serve as a classical correlate for quantal information measure defined by negentropy.

It is however essential that one accepts the possibility of Euclidian space-time regions predicted by TGD to serve as space-time correlates for the lines of generalized Feynman diagram and thus representation of matter. One must accept also the number theoretic vision that conscious information is possible in the intersection of real and p-adic worlds.

1. When should one use entanglement negentropy and when entanglement entropy based on real numbers is appropriate? It seems that entanglement negentropy makes sense at the passive end of CD at which state does not change and reduction to an eigen-space of density matrix has occurred for given sub-system-complement pair.

   At the active boundary of CD situation is different since the entanglement does not reduce to this simple form and one could argue that the ordinary entanglement entropy is natural notion. After all, future is uncertain!

2. For the regions with Euclidian signature representing generalized Feynman graphs with lines represented as deformations of CP_2 type vacuum extremals one must be very careful with the sign factors. One cannot distinguish between electric and magnetic contributions and the sign of the Kähler function is positive. It would be attractive to assign entropy or negentropy with elementary particles and identify it as Kähler function apart from possible numerical factor. Whether one has entropy or negentropy seems to be a matter of convention. Strict adherence to thermodynamical analogy would suggest the interpretation as entropy.

3. Entanglement negentropy assignable to strings connecting partonic 2-surfaces in Minkowskian regions is the quantal information measure. Strings are assignable to magnetic flux tubes carrying possible monopole flux.

4. The generalization of AdS/CFT duality suggests that the descriptions provided by Kähler function in Euclidian regions and fermionic strings in Minkowskian regions are dual. Could these two negentropies be identical as also quantum classical correspondence suggests.

   An immediate objection is that entanglement negentropy for the outcomes of state function reduction is is a discrete number: logarithm of integer. Kähler function cannot have discrete spectrum. One can consider also the active boundary of CD for which state-complement pairs would be characterized by ordinary entanglement entropy giving a continuous measure of entropy. Kähler function could have an interpretation as entropy as standard thermodynamics suggests.

The above interpretation says nothing about the Kähler action in Minkowskian regions. Both magnetic flux tubes and electric flux quanta are of special interest in Minkowskian regions. Could Kähler action also now have an interpretation as information measure? NE can be assigned to strings accompanying magnetic flux tubes carrying monopole flux. Could the Kähler action for flux tubes be identified as entanglement negentropy at the passive boundary of CD? Again the discontinuous spectrum of entanglement negentropy is a problem unless the parameters of flux tubes are quantized, which is in principle possible by preferred extremal property. Quantization of action is indeed a basic aspects of quantum classical correspondence and Planck constant was introduced originally as quantum of action.

But what about regions carrying Kähler electric fields and Kähler action and information with opposite sign. Is there any reasonable interpretation or should one assume that it is only the total Kähler action that matters and that total Kähler action corresponds to positive negentropy?

3 Logic And Fermions

The state basis for the fermionic Fock space has a natural interpretation as a Boolean algebra (fermion number $=1/0 \leftrightarrow$ yes/no). In this manner ordinary Boolean algebra is extended to vector space spanned by fermionic states. When cognitive fermion pairs are used instead of fermions, fermion number conservation does not pose any constraints and full linear superposition of the Boolean algebra elements is possible. An interesting question is whether one could consider ordinary Boolean logic as some kind of limit for the complex quantum logic.

The simplest TGD based model for thinking systems leads to the result that thoughts correspond to quantum states in discrete spaces. The reason is that slightly non-deterministic classical time evolution means a finite number of multi-furcations. These additional dynamical degrees of freedom correspond to N-element set labelling the different time evolutions associated with given initial values. This suggests that a suitably defined *binary* Hilbert space having Z_2 rather than complex numbers as a coefficient field could provide a simple quantum model for a thinking system. This raises the following question.

What would a quantum field theory in discrete space and with the field of complex numbers replaced with binary numbers Z_2 (0, 1/Yes, No) look like?

The answer is following.

1. The state basis of the quantum field theory defined in N-element set is nothing but a Boolean algebra consisting of 2^N elements: all possible statements about the N elements interpreted as propositions! Bosons and fermions are one and the same thing and behave like fermions since occupation number can have only the values 0 and 1.

2. The requirement that triangle equality for the inner product is satisfied, does not allow linear superposition and one must choose some orthogonal basis for the space. The absence of quantum superposition means that theory is completely classical. Thus it seems that Boolean QFT is completely classical and the transition from classical mechanics to quantum theory could be regarded as a transition from binary QFT to complex QFT or from a binary logic to complex logic.

3. Quantization means construction of statements about statements: the simplest model for an abstraction process one can imagine! One can of course continue this quantization: second, third, etc., quantization is possible and this corresponds to a construction of statements about statements about..... Hence a direct connection with the ideas about genetic code emerges.

4. Also the state basis in the Fock space of the ordinary fermions has interpretation as a Boolean algebra, all possible statements about some propositions (particle with a definite spin component is at point x).

3.1 The State Basis Of Fermionic Fock Space As Boolean Algebra

The state basis of a fermionic Fock space can be interpreted as a basis of a Boolean algebra. In quantum TGD all elementary particles are constructed using fermionic oscillators operators. This

suggests that entire quantum field theory is actually a representation of Boolean algebra and N-fermion states have interpretation as statements about basic propositions labelled by the indices labelling fermionic oscillator operators. In particular, WCW spinor structure is constructed in terms of the fermionic oscillator operators for the second quantized spinor fields on space-time and this suggests a deep connection between spinor geometry and logic. Perhaps one could say that quantum logic is C-valued in the sense that all complex superpositions of a statement and its negation are possible.

In Boolean algebra one can select the maximum number of 2^{N-1} statements consistent with given atomic statement (one bit fixed) statements as axioms. An interesting possibility is that only these statements consistent with given atomic statement (one bit fixed) are physically realized so that the number of states is reduced by a factor of one half. Amusingly, in the ordinary fermionic field theory the states created by a finite number of oscillator operators are the counterparts of these preferred statements, their negations would correspond to a vacuum state obtained as an infinite product of all creation operators annihilated by creation operators. The states created by annihilation operators from this states are not allowed in QFT since they would have infinite energy.

One can identify the complex valued linear space of fermions as a generalization of Boolean algebra to complex Hilbert space. Cognitive fermion pairs could provide realization for this space as pairs of fermion and anti-fermion belonging to different space-time sheets and representing logical statement and its negation: the automatic presence of negation is rather natural from the point of view of consciousness theory. The splitting of the wormhole contacts connecting the space-time sheets gives rise to annihilation process generating fermion and anti-fermion pair (fermionic quantum numbers reside on the boundary components of the split wormhole contact). In this manner one avoids problems related to fermion number conservation encountered otherwise in physical realization of the fermionic logic. Alternative possibility is to assume fixed number of fermions and associate truth values with the direction of spin.

3.2 Boolean Algebra As Boolean QFT

Boolean algebra $B(N)$ is generated by all possible yes/no statements about N propositions. It consists of sequences of N binary digits of form $(...,1,0,0,..,1)$ having value of 0 or 1. Addition is with respect to Z_2 so that $1+1=0$. Boolean algebra is Z_2 linear space and the elementwise multiplication of the binary digits in the string makes it algebra. $(0,0,0,..)$ and $(1,1,....,)$ are zero and unit elements of the algebra.

Geometrically Boolean algebra $B(N)$ corresponds to all possible subsets of an N-element set. Sum corresponds to a symmetric difference (take the union of sets and throw away the common elements). Multiplication corresponds to the intersection of the sets. Entire set represents unit element and empty set zero. Empty set is not physically realizable, or equivalently, the zero element of the Boolean algebra does not correspond to a physical state in the Z_2 Hilbert space defined by the Boolean algebra.

Quantum field theory in N-element set formed by the basic propositions (analogous to 3-space in QFT) means associating to each element of the N-element set creation and annihilation operators and postulating standard commutation relations with them:

$$[a^\dagger(i), a(j)] = 1 \quad .$$

One can also consider fermions that is anti-commutation relations but since -1=1 in Boolean algebra, they are equivalent with the bosonic commutation relations so that Boolean bosons and fermions are one and the same thing in the Boolean QFT.

The states of this QFT are constructed in the usual manner. The only difference is the occupation numbers are Z_2 valued and are either one or zero just as in the case of fermions. Thus Boolean particles are fermions always. Since N creation operators are involved one obtains a space generated by 2^N states. The proposition and its negation correspond to the states created by, say I oscillator operators and the dual of this state created by the remaining $N-I$ oscillators operators. Statement corresponds to I particles and its negation to I holes in the dual ground state containing all N oscillator operators.

Thus the state basis is nothing but the Boolean algebra associated with the N element set! Thus the state basis of Z_2 valued quantum field theory in the set of N propositions is nothing but

the formation of all possible statements about these statements: a model for abstraction process. One can apply this process to the 2^N-1 element set and by continuing this process get a sequence of second quantizations as a sequence of abstractions.

The assumption of unrestricted linear superposition in Z_2 Hilbert space leads to difficulties with Schwartz and triangle inequalities. The physical interpretation of the theory requires that inner product satisfies Schwartz inequality

$$|(x,y)| \leq |x||y| \quad .$$

Linear superposition allows states, say y, with zero norm since any superposition of even number of orthonormal states has zero norm in Z_2. The norm of the inner product of one of the basis states appearing in zero norm state, call it x, with the zero norm state y equals to one and is not smaller than the product of the norm of the basis state and state with vanishing norm: one obtains $1 < 0$, which does not make sense if inner product is interpreted as real number (as a Z_2 valued number one could perhaps say $1 = -1 < 0$). One ends up to difficulties also with the triangle inequality: $|x+y| \leq |x|+|y|$ if x and y are zero norm states with single common element of orthonormal basis so that one has $|x+y| = 1$.

The only possible manner to save Schwartz and triangle inequalities is to assume that linear superposition is not allowed for Z_2 Hilbert space. This in turn means that situation is completely classical! If the set generating Boolean algebra consists of entire 3-space, this means that every state is gauge equivalent with an N-particle state of completely localized particles. This in turn implies that Boolean QFT should be more or less equivalent with classical mechanics and one could understand the transition from classical physics to quantum physics as the replacement of Z_2 with complex numbers C as the coefficient field of the state space.

One can change state basis by unitary transformations. Unitary matrices are obtained from orthogonal Z_2 valued unit vectors possessing entries equal to 1 or 0. Any unitary matrix corresponds to a matrix representing the permutation of 2^N elements of the basis of the Boolean algebra. Time development operator in this quantum field theory is always defined for a *finite* time interval only (the length of the "chronon" is fixed naturally in p-adic QFT) and represents a permutation of this basis. In particular, a nonlinear transformation of the oscillator operators in general occurs. All unitary transformations are permutations, which do *not* lead to state basis involving superpositions of the basic states. This is in accordance with the observation that Boolean QFT is completely classical.

3.3 Fermions, Zero Energy Ontology, And Boolean Cognition

Fermionic Fock state basis defines naturally a quantum version of Boolean algebra. In zero energy ontology predicting that physical states have vanishing net quantum numbers, positive and negative energy components of zero energy states with opposite fermion numbers define realizations of Boolean functions via time-like quantum entanglement. One can also consider an interpretation of zero energy states in terms of rules of form $A \to B$ with the instances of A and B represented as elements Fock state basis fixed by the diagonalization of the density matrix defined by $M-$-matrix. Hence Boolean consciousness would be basic aspect of zero energy states. Physical states would be more like memes than matter. Note also that the fundamental super-symmetric duality between bosonic degrees of freedom (size and shape of the 3-surface) and fermionic degrees of freedom would correspond to the sensory-cognitive duality.

This would explain why Boolean and temporal causalities are so closely related. Note that zero energy ontology is certainly consistent with the usual positive energy ontology if unitary process U associated with the quantum jump is more or less trivial in the degrees of freedom usually assigned with the material world. There are arguments suggesting that U is tensor product of of factoring S-matrices associated with 2-D integrable QFT theories [K6]: these are indeed almost trivial in momentum degrees of freedom. This would also imply that our geometric past is rather stable so that quantum jump of geometric past does not suddenly change your profession from that of musician to that of physicist.

3.4 Negentropic Entanglement, Fuzzy Logic, Quantum Groups, And Jones Inclusions

Matrix logic [A3] emerges naturally when one calculates expectation values of logical functions defined by the zero energy states with positive energy fermionic Fock states interpreted as inputs and corresponding negative energy states interpreted as outputs. Also the non-commutative version of the quantum logic, with spinor components representing amplitudes for truth values replaced with non-commutative operators, emerges naturally. The finite resolution of quantum measurement generalizes to a finite resolution of Boolean cognition and allows description in terms of Jones inclusions $\mathcal{N} \subset \mathcal{M}$ of infinite-dimensional Clifford algebras of the world of classical worlds (WCW) identifiable in terms of fermionic oscillator algebras. $\mathcal{N}$ defines the resolution in the sense that quantum measurement and conscious experience does not distinguish between states differing from each other by the action of $\mathcal{N}$.

The finite-dimensional quantum Clifford algebra $\mathcal{M}/\mathcal{N}$ creates the physical states modulo the resolution. This algebra is non-commutative which means that corresponding quantum spinors have non-commutative components. The non-commutativity codes for the that the spinor components are correlated: the quantized fractal dimension for quantum counterparts of 2-spinors satisfying $d = 2cos(\pi/n) \leq 2$ expresses this correlation as a reduction of effective dimension.

The moduli of spinor components however commute and have interpretation as eigenvalues of truth and false operators or probabilities that the statement is true/false. They have quantized spectrum having also interpretation as probabilities for truth values and this spectrum differs from the spectrum $\{1, 0\}$ for the ordinary logic so that fuzzy logic results from the finite resolution of Boolean cognition [K32].

3.5 Cognitive Codes And Fermions

p-Adic length scale hypothesis leads to the idea that each $p \simeq 2^k$, k integer, defines a hierarchy of cognitive codes with code word having duration given by the n-ary p-adic time scale $T(n, k)$ and number of bits given by any factor of k. Especially interesting codes are those for which the number of bits is prime factor or power of prime factor of k. $n = 2$ seems to be in special position in zero energy ontology. This is a strong quantitative prediction since the duration of both the code word and bit correspond to definite frequencies serving as signatures for the occurrence of commutations utilizing these codes.

If k is prime, the amount of information carried by the codon is maximal but there is no obvious manner to detect errors. If k is not prime there are several codes with various numbers of bits: information content is not maximal but it is possible to detect errors. For instance, $k = 252$ gives rise to code words for which the number of bits is $k_1 = 252, 126, 63,\ 84, 42, 21_2, 9,\ 7, 6_2, 4, 3_2, 2$: the subscript $_2$ tells that there are two non-equivalent manners to get this number of bits. For instance, $126 = 42 \times 3$-bit codon can have 42 -bit parity codon: the bits of this codon would be products of three subsequent bits of 126-bit codon. This allows error detection by comparing the error codon for communicated codon and communicated error codon.

Mersenne primes are especially interesting as far as cognitive codes are considered the Mersenne prime M_{127} assignable to electron is of special interest since the corresponding time scale for CD is.1 seconds whereas the duration of bit corresponds to the time scale of 1 ms assignable to quark CDs.

3.5.1 Combinatorial Hierarchy as a hierarchy of "genetic codes"

The simplest model for abstraction process is based on the process in which one forms first all possible Boolean statements about N basic statements, 2^N altogether. If one drops one of the statements one has $M_N = 2^N - 1$ statements: M_N is Mersenne number. The motivation for the dropping of one statement might be that in set theoretical realization one of the statements corresponds to empty set and is not realizable. Alternatively, in the realization based on many-fermion states, vacuum state could correspond to this kind of state. One can form also statements about statements: the first level of abstraction. This leads to $M_{M_N} = 2^{M_N} - 1$ many-fermion states. Construction is especially intersting if the numbers $M(M_N)$ are primes, so called Mersenne primes.

Indeed, in some cases one obtains hierarchies of Mersenne primes by repeating the construction as long as it works.

The so called Combinatorial Hierarchy, shown already earlier to provide an explanation for the numbers of the Genetic Code, emerges as the most notable hierarchy. The Combinatorial Hierarchy [A7] consists of the Mersenne numbers $2, M(1) = 3, 7$, $127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitly listed ones are known to be primes. Combinatorial Hierarchy emerges from a model of abstraction process as subsequent transitions from level to metalevel by forming Boolean statements about Boolean statements of level n and dropping one statement away and starting from $n = 2$ basic statements. Combinatorial Hierarchy results also by constructing the sets of all subsets with empty set excluded starting from two element set.

The set of statements at level n can be given a structure of Finite Field $G(M(n), 1)$ if $M(n)$ is prime. The multiplicative groups $Z_{M(n)-1}$ form a nested hierarchy and the coset spaces $Z_{k_n} \equiv Z_{M(n+1)-1}/Z_{M(n)-1}$ are cyclic groups. Combinatorial Hierarchy based model of Genetic Code explains the number of DNA: s and amino-acids and the representation of words of the GC as triplets of 4 different codons. Amino-acids correspond to $k_{n=3} = 21$ axioms of a formal system defined by $n = 3$ level of Combinatorial Hierarchy having a unique imbedding as the group $Z_{k_n} \subset Z_{M(n)-1} = Z_{126}$ and DNA: s correspond to the set $X_{N(DNA)} \subset Z_{M(n)-1}$ of $N(DNA) = (M(n) + 1)/2 = 64$ statements consistent with given atomic statement (one bit fixed) at level n regarded as special cases of general theorems. GC corresponds to the mapping $x \to x^{k_{n-1}} = x^6$ in $Z_{M(n)-1}$ mapping DNA type statements to amino-acid type statements. The numbers of DNA: s coding single amino-acid are reproduced in a symmetry breaking mechanism involving the finite groups $Z_{p_{n-1}}$ and Z_{k_n} and symmetry breaking is in a well defined sense minimal. The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complicated lifeforms or forms of intelligence.

3.5.2 Boolean mind and memetic code

The original proposal for the realization of Boolean mind was in terms of sequences cognitive neutrino pairs. These can be interpreted as wormhole contacts carrying neutrino and antineutrino at the light-like wormhole throats and would thus represent boson like entities. In the framework of the standard model the proposal looks of course completely non-sensical. TGD however predicts the existence of long range classical electro-weak fields, and one might imagine that inside neutrino- whose Compton length corresponds to length scale of cell- intermediate gauge bosons behave like massless fields. Although neutrinos could be important, the time scale of corresponding CD - about 10^4 years - suggests that cognitive neutrinos might be important in much longer time scale than the.1 second time scale assignable to the memetic code.

The recent view about TGD allows a much more general view. Zero energy ontology allows to interpret the fermionic parts of zero energy states as quantum superpositions of Boolean statements of form $a \to b$ with a and b represented in terms of positive and negative energy parts of the zero energy state. If one has negentropic entanglement this kind of state has interpretation as an abstraction - a "law of physics" - representing as a quantum superposition various instances of a more general law.

The simplest situation corresponds to a CD having only single positive energy fermion and negative energy fermion at its light-like boundaries. The fermion number or spin or isospin of the fermion could represent qubit. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy, when combined with p-adic length scale hypothesis, led to a prediction of order .1 seconds for the duration of the "wake-up" period of sub-self corresponding to the codeword of the memetic code. Since the CD assignable to electron has time scale.1 seconds and the CD assignable to u and d quarks has time scale 1/1.28 milliseconds there is a temptation to proposed that the quark-like sub-CDs of electronic CD give to a realization of memetic code word as a sequence of 126 quark like sub-CDs. u and d quarks would be assigned to the magnetic flux tubes connecting DNA and the lipids of the cell membrane in the model of DNA as topological quantum computer. Clearly, beautiful connection between new elementary particle physics, genetic code, nerve pulse activity, DNA as topological quantum computer, logical thought, and the basic time scales of speech are suggestive.

This codeword consists of 126 bits represented by quarks such that the two possible magnetiza-

tion directions correspond to the two values of Boolean statement. This implies that the duration of single bit should 1/1260 seconds. The duration of the nerve pulse is slightly longer than this which might mean that the full memetic code is realized as membrane oscillations rather than nerve pulse patterns. Both hearing and vision have .1 second time scale as a fundamental time scale and sounds are indeed coded to membrane oscillations in ear.

One can consider also the realization of genetic code with six bits of the codon represented by various scaled up versions of quark CD coming as size powers of 2. In this case the ordering of the bits would come from the size of sub-CD whereas in previous example temporal ordering would define the ordering. It is not however clear whether the powers of two can be realized physically.

One can understand the number 126 as related to the total number of separately experienced frequencies in the interval $20 - 20.000$ Hz spanning 10 octaves. $10 \times 12 = 120$ is not far from 126: here 12 corresponds to 12 tones of basic music scale. Also speech has 10 Hz frequency as fundamental frequency. In visual primary cortex replicating triplets, 4-, 5- and 6-plets of spikes with highly regular intervals between spikes have been detected. The triplets are accompanied by ghost doublets. This would suggest a coding of some features of visual experience to reverberating mental images. The time scale for various patterns is.1 seconds. This could be seen as a support for the realization of some degenerate version of the memetic code as nerve pulse patterns.

The model for the memetic code encourages the following conclusions.

1. Membrane oscillation/nerve pulse patterns correspond to temporal sequences of magnetization directions for quarks representing yes/no Boolean statements.

2. The spin polarization of quarks is changed from the standard direction fixed by the spontaneous magnetization in the direction of axon by a ME moving parallel to axon, and inducing membrane oscillation or even a nerve pulse. Nerve pulses could correspond to a degenerate memetic code resulting by frequency coding for which the number of distinguishable code words is 64, and would thus naturally correspond to the reduction of the memetic code to the genetic code.

A very precise correspondence with the basic structures of the genetic code results. mRNA $\rightarrow$ protein translation corresponds to the translation of temporal sequences of magnetization directions to conscious cognitive experiences. Under very natural constraints the mapping to cognitive experiences is not one-to-one and the predicted degeneracy (2^{126} sequences correspond to $(2^{126}-1)/63$ cognitive experiences) can be understood.

One might think that the full memetic code is an evolutionary newcomer and involved only with the logical thought: this would explain the completely exceptional characteristics of human brain. The full memetic code could be realized for certain regions of brain only. These regions certainly include auditory pathways responsible for the comprehension of speech [K14, K22, K23, K26].

3.5.3 How nerve pulse patterns and membrane oscillations could be coded to Boolean statements?

The original proposal for the realization of the memetic code was based on the notion of cognitive neutrino pair. Zero energy ontology however disfavors this identification since the time scale assignable to CD of neutrino is of order 10^4 years. Therefore neutrinos would most naturally correspond to a time scale of consciousness much longer than the time scale of.1 seconds predicted to be present. If the proposed view about cell membrane is correct, classical weak fields should be important within the Compton length of any particle and therefore the interactions of neutrinos with Z^0 fields should be important as also the large chiral asymmetry in living matter suggests.

The realization of memetic codewords in terms of sub-CDs assignable to u and d quarks look much more attractive option since they have time scale of 1/1.28 millisecond.

1. The bit would correspond to quark existing in this kind of sub-CD. Memetic codon would correspond to electron's sub-CD containing a row of 127 quark sub-CDs. Standard physics interpretation could be as quantum fluctuation generating virtual pair of quark and negative energy antiquark. For non-standard values of $\hbar$ the durations of codewords and bits would be scaled up.

2. The time-like row of quark sub-CDs resides in em (and possibly also Z^0) field associated with the cell membrane and having the direction of the axon. There is a time-like row of quark sub-CD at some points of axon with one sub-CD per millisecond time interval between sub-CDs. DNA as topological quantum computer hypothesis suggests that each lipid could correspond to quark sub-CD so that many-quark system would be in question. The minimization of the magnetic energy for a given sub-CD fixes the direction of spin and one has spontaneous magnetization in the case that the direction of magnetic field inside quark sub-CD does not change during the pulse.

3. The time that it takes for a nerve pulse to traverse the point is slightly longer than millisecond. If the time which magnetic field has reversed direction is of order millisecond then the magnetic field experienced by quark can preserve its direction during the time interval that quark exists from the point of view of outsider. This is achieved if the temporal center of mass positions of the quark sub-CDs are given by $t_n = nz_0/v$, where z_0 is the distance between lipids containing quark sub-CD and the position of nerve pulse is given by $z = vt$, where v is the conduction velocity of nerve pulse. Unless this condition is satisfied, the direction of magnetic field changes during the time interval associated with sub-CD. In this case a superposition of bits identifiable as a qubit results.

4. This means that nerve pulse sequence defines a (qu-)bit sequence with the direction of spin telling whether there was nerve pulse present in particular sub-CD. The presence/absence of nerve pulse corresponds to true/false statement in accordance with neuro science intuition.

If this view is correct, the values of the positional coordinates and the velocity of the object of the perceptive field should correlate with the CP_2 orientation of the active neuron and/or ME(s) associated with it. First of all, the level of hologrammic activity for ME measured by the strength of the light-like em current depends on its CP_2 orientation. Secondly, different CP_2 orientations correspond to slightly different values of the membrane potential and could be directly mapped to the degree of alertness of neuron. For instance, if a moving object of the perceptive field is in nearby space and moves towards the perceiver, the (P_i, Q_i) values could be such that the resting potential is lowered and nearer to the critical value for firing. Also the light-like em currents associated with MEs would be stronger in this kind of situation.

4 Quantum Computationalism

TGD Universe can be formally regarded as infinite quantum computer like structure in the sense that each quantum jump involves the unitary process U analogous to a Schrödinger evolution lasting infinite time and is followed by state function reduction and state preparation process. Therefore TGD suggests what might be called quantum computationalism. Universe would be performing huge quantum computation and the computation like processes performed by us or by our brains would be only a ridiculously small portion of this computation. Of course, this must be taken as a rough metaphor, the quintessence of the conscious quantum computation like processes could be quite different from the essence of the ordinary quantum computation.

The average increment of the psychological time in quantum jump is rather small: the simplest guess suggest that the average quantum of psychological time is or order "CP_2 time", about 10^4 Planck times. This means that the relation of the information processing performed by biosystems to quantum jump would be the same as the relationship of macroscopic physics to physics in CP_2 scale about 10^4 Planck length scales. This would however mean an extremely short de-coherence time in an obvious conflict with the experimental facts. Macrotemporal quantum coherence, which corresponds to the formation of bound states, however effectively fuses a sequence of quantum jumps to a single quantum jump so that the de-coherence occurring otherwise in CP_2 time scale can be circumvented.

The notion of self is absolutely crucial for TGD approach to consciousness and makes possible to understand consciousness in macroscopic time scales. A very natural notion is that of cascades of selves within selves generated spontaneously or by quantum jumps. This implies a connection with the basic conceptual structure of computationalism. The cascades have natural modular structure, which is quintessential for the understanding of the symbol processing performed by brain. A

very attractive hypothesis is that selves within selves are conscious counterparts of computational agents or more or less equivalently, of the subroutines of computer program. Selves can perform two kinds of quantum jumps and a natural identification of these modes is as computational and sensory (input) modes. Subjective memory takes automatically care of output in the sense that the subjective history of sub-self is experienced as an abstracted memory by self.

Communication between selves could occur as it does between human beings. Also "mass media" at neuronal level seem to be possible and would make possible the concept of global workspace. Quantum jumps can be regarded hopping in the space of zero modes identifiable as fundamental order parameters and Haken's theory of feature recognition generalizes. Quantum entanglement in turn provides elegant realization of association concept so that the basic ideas of connectionism emerge naturally from quantum computationalism. There are also drastic differences with between TGD and computationalism, basically implied by the different concept of psychological time which implies that cognition has holistic aspect also with respect to time. Thoughts are definitely not deterministic computations and living systems are definitely not robots.

4.1 Computationalism And Connectionism

Computational approach to cognition [J19] is the dominating approach in cognititive and neuro sciences and has had undeniable successes. Computationalism is often identified as traditional AI based on the concept of truth preserving manipulation of symbols according to some fixed rules of the formal system. This approach indeed explains nicely computational aspects of mind. Combinatorial explosion is the basic failure of the approach at practical level. Connectionism relies on the concept of association and associative neural net provides a quantitative model for how brain learns. Connectionism is often regarded as a variant of the computationalism and it is believed that neural nets provide models for unconscious parallel information processing whereas conscious information processing is best modelled by hierarchical program like structures. The general philosophical shortcomings of these approaches are obvious: they cannot provide any insights to the problem how meaning, understanding, emotions and volition, which are factors crucially important for the functioning of conscious brain, arise. This has even led some advocates of this approach [J19] to believe that human brain, being computer basically, is simply incapable of understanding the problem of consciousness! This would probably be the case if human beings were robots: fortunately we are not!

4.1.1 Traditional AI approach

In the traditional AI approach brain is modelled as a complicated computer. Computation is realized using rigid algorithms, which are hierarchical structures consisting of subprograms. Using more abstract terminology, the basic concepts are symbols and agents, "demons". Symbols are inputs for "demons", subroutines of program manipulating symbols and creating new outputs as symbols. One could however interpret also agents themselves as symbols. The concept of global work-space [J10] realizes the intuition that short-term memory is available to many users. Also the concepts of belief and desire can be formulated without referring to consciousness. Beliefs are inscriptions about the world and desires are identified as goals. For instance, problem solving means simply making trials with the aim of minimizing the difference between goal and result of trial. The concept of representation is central. It is known that brain realizes several types of representations [J19]. Visual mosaic like representations, phonological representations in short-term memory consisting of few phonemes (say remembering phone number for some time), grammatical language like representations with hierarchical structures and "mentalese", which is the most abstract representation type summarizing in very implicit manner the essentials of, say, mathematical model.

Computationalism explains nicely the general features of language by providing a representation for the hierarchical structure of language. One can also easily think brain as a population of (possibly) conscious demons. Some demons receive sensory input, some demons process it and the ouputs of some demons are realized as motor outputs. It seems that this approach models quite satisfactorily those aspects of cognition, which can be realized as purely mechanical truth preserving symbol manipulation modellable universally by Turing machine. The best proof for the claim that computers have caught something about the basic structure of cognition is that computers

are already now able to beat chess champions. The weak point of the computationalism is its extreme rigidity: minor input error or programming error and program fails to work. Combinatorial explosion is second shortcoming. For instance, all possible melodies formed from finite number of musical notes with finite number of durations for each and lasting the typical length of musical piece is immense. In computer chess combinatorial explosion makes the simple-minded trial and error approach completely unpractical and the only possible manner to proceed is to teach the computer by mechanizing the human intuitions about good chess.

4.1.2 Connectionism and neural nets

Connectionism provides a modern version of associationism proposed by British philosophers Locke, Hume, Hartley, Berkeley and Mills. Behaviorism was the first purely mechanistic version of this approach but was quite too simplistic to work. Associationism consists of two laws. The first law states that the ideas which are often experienced together get associated: when one is activated also the other one gets activated. Second law states that similar ideas activate each other. Connectionism tries to realize these two aspects of associationism mathematically and construct practical realizations for associative thinking. Typical application would be feature recognition and machines learing automatically from their inputs some predetermined tasks.

Neural nets provide a mathematical model for the concept of association and associative learning. The simplest model for learning simply associates unique self-organized state of a dissipative neural net to the state of the external world represented as an external force driving the neural net. Dissipation realizes also the second law: if input is sufficiently similar to the standard input generating given standard output, the standard output is indeed generated. Also Haken's model for feature recognition realizes second law as a feature recognition based on non-equilibrium thermodynamics. Features correspond to equilibrium states of a nonlinear dissipative system (free energy minima for order parameters). If input creates initial output belonging to the attractor of the feature, dissipative dynamics takes care that the asymptotic output is feature.

Associative net can be regarded as a many-layered structure, in which the states of some nodes correlate strongly with the states of some other nodes. The state of node is characterized by a component of vector, whose components give the values of the amplitude in the nodes. For a given input the net rapidly achieves equilibrium in which the associations created by the input are determined by those nodes in which the amplitude is large. The equilibrium states of neural nets with coupling to external are identified as representations for stable mental states representing some states of the external world.

The flexibility of the neural nets is the strength of connectionism. Also combinatorial explosion can be avoided. Neural nets might indeed model lower level cognition which is mostly unconscious to us. The absence of the hierarchical structures means the loss of "expressive power" essential for higher cognition and leads to the problems described in [J19].

1. Connectionistic approach is not able to distinguish between individual and class: what is created from the inputs is some kind of average individual: neural network can learn to recognize human face but not a particular human face or to recognize particular human face but not to make abstraction about what human face looks like.

2. Second problem is so called compositionality: the ability of the representation to be build out of parts and represent the meaning of the whole deriving from the meanings of parts. A related problem are the difficulties in the identification of the meaning of linguistic expressions. For instance, the meanings of the expressions consisting of words "the child", "ate" and "the slug" depend on the order in which the words are represented and connectionism is not able to distinguish between "the child ate the slug" and "the slug ate the child". The natural ordering of symbols provided by hierarchical tree solves this problem in AI approach. Simple neural network learns easily to recognize picture containing horse but if the picture contains two horses, network fails completely!

3. The third problem is a combination of these two. An example from [J19] illustrates this. Network can learn to sum 1 and 3 to 4. When it learns to sum 2 and 2 to 4 it can lose the already learned ability. Second example: consider the expression "Every forty five seconds some-one in the United States sustains a head injury". Human brain can easily realize the

meaning of this sentence which suggests that quantification occurs in brain and human brain transforms the sentence either to expression "Every forty-five seconds {there exists an X[who gets injured]} " instead of "There exists an X{who every forty-five seconds[gets injured]} "

4. What multiplies human thoughts is recursion. We can take proposition and give it a role in another proposition and so on. In this manner a combinatorial explosion of propositions is generated. To get propositions-inside-propositions network, one could add a new layer of connections but this solution is clumsy and non-economical. The addition of a new level of abstraction would mean a new network containing additional level. In computationalism the solution of the problem is much more elegant. Each proposition is represented in long term memory once. One can of course combine computationalism and connectivism and use simple neural networks as basic modules of computer program like modular structure.

5. Neural net models, which realize connectionistic philosophy in practice, have serious problems in modelling long term memory. If its is assumed that long term memories are coded into the matrices defining output of the node in terms of its inputs, which are modified during learning process, the unavoidable conclusion is that new memories destroy the old ones. Childhood memories seem however to be the most stable ones.

4.2 How Connectionism Emerges From TGD Framework?

4.2.1 Brain as an associative net in TGD

TGD leads to a variant of connectionism which differs from the standard version in some crucial respects. Brain as a quantum self-organizing system moving in spin glass energy landscape generalizes the neural net realization of connectionism. The plasticity of the neural substrate corresponds directly to the spin glass property and the notion of frustration fundamental for spin glass type systems is guaranteed by the inhibitory/excitatory nature of nerve pulses. Neural net becomes dynamical rather than being a fixed structure. One can view brain as system moving in the space of neural nets and perceiving and affecting its own position in this abstract space.

Brain can be regarded as a conscious associative net developing by quantum self-organization to asymptotic self-organization patterns which correspond to recognized features, learned habits, skills $\cdots$: dissipation can be said to serve as fundamental Darwinian selector in this process. By music metaphor each neuron, when it fires, generates a characteristic neuronal experience possibly contributing to our conscious experience: only the intensity of this experience depends on the nerve pulse pattern. The firing of a neuron gives rise to a conscious neuronal association $A \to B$.

This would suggest that brain is like a conscious music instrument, or rather, entire orchestra, played by the nerve pulse patterns and our experiences corresponds to the sound patterns created by this orchestra. It has turned out that this view is probably quite not correct. Brain and body are much more. The music is at the level of sensory organs as sensory qualia, and neural activity cognizes, that is analyses the sensory music to notes and represents the notes. This view, which is certainly not possible in the standard neuroscience framework and surprisingly close to what a layman knowing nothing about neuroscience would think spontaneously, makes sense in TGD framework if one assumes that entanglement between brain and sensory organs binds sensory qualia with the cognitive associations generated by the sensory input. This view also allows to understand elegantly the differences between sensory experience, dreaming, hallucinations, and imagination. An essential element is the feedback from brain to sensory organs enabling "qualification" during dreaming and hallucinations. This feedback is also active during the ordinary wake-up consciousness.

Spin glass energy landscape is four-dimensional in a well defined sense and the identification of the long term memories as geometric memories solves the basic paradox of the neural net models of memory. One can also understand how brain knows that the mental image represents memory and why repetition and reverberation of nerve pulse patterns in neural circuits leads to learning and why emotional experiences are easily remembered.

4.2.2 Feature recognition

The first law of associationism states that similar ideas tend to induce each other. For instance, a part of familiar face in the visual field induces a memory about the entire face. In computational ap-

proach feature recognition is believed to involve unconscious low level parallel processing. [B3] [B3] has proposed an elegant model of feature recognition based on non-equilibrium thermodynamics. The features to be recognized represent the minima of the potential depending on order parameters and the presence of dissipative terms implies that system ends up to potential minimum representing feature.

Haken's theory generalizes to TGD context almost as such. Dissipative time evolution is replaced with quantum self-organization by quantum jumps and in each step entire macroscopic space-time surface is replace by a new one. The zero mode degrees of freedom of the configuration space are identifiable as fundamental order parameters and each quantum jump involves complete localization in continuous zero modes. The localization in discrete zero modes characterizing cognitively degenerate space-time surfaces need not be complete: what is needed is localization to a subset of space-time sheets for which the eigenvalues of the p-adic density matrix are degenerate. This means that the time evolution by quantum jumps corresponds to hopping in the space of zero modes, which leads to that part of zero mode sector, where WCW spinor field has largest value. The maxima of Kähler function are excellent candidates for the attractors of the quantum self-organization process.

A more concrete brain level model of feature detection based on the realization of the self-hierarchy as a hierarchy of Josephson currents frequency-modulating each other perhaps helps to clarify the abstract general ideas about conscious feature detection.

1. The feature to be detected is represented as a reference supra current flowing in a neural circuit and weakly coupled to a parallel neural circuit representing the input. When the supra currents are identical, constructive interference of the Josephson currents flowing between the two circuits occurs and induces large modulation of the rest potentials of neurons of the circuit and leads to a synchronous generation of nerve pulses. Synchronous neural firing can start under rather wide limits depending on the alertness of the neural circuit (how near to the threshold value resting potential is) controlled by the modulating Josephson currents also.

2. Synchronous neural firing wakes-up sub-self which starts to self-organize and develops into an asymptotic pattern representing a mental image about the detected feature. The final state depends only weakly on the initial state of the neural circuit representing self so that genuine feature detection is in question. For instance, some minimal number of neurons firing in the neural circuit leads to given final state pattern so that the constructive interference of the Josephson currents need not be maximal.

3. The self-organization patterns in neural circuits define a population of sub-selves defining cognitive mental images, features. These sub-selves wake-up and fall asleep (even periodically during their lifetime (after images)). Falling asleep occurs, when the sub-system generates a bound state entanglement with some other sub-system, and wake-up by a reduction of the bound state entanglement.

4. Self-organizing neural circuit starts to approach the maximum of "subsystem" Kähler function (recall that approximate representability of Kähler function as a sum of subsystem Kähler functions is probably possible) is accompanied by the wake-up of sub-self. This corresponds to the motion of neural circuit in its spin glass energy landscape induced by various neural transmitters inducing short term or long term changes in the synaptic contacts. Thus self-organization induces also a generalized motor action shifting the position of the neural circuit in the spin glass energy landscape.

5. Feature detection involves kind of *Eureka!* experience. Perhaps the sub-self representing the mental image about recognized object remains for some time irreducible and hence does not possess any sub-selves (and is in "enlightened" state). This could be the situation for some time until sub-selves are generated during self-organization and lead to the analysis of of the recognized feature.

One can ask whether it makes sense to speak about entanglement between different number fields. The original idea was that this might make sense. In the recent vision however fermions responsible for Boolean cognition reside in the intersection of reality and various p-adicities formed by an extension of rationals at the level of parameters characterized string world sheets and partonic

2-surfaces. Hence fermions and string world sheets are number theoretically universal rather than assignable to some particular number field. Hence for fermions the entanglement is also number theoretical universal and expressible in terms of numbers in the extension of rationals.

The emergence of a positive entanglement negentropy is a physical correlate for the experience of love, understanding, Eureka experience and various other experience with positive emotional coloring. Generation of negentropic entanglement can can give rise to experiences like seeing beauty, feeling truth, and feeling love. Both p-adic and real physics, cognitive and symbolic representations are involved automatically in the adelic view about physics in which all structures are Cartesian products of they real and p-adic variants.

4.2.3 Learning of associations

The second law of associationism states that ideas experienced simultaneously tend to form associations. TGD suggests two mechanisms for realizing associative learning.

1. The purely quantal mechanism realizes associations in terms of quantum entanglement. This mechanism would be extremely elegant because super position principle allows huge capacity of forming associations. Quantum entanglement however seems to associate parts to form wholes with the ensuing loss of conscious information about parts rather than giving rise to conscious associations $A \to B$. One could say that the association in question is spatial rather than temporal. Note also that quantum entanglement lacks the directional character of association. It seems that this mechanism is essential for associating various cognitive features at the level of brain with sensory qualia at the level of sensory organs.

2. In second mechanism the classical neural net type realization is replaced by a process in which sub-self wakes up another sub-self. A process in which presynaptic neuron wakes up postsynaptic neuron and the mental images of these neurons form the association, could indeed serve as building blocks of our associations.

It has turned out that these mechanisms are actually not mutually exclusive, and that both are involved with the association mechanism. The TGD based notion of sub-system, relying on the topological non-triviality of the many-sheeted space-time, makes possible for separate selves (unentangled systems) to share mental images via the entanglement of their sub-selves. Topologically this corresponds to the following situation. Two selves (say sensory mental image and cognitive mental image) are realized as disjoint space-time sheets S_i, $i = 1, 2$ and their sub-selves as smaller space-time sheets S_{ij} glued by wormhole contacts to the space-time sheets S_i. When sub-self space-time sheets S_{1j} and S_{2k} are connected by join along boundaries bonds, the fusion and sharing of these mental images occurs.

The neural network model for the formation of associations relies on the idea that some states of the neural net are in a correspondence with the states of the external world. Also the states of different layers of neural net have natural mutual correspondence. Association basically creates one-one map. In neural net models the interaction with external world occurs via driving force and dissipation leads to asymptotic states, which can be interpreted as association of net-states with the states of the external world. The problem of the neural network models is how the learning process could be realized in living brain. In particular, how two simultaneous ideas represented by the substates of neural net get associated with each other. This seems to require that the presence of two active nodes present in the net tends to strengthen their mutual coupling. There is a lot of empirical supports for this and neural transmitter action is an essential element of this process. In TGD framework this process corresponds to the gradual movement of neurons and brain in their spin glass energy landscape induced by neural transmitter action.

In TGD framework the formation of association $A \to B$ would mean that the stimulus A alone can generate B. This means that the sub-self representing mental image A tends to wake up the sub-self representing mental image B. At the neuronal level this simply means that the firing presynaptic neuron excites postsynaptic neuron so that it also fires: the long term changes of the synaptic connection promotes this ability. At the level of our mental images the waking up process must involve nerve pulse transmission from neural circuit representing sub-self A to the neural circuit representing sub-self B. Josephson current model suggests that during learning period, when A and B are experienced simultaneously, they are mapped to reference currents in feature

recognition network $A+B$. Later when only A serves as input, part A of the circuit $A+B$ begins to fire when it receives A as input. If the synaptic connections between circuits A and B have been strengthened during learning period, the firing spreads out to B and also B wakes up. This in turn leads to the self-organization process generating experience $A+B$.

Many associations are bi-directional: for instance, symbols for real world objects are bi-directional associations. In TGD framework one can model the generation of the bi-directional associations in classical sense along following lines. Denote by A and B the symbols to be associated: A and B correspond to sub-selves of say self X. Neural net philosophy suggests that A and B should co-operate to keep each other in wake-up state (alive!): self-organization by quantum jumps could lead to this kind of co-operation. This is achieved if sensory experiences stimulate automatically co-operative self-populations, whose members tend to keep each other awake. This model is consistent with the fact that associations do not involve conscious thought. For instance, A could generate nerve pulse patterns waking up B and vice versa. Note that at the next level of the self hierarchy this could be regarded as a formation of self-association $X \to X$ possibly giving rise to a stable short term memory and also as survival of self X guaranteed by co-operation of sub-selves.

4.3 Computationalism And TGD

Computationalism in strong sense (brains as deterministic machines) does not emerge from TGD. The basic reason is that the time concept is totally different from that of computationalism. One can say that quantum jumps select between different time evolutions and the overall-important modular structures result from self cascades.

4.3.1 How computationalism and TGD approach differ?

A good example is provided by vision discussed in [J19] . Vision builds representation or description of the world from sensory data. Since inverse optics is not possible, implicit assumptions about the structure of the external world are necessary. Typically illusions rely on the breaking of these implicit assumptions. Illusions are not always undesirable. Two-dimensional pictures are an example of an illusion making possible visual communication! Auto-stereograms [J19] consisting of diffuse soup of points are a particularly striking example of illusion: looking the picture for a sufficient time, one can experience a dramatic re-shapening of the experience: beautiful 3-dimensional picture emerges from the chaos. Auto-stereograms support the hypothesis that vision involves computational activities or quantum counterparts of them. This process can be seen as a school example about how brain adds to a pure sensory input symbolic and cognitive representations.

In TGD universe brain does not probably deduce the representation of the world from picture by a straightforward computation. Certainly the data and implicit or learned assumptions about the world appear as an input in some sense. Some kind of iterated guessing based on implicit assumptions seems to involved: guess is made and compared with the actual picture. Quantum self-organization indeed makes possible the iteration, being in itself an iterative process. Guesses are very probably based on the existing abstract data about possible configurations of the world. The paradigm of 4-dimensional brain allowing to realized long term memories as geometric memories could be crucial in this respect. One can wonder whether the implicit assumptions might also develop from temporal entanglements with larger selves (during sleep) giving rise to information about world in longer length and time scales.

Control of motion is second good example of what might happen. There is no deterministic program proceeding with respect to geometric time and selecting what happens next and creating the quantum history step by step. Rather, the entire pattern of motion is selected by the creation of the main program self by quantum jump. The subsequent quantum jumps occur in the cascade proceeding in top-to-bottom type manner to shorter spatial and temporal scales. Thus the main program corresponds to, say the pattern of large scale motion, and sub-programs correspond to the details of the motion. What is new as compared to computationalism is that the program is created while it runs.

At the level of CNS anatomy sensory perceptions and motor actions loook mirror images of each other. TGD suggests that they could be mirror images at much deeper level. Motor actions would be time reversal of sensory perception in appropriate time scales for MEs (topological light rays,

"massless extremals") and routinely involve breaking of the second law in this p-adic time scales. This assumption implies that motor action results like a painting starting from a rough sketch. Dissipation and its time reversal automatically perform Darwinian selection leading quantum jump by quantum jump to the final motor action. No detailed planning is needed. Motor imagination is motor action starting from some level above the muscles and motor skills can be learned by imagining them.

4.3.2 Real selves as symbols

The ability to think in terms of symbols is certainly one of the key features of intelligence. The hierarchical structure of selves within selves and the possibility of cascades creating selves within selves allows to interpret sub-selves of self as conscious representations for symbols, at least under certain additional conditions. The condition seems to be that symbol sub-self and the primary sub-self representing the real object must be able to wake-up each other bi-directionally. Symbol self and "real self" could also belong to different levels of the hierarchy. For instance, single neuron could serve as a representative of neuron group in the sense that neuron and neuron group can wake-up each other. Perhaps Grandma neuron serves as a symbol for a complicated experience of entire neuron group. Linguistic associations would certainly be sub-selves representing this kind of representative function very effectively. This kind of symbol neurons would correspond to leaders at the level of human society. Indeed, words can generate actions and word selves are excellent candidates for the leaders of the neuronal society!

Selves allow also other interpretations. In very general sense they can be identified as agents or "demons" in the sense of computationalism. Agents can be also regarded as counterparts of submodules of main program. The call of subroutine from main program could be regarded as a wake-up of subprogram self. The main program forms automatically abstraction of the entire subjective history of subprogram self. The input data of submodules realized as sub-selves is most naturally realized as sensory input. For instance, neurons are expected to have chemical senses making communication between neuronal selves possible [K13]. Nerve pulses provide obvious candidate for a communication mode.

The concept of global workspace [J10] is one of the basic concepts used in the modelling of cognition and short term memory. The model visualizes short term memory as a global workspace, kind of common blackboard seen by various agents. The agents in turn can add write data to the global work space. Communication via global workspace is clearly analogous to mass media. Communication via global work space could be realized as chemical communication. Hormonal system could be an example of mass media operating at the level of our conscious experience. A surprisingly large volume of brain is free of neurons and glial cells and there is experimental evidence for chemical communication occurring via this free volume [I2]. In TGD framework global work space could be also realized in terms of coherent photons if selves act as quantum antennas able to receive and send messages: this would be very much like mass media in neuronal and sub-neuronal length scales.

4.3.3 Wholes and parts, classes and individuals

Wholes contra parts and classes contra individuals are basic concepts of computationalism and should allow representation as quantum level concepts. Also in TGD framework these concepts emerge naturally. The sub-selves X_i of self X are individuals and a natural hypothesis is that X experiences X_i as separate sub-selves. The self Y at the next level of hierarchy containing X in turn experiences the set $\{X_i\}$ of sub-selves of X as an average $\langle X_i \rangle$, typical representative of class X. For instance, if sub-selves of X represent different faces, then Y forms abstraction about the concept of face.

"Whole" is a concept different from class. A good example of "whole" is letter F formed from smaller F: s. Whole is something more than a sum of individuals and the problem is to understand how this whole is represented at quantum level. A very natural hypothesis is that the whole formed by sub-selves is formed by quantum entanglement between sub-selves leading to the disappearance of the individual sub-selves. When entanglement is destroyed, sub-selves or some of them are experienced as separate: this mechanism could also be regarded as a quantum mechanism for the formation of associations. Sensory experiences would wake up sensory selves involving sensory

organ and parts of brain giving rise to different representations of sensory data and the analysis of sensory experience would involve the decomposition of these selves to sub-selves.

Our body consciousness provides testing ground these ideas. Contrary to the basic dogma of neuroscience, in TGD framework the fundamental representation of the body is formed by the body itself as is clear also on basis of the concept of self. Of course, representations at the level of brain are also involved and make possible the analysis of the body experience. We do not however experience our bodies as a huge number of separate cells. The explanation is that our sub-selves correspond to structures that are much larger than cell. Various parts of our body could obviously correspond to the sub-selves of our self. The fact that we recognize all parts of our body as such suggests that our self is at least as large as our body or perhaps even larger. Interestingly, in some brain disorders patient does not admit that some part of body, say left side of the body, belongs to them. This would suggest that the self of these persons is reduced to the self of the other side of the body rather than that of entire body.

4.3.4 Predictions and memories

The paradigm of 4-dimensional brain (and of 4-dimensional body and even of 4-dimensional Universe!) differentiates between TGD based computationalism and classical computationalism. One of the most important predictions is the possibility of two kinds of memories: geometric "memory" generating simulations of past and future and subjective memory making it possible to have genuine memories about previous moments of consciousness. The comparison of the predictions with what actually happened seems to be basic activity of conscious mind. The fundamental realizations of both subjective and geometric memory elegantly circumvent the memory storage problems encountered in the computationalistic approach and multiplied by the combinatorial explosion.

These basic memory types allow several realizations. The identification of immediate short term memories as subjective memories is very natural. Geometric memories seem to be the only reasonable candidate for long term memories. Procedural memories relying on association of say nerve pulse patterns with experiences are possible.

Self at a given level of hierarchy forms automatically abstractions about the wake-up periods of the lower level selves. This makes possible to form abstractions about the time development of sub-selves and to gain wisdom given by experience. Long term memories involve both the formation of abstractions as some kind of time averages and detailed information. This is difficult to realize in the neural network approach.

4.3.5 Boolean logic and logical deductions

One can easily invent models of logical reasoning but probably the most realistic model is based on representing the premises of the logical deduction using Boolean statements realized in terms of fermions. These cognitive representations defined in the intersection of realities and p-adicities symbolic representations, and generate a neural activity representing the logical deduction, which is basically realized using learned associations. This model involves minimum amount of p-adic physics, is essentially isomorphic with the model of imagination, and is consistent with neuroscience facts.

An interesting possibility is that many particle states of cognitive neutrino pairs providing representation of logical thoughts could replicate. This might be possible. If the macroscopic phase determined by cognitive neutrino pairs is completely fixed by the structure of mind-like space-time sheets then the replication of the material space-time sheet and mind-like space-time sheet would lead to the replication of thought. DNA replication seems to occur in too short length length scale to be associated with this process. Cell replication could however quite well involve replication of thoughts. Cell replication does not seem to occur at the level of brain. Presumably nerve pulses generating standardized patters of cognitive neutrino pairs have replaced direct decay of cell as a more effective manner to replicate thoughts and eventually even communicate them.

4.3.6 Beliefs and desires

Computational approach does not have much to say about emotions. Beliefs and desires are however concepts allowing symbolic (one might say computational) representation: this of course does not explain what gives for belief or desire its emotional content.

Beliefs could be very generally regarded as basic axioms of formal system from which various deductions by truth preserving symbol manipulations are obtained. The mathematical model behind numerical calculation is a nontrivial example of this kind of belief system. Desires can be realized in computational science in terms of goals assigned with the initial state. For instance, the desire of the problem solver is to solve the problem that is get from initial state to the desired final state by applying fixed rules. Initial state could correspond to the assumptions of a theorem and final state to the theorem itself. If it is possible to solve the problem at the level of symbolic representation, the solution of problem can be mapped to the real world. Beliefs and desires could easily be represented symbolically in terms of neural activity using associations. A Boolean representation of beliefs could be in terms of logical statements using cognitive neutrinos or real neutrinos.

It is not so easy to understand what gives rise to the conscious experience of belief or desire. The geometric time development can be regarded as a prediction of future (and past) whereas "reality" corresponds to the subjective time development. The belief about what happens in the future is a special belief and could be seen as "memories" with respect to the geometric time: seeing to the future. Intention would be the p-adic counterpart of this kind of belief, seeing to the p-adic future. A wide class of emotions could result from the comparison of the predicted and real. That predicted and real coincide, could correspond to nearly identical sub-selves able to form a bound state accompanied by a a period of macrotemporal quantum coherence and a positive emotion like understanding.

The fundamental desire of the sub-self is to stay conscious, to survive. Cognitive, symbolic, and Boolean representations would give for the desire of the mental images of the conscious world model to survive an interpretation as a higher level desire. Also beliefs might be determined to a large extend by the desire of the sub-selves to survive: giving up a belief means death of the corresponding mental images and unpleasant mental images are a threat for mental images defining the self model. We tend to have beliefs which do not threat our ego.

4.3.7 Simple model for problem solving

Problem solving is certainly quite high level cognitive skill. A good test for the proposed scenario is how simple conscious problem solving could proceed. The basic desire of problem solver is to achieve the goal given the initial state. Problem solver makes trials and when goal and achieved state are sufficiently near to each other problem can be said to be solved. The model for this activity could be roughly like follows:

1. Goal is represented as a physical state of some subsystem and the basic problem is how problem solver can compare the result of trial with the goal. It seems that all conscious comparisons must reduce at fundamental level to the comparisons of geometric and subjective time developments of some sub-self. Thus it seems that problem solver self must directly experiences whether the goal was achieved by experiencing how much the hoped for geometric time development and subjective time development generated by the trial resembled each other.

2. This approach as such is not practical. Standard computationalism would the comparison of the result of a trial to the goal necessitates circuit which carries out comparisons. This kind of circuit is easy to realize. For instance, Josephson junctions could physically realize the difference between the result of trial and goal as the phase difference between weakly coupled superconductors. To know whether the trial was successful, problem solver must compare the desire represented by a binary digit one in geometric memory with the result of comparison represented by a binary digit having one one or zero in subjective memory. For instance, limbic brain could be the seat of these binary digits and comparison could occur there.

3. Problem-solver sub-self generates solution trials. Most naturally this involves quantum jump leading to decomposition of problem solver self to two subsystems. This decomposition represents the trial. Good problem solver must be able to generate very many different trials: this means that entanglement entropy is almost constant function of sub-self generated in quantum jump.

4. Problem solver self performs the comparison. When output is "No" problem-solver self generates a new trial. System must have a *Eeureka!* experience, when the problem is solved. This is achieved if "problem solver" self is "enlightened" when it receives output "yes" from the comparison circuit. This means that problem-solver selves begins to make quantum jumps reducing matter-mind entanglement and does not generate trials anymore.

5. The trials could be representable as p-adic space-time sheets defining the initial states of the symbolic representation defining the world model and realized as patterns of neural activity based on association mechanism. Their transformation to real ones would initiate the simulation. Also this process is very similar to that behing logical reasoning and imagination.

There is no need to add that in reality problem solving is much more complicated procedure! The above model could however provide insight about the conscious experiences related to the problem solving.

4.3.8 Quantum computationalism in TGD Universe

Macrotemporal quantum coherence makes also quantum computation like processes possible since a sequence of quantum jumps effectively binds to a single quantum jump with a duration, which corresponds to the lifetime of the bound state. Quantum computation like process starts, when the quantum bound state is generated and halts when it decays. Spin glass degeneracy increases the duration of the quantum computation to time scales which are sensical for human consciousness. In case of cognitive quantum computation like processes the quantum coherence is stabilized by NMP.

1. Spin glass degeneracy provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the join along boundaries bonds/flux tubes and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis emerges.

2. Bio-systems would be especially attractive candidates for performers of both non-cognitive and cognitive quantum computation like processes. The binding of molecules by lock and key mechanism is a basic process in living matter and the binding of information molecules to receptors is a special case of this process. All these processes would involve new physics not taken into account in the standard physics based biochemistry.

3. The possibility of cognitive quantum computation like information processing forces generalize the standard quantum computer paradigm also because ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. Qubits must be replaced by qupits since for algebraic $R - R_p$ entanglement two-state systems are naturally replaced with p-state systems and for $R_{p_1} - R_{p_2}$ entanglement with $p_1 \times p_2$ state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which means gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127} - 1$ M_{127}-qupits making about 254 bits. The idea about neuron as a classical bit might be a little bit wrong!

4. It might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macrotemporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

The progress taken place in quantum TGD during the period 2005-2010 allows to add to this picture several new elements.

1. The hierarchy of Planck constants and identification of ordinary particles at magnetic flux tubes with arbitrarily large value of Planck constant as dark matter leads to the vision about DNA and nuclear and cell membrane acting as topological quantum computer with the

braiding of flux tubes defining the space-time correlate for the quantum computation [K8]. The intronic portions of genome are natural candidates for the parts of genome specialized to quantum computation like activities and for these purposes the exact nucleotide content of the DNA sequence is not crucial so that DNA looking like "junk" is not junk from the point of view of quantum computation.

2. Zero energy ontology brings in naturally the 4-D ensemble of quantum computations assignable to sub-CDs of given CD. The classical correlates for quantum computations are 4-D classical field patterns assignable to space-time surfaces inside CDs. Causal diamonds bring in the time scales of 1 ms and.1 s associated with quarks and leptons, which are also the time scales of nerve pulse activity and of memetic code. This supports the view that dark quarks at the ends of magnetic flux tubes connecting DNA nucleotides and the lipids of the cell membrane are indeed the key element of computation.

3. In the intersection of real and p-adic worlds negentropic entanglement is possible. This stabilizes qubits but makes them fuzzy. This requires reformulation of topological quantum computation in terms of the U-matrix characterizing U-process for zero energy states and restricted to the states with negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book).

4.4 How Brain Builds The Model Of The External World?

What we experience is not completely determined by the sensory data: a lot of computation like processes at the level of cortex is involved. In TGD generation of symbolic representations would perhaps be more appropriate term. The phenomenon of illusions, most importantly, our ability to see planar pictures as 3-dimensional, shows that this computation involves a model of external world based on definite assumptions [J19]. Stereo vision [J19] is a good example of a sensory experience involving a lot of cognitive processing at the level of cortex. Depth cannot be experienced directly and the deduction of the actual positions for the points of the visual field must involve large amount of cognitive processing carried out in cortex. At the level of conscious experience the fusion of right and left visual fields to single visual field seems to be responsible for the emergence of the 3-D visual experience.

That complicated information processing is involved is demonstrated by autostereograms, in which a chaotic set of points experienced as a planar picture organizes to a beautiful 3-dimensional picture after intensive concentration (all subject persons are not able to see the 3-dimensional picture). It is known that stereo vision develops in age of few months at the same time when some cortical neurons specialize to receive input from only single eye instead of superposing the inputs from both eyes. Brain is also able to estimate the state of motion of objects of visual field from sensory data and this must involve a lot of computation. The fact that some people cannot experience motion in the visual field provides a support for the claim that this experience is a result of a complicated neuronal processing. At first, the computational aspects of the conscious experience would seem to be in conflict with the idea that sensory organs are the primary sensory experiencers. The situation is however not so simple as the closer examination of the computational aspects of the visual experience demonstrates. The basic point is that brain quantum entangles to the sensory representation various symbolic and cognitive representations giving meaning to what is sensed.

4.4.1 TGD based view about construction of sensory representations

The motion of eye or head does not induce the sensation that the world is moving although the sensory image moves around the cortex. Rather, brain acts like a (possibly moving) canvas at which the sensory input is projected and monitored by an external observer. This very simple observation is a strong objection against the idea that the ultimate sensory and cognitive representations reside inside brain, and leads to the view that the magnetic flux tube structures associated with the primary and secondary sensory organs define a hierarchy of sensory and symbolic representations outside brain. Magnetic flux tube structures would serve as the sensory canvas to which sensory images are projected from brain and possibly from sensory organs and even neurons. MEs serve as projectors and place coding by magnetic transition frequency associated with ME wakes-up sensory

sub-selves at various positions of magnetic flux tubes having varying thickness and associate thus various sensory qualia and even more complex attributes to the objects of the perceptive field. Thus the experiencer would the complex containing so called material body and hierarchy of field bodies.

EEG MEs correspond to our level in this hierarchy of projections. The simplest possibility is that the sizes of these sensory selves are of the order of EEG ME sizes ($L(EEG) = c/f(EEG)$) and thus can be of the order of Earth size! Thus the ultimate sensory representations are magnetic gigants in TGD and diametrical opposites of the neurophysiological dwarfs of standard neuroscience populating also TGD brain.

The known strange effects of large scale perturbations of Earth's magnetic field on consciousness (say, statistics about the effects of magnetic storms in mental state and tectonic activity inducing UFO experiences) provide a rich palette of anomalies supporting this view. The conservation of magnetic flux makes the magnetic flux tube structures of Earth size very stable: thus physical death presumably means only that our magnetic body redirects its attention to something more interesting. Near death experiences discussed in more detail in [K3] indeed support this view. Of course, this view about human consciousness is not new, it is shared by all spiritual practices. What is new is the concrete physical model realizing this view physically.

It would seem that the generation of the visual experience involves some kind of iterative computational process laeding to an optimal conscious sensory representation of the external world. This process must involve a model of the external world, which is improved iteratively. Each computational step must provide an estimate for the various positional coordinates of the object and features associated with it and a subsequent comparison of the real sensory data with the virtual sensory data yielded by the model world. The virtual world sensory input yielded by this model is compared with the real world sensory input in comparison circuit and when virtual and real inputs are sufficiently near each other synchronous neural firing leading to a wake-up of sensory sub-self and conscious recognition of the object of the perceptive field occurs. This could also involve intermediate cognitive, symbolic, and sensory representations not conscious to us who see only the final product of this process. In case of vision the model suggests that both eyes yield actually stereovision separately in ordinary circumstances. This might be the case: one must hold second eye closed for sufficiently long time before the picture gradually flattens.

This quasi-computational process is cognitive process involving imagined sensory, motor and Boolean representations ("this is true" experiences) realized. If the primary qualia are at the level of sensory organs it is easy to understand why imagination lacks the sensory qualia. Only during dreams and hallucinations would the back-projection to the sensory organs occur and "qualiafy" the symbolic representations generated by imagination.

The original proposal was that imagination is a purely p-adic process involving transformation of p-adic space-time sheets to real ones. In the adelic vision this does not make sense. Both real and p-adic (cognitive) aspects are always present. If motor action is a geometric time reversal of sensory perception in relevant p-adic time scales, it is initiated at some level above muscles and proceed to higher levels so that there is no danger that real motor actions are generated. Dissipation and its time reversal implying a Darwinian selection of mental images are probably the basic tools of imagination and problem solving: second law becomes an ally rather than an enemy. Problem solving and motor actions quite generally start from a rough sketch and there is no need for rigid and bureucratic program structures as in case of AI. Program develops as it runs.

There are several information sources at use when cortex deduces the positional coordinates for the objects of the perceptive field. In case of vision the decomposition of the right and left visual fields to objects is an essential element of the approach. For instance, simple estimate for the distance of object results from the comparison of the positions of the images of object in the retina. If illumination is constant, the comparison of the intensities of the reflected light coming from various planar pieces of the surface representing object gives estimate for the normal direction of the planar piece. Also the fact, that some points of the object are not seen simultaneously by right and left eye can be used as a constraint. In case of autostereograms there is no decomposition into objects and the problem is to identify, which points of the right eye and left eye correspond to same point of the external world: the color of the points is obvious clue. Also long term memories about objects seen earlier are obviously involved.

In the simple situation that the visual world consists of simple objects, no comparison of the model world with the real world is needed provided that cortex is able to perform some simple

arithmetics (which is not at all obvious!). In the general situation experience is yielded by the iterative computation like process (actually a rather long sequence of quantum computations if single quantum computation lasts about 10^4 Planck times).

4.4.2 A possible model for the computational aspects of sensory experience

The mind-like space-time sheets in the regions of cortex and various brain nuclei could see each other in the illumination provided by the Bose-Einstein condensed photons propagating along axonal (possibly also microtubular) wave guides. This would make possible comparison circuits in which inputs from two different areas of brain to area of brain are compared. The comparison circuit based on Josephson currents is ideal for this purpose. In case that inputs are identical, synchronous neural activity results. The comparison of the images could be crucial in realizing the iterative evaluation of the computational aspects of sensory experience. This iterative comparison process need not be conscious to us.

From our point of view brain seems to generate only symbolic representations. Cortex might however also generate virtual world sensory experiences at lower levels of the self hierarchy and not conscious to us. These could be compared with the genuine sensory input in (say) thalamus and convergent iteration would lead to a resonant firing and conscious experience of recognition. This would explain the observed adaptive resonance phenomenon in which thalamo-cortical feedback loop directs conscious attention to those aspects of sensory percept which agree with the expectation. Direction of attention would mean generation of a sensory sub-self representing the recognized part of perceptive field. Novelty detection could occur at higher information processing level and could be based on inhibitory projections from feature detectors to the novelty detecting neural circuit.

Just to concretize the idea, one could imagine the following rough scenario for how the comparison involving neuronal sensory qualia (not ours) could proceed.

1. Neurons in some parts of brain, most naturally in the thalamus, have neural window to the primary sensory organ radiating coherent light propagating along microtubular waveguides to thalamus. Besides vision and perhaps even hearing, neurons would also have chemical senses and receptor-transmitter complexes would define different qualia. Different sensory modalities feed different regions of thalamus with difference wavelengths characterizing the sensory modality so that the neuronal window based on coherent light might be used by all sensory modalities to achieve this comparison. This is consistent with the fact that microtubuli are present in all axons. There is an intensive feedback from cortex to thalamus and this feedback could quite generally be related to the cognitive representations generated in cortex and communicated to thalamus for comparison. The results of the comparison are sent back to the cortex coded in nerve pulse patterns and change the properties of the model world to give a better fit.

2. The imagery model world consisting of neuronal mind-like space-time sheets in cortex represents the results of a cortical computation. Mind-like space-time sheets radiate coherent light with the intensity determined by the model of the external world specifying the intensity of the reflected light from a particular object. The simplest possibility is that the representation consists of mind-like space-time sheets whose size and shape are deduced from the size and shape of the objects and from the estimated values of the height function. Only the active cortical neurons send coherent light along microtubules to thalamus. The result of the comparison is coded to nerve pulse pattern and sent back to cortex to make possible next trial.

4.4.3 Connection with the observations of Barbara Shipman

There is also an interesting connection with the model the model of Barbra Shipman for the dance of honeybee [A6, A5, A4].

The model relies on the puzzling observation that the manifold $F_3 = SU(3)/U(1) \times U(1)$ parametrizing different choices of color quantum numbers seems to be involved with the dance [K13]. In TGD framework color rotations do not leave classical Z^0 and em fields invariant although induced Kähler field is color invariant. For instance, in a color rotation a pure Z^0 ME is in general

transformed to a ME carrying a light-like vacuum em current generating a hologram possibly acting as a biological control command. This suggests an explanation for the observations of Shipman and also that the canonical coordinates (P_i, Q_i) for the 6-dimensional symplectic space F_3 play crucial role in the construction of sensory representation. In fact, in Shipman's model the Hamiltonians associated with color isospin and hypercharge take the role of planar coordinates for the dance floor at which the dance of honeybee takes place. More generally, it might be possible to represent the position of the object of a perceptive field using some coordinates of F_3. The optimal situation would be that both the velocity and position would be coded to a point of F_3 so that CP_2 orientation of space-time sheet would represent position for an object of a perceptive field.

5 Number Theoretical Feats and TGD Inspired Theory of Consciousness

Number theoretical feats of some mathematicians like Ramanujan remain a mystery for those believing that brain is a classical computer. Also the ability of idiot savants - lacking even the idea about what prime is - to factorize integers to primes challenges the idea that an algorithm is involved. In this article I discuss ideas about how various arithmetical feats such as partitioning integer to a sum of integers and to a product of prime factors might take place. The ideas are inspired by the number theoretic vision about TGD suggesting that basic arithmetics might be realized as naturally occurring processes at quantum level and the outcomes might be "sensorily perceived". One can also ask whether zero energy ontology (ZEO) could allow to perform quantum computations in polynomial instead of exponential time.

The indian mathematician Srinivasa Ramanujan is perhaps the most well-known example about a mathematician with miraculous gifts. He told immediately answers to difficult mathematical questions - ordinary mortals had to to hard computational work to check that the answer was right. Many of the extremely intricate mathematical formulas of Ramanujan have been proved much later by using advanced number theory. Ramanujan told that he got the answers from his personal Goddess. A possible TGD based explanation of this feat relies on the idea that in zero energy ontology (ZEO) quantum computation like activity could consist of steps consisting quantum computation and its time reversal with long-lasting part of each step performed in reverse time direction at opposite boundary of causal diamond so that the net time used would be short at second boundary.

The adelic picture about state function reduction in ZEO suggests that it might be possible to have direct sensory experience about prime factorization of integers [L4]. What about partitions of integers to sums of primes? For years ago I proposed that symplectic QFT is an essential part of TGD. The basic observation was that one can assign to polygons of partonic 2-surface - say geodesic triangles - Kähler magnetic fluxes defining symplectic invariance identifiable as zero modes. This assignment makes sense also for string world sheets and gives rise to what is usually called Abelian Wilson line. I could not specify at that time how to select these polygons. A very natural manner to fix the vertices of polygon (or polygons) is to assume that they correspond ends of fermion lines which appear as boundaries of string world sheets. The polygons would be fixed rather uniquely by requiring that fermions reside at their vertices.

The number 1 is the only prime for addition so that the analog of prime factorization for sum is not of much use. Polygons with $n = 3, 4, 5$ vertices are special in that one cannot decompose them to non-degenerate polygons. Non-degenerate polygons also represent integers $n > 2$. This inspires the idea about numbers $\{3, 4, 5\}$ as "additive primes" for integers $n > 2$ representable as non-degenerate polygons. These polygons could be associated many-fermion states with negentropic entanglement (NE) - this notion relate to cognition and conscious information and is something totally new from standard physics point of view. This inspires also a conjecture about a deep connection with arithmetic consciousness: polygons would define conscious representations for integers $n > 2$. The splicings of polygons to smaller ones could be dynamical quantum processes behind arithmetic conscious processes involving addition.

5.1 How Ramanujan did it?

Lubos Motl wrote recently a blog posting (`http://tinyurl.com/zduu72p`) about $P \neq NP$ computer in the theory of computation based on Turing's work. This unproven conjecture relies on a classical model of computation developed by formulating mathematically what the women doing the hard computational work in offices at the time of Turing did. Turing's model is extremely beautiful mathematical abstraction of something very every-daily but does not involve fundamental physics in any manner so that it must be taken with caution. The basic notions include those of algorithm and recursive function, and the mathematics used in the model is mathematics of integers. Nothing is assumed about what conscious computation is and it is somewhat ironic that this model has been taken by strong AI people as a model of consciousness!

1. A canonical model for classical computation is in terms of Turing machine, which has bit sequence as inputs and transforms them to outputs and each step changes its internal state. A more concrete model is in terms of a network of gates representing basic operations for the incoming bits: from this basic functions one constructs all recursive functions. The computer and program actualize the algorithm represented as a computer program and eventually halts - at least one can hope that it does so. Assuming that the elementary operations require some minimum time, one can estimate the number of steps required and get an estimate for the dependence of the computation time as function of the size of computation.

2. If the time required by a computation, whose size is characterized by the number N of relevant bits, can be carried in time proportional to some power of N and is thus polynomial, one says that computation is in class P. Non-polynomial computation in class NP would correspond to a computation time increasing with N faster than any power of N, say exponentially. Donald Knuth, whose name is familiar for everyone using Latex to produce mathematical text, believes on $P = NP$ in the framework of classical computation. Lubos in turn thinks that the Turing model is probably too primitive and that quantum physics based model is needed and this might allow $P = NP$.

What about quantum computation as we understand it in the recent quantum physics: can it achieve $P = NP$?

1. Quantum computation is often compared to a superposition of classical computations and this might encourage to think that this could make it much more effective but this does not seem to be the case. Note however that the amount of information represents by N qubits is however exponentially larger than that represented by N classical bits since entanglement is possible. The prevailing wisdom seems to be that in some situations quantum computation can be faster than the classical one but that if $P = NP$ holds true for classical computation, it holds true also for quantum computations. Presumably because the model of quantum computation begins from the classical model and only (quantum computer scientists must experience this statement as an insult - apologies!) replaces bits with qubits.

2. In quantum computer one replaces bits with entangled qubits and gates with quantum gates and computation corresponds to a unitary time evolution with respect to a discretized time parameter constructed in terms of fundamental simple building bricks. So called tensor networks realize the idea of local unitary in a nice manner and has been proposed to defined error correcting quantum codes. State function reduction halts the computation. The outcome is non-deterministic but one can perform large number of computations and deduce from the distribution of outcomes the results of computation.

What about conscious computations? Or more generally, conscious information processing. Could it proceed faster than computation in these sense of Turing? To answer this question one must first try to understand what conscious information processing might be. TGD inspired theory of consciousnesss provides one a possible answer to the question involving not only quantum physics but also new quantum physics.

1. In TGD framework Zero energy ontology (ZEO) replaces ordinary positive energy ontology and forces to generalize the theory of quantum measurement. This brings in several new

elements. In particular, state function reductions can occur at both boundaries of causal diamond (CD), which is intersection of future and past direct light-cones and defines a geometric correlate for self. Selves for a fractal hierarchy - CDs within CDs and maybe also overlapping. Negentropy Maximization Principle (NMP) is the basic variational principle of consciousness and tells that the state function reductions generate maximum amount of conscious information. The notion of negentropic entanglement (NE) involving p-adic physics as physics of cognition and hierarchy of Planck constants assigned with dark matter are also central elements.

2. NMP allows a sequence of state function reductions to occur at given boundary of diamond-like CD - call it passive boundary. The state function reduction sequence leaving everything unchanged at the passive boundary of CD defines self as a generalized Zeno effect. Each step shifts the opposite - active - boundary of CD "upwards" and increases its distance from the passive boundary. Also the states at it change and one has the counterpart of unitary time evolution. The shifting of the active boundary gives rise to the experienced time flow and sensory input generating cognitive mental images - the "Maya" aspect of conscious experienced. Passive boundary corresponds to permanent unchanging "Self".

3. Eventually NMP forces the first reduction to the opposite boundary to occur. Self dies and reincarnates as a time reversed self. The opposite boundary of CD would be now shifting "downwards" and increasing CD size further. At the next reduction to opposite boundary re-incarnation of self in the geometric future of the original self would occur. This would be re-incarnation in the sense of Eastern philosophies. It would make sense to wonder whose incarnation in geometric past I might represent!

Could this allow to perform fast quantal computations by decomposing the computation to a sequence in which one proceeds in both directions of time? Could the incredible feats of some "human computers" rely on this quantum mechanism (see `http://tinyurl.com/hk5baty`). The indian mathematician Srinivasa Ramanujan (see `http://tinyurl.com/l42q7a2`) is the most well-known example of a mathematician with miraculous gifts. He told immediately answers to difficult mathematical questions - ordinary mortals had to to hard computational work to check that the answer was right. Many of the extremely intricate mathematical formulas of Ramanujan have been proved much later by using advanced number theory. Ramanujan told that he got the answers from his personal Goddess.

Might it be possible in ZEO to perform quantally computations requiring classically non-polynomial time much faster - even in polynomial time? If this were the case, one might at least try to understand how Ramanujan did it although higher levels selves might be involved also (did his Goddess do the job?).

1. Quantal computation would correspond to a state function reduction sequence at fixed boundary of CD defining a mathematical mental image as sub-self. In the first reduction to the opposite boundary of CD sub-self representing mathematical mental image would die and quantum computation would halt. A new computation at opposite boundary proceeding to opposite direction of geometric time would begin and define a time-reversed mathematical mental image. This sequence of reincarnations of sub-self as its time reversal could give rise to a sequence of quantum computation like processes taking less time than usually since one half of computations would take place at the opposite boundary to opposite time direction (the size of CD increases as the boundary shifts).

2. If the average computation time is same at both boundaries, the computation time would be only halved. Not very impressive. However, if the mental images at second boundary - call it A - are short-lived and the selves at opposite boundary B are very long-lived and represent very long computations, the process could be very fast from the point of view of A! Could one overcome the $P \neq NP$ constraint by performing computations during time-reversed re-incarnations?! Short living mental images at this boundary and very long-lived mental images at the opposite boundary - could this be the secret of Ramanujan?

3. Was the Goddess of Ramanujan - self at higher level of self-hierarchy - nothing but a time reversal for some mathematical mental image of Ramanujan (Brahman=Atman!), representing

very long quantal computations! We have night-day cycle of personal consciousness and it could correspond to a sequence of re-incarnations at some level of our personal self-hierarchy. Ramanujan tells that he met his Goddess in dreams. Was his Goddess the time reversal of that part of Ramanujan, which was unconscious when Ramanujan slept? Intriguingly, Ramanujan was rather short-lived himself - he died at the age of 32! In fact, many geniuses have been rather short-lived.

4. Why the alter ego of Ramanujan was Goddess? Jung intuited that our psyche has two aspects: anima and animus. Do they quite universally correspond to self and its time reversal? Do our mental images have gender?! Could our self-hierarchy be a hierarchical collection of anima and animi so that gender would be something much deeper than biological sex! And what about Yin-Yang duality of Chinese philosophy and the ka as the shadow of persona in the mythology of ancient Egypt?

5.2 Symplectic QFT, $\{3,4,5\}$ as Additive Primes, and Arithmetic Consciousness

For years ago I proposed that symplectic QFT is an essential part of TGD [K4, K30]. The basic observation was that one can assign to polygons of partonic 2-surface - say geodesic triangles - Kähler magnetic fluxes defining symplectic invariance identifiable as zero modes. This assignment makes sense also for string world sheets and gives rise to what is usually called Abelian Wilson line. I could not specify at that time how to select these polygons in the case of partonic 2-surfaces.

The recent proposal of Maldacena and Arkani-Hamed [B4] (see `http://tinyurl.com/ych26gcm`) that CMB might contain signature of inflationary cosmology as triangles and polygons for which the magnitude of n-point correlation function is enhanced led to a progress in this respect. In the proposal of Maldacena and Arkani-Hamed the polygons are defined by momentum conservation. Now the polygons would be fixed rather uniquely by requiring that fermions reside at their vertices and momentum conservation is not involved.

This inspires the idea about numbers $\{3,4,5\}$ as "additive primes" for integers $n > 2$ representable as non-degenerate polygons. Geometrically one could speak of prime polygons not decomposable to lower non-degenerate polygons. These polygons are different from those of Maldacena and Arkani-Hamed and would be associated many-fermion states with negentropic entanglement (NE) - this notion relates to cognition and conscious information and is something totally new from standard physics point of view. This inspires also a conjecture about a deep connection with arithmetic consciousness: polygons would define representations for integers $n > 2$. The splicings of polygons to smaller ones could be dynamical quantum processes behind arithmetic conscious processes involving addition. I have already earlier considered a possible counterpart for conscious prime factorization in the adelic framework [L4].

5.2.1 Basic ideas of TGD inspired theory of conscious very briefly

Negentropy Maximization Principle (NMP) is the variational principle of consciousness in TGD framework. It says that negentropy gain in state function reduction (quantum jump re-creating Universe) is maximal. State function reduction is basically quantum measurement in standard QM and sensory qualia (for instance) could be perhaps understood as quantum numbers of state resulting in state function reduction. NMP poses conditions on whether this reduction can occur. In standard ontology it would occur always when the state is entangled: reduction would destroy the entanglement and minimize entanglement entropy. When cognition is brought in, the situation changes.

The first challenge is to define what negentropic entanglement (NE) and negentropy could mean.

1. In real physics without cognition one does not have any definition of negentropy: on must define negentropy as reduction of entropy resulting as conscious entity gains information. This kind of definition is circular in consciousness theory.

2. In p-adic physics one can define number theoretic entanglement entropy with same basic properties as ordinary Shannon entropy. For some p-adic number fields this entropy can be

negative and this motivates an interpretation as conscious information related to entanglement - rather to the ignorance of external observer about entangled state. The prerequisite is that the entanglement probabilities belong to an an extension of rationals inducing a finite-dimensional extension of rationals. Algebraic extensions are such extensions as also those generate by a root of e (e^p is p-adic number in Q_p).

A crucial step is to fuse together sensory and cognitive worlds as different aspects of existence.

1. One must replace real universe with adelic one so that one has real space-time surfaces and their p-adic variants for various primes p satisfying identical field equations. These are related by strong form of holography (SH) in which 2-D surfaces (string world sheets and partonic 2-surfaces) serve as "space-time genes" and obey equations which make sense both p-adically in real sense so that one can identify them as points of "world of classical worlds" (WCW).

2. One can say that these 2-surfaces belong to intersection of realities and p-adicities - intersection of sensory and cognitive. This demands that the parameters appearing in the equations for 2-surface belong algebraic extension of rational numbers: the interpretation is that this hierarchy of extensions corresponds to evolutionary hierarchy. This also explains imagination in terms of the p-adic space-time surfaces which are not so unique as the real one because of inherent non-determinism of p-adic differental equations. What can be imagined cannot be necessarily realized. You can continued p-adic 2-surface to 4-D surface but not to real one.

There is also second key assumption involved.

1. Hilbert space of quantum states is *same* for real and p-adic sectors of adelic world: for instance, tensor product would lead to total nonsense since there would be both real and p-adic fermions. This means same quantum state and same entanglement but seen from sensory and various cognitive perspectives. This is the basic idea of adelicity: the p-adic norms of rational number characterize the norm of rational number. Now various p-adic conscious experiences characterize the quantum state.

2. Real perspective sees entanglement always as entropic. For some finite number number of primes p p-adic entanglement is however negentropic. For instance, for entanglement probabilities $p_i = 1/N$, the primes appearing as factors of N are such information carrying primes. The presence of these primes can make the entanglement stable. The total entropy equal to the sum of negative real negentropy + various p-adic negentropies can be positive and cannot be reduced in the reduction so that reduction does not occur at all! Entanglement is stabilized by cognition and the randomness of state function reduction tamed: matter has power over matter!

3. There is analogy with the reductionism-holism dichotomy. Real number based view is reductionistic: information is obtained when the entangled state is split into un-entangled part. p-Adic number based view is holistic: information is inthe negentropic entanglement and can be seen as abstraction or rule. The superposition of state pairs represents a rule with state pairs (a_i, b_i) representing the instance of the rule A$\leftrightarrow$B. Maximal entanglement defined by entanglement probabilities $p_i = 1/N$ makes clear the profound distinction between these views. In real sector the negentropy is negative and smallest possible. In p-adic sector the negentropy is maximum for p-adic primes appearing as factors of N and total negentropy as their sum is large. NE allows to select unique state basis if the probabilities p_i are different.

   For $p_i = 1/N$ one can choose any unitary related state basis since unit matrix is invariant under unitary transformations. From the real point of view the ignorance is maximal and entanglement entropy is indeed maximal. For instance, in case of Schrödinger cat one could choose the cat's state basis to be any superposition of dead and alive cat and a state orthogonal to it. From p-adic view information is maximal. The reports of meditators, in particular Zen buddhists, support this interpretation. In "enlightened state" all discriminations disappear: it does not make sense to speak about dead or alive cat or anything between these two options. The state contains information about entire state - not about its parts. It is not information expressible using language relying on making of distinctions but silent wisdom.

5.2.2 How do polygons emerge in TGD framework?

The duality defined by strong form of holography (SH) has 2 sides. Space-time side (bulk) and boundary side (string world sheets and partonic 2-surfaces). 2-D half of SH would suggest a description based on string world sheets and partonic 2-surfaces. This description should be especially simple for the quantum states realized as spinor fields in WCW ("world of classical worlds"). The spinors (as opposed to spinor fields) are now fermionic Fock states assignable to space-time surface defining a point of WCW. TGD extends ordinary 2-D conformal invariance to super-symplectic symmetry applying at the boundary of light-cone: note that given boundary of causal diamond (CD) is contained by light-cone boundary.

1. The correlation functions at imbedding space level for fundamental objects, which are fermions at partonic 2-surfaces could be calculated by applying super-symplectic invariance having conformal structure. I have made rather concrete proposals in this respect. For instance, I have suggested that the conformal weights for the generators of supersymplectic algebra are given by poles of fermionic zeta $\zeta_F(s) = \zeta(s)/\zeta(2s)$ and thus include zeros of zeta scaled down by factor 1/2 [K9]. A related proposal is conformal confinement guaranteeing the reality of net conformal weights.

2. The conformally invariant correlation functions are those of super-symplectic CFT at light-cone boundary or its extension to CD. There would be the analog of conformal invariance associated with the light-like radial coordinate r_M and symplectic invariance associated with CP_2 and sphere S^2 localized with respect to r_M analogous to the complex coordinate in ordinary conformal invariance and naturally continued to hypercomplex coordinate at string world sheets carrying the fermionic modes and together with partonic 2-surfaces defining the boundary part of SH.

Symplectic invariants emerge in the following manner. Positive and negative energy parts of zero energy states would also depend on zero modes defined by super-symplectic invariants and this brings in polygons. Polygons emerge also from four-momentum conservation. These of course are also now present and involve the product of Lorentz group and color group assignable to CD near its either boundary. It seems that the extension of Poincare translations to Kac-Moody type symmetry allows to have full Poincare invariance (in its interior CD looks locally like $M^4 \times CP_2$).

1. One can define the symplectic invariants as magnetic fluxes associated with S^2 and CP_2 Kähler forms. For string world sheets one would obtain non-integrable phase factors. The vertices of polygons defined by string world sheets would correspond to the intersections of the string world sheets with partonic 2-surfaces at the boundaries of CD and at partonic 2-surfaces defining generalized vertices at which 3 light-like 3-surfaces meet along their ends.

2. Any polygon at partonic 2-surface would also allow to define such invariants. A physically natural assumption is that the vertices of these polygons are realized physically by adding fermions or antifermions at them. Kähler fluxes can be expressed in terms of non-integrable phase factors associated with the edges. This assumption would give the desired connection with quantum physics and fix highly uniquely but not completely the invariants appearing in physical states.

The correlated polygons would be thus naturally associated with fundamental fermions and a better analogy would be negentropically entangled n-fermion state rather than corresponding to maximum of the modulus of n-point correlation function. Hierarchy of Planck constants makes these states possible even in cosmological scales. The point would be that negentropic entanglement assignable to the p-adic sectors of WCW would be in key role.

5.2.3 Symplectic invariants and Abelian non-integrable phase factors

Consider now the polygons assignable to many-fermion states at partonic 2-surfaces.

1. The polygon associated with a given set of vertices defined by the position of fermions is far from unique and different polygons correspond to different physical situations. Certainly one must require that the geodesic polygon is not self-intersecting and defines a polygon or set of polygons.

2. Geometrically the polygon is not unique unless it is convex. For instance, one can take regular n-gon and add one vertex to its interior. The polygon can be also constructed in several manners. From this one obtains a non-convex $n+1$-gon in $n+1$ manners.

3. Given polygon is analogous with Hamiltonian cycle connecting all points of given graph. Now one does not have graph structure with edges and vertices unless one defines it by nearest neighbor property. Platonic solids provide an example of this kind of situation. Hamiltonian cycles [A1, A2] are key element in the TGD inspired model for music harmony leading also to a model of genetic code [K22] [L2].

4. One should somehow fix the edges of the polygon. For string world sheets the edges would be boundaries of string world sheet. For partonic 2-surfaces the simplest option is that the edges are geodesic lines and thus have shortest possible length. This would bring in metric so that the idea about TGD as almost topological QFT would be realized.

One can distinguish between two cases: single polygon or several polygons.

1. One has maximal entanglement between fundamental fermions, when the vertices define single polygon. One can however have several polygons for a given set of vertices and in this case the coherence is reduced. Minimal correlations correspond to maximal number of 3-gons and minimal number of 4-gons and 5-gons.

2. For large $h_{eff} = n \times h$ the partonic 2-surfaces can have macroscopic and even astrophysical size and one can consider assigning many-fermion states with them. For instance, anyonic states could be interpreted in this manner. In this case it would be natural to consider various decompositions of the state to polygons representing entangled fermions.

The definition of symplectic invariant depends on whether one has single polygon or several polygons.

1. In the case that there are several polygons not containing polygons inside them (if this the case,then the complement of polygon must satisfy the condition) one can uniquely identify the interior of each polygon and assign a flux with it. Non-integrable phase factor is well-defined now. If there is only single polygon then also the complement of polygon could define the flux. Polygon and its complement define fluxes Φ and $\Phi_{tot} - \Phi$.

2. If partonic 2-surface carries monopole Kähler charge Φ_{tot} is essentially $n\pi$, where n is magnetic monopole flux through the partonic 2-surface. This is half integer - not integer: this is key feature of TGD and forces the coupling of Kähler gauge potential to the spinors leading to the quantum number spectrum of standard model. The exponent can be equal to -1 for half-odd integer.

   This problem disappears if both throats of the wormhole contact connecting the space-time sheets with Minkowski signature give their contribution so that two minus-signs give one plus sign. Elementary particles necessarily consist of wormhole contacts through which monopole flux flows and runs along second space-time sheet to another contact and returns along second space-time sheet so that closed monopole flux tube is obtained. The function of the flux must be single valued. This demands that it must reduce to the cosine of the integer multiple of the flux and identifiable as as the real part of the integer power of magnetic flux through the polygon.

The number theoretically deepest point is geometrically completely trivial.

1. Only $n > 2$-gons are non-degenerate and 3-, 4- and 5-gons are prime polygons in the sense that they cannot be sliced to lower polygons. Already 6-gon decomposes to 2 triangles.

2. One can wonder whether the appearance of 3 prime polygons might relate to family replication phenomenon for which TGD suggests an explanation in terms of genus of the partonic 2-surface [K5]. This does not seem to be the case. There is however other three special integers: namely 0,1, and 2.

The connection with family replication phenomenon could be following. When the number of handles at the parton surface exceeds 2, the system forms entangled/bound states describable in terms of polygons with handles at vertices. This would be kind of phase transition. Fundamental fermion families with handle number 0,1,2 would be analogous to integers 0,1,2 and the anyonic many-handle states with NE would be analogous to partitions of integers $n > 2$ represented by the prime polygons. They would correspond to the emergence of p-adic cognition. One could not assign NE and cognition with elementary particles but only to more complex objects such as anyonic states associated with large partonic 2-surfaces (perhaps large because they have large Planck constant $h_{eff} = n \times h$) [K21].

5.2.4 Integers $(3,4,5)$ as "additive primes" for integers $n \geq 3$: a connection with arithmetic consciousness

The above observations encourage a more detailed study of the decomposition of polygons to smaller polygons as a geometric representation for the partition of integers to a sum of smaller integers. The idea about integers $(3,4,5)$ as "additive primes" represented by prime polygons is especially attractive. This leads to a conjecture about NE associated with polygons as quantum correlates of arithmetic consciousness.

1. Motivations

The key idea is to look whether the notion of divisibility and primeness could have practical value in additive arithmetics. 1 is the only prime for addition in general case. $n = 1 + 1 + ...$ is analogous to p^n and all integers are "additive powers" of 1.

What happens if one considers integers $n \geq 3$? The basic motivation is that $n \geq 3$ is represented as a non-degenerate n-gon for $n \geq 3$. Therefore geometric representation of these primes is used in the following. One cannot split triangles from 4-gon and 5-gon. But already for 6-gon one can and obtains 2 triangles. Thus $\{3,4,5\}$ would be the additive primes for $n \geq 3$ represented as prime polygons.

The n-gons with $n \in \{3,4,5\}$ appear as faces of the Platonic solids! The inclusions of von Neumann algebras known as hyperfinite factors of type II_1 central in TGDs correspond to quantum phases $exp(\pi/n)$ $n = 3,4,5....$ Platonic solids correspond to particular finite subgroups of 3-D rotation group, which are in one-one correspondence with simply laced Lie-groups (ADE). There is also a direct connection with the classification of $\mathcal{N} = 2$ super-conformal theories, which seem to be relevant for TGD.

I cannot resist the temptation to mention also a personal reminiscence about a long lasting altered state of consciousness about 3 decades ago. I called it Great Experience and it boosted among other things serious work in order to understand consciousness in terms of quantum physics. One of the mathematical visions was that number 3 is in some sense fundamental for physics and mathematics. I also precognized infinite primes and much later indeed discovered them. I have repeatedly returned to the precognition about number 3 but found no really convincing reason for its unique role although it pops up again and again in physics and mathematics: 3 particle families, 3 colors for quarks, 3 spatial dimensions, 3 quaternionic imaginaryunits, triality for octonions, to say nothing about the role of trinity in mystics and religions. The following provides the first argument for the special role of number 3 that I can take seriously.

2. Partition of integer to additive primes

The problem is to find a partition of an integer to additive primes $3,4,5$. The problem can be solved using a representation in terms of $n > 2$-gons as a geometrical visualization. Some general aspects of the representation.

1. The detailed shape of n-gons in the geometric representation of partitions does not matter: they just represent geometrically a partition of integer to a sum. The partition can be regarded as a dynamical process. n-gons splits to smaller n-gons producing a representation for a partition $n = \sum_i n_i$. What this means is easiest to grasp by imagining how polygon can be decomposed to smaller ones. Interestingly, the decompositions of polytopes to smaller ones - triangulations - appear also in Grassmannian twistor approach to $\mathcal{N} = 4$ super Yang Mills theory.

2. For a given partition the decomposition to n-gons is not unique. For instance, integer 12 can be represented by 3 4-gons or 4 3-gons. Integers $n \in \{3,4,5\}$ are special and partitions to these n-gons are in some sense maximal leading to a maximal decoherence as quantum physicist might say.

   The partitions are not unique and there is large number of partitions involving 3-gons,4-gons, 5-gons. The reason is that one can split from n-gons any n_1-gon with $n_1 < n$ except for $n = 3,4,5$.

3. The daydream of non-mathematician not knowing that everything has been very probably done for aeons ago is that one could chose n_1 to be indivisible by 4 and 5, n_2 indivisible by 3 and 5 and n_3 indivisible by 3 and 4 so that one might even hope for having a unique partition. For instance, double modding by 4 and 5 would reduce to double modding of $n_1 \times 3$ giving a non-vanishing result, and one might hope that n_1, n_2 and n_3 could be determined from the double modded values of n_i uniquely. Note that for $n_i \in \{1,2\}$ the number $n = 24 = 2 \times 3 + 2 \times 4 + 2 \times 5$ playing key role in string model related mathematics is the largest integer having this kind of representation. One should numerically check whether any general orbit characterized by the above formulas contains a point satisfying the additional number theoretic conditions.

   Therefore the task is to find partitions satisfying these indivisibility conditions. It is however reasonable to consider first general partitions.

4. By linearity the task of finding general partitions (forgetting divisibility conditions) is analogous to that of finding of solutions of non-homogenous linear equations. Suppose that one has found a partition

$$n = n_1 \times 3 + n_2 \times 4 + n_3 \times 5 \leftrightarrow (n_1, n_2, n_3) \quad . \tag{5.1}$$

   This serves as the analog for the special solution of non-homogenous equation. One obtains a general solutions of equation as the sum $(n_1 + k_1, n_2 + k_1, n_3 + k_3)$ of the special solution and general solution of homogenous equation

$$k_1 \times 3 + k_2 \times 4 + k_3 \times 5 = 0 \quad . \tag{5.2}$$

   This is equation of plane in N^3 - 3-D integer lattice.

   Using $4 = 3 + 1$ and $5 = 3 + 2$ this gives equations

$$k_2 + 2 \times k_3 = 3 \times m \quad , \quad k_1 - k_3 + 4 \times m = 0 \quad , \quad m = 0,1,2,... \tag{5.3}$$

5. There is periodicity of $3 \times 4 \times 5 = 60$. If (k_1, k_2, k_3, m) is allowed deformation, one obtains a new one with same divisibility properties as the original one as $(k_1 + 60, k_2 - 120, k_3 + 60, m)$. If one does not require divisibility properties for all solutions, one obtains much larger set of solutions. For instance $(k_1, k_2, k_3) = m \times (1, -2, 1)$ defines a line in the plane containing the solutions. Also other elementary moves than (1,-2,1) are possible.

One can identify very simple partitions deserving to be called standard partitions and involve mostly triangles and minimal number of 4- and 5-gons. The physical interpretation is that the coherence is minimal for them since mostly the quantum coherent negentropically entangled units are minimal triangles.

1. One starts from n vertices and constructs n-gon. For number theoretic purposes the shape does not matter and the polygon can be chosen to be convex. One slices from it 3-gons one by one so that eventually one is left with $k \equiv n \mod 3 == 0,1$ or 2 vertices. For $k = 0$ no further operations are needed. For $k = 1$ *resp.* $k = 2$ one combines one of the triangles and

edge associated with 1 *resp.* 2 vertices to 4-gon *resp.* 5-gon and is done. The outcome is one of the partitions

$$n = n_1 \times 3 \ , \quad n = n_1 \times 3 + 4, n = n_1 \times 3 + 5 \tag{5.4}$$

These partitions are very simple, and one can easily calculate similar partitions for products and powers. It is easy to write a computer program for the products and powers of integers in terms of these partitions.

2. There is however a uniqueness problem. If n_1 is divisible by 4 or 5 - $n_1 = 4 \times m_1$ or $n_1 = 5 \times m_1$ - one can interpret $n_1 \times 3$ as a collection of m_1 4-gons or 5-gons. Thus the geometric representation of the partition is not unique. Similar uniqueness condition must apply to n_2 and n_3 and is trivially true in above partitions.

   To overcome this problem one can pose a further requirement. If one wants n_1 to be indivisible by 4 and 5 one can transform 2 or or 4 triangles and existing 4-gon or 5-gon or 3 or 6 triangles to 4-gons and 5-gons.

   (a) Suppose $n = n_1 \times 3 + 4$. If n_1 divisible by 4 *resp.* 5 or both, $n_1 - 2$ is not and 4-gon and 2 3-gons can be transformed to 2 5-gons: $(n_1, 1, 0) \to (n_1 - 2, 0, 2)$. If $n_1 - 2$ is divisible by 5, $n_1 - 3$ is not divisible by either 4 or 5 and 3 triangles can be transformed to 4-gon and 5-gon: $(n_1, 1, 0) \to (n_1 - 3, 2, 1)$.

   (b) Suppose $n = n_1 \times 3 + 5$. If n_1 divisible by 4 *resp.* 5 or both, $n_1 - 1$ is not and triangle and 5-gon can be transformed to 2 4-gons: $(n_1, 0, 1) \to (n_1 - 1, 2, 0)$. If $n_1 - 1$ is divisible by 4 or 5, $n_1 - 3$ is not and 3 triangles and 5-gon can be transformed to 2 5-gons and 4-gon: $(n_1, 0, 1) \to (n_1 - 3, 1, 2)$.

   (c) For $n = n_1 \times 3$ divisible by 4 or 5 or both one can remove only $m \times 3$ triangles, $m \in \{1, 2\}$ since only in these case the resulting $m \times 3$ (9 or 18) vertices can partitioned to a union of 4-gon and 5-gon or of 2 4-gons and 2 5-gons: $(n_1, 0, 0) \to (n_1 - 3, 1, 1)$ or $(n_1, 0, 0) \to (n_1 - 6, 2, 2)$.

   These transformations seem to be the minimal transformations allowing to achieve indivisibility by starting from the partition with maximum number of triangles and minimal coherence.

Some further remarks about the partitions satisfying the divisibility conditions are in order.

1. The multiplication of n with partition (n_1, n_2, n_3) satisfying indivisibility conditions by an integer m not divisible by $k \in \{3, 4, 5\}$ gives integer with partition $m \times (n_1, n_2, n_3)$. Note also that if n is not divisible by $k \in \{3, 4, 5\}$ the powers of n, n^k has partition $n^{k-1} \times (n_1, n_2, n_3)$ and this could help to solve Diophantine equations.

2. Concerning the uniqueness of the partition satisfying the indivisibility conditions, the answer is negative. $8 = 3 + 5 = 4 + 4$ is the simplest counter example. Also the m-multiples of 8 such that m is indivisible by 2,3,4,5 serve as counter examples. 60-periodicity implies that for sufficiently large values of n the indivisibility conditions do not fix the partition uniquely. (n_1, n_2, n_3) can be replaced with $(n_1 + 60 + n_2 - 120, n_3 + 60)$ without affecting divisibility properties.

3. Intriguing observations related to 60-periodicity

60-periodicity seems to have deep connections with both music consciousness and genetic code if the TGD inspired model of genetic code is taken seriously code [K22] [L2].

1. The TGD inspired model for musical harmony and genetic involves icosahedron with 20 triangular faces and tetrahedron with 4 triangular faces. The 12 vertices of icosahedron correspond to the 12 notes. The model leads to the number 60. One can say that there are 60 +4 DNA codons and each 20 codon group is 60=20+20+20 corresponds to a subset

of aminoacids and 20 DNAs assignable to the triangles of icosahedron and representing also 3-chords of the associated harmony. The remaining 4 DNAs are associated with tetrahedron.

Geometrically the identification of harmonies is reduced to the construction of Hamiltonian cycles - closed isometrically non-equivalent non-self-intersecting paths at icosahedron going through all 12 vertices. The symmetries of the Hamiltonian cycles defined by subgroups of the icosahedral isometry group provide a classification of harmonies and suggest that also genetic code carries additional information assignable to what I call bio-harmony perhaps related to the expression of emotions - even at the level of biomolecules - in terms of "music" defined as sequences 3-chords realized in terms of triplets of dark photons (or notes) in 1-1 correspondence with DNA codons in given harmony.

2. Also the structure of time units and angle units involves number 60. Hour consists of 60 minutes, which consists of 60 seconds. Could this accident somehow reflect fundamental aspects of cognition? Could we be performing sub-conscious additive arithmetics using partitions of n-gons? Could it be possible to "see" the partitions if they correspond to NE?

4. Could additive primes be useful in Diophantine mathematics?

The natural question is whether it could be number theoretically practical to use "additive primes" $\{3,4,5\}$ in the construction of natural numbers $n \geq 3$ rather than number 1 and successor axiom. This might even provide a practical tool for solving Diophantine equations (it might well be that mathematicians have long ago discovered the additive primes).

The most famous Diophantine equation is $x^n + y^n = z^n$ and Fermat's theorem - proved by Wiles - states that for $n > 2$ it has no solutions. Non-mathematician can naively ask whether the proposed partition to additive primes could provide an elementary proof for Fermat's theorem and continue to test the patience of a real mathematician by wondering whether the parition for a sum of powers $n > 2$ could be always different from that for single power $n > 2$ perhaps because of some other constraints on the integers involved?

5. Could one identify quantum physical correlates for arithmetic consciousness?

Even animals and idiot savants can do arithmetics. How this is possible? Could one imagine physical correlates for arithmetic consciousness for which product and addition are the fundamental aspects? Is elementary arithmetic cognition universal and analogous to direct sensory experience. Could it reduce at quantum level to a kind of quantum measurement process quite generally giving rise to mental images as outcomes of quantum measurement by repeated state function reduction lasting as long as the corresponding sub-self (mental image) lives?

Consider a partition of integer to a product of primes first. I have proposed a general model for how partition of integer to primes could be experienced directly [L4]. For negentropically entangled state with maximal possible negentropy having entanglement probabilities $p_i = 1/N$, the negentropic primes are factors of N and they could be directly "seen" as negentropic p-adic factors in the adelic decomposition (reals and extensions of various p-adic number fields defined by extension of rationals defined the factors of adele and space-time surfaces as preferred extremals of Kähler action decompose to real and p-adic sectors).

What about additive arithmetics?

1. The physical motivation for n-gons is provided symplectic QFT [K4, K30], which is one aspect of TGD forced by super symplectic conformal invariance having structure of conformal symmetry. Symplectic QFT would be analogous to conformal QFT. The key challenge is to identify symplectic invariants on which the positive and negative energy parts of zero energy states can depend. The magnetic flux through a given area of 2-surface is key invariant of this kind. String world sheet and partonic 2-surfaces are possible identifications for the surface containing the polygon.

   Both the Kähler form associated with the light-cone boundary, which is metrically sphere with constant radius r_M (defining light-like radial coordinate) and the induced Kähler form of CP_2 define these kind of fluxes.

2. One can assign fluxes with string world sheets. In this case one has analog of magnetic flux but over a surface with metric signature (1,-1). Fluxes can be also assigned as magnetic fluxes

with partonic 2-surfaces at which fundamental fermions can be said to reside. n fermions defining the vertices at partonic 2-surface define naturally an n-gon or several of them. The interpretation would be as Abelian Wilson loop or equvalently non-integrable phase factor.

3. The polygons are not completely unique but this reflect the possibility of several physical states. n-gon could correspond to NE. The imaginary exponent of Kähler magnetic flux Φ through n-gon is symplectic invariant defining a non-integrable phase factor and defines a multiplicative factor of wave function. When the state decomposes to several polygons, one can uniquely identify the interior of the polygon and thus also the non-integrable phase factor.

   There is however non-uniqueness, when one has only single n-gon since also the complement of n-gon at partonic 2-surface containing now now polygons defines n-gon and the corresponding flux is $\Phi_{tot} - \Phi$. The flux Φ_{tot} is quantized and equal to the integer valued magnetic charge times 2π. The total flux disappears in the imaginary exponent and the non-integrable phase factor for the complementary polygon reduces to complex conjugate of that for polygon. Uniqueness allows only the cosine for an integer multiple of the flux.

   The non-integrable phase factor assignable to fermionic polygon would give rise to a correlation between fermions in zero modes invariant under symplectic group. The correlations defined by the n-gons at partonic 2-surfaces would be analogous to that in momentum space implied by the momentum conservation forcing the momenta to form a closed polygon but having totally different origin.

Could it be that the wave functions representing collections of n-gons representing partition of integer to a sum could be experienced directly by people capable of perplexing mathematical feats. The partition to a sum would correspond to a geometric partition of polygon representing partition of positive integer $n \geq 3$ to a sum of integers. Quantum physically it would correspond to NE as a representation of integer.

This might explain number theoretic miracles related to addition of integers in terms of direct "seeing". The arithmetic feats could be dynamical quantum processes in which polygons would decompose to smaller polygons, which would be directly "seen". This would require at least two representations: the original polygon and the decomposed polygon resulting in the state function reduction to the opposite boundary of CD. An ensemble of arithmetic sub-selves would seem to be needed. NMP does not seem to favour this kind of partition since negentropy is reduced but if its time reversal occurs in geometric time direction opposite to that of self it might look like partition for the self having sub-self as mental image.

6 Holographic Brain And Quantum TGD

Brain as a hologram paradigm states that one cannot locate the information in brain in any specific region. There is indeed considerable empirical support for this hypothesis [J17, J15, J14].

6.1 Evidence For Holographic Brain

The first empirical motivations for holographic brain came from the experiments of Lashley [J15] with rats. Psychologist Karl Lashley started 1920 lifelong study of the effect of brain vaults in memory. Lashley studied the behaviour of rats in mazes and found that the reduction of the brain tissue did not destroy the visual memory of rats totally, only the intensity of the memory was weakened. This led to the introduction of the terms mass action and equi-potentiality. Mass action says that the intensity of the memory depends on the amount of the brain tissue present and equi-potentiality says that each neuron carries the memory traces. The experiments of Lashley lead to the idea that the memory storage mechanism in brain is non-local and hologram like.

In 1948 physicists Dennis Gabor discovered the idea of optical hologram and within twenty years the same principles had been applied to brain. What hologram stores is the information about both amplitude and phase of incoming light wave, quantum mechanically identifiable as the order parameter characterizing coherent light. What makes holographic information storage so attractive is its extreme robustness and flexibility: a small piece of hologram carries same information as entire

hologram, albeit in blurred form. Philip Westlake [J18] was one of the first mathematicians to argue that hologram priciple matches with what brain does with the information. Karl Pribram [J14] and colleagues have done a lot of experimental work with monkeys using the holographic theory to see in detail how the theory makes it possible for brains to remember. The book "Shuffle brain" [J17] popularizes in an enjoyable manner the idea of holographic brain and the work Pietch with salamanders. The experimental work of Pietch provides rather convincing experimental support for the idea of holographic data storage [J17] . The experiments of Pietch with salamanders involved the cutting the brain of the salamander to pieces, shuffling the pieces randomly and putting them back together: no detectable changes in the behaviour of salamander occurred as a result of this operation! It is hard to imagine a computer which would function after this kind of treatment.

Holographic data storage is extremely flexible and stable. Since brains have developed in jungle rather than in safe computer laboratory, these properties make the idea of holographic brain much more attractive than the paradigm of computer brain. Also transformations between sensory modalities are easily realized. For instance, acoustic holograms can be transformed to optic holograms. One can however also invent objections against holographic data and memory storage.

1. The creation of hologram is based on the interference of a reference beam of light with the beam of light reflected from the object. The reading of the hologram is done by using reference beam to regenerate the original picture. It is however not clear whether this kind of mechanism is possible to realize at the level of brain. Furthermore, in reality it is the real beam which stimulates memory recall rather than the hypothetical reference beam! It seems that comparison of reference pattern representing the expected experience with input is what happens in brain rather than illumination of holograms.

2. In order to have holographic memory, it should be possible to code very many holograms simultaneously to single hologram. Multiple holograms are indeed possible [J17]. One must however admit that the idea about storing large number of temporal events to same multiple hologram does not look very attractive. The identification of the long term memory as geometric memory solves these problems in TGD framework so that hologram idea could survive as a a restricted principle determining how the experience is generated.

3. The structure of the human brain suggests that data representation is not completely hologram like. For instance, the various phonemes are recognized by well defined regions located in linguistic areas of the brain like potatoes in the field. The differences between right and left brain are a challenge for the hologram idea in its simplest form. One must however notice that it is brain functions that are localized whereas data storage could quite well be hologram like. Of course, it could quite well be that brain decomposes into regions in which data represented as a hologram is different: for instance, different sensory modalities seem to use different regions of brain. In particular, the existence of various sensory homunculi in brain is consistent with the holographic data representation.

6.2 Three Explanations For The Hologram Like Properties Of Brain

The fact is that brain seems to be extremely flexible and this does not fit nicely with the idea that brain is some kind of extremely complicated electronic circuit. Hologram like data storage in which each neuron is like a part of hologram provides only one explanation for the empirical data. The common feature of TGD based explanations is that conscious experience is not so strongly dependent on the neurophysiogical state of the neural substrate as the vision about brain as a computer would suggest.

1. Quantum self-organization implies that systems self-organize to dynamical patterns which do not depend very much on the initial state. For sufficiently simple brains, whose presence is not absolutely crucial for the "household" activities of the organism, this could be all that is needed. For instance, the ability of a lizard to generate a new head supports this view. Salamanders are simple creatures and the mere quantum self-organization without recourse to hologram memory could explain the results of the experiments of Pietch.

2. TGD based model of conscious brain relies on self hierarchy realized in terms of various Josephson currents forming a master-slave hierarchy. Josephson currents do not depend very strongly on the material substrate of brain. Josephson currents and associated supra currents allow also basic wave like phenomena like interference crucial for hologram model. Comparison circuits formed by weakly coupled super conductors and constructive interference of Josephson currents provide a quantum model of brain which resembles hologram model but also differs from it in certain crucial aspects. In particular, reference ray is replaced by reference current representing expected experience. Also comparison circuits in which parallel supra currents of same intensity flow in coupled superconductors, are possible. In this case large Josephson net current is generated by constructive interference of Josephson currents when the phases of supra currents differ by a constant phase.

3. It might be that brain is indeed hologram like in some sense although reference rays are probably not involved. In TGD framework it seems to be possible to abstract from the hologram idea its essentials, namely the fact that a piece of hologram is like a small window. This makes it possible to circumvent the most obvious objections against the idea.

   i) The essential feature of the hologram is that a small piece of a hologram acts like a window. The visual experience is not changed much even when one perceives through a small window. Hence one could give up the assumption that brain prepares holograms. Rather, one could consider the possibility that neurons see part of the same sensory scene through neuronal windows. Seing would be made possible by some field like quantity whose values would be determined by its sources in the same non-local manner as electromagnetic field is determined by its sources. Sources could be either objects of the external world or of model world generated by sensory experience, consisting perhaps of mind-like space-time sheets. Massless fields are especially attractive alternative since the form of the wave is preserved during propagation. Hence coherent photons generated by so called massless extremals [K18] assumed to be associated with the linear structures like microtubules contained inside every axon, are especially promising as a tool of neuronal vision.

   ii) TGD framework provides extremely general mechanisms of subjective and geometric memory corresponding to actual memories and expectations for what will happen and possibly happened. In principle it is possible to avoid memory storage completely. The experiments of Lashley could be understood by assuming only that the sensory data are experienced through neuronal windows. Thus there is no need to store memories in multiple holograms and even holograms are un-necessary. All boils down to the idea of neural window and TGD based quantum model of memory.

   iii) The existence of sensory homunculi is not in conflict with the holographic data representation. What happens is that single neuron sees part of the perceptive landscape through a window. Each neuron could be specialized to particular task, such as recognizing whether particular feature is present in the sensory landscape. This would involve simple comparison circuit making possible feature recognition perhaps involving neuronal wake-up. Feature recognition could rely basically on the generalization of Haken's theory [K27].

6.3 From Holographic Brain To Neuronal Window?

6.3.1 The notion of neural window

All sensory experiences should reduce to representations generated by zero modes, in particular zero modes characterizing classical Kähler field, which can reduce to pure electromagnetic (vision?) or Z^0 field (auditory experience?). If the primary or secondary stimuli generate Kähler electric fields proportional to the gradient of the intensity one can understand the generation of the objects of the perceptive field. If the gradient is strong, as it is on the boundary of the image of the object, the conservation of the Kähler electric flux forces the generation of mind-like space-time sheet at which part of the flux goes. Thus secondary sensory organ would automatically create representation for the objects of the perceptive field as mind-like space-time sheets, which in turn could give rise to selves representing objects of the perceptive field as mental images.

The idea that parts of brain automatically form a model for the objects of the external world as mind-like space-time sheets suggests an interesting connection with the holographic model of

brain [J17] and with micro-tubules as quantum antenna hypothesis [K18].

1. If mind-like space-time sheets are massless extremals, they act as quantum antennae and generate coherent photons. Axons contain microtubules and this leads to ask whether these axons could serve as wave guides for the coherent light generated by the mind-like space-time sheets representing the objects of the external world. Also the vacuum currents associated with these microtubular massless extremals could code the intensity of the coherent light emitted by the mind-like space-time sheets. If either of these guesses is correct, axons provide neurons with a direct sensory window to the representation of the external world formed by the mind-like space-time sheets residing at sensory organs. Coherent photons would also give rise to neuronal lingua franca realized as a direct neuronal/microtubular vision.

2. Sensory window would be in question in a rather literal sense. The fact that a piece of hologram provides the representation given by the entire hologram, albeit in a somewhat blurred form, is essentially equivalent with the possibility to see through a small window. Therefore the idea about neuronal window is in accord with the holographic model of brain [J17, J14], which is based on the idea that all neurons receive more or less the same sensory input, analogous to the visual experience generated by a piece of hologram. Clearly, coherent photons would serve as kind of mass media at the level of brain.

3. What is interesting is that the decomposition of the neuronal vision to a large number of different views represented by small groups of light sensitive neurons could even help to build monocular stereoscopic vision since much more information would be used about the visual field.

4. Music metaphor provides a considerable restriction to the neuronal window idea. The Bose-Einstein condensed photons should correspond to single frequency equal to some cyclotron frequency. Thus it would seem that the sensory input of single neutron is yes/no type. The neuronal window however makes however still sense for neuronal groups: in this case the input would be determined by light and dark pixels. Various nuclei or brain could thus have neuronal windows to cortex and other nuclei of brain.

6.3.2 Neural window and imagery

Mental imagery is something which is difficult to understand in the framework of the standard neuro science. There are empirical results suggesting that mental images correspond to patterns of activity inside cortex, which are three-dimensional and continuous so that neural activation provides a concrete recognizable image about object [J19]. Rather remarkably, also imaginative thought resembles very much visual imagery as is clear from the fact that language is full of visual metaphors [J19]. It is also known that imagery uses same regions of cortex as real sensory experience and the problem is to understand why there is genuine sensory experience involved with imagery.

In the framework of the standard neuroscience the obvious question is why the pattern of the imagery activity is not accompanied by a direct sensory experience. Also the boundary between direct sensory experience and imagination is sometimes problematic: for instance, in the state between sleep and awake, sensory images often enter into mind. During dreams one can have sensory images and eidetic memory is essentially sensory memory. I have a personal experience about extended state of consciousness, or rather whole-body consciousness (this experience actually made me consciousness theoretician!). During this state I could see my thoughts as vivid visual images and had also peculiar odour and taste experiences also reported to occur during mystic experiences. Could the correct interpretation be that thalamus, cortex and sensory organs temporarily formed a larger self during this experience?

If one accepts that sensory qualia are at the level of sensory organs and neural activity only builds symbolic and cognitive representations, it is easy to understand the difference between imagination and sensory perception. Sensory imagination is sensory perception without sensory qualia. Quantum entanglement between sensory organs and cortex and TGD based view about long term memory resolves the obvious objections against this view.

This does not exlude the possibility that neurons have chemical senses and even see and hear. Neurons would not only contribute to our experience. Neurons able to perceive sensorily would

be probably much more effective information processors than neurons which are blind and deaf. Therefore the notion of neuronal window could be useful metaphor in the modelling the neuronal basis of the mental imagery. For instance, the understanding of processes like rotation of an imagined object of visual field provides an exciting challenge. The rotation of mind-like space-time sheet should induce the rotation of the region containing nerve pulse activity. Neuronal window idea suggest that the imagined rotation of the object involves virtual sensory experience generated in the somatosensory- auditory-visual association region of the neocortex (note that only humans have these association regions). This region would be able to form representations of the basic objects of the perceptive field and manipulate them. The imagined rotation of the object could occur here and would be observed by the primary sensory regions.

Sensory perceptions involve a lot of computation like processing at the level of cortex (consider stereo vision as an example), which can be naturally identified as imagination yielding successive models for the external world as consisting of familiar objects. Both the imagined world represented by the mind-like space-time sheets inside cortex and the mind-like space-time sheets in the sensory organ could be seen by the secondary sensory organs in thalamus and compared to see whether the imagined world yields the same sensory input as the real world. The result of the comparison would be fed back to cortex as a nerve pulse pattern serving as a feedback modifying the model.

6.3.3 Neuronal window and blind sight

The phenomenon of blind sight [J20] suggests that there is kind of a Zombi within us [J9], which can see but that this vision does not give rise to a conscious vision. Typically persons who have blind sight can grasp the object of the visual field once they have been told that it contains the object. The Zombi within us seems to be much more rapid and reliable than the conscious "I" in its responses but it seems to be much less flexible. It also seems that Zombi within us cannot be cheated by illusions unlike conscious "I", which suggests that much less theorizing and pattern recognition is involved. Rapid responses of Zombies within us are certainly consistent with the fact that cortical processing is not involved. Non-flexibility would be the price paid for the reliability and absence of higher level cognitive processing.

One can imagine many models for Zombi within us and probably there are many of them (and they are actually not Zombies at all!).

1. Thalamus projects sensory data to amygdala which is often called brain inside brain, or emotional brain. Amygdala would thus have neuronal window to to thalamus and could give rise to unconscious-to-us mental activity responsible also for the blind sight. Also the sensory perception at the level of retinae might be enough if one assumes that primary sensory qualia are at the level of sensory organs.

2. Formation of the symbolic representations for the objects of the perceptive field could occur also in the thalamic nuclei.

3. The decomposition of the perceptive field to objects could occur for the first time already at the level of retina and the coherent light from the mind-like space-time sheets provides a representation of the visual field seen by neurons of thalamus, whose regions serve as secondary secondary organs identifiable Zombies within us (Zombies only from our view point!).

6.4 Possible Evidence For The Neuronal Window Idea

To find whether the neuronal window based on coherent light hypothesis could make sense, it would be important to eliminate the effects of the higher level information processing. This requires the study of simple organisms having primitive sense of vision. There is indeed experimental support for identifying the coherent states of photons as associated with vision. It is known that some mono-cellulars possess elementary vision based on the microtubules [I3]. The emergence of the multi-cellulars during the Cambrian explosion was preceded by the appearance of the microtubules. If the emergence of the microtubules meant the emergence of the visual consciousness in the length scale of the cell, then the formation of the multi-cellulars as cell societies can be understood as a natural consequence.

The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. The coherent light in question could be identifiable as bio-photons of Popp [I6]. The architecture of retina is "wrong" from the engineering point of view. The ganglial axons feeding sensory input to brain are in front of the retina. This is in accordance with the TGD based model of vision in which the photons of incoming light Bose-Einstein condense on the ganglial axons and amplify the signal to the thalamus.

A further piece of evidence comes from the work of Callahan about the sense of smell of insects [I7]. Many insects, such as moths and ants, are known to be attracted by light, say candles and electric lamps and Callahan took as his challenge to understand what is involved. Callahan discovered that insect's olfaction is not based on chemistry (alone) but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other biomolecules. Insects see rather than smell the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify the incoming infrared radiation. Callahan also observed that the oscillation of insect antennae induce maser like emission from scent/etc. molecules by creating an oscillating emf. Thus sensory experiencing seems to involve active participation from the part of insect. In any case, the results of Callahan suggest that coherent light could be important also in our neuronal sensory experiencing.

The infrared light emissions from pheromones mediate sexual messages in case of insects. Quite remarkably, pheromones are known to mediate sexual and social signals also in case of many mammals. For instance, certain chemical messages from a female mouse can make male mouse to mate immediately while certain chemical messages from other males make him agressive. Many mammals, for instance rodents, are known to possess vomeronasal organs, small cigar like sacks containing neurons and having length of order few millimeters [J1], giving rise to an accessory olfactory system, which is known to have much more primitive structure and to work in different way than the ordinary olfactory system. It is also known that this systems bypasses cerebral cortex in rodents. There is evidence that even humans have the ability to sniff certain chemicals mediating social and sexual signals without being aware of it and there is already now an entire perfume industry based on this evidence. The chemicals giving rise to sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in case of both insects and mammals, is hardly an accident and suggests that the sensory mechanism must be the same and be based on the infrared emissions by pheromones. If the response is at neuronal level and if the cortex is not involved, one could understand why these messages are not experienced consciously. One could test this hypothesis by finding whether coherent infrared radiation at frequencies emitted by pheromones can affect the behaviour of higher mammals including humans.

There is a further peculiar co-incidence: the cascade of transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odours whereas the receptor cells that respond to sound use a very different system [J1]. Could this mean that also the experience of odour primarily involves the detection of (also) infrared light so that humans would not basically differ from insects or that olfactory system has evolved from the receptor neurons originally sensing infrared light? This would conform with the idea that the Kähler field generated in ear corresponds to classical Z^0 field, which does not generate coherent photons but couples with neutrinos. One must however notice that the resemblances between visual and linguistic imagery suggest that some part of ear generates cognitive representation based on coherent light and experienced by the secondary sensory organs in the thalamus.

6.5 Massless Extremals As Quantum Holograms

It took long time to really understand what MEs really and along with this understanding came the vision about precisely how MEs could act as holograms and what biological functions these holograms could correspond to. It indeed seems that massless extremals (MEs) are perhaps the most fundamental solutions of the field equations as far as TGD inspired theory of consciousness is considered. What is important is that MEs play both the roles of quantum gravitational holograms [B1] and dynamical holograms [B2].

The hologram principle of quantum gravitational theories roughly states that the quantum theory in space-time with boundary reduces to a conformal quantum field theory at the boundary. If Kähler action were deterministic, precisely this would happen. The construction of the WCW

geometry relies crucially on the assumption that the complications due to the non-determinism of Kähler action do not radically modify the picture resulting assuming complete determinism.

It has indeed turned out that the basic construction in which everything to the light-like boundary of M^4_+ (moment of big bang) acting as a hologram in quantum gravitational sense and defining conformal quantum theory, generalizes. The basic construction survives as a template of a more general construction in which also the light-like boundaries of MEs having always light-like M^4_+ projection are taken into account besides δM^4_+ as surfaces at which initial values can be prescribed arbitrarily. This brings in also time effectively absent in a strictly deterministic theory. The quantum gravitational hologram defined by δM^4_+ is replaced by a fractal structure formed by δM^4_+ and Russian doll hierarchy of the light-like boundaries of MEs inside MEs. The super-symplectic and superconformal invariances of the light-like boundaries generalize in an elegant manner on basis of the basic properties of MEs.

There are good reasons to expect that the light-like selves defined by the boundaries of MEs are fundamental in TGD inspired theory of consciousness. The super-symplectic quantum states associated with the light-like boundaries are genuine quantum gravitational states defined by WCW spinor fields, whose dependence on configuration space fiber degrees of freedom does not reduce to mere vacuum functional, and therefore do not possess any quantum field theoretic counterparts. They are state functionals in the world of worlds, so to say, and therefore should represent highest level in the hierarchy of quantum control in living systems.

MEs carry light-like vacuum currents. In passive state these currents are Z^0 currents whereas in active state, obtained by a color $SU(3)$ rotation, the current is electromagnetic and generates coherent state of photons. One can say that the light-like current provides a dynamical variant of the diffraction grating defined by the ordinary static hologram. This leads to a model of living matter in which the coherent states of ordinary photons and colored WCW photons act as control commands. Their phase conjugates (time reversals) in turn correspond to the time reversed commands. What is especially beautiful is that simple reference wave can activate arbitrarily complex hologram acting as a control command. This provides new visions about healing by time reversed reference waves forcing the biological program responsible for an illness like cancer to run backwards in time. One can also construct a general theory of sensory representations based on MEs [K25]. To sum up, it seems that the hologram principle is they key element of brain and biological functioning but in a sense somewhat different from what it was believed to be by the pioneers.

6.6 The Notion Of Conscious Hologram

The notion of conscious hologram is the last step in the development of ideas related to biholograms. The basic challenge is to generalize the notion of the ordinary hologram to that of a *conscious* hologram, about which bio-holograms would be examples. The notion of quantum gravitational hologram is defined at the level of geometric, purely physical existence whereas conscious holograms exist at the level of subjective existence defined by the sequence of quantum jumps and giving rise to the self hierarchy. Of course, these two notions of hologram must be closely related.

The notion of conscious hologram combines the saint and sinner aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand.

In nutshell, the notion of conscious hologram follows from the topological field quantization. Classical fields and matter form a Feynman diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules, ...), and virtual bosons are replaced by topological light rays ("mass-less extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to "real photons" are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by "virtual photon" MEs also analogous to laser beams. Hence

also "self-holograms" with no laser beam from external world are possible (brain without sensory input).

The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as mass-less particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length. The particle like high frequency MEs induce "bridges" between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. Under certain conditions the leakage followed by dropping back to the larger space-time sheet can also give rise to a many-sheeted laser. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competition.

The 3-D vision associated with ordinary holograms generalizes to stereo consciousness resulting in the fusion of mental images associated with the points of conscious hologram [K2].

7 Four-Dimensional Fractal Brain As An Associative Net

The identification of brain as 4-dimensional fractal associative net seems to provide a promising paradigm for the understanding of brain functioning. The associative net structure and mere real physics considerations are certainly not all that is needed. p-Adic physics as physics of cognition means that fundamental cognitive representations correspond to p-adic space-time regions, and, needless to say, in this respect huge amount of work remains to be done in order to build connections between theory and observations. In the following only the real physics aspects of brain as an associative net are considered.

7.1 Brain As An Associative Net

The notion of associative net suggests a general paradigm making it possible to understand brain functioning. The subjective time development of an associative net consists of experiences representing associations $A \to B$. In case of brain associative net is a network of neurons. "A$\to$ B" association is made possible because the emission of synaptic vesicles implies that postsynaptic and presynaptic neuronal space-time sheets form a connected space-time sheet. A is represented by the various presynaptic inputs and B corresponds to the output of the postsynaptic neuron. A and B can correspond to various sensory qualia or Boolean statements represented in terms of memes which in turn decompose into sequences of codons consisting of 126 binary digits and represented in terms of cognitive neutrino-antineutrino sequences. Memetic codons could also have interpretation as binary representations of integers providing quantitative measures for qualities. In Boolean case associations are experienced as logical implications "If A then B" is true. A and B can represented arbitrarily complicated statements composed of elementary statements. Neuron receives the conclusions of postsynaptic neuron as premises and feeds its own conclusion as premises to its own postsynaptic neuron.

Self-organization by quantum jumps selects gradually the allowed "A $\to$ B" correspondences as asymptotic self- organization patterns. Quantum self-organization and quantum statistical determinism suggest a natural Darwinian selection of the memes caused by the dissipation inside self and completely analogous to protein folding. The correspondences $A \to B$ would be determined by chemical macro variables characterizing the state of the neuron and chemical transmitters would play a crucial part in the learning of the responses. Synchronization is necessary for the function of the network. Emotional control can modify the associations "A$\to$ B" in long time scale (conditioning and de-sensitization): for instance, some conditions belonging to premises A of Boolean association drop away or B can change.

7.2 4-Dimensional Fractal Brain

One needs two additional principles in order to have vision about brain a la TGD.

1. Brain is 4-dimensional in well-defined and very restricted sense. This follows from the classical non-determinism of Kähler action. Self-organization by quantum jumps replaces the classical space-time surface repeatedly with a new one and the final result represents classically the activity as it would be detected by a completely mechanical instrument. One can say that the classical time development describing say sensory experience, long term memory, motor activity or logical thought is gradually refined by starting from a rough sketch and making successively finer corrections iteratively. The process is like making a painting stating from a rough sketch. The four-dimensionality of the brain and difference between subjective and geometric time is absolutely essential element.

2. Fractality is second element. The successive refinement process proceeds from long to short time and spatial length scales. Thus large and slow neural circuits correspond to rough sketches and small and rapid circuits to small details. Small circuits are simultaneously active (in sense of subjective time) in the entire space-time region defining the duration of the activity. Thus again the 4-dimensionality of brain is crucial.

The notion of associative net suggests a very general view about how brain functions and gives rise to conscious experiences. Brain itself is a huge associative circuit but decomposes into more or less autonomous subcircuits.

7.3 Sensory Experiences, Logical Thinking, Associations And Simulations

The notion of associative net allows readily to understand what happens in sensory experiencing, logical thinking, formation of associations and imagination

1. Sensory representations are formed by an iterative process involving comparison which takes also care about the computation of unknown data such as distances of the objects of the perceptive field. For instance, various cortico-thalamic loops could be related this process. The updating of the zero modes of the sensory inputs from sensory organs is performed in the thalamic neurons receiving real sensory input from the sensory organ and expected sensory input from cortex. An automatic comparison process possibly realized at quantum level in terms of two weakly coupled super conductors is in question [K19, K20]. This process involves also the concentration of attention to specific features of the sensory experience.

2. Neuronal input represents in general case several sensory modalities and conscious output single sensory modality or "Boolean quale" represented by memetic codon. Thus associative circuits can represent the formation of associations in associative regions of brain. Note however that pre- and postsynaptic neurons in principle represent always an association at the neural level and neuronal associations are basic building blocks of "our" associations involving entire groups of neurons and entire neural circuits. Also the formation of associations is very probably an iterative process.

3. The circuits of the associative net provide an ideal realization for predictive simulations of type $A \to B \to ....$ in terms of various kinds of sensory qualia. This makes possible imagination. The difference with respect to the standard neural net is that conscious neuron represents some sensory modality or Boolean modality: this makes the simulation "real" and assigns meaning to nerve pulse patterns: note that the generation of meaning is basic problem of the neural net models of consciousness. This kind of simulation circuits are expected to be related with frontal lobes and to be crucial for the planning of the future activities. Motor circuit involving basal ganglia, thalamus and prefrontal cortex is also a possible example of this kind of circuit. Again iteration bringing in more and more details to the motor plan is involved.

4. Logical deductions do not differ from simulation in an essential manner: the only difference is the replacement of the temporal causation by logical causations. In case of logical deductions premises and conclusions are coded to memetic codons represented by cognitive neutrino pairs. Much of our logical thinking might be actually habitual and almost deterministic deduction sequences associated with circular loops and unconscious to us. Logical consistency

is thus not guaranteed and, unless the brain of a ideal mathematician is not in question, and results only from the logical consistency of the external world.

7.4 Formation Of Long Term Memories

Associative circuit give rise to learning of long term memories. Short term memories correspond to reverberating nerve pulse patterns in closed circuits giving rise to a repetition of the same component of experience again and again. In Boolean case periodic association sequences represented by closed loops $A \to B \to ...A$ correspond to tautologies. Reverberating memories are remembered with high probability if long term memories are realized as geometric memories. The reason is that there is high probability for a randomly generated cognitive space-time sheet in geometric past to reside on the region occupied by a reverberating loop. Repetition is the manner to learn. It is rather plausible that Nature has discovered effective learning in this manner and there are indeed circuits associated with long term learning.

A quite recent finding in neuroscience is that during the learning of spatial tasks hippocampus and some other parts of brain generate long spike sequences. Typical interval between spikes varies between 1-2 milliseconds. This would mean that a sequence of 126 spikes would correspond to.1-.25 seconds which is of the same order of magnitude as the duration of our self identified as the duration of immediate sensory memory. Also long term memories are constructed as kind of artworks or charicatures.

7.5 Planning And Realization Of Motor Programs

Associative circuits are associated with planning and realization of the motor programs.

1. Motor activity is the reverse of sensory experiencing in a well-defined sense. The imagined motion of the object in the working memory representing perceptive field is transformed to the motion of the real world counterpart of the object so that motor organs are like puppets bound to axonal strings and moved by the little man in the brain. The perceptive field, where imagined motion occurs is located in the frontal cortex with primary motor cortex excluded. Several copies of the perceptive field providing different representation of the perceptive field are probably involved as "working memories". These working memories are formed by topographical maps between different parts of brain.

2. Planning of the motor action is almost motor action: the only difference is that the last stage when nerve pulse patterns characterizing the motion are fed to motor organs is not performed. Plan is essentially four-dimensional pattern of nerve pulse activity.

3. The ability to realize plan seems to require that it is memorized: this would require that the performance of the motor activity is repeatedly imagined and finally allowed to occur. Thus the nerve pulse activity representing plan becomes a periodical nerve pulse pattern and the actual motion starts when the coupling to primary organs is turned on. As a matter fact, 4-dimensional brain allows to give up the assumption about reverberation. Also the activation of a motor plan in the geometric past could be possible! This would be consistent with the results of the experiments of Libet about active aspects of consciousness: what was observed that neural activity started before the conscious decision to raise index finger. The relevant time scale would be of the order of second. Of course, an interesting question is whether adult person could initiate in the geometric childhood a motor action affecting dramatically the geometric present, say leading to traffic accident! This possibility would seem to lead to paradoxal looking consequences.

4. Learning of a motor skill presumably means that motor plans very rapidly self-organize to their final shapes. Learned skills correspond to motor plans which are winners in the Darwinian selection associated with self-organization.

5. The realization of the motor plan requires initial value sensitivity and muscles indeed provide an excellent example of an initial value sensitive system in which single nerve pulse generates macroscopic motion.

Motor action is planned and performed as a four-dimensional pattern. Construction of the motor plan means that *four-dimensional* virtual perceptive landscape is gradually deformed into the desired shape. Motor activity can be seen as a fractal top-down process analogous to the construction of a space-time fractal: fractal classical determinism of Kähler action is absolutely crucial for this and $1/f$ noise [K20] is one of the consequences of the fractality. The non-determinism of the p-adic differential equations is very probably a direct correlate of the classical non-determinism of the Kähler action.

Macroscopic motor activity starts from a rough 4-dimensional sketch of motion which is gradually refined to the final artwork and possibly memorized to represent a reverberating structure. The sketch and its various refinements are represented at the virtual perceptive landscape of the premotor cortex. More concretely:

1. First a large quantum jump realizing in rough sense the motor action occurs (for instance, hand grasps the object): this corresponds to certain classical time development starting in geometric past on new space-time surface. This stage corresponds to the activation of slow and large neural circuits with time scale characterizing the entire motion. This is like construction of the first sketch of a 4-dimensional fractal representing motor plan.

2. After this a cascade of smaller scale quantum jumps adding details to the motor plan occur: this is like adding further details to a four-dimensional fractal. The neural circuits involved are smaller and faster. Addition of details takes places in the entire time interval T of the geometric time associated with the full motion. This involves multitime moments of consciousness so that also neural circuits are active in the geometric interval defined by T.

7.6 Language

Memetic codons represented as temporal sequences of 126 binary digits should be the basic building blocks of the linguistic consciousness. The value of single binary digit is represented at the neural level by the presence/absence of nerve pulse and at the level of cognitive consciousness by the direction of the spin of the cognitive antineutrino. Boolean interpretation is not necessary: the interpretation of the sequences of 126 bit as integers providing quantitative measures for, say the intensities of the sensory experiences, is also possible. The proposed quantum models for the quantum correlate of hearing and for Boolean mind [K17, K13, K14] suggest that sound frequencies are mapped to Z^0 magnetic cyclotron frequencies of ions whereas thinking corresponds to Z^0 magnetic cyclotron frequency which is above the range of the audible sound frequencies. This supports the idea that memetic codons are as such experienced as some kind of internal speech and also that only certain brain regions allow Boolean mind: the generation of cognitive neutrino pairs indeed requires strong axonal Z^0 magnetic fields which could be present only in the postsynaptic axons of the associative regions of cortex.

The differences between right and left brain suggest that the output axons in the associative regions of left brain represent information using cognitive neutrino pairs whereas the corresponding axons in the right brain hemisphere could represent information in terms of Z^0 cyclotron frequency varying above the audible frequency range (left brain talks and right brain sings!). If audible frequencies are involved, Josephson frequencies must be sufficiently far from cyclotron frequencies so that right brain imagines of hearing the thoughts rather than actually hears them. Unless higher harmonics of the cyclotron frequency are used (which is quite possible!), this requires parallel mode of representation since music metaphor suggests that the Z^0 cyclotron frequency of the axon is not variable.

Language circuits would be involved with the translation of the Boolean statements to linguistic expressions coded eventually to motor activities yielding speech. This process is only special case of a motor activity and thought as an internal speech is like a motor plan. Language represents one possible realization of the memetic code analogous to the translation of DNA sequences to proteins. It is instructive to look what contraints the memetic code poses on the general structure of language. The first empirical fact is that the meaning of the linguistic experience is insensitive to the local variations in the speed of speech. In particular, the repetition of a phoneme is usually interpreted as providing no additional purely linguistic information. On the other hand, the linguistic meaning of speech is determined by its purely local structure.

These facts are consistent with the hypothesis that phonemes are the basic codons of speech having fixed duration and that a repeated phoneme has the same linguistic meaning as single phoneme. This supports the identification of the phonemes as representations of the memetic codons: phoneme would thus represent single linguistic sub-self. By the previous estimate the duration of the memetic codon should have duration in the range $.1 - .25$ seconds. A more precise estimate comes from the detailed model for the physical realization of the memetic code and from the model of nerve pulse [K14, K23]: the resulting estimate for the duration of the memetic codon is about .14 seconds. The facts that a frequency $f \sim 10$ Hz represents the fundamental frequency associated with speech organs and that 20 Hz frequency represents the lower limit for the audible frequencies are consistent with the identification of the phonemes as linguistic images of the memetic codons.

Note that cognitive neutrino pairs of duration of order one millisecond are not experienced as separate components of conscious experience if time averaging is involved with temporal binding. This is consistent with the fact that language does not contain any smaller consciously experienced constituents than phonemes. Not that speech represents (very-!) many-to one expression of the memetic code (faithful coding would require language with 2^{126} different phonemes: this gives good idea about the present evolutional level of human culture!). Genetic code is not unique and some cell organelles, such as mitochondria, possess their own genetic code. Various languages could correspond to different translations of the memetic code to nerve pulse patterns in turn coded to motor activities representing expressions of language. The Mersenne prime $2^{127} - 1$ could be clearly re-christened to be the number of Babel!

8 Connection With The Neuroscience View About Brain

In the following an attempt to formulate a connection with the brain as it is seen in neuroscience is made. Learning is basic aspect of intelligence and the discussion concentrates on this aspect of intelligence.

8.1 A Simple Model For Cognition

Self hierarchy and summation hypothesis allows to construct a very general model for cognitive processes including as a special case thinking, analysis of visual experience, and language. In nutshell: cognitive process could be regarded as cascade like process leading to a generation of selves followed by generation of sub-selves for these leading to.... Quantum jump becomes the building block of cognition and thought but is not sufficient alone. p-Adic space-time sheets as correlates of cognition provide geometric correlates for thoughts, intentions, plans, etc.. are a fundamental element of cognition. The intersection of real and p-adic worlds understood as partonic 2-surfaces allowing an interpretation in both real and p-adic sense and the intersections of real and p-adic partonic 2-surfaces consisting of rational and common algebraic points define cognitive representations. Negentropic entanglement is possible only in the intersection in accordance with with the vision that cognitive representations carry the information.

8.1.1 Quantum criticality of TGD and existence of selves

The model of cognition provides a new view to the role of quantum criticality of TGD. One consequence of the quantum criticality could be the existence of a lot of sub-systems which are near the critical line at which phase transition changing the local topology (real or p-adic) occurs. TGD universe would be in a state of maximal alertness ready to generate cascades of selves representing cognitive acts. Our cognitive acts would be only part of the cognitive acts of the entire Universe proceeding from top to bottom as infinite trees with branches representing new selves and nodes representing moments of wake-ups for the selves. Or expressing it in the terminology of AI: we would be like subprograms of infinite program represented by entire universe. The presence of higher level selves means that cognitive acts can proceed from the level of even entire biosystem to the level of DNA. This encourages to interesting speculations: for instance, the ideas of Sheldrake about learning at the level of species and even biosphere might find justification [K27].

Number theoretical criticality is an important aspect of quantum criticality and is taken to mean that life and conscious intelligence reside in the intersection of real and p-adic worlds, where discrete cognitive representations are possible.

8.1.2 Quantum jump as cognitive process

U process followed by a cascade of state function reductions will be identified as the basic cognitive act.

1. State function reduction can be characterized as a binary tree. At each step of the state function reduction cascade some sub-selves manage to remain unentangled, some sub-selves lose their consciousness by developing entropic bound state entanglement, or experience expansion of consciousness by entangling negentropically. A particular branch of the process stops if sub-self allows no decomposition to entropically entangled but otherwise free pieces. What is new is that the entanglement is also time-like and time-like entanglement turns out to be central for understanding of what happens in learning.

2. The binary tree of state function reduction has a natural ordering. This ordering need not have any correlate at the level of geometric time. At the level of subjective time and conscious experience the correlate for ordering could exist but if self experiences its sub-selves as averages of sub-sub-selves this cascade is experienced only partially by given sub-self. One can of course argue that self wakes up in each quantum jump separately and quantum jump sequence should be seen as a sequence of "awakenings" (I used this term earlier): this awakening is however something different from the emergence of mental image. Maybe time-like negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is which binds this sequence of "awakenings" to a continuous stream of consciousness that we experience.

3. The outcome of the state function reduction is random when it leads to un-entangled sub-self but statistical determinism implies reliability at the level of ensemble. For negentropic entanglement state function reduction is nearly deterministic process and in this case one can speak in reasonable approximation about an iteration of a unitary processes defined by the powers of U. This iterative process defines a self-organization process expected to be also behind learning.

4. One possible interpretation of the self cascade is as a representation for an abstraction process representing thoughts about thoughts about... Our poor ability to form statements about statements about... would correspond to the fact that self experiences only its sub-selves directly. Another interpretation is as analysis, in which initial experience gradually sharpens and gets more and more structured during the decomposition into sub-selves. Sub-selves could be thought as symbols of language or as logical statements or objects in picture: interpretation depends on what kind of cognitive process is in question. This process occurs in several time scales- even in the time scale defined by human life cycle. The modular structure of cognitive acts is also analogous to the modular structure of a computer program: starting of subprogram means the reduction of entanglement for the corresponding subsystem.

One can see this process also at the level of imbedding space correlates.

1. Selves wake up and begin to perform quantum jumps. The imbedding space counterpart for self is CD (causal diamond) characterized by time scale coming as powers of two and is scaling like the value of Planck constant. Subselves correspond to sub-CDs. Wake-up requires a feed of metabolic energy to destroy the bound state entanglement. Self could be also created from vacuum or disappear to it in a quantum jump generating a completely new CD or annihilating it.

2. Cognitive process proceeds in a cascade like manner starting from the root of tree formed by CDs and going downwards along the tree choosing at each node some branches. For instance, understanding of a sentence would correspond to waking up of large self A representing sentence in its entirety, words its sub-selves B_i, phonemes to sub-selves C_{ij} of B_i, etc...

waking-up in this order. Similarly, the act of decomposing the figure to objects and of objects to sub-objects would correspond to a temporal sequence generating selves within selves. Negentropic entanglement would be crucial for experiencing both the whole and the parts simultaneously. Background would be the largest conscious self and objects would correspond to a sequence of selves. Selves C_{ij} and further sub-selves can be generated before generation of next C_{i+1}: this should occur in case linguistic mental image: generation of word self would be followed by the generation of syllables and phonemes and only after this would next word be generated. Time non-locality of self experience with respect to geometric and subjective time would be essential.

8.2 Cognition, Learning, And Negentropic Entanglement At The Level Of Brain

Negentropic entanglement is information carrier and learning is gaining information. Does this mean that learning takes place automatically in the intersection of real and p-adic worlds? Unitary U-matrix between zero energy states characterizes single step of quantum jump sequences and for negentropic states the state function reduction is not random process and in the first approximation U^N characterizes the outcome of N subsequent quantum jump so that learning process should be characterized by the iteration defined by the powers of U.

In neuroscience synaptic contacts are believed to be crucial for cognition, learning, and memory and it is interesting to try to relate this picture to the TGD based vision about conscious information and learning. How negentropic entanglement could be realized at the level of brain? Is it time-like, space-like, or both? Can one assign the generation of negentropic entanglement between neurons to the attachement of neurotransmitter to receptor? Can one relate the general quantum model of learning to the neuroscience based model of learning relying on the growth of brain cells, synaptic contacts, and synaptic plasticity?

8.2.1 The picture of the standard neuroscience about learning

It is good to summarize first the vision of standard neuroscience about the neural correlates of learning.

1. Basic notions

Synaptic transmission [J3, J8] is believed to be a key element of brain consciousness. Synaptic transmission takes place as synaptic vesicles carrying neural transmitter. Given neuron can release several transmitters. The transmitter molecules bind to the receptors at the postsynaptic cell membrane. Depending on whether this process leads to a de-polarization or hyper-polarization one speaks of excitatory or inhibitory receptors (activation potentials). Since most transmitters attach mostly to either kind of receptor, one speaks about excitatory and inhibitory transmitters although this terminology is misleading. Receptors can be classified to relatively simple ion channel receptors and more complex receptors involving second messenger proteins.

The belief is that the primary process does not involve communications with genome but if one accepts the DNA as topological quantum computer picture-in particular, on the existence of magnetic flux tubes connecting cell membrane and DNA nucleotides- the possibility that these communications are an essential element of process and that a new kind of gene expression at cell membrane level is involved. The communication to the DNA could take with light velocity if massless extremals are involved.

The synaptic strength characterizes the sensitivity of the postsynaptic neuron to the firing of the presynaptic neuron. It depends on the density of receptors and their activity as well as the total amount of neural transmitter transferred between neurons determined by the number of synaptic vesicles transmitted. This in turn depends on the size of the synaptic button. All these parameters are affected in learning understood as a change of synaptic strengths. It must be emphasized that learning in this sense should be seen as a neural correlate for conscious (or unconscious-to-us) learning and possibly of memory. What is essential that the respose of the postsynaptic neuron changes. This picture relies on the technical assumption that learning reduces to the changes of synaptic strengths. This assumption is probably an over-idealization: much more probably happens.

2. Learning at brain level

Learning in the sense as it is defined above can take place at the level of both anatomy and physiology. Learning at the level of anatomy can mean growth of new synaptic connections and of even new neurons. For instance, the growth of new neurons in hippocampus is now understood to be essential prerequisite for learning. It is believed that the information from the connections of old neurons is transferred to those of cortical neurons. This can of course happen but in TGD framework this is not necessary since the new view about time allows to interpret memory as communications with the brain of the geometric past.

Learning at the level of physiology is known as synaptic plasticity [J7] and involves several mechanisms. Synaptic plasticity means that the sensitivity of the postsynaptic neuron to the signals from presynaptic neuron can change.

1. Sensivity means essentially the probability for the firing as a response to the firing of presynaptic neuron and this is controlled by the sign and magnitude of the activation potential and the increase of the sensitivity means a generation of stronger de-polarization or weaker hyper-polarization. Postsynaptic neuron can become more or less sensitive to the presynaptic neuron whereas presynaptic neuron can send stronger signal by increasing the number of synaptic vesicles.

2. The change of the sensitivity of the postsynaptic neuron can take place several mechanisms [J7].

   (a) The first mechanism involves the modification of protein kinases whose function is to phosphorylate the receptor which means essentially providing it with metabolic energy. The effectiveness of the protein kinases is regulated. Second mechanism depends on second messenger neurotransmitters regulating gene transcription and regulates the levels of key proteins at synapses. Gene expression is affected in this mechanism and the effect is long-lasting.

   (b) Third mechanism affects the number of ion channels (ion transfer between cell interior and exterior is basically responsible for the activation potential) and is involved with long term potentiation (LTP [J6]) and - depression (LTD [J5]) believed to be central mechanisms of learning memory. LTP is believed to be of central importance in hippocampus. The change of the density of receptors is one manner to achieve LPT or LTD. For so so called AMPA receptors [J2] to which glutamate binds this mechanism is well-established. Also phosphorylation and dephosphorylation of AMPA receptors and change in the probability of glutamate release is a decisive factor.

3. The notion of Hebbian learning [J4] applies to LTP. Hebbian rules summarizes the above picture as simple mathematical rules allowing computer modelling. When pre-synaptic and postsynaptic neurons fire simultaneously, synaptic connections are affected. Weak stimulations of several pathways add up. Also temporal summation takes place if the frequency of firing is high enough. Strong stimulation of one pathway affects also other pathways. More general formulation of the rules does not require the firing of the postsynaptic neuron. For anti-Hebbian learning de-sensitization takes place. Also non-Hebbian learning is believed to take place.

4. The change of the postsynaptic action potential need not be the only outcome of learning. If this were the case, the huge number of neural transmitters and receptors inducing different responses would not be needed. The change of the sensitivity is only one aspect of learning and as its relationship to conscious learning is unclear.

8.2.2 TGD based vision about cognition and learning

In the following a brief summary about TGD inspired view concerning cognition and learning in general and at brain level is given.

1. Basic ideas

The general ideas about cognition have been also discussed but is useful to summarize them again.

1. Sub-self interpreted as a mental image is key notion. Subselves wake-up, fall asleep, and fuse together losing consciousness or experiencing expansion of consciousness.

2. The cascade of state function reductions can be regarded as an analysis leading to a final state in which sub-selves are either entropically or negentropically entangled systems. The latter systems can be seen as negentropic mental images resulting as sub-selves fuse together. In the case that two sub-selves are involved, the resulting mental image can be regarded as an abstraction or rule such that the state pairs appearing in the superposition correspond to the instances of the rule. If one state pair dominates then association in classical sense is in question in good approximation.

3. Negentropic entanglement can take place between systems which belong to same or different number fields and gives rise to various kinds of conscious experiences. At least in the case that the other system is p-adic, negentropic entanglement should be a correlate for the conscious experience of understanding.

4. Zero energy states for brain represent rules as pairs of positive energy (initial) and negative energy (final) states. M-matrix characterizes zero energy state and defines a rule representing "laws of physics" at the level of conscious experience. Different M-matrices are orthonormal with respect to each other and in ensemble all of them appear and each of them can be also regarded as representing one particular instance of a rule.

A new element is that unitary time evolution characterized by U-matrix forces the learning to occur in the sector of state space containing zero energy states for which positive and negative energy parts of the states are negentropically entangled. U-matrix and its powers characterize the learning process. When the states are negentropically entangled, state function reduction for M-matrix is not a random process but leads to a unique state maximing negentropy and in a good approximation the restriction of U matrix to these states codes for the evolution of M-matrix. U^N restricted in this manner characterizes the M-matrix after N quantum jumps. Therefore learning is unvoidable in the case of negentropic states and U^N at the limit of large number of quantum jumps characterizes the learning. The value of N is of course limited by the size of CD assigned to the learning system. One can of course wonder whether the unitary period is following by a return to unentagled state via the liberation of metabolic energy associated with the negentropic entanglement.

The powers of U define an iterative map and iterative maps are the key element of self organization and also one of the main tools of generating fractals [K27]. Quantum classical correspondence therefore suggests that 4-D fractal self-organization patterns define the space-time correlates for learning.

2. General view about learning at the level of brain

M-matrix for brain codes its view about laws of physics. In diagonal form represents pairing of initial and final states as rules $A \to B$. For instance, in fermionic degrees of freedom these rules can be interpreted as Boolean rules. More generally, the interaction as quantum associations containing superposition of instances of the associations are in question. Huge quantum superposition of rules is possible since the number of neurons large and the information storage capacity of entanglement increases exponentially with the number of neurons.

U-matrix approximated as a matrix restricted to represent unitary evolution of negentropic zero energy states assignable to brain provides the first principle description for learning as the sequence of powers U^N. In the models of associative learning learning is reduced to a local process expressible in terms of changes of the synaptic contacts. This suggests that the basic building block of U matrix is synaptic transmission. This means an analogy with the basic braiding operation of the neighboring strands represented as R-matrix defining the unitry matrix for topological quantum computation [K8]. There is also an analogy with generalized Feynman diagrams. The incoming particles would be neurons. Synaptic transmission analogous to particle exchange between two neurons. U matrix can be regarded as a quantum superposition over all possible diagrams containing arbitrary number of synaptic transfers. Multiverse picture at neural level thus results as one might expect since macrotemporal and macroscopic quantum coherence is involved. If the situation reduces in a reasonable approxiation to a description in terms of synaptic transfers one

can in principle describe synaptic plasticity, LTP, and LTD and other mechanisms to in terms of the basic building block of U associated with the synaptic transmission and mathematically analogous to Feynman propagator. The binding to the receptor could induce communications with genome and also the U-matrix assignable to topological quantum computations at the DNA level might be involved.

As such this picture provides only a first principle formulation for what conscious learning is and it requires a work to deduce predictions testing this vision or at least to gain understanding using this vision. A key aspect of negentropic entanglement is that it carries metabolic energy. This has been already proposed to provide a first principle explanation for the notion of the high energy phosphate bond crucial for the understanding of $ATP \to ADP + P_i$ process defining the key stop of metabolism [K12].

Also space-like negentropic entanglement is possible for positive (negative) energy parts of the states. In particular, negentropic entanglement between presynaptic neuron and postsynaptic genome generated by the attachment of the transmitter to the receptor might make sense. There is temptation to assign to this connection a magnetic flux tube identified as a carrier of metabolic energy released in the process and inducing ionic currents leading to the processes affecting the synaptic strength as well as the states of neurons involved. The larger the metabolic energy release is, the more intense are the ionic currents involved and the stronger the modification is. This would provide a first principle explanation for why more effective phosphorylazation of the receptor as a correlate for learning. Of course, the explanation works even without the heavy conceptual machinery if one is ready to accept the somewhat nebulous notion of high energy phosphate bond.

8.3 Negentropic Entanglement And The Role Of Neurotransmitters

Soon after starting to develop TGD inspired theory of consciousness, I somehow ended up to an email correspondence with Gene Johnson who insistently emailed me links to abstracts about neuroscience. I read the classic Bible about brain by Kandel *et al* [J13] and tried to make sense of it in my own conceptual framework. This was of course hopeless task since I had only the notions of quantum jump and self. The feeling that something very simple -about which I do not and perhaps cannot ever have a slightest clue- must be behind this incredible complexity made the situation really frustrating. The deeper meaning of EEG, nerve pulse neurotransmitters, hormones- actually of entire brain chemistry and also biochemistry- remained a total mystery.

8.3.1 Development of ideas

After the required number of years however some concrete ideas began to emerge.

1. The notion of magnetic body with fractal onion-like structure meant a decisive step of progress. Also the hierarchy of Planck constants and dark matter as controller of visible matter in living systems emerged. The function of EEG as communication and control tool of magnetic body using biological body as a motor instrument and sensory receptor looked very natural. This led also to a proposal that there is an entire hierarchy of EEGs and their variants. After several trials a vision about nerve pulses as concomitants of quantum level communications emerged as also a vision about DNA as topological quantum computer based on the flux tubes connecting DNA nucleotides with the lipid layers of cell membrane emerged and providing a function for the intronic portions of genome as carriers of quantum computer programs [K8].

2. Also a vision about the biochemical role of dark matter evolved. In particular, phase transitions reducing Planck constant for a magnetic flux tube would induce its contraction and force biomolecules near to each other. This would explain the miracles of DNA replication, translation, and transcription and quite generally the processes known as aggregation of proteins. The reconnection of magnetic flux tubes changing the topology of the biological Indra's net would be also a central mechanism.

3. The model of nerve pulse and the vision about living matter as a kind of dynamical Indra's net led to a first clear idea about the role of neural transmitters. Transmitters are classified to inhibitory or excitatory depending on whether they increase or reduce the magnitude of

the membrane potential. This property is however a property of the receptor rather than that of the transmitter. The same transmitter can have both excitatory and inhibitory receptors although often either receptor type dominates. The proposal was that neural transmitters are associated with the ends of the links of the 4-dimensional web connecting neurons to each other. Neurotransmitter attaches to the plug defined by the receptor connecting the communication wire from presynaptic neuron to the flux tube leading to the passive portion of postsynpatic DNA strand acting as sensory receptor. This would make possible rapid communications to DNA. The corresponding active portion of DNA strand could then respond by generating an activity at the level of cell membrane. This conforms with the general idea that proteins represent only one particular outcome of the gene expression. This left open the question whether the excitatory-inhibitory dichotomy could have some deeper meaning.

4. Also it became clear the emotions and information are closely related and that peptides acting both as neurotransmitters and hormones are crucial for emotions [J11]. I proposed that emotions are "entropic" qualia. Although I realized the importance of negentropic entanglement I did not have time or I was not able to realize how far reaching this notion actually is.

8.3.2 Is genome a fractal counterpart of brain?

Fractality replaces standard reductionism in TGD Universe. An old idea inspired by p-adic length scale hypothesis is that the binary structures associated with p-adic scales $L(k) \propto 2^{k/2}$ and $L(k+2)$ define a fractal hierarchy. Brain hemispheres would represent one example of this kind of pair, lipid layers ofe cell mebrane second one, and DNA double strand third one. Just for fun one could assume that the structure and functions of brain hemispheres have fractal analogs at the level of DNA double strand and vice versa and look what kind of questions this inspires.

1. Could the identical structures of DNA strands correspond to the anatomical similarity of right and left brain and could the functional asymmetry of the strands correspond to the laterizalization of brain function? Could the genome act as the brain of cell? Could various brain areas have counterparts at the level of DNA? Could the hydrogen bonds between nucleotides serve as the counterpart of corpus callosum? Could the splitting of these bonds during transcription and replication correspond to what happens to a split brain patient?

2. Before continuing it must be made clear that the global identification of right-left dichotomy with holistic-reductionistic dichotomy is wrong. One can however consider its local variant with holism and reductionism assigned do the pairs of right and left brain areas. For instance, in contrast to the naive rule the emotional right (left) brain (amygdala) would be reductionistic (holistic, negentropic) whereas the intellectual right (left) would be holistic (reductionistic, entropic). The practical reason to the division to the entropic and negentropic pieces could relate to the metabolism. The entropic regions could provide the binding energy as a usable energy to the positive energy negentropic entanglement. Good is not possible without Evil! There are no winners without loosers!

   Right brain is specialized in spatial thinking and left brain to verbal thinking and arithmetics: the geometry-algebra division of mathematics! Right brain is not so good in motor actions as left brain as any right-handed person knows. Right brain is however better in tactile sensing: right handed persons tend to use left hand for touching objects to get an idea about their shape. Also this can be understood in holistic-reductionistic picture.

3. Apart from reflex actions almost all activities of the body seem to be controlled to a high degree by brain. Could also the activitites of cell be regarded as motor actions of the genome acting as the brain of cell receiving sensory imput from the cell membrane? Could one identify the analogs of sensory areas receiving information from cell membrane, processing, and sending it to the association areas? Could the analogs associative areas be identified as intronic portions of DNA performing topological quantum computations and communicating the outcome to the higher motor areas at the intronic portions of the of the complementary strand, wherefrom they would be communicated to the primary motor areas identifiable as the regions of DNA expressing themselves either chemically (RNA and proteins), as activitites

generated directly at the level of cell membrane, or electromagnetically? For instance, could neurotransmitter in the receptor generate the feed of sensory input to the genome inducing the change of the membrane potential as the counterpart of motor action. Could prokaryotes without introns be analogous to brain with only primary sensory and motor areas or to mere ladder-like nervous system?

One could argue that the analogy between DNA are brain fails because second DNA strand is completely passive whereas both brain hemispheres express themselves via motor actions. This is not the case! Both DNA strand has regions expressing themselves but the transcription takes place in opposite directions. Hence DNA strands have motor and sensory areas as also brain does, and the natural guess is that primary motor areas correspond to the areas expressing themselves in terms of RNA, proteins, and possibly also as actions at the level of cell membrane. Primary sensory areas would correspond to to regions complementary to the primary motor regions.

4. What right brain sings-left brain talks metaphor could mean in this picture? Pitch-rhythm dichotomy is more technical expression for this dichotomy. Function providing local data and its Fourier transform providing global data is more abstract representation for this dichotomy and Uncertainty Principle for momentum and position relates closely to these two representations of information. This dichotomy could reflect the presence of two different natural time scales and millisecond time scale for nerve pulses and.1 second time scale for moments of sensory experience are the natural candidates.

   If so, this dichotomy could directly reflect the different time scales assignable to u and d type quarks (1 millisecond) and to electron (100 ms) and reduce to the level of elementary particle physics. This dichotomy would also have fractally scaled up variants made possible by the hierarchy of Planck constants. The analog of Fourier transform would be the negentropic unentanglement of sub-CDs (assignable to quarks) to single mental image inside electron's CD. The analog of function itself would be a collection of sub-CDs representing separate unentangled mental images assignable to individual nerge pulses in millisecond time scale. Also the topological quantum computations assigned to the intronic portions correspond to different time scales due and reflect quark-lepton dichotomy. The quarks in question could be the quarks assigned to the ends of flux tubes in the model of DNA as topological quantum computer.

5. This raises some questions. Could the gene expressions of the two strands somehow reflect this dichotomy? For instance, could the flux tube structures assignable to the amino-acid sequences correspond to the millisecond and 100 ms scales assignable to quarks and electron have the property that also the functioning of these proteins is characterized by these typical time scales? According to [I10] the time scales of protein folding vary from.1 s to 10^3s. According to Wikipedia [I1] the typical time scale is 1 millisecond which suggests that the time scales correspond to two ranges beginning from ms and 100 ms respectively. There are also short proteins for which the folding takes place in microsecond time scales which might relate to the CD of proton.

8.3.3 What can one say about the function of neurotransmitters?

Can one say anything interesting about the function of neurotransmitters if one combines this highly speculative picture- which can be defended only by the belief on fractality as universal principle- with the idea that bound state and negentropic entanglement make possible the fusion of mental images.

1. Suppose that the fusion of neuronal mental images is required to build higher level mental images that we experience. Suppose that neuronal mental images involve DNA in an essential manner. Suppose that magnetic flux tubes serve as correlates for the entanglement so that the transmission of nerve pulse from pre-synaptic neuron to post-synaptic one creates a flux tube connection between neurons possibly extending to the genome of the post-synaptic neuron. The transmitter at the end of flux tube attached to the receptor acting as a plug would build this connection to some part of DNA specialized to receive particular kind of sensory

data from a particular region of cell membrane with complementary strand activating as a response a motor function inducing gene expression at cell membrane level. Gene expression as build-up of proteins would not be necessary and is also too slow for neural activities.

2. Suppose that the entanglement between neurons generated in this process is always negentropic as the interpretation as the idea about neural correlate for a conscious association suggests. One could also ask whether the neurons could entangled entropically and whether the entropic-inhibitory association could make sense. This does not lead to anything interesting and entropic entanglement between neurons should be regarded as a pathological condition. Note that neuron-neuron entanglemement would be naturally time-like and in this case only negentropic entanglement might be meaningful.

   (a) To gain some perspective consider the activation of cell in general by some external perturbation from the resting state to the active state (here I have learned a lot from email correspondence with Vladimir Mateev) In the resting state the proteins inside cell are passive -or rather, forced to be passive- as one might expect on basis of the general vision about homeostasis. The unfolded proteins and unfolded portions of the folded proteins are connected by hydrogen bonds to ordered water so that the folding occurring otherwise spontaneously is prevented. One can say that the cellular winter prevails. The situation is however nearly critical and if external perturbation occurs cell liberates metabolic energy melting the ice and spring comes. Also the outer surfaces of globular proteins are hydrogen bonded and when the ordered water melts, spontaneous melting of the protein takes place leading to a partial unfolding.

   The resulting folded proteins and partially unfolded globular proteins interact by forming aggregates and this activity would naturally involve $\hbar$ reducing phase transitions and flux tube reconnections. In TGD based model the mechanism of both folding and melting would be the liberation of metabolic energy destroying the hydrogen bonds and the energy for this comes from the ATP containing positive energy negentropic bond between O=s of phosphates.

   (b) Similar situation could prevail at the cell membrane. One can imagine that cell membrane is like a particle at the bottom of a small potential well. At the other side there is a deep well representing the generation of nerve pulse and at the other side a high wall corresponding to hyper-polarization requiring energy. Both polarization and hyper-polarization are prevented by the freezing of protein activities needed to induce them. The flux tubes connecting the presynaptic neuron and receptor and possibly genome are always negentropic and their formation can as such serve as the signal leading to the partial melting of the ordered water making possible to generate action leading to either de-polarization or hyper-polarization. The signal could be just the additional metabolic energy making it possible for these transitions to occur.

   (c) This picture does not require any communications from the receptor to the genome and in the simplest situation the resulting action could be seen as the analog of reflex action. These communications could of course be present and the negentropic entanglement could make it easier to induce de-polarization also now. Also the question whether excitatory-inhibitory dichotomy for the receptors has some deeper meaning apart from taking the neuron nearer to or farther from criticality for firing remains unanswered.

9 Could TGD Provide Justification For The Ideas Of Rupert Sheldrake?

Rupert Sheldrake [I8] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. In the following I describe briefly the theory of Sheldrake and consider a TGD variant of of the theory.

9.1 Sheldrake's Theory

The following summarizes very briefly the basic ideas of Sheldrake's theory.

1. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit, it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of individuals with new habit to a population having the same habit. Morphic field provides a representation for a habit and resemble the concept of meme in this respect. Sheldrake states the basic assumptions of his theory in the following manner:

   The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels. And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

2. Sheldrake defines morphic fields in the following manner:

   Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. "We don't invent the English language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar. "

   "Alike likes alike" rule states that learning induces learning only in the members of same species. This suggests that the morphic fields correlate strongly with genome.

4. *Sheldrake represents the learning of language as a good example of morphic resonance.*

   Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened over-well, we don't know how long human language has been around, at least 50, 000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

5. *Sheldrake notices also that morphic resonance and morphic fields are not all what is needed to understand evolution.*

   The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

9.2 TGD Based Interpretation Of Morphic Fields And Collective Memory

I have proposed for more than decade ago a TGD based formulation justifying the basic ideas of Sheldrake to some degree. The recent formulation involves several new elements. Zero energy ontology implying that WCW ("world of classical worlds") spinor fields allow an interpretation as memes or morphic fields, the model for living matter in which the notion of magnetic body plays a key role, and the model of DNA as topological quantum computer allowing to identify the morphic quanta relevant for living matter.

9.2.1 WCW spinor fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW . The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub- WCW s association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future light-cone M^4_+ is quantized for positive energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that lower tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of upper tip to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K29]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub- WCW s with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom generalize those of a quantum field in Minkowski space.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [A6]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ("orbital") degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

9.2.2 WCW spinor fields as morphic fields?

The interpretation of the WCW spinor fields as memes or morphic fields is encouraged by two observations.

1. Zero energy states have an interpretation as Boolean rules $A \to B$ as well as self-organization patterns. Fermion number 1 and 0 for a given fermion mode represents values of one particular Boolean statement in positive *resp.* negative part of the state. The instances of A are assigned to the positive energy (initial) state and those of B to the negative energy (final) state and the quantum superposition of the paired instances defines the rule. Since time-like entanglement coefficients define M-matrix, the interpretation as a law of physics coded to the structure of the physical state itself is possible. Fermionic degrees of freedom correspond to the spin

indices of WCW spinor fields. Besides this there are "orbital" degrees of freedom in the moduli space for CDs and in the space of deformations of light-like 3-surfaces. It is natural to assign these degrees of freedom to sensory perception.

2. The p-adic description of cognition involves a generalization of the notions of number and of imbedding space. The hierarchy of Planck constants means a further generalization of the notion of imbedding space by replacing it with a book like structure. It seems that the discrete intersection of real and p-adic partonic 2-surfaces consisting of points in algebraic extension of rationals is crucial from the point of view of consciousness theory. This is true also for the intersection of real and p-adic variants of WCW identified as 3-surfaces whose mathematical representation makes sense in both real and p-adic number fieldsin preferred coordinate fixed by symmetries.

   The first intersection is expected to be relevant at quantum field theory limit, which involves the replacement of the partonic 2-surfaces with a discrete subset of points carrying quantum numbers. The second intersection is relevant in the full quantum theory. The notion of number theoretic Shannon entropy having negative values makes sense in both intersections since entanglement probabilities must make sense in both number fields so that they are rational or belong to an algebraic extension of rationals. In these intersections of realities and various p-adicities the evolution of memes is expected to take place.

   One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

If one defines morphic field so that also ideas and imagined things, simply memes, are included within the scope of definition, one is led to ask whether the p-adic description of imagination as space-time WCW spinor fields in the space of 2-surfaces allowing continuation by strong form of holography to some p-adic sectors but not necessarily to real sector could represent morphic fields in this generalized sense.

One can however criticize the proposed definition as quite too general: every zero energy state would define morphic field!

9.3 Magnetic Body As Morphic Field

The second option is more concrete and assumes that morphic fields correspond to space-time surfaces which in ZEO are analogous to behavioral patterns and functions. Since magnetic body carrying dark matter is intentional agent in TGD Universe, morphic fields of Sheldrake [I8, I9] could be therefore replaced with field body: magnetic body and the "topological light rays" serving as correlates of dark photon beams are involved and are parallel to flux tubes and topologically condensed at them.

Magnetic body - and even more so topological light rays - are essentially 4-D objects, a temporal pattern of topologically quantized fields associated with a pair of 3-D magnetic bodies at the opposite boundaries of CD. Magnetic body having an ion-like structure would serve as a template for the biological system and its evolution. The lowest layers of the onion would correspond to flux tubes connecting biomolecules. DNA and nuclear and cell membranes would have magnetic bodies having connections to larger magnetic bodies, such as magnetic Mother Gaia.

The findings of Levin [I5] and others about what happens to cut planaria can be understood if the replication of of magnetic body precedes the replication of the biological body [L3]. The replication of magnetic body would be analogous with the decay of particle in the vertex of Feynman diagram (particles are replaced with 3-surfaces in TGD).

The experiments indicate that also memories interpreted as learned behaviors are replicated in the sense that the new worms resulting from the pieces of the cut worm have the memories of uncut worm and the replication of magnetic body in the sense of ZEO would explain this (the pair of 3-surfaces at opposite ends of CD would replicate). The replication of behaviours could be seen as replication of memes. This would help to understanding how skills can be discovered by several individuals simultaneously and how learning of skill becomes easier when it is already possessed by several individuals.

The following is an attempt to define morphic resonance using language of TGD.

1. Morphic resonance would relate to the presence of collective levels of consciousness. They could have direct counterparts as a hierarchy of genomes in which genomes of cells could form coherent units in the sense that their magnetic bodies fuse to larger ones. Also the genomes of different organisms could fuse to single super-genome in this manner. In this case, then morphic resonance could manifest itself as a collective gene expression. One manifestation would a discovery of same thing in separate places simultaneously due to the fact that the problem solving would also take place at collective level.

2. Negentropic entanglement resources generated in the quantum evolution would give rise to "Akashic records", which would serve as universal library from which any-one could loan a book. Independent discovery of same idea at different places and times would not be actually independent since the needed information could derive from "Akashic records".

3. In ZEO 3-D self-organization becomes 4-D self-organization for spatio-temporal patterns since also the geometric past changes in quantum jump. At space-time level this means that space-time surfaces representing temporal patterns of various fields would becomes the basic patterns. Quantum states would correspond to superpositions of these temporal patterns. This would mean that morphic resonance would be essentially 4-D: behaviors/skills could be learned from "Akashic records".

4. Morphic resonance would also correspond to resonance in concrete sense. Only the flux tubes of two magnetic bodies having the same value of magnetic field and thus same cyclotron frequency scale and same thickness could fuse by reconnection. Also the values of h_{eff} should be same. This might also explain $h_{eff} = h_{gr}$ as a condition guaranteeing the resonant interaction between biological organisms with conscious entities in scale of Earth and Sun.

9.3.1 Morphic fields relevant to living matter

All zero energy states have interpretation as memes or quanta of morphic fields in TGD framework. One can however ask what zero energy states are relevant for biological systems.

1. The memes relevant to living matter must have a very concrete connection to biology. DNA as topological quantum computer hypothesis states the magnetic flux tubes connecting nucleotides to lipids of nuclear and cell membranes define braid strands needed to realize topological quantum computations. Nerve pulse patterns induce fluid flows of cytoplasma and of lipids in turn inducing time-like braidings defining running topological quantum computation programs and their memory representations as space-like braidings in the final state. These programs living (in very literal sense) in the brains of geometric future and past define a 4-D population of memes. The intronic part of the genome is specialized to topological quantum computations and the time scale in this case can be and must be faster than for the chemical gene expression. The repetitive character of many intronic DNA sequences regarded as evidence for their junk character does not mean any restriction for topological quantum computation.

2. The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion-like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism. The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field

representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

3. Morphic resonance and alike likes alike rule can be understood from the condition that the intronic parts of genomes must be similar enough to allow the realization of the topological quantum computation. Also neuronal pathways involved must resemble each other in order that spatial nerve pulse patterns can be re-produced faithfully enough. Also the evolutionary levels must be more or less the same in order that the topological quantum computation has same meaning for the receiver and sender. Therefore the collective memory might be restricted to the level of species. This might be however too strong an assumption. For instance, shamanism could represent an example of interspecies memory. The TGD based view about memory allows also the possibility to use the memories of the already deceased members of species which can in principle continue to exist in the geometric past.

4. The general vision about evolution as recreation of the quantum Universe implies that creativity is in very literal sense a basic aspect of TGD Universe. The U process represents the creative aspect of consciousness generating quantum super-position of Universes from which generalized state function reduction process selects the outcome. Both volitional actions and sensory perception involves the selection but quantum statistical determinism implies that sensory percepts are usually predictable.

9.3.2 Collective memory, geometric memory and self hierarchy

The notion of species memory is rather radical departure from the teachings of standard neuroscience so that TGD based view about memory deserves a separate discussion.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, the idea about collective memory makes sense and generalizes to an entire hierarchy of them.

Geometric memory provides a promising candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. In zero energy ontology these space-time sheets are associated with sub-CDs of CD associated with self. Both time-like entanglement between sub-CDs of recent and past implying sharing and fusion of mental images an classical communications between these CDs are possible and give rise to episodal memories (direct re-experiences) and symbolic memories.

Since both geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the space-time sheets of the geometric past as its sub-selves and experiences these memories. Thus geometric memory is consistent with Sheldrake's claims and to some degree supports them.

9.3.3 Language learning and morphic resonance

The easiness of children to learn language could have explanation in terms of morphic resonance. The strong quantum entanglement between the child and parents, especially mother, could make the morphic resonance possible in the proposed sense. One can even imagine that mother's magnetic body directly induces nerve pulse sequences representing linguistic memes in the brain of child.

One can of course wonder why it is so difficult for the older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. Older people learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are older people so far from quantum criticality that the

large fluctuations leading to the generation of the new level of self-organization are not possible anymore? The reason could also relate to the degeneration of the magnetic flux tubes circuits due to ageing so that new topological quantum computation programs are not establishes so easily anymore.

9.3.4 Self hierarchy, bio-feedback and sociofeedback

Magnetic bodies act as intentional agents in the proposed model. They form also a hierarchy analogous to master-slave hierarchy. The proposed mechanism of collective learning involves the magnetic body of Earth in an essential manner. Also magnetic bodies of larger structures could be involved: there is indeed evidence that remote cognition involves galactic magnetic fields [K24] , [J12].

The phenomenon of bio-feedback provides direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens is needed: the volition is enough. The explanation would be that the information provided by the monitoring goes to the magnetic body of the person which reacts by sending control signals to the brain. The already existing magnetic flux tube connections guarantee that the volitional act affects the neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

An interesting test for the idea that people very close to each other could directly affect the brain function of each other would be biofeedback in which subject person tries to affect the behavior of a neuron of a close friend or relative. Mother and child might be an optimal choice in this respect.

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