Re-examination of the basic notions of TGD inspired theory of consciousness

M. Pitkänen
Email: matpitka6@gmail.com.
http://tgdtheory.com/.

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Abstract

TGD inspired theory of consciousness is based on certain basic assumptions such as the identification of state function reduction as a measurement of universal observable identified density matrix characterizing entanglement and Negentropy Maximization Principle (NMP) as fundamental principle. Both the adelic approach and the notion of "World of Classical Worlds" (WCW) force to challenge these assumptions.

1. Adelic approach strongly suggests the reduction of NMP to number theoretic physics somewhat like second law reduces to probability theory: there would be no need to postulate NMP as a separate principle and NMP would hold true only in statistical sense so that we would not live in the best possible world as strongest form of NMP would imply. The dimension of the extension rationals characterizing the hierarchy level of physics and defined an observable measured in state function reductions is positive and can only increase in statistical sense. Therefore the maximal value of entanglement negentropy increases as new entangling number theoretic degrees of freedom emerge. $h_{eff}/h = n$ identifiable as factor of Galois group of extension characterizes the number of these degrees of freedom for given space-time surfaces as number of its sheets.

2. State function reduction is hitherto assumed to correspond always to a measurement of density matrix which can be seen as a reaction of subsystem to its environment. This makes perfect sense at space-time level. Higher level measurements occur however at the level of WCW and correspond to a localization to some sector of WCW determining for instance the quantization axes of various quantum numbers. Even the measurement of $h_{eff}/h = n$ would measure the dimension of Galois group and force a localization to an extension with Galois group with this dimension. These measurements cannot correspond to measurements of density matrix since different WCW sectors cannot entangle by WCW locality.

Contents

1   Introduction

TGD inspired theory of consciousness is based on certain basic assumptions such as the identification of state function reduction as a measurement of universal observable identified density matrix characterizing entanglement and Negentropy Maximization Principle (NMP) as fundamental principle. Both the adelic approach and the notion of "World of Classical Worlds" (WCW) force to challenge these assumptions.

1.1   Do all state function reductions correspond to measurements of density matrix?

The earlier approach has assumed that state function reduction always corresponds to a measurement of density matrix serving as a universal observable. Measurement of density matrix allows to measure simultaneously arbitrary number of commuting observables by assuming to be a function of product of measured commuting observables represented as matrices. This makes sense at space-time level but at the level of WCW one encounters difficulties. For instance, the choice of quantization axis corresponds to a higher level choice localization to a sector of WCW with moduli characterizing this choice. Also the measurement of $h_{eff}/h = n$ measuring the dimension of Galois group would make sense and force a localization to an extension with Galois group with this dimension. Single entanglement between different points of WCW is not possible (WCW spinor field is analogous to classical spinor describing single particle state and no second quantization is assumed at the level of WCW and one has complete locality), this selection cannot correspond to a measurement of density matrix.

But is the measurement of density matrix really the only possible quantum measurement and does it correspond to act of goal directed intentional free will? Density matrix characterizes entanglement with environment. Is the measurement of density matrix only a reaction: a choice amongst given alternatives. Eastern philosophers make a sharp distinction between real intentional action and mere reaction. For instance, Krishnamurti talks a lot about this and sees that basically all problems of human kind is that we have not been able to transcend to the level at which our actions would be more than reactions.

Genuine intentional actions would very naturally correspond to self measurements realized as WCW localitions such as fixing the quantization axis, or selecting the extension of rationals defining particular evolutionary level of adele hierarchy, or choosing the boundary of CD at which state function reductions occur (arrow of geometric time) are possible.

1.2   Is NMP a fundamental principle or does it follow from adelic physics?

NMP has been regarded as a fundamental principle of TGD inspired theory of consciousness. Adelic approach however strongly suggests the reduction of NMP to number theoretic physics somewhat like second law reduces to probability theory: there would be no need to postulate NMP as a separate principle and NMP would hold true only in statistical sense so that we would not live in the best possible world as strongest form of NMP would imply. The dimension of the extension rationals characterizing the hierarchy level of physics and defined an observable measured in state function reductions is positive and can only increase in statistical sense. Therefore the maximal value of entanglement negentropy increases as new entangling number theoretic degrees of freedom emerge. $h_{eff}/h = n$ identifiable as factor of Galois group of extension characterizes the number of these degrees of freedom for given space-time surfaces as number of its sheets.

This forces to re-think what happens in the state function reduction in which the passive boundary of state function reduction becomes opposite boundary meaning death of self and its

re-incarnation as time-reversed self: this reduction has been seen as strongest support for NMP as fundamental principle rather than consequence of adelic physics. The new view relies of the observation that the states at passive boundary are eigenstates of some observables, call them passive observables. The reductions at active boundary must correspond to measurements of observables commuting with the passive observables. Self as a generalized Zeno effect can live only as long as it is able to measure observables commuting with the passive ones. The increase the dimension of extension of rationals in unitary time evolutions between reductions - number theoretic evolution - could generate new observables commuting with the passive observables. Self lives as long as it evolves.

In the sequel I describe briefly the basic of TGD inspired theory of consciousness as generalization of quantum measurement theory to ZEO (ZEO), describe the definition of self, consider the question whether NMP is needed as a separate principle or whether it is implied is in statistical sense by the unavoidable statistical increase of $n = h_{eff}/h$ if identified as a factor of the dimension of Galois group extension of rationals defining the adeles, and finally summarize the vision about how p-adic physics serves as a correlate of cognition and imagination.

In the sequel I will use some shorthand notations for key principles and notions. General Coordinate Invariance (GCI); World of Classical Worlds (WCW); Strong Form of GCI (SGCI); Strong Form of Holography (SH); Preferred Extremal (PE); Zero Energy Ontology (ZEO); Negentropy Maximization Principle (NMP); Negentropic entanglement (NE) are the most often occurring acronyms.

2 From quantum measurement theory to a theory of consciousness

The notion of self can be seen as a generalization of the poorly defined definition of the notion of observer in quantum physics. In the following I take the role of skeptic trying to be as critical as possible.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. The density matrix was assumed to define the universal observable. Note that a density matrix, which is power series of a product of matrices representing commuting observables has in the generic case eigenstates, which are simultaneous eigenstates of all observables. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

2.1 Self as generalized Zeno effect

The precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO (ZEO) only rather recently (2014).

1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant - "small" state function reductions. The parts of zero energy states at second boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontolo1gy these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.

2. The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The

sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

2.2 State function reductions at the level of WCW

One can identify several rather abstract state function reductions selecting a sector of WCW.

1. There are quantum measurements inducing localization in the moduli space of CDs with passive boundary and states at it fixed. In particular, a localization in the moduli characterizing the Lorentz transform of the upper tip of CD would be measured. The measured moduli characterize also the analog of symplectic form in M^4 strongly suggested by twistor lift of TGD - that is the rest system (time axis) and spin quantization axes. Of course, also other kinds of reductions are possible.

2. Also a localization to an extension of rationals defining the adeles should occur. Could the value of $n = h_{eff}/h$ be observable? The value of n for given space-time surface at the active boundary of CD could be identified as the order of the smallest Galois group containing all Galois groups assignable to 3-surfaces at the boundary. The superposition of space-time surface would not be eigenstate of n at active boundary unless localization occurs. It is not obvious whether this is consistent with a fixe value of n at passive boundary.

   The measured value of n could be larger or smaller than the value of n at the passive boundary of CD but in statistical sense n would increase by the analogy with diffusion on half line defined by non-negative integers. The distance from the origin unavoidably increases in statistical sense. This would imply evolution as increase of maximal value of negentropy and generation of quantum coherence in increasingly longer scales.

3. A further abstract choice corresponds to the the replacement of the roles of active and passive boundary of CD changing the arrow of clock time and correspond to a death of self and re-incarnation as time-reversed self.

2.3 Can the reductions at the level of WCW reduce to measurements of density matrix?

Can one assume that these measurements reduce to measurements of a density matrix of either entangled system as assumed in the earlier formulation of NMP, or should one allow both options. This question actually applies to all quantum measurements and leads to a fundamental philosophical questions unavoidable in all consciousness theories.

1. Do all measurements involve entanglement between the moduli or extensions of two CDs reduced in the measurement of the density matrix? Non-diagonal entanglement would allow final states states, which are not eigenstates of moduli or of n: this looks strange. This could also lead to an infinite regress since it seems that one must assume endless hierarchy of entangled CDs so that the reduction sequence would proceed from top to bottom. It looks natural to regard single CD as a sub-Universe.

   For instance, if a selection of quantization axis of color hypercharge and isospin (localization in the twistor space of CP_2) is involved, one would have an outcome corresponding to a quantum superposition of measurements with different color quantization axis!

Going philosophical, one can also argue, that the measurement of density matrix is only a reaction to environment and does not allow intentional free will.

2. Can one assume that a mere localization in the moduli space or for the extension of rationals (producing an eigenstate of n) takes place for a fixed CD - a kind of self measurement possible for even unentangled system? If there is entanglement in these degrees of freedom between two systems (say CDs), it would be reduced in these self measurements but the outcome would not be an eigenstate of density matrix. An interpretation as a realization of intention would be approriate.

3. If one allows both options, the interpretation would be that state function reduction as a measurement of density matrix is only a reaction to environment and self-measurement represents a realization of intention.

4. Self measurements would occur at higher level say as a selection of quantization axis, localization in the moduli space of CD, or selection of extension of rationals. A possible general rule is that measurements at space-time level are reactions as measurements of density matrix whereas a selection of a sector of WCW would be an intentional action. This because formally the quantum states at the level of WCW are as modes of classical WCW spinor field single particle states.

5. If the selections of sectors of WCW at active boundary of CD commute with observables, whose eigenstates appear at passive boundary (briefly *passive observables*) meaning that time reversal commutes with them - they can occur repeatedly during the reduction sequence and self as a generalized Zeno effect makes sense.

   If the selections of WCW sectors at active boundary do not commute with passive observables then volition as a choice of sector of WCW must change the arrow of time. Libet's findings show that conscious choice induces neural activity for a fraction of second before the conscious choice. This would imply the correspondences *"big" measurement changing the arrow of time - self-measurement at the level of WCW - intentional action* and *"small" measurement - measurement at space-time level - reaction*.

   Self as a generalized Zeno effect makes sense only if there are active commuting with passive observables. If the passive observables form a maximal set, the new active observables commuting with them must emerge. The increase of the size of extension of rationals might generate them by expanding the state space so that self would survive only as long at it evolves.

   Otherwise there would be only single unitary time evolution followed by a reduction to opposite boundary. This makes sense only if the sequence of "big" reductions for sub-selves can give rise to the time flow experienced by self: the birth and death of mental images would give rise to flow of time of self.

A hierarchical process starting from given CD and proceeding downwards to shorter scales and stopping when the entanglement is stable is highly suggestive and favors self measurements. CDs would be a correlate for self hierarchy. One can say also something about the anatomy and correlates of self hierarchy.

1. Self experiences its sub-selves as mental images and even we would represent mental images of some higher level collective self. Everything is conscious but consciousness can be lost or at least it is not possible to have memory about it. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

2. By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J3] could be understood as

a sharing of mental images between brain hemispheres, which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

3. At the level of 8-dimensional imbedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. For instance .1 second time scale defining sensory chronon corresponds to the secondary p-adic time scale characterizing the size of electron's CD (Mersenne prime M_{127}), which suggests that Cooper pairs of electrons are essential for the sensory qualia.

The above argument states that the measurements at the level of WCW cannot be regarded as measurements of a density matrix since no second quantization at level of WCW is carried out. About a year after developing this argument I realized that the hierarchy of infinite primes suggests an infinite hierarchy of second quantizations. Could the counterpart for the hierarchy of infinite primes be realized at WCW level automatically? One can indeed interpret the measurements at WCW as either localizations or as reductions of entanglement between states associated with different points of WCW. The point is that the disjoint union of 3-surfaces X^3 and Y^3 can be regarded either as a pair (X^3, Y^3) of 3-surfaces in $WCW \times WCW$ or as a 3-surface $Z^3 = X^3 \cup Y^3 \subset WCW$. The general identity behind this duality $WCW = WCW \times WCW = ... = WCW^n = ...$

One could think the situation in terms of $(X^3, Y^3) \in WCW \times WCW$ in which case one can speak of entanglement between WCW spinor modes associated with X^3 and Y^3 reduced by the measurement of density matrix. Second interpretation as a localization of wave function of $Z^3 = X^3 \cup Y^3 \in WCW$.

2.4 Experimental support for the relative arrow of time

It has been found that the arrow of time is relative [?] (see `http://tinyurl.com/yatp6dum`). Expressing this in more cautious terms, heat can flow from from system with temperature T_1 to a system with temperature $T_2 > T_1$ if there is correlation between the two systems meaning that the density matrix for the two nuclear systems (samples consisting of hydrogen atoms and carbon atoms) is not mere tensor product of density matrices but contains an additional term describing correlation. It must be emphasized that this finding is not in conflict with the standard view about second law which only says that heat flows from system with higher temperature to that with lower temperature provided that there are no correlations between the systems.

The argument runs as follows. The mutual information for the uncorrelated systems vanishes, and since it can only increase this implies flow of heat in the standard direction. If the mutual information is non-vanishing in the initial situation (due to the correlation) it can also decrease and this can give a heat flow in non-standard direction. This has been observed.

Although one can model the finding using standard thermodynamics, one can ask whether something deeper might be involved. Should one be cautious and talk only about the changing direction of heat flow due to the breaking of the basic assumptions of thermodynamics, and avoid speaking about direction of thermodynamical time? Or could a genuine change of the arrow of time take place? Going even deeper, one must ask what thermodynamical time, the time of physicist (geometric time), and the arrow of time do really mean? What is the relationship between these two times? This leads to ponder questions about the basics of quantum measurement theory and here I can only consider TGD based vision [L1].

1. The basic prediction of zero energy ontology (ZEO) is that the arrow of geometric time can have both signs whereas the arrow of subjective time (relating closely to thermodynamic time) defined by experience created by sequence of state function reductions is always the same. The arrow of geometric time is indeed relative. The flow of geometric time corresponds to the increase of distance between tips of causal diamond (CD) and the increase in particular reduction is at either tip of CD and in this manner defines arrow of time. CD grows either

"upwards" or "downwards". A geometric measure for experienced time is that distance between the tips of CD which always increases.

Time reflection symmetry (T) with respect to the center of CD is broken in TGD: the classical time evolutions of space-time surfaces are not T mirror images of each other. This is true also for the quantal evolutions defined by zero energy states essentially as quantum superpositions of classical evolutions. States and their time reversals obey the initial conditions at opposite boundaries of CD. Arrow of time is forced by the place (either boundary of CD), where initial conditions are posed, not by the initial conditions themselves.

2. One must however remember that ZEO describes genuine quantum systems whereas thermodynamics decribes ensemble, which is a highly idealized notion. In ZEO arrow of geometric time would change in each "big" quantum jump and would remain the same during the sequence of "small" state function reductions defining the counterpart of Zeno effect or weak measurement.

3. Initial conditions breaking the basic assumptions of thermodynamics induce correlations and the heat flow in "wrong" direction in the model for the finding. The arrow of time is claimed to be changed in time interval of length of order 2 millisecond. Interestingly, millisecond happens to characterize the time scale of nerve pulse and ZEO predicts that in living matter the change of the arrow of time takes place routinely. In ZEO based description the growth of the temporal distance between the tips of CD would be of order 2 milliseconds.

It would be however the opposite boundary of CD in geometric past that would recede farther away. One can argue that it is not possible measure the position of the past boundary of CD directly. But is it possible to measure the distance between the tips of CD indirectly from the behavior of the ensemble? ZEO would suggest that the time appearing in the Hamiltonian modelling the system corresponds to the distance between tips of CD and never decreases. The change of the direction of heat flow would correspond to the reduction to the original boundary of CD in the experiment and the correlation would make ZEO visible.

If the two descriptions are equivalent, the initial correlations for the ensemble force should correspond to posing initial conditions at the non-standard boundary of CD leading to the reversal of the arrow of time. The very act of posing the correlations would correspond to a "big" state function reduction to opposite boundary of CD. In standard quantum measurement theory state preparation indeed corresponds to this state function reduction so that the two descriptions might be consistent.

3 Negentropy Maximization Principle

Negentropy Maximization Principle (NMP [K3]) stating that the reduction of entanglement entropy is maximal at a given step of state function reduction process following U-process is the basic variational principle for TGD inspired theory of consciousness and says that the information contents of conscious experience is maximal. Although this principle is diametrically opposite to the second law of thermodynamics it is structurally similar to the second law. NMP does not dictate the dynamics completely since in state function reduction any eigen state of the density matrix is allowed as final state. NMP need not be in contradiction with second law of thermodynamics which might relate as much to the ageing of mental images as to physical reality.

3.1 Basic Form Of NMP

Negentropy Maximization Principle (NMP) in its original form codes for the basic rules of the standard state function reduction and implies that system ends up to an eigenstate of the density matrix identified as observable. In TGD framework must ask whether NMP should be restricted only to the entanglement between zero modes of WCW representing classical degrees of freedom and quantum fluctuating degrees of freedom or generalize it to apply to any pair of subsystems so that state function reduction sequence could be regarded as a sequence of self measurements. I have chosen the latter option as a working hypothesis.

NMP that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step of the process. State function process could proceed at the level of all CDs. It is not clear whether one can assign any geometric time duration to this process or whether there is any need for this. If the subsystem allows entangled pairs of free systems (no binding energy) there is more or less unique pair with the maximal entanglement entropy and NMP therefore implies a decomposition to a unique pair of unentangled systems. The process repeats itself for these systems and stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. Number theoretic entanglement entropies mean an important modification of this picture.

3.2 Weak Form Of NMP

The notion of number theoretic entropy obtained by can be defined by replacing in Shannon entropy the logarithms of probabilities p_n by the logarithms of their p-adic norms $|p_n|_p$. This replacement makes sense for algebraic entanglement probabilities if appropriate algebraic extension of p-adic numbers is used. What is new that entanglement entropy can be negative, so that algebraic entanglement can carry information and NMP can force the generation of bound state entanglement so that evolution could lead to the generation of larger coherent bound states rather than only reducing entanglement. A possible interpretation for algebraic entanglement is in terms of experience of understanding or some positive emotion like love.

Standard formalism of physics lacks a genuine notion of information and one can speak only about increase of information as a local reduction entropy. It seems strange that a system gaining wisdom should increase the entropy of the environment. Hence number theoretic information measures could have highly non-trivial applications also outside the theory consciousness.

NMP combined with number theoretic entropies leads to an important exception to the rule that the generation of bound state entanglement between system and its environment during U process leads to a loss of consciousness. When entanglement probabilities are rational (or even algebraic) numbers, the entanglement entropy defined as a number theoretic variant of Shannon entropy can be non-positive (actually is) so that entanglement carries information. NMP favors the generation of algebraic entanglement. The attractive interpretation is that the generation of algebraic entanglement leads to an expansion of consciousness ("fusion into the ocean of consciousness") instead of its loss.

State function reduction period of the quantum jumps involves much more than in wave mechanics. For instance, the choice of quantization axes realized at the level of geometric delicacies related to CDs is involved. U-process generates a superposition of states in which any sub-system can have both real and algebraic entanglement with the external world. If state function reduction involves also a choice between generic and negentropic entanglement (between real world, a particular p-adic world, or their intersection) it might be possible to identify a candidate for the physical correlate for the choice between good and evil. The hedonistic complete freedom resulting as the entanglement entropy is reduced to zero on one hand, and the algebraic bound state entanglement implying correlations with the external world and meaning giving up the maximal freedom on the other hand. The hedonistic option is risky since it can lead to non-algebraic bound state entanglement implying a loss of consciousness. The second option means expansion of consciousness - a fusion to the ocean of consciousness as described by spiritual practices. Note that if the total entanglement negentropy defined as sum of contributions from various levels of CD hierarchy up to the highest matters in NMP then also sub-selves should develop negentropic entanglement. For instance, the generation of entropic entanglement at cell level can lead to a loss of consciousness also at higher levels. Life would evolve from short to long scales.

The consistency with quantum measurement theory leads to an important constraint on the density matrix giving rise to negentropic entanglement. The density matrix of the final state must be a projector as in the ordinary quantum measurement theory. It's dimension can be however higher than one now. Therefore negentropic entanglement cannot be confused with real entanglement and there is no problem due to the fact that for real number based entanglement it is impossible to know in practice whether the entanglement coefficients are rational numbers. The entanglement giving rise to a density matrix, which is projector corresponds in the 2-particle case entanglement matrix proportional to unitary matrix typical for quantum computer type systems.

TGD inspired theory of consciousness forces to challenge the hypothesis that NMP always forces the state function reduction to the sub-space defined by the projector with maximal dimension appearing in the decomposition of the density matrix. NMP would not allow the self to make choices, which are bad deeds in the sense that they do not increase maximally the negentropic resources of the Universe. We would live in the best possible Universe becoming better all the time. This is obviously too good to be true.

A weaker form of NMP allows the choice leading to maximal negentropy gain but allows also those choices for which the reduction occurs to a sub-space of the space defined by projector. When this sub-space is 1-dimensional standard quantum measurement results and the self is isolated from the target of observations. Negentropic entanglement has interpretation as attention with positively colored contents of consciousness. Experience of love would be one attribute of this kind of state. Weak form of NMP would be like God allowing the sinner to chose between Good and Evil.

3.2.1 Do positively colored emotions allow a representation of Boolean logic?

Weak form of NMP allows the state function reduction to occur in $2^n - 1$ manners corresponding to subspaces of the sub-space defined by n-dimensional projector if the density matrix is n-dimensional projector (the outcome corresponding to 0-dimensional subspace and is excluded). If the probability for the outcome of state function reduction is same for all values of the dimension $1 \leq m \leq n$, the probability distribution for outcome is given by binomial distribution $B(n,p)$ for $p = 1/2$ (head and tail are equally probable) and given by $p(m) = b(n,m) \times 2^{-n} = (n!/m!(n-m)!) \times 2^{-n}$. This gives for the average dimesion $E(m) = n/2$ so that the negentropy would increase on the average. The world would become gradually better. Note that one assumes that there is some preferred basis for the states and these numbers apply when this basis is given.

One cannot avoid the idea that these different degrees of negentropic entanglement could actually give a realization of Boolean algebra in terms of conscious experiences.

1. There should be a mapping of k-dimensional subspaces of n-dimensional space to the fermionic representation of Boolean algebra

2. Could one speak about a hierarchies of codes of cognition based on the assignment of different degrees of "feeling good" to the Boolean statements? If one assumes that the n:th bit is always 1, all independent statements except one correspond at least two non-vanishing bits and corresponds to negentropic entanglement. Only of statement (only last bit equal to 1) would correspond 1 bit and to state function reduction reducing the entanglement completely (brings in mind the fruit in the tree of Good and Bad Knowlege!).

3. A given hierarchy of breakings of super-symplectic symmetry corresponds to a hierarchy of integers $n_{i+1} = \prod_{k \leq i} m_k$. The codons of the first code would consist of sequences of m_1 bits. The codons of the second code consists of m_2 codons of the first code and so on. One would have a hierarchy in which codons of previous level become the letters of the code words at the next level of the hierarchy.

In fact, I ended up with almost Boolean algebra for decades ago when considering the hierarchy of genetic codes suggested by the hierarchy of Mersenne primes $M(n+1) = M_{M(n)}$, $M_n = 2^n - 1$.

1. The hierarchy starting from $M_2 = 3$ contains the Mersenne primes $3, 7, 127, 2^{127} - 1$ and Hilbert conjectured that all these integers are primes. These numbers are almost dimensions of Boolean algebras with $n = 2, 3, 7, 127$ bits. The maximal Boolean sub-algebras have $m = n - 1 = 1, 2, 6, 126$ bits.

2. The observation that $m = 6$ gives 64 elements led to the proposal that it corresponds to a Boolean algebraic assignable to genetic code and that the sub-algebra represents maximal number of independent statements defining analogs of axioms. The remaining elements would correspond to negations of these statements. I also proposed that the Boolean algebra with $m = 126 = 6 \times 21$ bits (21 pieces consisting of 6 bits) corresponds to what I called memetic code obviously realizable as sequences of 21 DNA codons with stop codons included. Emotions and information are closely related and peptides are regarded as both information molecules and molecules of emotion.

3. This hierarchy of codes would have the additional property that the Boolean algebra at $n + 1$:th level can be regarded as the set of statements about statements of the previous level. One would have a hierarchy representing thoughts about thoughts about.... It should be emphasized that there is no need to assume that the Hilbert's conjecture is true.

One can obtain this kind of hierarchies as hierarchies with dimensions $m, 2^m, 2^{2^m}, ...$ that is $n(i+1) = 2^{n(i)}$. The conditions that $n(i)$ divides $n(i+1)$ is non-trivial only for at the lowest step and implies that m is power of 2 so that the hierarchies starting from $m = 2^k$. This is natural since Boolean algebras are involved. If n corresponds to the size scale of CD, it would come as a power of 2.

p-Adic length scale hypothesis has also led to this conjecture. A related conjecture is that the sizes of CDs correspond to secondary p-adic length scales which indeed come as powers of two. In case of electron this predicts that the minimal size of CD associated with electron corresponds to time scale $T = .1$ seconds, the fundamental time scale in living matter (10 Hz is the fundamental biorhythm). It seems that the basic hypothesis of TGD inspired partly by the study of elementary particle mass spectrum and basic bio-scales (there are 4 p-adic length scales defined by Gaussian Mersenne primes in the range between cell membrane thickness 10 nmandsize 2.5 μm of cell nucleus!) follow from the proposed connection between emotions and Boolean cognition.

Hilbert's conjecture relates in interesting manner to space-time dimension. Suppose that Hilbert's conjecture fails and only the four lowest Mersenne integers in the hierarchy are Mersenne primes that is $3, 7, 127, 2^{127} - 1$. In TGD one has hierarchy of dimensions associated with space-time surface coming as 0, 1, 2, 4 plus imbedding space dimension 8. The abstraction hierarchy associated with space-time dimensions would correspond discretization of partonic 2-surfaces as point set, discretization of 3-surfaces as a set of strings connecting partonic 2-surfaces characterized by discrete parameters, discretization of space-time surfaces as a collection of string world sheet with discretized parameters, and maybe - discretization of imbedding space by a collection of space-time surfaces. Discretization means that the parameters in question are algebraic numbers in an extension of rationals associated with p-adic numbers.

In TGD framework it is clear why imbedding space cannot be higher-dimensional and why the hierarchy does not continue. Could there be a deeper connection between these two hierarchies. For instance, could it be that higher dimensional manifolds of dimension $2 \times n$ can be represented physically only as unions of say n 2-D partonic 2-surfaces (just like $3 \times N$ dimensional space can be represented as configuration space of N point-like particles)? Also infinite primes define a hierarchy of abstractions. Could it be that one has also now similar restriction so that the hierarchy would have only finite number of levels, say four. Note that the notion of n-group and n-algebra involves an analogous abstraction hierarchy.

3.3 Can One Define Measures For The Information Contents Of Mental Image?

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 for the initial and final quantum histories. Negentropy gain is the most natural information measure of this kind. For instance, the sum of the net entanglement negentropy gains over the steps of the self measurement cascade could define a quantity characterizing net information gain for a single moment of consciousness at each step.

One could also information measure to selves as the entanglement negentropy after the state function reduction process has ended. This would assign to each subsystem stable under NMP a negentropy. For bound state entanglement this information would be negative but for negentropic entanglement it would be positive. One can ask whether the hypothesis that this information increases during quantum jump sequence is equivalent with NMP. In the case of entire Universe the application of this principle becomes problematic.

Entropy gradients with respect to subjective time could be used to characterize how the information gain of conscious experience of self changes. These gradients approach zero when self approaches thermal equilibrium. In TGD framework entropy 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 [J2]). 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 sex and spiritual experiences present already at the molecular level?) and macro temporal quantum coherence so that quantum computer like operations might become possible.

3.3.1 Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that life and conscious intelligence reside in the intersection of the real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entanglement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP.

1. For the minimal option life would be also effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world sheets partonic two-surfaces appears in U-matrix so that only the data from rational and some algebraic points of the partonic 2-surface dictate U-matrix. This means discretization at parton level and something which might be called number theoretic quantum field theory should emerge as a description of intentional action.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K2]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K4].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

3.4 Hyper-Finite Factors Of Type II$_1$ And NMP

Hyper-finite factors of type II$_1$ bring in additional delicacies to NMP. The basic implication of finite measurement resolution characterized by Jones inclusion is that state function reduction can never reduce entanglement completely so that entire universe can be regarded as an infinite living organism. It would seem that entanglement coefficients become $\mathcal{N}$ valued and the same is true for eigen states of density matrix. For quantum spinors associated with $\mathcal{M}/\mathcal{N}$ entanglement probabilities must be defined as traces of the operators $\mathcal{N}$. An open question is whether entanglement probabilities defined in this manner are algebraic numbers always (as required by the notion of number theoretic entanglement entropy) or only in special cases.

4 p-Adic physics as correlate of cognition and imagination

The items in the following list give motivations for the proposal that p-adic physics could serve as a correlate for cognition and imagination.

1. By the total disconnectedness of the p-adic topology, p-adic world decomposes naturally into blobs, objects. This happens also in sensory perception. The pinary digits of p-adic number can be assigned to a p-tree. Parisi proposed in the model of spin glass [B1] that p-adic numbers could relate to the mathematical description of cognition and also Khrennikov [J1] has developed this idea. In TGD framework that idea is taken to space-time level: p-adic space-time sheets represent thought bubbles and they correlate with the real ones since they form cognitive reprentations of the real world. SH allows a concrete realization of this.

2. p-Adic non-determinism due to p-adic pseudo constants suggests interpretation in terms of imagination. Given 2-surfaces could allow completion to p-adic preferred extremal but not to a real one so that pure "non-realizable" imagination is in question.

3. Number theoretic negentropy has interpretation as negentropy characterizing information content of entanglement. The superposition of state pairs could be interpreted as a quantum representation for a rule or abstracted association containing its instances as state pairs. Number theoretical negentropy characterizes the relationship of two systems and should not be confused with thermodynamical entropy, which characterizes the uncertainty about the state of single system.

The original vision was that p-adic non-determinism could serve as a correlate for cognition, imagination, and intention. The recent view is much more cautious. Imagination need not completely reduce to p-adic non-determinism since it has also real physics correlates - maybe as partial realizations of SH as in nerve pulse pattern, which does not propagate down to muscles.

A possible interpretation for the solutions of the p-adic field equations would be as geometric correlates of cognition, imagination, and perhaps even intentionality. Plans, intentions, expectations, dreams, and possibly also cognition as imagination in general could have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is the 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 most feasible view is that the intersections of p-adic and real space-time surfaces define cognitive representations of real space-time surfaces (PEs, [K1, K5, K6]). One could also say that real space-time surface represents sensory aspects of conscious experience and p-adic space-time surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics.

The identification of p-adic pseudo constants as correlates of imagination at space-time level is indeed a further natural idea.

1. The construction of PEs by SH from the data at 2-surfaces is like boundary value problem with number theoretic discretization of space-time surface as additional data. PE 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 in real context.

2. In p-adic sectors the integration constants are replaced with pseudo-constants depending on finite number of pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces. The fixing of the discretization of space-time surface would allow to fix the p-adic pseudo-constants. Once the number theoretic discretization of space-time surface is fixed, the p-adic pseudo-constants can be fixed. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets, partonic 2-surfaces, and number theoretic discretization but not allowed in real context.

Could these p-adic PEs correspond to imaginations, which in general are not realizable? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could one identify non-realistic imaginations as the modes of WCW spinor fields for which 2-surfaces are not extendable to real space-time surfaces and are localized to 2-surfaces? Could they allow only a partial continuation to real space-time surface. Could nerve pulse pattern representing imagined motor action and not proceeding to the level of muscles correspond to a partially real PE?

Could imagination and problem solving be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real PEs? If so, 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.

3. An interesting question is why elementary particles are characterized by preferred p-adic primes (primes near powers of 2, in particular Mersenne primes). Could the number of realizable imaginations for these primes be especially large? Quite generally, those extensions for which the number of realizable imaginations is maximal would be the fittest in number theoretic fight for survival. The ramified primes assigned to these extensions would in turn define the preferred p-adic primes. Ann open question is what are the fittest extensions and whether the p-adic primes coming as powers of two or of small primes are associated with these extensions.

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that SH derivable from - you can guess, strong form of General Coordinate Invariance (Einstein again!), plays an absolutely central role in it.

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