# Classical non-determinism in relation to holography, memory and the realization of intentional action in the TGD Universe

January 11, 2026

Matti Pitkänen

**orcid**:0000-0002-8051-4364.
**email**: matpitka6@gmail.com,
**url**: http://tgdtheory.com/public_html/,
**address**: Valtatie 8, as. 2, 03600, Karkkila, Finland.

## Contents



**Abstract**

Gary Ehlenberg sent a link to an interesting Quanta Magazine article with the title "'Next-Level' Chaos Traces the True Limit of Predictability". The article discusses the limits to classical predictability as effective non-determinism due to non-computability caused by the initial value sensitivity although the classical dynamics is deterministic. There is also a genuine non-predictability due to non-determinism of quantum theory and quantum statistical determinism makes predictability possible in this case.

Holography, which is not discussed in the article, simplifies the situation enormously since roughly one half of boundary values of initial values are reduced. In wave mechanics, holography corresponds to Bohr orbitology. In complex analysis, the holography corresponds to the reduction of the data defining the analytic function reduces to the residues at poles and discontinuities at cuts.

In the TGD framework holography boils down to holography= holomorphy principle and allows an interesting point of view to the notion of classical chaos. The extremely nonlinear partial differential equations are reduced to algebraic equations. The case of 2-D minimal surfaces suggests that the holography is not completely deterministic and this forces zero energy ontology (ZEO). The discrete degrees of freedom related to classical non-determinism make conscious memory possible and could relate to the realization of intentions as actions. Number theoretic vision suggests that p-adic and adelic physics serves as correlates for cognition and intentionality and that p-adic non-determinism and classical non-determinisms in the real sector could relate. ZEO suggests a concrete mechanism for how intentions are realized as actions.

# Contents

# 1 Introduction

Gary Ehlenberg sent a link to an interesting article with title "'Next-Level' Chaos Traces the True Limit of Predictability" (see this).

The article discusses the limits to classical predictability as effective non-determinism due to non-computability caused by the initial value sensitivity although the classical dynamics is deterministic. There is also a genuine non-predictability due to non-determinism of quantum theory and quantum statistical determinism makes predictability possible in this case.

Holography, which is not discussed in the article, simplifies the situation enormously since roughly one half of boundary values of initial values are reduced. In wave mechanics, holography corresponds to Bohr orbitology. In complex analysis, the holography corresponds to the reduction of the data defining the analytic function reduces to the residues at poles and discontinuities at cuts.

In the TGD framework holography boils down to holography= holomorphy principle and allows an interesting point of view to the notion of classical chaos. The extremely nonlinear partial differential equations are reduced to algebraic equations and the holography is not expected to be completely deterministic.

In the TGD framework, classical non-determinism is closely related to conscious experience, in particular to the realization of conscious memories. The quantum measurements in the degrees of freedom associated with the classical non-determinism correspond to self-measurements giving rise to conscious experience. Zero energy ontology (ZEO) defines quantum ontology and plays a key role in the understanding of conscious experience. Number theoretical vision brings in p-adic number fields and adeles as correlates of cognition and intentionality. This raises the question of whether and how the classical non-determinism does relate to the p-adic non-determinism.

The question of how intentions are realized as actions also emerges. ZEO predicts that the arrow of time is changed in "big" state function reductions (BSFRs) and this makes possible a quantum version of trial and error process. The number theoretic vision implies Negentropy Maximization Principle stating that the algebraic complexity of space-time surfaces increases in a statistical sense. This implies evolution in all scales. This raises hope about the realization of intentional actions realized as p-adic space-time surfaces as actions realized as corresponding real space-time surfaces by using a quantal trial and error process.

These ideas and questions will be discussed in the sequel.

# 2 Holography= holomorphy principle, classical *viz.* p-adic non-determinism, ZEO, and the realization if intentions as actions

Holography= holomorphy principle suggests a failure of an exact classical determinism. A natural guess is that this non-determinism relates to p-adic non-determinism. ZEO suggests a general view about conscious memory and intentional action as a quantal trial and error process. The obvious idea is that the realization of intentions as actions in some sense assigns to p-adic space-time surfaces real space-time surfaces whereas the formation of cognitive representations would do the opposite.

## 2.1 Holography and classical non-determinism

Holography, as it is realized in the TGD framework, allows an interesting point of view to the notion of classical chaos. This view is not considered in the article. In the TGD framework, there is also a close relation to the question about how intentions are realized as actions.

1. Holography reduces the initial data at the fundamental level (space-times as surfaces) roughly by one half and space-time surfaces as orbits of 3-surfaces identified as particle like entities

are analogous to Bohr orbits for which only initial positions or momenta can be fixed. This increases predictability dramatically [L7, L8].

2. Holography= holomorphy principle reduces the extremely nonlinear field equations of TGD to algebraic extensions and one obtains minimal surfaces irrespective of action principle if it is general coordinate invariant and involves only the induced geometry. The space-time surfaces are roots of pairs of polynomials or even analytic functions $f = (f_1, f_2)$ of one hyper complex coordinate and 3 complex coordinates of $H = M^4 \times CP_2$. Field equations are more like rules of logic rather than an axiom system. This implies enormous simplification. Solutions are coded by the Taylor coefficients of $f_1$ and $f_2$ in an extension E or rationals and for polynomials their number is finite [L4, L9].

   One obtains new solutions as roots of maps $g \circ f$ , where $g : C^2 --> C^2$ is analytic. The iterations of $g$ give rise to the analogs of Mandelbrot fractals and Julia sets so that in this sense classical chaos, or not actually chaos but complexity, emerges. For the iteration of hierarchies $P = g \circ g.... \circ f$ the complexity increases exponentially since the degree P and the dimension of the corresponding algebraic extension increases exponentially. The roots for the iterates can be however calculated explicitly. The interpretation could be as a classical geometric correlate for an abstraction hierarchy.

3. Already 2-D minimal surfaces representable as soap films are non-deterministic. Soap films spanned by frames are not unique. Now frames would be represented by 3-surfaces and possibly lower-D surfaces representing holographic data. The second, passive, light-like boundary of the causal diamond CD is the basic carrier of holographic data. Also the light-like partonic orbits as interfaces between Minkowskian and Euclidean space-time regions carry holographic data. They serve as building bricks of elementary particles. At 3-D frames minimal surface property fails and field equations on the classical action and express conservation laws for isometry charges for the action in question?

   This is expected to give rise to a finite classical non-determinism. It would be essential for the quantum realization of conscious memory since small state function reductions (SSFRs) do not destroy the classical information about the previous SSFRs [L6]. The information is carried by the loci of classical non-determinism having as a counterpart quantal non-determinism assignable to conscious experience.

## 2.2 The relationship between classical p-adic non-determinisms

How could classical non-determinism relate to p-adic non-determinism and to the realization of intentions as transformation of intentions as p-adic space-time surfaces to real space-time surfaces?

1. In adelic physics real and p-adic space-time surfaces are assumed to satisfy essentially the same algebraic field equations. The p-adic and real Taylor coefficients of $f = (f_1, f_2)$ might however relate by canonical identification which maps p-adic numbers in continuous way to reals [L1]. The inverse of the canonical identification as map from reals to p-adics is 2-valued for finite sequences of pinary digits, which in real contex can correspond to a finite or infinite sequence of pinary digits (1=.999...).

   The conjecture is that ramified primes of polynomials (and their generalization) correspond to preferred p-adic primes appearing in p-adic mass calculations and satisfying p-adic length scale hypothesis [L3, L9].

2. What is the relationship between the classical non-determinism and p-adic non-determinism, tentatively identified as a correlate for the non-determinism of imagination and intentionality? Could intentions classically correspond to the solutions of p-adic field equations with the polynomial coefficients, which have values in the extension $E$ but are pseudo-constants having vanishing derivative and are constant only inside regions of the space-time surface?

   Is it also possible to obtain real solutions with piece-wise constant Taylor coefficients of $f$? Does real continuity and field equations (holomorphy in $H$) allow this? Is it possible to glue together solutions defined by different analytic functions $f$? Does this pose additional conditions to the Taylor coefficients as pseudo constants? If so, realizable intentions would correspond to p-adic space-time surfaces, which also have real counterparts. Also real space-time surfaces would have piecewise constant Taylor coefficients changing at the interfaces of two regions.

A concrete guess is that the gluing of solutions with different choices of $f$ can take place along light-like surfaces since in classical field theories light-like surfaces are seats of non-determinism. Partonic orbits are such surfaces and wormhole contact could define one possible mechanism of gluing together two Minkowskian space-time sheets defined by different choices $f$.

## 2.3 How intentions could be realized?

Zero energy ontology (ZEO), Negentropy Maximization Principle [K1]) [L2], the TGD view of conscious memory suggest guidelines for how intentions could be realized. One must however define the basic notions.

1. Suppose that intention could be realized as a p-adic space-time surface for some primes p, perhaps the ramified primes assignable to the polynomials defining the space-time surface considered. Assume that the realization of intention corresponds to a real space-time surface. p-Adic space-time surfaces are mapped in a continuous way to each other by canonical identification which is most naturally realized at the level of WCW for the Taylor coefficients of $f$ and $g$.

   The number of coefficients is finite for polynomials and should have a representation at the space-time level as space-time points. I have proposed [L9], how the representation as roots of $(f_1, f_2)$ (4-D space-time surfaces) gives rise to a simpler representation of roots ordinary complex numbers assignable to specific space-time points.

2. Carving a statue proceeding from a rough sketch to complete artwork serves as a metaphor for the realization of intentional action. This means that the realization of intention is only in a certain resolution. This means number theoretical discretization in terms of algebraic numbers of extension. At the level of WCW this could correspond to a use of finite extension $E$ of rationals.

   Could the iteration of $g$ with $g(0,0) = (0,0)$ define an increase in the resolution and to the addition of details and complexity. What is the significance of the fact that the roots of $g$ correspond to disjoint space-time surfaces. Do they correspond to separate space-time surfaces? What if the iterate is too large to fit into the CD.

3. Conscious memory is expected to have a role in the process. The SSFRs select between different superpositions of Bohr orbits and conscious memory makes it possible to remember the initial state at the passive boundary and the subsequent states. It would be natural to assume that there is a comparison of the outcome from a sequence of SSFRs with the goal.

   How could the goal be represented consciously? Could it correspond to a lower level in the self hierarchy: the level immediately below a given level gives rise to mental images. If the goal is represented as a mental image the outcome from a given number of SSFRs could be compared with it to see whether the iteration converges.

The following overall view about the realization of intention as action could serve as a starting point.

1. At the level of the world of classical worlds (WCW) quantum states are superpositions of Bohr orbits in both real and p-adic degrees of freedom. The ends of 3-surfaces are fixed at the passive boundary of causal diamond (CD) during a sequence of "small" state function reductions (SSFRs) giving rise to a conscious entity self. SSFRs correspond to quantum measurements in internal degrees of freedom including those associated with classical non-determinism. Cognition can be assigned with these degrees of freedom. The size of CD also increases in the sequence of SSFRs and this gives rise to the experienced arrow of geometric time.

In "big" state function reductions (BSFRs) the roles of boundaries of CD change and passive boundary becomes active. The arrow of time changes and the conscious entity defined by the sequence of SSFRs dies or falls asleep. Pairs of BSFRs make possible a trial and error process in which the initial values of holography at the passive boundary are changed.

2. Could the realizable intentions have as quantum counterparts sequences of small state function reductions (SSFRs)? What the attempt to realize an intention could mean at the quantum level? Could for a given intention only a finite number of SSFRs be possible: the real counterparts for the p-adic pseudo constants would not allow a realization for longer sequences of SSFRs requiring larger CDs.

   After that a big state function reduction (BSFR) would take place and reverse the arrow of time: the sequence of SSFRs as self would "die" or fall asleep. After the second BSFR (wake-up) one would have a new trial for the realization of intention. Since the extension of rationals increases in size, the next real could contain more SSFRs, the updated holographic data could make the life of the new self as an attempt to realize a slightly modified intention longer.

3. Negentropy Maximization Principle [K1]) [L2] states that the algebraic complexity can only increase in statistical sense since the number of algebraically more complex space-time surfaces is infinitely larger than those, which are less complex. This applies also to the interactions of $g : C^2 \to C^2$. The hierarchy of maps $g \circ g...g \circ f$ would give exponentially increasing complexity and dimension of extension of rationals if $g(0,0) = (0,0)$ so that also $f = 0$ would define one of the roots of $g$. Reflective levels would make it easier to realize the intentions by increasing exponentially the number of roots of $g \circ ... \circ g$, which are in fact disjoint space-time surfaces. One obtains a disjoint union of space-time surfaces as roots unless $f$ is a prime in the sense that it does not allow a decomposition $f = g \circ h$. Prime surfaces are connected. Fundamental space-time surfaces and fundamental intentions would be primes in this sense.

## 2.4 Does the union of disjoint roots of $g_1 \circ ...g_n \circ f$ represent the concept as a set?

The space-time surfaces defined as roots of $g \circ ...g \circ f$, where $f$ is a prime polynomial and $g(0,0) = (0,0)$, form a kind of ensemble of disjoint space-time surfaces. Abstraction means formation of concepts and classically concept is the set of its different instances. Could this union of disjoint space-time surfaces as roots represent a concept classically?

What comes to mind are biological systems consisting of cells: do they represent a concept of a cell? What about a population of organisms? What about an ensemble of elementary particles: could it represent the concept of, say, electrons?

1. Holography= holomorphy principle would be essential for the realization of the geometric correlate of collective quantum coherence. Only initial 3-surfaces defining holographic data matter in holography. The 4-D tangent spaces defining the counterparts for initial velocities cannot be chosen freely. This would force a coherent synchronous motion. Also classical non-determinism would be present. Could it correspond to piecewise constant Hamilton-Jacobi structure with different structure assigned to regions of the space-time surface.

2. The Hamilton Jacobi structure of all members of the ensemble from by the roots of $g \circ ...g \circ f$ is the same so that they can be said to behave synchronously like a single quantum coherent system. Could the loss of quantum coherence mean splitting: $p^k$ roots forming a coherent structure would decompose to $p^{k_1}$ sets with different H-J structures containing $p^{k-k1}$ roots. Cognitive ensemble, as a representation of a concept, would decompose to ensembles representing $p^{k_1}$ different concepts. Is continual splitting and fusion taking place? Could this conceptualization make possible conceptualized memory: the image of the house would be represented by an ensemble of images of houses as kind of artworks.

I have often enjoyed looking at a crop field in a mild summer wind. To me, the behaviour suggests quantum coherence.

1. Crop field in the wind seems to behave like a single entity. Could the crop field correspond to an abstraction of the notion of crop as a set of its instances, realized as a set of space-time surfaces realized as roots of for $g \circ .... \circ f$. Also more general composites $g_1 \circ g_2 ... g_n \circ f$ $g_i(0,0)$ are possible. The roots could also represent the notion of a crop field in wind as a collection of crops, each moving in wind as a particular motion of air around it.

2. Do I create this abstraction as a conceptualization, a kind of thought bubble, or does the real crop field represent this abstraction? Could $f$ correspond to the primary sensory perception and does cognition generate this set (not "in my head" but at my field body) as a hierarchy of iterations and an even more general set of g-composites? Different observers experience crop fields very differently, which would suggest that this is a realistic view.

3. If this set represents the real crop field, there should also be a space-time surface representing the environment and the wind. Could wormhole contacts connect these surfaces representing the concept and the environment to a single coherent whole.

   The usual thinking is that crops from uncorrelated systems and wind as a motion of air causes the crops to move. The coherent motion would correspond to a collective mode in which crops move in unisono and synchronously. What creates this coherent motion? Could macroscopic quantum coherence at the level of the field body be the underlying reason in the TGD Universe?

4. How to describe the wind if one accepts the crop field in wind itself represents the notion of crop in wind? Usually wind is seen as an external force. Coherent motion correlates with the wind locally. What does this mean? How could one include the wind as a part of the system? Wind should affect the crops as roots of $g \circ ....g \circ f$. Each root should correspond to a specific crop affected locally by the wind. Or should one accept that the concept of crop field in the wind is realized only at the level of cognition rather than at the level of reality?

## 2.5 Simulation hypothesis and TGD

The original simulation hypothesis (see this did not make sense to me since I find it impossible to imagine how the simulation hypothesis could solve any problem of physics or of theory of consciousness. Living systems are of course mimicking each other all the time so that conscious simulation is a very real phenomenon.

The new view of the simulation hypothesis (see this) seems to be analogous to what the simulation of a second computer by computer means. Already in classical physics, the coupling of two systems, in particular resonance coupling, produces what might be called a simulation. Complex enough simulating a simpler system can produce rather faithful simulations. This is not new but makes sense.

The ability to simulate is the key property of computers and the natural question is how the simulations are realized in the TGD inspired theory of consciousness [L13], where one must speak of conscious simulations.

1. In TGD inspired theory of consciousness perception as a sequence of quantum measurements produces representations of an external system and the slightly non-determinism internal degrees of freedom of the space-time surface representing conscious entities can produce this kind of simulation in the more complex system, a kind of cognitive model. The hierarchy of algebraic extensions of rationals defines the entire complexity hierarchy.

2. Holography = holomorphy hypothesis [L4, L9, L5, L11] makes this view concrete. Consider as an example two systems described as roots of $(f_1, f_2) = (0, 0)$ and say $(g^{\circ n} \circ f_1, f_2) = (0, 0)$. Here $f_i$ are analytic functions of generalized complex coordinates of $H = M^4 \times CP_2$ (one hypercomplex coordinate is involved). The latter system has for any $n$ as its roots also $(f_1, f_2) = 0$ for $g(0) = 0$ and the latter system can simulate the first system exactly at the space-time level. The larger the value of $n$, the higher the simulatory capacities. One obtains simulations and simulations of simulations of ... .

3. For elementary particles the p-adic length scale hypothesis [L10, L14], stating that p-adic primes $p$ near the power of 2 are important, could mean the following. Polynomials $g$ with

prime degree $p$ are of special interest since they cannot be decomposed with respect to $\circ$. For any $(f_1, f_2)$ defining kind of ground state, one can have any prime polynomial $g$ of prime degree $p$ and form iterates $g^{\circ n}$. For $p \in \{2, 3\}$, one can solve the roots of the iterates $g^{\circ n}$ exactly (Galois) [L12]. This suggests that the p-adic length scale hypothesis is true for $p \in \{2, 3\}$ and they form cognitive hierarchies by iterations. There is indeed evidence also for $p = 3$ in biology [**?**, **?**] (see this).

# REFERENCES

## Books related to TGD

[K1] Pitkänen M. Negentropy Maximization Principle. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/nmpc.pdf, 2023.

## Articles about TGD

[L1] Pitkänen M. Philosophy of Adelic Physics. Available at: https://tgdtheory.fi/public_html/articles/adelephysics.pdf., 2017.

[L2] Pitkänen M. Negentropy Maximization Principle and Second Law. Available at: https://tgdtheory.fi/public_html/articles/nmpsecondlaw.pdf., 2021.

[L3] Pitkänen M. Two objections against p-adic thermodynamics and their resolution. https://tgdtheory.fi/public_html/articles/padmass2022.pdf., 2022.

[L4] Pitkänen M. About Langlands correspondence in the TGD framework. https://tgdtheory.fi/public_html/articles/Frenkel.pdf., 2024.

[L5] Pitkänen M. Holography=holomorphy vision in relation to quantum criticality, hierarchy of Planck constants, and $M^8 - H$ duality. https://tgdtheory.fi/public_html/articles/holoholonumber.pdf., 2024.

[L6] Pitkänen M. How subjective memories are realized in TGD inspired theory of consciousness? https://tgdtheory.fi/public_html/articles/memorytgd.pdf., 2024.

[L7] Pitkänen M. TGD as it is towards the end of 2024: part I. https://tgdtheory.fi/public_html/articles/TGD2024I.pdf., 2024.

[L8] Pitkänen M. TGD as it is towards the end of 2024: part II. https://tgdtheory.fi/public_html/articles/TGD2024II.pdf., 2024.

[L9] Pitkänen M. A more detailed view about the TGD counterpart of Langlands correspondence. https://tgdtheory.fi/public_html/articles/Langlands2025.pdf., 2025.

[L10] Pitkänen M. A refined view of the phenomenology of hadron physics and p-adic mass calculations. https://tgdtheory.fi/public_html/articles/padmass2025.pdf., 2025.

[L11] Pitkänen M. Gödel,Lawvere and TGD. https://tgdtheory.fi/public_html/articles/Gtgd.pdf., 2025.

[L12] Pitkänen M. Holography = holomorphy vision and elliptic functions and curves in TGD framework. https://tgdtheory.fi/public_html/articles/Weierstrass.pdf., 2025.

[L13] Pitkänen M. The recent view of TGD inspired theory of consciousness and quantum biology. https://tgdtheory.fi/public_html/articles/consc2025.pdf., 2025.

[L14] Pitkänen M. Does the notion of Teichmüller element cure the problem of p-adic mass calculations due to the slight failure of Lorentz invariance? https://tgdtheory.fi/public_html/articles/padmass2026.pdf., 2026.