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1 Introduction

Finding a theory of everything (ToE) that harmonizes the stochastic, microscopic quantum world with the deterministic, perceivable universe poses one of the major challenges in modern physics. Numerous ToE candidates have been brought forward in the past, most popular the diverse flavours of supergravity-, string- and M-theory [1, 2, 3]. However, all these theories are based on purely speculative assumptions (e.g. the 11 dimensions proposed in M-theory), have questionable predictive power and limited theoretical ground. These ToE candidates further suffer from their immense mathematical complexity and the requirement for finest parameter tuning in order to mimic only selected aspects of quantum mechanics (QM) and Einstein's general relativity theory (GRT). Unsurprisingly, none of the existing ToE[4] candidates is even close to being experimentally verifiable with physical methods of today or the foreseeable future. Expanding and refining existing ToE proposals is unlikely to overcome these profound obstacles, but rather prone to ever increasing mathematical complexity and therefore room for pure speculation.

In principle, a ToE should not only explain gravity and quantum mechanics out of one single model, but every physical phenomenon in the universe. Several authors have suspected a fundamental relationship among at first sight very different domains: Intelligent decision making [5, 6, 7, 8, 9], the mysterious quantum measurement process and gravitation in terms of Einstein's general relativity theory (GRT)[10, 11]. Consequently, all three of the aforementioned domains might represent a valid entry point to some kind of theory of everything (ToE) [12, 13]. However, so far, the problem of emergent reality[14, 15] has been tackled almost exclusively from the quantum perspective, while the other two, possible routes were largely ignored (Figure 1).

In this work, I present GenI ([dʒiːnaɪ] for generic intelligence), a swarm-like stochastic model inspired by artificial intelligence (AI) that transcends the gap between GRT and QM and unlocks a completely new path towards a ToE. GenI operates on a swarm-like construct and implements a competition of ideas resulting in a rather chaotic selection process directed by a small set of simple rules. Remarkably, the probability distribution for idea selection only depends on the system's state at the beginning and precisely matches quantum measurement predictions. At the same time, the dynamics of the GenI process locally follow geodetic lines in a four dimensional Riemann space whose metric fully satisfies the requirements of Einstein's field equation. Besides the demonstrated theoretical validity, its mathematical simplicity, robustness and possible experimental accessibility distinguish GenI from all established ToE candidates.

The GenI model proposes a simple and elegant solution to the GRT vs QM dilemma and thereby unveils a fundamentally different perspective onto our universe.

2 Results

2.1 The GenI model

Biological swarms are comprised of relatively simple individuals that collectively perform surprisingly well in solving complex problems, e.g. maximizing survival and reproduction.

Fish swarms, for instance, decide on their movement by following a simple set of local rules generally obeyed by each swarm member [16]. From time to time, however, individuals make mistakes and disrespect the swarm's inner rule set. Remarkably, this seemingly imperfection appears to be a key ingredient of a swarms success in using and exploring its environment. With a certain probability, the swarm will follow its runaway individuals, resulting in sudden, highly dynamic changes in the swarm shape and swimming direction. In case the unexpected turn appears to improve the swarm's well-being or chance of survival it can keep going and explore. Hence, random mistakes by individuals enable the swarm to transcend the boundaries imposed by its own, inner laws, providing an enormous flexibility and exploratory potential eventually enabling creative problem solving.

GenI mimicks this swarm-like decision making strategy. In strong contrast to previous AI algorithms inspired by collective swarm intelligence, however, GenI implements a by far higher, so-far unexplored degree of randomization and uses an innovative swarm formalization introduced below.

The exclusive purpose of a GenI swarm S is to make a decision from a given set of options. The GenI swarm consists of an arbitrary but finite number of abstract individuals s_j. "Abstract" here means that swarm members are defined by a set of type-specific characteristics. You may imagine each member e.g. as comprising a infinitesimally small sphere with an individual number on it.

Alike biological swarms, the GenI swarm reacts to changes in its environment. The way the GenI swarm responds is thereby defined by the GenI process.

The size of the swarm as well as its individuals will change dramatically over time. Thus, a swarm behaves somewhat similar to a flame, constantly sucking "material" from its surroundings and "burning" it in order to grow or shrink, while dynamically changing its shape.

In the following, I will repeatedly return to this picture of a flame to illustrate GenI's basic features.

The shape of a swarm at a specific moment is referred to as "state". The state hides most of the swarm's inner swarm complexities and is represented by an array of n complex numbers, which I will refer to as the "amplitudes". "n" thereby determines the maximum number of possible choices the swarm may decide about. It is calculated by mapping each swarm member to a complex vector which are then all summed up.

Importantly, a swarm incorporates a significant number of entities that are hidden from the state view, as for any pair $s, t \in S$ with $s \mapsto w$, $t \mapsto -w$ the aforementioned sum is zero. A maximal set N_S of such *null pairs* represents the *entropy* of the swarm and $S \backslash N_S$ is a *entropy freed swarm*. For large swarms these null pairs are typically in the majority (Figure 2). They serve as "burning material" to keep the "flame" alive. Importantly, a real flame also needs continuous oxygen supply to keep the burning reaction going.

The corresponding counterpart ingredient in GenI is the *excitation*, which is provided by the *environment*, defined by a set of n independent vectors $B_E = \{a_j : j = 1 \dots n\} \subset \mathbb{C}^n$. These vectors represent the possible options a_j the swarm S can choose from. The resulting swarm's shape is dependent on the environment and defined by $state(S) = \sum_{j=1}^{n} \beta_j a_j$. The component $\beta_j a_j$ refers to the *idea* of S about option j and $\beta_j \in \mathbb{C}$ its *amplitude*. Taken together, the state of a swarm represents a superposition of ideas about a given set of options defined by the environment (see also [17]).

The entropy is essential to keep the GenI process running with high volatility. It is responsible for the seemingly chaotic characteristics of the GenI decision making process.

GenI swarms can generally be classified into *P-swarms* (for Pauli-swarm) and *E-swarms* (for eigenvector-swarm).

The P-swarms implement decision making based on only two possible options (YES-NO type). This is the basic GenI swarm type that demonstrates the full power of the GenI model. Its members each map to one of the 16 elements of the well known Pauli group denoted by $\{i^k p_j : j, k = 0 \dots 3\}$. Thus the swarm individuals are grouped into a few image types p_j, where p_0 represents the identity in $Mat(2x2, \mathbb{C})$, i the imaginary unit and p_1,p_2,p_3 the three Pauli matrices.

Any P-swarm S thus receives an image in a two dimensional complex matrix algebra. A linear *perspective* transformation maps the resulting operator onto a two dimensional complex state. This is achieved by right multiplying a fixed perspective vector $v \in \mathbb{C}^2$. So the two dimensional state of the swarm is determined by Sv. The operator image of S on the other hand can be used to derive an internal environment in terms of its inbound symmetries. Such an environment is sometimes referred to as an *observable*, which is the usual notation in QM for a hermitian operator. The observables' (orthonormal) eigenvector base then defines the environment introduced above.

E-swarms are leveraged to implement decision making among many possible options. Its individuals map directly to vectors. A perspective transformation is not needed here and no operator image gets exposed to determine any internal environment. In case of two choices E- and P-type swarms are typically equivalent with respect to the statistically expected outcome of the

GenI process.

The dynamical features of the model are governed by the GenI process. It operates both at the swarm level and at the state level and implements a competition amongst ideas of a swarm
$S = \sum_{j=1}^{n} \beta_j a_j$. During the decision making process, the swarm carries out a random walk within a given environment constrained by only three simple, local rules (Figure 3): 1. Increase entropy, 2. lower the excitation value, and 3. disregard the rules whenever you want (see below).

Importantly, the fail rate of meeting the second rule is high, enabling the swarm to carry out unpredictable walks and fully explore the environment (Figure 4).

A full iteration of the GenI algorithm starts by adding entropy to each idea according to its amplitude β_j. Next, the corresponding excitation values are calculated as $\epsilon_j(S)^2 := 4\frac{|\beta_j|^2 \sum_{k \neq j} |\beta_k|^2}{\left(\sum_{k=1}^{n} |\beta_k|^2\right)^2} \in [0, 1]$ (see Methods). In the third step all the null pairs (s, t) that represent the entropy of the swarm are determined.

Null pairs can then be split up (i.e. *burned*) or left untouched. The probability for splitting up a given null pair is ϵ_j^2 hence characterizing the burn rate. In that case s stays with the swarm and t leaves it or vice versa. The probability distribution for s to leave or to stay is, in most cases, only slightly distorted towards one or the other. More specifically, the probability for s to stay is $\frac{\epsilon_j(S \backslash \{s\})}{\epsilon_j(S \backslash \{s\}) + \epsilon_j(S \backslash \{t\})}$. This rule sets a weak trend towards lower excitations. The process stops as soon as all the excitations values become zero, i.e. the swarm reached a final decision.

I implemented the GenI process in JAVA (see data availablity section) and generated all the statistical data out of this reference implementation.

2.2 QM measurement statistics

Looking at the chaotic behaviour of the GenI decision making process as documented in figure 4, it would be counter-intuitive to expect any well defined statistics regarding the process outcome.

However, GenI's few quite simple rules lead the swarm state to one of the given environment options a_j with a surprisingly well defined probability distribution. This distribution exactly matches the well known predictions of quantum measurements on a physical particle given by $\frac{|\beta_j|^2}{\sum_{k=1}^{n} |\beta_k|^2}$. Also all the characteristics of sequential spin measurements with varying observables (e.g. different space directions) are fully met by the model (see methods section). Importantly, these remarkable characteristics are intrinsic to the GenI process, i.e. they occur without any requirement for parameter tuning.

Performing simulations on P-swarms clearly support the hypothesis, that the frequencies are indeed produced by a probablility distribution according to quantum measurements on spin½ particles (Figure 5). Equally, simulations on E-swarms demonstrate, that the observed frequencies get produced by a probability distribution $p_j = \frac{|\beta_j|^2}{\sum_{k=1}^{n}|\beta_k|^2}$ according to swarm amplitudes $S = \sum \beta_j a_j$ (table 2).

Tests have been performed for one up to millions of swarm members, starting with tons of entropy or no null pairs at all. The statistics robustly meet quantum measurement predictions producing chi square test values within 95% confidence. Swarm sizes are ultimately restricted only by the hardware capabilities that perform the simulation.

The decision process evolves completely chaotic in every aspect. This is true for the paths of amplitudes in the complex plane (Figure 6c), as well as for the evolution of absolute amplitudes over time (Figure 6a). These findings demonstrate the unpredictable nature of the GenI decision process.

The picture is similar for E-swarms and P-swarms with a slightly different pattern only for the entropy evolution (Figure 7).

2.3 Spacetime metric

General relativity is the world of continuity, unrestricted predictability of the past and the future, differentiable manifolds, four-dimensional spacetime and an reversible timeline. In sharp contrast to this, the GenI process is jumpy, discrete, chaotic, completely unpredictable, multidimensional with a clear unidirectional timeline.

However statistically the chaos can be averaged out and the discreteness of the process steps blurs with the increasing number of iterations. The resulting dynamics indeed satisfy Einstein's field equation as will be shown. To make meaningful progress at this point, one has to consider GRT as being a statistical theory and that the time is not a continuous, but a discrete variable. Several authors have already suspected this before[18].

Now taking the iteration count as a time variable, then for one single burn step we get
$\frac{db_j}{dt}\sum_{k=1}^{n} b_k^2 = \frac{1}{b_j}\left(b_j^2 - \sum_{k\neq j} b_k^2\right)$ where $b_j = |\beta_j|$.

We will focus here on the decision process with only two choices operating on an E-swarm. In this case we get simply $\frac{dx}{dt} = \frac{1}{x}\frac{x^2-y^2}{x^2+y^2}$ and $\frac{dy}{dt} = \frac{1}{y}\frac{y^2-x^2}{x^2+y^2}$ for a swarm $S = \beta_1 a_1 + \beta_2 a_2$ where $\beta_1 = xe^{i\phi_x}, \beta_2 = ye^{i\phi_y}$.

A map into a 4-dimensional manifold is chosen as
$\vec{X} = \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} t \\ \langle p_1 S \mid S\rangle \\ \langle p_2 S \mid S\rangle \\ \langle p_3 S \mid S\rangle \end{bmatrix} = \begin{bmatrix} t \\ 2cxy \\ 2sxy \\ x^2 - y^2 \end{bmatrix}$ and the process time t as the path variable where $c = \cos(\phi_x - \phi_y), s = \sin(\phi_x - \phi_y)$.

Applying the Hamiltonian minimal principle to determine the coefficients in the relativistic line element $ds^2 = Adt^2 - B_1 dx_1^2 - B_2 dx_2^2 - B_3 dx_3^2$ finally results in a metric

$$g_{\mu\nu} = \frac{x_1^2+x_2^2}{x_1^2+x_2^2+x_3^2} e^{-\frac{x_3^2}{x_1^2+x_2^2}} \begin{bmatrix} 32\left(1+\frac{x_3^2}{x_1^2+x_2^2}\right) & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -\left(2+\frac{x_3^2}{x_1^2+x_2^2}\right) \end{bmatrix}$$

that is indeed consistent with the requirements of GRT. It determines a curved spacetime so that the Genl process locally follows geodetic lines on timelike paths. When the swarm has made its decision the metric collapses to zero. The swarm's image in spacetime always ends up in a singularity. From here it is a straightforward exercise to determine the left side of Einstein's field equation

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\kappa T_{\mu\nu}$$

and thus conclude a mass-energy distribution that represents the right side.

3 Discussion

A ToE that unifies QM and GRT has been a long-sought goal in modern physics. Previous approaches almost exclusively focused on QM as a potential ToE entry point. This was probably due to a wide agreement within the physics community that QM would likely represent the universe's most basic operation principle and should consequently imply GRT as well as any other physical law.

In this work, I took a radically different approach by developing a theoretical model for intelligent decision making with the principle aim to better understand intelligent behaviour and consciousness as well as to advance AI implementation. To my own surprise, the presented GenI decision making model strongly suggests a fundamental relationship between intelligence, QM and GRT. More specifically, all three domains simply represent different aspects of a previously unknown, swarm-like stochastic process operating at the very basis of our universe. Gravitation, space and time as formulated in GRT are thereby specific traits of the 'inner' view of the swarm itself, while QM describes the outer view in which the 'inner' parameters of space and time are irrelevant. Hence, GRT cannot be directly derived from QM (or vice versa), as unsuccessfully tried in the past. Both theories rather represent different perspectives onto the same, more fundamental principle formalized in GenI.

Compared to the extremely complex supergravity-, string- and M-theories aiming at explaining gravity and spacetime from the quantum perspective, the simplistic GenI model is profoundly superior. It necessitates only a small set of simple assumptions and rules and does not require any further fine-tuning of model parameters to function robustly. As its underlying mathematics are basic and straight-forward, GenI is also highly preferable according to ancient Occam's razor principle[19]. Finally, GenI could be readily examinable experimentally from various angles (see below).

Therefore, my work has far-ranging, at first sight likely irritating consequences for our understanding of what makes up the universe and how it evolves. The perceivable universe appears not to be developing according to a Schroedinger equation, as usually assumed in modern physics without any explicit justification. It rather develops according to a QM measurement process, i.e. its wave function is collapsing. Importantly, this collapse is independent of any external observer or environment, as GenI's basic P-swarm process is directly self referential. The swarm is capable to observe itself, define its targets and thereby conduct the wave function collapse completely on its own. The particular role of gravitation in this wave function collapse is in determining its inner dynamical rules rather than being its initializer.

GenI may well allow abandoning dark matter, dark energy and/or gravitons, all of which look merely like artefacts of an incomplete theory and hence still resist any experimental confirmation. Similarly, the mysterious big bang may simply resolve into a change in perspective. As has been shown, the GenI process results in a singularity when reaching its very final decision. However, even the slightest change in perspective immediately triggers swarm movement, thereby creating a new spacetime metric. So the process jumps out of the singularity and starts running again. Possible causes for such a perspective change remain to be explained. At the same time, the concept of the stochastic process avoids the idea of a loss of information in the supposed collapse of the wave function. This much-debated problem, which led, for example, to Everett's [20] many-world theory, only takes place by ignoring the process between the beginning of a measurement and its end result. When following the GenI model as an interpretation of the measurement process, such constructs are unnecessary, simply because there is no collapse at the swarm level.

From a more general viewpoint, the GenI model can help to better understand processes that may at first sight look completely random. This is true not only for the measurement process in QM as shown here, but also for the evolution of live by genetic variation and subsequent selection, the decision making in social teams and many more. In all of these areas, GenI should allow predictions readily accessible with existing technologies. Finally, provided the GenI process indeed underlies the fuzzy concepts of consciousness and intelligent behaviour, these phenomena may be much more common in our universe than we expected until today.

More recently, the subject of consciousness has indeed become the focus of scientists who discuss its significance in the universe within multidisciplinary working groups. It is possible that consciousness, if properly defined, is a fundamental property of all matter and not, as previously thought, a phenomenon that only arises from its sufficiently complex accumulation virtually out of nothing.

Common to all these initiatives is the lack of a verifiable mathematical model consistent with existing physical theories that could solidly support such a thesis. This work describes such a model that not only has the potential to reconcile the two basic physical theories, but also takes the topic of intelligent decision-making centre stage. GenI describes a fundamental change of perspective not only for physics. It basically means that gravity is nothing else than a side effect of an evolutionary selection process. Conversely, a strong selection pressure of biological systems should show up in statistical distortions, which can not be explained by known natural laws.

"It will need a profound change of viewpoint, which makes it hard to speculate on the specific nature of the change. Moreover, it will undoubtedly look crazy!" suspected Penrose 1995 in 'shadows of the mind' when reasoning about possible approaches towards a truly generalizable ToE. In 'What Remains To Be Discovered' John Maddox highlighted 1998 "As with æther, serious people hunt for the constituents of the missing mass without acknowledging that the whole idea may be no more than a sign that present understanding of the universe is incomplete, as was Maxwell's electromagnetism without relativity. (...) My hunch is that the future will follow the past in revealing a new nest of Russian dolls to be unscrewed." And 2007 in 'THE ROAD TO REALITY' Penrose realized almost resignedly "(...) I do not believe that we have yet found the true road to reality".

I do not want to claim yet, that GenI points towards this road to reality. It remains to be demonstrated, for instance, that the beautiful performance of GenI in multiple dimensions gives as well rise to a space time compatible with GRT as has been shown for two degrees of freedom. At least, however, I took the first few humble steps on a path that nobody seriously tried before. We will see where it leads us.

4 The GenI process

The GenI process describes a time-discrete stochastic process $X : [0,1] \times \mathbb{N}_0 \to 2^E$ in the state space of the finite subsets of a countable set *E*, together with a mapping $2^E \to \mathbb{C}^n$ of the power set on *E* into an n-dimensional complex vector space. In principle, it can be classified as a Markov chain of first order, with variable transition probabilities $P(X_{n+1}|X_n)$.

There are two expressions of the GenI process, for $n \geq 2$ and for $n = 2$.

4.1 GenI Process on eigenvector swarms

4.1.1 Background

The GenI random process determines changes in the complex vector space from the random behaviour of independent individuals within a swarm-like construct (figure 3). The swarm has a superposition state $\sum_{j=1}^{n} \beta_j e_j \in \mathbb{C}^n$, that controls the individual activities via a target function. The amplitudes $\beta_j e_j$ are also called ideas (cf "Generalized Quantum Modeling"[17]). γe_j after a finite number of steps, with the well-defined probability $\frac{|\beta_j|^2}{\sum_k |\beta_k|^2}$. The individuals follow defined rules and are allowed to make mistakes, based on the processes in simulated shoals of fish[16]. The GenI algorithm starts a chaotic decision-making process as a competition of ideas, such as running in a team that has to choose from a limited number of solutions to a given task. In the course of the process, a selection mechanism leads to ideas becoming extinct one after the other until finally just one survives that represents the solution to the problem.

4.1.2 Definition

4.1.3 Terminology

Definition 1 *Let E be a countable set and* $\tilde{E} := \{S \subset E : |S| < \infty\} \subset 2^E$ *the set of finite subsets of* E. *Next* $B = (e_1, \ldots, e_n)$ *the canonical basis in* $\mathbb{C}^n$ *and* $\tilde{B} := \{i^k e_j : k = 0 \ldots 3, j = 1 \ldots n\}$ *, where* i *is the imaginary unit in* $\mathbb{C}$ *.*

A given $\rho : E \to \tilde{B}$ *maps each element of* E *into* $\tilde{B}$ *, so that* $\forall e \in \tilde{B} : |\rho^{-1}(\{e\})| = \infty$ *. For a set* $S \in \tilde{E}$ *the complex vector* $\rho(S) := \sum_{s \in S} \rho(s) = \sum_j \beta_j e_j$ *denotes its state with complex* ***amplitudes*** β_j *. Each such set* S *is called an Eigenvector-swarm or* ***E-swarm****.*

A pair $s, t \in E$ *with* $\rho(s) + \rho(t) = 0$ *is a* ***null pair****. A tuple* (s_0, s_1, s_2, s_3) *is called a* ***null ring*** *generated by* s_0 *, if* $\exists j : \rho(s_k) = i^k e_j$ *.*

A set $N \in \tilde{E}$ *is called a* ***null set****, if* $\rho(N) = 0$ *. A maximal null set* $N \subset S$ *is called the* ***entropy*** *of* S *and* $S \setminus N$ *the* ***entropy free residual swarm****.*

The term $\epsilon_j(S) := 2\frac{|\beta_j|\sqrt{\sum_{k\neq j}|\beta_k|^2}}{\sum_{k=1}^{n}|\beta_k|^2} \in [0;1]$ *denotes the* ***excitation*** *of the swarm in index* j*.*

Algorithm

Definition 2 *Let* $S^{(l)} = S_D^{(l)} + N_S^{(l)}$ *be a series of swarms (as an instantiation of* $X(\omega, l)$ *) with the respective separation into a maximal null swarm* $N_S^{(l)}$ *and the entropy free residual swarm* $S_D^{(l)}$ *,* $\rho(S^{(l)}) = \sum_{k=1}^{n} \beta_k^{(l)} e_k$ *the respective state and* $\epsilon_j^{(l)} := \epsilon_j(S^{(l)})$ *the excitations (figure 6).*

Step 1: *Set* $l \leftarrow 0$ *and start with a given swarm* $S^{(0)}$ *.*

Step 2: *If* $\forall j : \epsilon_j^{(l)} = 0$ *, then finish the process.*

Step 3: *Each element* $s \in S_D^{(l)}$ *generates an additional null ring within the swarm.*

Step 4: *Each null pair* $r, t \in N_S^{(l)}$ *(including the newly generated) with* $\rho(r) = i^k e_j$ *,* $\rho(t) = -i^k e_j$ *gets selected with probability* $p = \epsilon_j^{(l)2}$ *(and "burned" in the next step).*

Step 5: *For each selected null pair* $r, t \in N_S^{(l)}$ *,* t *leaves the swarm with probability* $\frac{\epsilon_j(S\setminus\{r\})}{\epsilon_j(S\setminus\{r\})+\epsilon_j(S\setminus\{t\})}$ *. Otherwise* t *stays and* r *leaves the swarm.*

Step 6: *The resulting swarm is* $S^{(l+1)}$ *.*

Step 7: *Set* $l \leftarrow l + 1$ *and start over with step 2.*

Interpretation

As soon as the excitation disappears in each index, the process naturally comes to rest in step 4 (except for the hard abort condition in step 2), since no null pair is "burned" and the state of the swarm no longer changes. The role of the excitation here reminds of the dynamics of a grain of sand in the formation of the Chladnic sound figures. On the other hand, excitation as a target in step 5 leads to a systematic distortion from 50% likelihood for an individual to remain. This leads here to an improved tendency to reduce the excitation. The following interpretation is obvious based on biological swarm behaviour: Each individual tends to follow the rule "reduce the excitation. It remains free in its decision to do nothing (step 4), to follow the rule, or to disregard it (step 5).

4.1.4 Simulation

The reference implementation under JAVA (table 1) shows an excellent convergence of the process. Table 2 on page 33 shows an example of the result of 1000 simulation runs (each simulation run aborts after more than 500 iterations or for swarm sizes> 10 million for performance reasons)

These results (table 2) support the **statement of convergence (hypothesis):**

Theorem 1 *Let* $S^{(0)} = S$ *be a given E-swarm with* $\rho(S) = \sum_{j=1}^{n} \beta_j a_j$ *,* $n \geq 2$ *,* $b_j = |\beta_j|$ *,* $|S| = \sqrt{\sum b_j^2}$ *.*

Let $S : \mathbb{N}_0 \times [0;1] \to \tilde{E}$ *be a GenI process with* $\rho(S^{(m)}(\omega)) = \sum \beta_j^{(m)}(\omega) a_j$ *.*

Then $P\left(\tilde{S}^{(m)} \underset{m\to\infty}{\longrightarrow} \gamma a_j\right) = P\left(\sum_{k\neq j} b_k^{(m)2} \underset{m\to\infty}{\longrightarrow} 0\right) = \frac{b_j^2}{|S|^2}$ *.*

4.2 GenI process on Pauli swarms

The P(auli) process represents a special version of the GenI process for binary YES-NO decisions. It determines a time discrete stochastic process $X : [0;1] \times \mathbb{N}_0 \mapsto 2^E$ in the state space of finite subsets of a countable set E, together with a map $\rho : 2^E \to \mathbb{C}^{2\times 2}$ from the power set on E into the complex matrix algebra $\mathbb{C}^{2\times 2}$, a perspective vector $v \in \mathbb{C}^2$ and a basis $a_1, a_2 \in \mathbb{C}^2$.

4.2.1 Background

The GenI random process determines changes in the complex vector space out of the random behavior of independent individuals within a swarm-like construct. The swarm S has an image $\rho(S) \in \mathbb{C}^{2\times 2}$ in the complex matrix algebra. Together with a perspective $v \in \mathbb{C}^2$, the state of the swarm is determined by $\tilde{S} = \rho(S)v$. A basis $a_1, a_2 \in \mathbb{C}^2$ is called the environment and represents the options under which the swarm makes a decision. This can also be the eigenvectors of $\rho(S) \in \mathbb{C}^{2\times 2}$ itself and so create a self-reference. The environment, perspective and state of the swarm control the individual activities via a target variable (excitation). The amplitudes $\beta_j a_j$ in the decomposition are also referred to as ideas with respect to the environment (see regarding "Generalized Quantum Modeling" [17]). The swarm takes one of the eigenstates γa_j after a finite number of steps, with the well-defined probability $\frac{|\beta_j|^2}{|\beta_1|^2+|\beta_2|^2}$. The individuals follow defined rules and are allowed to make mistakes, based on the processes in simulated shoals of fish[16]. The GenI algorithm starts a chaotic decision-making process as a competition of ideas, such as running in a team that has two possible solutions to a given task. In the course of the process, a selection mechanism leads to the survival of only one of the two ideas that represents the solution to the problem. The model in principal allows a moving environment (figure 7).

4.2.2 Definition

Terminology

Definition 3 *Let E be a countable set and $\tilde{E} := \{S \subset E : |S| < \infty\} \subset 2^E$ the set of finite subsets of E. Next $P = (p_0, p_1, p_2, p_3) \subset \mathbb{C}^{2\times 2}$ the Pauli matrices and $\tilde{P} := \{i^k p_j : k = 0\dots 3, j = 1\dots n\}$ the image of the Pauli group in the complex matrix algebra as its irreducible representation with its center $C = \{1, i, -1, -i\} \subset \tilde{P}$.*

*Any subset $S \in \tilde{E}$ is called a Pauli-Swarm or a **P-Swarm**. A given $\rho : E \to \tilde{P}$ maps each element of E onto one element of the Pauli group, so that $\forall e \in \tilde{P}$: $|\rho^{-1}(\{e\})| = \infty$.*

*A basis $a_1, a_2 \in \mathbb{C}^2$ is called an **environment**, a non zero vector $v \in \mathbb{C}^2$ a **perspective**.*

*For a swarm $S \in \tilde{E}$ denotes $\rho(S) := \sum_{s\in S} \rho(s)$ its matrix image, $\tilde{S} = \rho(S)v := \beta_1 a_1 + \beta_2 a_2$ its **state** with complex **amplitudes** β_j at the given environment and perspective.*

*A pair $s, t \in E$ with $\rho(s) + \rho(t) = 0$ is a **null pair**. A tuple (s_0, s_1, s_2, s_3) is called a **null ring** generated by s_0 , if $\exists j : \rho(s_k) = i^k p_j$ (it actually resembles a coset $\rho(s_j)C$).*

*A set $N \in \tilde{E}$ is called **null set**, if $\rho(N) = 0$. A maximal null set $N \subset S$ ist called the **entropy** of S and $S \setminus N$ its **entropy freed residual swarm**.*

*The term $\epsilon(S) := 2\frac{|\beta_1||\beta_2|}{|\beta_1|^2+|\beta_2|^2} \in [0; 1]$ denotes the **excitation** of the swarm.*

4.2.3 Algorithm

Definition 4 *Let $S^{(l)} = S_D^{(l)} + N_S^{(l)}$ be a series of swarms (as an instance von $X(\omega, l)$) with the respective separation in a maximal null swarm $N_S^{(l)}$ and the entropy freed residual swarm $S_D^{(l)}$, $\tilde{S}^{(l)} = \beta_1^{(l)} a_1 + \beta_2^{(l)} a_2$ the respective states and $\epsilon^{(l)} := \epsilon(S^{(l)})$ the excitations.*

Step 1: *$l \leftarrow 0$ and start with a given swarm $S^{(0)}$.*

Step 2: *$\epsilon^{(l)} = 0$, then finish the process.*

Step 3: *$s \in S_D^{(l)}$ generates an additional null ring within the swarm.*

Step 4: *$r, t \in N_S^{(l)}$ (including the newly generated) gets selected with probability $p = \epsilon^{(l)2}$ (and gets "burned" in next step).*

Step 5: *$r, t \in N_S^{(l)}$, t leaves the swarm with probability $\frac{\epsilon(S\backslash\{r\})}{\epsilon(S\backslash\{r\})+\epsilon(S\backslash\{t\})}$. Otherwise t stays and r leaves the swarm.*

Step 6: $S^{(l+1)}$.

Step 7: $l \leftarrow l + 1$ *and start over with step 2.*

4.2.4 Simulation

The reference implementation under JAVA (table 1) shows an excellent convergence of the process at any fixed environment and perspective according to figure 5 on page 40.

The results support the **statement of convergence (hypothesis)**:

Theorem 2 *Let $S^{(0)} = S$ be a given P-swarm with $\tilde{S} = \beta_1 a_1 + \beta_2 a_2$, $b_j = |\beta_j|$, $|S| = \sqrt{b_1^2 + b_2^2}$, at any fixed environment (a_1, a_2) and perspective v.*

Let $S : \mathbb{N}_0 \times [0;1] \to \tilde{E}$ be a P-process with $\tilde{S}^{(m)}(\omega) = \beta_1^{(m)}(\omega) a_1 + \beta_2^{(m)}(\omega) a_2$.

Then

$P\left(\tilde{S}^{(m)} \underset{m\to\infty}{\longrightarrow} \gamma a_j\right) = P\left(\sum_{k\neq j} b_k^{(m)2} \underset{m\to\infty}{\longrightarrow} 0\right) = \frac{b_j^2}{|S|^2}$, *where* $j, k \in \{1, 2\}$.

5 Physical reality

5.1 Quantum measurements

First of all, the GenI process was designed as a model for decision making through evolutionary selection. However, it is now obvious that the statistics of the GenI process correspond exactly to the predictions expected from quantum measurements. At the same time, the concept of the stochastic process avoids the idea of a loss of information in the supposed collapse of the wave function (state). This much-debated problem, which led, for example, to Everett's [20] many-world theory only takes place by ignoring the process between the beginning of a measurement and its end result. When following the GenI model as an interpretation of the measurement process, such constructs are unnecessary, simply because there is no collapse at the swarm level.

In addition, the construction of P-swarms strongly reminiscent of the approach of Carl Friedrich von Weizsäcker in the introduction of his ur-alternatives (archetypal objects) to reconstruct quantum mechanics [21]. It allows a new perspective on this old idea, even if his basic assumption has proved false in the face of the violation of Bell's inequality [22].

In principle the multi choice E-swarm concept can get derived by combining P-swarms in a way well known to theoretical Physics. So, in order to enable more than two choices, two or more P-swarm tensor images can get combined to form a higher order tensor algebra. Such a construct relates to a swarm composed of strings of P-swarm individuals. A higher order P-swarm then is simply a set of such strings. Basically this is exactly where to look for.

Given two swarms S and U the union $S \cup U$ is simply a bigger swarm whereas the set product $S \times U$ is certainly something else. With respect to the algebraic image we can define a map $\rho : S \times U \to A_P \otimes A_P$ by $\rho(s,u) = \rho(s) \otimes \rho(u)$ leading directly to $\rho(S \times U) = \sum_{\substack{s \in S \\ u \in U}} \rho(s) \otimes \rho(u)$.

Given an array of N swarms $S_1, \ldots, S_N$ we define $\rho : S_1 \times \ldots \times S_N \to \otimes_1^N A_P$ by $\rho(s_1, \ldots, s_N) = \rho(s_1) \otimes \ldots \otimes \rho(s_N)$ the ordinary tensor product and for any $U \subset S_1 \times \ldots \times S_N = S$ we get $\rho(U) = \sum_{(s_i)_{i=1\ldots N} \in U} \rho(s_1) \otimes \ldots \otimes \rho(s_N)$.

It is now clear how high order swarms may map to any high order tensor algebra. Again we have a canonical base $(p_{i_1} \otimes \ldots \otimes p_{i_N} : i_k \in \{0; 1; 2; 3\})$ of $\mathbb{C}$-dimension 4^N, respectively 2^N after applying a perspective $v \otimes \ldots \otimes v$. Such a high order algebra gives rise to more simplifications. Well known from QM is a symmetry transformation by considering the elements in $(s_1, \ldots, s_N)$ indistinguishable. Summarizing over all Permutations reduces the dimension finally down to $N+1$. This representation only considers the number of YES' from $0 \ldots N$ as allowed environment options, while disregarding who specifically said YES and who answered NO. In QM each of these numbers typically relates to an eigenvector of a suitable observable.

So E-swarms are a complementary swarm concept that simplifies many of the problems to be expected otherwise and in case of two dimensions it is equivalent to the binary P-model with respect to the statistics produced by the GenI process.

5.2 Transformations

To be relevant for QM, the transformation behaviour has to be considered when switching the environment. Basically the GenI model meets the typical QM transformations by design. So changing the environment provides a transformation adapting the amplitudes in exactly the way, that a change of QM observable would do. Basically, that's enough.

Nevertheless, I would like to show you this behaviour with a specific example. In case of a YES-NO type decision, let an orthonormal base $a_1, a_2 \in \mathbb{C}^2$ be the chosen environment. The Pauli matrix p_3 is the typical observable for QM spin measurements along a z-axis in 3-dimensional space. Then (a_1, a_2) are its eigenvectors with eigenvalues ± 1.

Let $Sv = xe^{i\phi_x}a_1 + ye^{i\phi_y}a_2$, $x, y \in \mathbb{R}_0^+$, $s = \sin(\phi_x - \phi_y)$, $c = \cos(\phi_x - \phi_y)$, and $\vec{r}(Sv) = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} \langle p_1 Sv \mid Sv \rangle \\ \langle p_2 Sv \mid Sv \rangle \\ \langle p_3 Sv \mid Sv \rangle \end{bmatrix} = \begin{bmatrix} 2cxy \\ 2sxy \\ x^2 - y^2 \end{bmatrix}$

Then the GenI process excitation $\epsilon^2 = x_1^2 + x_2^2 \to 0$ and $x_3 \to \pm r$. Now spin-up/-down along the z-axis is indeed represented by a final state given by $\vec{r} = \begin{bmatrix} 0 \\ 0 \\ \pm r \end{bmatrix}$.

Switching the observable to p_1 and hence the environment to the according eigenvectors (a'_1, a'_2) with eigenvalues ± 1 gives $Sv = x'e^{i\phi'_x}a'_1 + y'e^{i\phi'_y}a'_2$ and $\vec{r}' = \begin{bmatrix} x'^2 - y'^2 \\ 2c'x'y' \\ 2s'x'y' \end{bmatrix}$ Again the behaviour meets the conditions of QM spin measurement along the x axis.

In general I may choose an arbitrary space direction for spin measurement. It is well known, that the formal Pauli vector (p_1, p_2, p_3) transforms exactly as the three dimensional axes do.

Finally it looks like I could define the GenI process also in terms of the special mapping in $\mathbb{R}^3$. But that is not true. There is no way, for example, to represent the swarm entropy. Splitting up a null pair leads to two identical vectors $\vec{r}(Sv) = \vec{r}(-Sv)$.

5.3 Process behaviour

Having made a decision about an environment B the Genl process finally stops. At this point the swarm's state matches exactly one of the given options with no idea left about all the others. If we present B again nothing will happen and the swarms sticks to its previous decision according to definition 4.

Now change the environment to B'. The swarm state that previously got definite about an option of B now may be completely open with respect to B'. The new amplitudes are well defined by the transformation $B \to B'$. So the process newly starts over to reach the according answer to the new question. If B is presented again, then the swarm can be completely undecided now, without any memory of its former state, and come to a different decision than the first time. Due to the design of the Genl model, this behaviour copies exactly the conditions that are found in quantum mechanics when changing the observable after a completed measurement. Such a case occurs, for example, when measuring the spin of an electron once in the z-direction, then in the x-direction, and finally again in the z-direction.

A P-swarm S may act according to its internal environment under a given perspective v. Let A_S be an internal observable derived from the operator image of S, whose eigenvectors determine an environment B_S. For example $A_S = \frac{1}{2}(S + S^\dagger)$ would do, or any other suitable linear operator with a well defined functional relationship to S. As soon as it comes to a final decision about one of the two (now moving) options the process stops according to definition 4. At that time Sv has arrived at an eigenvector of A_S. Now any change of the perspective $v \to v'$ obviously restarts the Genl process immediately, because A_S stays unchanged while Sv' in general no longer represents one of its eigenvectors.

5.4 Process statistics

Let us now take a statistical view on the process in case of large amplitudes. Choose $S = \sum_{j=1}^{n} \beta_j a_j$, $\beta_j = c_j + id_j$ and n_j null pairs according to each idea.

Step 3 in definition 2 implies that for each j exactly $2(|c_j| + |d_j|)$ null pairs get acquired, half of them potentially altering the real part and the imaginary part respectively.

Step 4 results in burning at average $\epsilon_j^2(2\,|c_j| + 2\,|d_j| + n_j)$ of the old and the newly acquired null pairs and leaving $n'_j = (1 - \epsilon_j^2)(2\,|c_j| + 2\,|d_j| + n_j)$ of them to the next iteration.

Now look at a single burn event.

The probability to increase c_j by ± 1 is

$$P(\Delta c_j = \pm 1) = \frac{\epsilon_j(c_j \mp 1)}{\epsilon_j(c_j - 1) + \epsilon_j(c_j + 1)} \tag{1}$$

where the target value is $\epsilon_j = 2\frac{b_j\sqrt{\sum_{k\neq j} b_k^2}}{\sum_{k=1}^{n} b_k^2}$.

Hence the observed distribution in most cases is nearly uniform $P(\Delta c_j = \pm 1) \approx \frac{1}{2}\left(1 \mp \frac{c_j}{b_j^2}\right) \approx \frac{1}{2}$.

The process now results in a mean value
$mean(\Delta c_j) = \frac{\epsilon_j(c_j-1)-\epsilon_j(c_j+1)}{\epsilon_j(c_j-1)+\epsilon_j(c_j+1)} \approx -\frac{1}{\epsilon_j}\frac{\partial \epsilon_j}{\partial c_j} = -\frac{\partial ln(\epsilon_j)}{\partial c_j}$.
With $\ln(\epsilon_j) = \ln(2) + \ln(b_j) + \frac{1}{2}\ln\left(\sum_{k\neq j} b_k^2\right) - \ln\left(\sum_k b_k^2\right)$ we get $\frac{\partial \ln(\epsilon_j)}{\partial c_j} = \frac{\partial \ln(\epsilon_j)}{\partial b_j}\frac{\partial b_j}{\partial c_j} = \left(\frac{1}{b_j} - 2\frac{b_j}{\sum_k b_k^2}\right)\frac{c_j}{b_j}$ and hence
$mean(\Delta c_j) = -\frac{c_j}{b_j^2}\left(1 - 2\frac{b_j^2}{\sum_k b_k^2}\right)$
$= -\frac{c_j}{b_j^2}\left(\frac{\sum_{k\neq j} b_k^2}{\sum_k b_k^2} - \frac{b_j^2}{\sum_k b_k^2}\right)$
$= \frac{c_j}{b_j^2}\left(\cos(\frac{\Phi_j}{2})^2 - \sin(\frac{\Phi_j}{2})^2\right)$

where $\cos(\frac{\Phi_j}{2}) := \frac{|\langle S|a_j\rangle|}{|S|} = \frac{b_j}{\sqrt{\sum_k b_k^2}}$.

The same relation holds for the imaginary part d_j.

On average is $\Delta b_j = |\beta_j + \Delta\beta_j| - |\beta|_j$
$= \sqrt{(c_j + \Delta c_j)^2 + (d_j + \Delta d_j)^2} - \sqrt{c_j^2 + d_j^2}$
$\approx \frac{c_j}{b_j}\Delta c_j + \frac{d_j}{b_j}\Delta d_j$ for each amplitude. So

$$mean(\Delta b_j) = \frac{1}{b_j}\left(\cos(\frac{\Phi_j}{2})^2 - \sin(\frac{\Phi_j}{2})^2\right) = \frac{1}{b_j}\cos(\Phi_j) \in [-\frac{1}{b_j}; \frac{1}{b_j}] \tag{2}$$

for each single burn event.

Now take the number of burn steps as time axis leading to a system of nonlinear differential equations that should approximately describe the process dynamics at a statistical level:

$$\frac{db_j}{dt}\sum_{k=1}^{n} b_k^2 = \frac{1}{b_j}\left(b_j^2 - \sum_{k\neq j} b_k^2\right) \tag{3}$$

Such a single burn step given in equations (2) and (3) basically exposes some sort of a force overlaying the random movements and leading to a probability distortion toward selected directions.

As you see from equation 3 any b_j tends to increase the according amplitude only if its square is larger than the sum of all the others. Otherwise it tends to decrease further. This effectively limits the swam amplitudes and avoids any catastrophic behaviour for almost all of the process time. Additionally the change rate (and hence the probability distortion) is tiny for high amplitudes in the order of $\frac{1}{b_j}$.

5.5 A spacetime geometry

I will focus here on the decision process on an E-swarm S with only two choices and make some definitions to improve readability.

The swarm is decomposed as $S = \beta_1 a_1 + \beta_2 a_2$ where $\beta_1 = xe^{i\phi_x}, \beta_2 = ye^{i\phi_y}$, $b = |S| = \sqrt{x^2 + y^2}$.

Equation 3 gives $\frac{dx}{dt} = \frac{1}{x}\frac{x^2-y^2}{x^2+y^2}$ and $\frac{dy}{dt} = \frac{1}{y}\frac{y^2-x^2}{x^2+y^2}$ and hence $\frac{d}{dt}|S|^2 = 2x\frac{dx}{dt} + 2y\frac{dy}{dt} = 0$. So the norm b of S is a process constant.

Now I have to define an appropriate metric in spacetime that allows the process dynamics to follow geodetic lines. This means I have to find real functions A, B_1, B_2, B_3 so that the path length $\int ds$ gets stationary with the line element

$$ds^2 = Adx_0^2 - B_1 dx_1^2 - B_2 dx_2^2 - B_3 dx_3^2 \tag{4}$$

.

Now choose the map $\vec{X} = \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} t \\ \langle p_1 S \mid S\rangle \\ \langle p_2 S \mid S\rangle \\ \langle p_3 S \mid S\rangle \end{bmatrix} = \begin{bmatrix} t \\ 2cxy \\ 2sxy \\ x^2 - y^2 \end{bmatrix}$ and the process time t as the path variable where $c = \cos(\phi_x - \phi_y), s = \sin(\phi_x - \phi_y)$.

Let $r = \sqrt{{x_1}^2 + {x_2}^2} = 2xy$.

I get $\dot{\vec{X}} = \begin{bmatrix} \dot{x_0} \\ \dot{x_1} \\ \dot{x_2} \\ \dot{x_3} \end{bmatrix} = \begin{bmatrix} 1 \\ -4c\frac{x_3^2}{rb^2} \\ -4s\frac{x_3^2}{rb^2} \\ 4\frac{x_3}{b^2} \end{bmatrix}$

and $\ddot{\vec{X}} = \begin{bmatrix} \ddot{x_0} \\ \ddot{x_1} \\ \ddot{x_2} \\ \ddot{x_3} \end{bmatrix} = \begin{bmatrix} 0 \\ -16c\frac{x_3^2}{rb^4}\left(2 + \frac{x_3^2}{r^2}\right) \\ -16s\frac{x_3^2}{rb^4}\left(2 + \frac{x_3^2}{r^2}\right) \\ 16\frac{x_3}{b^4} \end{bmatrix}$

Now I am going to determine the functions A, B_j. The line element 4 leads to the Lagrange term $L = \frac{1}{2}\left[A\dot{x}_0^2 - \sum_j B_j \dot{x}_j^2\right]$ according to the Hamiltonian extremal principle. The Euler-Lagrange equations $\frac{d}{dt}\frac{\partial L}{\partial \dot{x}_j} - \frac{\partial L}{\partial x_j} = 0$ finally result in

$$2\frac{\partial A}{\partial \dot{x}_0}\dot{x}_0\ddot{x}_0 + 2A\ddot{x}_0 - 2\sum_{k=1}^{3}\frac{\partial B_k}{\partial \dot{x}_0}\dot{x}_k\ddot{x}_k - \frac{\partial A}{\partial x_0}\dot{x_0}^2 + \sum_k \frac{\partial B_k}{\partial x_0}\dot{x_k}^2 = 0 \quad (5)$$

and for $j = 1 \ldots 3$

$$2\frac{\partial A}{\partial \dot{x}_j}\dot{x}_0\ddot{x}_0 - 2\sum_k \frac{\partial B_k}{\partial \dot{x}_j}\dot{x}_k\ddot{x}_k - 2B_j\ddot{x}_j - \frac{\partial A}{\partial x_j}\dot{x_0}^2 + \sum_k \frac{\partial B_k}{\partial x_j}\dot{x_k}^2 = 0 \quad (6)$$

The basic symmetry of the process space suggests $B_1 = B_2 = B(\frac{r}{x_3}), B_3 = C(\frac{r}{x_3}), A = A(\frac{r}{x_3})$. So all functions do not depend on x_0 and the $\dot{x}_j$. Then 5 is identical zero and the above terms now get inserted into the remaining geodetic equations 6 :

$$0 = -2B_j\ddot{x}_j - \frac{\partial A}{\partial x_j}\dot{x_0}^2 + \sum_{k=1}^{3}\frac{\partial B_k}{\partial x_j}\dot{x_k}^2 \quad (7)$$

With $z = \frac{r}{x_3}$ I get $\frac{\partial}{\partial x_1} = \frac{c}{x_3}\frac{d}{dz}$, $\frac{\partial}{\partial x_2} = \frac{s}{x_3}\frac{d}{dz}$, $\frac{\partial}{\partial x_3} = -\frac{r}{x_3^2}\frac{d}{dz}$.
Now let's do the calculations:

$$\begin{aligned}
0 &= -2B_1\ddot{x}_1 - \frac{\partial A}{\partial x_j}\dot{x}_0^2 + \frac{\partial B}{\partial x_1}(\dot{x}_1^2 + \dot{x}_2^2) + \frac{\partial C}{\partial x_1}\dot{x}_3^2 \\
&= 32Bc\frac{x_3^2}{rb^4}\left(2 + \frac{x_3^2}{r^2}\right) - A'\frac{c}{x_3} + 16cB'\frac{x_3^3}{r^2b^4} + 16cC'\frac{x_3}{b^4} \\
&= 16\frac{x_3c}{b^4}\left(2B\frac{x_3}{r}\left(2 + \frac{x_3^2}{r^2}\right) - \frac{1}{16}A'(1 + \frac{r^2}{x_3^2}) + B'\frac{x_3^2}{r^2} + C'\right)
\end{aligned}$$

and

$$\begin{aligned}
0 &= -2B_3\ddot{x}_3 - \frac{\partial A}{\partial x_3}\dot{x}_0^2 + \frac{\partial B}{\partial x_3}(\dot{x}_1^2 + \dot{x}_2^2) + \frac{\partial C}{\partial x_3}\dot{x}_3^2 \\
&= -32C\frac{x_3}{b^4} + \frac{r}{x_3^2}A' - 16\frac{r}{x_3^2}B'\frac{x_3^4}{r^2b^4} - 16\frac{r}{x_3^2}C'\frac{x_3^2}{b^4} \\
&= -16\frac{r}{b^4}\left(2C\frac{x_3}{r} - \frac{1}{16}(1 + \frac{r^2}{x_3^2})A' + B'\frac{x_3^2}{r^2} + C'\right)
\end{aligned}$$

After substituting with z we find

$$2B\frac{1}{z}\left(2 + \frac{1}{z^2}\right) - \frac{1}{16}(1 + z^2)A' + B'\frac{1}{z^2} + C' = 0 \quad (8)$$

$$2C\frac{1}{z} - \frac{1}{16}(1 + z^2)A' + B'\frac{1}{z^2} + C' = 0 \quad (9)$$

so that $C(z) = B(z)\left(2+\frac{1}{z^2}\right)$, $C'(z) = B'(z)\left(2+\frac{1}{z^2}\right) - 2B\frac{1}{z^3}$ and with equation 8

$0 = \frac{4}{z}B + 2B'\left(1+\frac{1}{z^2}\right) - \frac{1}{16}(1+z^2)A'$

We have to make sure that the process follows timelike paths. That means $\dot{s}^2 = A - B(\dot{x}_1^2 + \dot{x}_2^2) - C\dot{x}_3^2 >= 0$.

We have $\dot{x}_1^2 + \dot{x}_2^2 = 16\frac{x_3^4}{r^2 b^4} \leq 16\frac{x_3^2}{r^2}$ and $\dot{x}_3^2 = 16\frac{x_3^2}{b^4} \leq 16$.

The relation
$A \geq 16\frac{x_3^2}{r^2}B + 16C = 16\frac{x_3^2}{r^2}B + 16B\left(2+\frac{x_3^2}{r^2}\right) = 32B\left(\frac{x_3^2}{r^2}+1\right)$ suggests to choose $A = 32B\left(\frac{x_3^2}{r^2}+1\right) = 32B\left(1+\frac{1}{z^2}\right)$.

Now
$0 = \frac{4}{z}B + 2B'\left(1+\frac{1}{z^2}\right) - 2(1+z^2)\left(B'\left(1+\frac{1}{z^2}\right) - \frac{2}{z^3}B\right) = \frac{4}{z}\left(2+\frac{1}{z^2}\right)B - 2(1+z^2)B'$
leads to
$B = k\frac{z^2}{1+z^2}e^{-\frac{1}{z^2}}$,

$C(z) = k\frac{2z^2+1}{1+z^2}e^{-\frac{1}{z^2}}$, and

$A = 32ke^{-\frac{1}{z^2}}$

The metric now looks like

$$M = \frac{z^2}{1+z^2}e^{-\frac{1}{z^2}}\begin{bmatrix} 32\left(1+\frac{1}{z^2}\right) & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -\left(2+\frac{1}{z^2}\right) \end{bmatrix}.$$

Theorem 3 *Let $S = \beta_1 a_1 + \beta_2 a_2$ a E-swarm, $\beta_1 = xe^{i\phi_x}, \beta_2 = ye^{i\phi_y}$ and $\vec{X} = \begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} t \\ 2cxy \\ 2sxy \\ x^2-y^2 \end{bmatrix}$ a map into a 4-dimensional manifold where t is the Genl process time and $c = \cos(\phi_x - \phi_y), s = \sin(\phi_x - \phi_y)$.*

The metric tensor

$$g_{\mu\nu} = \frac{x_1^2+x_2^2}{x_1^2+x_2^2+x_3^2}e^{-\frac{x_3^2}{x_1^2+x_2^2}}\begin{bmatrix} 32\left(1+\frac{x_3^2}{x_1^2+x_2^2}\right) & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -\left(2+\frac{x_3^2}{x_1^2+x_2^2}\right) \end{bmatrix}$$

determines a curved spacetime so that the Genl process locally follows geodetic lines on timelike paths. It has a singularity at $r = 0$ that marks the final end of the process where r collapses from a value ≥ 1 to 0.

From here it is obviously a straightforward exercise to determine the

left side of Einstein's field equation.

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\kappa T_{\mu\nu}$$

and thus conclude a mass-energy distribution that represents the right side. This may look like you're teasing the horse from behind. And indeed, the usual way is to start with a known right-hand side and derive the metric from there due to known symmetries. However, here we are completely free to construct a suitable mass energy distribution that fits the now known metric. Suffice it to say that such a distribution exists.

Referencing definition 1 on page 16 we could write the metric in terms of the excitation $\epsilon = \frac{2xy}{x^2+y^2} = \frac{r}{b^2} = \sin(\Phi)$

$$g_{\mu\nu} = e^{-\cot(\Phi)} \begin{bmatrix} 32 & 0 & 0 & 0 \\ 0 & -\sin(\Phi)^2 & 0 & 0 \\ 0 & 0 & -\sin(\Phi)^2 & 0 \\ 0 & 0 & 0 & -\left(1+\sin(\Phi)^2\right) \end{bmatrix} \tag{10}$$

to demonstrate how the process target function governs the metric. It has singularities at $\Phi \in \{0, \pi\}$ where the process stops and the metric vanishes to zero.

The case discussed before marks the most simple situation equivalent to a measurement on one single spin½ particle. But how about many choices as represented by a swarm and environment with many dimensions?

Let $S = \sum_{j=1}^{N} \beta_j a_j$, $\beta_j = x_j e^{i\phi_j}$.

Then one suggestion is to extend the map above by $\vec{X}_j$

$$= \begin{bmatrix} t \\ 2\cos(\phi_j) x_j \sqrt{\sum_{k\neq j} x_k^2} \\ 2\sin(\phi_j) x_j \sqrt{\sum_{k\neq j} x_k^2} \\ x_j^2 - \sum_{k\neq j} x_k^2 \end{bmatrix} = \begin{bmatrix} t \\ 2c_j x_j y_j \\ 2s_j x_j y_j \\ x_j^2 - y_j^2 \end{bmatrix}.$$

This map correspond to a separation $S = \beta_j a_j + \sum_{k\neq j} \beta_k a_k = \beta_j a_j + y_j u_j$ with real y_j and a normalized vector $u_j \in \mathbb{C}(a_k)_{k\neq j}$. Applying the Genl process on S results for each index to the well known dynamics.

However performing similar calculations as before leads to a metric

$$g_{\mu\nu} = e^{-\cot(\Phi_j)} \begin{bmatrix} 32 & 0 & 0 & 0 \\ 0 & -\sin(\Phi_j)^2 & 0 & 0 \\ 0 & 0 & -\sin(\Phi_j)^2 & 0 \\ 0 & 0 & 0 & -\left(1+\sin(\Phi_j)^2\right) \end{bmatrix}$$

for each such index j according to equation 10. The according maps however have a different context and should not cover the same area of the manifold M. They have to be located at different points $P_j \in M$. This means that the comprehensive spacetime combines individual bubbles of local spacetime structures. Right now the extension of the model looks not like a straightforward exercise and I will certainly investigate further on that.

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6 Tables

Table 1: **Data availability.** The JAVA reference implementation of the GenI process is available on https://github.com/genreith/BZuS.git [23] with sources, test data and test scripts to reproduce any of the results demonstrated here.

Type	Requirements
Hardware:	AMD FX-8350 Eight-Core Processor 4.00 GHz 32 GB RAM
Operating System:	Windows 7 Ultimate (64-bit) with Service Pack 1
Java runtime:	Java 8 Update 121 (64-bit)
IDE:	Eclipse IDE for Java Developers, Version: Neon.3 Release (4.6.3), Build id: 20170314-1500
Development:	Java SE Development Kit 8 Update 121 (64-bit)
Quickstart	Download https://github.com/genreith/BZuS/tree/master/FlameModel/TestData inclusive the /log and /xml directories to your computer. Call "java -jar Flame.jar" Choose "File -> Load" and navigate to the /xml directory. "Load file" and "run". If warning appears, try "Load Batch" instead "Load"

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Table 2: **E-swarm statistics.** Genl model output runing 1000 measurements within a 10 options environment. Statistical numbers (results) are compared to the target values (targets rounded to next integer) to be expected from quantum measurements. The chi test value 7.86 is much lower that the critical value 16.91 at 95% confidence level. The target values represent the expected probabilities given by $p_j = \frac{b_j^2}{\sum b_k^2}$. Sigmas are calculated from target probabilities by $\sigma_j^2 = \frac{1}{n} p_j (1 - p_j)$. The simulation stops after 500 iterations or if swarm size exceeds ten million or as soon as the maximal square absolute value of an amplitude gets bigger than 100 times the second largest amplitude. In the latter case that index is chosen as result. Otherwise the iterated series is considered divergent. This pragmatic approach causes only insignificant probability artefacts.

	idea 1	idea 2	idea 3	idea 4	idea 5	idea 6	idea 7	idea 8	idea 9	idea10
targets=	132	81	97	78	11	206	3	336	36	3
results=	135	74	99	76	15	189	1	357	36	1
sigma=	10.7	8.6	9.4	8.5	3.3	12.8	1.8	14.9	5.9	1.8
measurements scheduled: 1000						divergent: 17			convergent: 983	
statistics:										
chi test value: 7.86						chi critical at 95%: 16.91898				
medium size=300418			sigma=281543			max size=1008512			min size= 9695	
medium abs= 500			sigma= 471			max abs= 4084			min abs= 23	

7 Figures

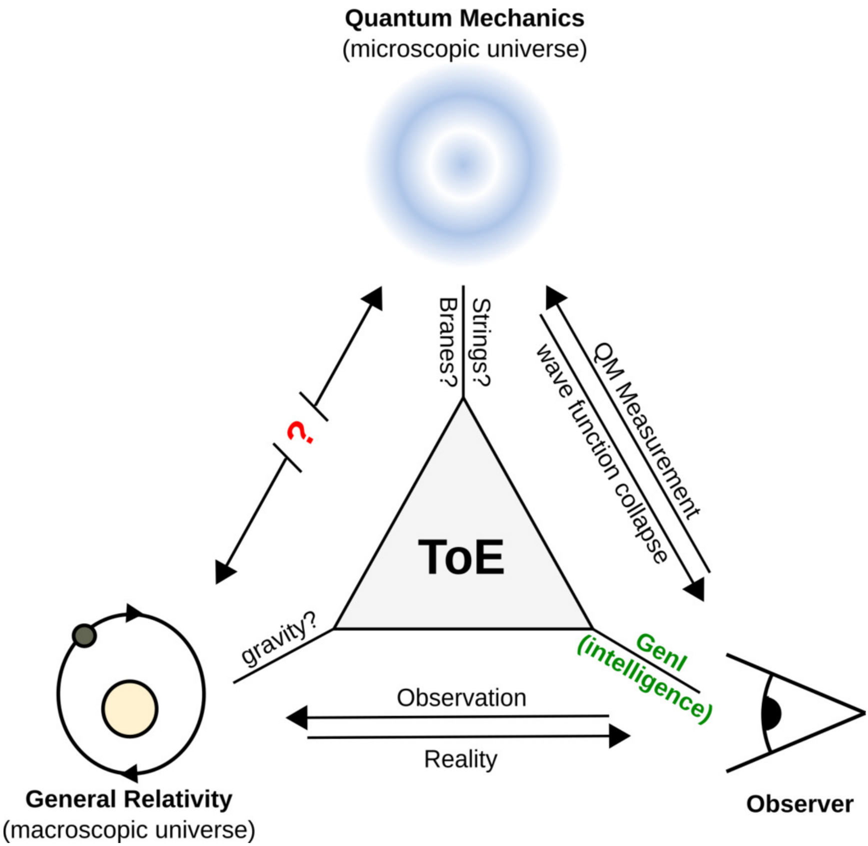

Figure 1: **Entry points to a ToE** Three at first sight very different areas: quantum mechanics, general relativity and intelligent behaviour. Each of these should be considered as an entry point for a ToE. The relationship between GRT and QM remains unclear. In QM, the observer is always part of the observation insofar as the quantum measurement itself causes the collapse of the wave function. Within GRT the observer always stands outside the system to be measured and any observation can in principle be carried out without affecting it.

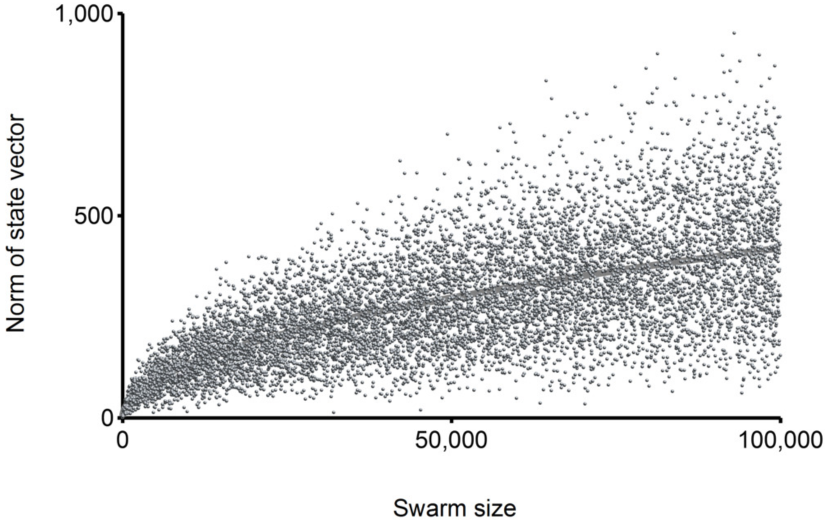

Figure 2: **Impact of swarm size on amplitudes.** Scatter chart showing swarm sizes versus state vector norms. Swarms were generated at sizes from 1 to 100,000 and randomly selected types of swarm individuals. The entropy decouples the swarm size from the norm of its state. The amplitude trend line shown is of order $\sqrt{size}$

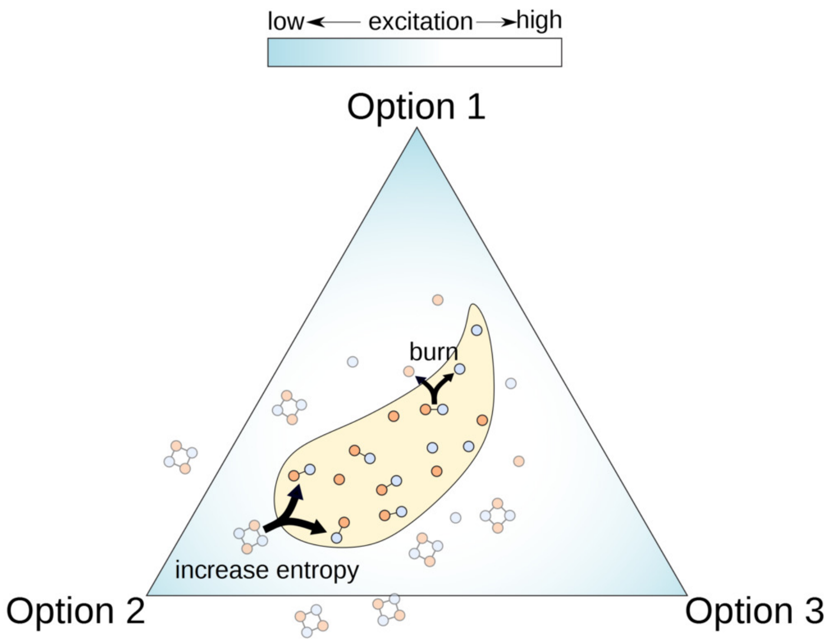

Figure 3: **The Genl process.** The Genl swarm constantly sucks null rings from its environment and burns them randomly. The Genl process sets a gradient towards reducing the excitation. The swarm's state finally arrives at one of the given options.

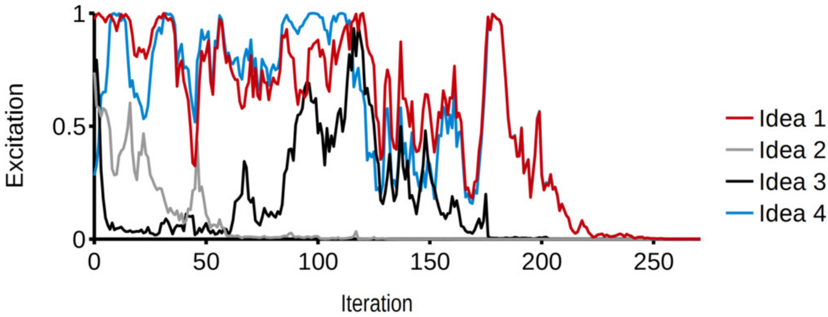

Figure 4: **Disrespecting the inner rules enables the GenI swarm to fully explore its environment.** Shown are excitation values for each idea evolving along the indicated number of iterations. The GenI process provides a gradient pointing towards lower excitation values for each idea. Due to random disrespect of the swarm's inner rules, no persistent monotony in swarm behavior does occur at any time.

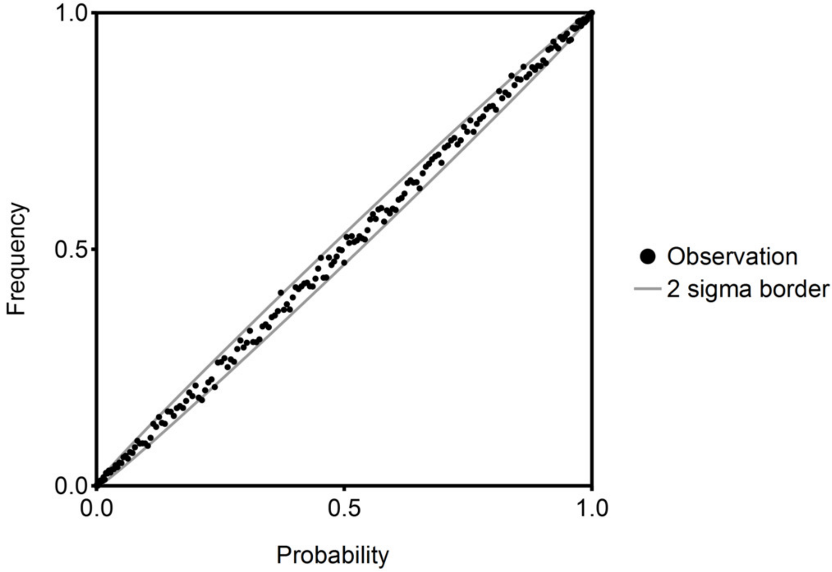

Figure 5: **P-swarms observations along target values from 0 to 1.** The sample comprises 1000 measurements each on 201 test points. More than 97% of observed frequencies are in the 2 sigma interval around the target values expected from quantum measurements. The chi square test value 92.6 is much lower than the critical level 168 at 95% confidence and 200 degrees of freedom.

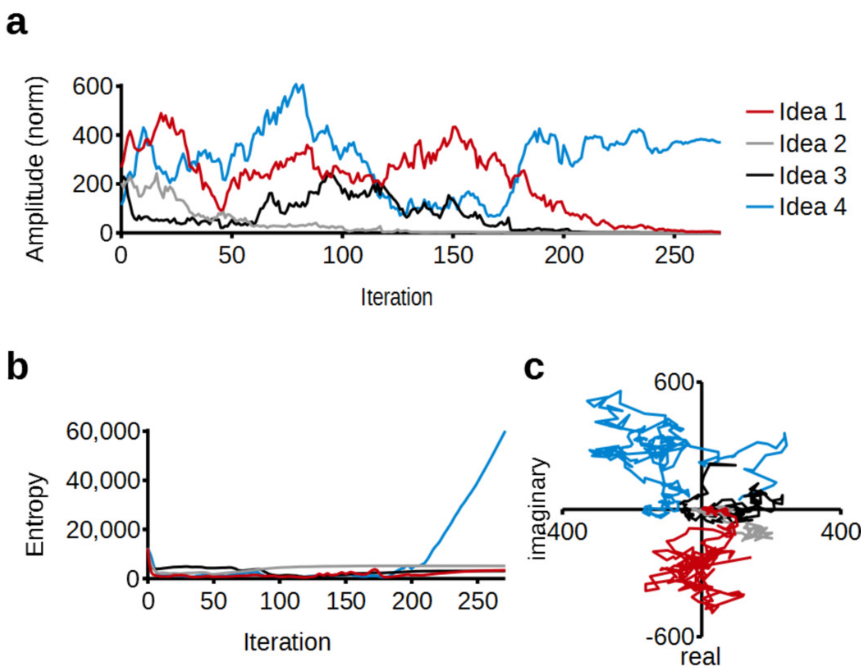

Figure 6: **Competition of ideas within an E-swarm.** Graph a shows the evolution of absolute amplitudes during a GenI process operating in a four options environment. Due to its intrinsically chaotic behavior, it is impossible to predict the GenI process evolution at any point. Interestingly, here the option with the lowest initial chance finally wins. Chart b shows the according evolution of entropy rising dramatically at the end for the winning idea. Figure c displays the native paths of each idea in the complex plane.

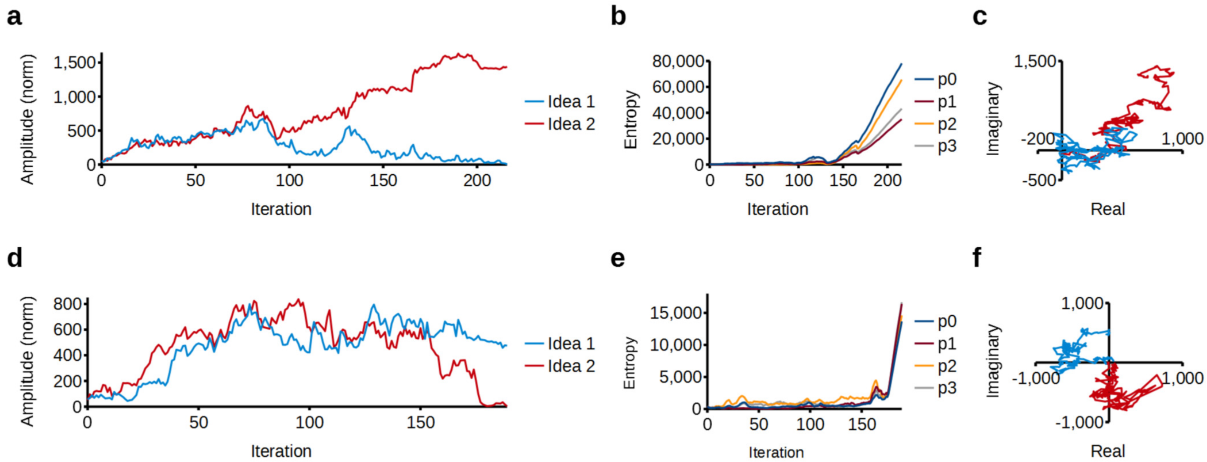

Figure 7: **Competition within a P-swarm.** The diagrams a-c demonstrate the GenI process evolution using a fixed perspective $p = (1, 1)$ under an external environment defined by the observable p_3. Diagrams d-f show another test case under the internal environment defined by the swarm itself. Graphs a/d show the evolution of absolute amplitudes. Charts b/e show the according evolution of entropy for each type according to the swarm member images in $\{p_0, \ldots, p_3\}$. Null pairs for P-swarm do not relate to environment options as is true for E-swarms. Figures c/f display the native paths of each idea in the complex plane.

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