On the Principles of Efficient Computation in Nature
A Generalization of Merge under the Strong Minimalist Thesis as a Conceptualization of the Physical Basis for Information Processing and Decision Making

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Abstract

In this paper, I provide an axiomatized framework that allows me to develop a model for how an organism processes information and makes decisions. I first establish the basic framework, taken form the theory of computation and mereology. This enables me to axiomatize a proposal made by Isaac Newton. He postulates an entity that exists in all concrete objects and processes information and makes decisions. The model rests on Noam Chomsky's current theory about how an organism is able to use language. This capacity requires a physically realized recursive procedure in the mind-brain of an organism that obeys the principle of least action. Massimo Piattelli-Palmarini and Giuseppe Vitiello have demonstrated that this process is isomorphic to the quantum field theory of many-body physics. Following a proposal from neuroscience made by Randy Gallistel for a neuron as a computational machine, I define a model for a computational unit that processes information. Finally, I turn to a proposal made by Roger Penrose. I show that the model lends itself to an interpretation where an organism takes in information, processes this information and can make the decision to send out information. I end by stating some observable predictions.

Keywords: Syntax, Semantics, Computation, Principle of Least Action, Decision Making, Information Processing, Biolinguistics, Neuroscience, Physics, Theoretical Philosophy.

1 Introduction

My aim is to develop an argument set within a framework taken from contemporary philosophy of language and metaphysics. The premises are taken from arguments presented by different authors from different fields. Furthermore, I only use some of their basic ideas. My goal is to develop a model within an axiomatized framework that shows the principles by which an organism can process information and make decisions.

Contemporary analytic philosophy provides a highly formalized background for the aim of this paper. By using only some of the most general assumptions, it is possible to

provide clear interpretations of the different proposals used in this paper within a unified framework. Within this framework, I focus on what, to the best of my knowledge, is the most advanced theory about the way the mind-brain works that is known today. This theory has been developed by Noam Chomsky and others within the so-called "Minimalist Program". The central notion *Merge* is taken to work in the simplest way possible, this is called the "strong minimalist thesis" (SMT).[1] Therefore, my goal is to derive a relation Σ as a generalization of *Merge* under SMT from an axiomatized theory under the principle of energy minimization and from observations.

In order to do this, I first introduce the formal framework, using the concept of computation as a way to represent the physical world, as well as the concept of states taken from contemporary semantics. This then allows me to define a relation Σ holding between two partially ordered sets, each representing a particular universe.

This state space allows me to axiomatize a proposal made by Isaac Newton in the *Principia Mathematica*. There exists an entity S that is part of all concrete objects. This entity has certain properties.[2] Here, I'm only concerned with two of them, S processes information and S makes decisions. I lay down the two properties as axioms for the theory. This then allows me to derive an asymmetry between the respective universes.

This asymmetry entails that an observer of the physical universe cannot in general observe the behavior of S. Only in certain cases can S be observed. This leads to the following hypotheses. If S can be observed, then this signals that the asymmetry is broken. I will show that in these cases, there must be a measurable difference for an observer within the physical universe. For if S exists and carries out work, S requires energy. This additional amount of energy must be, in principle, measurable for an observer in the physical universe.

In order to understand the behavior of S, I turn to Noam Chomsky's proposal. There is a recursive procedure *Merge*. *Merge* is physically realized within the mind-brain of an organism. *Merge* takes in discrete entities, either atomic or composed, and generates a new entity from these two. When a phase is reached, the composed expression is interpreted, i.e. the information is accessible for further operations.

The cornerstone of Chomsky's theory is the claim that *Merge* works in the simplest way possible. We will see that within the present framework, both *Merge* and SMT can be given a precise interpretation that allows for a generalization of Chomsky's proposal as one way for an organism, with or without linguistic capacities, to process information. We will see that it is consistent with observation that it is not the availability of *Merge* that distinguishes humans from other organisms, but rather the capacity to make free decisions that allows for language use.

The first step in this generalization has been presented by Massimo Piattlelli-Palemrini and Giuseppe Vitiello. They show an isomorphism between *Merge* under SMT and the

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[1]Chomsky 2013

[2]Cohen, Whitman, and Budenz 1999

formalism of quantum field theory of many-body physics.[3] This structure preserving relation links the macroscopic biological processes to the underling microscopic processes, describable by the proposed formalism.

The next step is to define a model for an organism. I use a proposal by Randy Gallistel who argues that each neuron is a computational machine that takes in information, processes the information and can send information out.[4] The model is derived by abstracting away from a real neuron. Rather we work with an some object N, such that the object constitutes a boundary and within that boundary S can be observed. In other words, within that boundary, the asymmetry is broken.

We then say that within N there is an S such that S takes in information, processes the information and makes the decision about sending information out. Since S can carry out $Merge$ under SMT and because of the isomorphism, it is possible to define a function that maps the S onto the development of a state vector and into the physical universe. In other words, we gain a description of the energy required to carry out a computational step of N.

Taking the total amount of energy required for one computational step into account, we can define two types of decisions as the difference between the total amount and the amount that is needed taking only physical processes into account. The cases where the difference is zero are the cases where S is unobservable within the physical universe. The cases where the difference is not zero are the cases where S is observable. I then introduce further a distinction for the later cases such that there are bounded decisions. That is to say, decisions where S is observable, but there are causal influences. Finally, there are the case where S is observable, but there are no causal influences, we call these "free decisions".

The last step in the generalization is to turn to an argument presented by Roger Penrose.[5] Penrose proposes that there must be something that can induce state reduction as a real physical process. I will show that Penrose's proposal lends itself to an interpretation within the present framework. More specific, Penrose proposes that if a sufficiently massive object is brought in superposition, then the energy required to do so is inversely proportional to the average time until state reduction is achieved and proportional to the reduced Plank constant.[6] By identifying S as an entity that can induce superposition by means of making a decision, I show that Penrose's proposal is consistent with the view that S corresponds to a state vector of a system for which the asymmetry is broken. S selects elements in accordance with $Merge$ under SMT by bringing each element into superposition. If the number of states l approaches a limit L, that is, if the average reduction time approaches zero, a symmetry brake of the system occurs. This symmetry break corresponds to a decision made by S. After the symmetry break, the system achieves a

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[3]Piattelli-Palmarini and Vitiello 2017

[4]C R Gallistel 2017

[5]Penrose 1994

[6]Hameroff and Penrose 2014

phase that corresponds to a definite state.

The conclusion is that we have a model for how an organisms can take in information, processes the information and can make the decision to send information out. I predict that for each N that satisfies the conditions, there will be an $S(N)$ such that it can be expected to be found between an lower limit, determined by a minimal mass and an upper limit, determined by Penrose's criterion. S will be observable, if the additional energy required is measurable against the background noise of the environment in which $S(N)$ lives. I end by stating a list of predictions.

2 The Framework

I begin by laying out the model and explaining the choice of the different axioms. I then show that the chosen ontology allows for the representation of the physical universe in terms of Turing machines and a representation of the operations of an entity S where the possible operations of S are related to corresponding physical processes. I then define a relation Σ between the partially ordered sets $\mathbb{S}$ and $\mathbb{TM}$. I show that the relation $\Sigma(S, TM)$ is an asymmetrical relation. There are operations carried out by S that cannot be represented by TMs. Under the assumption that all physical processes can be represented by TMs, it follows that if S exists, then S exists in an *metaphysical universe* $\mathbb{S}$. An observer in the *physical universe* $\mathbb{TM}$ can, in general, only observe processes representable by TMs. Therefore, the asymmetry entails that the theory is observer relative.

Let us begin with the concept of computation. It is standard today to think of the world as being representable by computational procedures. When I talk about physical processes, I assume that any physical process can be represented by means of Turing machines (TMs). Each Turing machine can be specified as a 7-tuple:

Definition 1 $TM = \langle Q, \Gamma, b, Z, \delta, q_0, F \rangle$: *such that Q is a finite, non-empty set of states; & Γ is a finite, non-empty set of alphabet symbols; & $b \in \Gamma$ is the blank symbol; & $Z \subseteq \Gamma \backslash \{b\}$ is the set of input symbols; & $q_0 \in Q$ is the initial state; & $F \subseteq Q$ is the set of final states; & $\gamma : (Q \backslash F) \times \Gamma \nrightarrow Q \times \Gamma \times \{L, R\}$ is the transition function.*

The function γ is defined from computational states to computational states. Suppose the TM is in the state (q, X_i), then the function δ yields (p, Y, L). That is, the next step is a step to the left. Informally, we think in this case of a TM as starting at the state q, it scans the content of X_i and writes Y. Then, it moves left and halts in the state p in the position $i - 1$.[7]

Now, we take the set of all $TM \in \mathbb{TM}$ and we restrict this set to all and only the TMs that represent physical, i.e. causal processes. With this stipulation in place, we can say that the set $TM \in \mathbb{TM}$ can be used to represent all states of the physical universe.

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[7]Hopcroft, Motwani, and Ullman 2001, p. 320

The notion of a 'state' can be given a precise meaning within a framework developed by the philosopher Kit Fine. In recent years, the Kit Fine has made major contributions to the development of a semantics, called "Truthmaker Semantics".[8] I will use some minimal components thereof. Before I can do this, I have to introduce the mereological notion of 'parthood' in a sufficiently clear form: We assume a basic theory of *First Order Predicate Logic* wit *identity*. Then we introduce the symbol '$\sqsubset$' to express the proposition *that a is part of b* ($a \sqsubset b$) and add three axioms to our theory:

Axiom 1 *Reflexivity:* $x \sqsubset x$

Axiom 2 *Transisitivity:* $(x \sqsubset y \land y \sqsubset z) \rightarrow x \sqsubset z$

Axiom 3 *Anti-symmetry:* $(x \sqsubset y \land y \sqsubset x) \rightarrow x = y$

These three axioms constitute partial order. So, if we take a set of states S, then we have a partially ordered set $(\mathbb{S}, \sqsubset)$.

Since a partial order can be imposed on any set, we also assume the model $(\mathbb{TM}, \sqsubset)$ to be part of our theory. If we assume $\mathbb{S}$ to be infinite, and since $\mathbb{TM}$ is enumerable, they are of the same cardinality and we can define the cross product $\mathbb{S} \times \mathbb{TM}$.

Since both sets are partially ordered, we get what is known as the *product order* for the cross product. For any two tuples $\langle S_i, TM_i \rangle$ and $\langle S_j, TM_j \rangle$, $\langle S_i, TM_i \rangle \sqsubset \langle S_j, TM_j \rangle$ iff $S_i \sqsubset S_j$ and $TM_i \sqsubset TM_j$.

With this formal background in place, we can define a relation Σ. This relation is an equivalence relation between $\mathbb{S}$ and $\mathbb{TM}$, defined by the product order. This relation Σ will be the focus of interest in what follows. Before I go on, I have to lay down two further clauses that are taken directly from Fine. We only look at states and we define 'fusion' (denoted by '$\sqcup$') via parthood: A state is the fusion of its parts.[9]

Axiom 4 *Closure: The fusion $S_1 \sqcup S_2 \sqcup S_3 \sqcup \ldots$ of some states $S_1 \sqcup S_2 \sqcup S_3 \sqcup \ldots$ is also a state.*

Axiom 5 *Convexity: For any state S_j lying between two states S_i and S_k, it is the case that S_i is part of S_j and S_j is part of S_k.*

Closure and convexity ensure that any state will have highest lower bounds and one least upper bound. In other words, we are dealing with semi-latices structures. This notion of structure will be central to what follows.

Since we have defined TMs as states, we can treat them in the same way: A fusion of two TMs is itself a TM and for any TM_j lying between a TM_i and TM_k it is the case that $TM_i \sqsubset TM_j$ and $TM_j \sqsubset TM_k$.

This ensures that we select only the TMs such that the TM has some highest lower bounds and it terminates at an lowest upper bound.

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[8] See, for instance, Fine 2017
[9] Fine 2017, pp. 627-628

We are now in a position to formulate two final axioms for our theory. The justification for these two additional axioms comes directly from Isaac Newton who postulates in the last paragraph of the *General Scholium* of the *Philosophia Naturalis Principia Mathematica* the existence of a certain entity. This entity exits in all objects and has, according to Newton, two properties that are of interest to us.

Newton postulates that this "very subtle entity" is the *cause "by which all sensation is stimulated, and the limbs of animals are moved at will"*. The laws by which this entity operates are unknown. As Newton says *"[we don't have] at hand a sufficient number of experiments by which to determine and demonstrate the laws of action of this [entity] accurately, as ought to be done."*[10][11]

We quantify over all $S \in \mathbb{S}$ and we state the following two axioms:

Axiom 6 *S decides to move.*

Axiom 7 *S stimulates sensation*

We give the axioms the following interpretation.

Definition 2 *S decides iff for any step of a TM, there is an S, such that S decides to carry the step out or not.*

Definition 3 *S stimulates sensation iff S processes information. & S processes information iff the corresponding TM makes a step.*

This interpretation of Newton's proposal by axiomataisation within a precisely defined framework is the basis for everything that follows.

2.1 Asymmetry

I now show that the relation Σ is no longer an equivalence relation but rather an asymmetric one.

Σ maps two partially ordered sets. So, if there is an S, then there is a corresponding TM. Take any arbitrary S, if S decides, then there is a TM that either carries a step out or not.

Take any arbitrary TM. For a TM to carry out a step, then the TM has to start. To start, a TM must have a previous step that starts it. Take the successor function

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[10]Cohen, Whitman, and Budenz 1999, pp. 588-589

[11]Here is the paragraph in full: *Something might now be added about a certain very subtle spirit that pervades all dense bodies and is concealed in them, by whose force and actions the particles of bodies attract each other when separated by very small intervals, or cohere when contiguous; and by which electric bodies act at greater distances, both repelling and attracting neighboring corpuscles; and by which light is emitted, reflected, refracted and inflected, and heats bodies; and by which all sensation is stimulated, and the limbs of animals are moved at will for this is done by the vibrations of this spirit transmitted through the solid capillaments of the nerves from the external organs of sensation to the brain, and from the brain to the muscles. But these things cannot be explained in a few words, nor have we at hand a sufficient number of experiments by which to determine and demonstrate the laws of action of this spirit accurately, as ought to be done."*

$S(n) = n + 1$ and assume a *TM* that only carries out this function. Then, for the step $S(0)$ there is no previous step by definition. And so, no *TM* can start itself.

Therefore, Σ is an asymmetric relation. We have two universes, such that the asymmetry holds between the universes.

Let us now look at a universe where any causal process can be represented by a *TM*. And the universe contains nothing but causal processes. Then in this universe, Σ tells us that S is also a causal process. If S caries out a causal process, then S carries out work and so, S requires energy.[12] In other words, if S decides to carry out work, there is a finite amount of energy required. We denote this amount of energy by 'Δ_S'.

Consider an arbitrary S at time t and let S decide. Then there are two options: carry the step out or not. In the second case, there is no change, no change requires no work and so $\Delta_S = 0$. In the first case, there is change and so, $\Delta_S \neq 0$.

2.2   Observer Relative

We can now say how an observer in the physical world relates to S. For any causal process where $\Delta_S = 0$ we say that the asymmetry holds. For any case where $\Delta_S \neq 0$, we say that the asymmetry is broken. For the later cases, I postulate that S observes the principle of least action. That is to say, S uses the minimal amount of energy possible.

Energy Minimization Principle: For any action of S, S minimizes the amount of energy required.

$$min(\Delta_S)$$

Given this principle, we can say what it is for S to make a choice:

Definition 4 *S has a number n of choices iff for any S_i at time $t = 0$, there is a number n of states at time $t > 0$, S_i fuses with at least one of them.*

The possible choices are determined by the causal processes. Because of axioms 4 and 5, we can be certain that for any highest lower bounds and least upper bound, there will be the fusion of all states between them. Then, Σ tells us that for each possible model that satisfies Σ, there are corresponding causal processes.

We can then say that for each lowest upper bound, if there is a choice between the models, S will always choose the model that corresponds to the simplest causal processes. And so, the total amount of energy required to reach a state will be the sum of the individual choices made by any S_i that is part of S

$$min(\Delta_S) = min\Delta_{S_1} + min\Delta_{S_2} + min\Delta_{S_3} + \ldots + min\Delta_{S_n}$$

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[12]Meschede 2015

Σ is then a relation that maps minimized states to the causal processes that require the least amount of energy necessary for them to take place.

We get the following picture. Since Σ is asymmetric, an observer in the physical universe is only be able to observe the behavior of S if S decides to change a state. For all other cases, the observer is unable to distinguish any two cases where a process is forced by external causes from a process where S does not decide, but the process is carried out anyway. In this case, the observer cannot exclude the possibility that $S = TM$. And so, an observer cannot see S as a part of TM. So, the asymmetry entails anti-symmetry, but for the observer of TM, the impossibility to distinguish between S and TM, the anti-symmetry does not entail asymmetry, since there are cases where $S = TM$.

If, on the other hand, S is observable, that is, if S can be measured, then we know that this signals that the asymmetry is broken. It is this class of cases that we will be concerned with in what follows. For know, I turn to Chomsky's theory.

3 The Generalization of *Merge* under *SMT*

Noam Chomsky is the founder of generative linguistics and has been a leading figure in the field ever since. From the earliest attempts to construct *Phrase Structure Grammars* to the current *Minimalist Program*, he and others have reduced the complexity of language to a simple underlying procedure. This physically realized recursive procedure *Merge* works in the simplest way possible. This is known as the strong minimalist thesis (*SMT*). *Merge* takes in elements, either atomic or composed and constructs new elements from them.[13] The constructed elements have a semantic interpretation, in other words, they contain information.

It is this simple core system, the operations of *Merge* under *SMT* that allows us to represent the behavior of S under $min(\Delta_S)$.

Given the framework and the asymmetry, I now show that *Merge* under *SMT* can be represented in the theory under the assumption of the energy minimization principle. I show that this representation allows for the generalization of *Merge* in terms of a function f_M. f_M is defined as a function that maps two TMs, TM_i and TM_j, onto one TM_k such that TM_k is the result of the decisions by S_i and S_j to fuse.

In other words, we use the relation $\Sigma(S, TM)$ to define *Merge* as a computational procedure TM and then we characterize this procedure as a function that acts on symbols in accordance with the operations of S.

Merge is defined as follows:

Definition 5 *Merge takes two elements, A and B, and constructs a new element, C*

$$M(A, B) = C$$

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[13]Chomsky 2013

The two ways in which f_M can operate are given by *Internal Merge* (IM) and *External Merge* (IM). *EM* selects two objects and generates a new one. IM selects two objects, where one is contained in the other, and generates a new object.[14] We can define the two cases of *Merge* in terms of S as follows:

$$f_M(S_i, S_j) = \begin{cases} f_{IM} = S_{k_1} & \text{such that} \quad S_i \sqcup S_j \wedge (S_i \sqsubset S_j \veebar S_j \sqsubset S_i) \\ f_{EM} = S_{k_2} & \text{such that} \quad S_i \sqcup S_j \wedge \neg(S_i \sqsubset S_j \wedge S_j \sqsubset S_i \end{cases}$$

f_M is thus a function defined over the a model that satisfies Σ. We get hierarchically ordered states such that each lower state is part of the higher state and either the lower states are not part of one another or one of them is part of the other. We call a highest lower bound 'atomic' and we call any other state 'constructed'.

If *Merge* is carried out, there are two states and for each state, each respective S makes the decision to fuse with another state. Each S can only fuse with another state if there is a corresponding process that allows this. In the physical universe, this means that two objects have to interact in a way that they both form a new object. Since the new object corresponds to a state, there is an $S_{k_{1,2}}$ that is the result of the fusion S_i and S_j. The energy required is the sum of $\Delta_{S_i} + \Delta_{S_j} = \Delta_{S_k}$.

We can formulate two conditions on *Merge* under SMT. It is always simpler not to change something then to change it and it is always simpler not to order something then to order it.[15] Both conditions follow for S automatically.

If $S_{i,j}$ would make the decision to change, $S_{i,j}$ would not be part of S_k (because it would not be identical) and since $S_{i,j}$ are parts, there is no hierarchical distinction between them, and so no operation of S is required. Since the corresponding processes take place at some time t, we can have two processes TM_i and TM_j taking place at the same time $t = 0$, where we generate a state S_k which is hierarchically higher and corresponds to a process that takes place at some later time $t > 0$. Now, if S_i would make the decision to fuse with S_j, and S_j would not make the decision to fuse with S_i, S_j would not be part of S_k. So, we know that decisions of S are always on the same hierarchical level iff they take place at the same time.

It follows that f_M is at least a two valued function. We can also show that f_M is at most a two valued function.

If either S_i or S_j would have made the choice to interact with some other S_x at the same time, for each S, there would have been an additional decision to interact with each other. And so, the energy required to form S_x would be the sum $\Delta_{S_i} + \Delta_{S_x}$. Which in turn yields $\Delta_{S_i} < \Delta_{S_i} + \Delta_{S_x}$.

Therefore, $min(\Delta_S)$ tells us that *Merge* can at most be a binary operation.

We have seen how the core system of language can be represented by the way S generates hierarchically structured states corresponding to causal processes, where each

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[14]Chomsky 2013, p. 40
[15]Chomsky 2013, p. 40

state has lower bounds and an upper bound. The elements in this semi-lattice have hierarchical order that corresponds to the order of operations in time. So, we can think of S as generating structures that preserve a hierarchical order over time where we get an order parameter θ by the total amount of energy required to generate that structure. The total amount of energy required is given by $\Delta_{TM} + \Delta_S = \theta$.

We can also formulate expectations for the processes that are observable. The processes will correspond to hierarchically structured states, such that the states remain unchanged and there are states on a level $\theta = n$, that are part of some state on a level $\theta = n + 1$ and both states fuse. This allows us to formulate the following two hypothesis for physically realized processes. That is we are looking for objects in the physical universe that have the following two properties:

φ_1 There are interactions of objects such that the objects form a new object while the interacting objects remain unchanged.

φ_2 There are interactions where an element is either cut out of or copied from an object and used in the construction of the new one.

We now have a way to describe the operations of S in the physical world by means of f_M. It is now time to set up our model for the operations of S.

4 Conceptual Model for the Physical Realization of Merge

The neuroscientist Randy Gallistel has long argued that we might find the physical realization of functions not on the neuronal level, but rather at the level of molecules.[16] He regards each neuron (N) as a computational machine that takes in information, processes the information on the molecular level and then either sends out a signal or merely changes its configuration.[17] This conceptualization satisfies axiom 6 and axiom 7. We can thus postulate that there is a discrete object that realizes the function f_M on the molecular level. Furthermore, it follows from $min\Delta_S$ that the level on which f_M is realized will always be the level where an operation requires the least amount of energy. Thus, if the computational capacity of a single object is not sufficient, any number of objects will be used in conjunction.

Now, we can abstract from this and postulate that N is represented by $\mathbb{S}$ and $\mathbb{TM}$ and $\Sigma(S, TM)$. We can then represent an operation of S as being carried out on some possible level of energy (which we take to be a constant k). We represent the total energy required as an equation that represents information input (II), information processing (IP) and information output (IO) under the condition that the system has to return to the level it is at.

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[16] Charles R Gallistel and King 2011
[17] C R Gallistel 2017

$$\Delta_{S(N)} = \Delta_{II} + \Delta_{IP} - \Delta_{IO} = k$$

If we think of this equation as a description of the physical processes, we can define a function for the observed change in difference of energy depending on time.

$$\Delta_{S(N)}(t) = \Delta_{II}(t) + \Delta_{IP}(t) - \Delta_{IO}(t)$$

This function describes the change of the state of a system by actions of S at time t. The possible actions of S are given by f_M. We think of $S(N)$ as a discrete object such that for each such object, there is an S such that $S = (S_{i_1} \sqcup S_{i_2} \sqcup S_{i_3}, ..., \sqcup S_{i_n}) \sqcup (S_{j_1} \sqcup S_{j_2} \sqcup S_{j_3}, ..., \sqcup S_{j_{n-1}}), ..., \sqcup S$. This $S(N) = S$ will be our concern.

Furthermore, we know that the observable objects must satisfy the properties φ_1 and φ_2. That is to say, we expect that the discrete entities exist and that we can observe how f_M is carried out by combining objects such that φ_1 and φ_2 are satisfied.

In order to understand how $S(N)$ operates, I now turn to a proposal for the underlying dynamics of the system.

5   Merge and the Isomorphism with Quantum Field Theory

In a recent paper Massimo Piattelli-Palmerine and Giuseppe Vitiello argue that there is an isomorphism between $Merge$ under SMT and the formalism of many-body physics.[18] Since $S(N)$ is defined as a way to represent $Merge$ under SMT, the isomorphism holds. Thus, we can give our model a description in terms of the formalism of many-body physics.

To do this, I first restrict the states to the domain of $S(N)$. So, our model involves all and only those states that can be part of $S(N) = S$. Then, we represent a state S as a vector $\begin{pmatrix} 0 \\ 1 \end{pmatrix}$ or $\begin{pmatrix} 1 \\ 0 \end{pmatrix}$ respectively. Thus, we take the vector space of states and the Pauli matrices $\sigma_i, i = 1, 2, 3$ and the unite matrix I. The matrices operate on the basis formed by the states, from now on denoted by '$|0\rangle$' or '$|1\rangle$'. We can now think of $S(N)$ as being a system whose states can be represented as either denoting different levels of one S_i or of denoting two different $S_{i,j}$. The states are now taken to be fermion-like eigenstates of σ_3 with eigenvalues $\pm 1/2$. We have the $SU(2)$ group and $su(2)$ algebra as well as the commutation relations $[\sigma_3, \sigma^\pm] = \pm \sigma^\pm$ and $[\sigma^- \sigma^+] = -2\sigma_3$.

We thus think of the operations of $S(N)$ as an operation on a collection of L binary objects. An operation of S can thus be represented for each i as the ground state $|0\rangle_i$ or

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[18]Strictly speaking, they show the isomorphism for the generation of an *X-Bar* tree. Since an *X-Bar* tree can be obtained by $Merge$ under SMT, I substitute the terminology.

the exited state $|1\rangle_i$ with $i = 1, 2, 3, ..., L$.[19]

This enables us to think of the actions of S as remaining in the ground state, going into the exited stat, remaining in the exited state and going from an exited stage into the ground state.

Schematically, and dropping the index, we may represent this as follow:

$$|0\rangle \longrightarrow |0\rangle$$
$$|0\rangle \longrightarrow |1\rangle$$
$$|1\rangle \longrightarrow |1\rangle$$
$$|1\rangle \longrightarrow |0\rangle$$

We can then represent the operations of S by applying the operations. If S does not decide, the system remains in the ground state. If S decides to fuse in accordance with f_{EM}, the system goes into an exited state. If S decides to fuse in accordance with f_{IM} it remains on the same level, since it fuses a element of a structure with itself. If $S(N) = S$ the system returns into the ground state. **??**

Thus, using the results of Piattelli-Palmerini and Vitiello, we gain a description of how S operates in terms of a recursive dynamical process of the $SU(2)$ group and $su(2)$ algebra.

Let us now consider the product space for a large number of states L. We can represent this via factor states $\prod_{i=1,L} |S_i\rangle \equiv |S_1, S_2, S_3, ..., S_i, ...,\rangle$. For each $i = 1, 2, 3...L$, with S_i either 1 of 0.[20]

The total state where $S(N) = S$ is the state $|l\rangle$ such that the system is in superposition of all states that are part of S with l exited state and $L - l$ in the ground state. The difference between the number of elements in the exited state verses the ground state is identified with the order parameter θ.

Now, suppose $l \longrightarrow \infty$, then it can be shown that the system of fermion-like eigenstates undergoes a dynamical rearrangement of symmetry and the algebra contracts into a boson algebra.[21] This spontaneous breakdown of symmetry corresponds to $\theta \neq 0$, that is to $S(N) = S$. That is to say, the space of states of the system splits into infinitely many unitary inequivalent subsystem. Each subsystem represents a possible phase of the system and corresponds to a possible value for θ

We can thus represent the actions of S as selecting states, corresponding to information intake, processing the information by bringing the states in superposition. If S reaches a limit, the decision to send information out is made and the system goes into a definite phase determined by θ. The system has thus send out information and has returned to its ground state determined by $\Delta_{S(N)} = k$.

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[19] Piattelli-Palmarini and Vitiello 2017, p. 3
[20] Piattelli-Palmarini and Vitiello 2017, p. 6
[21] Piattelli-Palmarini and Vitiello 2017, pp. 6-7

Now, we get a description of how S can operate on a microscopic level and be able to reach a macroscopic level. We can explain the dynamics of $\Delta_S(t)$ as the result of information processing describable by the underlying dynamics of quantum field theory. We can go even further. Up until now, talking in terms of the actions of S has been under the assumption that $\Delta_S = 0$ or $\Delta_S \neq 0$. In other words, the process is the same for all cases and so, we have primarily described information processing, which works the same in both cases. Now, let us consider if we can get an explanation for the way S actually makes decisions. This will enable us to formulate conditions for S to make bounded and free decisions. This will yield the prediction that there are upper and lower bounds for $S(N)$. To do this, I turn to a proposal by Roger Penrose.

6 The Penrose Criterion

The physicist and mathematician Roger Penrose has long argued that state reduction must be explained as a real physical procedure.[22] His argument runs as follows. Consider a sufficiently large object and consider the energy required to bring this object into superposition. We then consider the space-time separation given by the superpositioned mass. Penrose proposes that the average time for state reduction is inversely proportional to the energy required and proportional to the reduced Plank constant. Thus, Penrose proposes that state reduction is induced as the total amount of energy increases.[2324]

$$\tau \approx \frac{\hbar}{E_G}$$

We can say that S selects the states. The selection yields the energy for the state to go into superposition. As the total number of states goes against infinity, the average reduction time approaches 0. When $S(N) = S$, the state reduction is induced. This corresponds to a decision by S to send information out. This symmetry break corresponds to a decision where $S(N) = S$. The definite state obtained is the lowest energy state possible for the system to have. Since this state is determined by the decision of any S_i to fuse and thus generate a structure, this information is carried over by θ and S is in a defined state corresponding to θ.

Now, so far I have not considered the distinction between free and bounded decisions. We define a bounded decision as a decision where a cause is identifiable. If we identify the cause with information intake, then we can define fully bounded decisions with the cases where $\Delta_S = 0$. We can also define partially bounded decisions by defining information intake as not fully sufficient to cause a decision. So, $\Delta_S \neq 0$. We can also define cases

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[22]Penrose 1994

[23]Hameroff and Penrose 2014, p. 53

[24]Where $\tau \approx \Delta_{t_{B-A}} \approx 23ms$, $\hbar$ is the reduced Plank constant. And E_G is the gravitational self energy or the degree of space-time separation given by the super positioned mass.

where there is no cause, that is to say $\Delta_S = max$.

Note that we get different descriptions of processes: There are processes that correspond to causal processes without any additional requirements. Finally, there are processes that correspond to particular causes, but require an additional decision to be carried out. There are also processes where no cause can be identified. These free decisions would enable an S to generate any possible structure, while the former are bounded to particular causes. Thus, we can recover the unique human capacity to generated in infinite number of expressions by postulating that humans can make uncaused decisions. This is possible, because axiom 7 tells us nothing about the conditions for S to make a decision.

Now, Penrose's criterion tells us that in order to reach a time scale observable on the macroscopic level, there must be a minimal mass involved. Furthermore, there must be an upper limit given by the total amount of energy involved. Thus, if $\Delta_S \neq 0$, we must in principle be able to observe the operations of S within these limits.

Since we might expect to find different physical realizations that enables S to operate, we might expect to find S for different limits. In the case of our model, we know that the physical realization must at least be on a level that allows for operations that satisfy φ_1 and φ_2. Because of the necessity of a minimal mass, we also can expect to find that $S(N) = S$ operates at most at this level. If $S(N)$ can implement different functions, we can expand the model, depending on the functions that S can carry out in accordance with Penrose's criterion. So, S is scale invariant. We can thus think of S as a system that can span different levels.

Furthermore, it is possible that the additional energy cannot be distinguished against the background noise of the environment. In this case, we might not be able to distinguish cases where $\Delta_S \neq 0$ from random events. This can only be decided by means of an experiment where the total amount of energy that an organism takes in from the environment is compared to the total amount of energy that it gives of when it makes decisions. If the difference is not zero, then, by the law of energy conservation, this is consistent with the possibility that the physical universe is an open system.

7   Conclusion

I have presented a model for the way an organism processes information and makes decisions. This model yields the prediction that we can get information coming from a metaphysical universe which is otherwise only indirectly observable by the conditions for how an organism can processes information and what kind of decisions it can make.

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