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1. Free Will Systems

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2. Preface

We have a significantly strong sense of being able to freely choose, at least to a certain non trivial extent, our own thoughts and actions. We sense that even though we are not always able to do whatever we want, for example under restrain, what we do is for the most part what we decide to do. Even under coercion, for instance, we clearly sense that we ultimately agree to delegate control based on some cost/benefit balance and we can always take control back if the cost becomes too high. That is, we clearly sense to have **free-will**.

On the other hand, as soon as we start to rationally think about it, it becomes less and less clear what sort and degree of free-will we have, if we do at all. Is it *freedom of action*? *freedom of thought*? *freedom of choice*? the *ability to do otherwise*? Do we all have the same free-will whether children or adult, educated or illiterate, physically/mentally ill or healthy? now and then? How does our free-will, whatever and however that is, relates to moral responsibility?

Not only is it difficult to rationalize our strong sense of free-will on itself, it happens to conflict more and more with our progressive view of the world. Already at the ancient times, when we knew little about nature and our fate was considered to be in the hand on Gods, thinkers wondered how can we have freedom of choice if our fate is to be decided, even if only partially, by such deities. Later, we started to take note of the way in which the components of the universe (such as atoms) work, everywhere from rocks to our body, and nothing seemed to indicate that there is free-will in such components, which makes it even more difficult, if not straight up incompatible, to make sense of our strong sense of having free-will nonetheless.

This conflict between our strong sense of having free-will and the difficulty of constructing a proper model for it that rationally coexist with our models of the world is known as **the free-will problem**, and it’s been around for thousands of years (see Doyle 2011, ch. 7 for a detailed account of the history of the problem).

Being such an ancient problem, almost every opinion about it has been written, reviewed and debated. From the idea that free-will is just an illusion (the most popular these days), to the idea that we humans, or at least brain-possessing animals, have free-will despite the way the universe works, to the idea that in fact the universe does not really work the way we commonly think and itself possesses free will (Conway and Kochen 2006)

This book joins the worldview of the last group: that we humans do in fact have free-will because free-will is a fundamental property of the very fabric of the universe (thus, not just us but *everything* has it).

In order to present such a thesis, this book is divided in 3 parts.

In part one, the idea of free-will itself is decomposed and elaborated in detail, and the concept of a free-will system is presented. A free-will system is proposed as a system in which *all* its elements have free-will yet it can self-organize in such a way as to *display* the sort of deterministic patterns we observe in, for example, nature.

In part two, a specific metaphysical worldview is *postulated* in which the actual universe is presented as a model for a free-will system, such that human free-will, for example, can be both explained and properly characterized on the basis of that worldview.

In part three, the practical and conceptual consequences of the proposed metaphysical worldview, such as possible ways to test the postulates, considerations about the future and the nature of predictability (specially on natural sciences), evolution, moral responsibility, etc… are discussed.

Finally, an appendix, after part three, attempts to elaborate the basis of a calculus of free-will operators.

The reader should know that this book does not pretend to contain the solution to such an ancient problem. It does make a stance (that we do have free-will), and tries to provide conceptual support for that claim using a bottom-up approach that, based on the proposition of how things *could* be and work, attempts to find human free-will and to match our current models of nature. But this book does not pretend to show that things really are and work that way, only that they could in the sense that all our current physical models are compatible with it.

In that sense, this book merely adds yet another metaphysical view to the problem of free-will.

3. Overview of Dynamic Systems

3.1. Objects and States

An *object* is any part of reality (actual or imaginary, concrete or abstract) that is somehow *distinguished* from everything else (see Spencer-Brown 1994; and Kauffman 2014 for a formal treatise of "distinctions"). Intuitive examples include *physical* macroscopic objects such as a rock, a planet or a galaxy; *metaphysical* objects such as persons or pets; and *abstract* objects such as numbers, words or drawings. In physics, for instance, an object is usually referred to as a (physical) "system", and the distinction is drawn when it is considered to be possible to isolate it from the rest of the universe: a rock, for example, is an object (or a physical system) for it can be physically separated from the surroundings such that certain properties about it remain the same when placed under many different environments and it goes through certain physical processes, that is, *when the distinction persist*. A subatomic particle, such as an electron, is also a physical object (or system) for it also can be persistently distinguished from other electrons and the rest of the atom on several different scenarios and through different processes.

An object is a distinction, but distinctions are usually *drawn* rather than inherent. For example, a rock is really just a continuously mutating collection of molecules which just happen to be of a different type from the type of molecules usually found in the environment right around the rock, such as gas, water or dirt. That difference in molecule types gives the collection of molecules—as a whole—a certain set of characteristics from which the distinction can easily be drawn (such as cohesion to form a solid body and surface texture to look a certain way when light reflects on it). It is the *operation* of drawing the distinction what dynamically determines what the rock is, and it involves the participation of an *external agent* drawing the distinction (whether is a person looking at it, or a mechanical device separating it from other objects). Let us then define a **proper object** as any object that *inherently* distinguishes all by itself without the participation of any external agent explicitly drawing the distinction. The simplest examples of proper objects can be found in the abstract world. For example, a two-dimensional circle of radius "R" centered on the origin of a certain Cartesian coordinate system is a distinct proper object all by itself and there is no need to explicitly *draw* a distinction in order for the circle to be itself. So is a number, or a word. Actual *proper objects* in the real world are much more difficult to correctly identify. All our models of the physical universe, from planets to rivers to atoms to quarks, are based on carefully but artificially drawn distinctions based on observations and experiments, but these do not all by themselves stand out as objects. They are only so because *we* distinguish them from the rest of the world. Still, the concept and alleged reality of *actual proper objects* is central to the problem of free will, so this will be covered in more detail through the rest of the this work.

State is the collection of properties of, about, or on an object. Simple examples for *physical* objects include *temperature, acceleration, color, or shape*. For *metaphysical* objects, examples include *emotion, knowledge or motivation*. For *abstract* object, could be *"a list of numbers that represent something that is encapsulated in the abstraction"* or *"the style used on a piece of art"*. In general, the word "state" is used to refer to *all* of the properties of an object, *everything* that is to know, or can be known, about it. Thus, strictly speaking, "position" or "knowledge of history", are partial or sub states. However, in many contexts, only a part of the state, such as "position" alone, can be referred to as "the" state, even though is strictly just partial.

For any given object, some properties are independent of anything external to the object, for example, the radius of a circle is independent of anything but that circle. Other properties are only the result of interaction between the *referent* object (whose property is considered) and a *reference* object(s) (the things that interacts with the referent). For example, the weight of a physical object depends on a property of the object itself, the rest mass, but also on the Earth whose gravitational field gives weight to the object (and the position of the object relative to the center of the Earth). Independent properties, such as the "rest mass" of a physical object (when considering the simplified models of the so-called "classical mechanics"), are the same regardless of the external conditions of the object (the rest mass is the same here or Mars), unlike dependent properties, such as the weight of an object, which is different here than in Mars.

> The **Internal Property** of an object is any property that is independent of anything outside the object (such as the number of words on a book).

> The **External Property** of an object is any property that derives from the interaction between the object and its environment (such as the potential energy that a physical object possesses by being in a certain position within a certain "field", like gravity).

Now let us say that an object then *possesses* **an internal state** (the set of all internal properties), and *displays* **an external state** (the set of all external properties)

Notice that virtual objects also have properties (hence both internal and external state). An obvious example could be the "remaining strength" of a video-game avatar. A less obvious but still correct example could be "the (average) food-serving speed of a McDonalds store". Although the serving is the result of physically concrete actions and the speed in question can be properly traced back to concrete, not virtual, entities; the "average food serving speed" property does not refer to any concrete physical entity. Is not the "order-taking" speed of Bob, or the "burger-cooking" speed of Alice that is being considered, but that of the virtual object that is the store as a whole. It does not matter which concrete actual persons work on the store (Bob, Alice or both), the store still has a well defined, perfectly observable, average food-serving speed.

In order for *us* to make any informational use of the properties (internal or external) of an object, they need to be given a representation. For example, in the field of physics, the representation comes out of *quantification*: that is, a process known as *measurement* assigns a numeric value—a quantity—to the property. Having properties represented by numbers allows us not only to be as exact and precise as possible but to operate mathematically with them and relate different properties of an object (such as its position and speed), or among objects (such as the gravitational force between a pair of objects). Even if a measurement is performed by subjectively mapping the property to a variable on an arbitrary scale, such as when a doctor asks a patient to rank their own pain on a scale from 1 to 5, once a property has been formally quantified (represented numerically) it can be logically and mathematically used (for example, the doctor can formally record the reported pain rank, then other health care professionals can look at it and infer what to do). Outside the mathematically oriented world of Science, properties might not be quantified but they are still represented via *qualification*. For example, a snack could be qualified as tasty or dull, and that adjective—that quality—becomes the representation of that property of the given snack.

> A **Variable** is any representation, whether quantity or quality, of an internal or external property of an object.

> An **Observable** is any property of an object for which a *process* mapping such property to a *variable* exists (even if only in theory).

> An **Observation** is the actual process mapping an observable to a variable.

> An **Observer** is any agent carrying out an observation.

In this work, the term *property*—whether internal or external—refers to the characteristic of an object regardless of anything *we* can tell about it. A *variable*, on the other hand, is a representation of a property that an observer creates within its cognitive world. For example, in physics, we describe the position of an object in terms of variables, but the object is at a certain "place" (whatever and whenever that is so) regardless of our attribution of its position. Even if in reality the there is no such thing as a "position property", there is, necessarily, *some* property or properties *from* which we attribute the variable "position". This distinction is important in developing certain concepts that are fundamental to the problem of free-will.

Specially within Science, variables are usually governed by mathematical equations (or other *formal methods*) which predict their values in different conditions, such as the passage of time or as the result of interaction. Calculations might yield exact values, intervals or probabilities, but in all cases, what is expressed by the equations, or the so-called “Laws of Science”, is the *expected* value of the variables of an object according to any particular theory or model. Therefore:

A **Prediction**, or **Formal Variable**, is a variable given by a mathematical or logical expression.

A **Measurement**, or **Empirical Variable**, is the variable obtained by empirical observation.

While a measurement is a form observation by which we *empirically* obtain a variable representing a property, a mathematical or logical expression is also considered an observation, one by which we formally calculate the expected variable for a property. That is, an observable is any property that can be observed (obtain a variable as a representation of it), whereas by measurement or prediction.

This distinction between properties, variables, observables, predictions and measurements is important for the development of the concepts in this work, but have in mind that these terms are sometimes used interchangeably or ambiguously on certain contexts.

A measurement is then an empirical variable that is effectively obtained by an empirical observation process, as opposed to a formal variable that is, for instance, just calculated from an equation. This distinction is often implied, or omitted, but is critical since predictions are dependent on our own theories and models of reality whereas measurements are dependent on reality itself. It is the degree of correlation between formal and empirical variables (that is, predictions and measurements) which determines the value of a given scientific theory.

Notice that an observable requires that a suitable representation exists (usually a properly defined quantity), but does not demand the actual existence of empirical observation, only that empirical observation is possible. For example, each and every planet on the Universe is considered to be an observable even if we had never yet actually observed each and every planet. On the other hand, there could be proposed properties of an object that are not (yet at least)* *observables. A classic example are most of the consciousness-related properties of human beings. A (proposed) property of an object that is not (yet at least) quantifiable, or at least qualifiable, is not an observable for there isn’t even a proper process for obtaining a representation of it (a variable, even if only formal).

While *properties* refer to features of a reality, *variables* refer to features of our models of the reality. While ideally, variables directly map to properties, that is not necessarily the case, and the difference might be significant. In quantum mechanics, for example, observables (such as the spin of a particle) are perfectly defined in the models of the theory but is not clear what property or properties of the actual reality they derive from. Similarly, we have very useful *operational definitions* of, for example, emotional states, with variable values such as “sad”, “happy”, “worried”, etc… yet the properties of human psyche and/or neurology that underlies those abstract representations are unknown.

Since variables, by which we represent and operate on observables (whether the position of an object or the amount of knowledge of a person), are only implicitly *correlated* with one or more properties of the objects they refer to, but are not directly said properties, any characteristics or conclusions that are found in the abstract realm of the models and operations that we construct with these variables, are only indirectly correlated with actual features of the system being modeled (such as physical reality). For example, we constructed the so-called “Laws of Physics” which are models of physical reality in which the prediction of future events is possible. The nature of any correlation between a predicted future observable, such as the position of an object moving due to gravity, and any actual future property or properties from which the variable position derives, is not given by said models and we can only postulate a metaphysical presupposition to explain the link between future variables and future properties. The most common such metaphysical presupposition is the so-called “determinism” that postulates that physical objects are bound to follow a predetermined sequence of state transitions, one that is “out there” and merely discovered by science and formulated in the laws of physics. This work on free-will proposes an alternative presupposition to explain the correlation between future variables and future properties.

3.2. Change

Consider the following:

- Several readings of terrain altitude at different places.
- Several moves of the white pieces of a chess play.
- Different colors preferred by individual persons in a group.

- Different positions of an object that is moving around.

Each of the items in that list is a form of sampling:

> A **Sampling**[1] is a collection of *values* each associated with a *marker*, where each (*value*, *marker*) pair is a *sample*.[2]

These are examples of samplings for the above list:

- $\{(0m, place_0),(200m, place_1),(1000m, place_2)\}$[3]
- $\{(Be5, 1),(Nf3, 2)\}$[4][5]
- $\{(red, Bob),(blue, Alice)\}$
- $\{(point_0, instant_0),(point_1, instant_1)\}$

All samples have a *marker*, that is, a representation of where (or when) you get the given value. Often, the markers are implicit, as in a sequence of game moves, in which case the markers are just the step index. All markers in a sampling can be *ordered*, and most markers have a natural ordering. For example, instants in time, or step indices, are naturally ordered increasingly. The markers for terrain altitudes are usually ordered from sea to inland, and in the case of persons with their preferred colors, any ordering would do, such as the names alphabetically. Although most markers have a natural ordering, is always possible to apply a different one; for example, instants in time can be ordered backward, into the past.

An **observation constructs a sample**. That is, there is always a marker deliberately associated with the property that is mapped to a variable. With no marker (without a *where* or *when*) there is no observation. If the marker is a time instant, we have a *temporal observation*[6]

> A **Pathline**[7] is a sampling that is sorted by sequencing the markers using a particular ordering.

For example, if we sort the places at which terrain altitudes have been observed (sampled) from sea to inland along a certain path, we get a *terrain altitude pathline*.

> A **Timeline** is a pathline in which the markers are time instants.

A Pathline is the simplest *representation* of **change**.

For example, we see altitude *changing* as we walk from sea into the mainland; or preferred colors *changing* as we survey one person after another. Likewise, the positions of chess pieces *change* at each step, so do the positions of a moving object. A timeline (which is a special type of pathline) is then the simplest representation of **temporal change**.

A fundamental characteristic of any pathline (hence any timeline) is that it *represents* change, discretely. Change itself is not defined by pathlines, rather, pathlines are a *view* on change that results from sampling, and sorting the samples.

> An **event** is a sample whose marker is a time instant.

Hence, a timeline is a *chronologically* ordered sequence of events.[8]

A second fundamental characteristic of any pathline (hence any timeline) is that it *only* results from both *sampling* and *sorting*. That is, there has to be a deliberate association between a value and a marker (i.e. an observation),

[1] The concept of *Sampling* is presented here in a way that fits the purpose of this work, but the reader should know that if differs somehow from the formal *Sampling Theory* of Statistics.
[2] In Sampling Theory, *samples* are just values, and the *marker* is implicitly given as a nonsignificant index into the sequence in which the samples are taken. Here, however, the *marker* of each sample is instrumental in the development of a view on change and time, which is why is formalized and given a special treatment.
[3] The place markers here would be GPS coordinates.
[4] The *value* of the samples in these example pairs are chess moves using the so called *Standard Algebraic Notation* for chess.
[5] In this case, the *marker* is an index to the step along the play.
[6] In Physics, observations are, by default, implicitly temporal.
[7] The term pathline is borrowed from *Fluid Dynamics*, where a pathline is the trajectory of any particle moving in a fluid. In this work, however, the term is used to refer to a generalization of *timeline* that incorporates non-temporal change.
[8] And one can sort time instants decreasingly, in which case we have a backward, or reversed, timeline.

and the markers need to be deliberately sorted. Without markers there are just values (altitudes, colors, positions) in a collection, and without sorting, there is a collection of observations but not a sequence.

It is the sorting of the markers in a collection of observations, that is, the *sequencing* of the observations, what makes a pathline a representation of change. For example, terrain altitude only changes if and when we correlate each altitude with places along a certain specific path. Otherwise, there are just different terrain altitudes, but there is no altitude change. There has to be a *path* along which the altitude is sampled in order to establish *change*.

Likewise, a given *occurrence* is only a temporal observation, that is, an event, if it is *marked* with an instant of time, even if such marking is implicit and subconscious as we ordinarily do. And, different events represent change *because* time instants are naturally sorted increasingly. That is, events, being at time instants, are automatically chronologically sequenced by virtue of the natural increasing ordering of time instant markers[9]

Is trivial to see that in the example cases of terrain altitudes, or color preferences, change and its ordering is relative to the *arbitrary* choice of path. One can chose any path to sample altitudes and each will result on a different pathline, with its own sequence of–changing–altitudes.

Furthermore, one can choose a terrain altitude sampling path for which the altitude happens to be always the same.[10] In that case, there is sampling, there is also a pathline since the markers (GPS coordinates) *can* be ordered along the path,[11] but there is no change. That is, while a pathline is the simplest representation of change, not all pathlines–or subsets of pathlines–do represent change.

Since it is the sequencing of samples along a pathline (or timeline) what makes it a representation of change, then change so represented can always be considered to be decomposable in two dimensions: in one dimension there are the values which are sampled (altitudes, colors, positions); in the other, the markers and its ordering (places, persons, instants). Have in mind that even though most markers–such as instants–have a natural ordering, a pathline includes a particular ordering that might or might not be the natural one. For instance, a timeline can be backwards.

For a sampling to be a pathline, markers need to be *orderable* and in any given pathline, they are so ordered (for example, decreasingly in a backward timeline). Consequently, *any* two samples in a pathline can be related to each order as one marker being *smaller*, *equal*, or *greater* than the other. Thus, any two samples are *before*, *simultaneous*, or *after* each other.[12] Furthermore, given any pathline, it is always possible to pick an *origin*–the *present*–then *label* any sample with the *distance* to the sample chosen as *origin* (or *present*).[13] This labeling then *partitions* the pathline in (*past*,*present*,*future*) with respect to the origin selected.

4. References

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[9]And time instants are *not* naturally ordered increasingly because of some metaphysical or fundamental property of time, or because of our psychological perception of it, but due to the simple fact that time instants are given by real numbers, and all real numbers are naturally ordered increasingly.

[10]in Cartography, such a path is called a **contour line** (a form of **isoline** in which the constant value is altitude).

[11]Any collection of points that lie on a curve can be ordered along the curve in different ways. One example, known as *arc length parameterization*, is by mapping each point to a real value measuring the distance that needs to be traveled from some arbitrary *starting* point on the curve to reach the point.

[12]with respect to whatever ordering was used in the pathline.

[13]As long as a *metric* can be applied to the markers in order to define a distance between any two. This is the case with markers represented by natural or real numbers, such as *positions along a path*, heights, or time instants.