Is reality digital or analog?

1. Introduction

This essay addresses the question "Is reality digital or analog?" by:

a) considering a range of possible realities and Universes
b) proposing a hypothetical Universe, based on a fundamental physical unit which has a combination of digital and analog characteristics
c) reviewing issues relating to possible pure digital and pure analog Universes
d) proposing an answer to the essay question, within this framework.

The sections of this essay are:

1. Introduction
2. Characteristics of Pre-Universes
3. How a Universe might develop from a pre-Universe
4. Evolution of a coherent Universe
   a) initial growth
   b) random variations
   c) patterns
5. The laws of physics in such a Universe
   a) movement
   b) gravity
   c) relativity
   d) other aspects
6. Discussion of the limitations of pure digital and pure analog models
7. Reviewing the essay's sub-questions
8. Summary response to the essay question

2. Characteristics of Pre-Universes

For this essay we conceptualize characteristics of a class of pre-Universes. A pre-Universe is quite empty and featureless with zero net energy. Some pre-Universes may have potential for local temporary fluctuations; these are the ones of interest.

A pre-Universe which could lead to a Universe is postulated as follows:

- the pre-Universe is generally featureless with no observable structure or time, but with very small fluctuations in its insubstantial fabric. These are random wave-like fluctuations, of zero net energy, combining negative and positive amplitudes. These would (usually) be short-lived and would die out by re-combining into a zero-energy state.
- in a pre-Universe of interest, there would be potential for these fluctuations to evolve into something more complex, as described in Section 3 below
- other pre-Universes may exist but would not be of as much interest.

A pre-Universe is hard to conceptualize, but since any conceivably small event or fluctuation, no matter how small, could happen in a pre-Universe, it is reasonable to say that a pre-Universe is **continuous**, or at least that many possible pre-Universes are continuous.

3. How a Universe might develop from a pre-Universe

A multi-step process can be envisaged which leads from a pre-Universe to a more coherent Universe, as follows.

A basic fluctuation arises as a small random flicker in the pre-Universe. Such fluctuations could be frequent but irregular and random, with zero net energy. The wavelength and frequency of the wave depend on the (currently unknown) rigidity of the fabric of the pre-Universe. These fluctuations would be one-dimensional and short-lived; they would die out through re-combination to zero energy or through natural damping.

In a very small proportion of cases, a secondary fluctuation forms, by the same random process, on the surface of a primary one-dimensional fluctuation (a 1DF). This creates a two-dimensional fluctuation (2DF), which is also unstable and short-lived, collapsing to zero energy.

In an even smaller proportion of cases, a third fluctuation forms on the surface of a 2DF. This creates a three-dimensional fluctuation (3DF). In a very small proportion of these cases, the three fluctuations are orthogonal, the amplitudes of the three fluctuations are the same, and the fluctuations are exactly in phase alignment (or opposite-alignment) in such a way that they pass energy to each other successively and mutually reinforce. They then form a coherent stable three-dimensional unit. The dynamics of this 3DF are so complex (like the "three-body problem" in mathematics) and self-sustaining that the 3DF does not collapse on itself.

This relatively complex combination of waves is the transition point at which analog and digital meet, and at which pre-Universe and Universe diverge. From this stage onward, there is a minimum fundamental unit.

We will call this 3DF unit a space-point or s-point.

Some features of the s-point are:

- it is not a particle, but a set of self-reinforcing fluctuations
- it is essentially mass-less
- it has a location, but because the components are fluctuating, it is slightly blurry – it does not have an absolutely fixed position or size
- the s-point has eight possible modes ie the eight possible combinations of the up-or-down fluctuations in three dimensions
- the cycle required to complete each sequence of three completed fluctuations of the s-point provides the fundamental time-measure of the Universe
- an s-point provides a seed for growth of a Universe, as set out below.

The transition point at which complex 3D fluctuations achieve near particle-like sustainability and complexity, and become s-points, can arise many times over (although it is very rare compared to the frequency of 1D fluctuations), and resulting s-points may have varying characteristics (specifically wavelength and amplitude). A small proportion of these cases of original s-points will evolve into viable stable Universes, and a smaller proportion into Universes containing sentient beings.

4. Evolution of a coherent Universe

a. Initial growth

Once an s-point is formed, it interacts with the adjacent fabric of the pre-Universe and sets it vibrating. The initial coherent s-point thus stimulates formation of additional adjacent coherent s-points, of the same dimensions and of opposite phase. This process continues successively in a spherical expansion which becomes rapid exponential inflationary growth, populating an expanding Universe which replaces the nullity of the pre-Universe with empty space which is much more tangible although mass-less, being an (initially incoherent) array of s-points.

In the initial stages, all s-point fluctuations vibrate in a complementary fashion with each adjacent fluctuation.

This expanding Universe is moderated by two main effects:

b) random variations
c) patterns

b. Random variations

Random variations of fluctuations arise, frequently and inevitably, from the same mechanism as creation of all basic fluctuations as discussed above. A basic variation occurs when a random fluctuation interferes with an existing fluctuation (eg with a 1DF within an s-point), thus changing the mode of the s-point.

Without these variations, there would be a “perfect” but simple, sterile Universe, vibrating in a single rhythm, and expanding forever.

Variations cause “imperfections” and allow for the possibility of diverse patterns of s-points forming. Each variation causes an exception to the neat complementary vibration of adjacent fluctuations. Where it occurs, it results in a reversal of the phase pattern of the affected fluctuation, a change in mode of the s-point, and an initially tiny change in the overall structure of the array of s-points. However, this tiny change could ripple through and cause major changes to the pattern. It is the interplay of all these interactions that activates this Universe.

Patterns arise which, because of their structure ie array of modes of s-points, are longer-lasting and “resist” change potentially caused by interaction with adjacent s-points and patterns. This is not an anthropomorphic use of the term “resist”; there are simply some patterns which by their structure and coherence tend to resist change. This is somewhat analogous to an eigen-vector in mathematics, which tends to resist transformation by other patterns (represented by matrices).

c. Patterns

Pattern-forming and pattern interaction are (initially) the most difficult aspects to grasp in this Universe.

Patterns are three dimensional arrays of s-points which demonstrate sustainability. Any array of s-points is equally valid, but only a very small proportion of all possible arrays form patterns which are sustainable. The simplest sustainable patterns form the fundamental "particles" or more generally units from which other patterns develop. For example, a Hydrogen atom would be one of the simplest sustainable patterns at the next higher level of complexity. Patterns can form at any scale, and there can be patterns of patterns eg molecules comprising multiple patterns of constituent atoms, which are groups of patterns of the more fundamental units.

The wavelength and amplitude of the original s-point may be critical parameters which determine whether viable patterns form.

A pattern is not a particle. In this model, there are no particles, at any level of complexity or observation. Every pattern is transient, but some have sustainability and repeatability, and are regularly observed.

Sustainable patterns have structures which are robust when interacting with adjacent patterns ie adjacent layers of s-points. Patterns are generally likely to be "spherically" symmetrical in three dimensions (ie **spherical** to the extent to which a 3D array which has discrete elements in three orthogonal dimensions approaches a smooth spherical shape). So they are composed of s-points in layers radiating from a centre. There will usually be significant repetition in the structure of alternate layers.

The structure of a pattern is a combination of:

- the number of layers in the pattern
- the mode of each s-point in each layer
- the sequence and repetition of layers

A stable pattern is a very coherent collection of s-points. It is coherent in the sense that it tends to retain structure when interacting with adjacent s-points, simply because of the structure and geometry of its pattern. Cellular Automata interactions and evolution (for example, as represented in John Conway's "The Game of Life") provide a two-dimensional example of the model for pattern interactions described here. The "rules" by which cells live and die in this Universe, and the extension to three dimensions, are areas for further work.

There is a hierarchy of stability: what we see as solid objects like hammers are more stable than (say) walnuts in most forms of interaction with each other or with other patterns. Some patterns are stable; some are even more coherent and tend to replicate themselves.

There is no preferred status or special property associated with s-points within a pattern. An s-point is in a particular mode (at a point of time) regardless of whether

this acts as part of a pattern or not. An s-point is not specifically identified as to whether it is in a pattern or not. There is no real distinction between (for instance) an s-point at the edge of a pattern, and the s-point next to it. There is no preferential distinction between adjacent s-points whether they are in random incoherent space, or are part of a pattern and adjacent to empty space, or are parts of adjacent coherent patterns.

The edge of a pattern is not uniquely and precisely defined for at least two reasons:

- each s-point is vibrating (fluctuating) dynamically and changing mode, and it is not possible to say which mode or even which s-point represents the edge
- because each s-point is fluctuating continuously, it would not be possible to measure the position of the edge precisely even if a particular s-point were identified as the edge

The edge of a pattern is continuously changing at the micro-level, but the multi-layer structure of a pattern means that the structure and composition of the s-points near the edge (and in the centre) retains typical characteristics.

A "small" or "weak" wave of fluctuations which approaches the edge of a pattern is repelled "easily" ie it is negated by a relatively thin layer of s-points and does not penetrate far into the pattern.

In addition to patterns which resist change to themselves, there are patterns which (simply because of their structure) tend to transform adjacent patterns to replicate themselves. A form of "physical evolution" occurs, resulting in survivor patterns (for example, the elements of the Periodic Table).

5. The laws of physics in such a Universe

In this discussion, parameters such as "small" and "frequent" are difficult to define, and are not quantified, but this does not invalidate the discussion. The discussion of physical laws for this hypothetical universe is different from our traditional models for the Universe, but the discussion necessarily uses traditional language (such as "object") mixed with new concepts in order to explain this model.

Many quantitative parameters of the hypothetical Universe arise from the characteristics of the sustainable patterns. These patterns form in coherent geometric shapes in three dimensions. For example, the pattern for a proton is larger and more complex than that for an electron, giving rise to the relative ratio of masses as measured in experiments.

a. Movement

In this hypothetical Universe, an object moves because the pattern of the object moves within the background framework of s-points. The pattern moves by transforming s-points successively in its path. And it moves because the ceaseless fluctuation of s-points and patterns around it "forces" it to move: it retains coherence but not position.

As mentioned above, Cellular Automata models provide a representation for this, ignoring the effects of random variation.

A pattern moves by transforming the s-points in front of it into the structure of the pattern. It could be said to populate or colonize the space in front of it with which it interacts. Because it is highly coherent, the pattern retains shape and size and it (conversely) de-colonizes the space it leaves behind, which "fills in" based on interactions with whatever the adjacent array(s) of s-points are, whether incoherent or coherent.

For example, in this Universe, a billiard ball moves when its pattern moves. Two billiard balls collide when their patterns collide and interact, and the result is two patterns moving off in different directions. Because the pattern for a billiard ball is very coherent, it continues to be a billiard ball (pattern), but the coherent pattern moves across the background framework of s-points in another direction.

The process of an interaction of two coherent object-patterns is not necessarily a single pass. It may be like the iterative interaction of ripples or standing waves from two pebbles thrown into a pond, in which the waves interact and progressively form new patterns and perhaps a new standing wave. With two highly-coherent object-patterns, both may well continue to be observed after the interaction, unless it has been so vigorous that only the most coherent one remains: a hammer pattern would then outlive a walnut pattern.

b. Gravity

The rate of formation of 1D fluctuations is very high (although it is hard to put an absolute measure on this). The random 1D fluctuations form a quantum foam throughout the Universe, the energy of which essentially powers the entire Universe. Without this foam providing both energy and uncertainty the Universe would be or become static and would not support life. These fluctuations also create the basis for gravity, as explained below.

Coherent patterns retain their coherence when interacting with "**external**" patterns, leading to the effects that sentient observers typically see as movement and forces.

Coherent patterns also retain their coherence when interacting with random fluctuations arising **internally** from the quantum foam; this leads to gravitational effects as follows.

When a random fluctuation arises internally within a coherent pattern, it creates an inconsistency in the pattern, which the structure of the pattern tends to resist or eliminate.

Internal inconsistencies are resolved in various ways, with the primary mechanism being to "resist and then expel" the stray fluctuation, to put it anthropomorphically. The effect is in fact simply interaction of s-points and patterns (as in a Cellular Automaton model) which, for a coherent pattern, tends to expel a stray fluctuation. When the expelled stray fluctuation reaches the edge of the coherent pattern it then interacts with the next s-point. If this s-point is part of incoherent empty space, the

interaction is often mutually destructive, and as a result an s-point disappears and space contracts. This is the effect we see as gravity, in which coherent objects are attracted closer to each other; this effect is really a collapsing of the empty space between objects.

The larger a pattern, and the more coherent (dense), the stronger is the gravitational effect because there are more stray fluctuations, and a higher number of them are expelled more quickly. This explains the correlation between Mass and Gravity of a pattern/object.

c. Relativity

In this Universe, the concept of the speed of an object is better described as the speed of transmission of a pattern.

The higher the speed of movement, the more s-points have to be transformed in each time period. There is a natural limit to the speed with which an object (pattern) can move or change, as the maximum speed with which it can transform adjacent points is limited by the beat (frequency) of the fluctuations. The higher the speed and acceleration of an object, the more s-points it is interacting with and trying to transform in each beat, and it appears to have the higher /increased mass associated with all the s-points with which it is interacting. So it becomes (at very high speed) measurably longer and more massive, corresponding to what is referred to as dilation. There is an asymptotic limiting effect which corresponds to the speed of light.

d. Other aspects

The only underlying variable (parameter) required in this model for creation of a Universe is the stiffness of the fabric of the pre-Universe, which determines the frequency of the random fluctuations.

The same effect, random 1D fluctuation creation, operates frequently and everywhere in empty space and among pre-existing 1D, 2D and 3D fluctuations. This random 1D fluctuation effect is the driver of:

- initial creation of an s-point
- variation within structured patterns as the Universe evolves, creating interactions which lead to what observers could see as forces, gravity, collisions and movement
- effects within unstructured space, resulting in collapse of space, which has gravitational and cosmological outcomes

In general, patterns interact in a large but limited number of ways which can be categorized into different classes at various scales or levels of observation, including nuclear, chemical or physical reactions etc.

A photon is a “stray” 1D fluctuation, which interacts in a limited way with s-points, without necessarily changing modes. It has no mass. A group of photons passing

through a pattern, and subsequently observed as "light", carry information with them on the structure of the pattern.

A black hole is an extreme pattern which is very uniform and simple, and in an interaction converts any other pattern into the form (pattern) of the black hole. It is like a zero matrix in matrix algebra.

The model in this paper potentially provides a basis for a complete theory for this hypothetical Universe. It only requires one initial parameter. It provides a basic mechanism and structure for physical laws from small-scale to large: from quantum effects to gravity and large-scale cosmology. These principles could be elaborated and extended as mathematical exercises.

6. Discussion of the limitations of pure digital and pure analog models

The main arguments against a pure **digital** reality for any Universe are clear:

- impossible infinities (eg of forces) are required at the surfaces of digital entities (a mathematical argument)
- the uncertainty principle is inconsistent with a pure digital principle, which should allow for precise measurement.

Questions arise under a possible assumption that the Universe once had no particles: how would the first particle come into being; what is the mechanism for creating a particle; what is the smallest particle (and what is it made of); where did the energy to create a particle come from?

Arguments against a pure **analog** reality include: why do we see "objects" with measurable size dimensions and end-points; how can we measure distances and lengths if everything is a wave (even acknowledging that we can only measure to limits consistent with the uncertainty principle); wouldn't a pure **analog** Universe resolve to a waveform which is the sum of all wave forms which (somehow) came into existence?

We could perhaps envisage a pure-wave Universe which is a complex multi-waveform, and subject to evolution under the forces of a quantum wave foam. But it is difficult to postulate how this would evolve into a Universe containing sentient beings, which seems to require more specific structure and a one-way arrow of time to generate an evolutionary process creating sentient complexity. Wave-forms may oscillate in a complex but cyclic way without generating the required level of complexity.

7. Reviewing the essay's sub-questions

Symmetries (geometric) emerge as significant and necessary features of a Universe containing sentient beings because only symmetric patterns are sustainable.

Because s-points have no mass, and are continuously fluctuating, the discreteness of space is not really measurable. Space is simultaneously contracting and collapsing, through the competing effects of colonization of empty space by s-points, and by collapse of s-points though negative interference.

The (unknown) relative frequency of formation events and collapse events among s-points will determine whether and for how long this Universe survives, and whether it collapses into itself.

Time is not reversible because of the random quantum foam giving birth to new 1D fluctuations. These fluctuations interact with s-points randomly and change the course of any sequence of interactions, which means that no sequence (of meaningful size) can be repeated exactly, whether "forward" or "backward".

A Universe of this sort could be represented to some degree by a Computational Algorithm or Cellular Automaton or digital computation, but the significant randomness caused by the quantum foam means that these models and calculations (no matter how intensive) will not be successful in modelling or predicting reality.

8. Summary response to the essay question

In the framework of this essay's hypothesis, the main question has separate answers relating to a pre-Universe and a Universe.

Since in some pre-Universe any small fluctuation could perhaps happen, it is reasonable to say that many conceivable pre-Universes are continuous.

The more important discussion, for most purposes, relates to a Universe containing sentient beings. A Universe is postulated to develop out of a pre-Universe by the process described, which starts with "crystallization" of analog/continuous waves into a discrete s-point, otherwise the pre-Universe continues as an undifferentiated foam. This creation of an s-point means that reality is based on a discrete unit, but one which is at the borderline between analog and discrete and retains some continuous characteristics.

The framework presented in this essay is based on trying to understand how a combination of digital and analog characteristics might create a viable, complex Universe.

So for this hypothetical Universe the answer to the question is: a specific combination of digital and analog fundamentals (creating an s-point with specific characteristics) is required to create and sustain a Universe.