The Physical World as a Virtual Reality Part II:

Simulating Space and Time

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"To me every hour of the light and dark is a miracle,
Every cubic inch of space is a miracle"

Walt Whitman

ABSTRACT

This paper explores the idea that the space-time of a virtual reality could appear to those within it as our space-time does to us. The likely processing needed to do this includes a dynamic information base, a discrete underlying grid and distributed processing. The simulation could present on the surface of a four-dimensional hyper-sphere, where an information processing grid calculates space, time and matter-energy entities. Grid node connections represent the directions of space and straight lines arise from node transfer calculations. A time that behaves like ours develops from the dynamic processing of state sequences, with the irreversible collapse of the quantum wave function giving the arrow of time. In the resulting model empty space is full of null processing, time is asynchronous cycle rates, objects are information waves and dark energy arises as light synchronizes space. Strangely, our world where time dilates, space bends and quantum existence smears behaves more like this model than an objective reality.

INTRODUCTION

A previous paper presented a prima facie case that the weirdness of modern physics is best explained by the physical world as a virtual reality (VR) rather than an objective reality (OR):

"*If the world is not a virtual reality, assuming it is so should soon generate outcomes inconsistent with observations, but if the world is indeed a virtual reality, it should consistently explain facts that objective reality theories cannot. Ultimately, the success or failure of the VR model depends upon how well it explains our world.*" [1]

This second paper develops the argument, suggesting how a space and time like ours could be simulated. Later papers address light (3), matter (4), and movement (5), respectively.

The barrier of objective reality

Whether we see our world as a virtual reality or not should depend on how it behaves. VR theory might contradict the positivist view that nothing exists outside the physical universe, but it does not contradict science. Rather, it is *assuming* VR theory impossible that short circuits science, which should evaluate hypotheses not presume them wrong. The assumption of objective reality is a mental cage for thought, that prevents us hearing a world that:

"*… has some important and surprising things to say about itself.*" [2] (p3).

VR theory is only on the table because objective reality theory doesn't explain modern physics. In an objective reality time does not dilate, space doesn't bend, objects don't teleport and universes don't pop into existence from nowhere. We would not doubt the world's objective reality if only it behaved so physically, but it does not. Adjectives like "strange", "spooky" and "weird" apply, and common sense

concepts like object, location, existence, time and space simply don't work. The world of modern physics doesn't behave at all as an objective reality should.

Method

Let us *assume* VR theory is true and follow the logic as far as it will go. The method is:

1. *Define the requirements*: What must a VR model do to simulate a word like ours?
2. *Design*: Specify a feasible design to current best practice.
3. *Validate*: Does the model match the physical world?
4. *Repeat:* Until design is impossible, logical inconsistency or prediction failure.

Deriving the laws of physics from basic information theory creates a case for VR theory. The consistency constraint is significant. Any information system can emulate *one* requirement by choosing assumptions, but to emulate many with minimal assumptions is more difficult. The guiding design principles are:

1. *Computing practice.* Follow computer science knowledge.

2. *Simplicity.* Given choices, take the simplest option.

If our world is a virtual reality there are certain things we cannot register, but when a world simulates another its rules *reflect* in the virtual reality, e.g. a screen's refresh rate limits how fast pixels move across it. If the world is created by information processing, *we can reverse engineer it*.

AN INFORMATION MODEL OF SPACE AND TIME

Introduction

A hundred years of research have verified quantum and relativity theories in sub-atomic and cosmic domains respectively, yet they conflict at the core. This is the quandary of physics today.

Quantum theory assumes an objective space-time background, yet relativity specifically denies such a fixed background. For quantum theory to satisfy relativity it would have to be *background independent*, i.e. not suppose a fixed background [3].

Equally, relativity assumes objects exist locally which quantum theory specifically states they do not. A theory of relativity that also satisfied quantum theory would have to be *location independent*, i.e. not suppose objects exist at specific locations.

These two great theories contradict because each was "contaminated" by an objective reality assumption the other debunked: quantum theory assumed objective space-time and relativity theory assumed objective existence. Each theory exposed the flaw of the other but ignored its own.

The proposed solution is to abandon objective reality entirely, arguing that *both object and background depend on information processing.* If neither objects nor space-time exist objectively, there is no fixed space-time to contain quantum theory nor are there any fixed location objects to move relative to others. VR theory rejects objective space, objective time, objective existence, objective movement and all concepts that assume independent substantiality.

The goal is to derive everything from information theory, with space, time, matter and energy as incidental outputs. In VR theory not only do photons and electrons arise from processing, the space in which they "move" is also thus created. So space both "calculates" objects [4] and is itself a calculation, i.e. everything begins with information. The premise that the physical world is a virtual reality may seem absurd, but thinking the unthinkable is often how science advances.

Overview

If Wheeler's "*It from Bit*" is literally true then information is the "quintessence" of the universe. Figure 1 shows the basic model:

1. *Physical reality*. Empirical or objective reality is created by information processing:
    a. *Matter-energy entities*. Program algorithms that pass between processing nodes
    b. *Space-time*. A virtual information transfer structure arising from node interactions.
2. *Processing grid*. Also called quintessence, veiled reality and external reality, is the processing network that creates both matter-energy and space-time.

The idea of something more fundamental than fundamental particles is not new:

1. *Fredkin*. His physics solution "*…only requires one far-fetched assumption: there is this place, Other, that hosts the engine that "runs" the physics*." [5] (p275)
2. *Wilczek*. Postulates what he calls the "*the Grid, that ur-stuff that underlies physical reality*" [2] (p111).
3. *D'Espagnat*. Suggests that everything arises from a "veiled reality" beyond time, space, matter and energy [6].
4. *Tegmark*. His External Reality Hypothesis (ERH) that "*There exists an external physical reality completely independent of us humans*" allows the Mathematical Universe Hypothesis (MUH) that: "*Our external physical reality is a mathematical structure*", which in turn allows the Computable Universe Hypothesis (CUH) that: "*The mathematical structure that is our external physical reality is defined by computable functions*" [7].
3. *Barbour*. Visualizes the quantum wave function as a "mist" arising from an underlying landscape, where "*The mists come and go, changing constantly over a landscape that itself never changes*" [8] (p230).

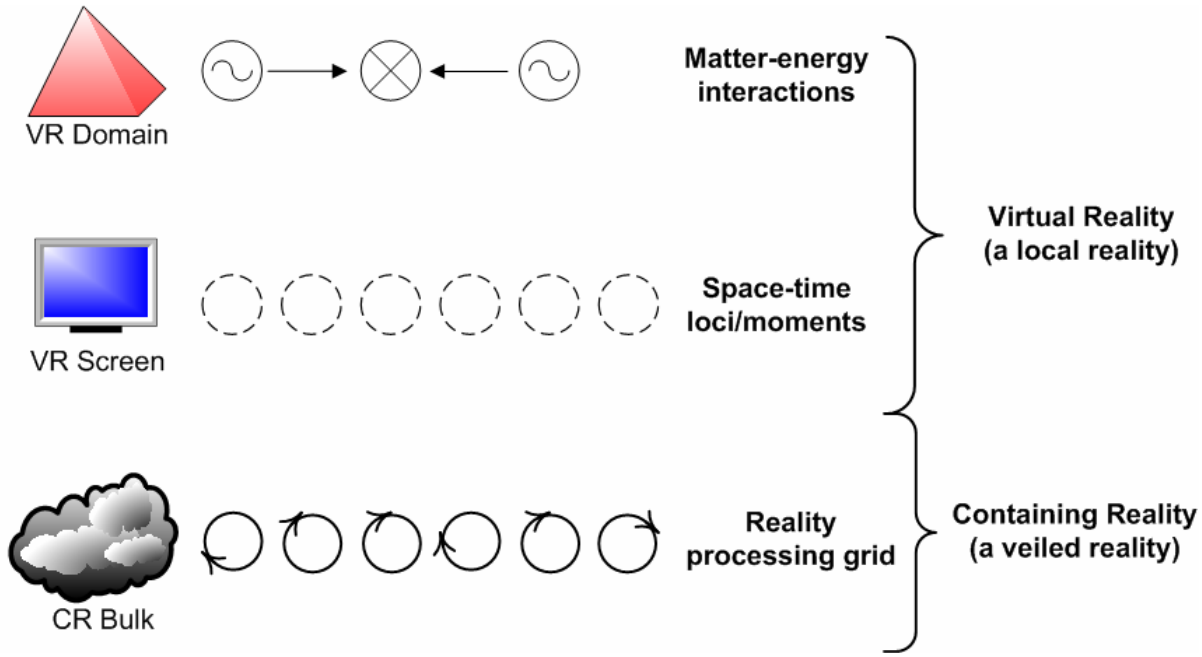

Figure 1. A virtual reality model

The *processing grid* of Figure 1 is an "other" to our reality as Fredkin proposes, and is a grid as Wilczek seeks. It also fits D'Espagnat's idea of a veiled reality, as when viewing a computer screen the underlying processing is "veiled" from the viewer by the screen itself. The Figure 1 physical world *is* a structure computed by an external reality as Tegmark hypothesizes, and Barbour's mists on a fixed landscape could be virtual events on an underlying processing landscape. As a city draws power from an electric grid so could the physical world draw existence from an information processing grid, where:

a. Space is the grid architecture.

b. Time arises from processing cycles.

c. Energy is information patterns in motion.

d. Matter is when information patterns "lock".

e. Fields are the properties of the processing grid.

To illustrate, imagine Second Life avatars in a forest (Figure 2). They *exist as information patterns* created by nodes on a screen that set pixel values. Each node has a fixed information capacity e.g. black-white screens set a few values but color screens set many. In the physical world as a virtual reality a three-dimensional "screen" sets complex values as matter-energy "pixels" move between nodes, just as pixels move across a screen. This information interacts to produce information processing, defined as the transformation of information values. However unlike the Internet these grid nodes transfer dynamic not passive data, i.e. active programs. The system has no storage as everything is just done now.

Figure 2. A virtual reality simulation

Programs move onscreen avatar patterns by "bit-shifting" them, i.e. copying each pixel in the pattern one node left, say. For a program to "move" an avatar through a forest it is logically just as easy for it to bit-shift the background forest, as both avatar and forest are pixels. If the forest behind him scrolls, the avatar "moves" through it, even while staying at the same spot on the screen.

The virtual reality has no fixed relation between grid nodes and VR pixels - the pixels of a particular leaf can be processed by any screen node. Only at a particular instant does a single pixel necessarily correspond to a single grid node. The processing grid of Figure 1 is not a fixed space, *it is what creates space*. Yet at any instant *one screen node processes one pixel*, i.e. one "point" in space. Entities then "interact" when they request processing from the same grid node. Postulating an underlying processing grid raises questions like:

1. *Architecture.* How do the grid nodes connect?
2. *Processing* What algorithms do the nodes calculate?
3. *Protocol.* What are the information transfer rules?
4. *Synchronization:* How do the nodes synchronize?
5. *Backup.* Are information copies kept?
6. *Recovery:* How to recover from an information error?
7. *Movement.* How do information patterns move?

This paper addresses questions 1-4, and later papers in this series address the others.

Dynamic information

Definition

Information defined as $Log_2(N)$ for N choices [9] depends on the choices available, e.g. two choices are one bit of information, 256 choices are 8 bits (one byte), and one choice (which is no choice at all) is zero information. While a book is generally taken to contain information, its text is fixed, so it represents only one choice - the way it physically is. By the definition this represents zero information, and indeed hieroglyphics do contain zero information if we cannot decipher them. A book only has information when it is read and choices create information, e.g. the first letter could be any alphabet letter, and so on. The information in a book *depends entirely on the receiver's decoding process.*

For example, if instead of reading every letter of a book one read every 10th letter, it would contain not only different information but a different amount of information. Hence if the encoding process is unknown the information is undefined, e.g. while the genetic alphabet is known the genetic code is not, as how gene "words" enhance and suppress each other is still unclear. Even the information in a simple electronic pulse is undefined. It can deliver one bit of information, but if it transmits ASCII value "1" it gives a byte of information, or if it means the first word "Aardvark" in a dictionary list it can be many bytes. A signal's information depends on the encoding process. Hence data compression can store the same information in a physically smaller signal by using more efficient encoding. Only when readers reverse the original encoding do the reader and the writer agree on the information in a book, i.e. such information is context dependent.

Static vs. dynamic information

To avoid confusion, let *static information* exist by virtue of an assumed encoding/decoding process, and *dynamic information* exist by the actual making of choices. Writing a book then is dynamic information as it could be written in many ways, so is reading a book as it can be read in many ways, but the book itself has no dynamic information as it is just one way. Unlike static information, dynamic information does not need an external "reader". *VR theory is based on dynamic not static information.*

This counters an argument that the physical world cannot be a virtual reality. If all digital simulations need an interpretive context to define what represents what, as noted above, then if these contexts derive from the physical world, the physical world cannot also be the output of such a simulation [10]. The logic is correct for static information, which requires a viewer, but does not apply to dynamic information that needs no interpreter. *The VR proposed here interprets itself.*

A universe "frozen" into a static state at a moment in time might have static information, as a book does, but who could "read" it? A frozen world has zero dynamic information as no choices are being made. It is as "dead" as the letters on this page without you the reader. Special relativity arose when Einstein imagined "surfing" a light wave "frozen" in space and time, i.e. with zero dynamic information. He concluded this was impossible and changed our view of space and time instead.

In our world the one thing that never changes is change itself. The laws of physics require it - special relativity ensures that light cannot freeze, and quantum mechanics makes all photons, electrons and quarks in the universe choose a quantum state every time they interact. The world's bubbling dynamic flux never ceases as far as we know. This makes sense for a virtual world that exists by dynamic information – if the processing stops the screen goes blank. The dynamic flux of our world derives from the definition of dynamic information.

Reality pixels

A digital space-time must be discrete as finite choices can't represent an infinite continuum. Continuously dividing up VR space gives a minimum "pixel" below which it is impossible to go.

Similarly continuously dividing up VR time gives a minimum "tick" of one processing cycle. If our world is virtual then there must be a space and time below which there is no space or time.

The Greek Zeno first noted how continuous space and time creates paradoxes [11]:

1. If a tortoise running from a hare occupies infinite space points sequentially the hare can't catch it, as every time it gets to where the tortoise was, the tortoise has moved on.
2. Conversely, if space-time is not infinitely divisible there is an instant when the arrow from a bow is in a fixed unmoving position, so how can many such instants beget movement?

The paradoxes remain today as infinities in physics equations that assume continuity, e.g. infinitely close charged particles experience an infinite force. Fortunately for logic the continuity of our world breaks down at the order of Planck length (10^{-33}m) and Planck time (10^{-43} sec). To examine such short distances one needs very short wavelength light, which means very high energy light. But putting too much energy into a small space gives a black hole, which screens information from us. If you probe the black hole with more energy it simply expands its horizon and reveals no more. In particle physics no-one knows what occurs below Planck length. Just as on closer inspection a TV screen is composed of dots, examining our physical reality gives Planck dots. Continuity seems a mathematical convenience rather than an empirical reality:

"… although we habitually assume that there is a continuum of points of space and time this is just an assumption that is … convenient … There is no deep reason to believe that that space and time are continuous, rather than discrete…" [12] p57

Today computer simulations of space-time regularly assume that space is a lattice of points and time is a sequence of cycles, e.g. loop quantum gravity [13] and cellular automata [14].

Trapped on a brane

So is the universe just a quantum computer embedded in space-time? For example:

"*Imagine the quantum computation embedded in space and time. Each logic gate now sites at a point in space and time, and the wires represent physical paths along which the quantum bits flow from one point to another.*" [15] (p172)

Since a virtual world cannot process itself [1], the physical world cannot be virtual and also carry out the processing that creates it. One cannot have one's virtual cake and eat it too, as the benefits of virtual reality have a logical "price" – there must be a containing reality.

In our world virtual realities exist on flat screens that we can see behind, as our reality contains them. In general, virtual realities appear on a containing reality surface, as an extra dimension is needed to express the information. A "surface" here is any space of at least one dimension below the containing reality – not just two dimensional surfaces. Note that a hologram is not a 3D simulation but a 3D "mirror" of the world - it no more simulates than a bathroom mirror does. Also note that a VR can present on a two-dimensional screen but represent a three-dimensional world, as simulations like Second Life do. Our world as a virtual reality presents most simply as a three dimensional surface within a four dimensional bulk:

"*When it comes to the visible universe the situation could be subtle. The three-dimensional volume of space might be the surface area of a four dimensional volume*" [12] (p180)

In 1919 Kaluza found that Einstein's general relativity equations written in four spatial dimensions gave Maxwell's equations, uniting quantum theory and gravity. However if objective space was four dimensional, gravity would vary as an inverse cube not an inverse square, and our solar system would collapse. To avoid this, and to explain why we can't see the extra dimension, Klein then proposed it was "curled up" in a tight circle. Moving into it quickly returned you to where you began. String theory

models a gravity like ours using six extra dimensions curled up inside our space, so the idea that we could exist on a brane of a higher-dimensional bulk is now established in string theory:

"*Physicists have now returned to the idea that the three-dimensional world that surrounds us could be a three-dimensional slice of a higher dimensional world.*" [16] (p52)

Yet why does an objective reality need six extra curled up dimensions it never uses? Is it not *existence geocentrism* to believe that our reality is the central reality? Why *must* any extra dimensions be curled up within our world? Certainly string theorists usually assume this, but not always. Randall and Sundrum's local gravity model reproduces relativistic gravity faithfully using an extra dimension of infinite length that is "sequestered" from our world [17]. Virtual reality theory simply goes a step further, arguing that an extra sequestered dimension is inevitable for a virtual reality. In VR theory we are constrained to the three dimensional world as an onscreen avatar is constrained to a screen.

Transverse waves need a free movement dimension to travel a surface, e.g. water waves can only travel a pool surface if it is free to move up and down. If the top of a pool is sealed in concrete, waves cannot travel its surface. The dimension of wave amplitude cannot be used as a dimension of wave travel for such a transverse wave. If we exist as transverse quantum waves on a three-dimensional surface, we cannot move from that surface without losing our existence. In VR theory the extra dimension wraps around our world rather than curls up within it, i.e. it is our universe that is constrained. In VR theory what we call the physical world does not contain extra dimensions but is rather contained by them.

Does space exist?

To know when virtual objects interact is not a trivial problem. The processing options are:

1. *Objects calculate interactions.* Each VR object calculation records its position relative to others to calculate collisions. In this case space literally does not exist in the simulation, but *each* photon, electron and atom in our universe would have to calculate its position relative to *every* other article in the universe - an enormous computing task.
2. *Space calculates interactions.* Each grid node processes a point of "space" *per cycle*, and objects are at the same point if they request processing from the same node for that cycle. Now calculating interactions is easier and space exists in the simulation as null processing.

Computing clearly favors the simpler option so which option does our reality favor? Whether our space exists apart from the objects within it has concerned the greatest minds of physics. Simply put: *if every object in the universe disappeared would space still be there*? Is space "something" or is it truly nothing?

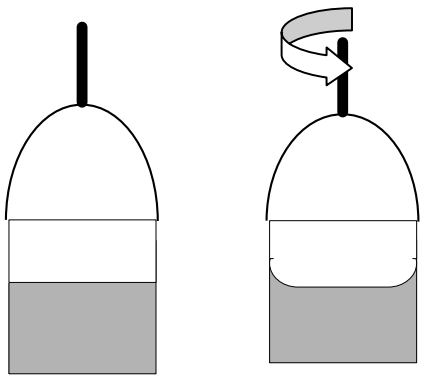

Figure 3. Newton's' bucket.

Newton saw space as a canvas upon which objects are painted, so it still existed even without objects. Liebniz found empty space as a substance with no properties unthinkable, so argued that what space "does" is done by object relations. He noted that in a vast empty space there is no "where" for an object to be, and that "distance" is only defined relative to other distances, e.g. a "meter" was the length between two marks on a platinum-iridium bar held in Paris. For Liebniz objects moved with respect to each other not an imaginary "space". If all the objects in the universe disappeared, he felt the illusion of space would also disappear.

Newton's reply to Leibniz's argument was Newton's bucket - imagine a bucket filled with water hanging from a rope that is spun around (Figure 3). First the bucket spins but not the water, but soon the water also spins and presses

up against the side to make a concave surface. If the spinning water moves with respect to another object, what is it? It can't be the bucket, as at the start when the bucket spins relative to the water the surface is flat. Only later when bucket and water spin at the same speed is it concave. In an otherwise empty universe where all movement is relative, Newton's spinning bucket should be indistinguishable from one that is still. Or consider a spinning ice skater in a stadium whose arms splay outwards due to the spin. One *could* see this as relative movement, as the stadium spinning around the skater, but if so the skater's arms would not splay. This suggests the skater *really is spinning* in space [18] p32.

This seemed to settle the matter until Einstein overturned Newton's idea of an absolute space through which objects move. Mach then tried to resurrect relative movement by arguing that the bucket water rotated with respect to *all the matter of the universe*. According to Mach, in a truly empty universe the surface of Newton's spinning bucket would remain flat and a spinning skater's arms would not splay outwards! This reflects how unsettling to object orientated physicists is the idea that space, which one cannot touch or measure, is:

"… *something substantial enough to provide the ultimate absolute benchmark for motion.*" [18] p37

The current verdict of physicists that "*space-time is a something*" [18] p75 meshes well with the VR hypothesis that space is null processing.

Distributed processing

The objective way to describe space is by absolute Cartesian coordinates (x, y, z), where objects with the same coordinates are at the same place. However this requires:

1. *A zero point*, i.e. a (0,0,0) "centre".
2. *A predefined size:* The maximum VR size defines coordinate memory, e.g. the point (2,9,8) in a 9 unit cube space must be stored as (002,009,008) for a 100 unit cube space.

Yet our universe seems to lack an absolute "centre", as its galaxies expand equally away from each other, not from a centre. Also the universe is still expanding at light speed so its maximum size seems still undefined. Cartesian coordinates would require a size allocated from the beginning, *i.e. before the big bang*. A virtual universe that expanded beyond its allocation would have a Y2K problem[1].

Cartesian coordinates work for small spaces but *wouldn't scale well* for a universe that has expanded at light speed for billions of years. In scalable network design both system load and the processing to handle it increase with size [19], e.g. new Internet nodes (ISPs) increase network load but also add more processing. If as network demand goes up so does supply, then the system can grow indefinitely. Scalability distributes control, so the Internet has no "control centre". While some saw this as a recipe for disaster, it turns out that sharing control lets the system evolve.

Suppose the information of space is not held centrally but distributed across the nodes of the grid network. Each node then only "knows" its neighbors, as Feynman it seems thought:

"*I remember … Richard Feynman … saying that he thought of a point in space-time as being like a computer with an input and output connecting neighboring points.*" [20] p138

As space expands, new nodes add both more space and more processing to manage it, so its "performance" doesn't change as it expands - a desirable feature for our universe. Giving each node a fixed amount of processing to manage its neighbors also localizes problems, as in a centrally processed system any infinity anywhere could "crash" the universe. Defining space locally doesn't allow an

[1] Before the year 2000 many older computers saved memory by storing years as two digits, e.g. 1949 would be stored as "49". The year 2000 gave the "Y2K" problem of no more coordinates available, as the year after 1999 was "00", which had already been used (for 1900). A lot of money was spent fixing this problem.

objective view, but recall this VR is viewed from within not without. An objective view is only necessary for an external observer. If all views are internal the only need is for *local consistency*.

Distributed processing means a finite section of space contains a finite amount of information, as in loop quantum gravity where a finite number of spin network nodes have a finite information capacity [21]. If black holes are the upper bound of information per node, then that they expand when objects (information) fall into them suggests that *finite space contains finite information.*

The architecture of space

It seems strange to talk of the architecture of space but computer simulations of space do:

> "*…we think of empty spacetime as some immaterial substance, consisting of a very large number of minute, structureless pieces, and if we let these … interact with one another according to simple rules … they will spontaneously arrange themselves into a whole that in many ways looks like the observed universe.*" [22] (p25)

The approach is to *derive* space from how grid processors connect, where objects are merely calculations that pass between node channels[2]. The question: "*Could one simulate a space like ours by information processing alone?*" illustrates Tegmark's "*Physics from scratch*" approach [7] (p6). To the strange question "*What does space do?"* one could reply that it should support:

1. *Dimensions*. Three degrees of movement freedom.
2. *Existence*. Objects exist within space.
3. *Interaction.* Space defines if entities interact.
4. *Geodesics.* Natural movement in apparent straight lines.

The goal is a distributed grid processing structure reflecting the above properties.

The Euclidean barrier

The idea of space is deeply embedded in our minds, so we tend to *assume* node structures that fit Euclidean space, e.g. we map a flat surface into triangles, squares or hexagons that can fill it completely, not circles which don't cover the area. Yet to limit that which creates space by the space it creates is the classic error of assuming objective reality. We exist in space, but what creates space need not do so, e.g. an ISP that creates cyber-space is not itself located there. Web "distance" is measured in mouse clicks not miles. Regular lattice computer simulations of space usually *assume* a fixed Euclidean space is the goal [23], yet our space curves and bends while Euclidean spaces do not. Our space *is an apparent Euclidean space not an actual one*. The goal is to model a space that behaves as ours does, not as we imagine it does.

In this model spatial terms like "close" and "straight" derive from the grid structure, e.g. a node connected directly to another is "close". Which node goes "where" is irrelevant, as the connections define the space, not the reverse. While the following diagrams use our space, don't imagine the nodes exist there. The logic follows Wilson's vision of a lattice of discrete points representing space, and Penrose's spin networks where the node vertices represent Planck volumes.

[2] A node channel is defined shortly

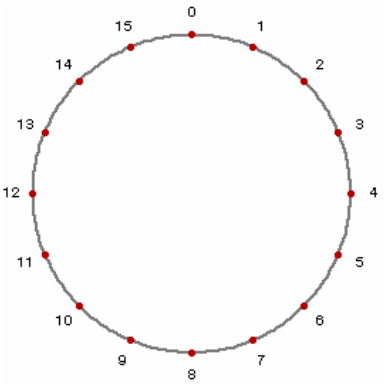

Figure 4. Discrete circle N=16.

Two dimensions

Imagine a set of nodes with equal and finite processing capacity. If each self-connects to two others the resulting *discrete circle* (Figure 4) defines a space of one dimension, with two directions, left and right, as each node has two neighbors.

To add another dimension "rotate" the discrete circle around any axis. Each rotated node now joins another discrete circle like the first, with the same number of points. Two different discrete circle sets give the node two "orthogonal" movement dimensions. The result can be visualized as a discrete sphere surface with longitudes and latitudes on a polar axis (Figure 5).

A two dimensional "flatlander" living on the surface of this sphere would see a world that is:

1. *Finite.* The space has finite number of points.
2. *Unbounded.* Moving in any direction never ends.
3. *Without a centre.* Every point on the surface of a sphere is the "centre".
4. *Approximately flat.* If the sphere is large enough.
5. *Simply connected.* Any loop on the sphere can be shrunk to a point.

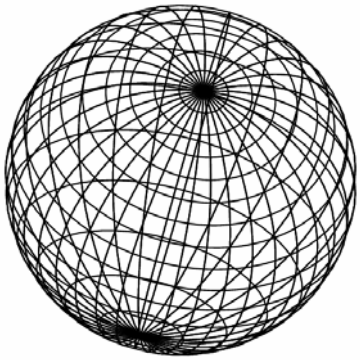

Figure 5. A discrete sphere

We can know if space is curved as the angles of triangles don't add up to 180°, but our space has been expanding at the speed of light for billions of years, so its curvature may no longer be discernible.

Discrete circles

One can view all symmetric polygons as discrete circles with an increasing number of points. In this view a triangle is a "3-circle", a square is a "4-circle", a pentagon a "5-circle", and so on, with an "N-circle" approximating a circle if N is large (Figure 6).

In Figure 5 a discrete sphere was obtained by rotating a discrete circle of N points around a pole. That pole then has N longitudes passing through it, giving a circle of N neighbors around it *on the sphere surface*. Yet the rotation making that node a pole was arbitrary, and rotating on any other axis would approximate the same ideal sphere. Different rotations merely change how the discrete sphere nodes are configured, i.e. their connections. *Any* node can be a pole as all the rotations involve the same number of nodes. Only the node connections change, which are very easy for a network to change.

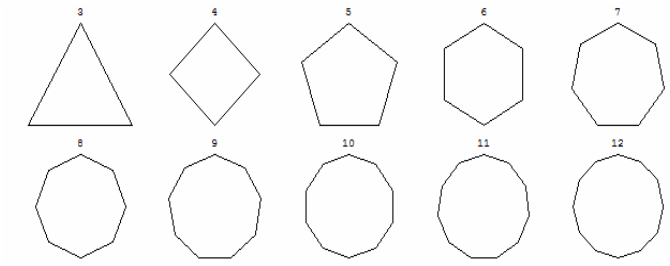

Figure 6. Discrete circles, N = 3-12

Hence each node can *locally configure itself as a pole*, with a discrete circle of neighbors around it each a different direction from that point. The connection requirement that each node has N neighbors is symmetric. Each node's local connections are veridical to an ideal sphere surface, i.e. they correctly approximate it. A 2D space can be modeled by locally defined discrete N-circles, with N a large

number.

Note that a lattice of hexagons, as war game simulations use, only allows six movement directions with a minimum event angle of 60°. In general for a two dimensional grid, N neighbors around a node allows N directions and minimum event angle of 360°/N. Discrete space predicts not only a Planck length but also a *Planck angle* for single node events. The constant number of grid neighbors N is the fine structure of space.

Yet there are no global coordinates - the coordinates of this space are defined on demand, after a focal node is chosen. This is *just in time computing*, where processing is not done until it is needed. When nodes change, the longitudes and latitudes of the space change. Each node "paints" its own coordinates when activated, i.e. has its own space.

However in such a space retracing a route backwards may not return one to the same start node, though it will be a true vicinity. Such a space could let "solid" objects pass through each other, as objectively it has "holes". This is only a problem if entity interactions in the world are based on exact locality. Fortunately again, in our world quantum objects don't exist at point locations but spread their existence over an area. If objects are smears not points, then interactions don't require exact point location matches, and objects will register as returning to the same point if they return to the correct vicinity. *The problems of an approximate space are offset by objects only having an approximate location.* The strange ability of quantum objects to exist inexactly conveniently avoids the problems of an inexact space.

Three dimensions

The mathematician Riemann first wondered if our three-dimensional space was the surface of a *hyper-sphere.* The same logic that created two dimensions from one can add a third dimension by "rotating" the Figure 5 sphere. Each node of the previous discrete sphere again gets a new discrete circle to create a third orthogonal dimension. We cannot imagine "rotating" a three dimensional sphere, but mathematically a hyper-sphere is well defined, and its "surface" is a three-dimensional space. The additional orthogonal dimension lets positive-negative information waves travel the surface, as explored in the next section.

Any discrete circle can be decomposed into component triangles, so any simulation based on discrete circles can also be modeled by triangles, as spin networks do. Computer simulations have explored building four dimensional space from four-simplices - four dimensional generalizations of triangles [22]. When these were joined at their faces the resulting space was irregular, sometimes a two-dimensional sheet and sometimes a crumpled vortex of infinite dimensions. Joining four dimensional elements need not produce a four dimensional space. A stable space only emerged when simplices had a forward/backwards "time" value, and only faces with the same time direction were joined. A stable space it seems needs a time-like directionality. In the VR model the "atoms" of space are nodes that all process existence in the same way, as the next section argues.

Virtual existence

Imagine the surface of a lake with frictionless waves moving and interacting across it. The waves appear to "move" across the water surface. However the water molecules themselves don't travel, they just vibrate up and down. What travels is the pattern we call a wave, which is by its nature information. Our "solid" world is proposed to arise at the quantum level in the same way – as information waves.

If our three-dimensional world is a surface in a four-dimensional bulk then it can support vibration into an extra dimension. This allows transverse waves to travel the surface as water waves do For example, the quantum wave function describes matter as a three-dimensional wave which sets values in a fourth "imaginary" dimension. A hyper-sphere surface has the extra dimension of the distance from its centre. If one imagines a three-dimensional sphere, its surface can vibrate in and out like bumps and dimples on a ball. This proposed *existence dimension* could take various forms:

a. *Space.* A stationary in/out circular vibration which is simple to calculate, gives an "empty" result, and allows continuous processing (Figure 7a).

b. *Light.* The same circular function moving gives a sine wave. As light presents as an electro-magnetic sine wave it could be space "on the move" (Figure 7b).

c. *Matter.* Quantum mechanics defines matter by Schrodinger's quantum wave function Ψ(x,y,z,t), which is *the ultimate formula describing matter in our world*.

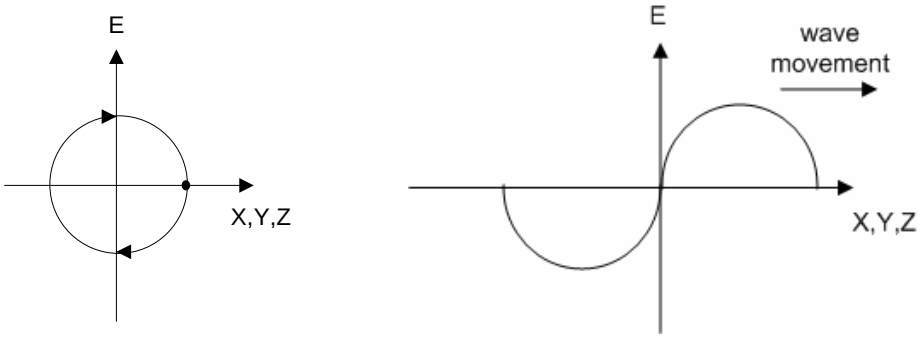

Figure 7a. Circular null processing (space), 7b. Moving circular processing (light)

How the function Ψ describes matter is discussed in more detail in the fourth paper in this series. This basic equation of quantum mechanics describes a three-dimensional wave whose value at any point is "something" that physics leaves vague. Schrodinger called it a "matter density" wave, because high values meant that matter was more likely to be there. Born called it a probability wave, as its amplitude squared gives the probability a particle like an electron exists to interact at any point. Yet when the electron does interact, *all* its mass appears there, not just some of it.

In the VR model Ψ is a vibration orthogonal to our world whose intensity is *probability of existence*. One would expect the ultimate formula of an objective reality to be something physical, not a probability. Yet the quantum wave function is a probability - an information quantity. As the physical world we know emerges from quantum probabilities, so substantial matter arises from insubstantial information.

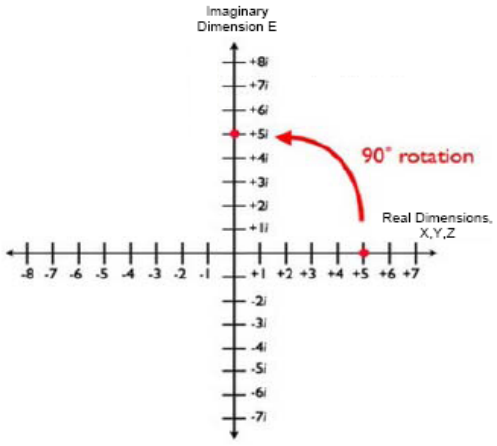

Figure 8. Complex number rotations

The quantum wave function does not derive from mass, momentum, velocity or any other physical property. It is itself, and the physical properties of the world derive from it, not the other way around. To demand that information only derives from matter is to see the situation backwards, like seeing the sun as circling the earth. In an objective reality electrons would exist with Ψ as a property, but in the VR view *the electron exists as Ψ,* and apart from this does not exist at all.

Complex numbers successfully describe electro-magnetic waves as rotations into an "imaginary" dimension[3] (Figure 8). Since they describe light so well it is

[3] The imaginary dimension is in units *i* where *i times i* = -1. In normal multiplication 5 multiplies by 4 *repeats* it four times to give 20. In complex numbers multiplying 5 by *i rotates* it by 90° into imaginary space (Figure 8), while multiplying 5 by 4*i* rotates it by 90° four times, which gives the original 5 again.

not a large step to suggest that light actually does rotate into an imaginary dimension, i.e. *that the imaginary dimension of complex numbers exists.*

If the electrons, quarks and light that make up our world are wave forms orthogonal to it, how can we detect them? We can if we exist as they do, rather than as objective observers in an objective world. As waves on a pool surface interact with one another, so the objects of the world could interact with us. The fields of physics (quantum, electromagnetic and gravitational) can then be aspects of the same quintessential existence vibrations.

Planar channels

In information terms the "job" of space is to define movement, and in our world rays of free light travel in straight lines, defined as the minimum distance between two points in space. The general term for a straight line is *geodesic*, e.g. on a curved surface like the earth longitudes and latitudes are the shortest distances between points, and so are geodesics even though they are curved. Geodesics define space, so if they change, space changes, e.g. in general relativity mass "curves space" by changing the geodesics.

Two dimensions

When a node in a grid simulating space receives an entity calculation, it must decide the next node to pass it on to. Nodes that pass on calculations in a consistent way will create constant passage-ways through space. For a node the problem is essentially given an "In" neighbor node, which neighbor is the "Out" node? In a two dimensional space where each node has a circle of neighbors the problem becomes: *What is the exit node for any discrete circle entry node?* This is essentially an information processing problem.

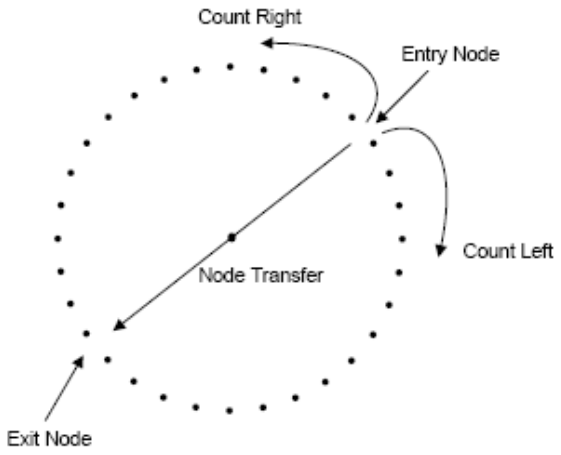

Figure 9. Planar circle entry/exit nodes.

For a circle of N nodes, choosing entry and exit nodes to be maximally "apart" gives the minimum travel route between any grid nodes. A series of such transfers traverses the fewest nodes for a route and the shortest traverse between nodes is a straight line. A node can find the "opposite" node to any entry node in a discrete circle by counting opposite ways from the entry point until overlap occurs (Figure 9). The fifth paper in this series argues that processing differentials (gravity) across a null processing grid (space) skew the exit node calculation, i.e. that gravity bends light by changing the geodesic calculation.

Three dimensions

Suppose the three dimension case is a simple extension of the just explained two-dimension logic. Now each node neighbor has many planar circles not just one to pass to. So the transfer problem is not just which exit node to pass to, but also which neighbor planar circle to pass to. Yet only one planar circle of an exit node will *overlap* the original circle, defined as a circle that shares three points (Figure 10). Each planar circle of a node can align with one and only one planar circle for each neighbor. If calculation transfers pass along a linked chain of planar circles, this would represent movement in the same plane. This, plus

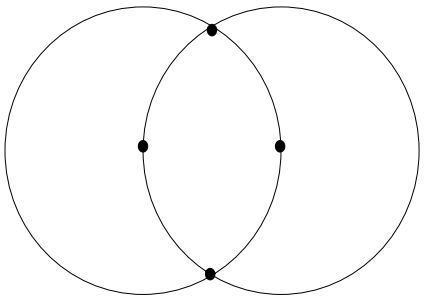

Figure 10. Planar circle overlap.

with maximally separated entry/exit nodes, generates "straight" lines.

The planar circles proposed to mediate all transfers will be called *node channels* or *planar channels*. Each channel has a fixed information transmission bandwidth. That basic quantum transfers occur in two-dimensions is not unthinkable, as evidence from quantum Hall physics supports models that use two-dimensional excitations called *anyons* to calculate quantum events [24]. Two-dimensional transfer also explains why light is polarized in a plane – it travels in node channels. A node's channels then correspond to the rays of polarized light that can pass through it, as Penrose also concluded:

"*A point in spacetime is then represented by the set of light rays that passes through it.*" [25] p110

Time is processing

It is often assumed that since space-time has four dimensions an extra Kaluza-Klein dimension implies five dimensions, but in the VR model the fourth dimension also creates a time, which supports:

1. *Unpredictability*. Without dynamic choice there is no information.
2. *Causality*. The world is causal.
3. *State sequences*. As our eye sees events, or as TV or movies show them.
4. *Irreversibility*. To create the arrow of time.

If the answer to the question "What is time?" is that *time is processing*, then the properties of time should arise from the nature of that processing. The concept of choice, at the heart of the definition of information, implies a "before" state and an "after" state. Before the choice there are many options, but after the choice there is only the chosen option. Choosing from options implies that the choice *causes* the final state. Conversely, if one cannot choose an option it is not an option, and if there are no options there is no information.

A series of such choices creates a sequence of chosen states which can represent an event. Movies digitally represent world events in this way – as a sequence of successive states run together. Likewise in quantum mechanics one state can: "*… evolve to a finite number of possible successor states*" [26] p1. It follows that given a fine enough sequence of states, continuous time is unnecessary. That our world *actually consists of* state sequences, and only state sequences, resolves Zeno's paradox, as then movement *is* indeed a sequence of "instants". If one replaces all the delta time (*dt*) values in the equations of physics with delta-sequence (*ds*) values[4], the formulas stay the same. Instead of approximating continuous time we approximate a very fine state sequence. If all that really exists are state sequences then continuous time, like continuous space, is just a convenient concept.

Barbour calls such sequences "time capsules", notes they can represent any dynamic event, and then suggests that the states that create these capsules may co-exist in a timeless universe [8] (p31). If so the states of time could literally be turned back and forth like pages in a book. Yet who would read this book of past, present and future? Without an external observer to "read" them, the static states of a time capsule would contain no information. A timeless universe that makes no choices contains no dynamic information. To see quantum states as static "things" that exist is treat them as objective realities, which this paper argues they are not. Here the information is not in static states which need a decoding context, but in the dynamic choices between them. What exists is not the states but only the dynamic choices, in a physics of 'Now' where: "*Past, present, and future are not properties of four-dimensional spacetime but notions describing how individual IGUSs {information gathering and utilizing systems} process information.*" [27] p101

[4] of small sequence steps.

Dynamic processing *only ever provides an eternal now*, whose choices continuously refresh. Yet even with this, and causality, a sequence of states can run either way. Most classical physics is reversible, e.g. if a movie of the earth orbiting the sun is run backwards, it obeys the same laws of physics. If physical laws can run backwards, then why can't time run the other way? Only an irreversible state change can give a single direction to the arrow of time, defined as a sequence of states. Fortunately again, quantum physics, comes to the rescue with what physicists call the "collapse of the wave function". This is a one-way state change that occurs when quantum entities interact with the world. An atom radiating light is a visible example. This collapse is random, i.e. not predicted by anything in the physical world, so outside classical laws. More details on the information simulation of this are given in the next paper in this series.

A virtual time like ours

Time can be simulated by processing that is dynamic, sequential, causal, and irreversible. Such a virtual time does not behave like an objective time, which should pass inevitably, based on its own nature, and not depending on anything else. However our time doesn't work that way.

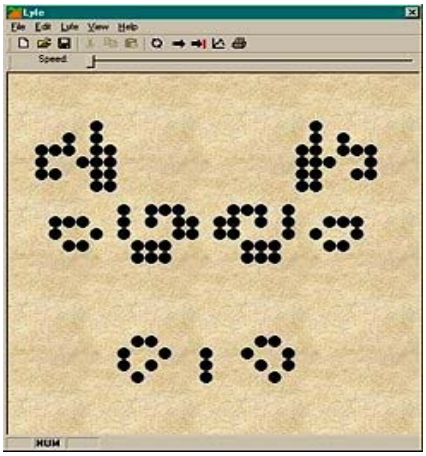

Figure 11. The game of Life

To see the difference, consider a simple simulation like John Conway's "Life" (Figure 11) where screen entities reproduce and die according to program rules, with blobs growing and contracting, until (often) a steady state is reached (http://abc.net.au/science/holo/lablife.htm). For a pixel entity within Life "time" is measured by the events that occur to it. If it experiences many events that constitutes (for it) a long time, while a few events are a short time. Our world measures time like this, e.g. atomic clocks effectively count events in our world.

Suppose a Life game that usually runs in 20 minutes runs again on a faster computer in only 2 seconds. The game takes less time, but within the virtual reality the passage of time is unchanged, as exactly the same number of events occurred. The processing ran faster in the containing reality, but the inhabitants of the virtual reality see no difference in their time because they experienced the same number of events. *Virtual time is entirely dependent upon processing cycles*.

In a centrally processed virtual reality processing load effects are undetectable to its inhabitants, e.g. if the Life simulation slows down, a pixel within it also slows along with everything else, and so sees no difference. However if processing is distributed, unequal loads allow unequal cycle rates, i.e. unequal time. If virtual time is measured by processing then nodes with different loads can cycle at different rates, e.g. if high mass or high speed required more processing, time would pass more slowly in that node.

This explains Einstein's twin paradox, where a twin travels the universe in a rocket that accelerates to near the speed of light, and returns a year later to find his brother an old man of 80. The rocket twin's travel increases his processing load, so fewer cycles occur for him, but he has no way to know his time is dilated. He just sees a normal year's worth of events pass by. However the physical world "screen" where his twin exists has no such load, and 80 years of events cycle by. Only when the two re-unite is it apparent that time passed differently for them. Note that neither is cheated of time as both get their allotted number of life events. Particle accelerator experiments show unequivocally that our time really does slow down as speed increases, so the twin paradox is reality not fantasy. Yet time in an objective reality would not behave like this. Our time behaves exactly as time in a distributed processing virtual reality would.

Time travel

Virtual time "ticks" as grid nodes complete processing cycles, and *no event can occur in less than one cycle*. This explains Einstein's conclusion that for light time stops. If movement is a basic operation the

maximum travel rate is one node per tick, which to us is the speed of light. If light travels at this maximum rate it cannot experience an event, as it moves to the next node before any event can occur. In one cycle it can move or interact but not both, so time as just defined does not pass for it.

If there is no common "now" is any time possible? That nodes can cycle at different rates doesn't let any node have any time. Processing slower or faster doesn't affect the *sequence* of states or their dynamic nature so time travel is still impossible, as the information paradoxes it creates show. In the grandfather paradox a man travels back in time to kill his grandfather, so he could not be borne, so he could not kill him, etc. One can have causality or travel back in time, but not both. Equally if I see forward in time that for breakfast I will have marmite on toast, I could choose not to, which means I did not see forward in time, etc. One can have dynamic choice or travel forward in time, but not both.

Yet note that only the interactions are irreversible. The processing that entities do *before* they interact can indeed run either way. If this, as argued, involves setting circular sequences of existence values, they can all run the other way. If matter is built up from clockwise processing, then anti-clockwise processing can give anti-matter. If time for us is our processing sequence, then anti-matter runs our time in reverse. Hence Feynman diagrams show anti-matter particles as going backwards in time when they enter events. This doesn't mean they can undo their interaction sequences any more than matter can, just that their existence processing sequence is reversed.

Summary

In a virtual reality the idea of time as an objective flow along which everything inevitably moves is an illusion. Rather than time depending on itself, it depends on processing cycles that vary with load. Time in our world works this way. Equally the idea of space as an objective backdrop upon which objects are placed is also an illusion. Rather than space existing by itself, it derives from node connections which are locally calculated. "Distance" between entities is the number of node transfers needed, and straight lines are node channel calculations subject to local processing loads, i.e. space can "bend". Space in our world behaves like the space of a virtual reality, not the space of an objective reality. What we call space and time may be only the by-products of the information processing: "*… many of today's leading physicists suspect that space and time, although pervasive, may not be truly fundamental.*" [18] (p471).

SOME IMPLICATIONS

The VR model gives a different view of our world and how it arose.

The big bubble

According to cosmology all the stars and galaxies are receding away from us. Either we just happen to be the centre of the universe (again), or the view is the same from all vantage points. How can space expand uniformly throughout itself not just at its edges? If the big bang exploded from a point in objective space the energy should flow out to the outskirts of the universe. Yet today cosmic background radiation (CBR) left over from the big bang is still visible as static on blank TV screens. If the big bang expanded outwards, why is it still here all around us?

Our space as the three dimensional surface of a four-dimensional hyper-sphere suggests answers. By analogy consider a sphere. Its two-dimensional surface is a "space" that expands equally everywhere as the sphere expands. This space has no centre and is unbounded (has no edge). Travel in any direction long enough returns you to the same point. An explosion at a point on the surface would go "out", but after a while would wrap around the sphere and be "everywhere". If our universe is the three-dimensional equivalent, cosmic background radiation is still all around us because it has circled the universe, perhaps many times. It is hard to imagine another reason why it is still here.

The VR model suggests some other possibilities:

1. *How could the universe begin as a point "singularity"?* The universe beginning at a point gives infinities for the equations of physics. If the universe is a hyper-sphere surface then it begins not as a unit point but as a unit *sphere*, which avoids infinities.
2. *As the universe expands, where does the space come from?* It is commonly assumed that as the universe expands we are on the outside (Figure 12a), as the term "Big Bang" implies. However it makes more sense if we are on the *inside* of the expanding 4D bubble (Figure 12b), as then new points of space come from the bulk into which the universe is expanding. This predicts a universe with a slight negative curvature.
3. *Why didn't the new universe immediately form a black hole?* A big crunch that contracted the current universe would soon form a massive black hole. If our universe began all at once then why didn't it do the same? One explanation is that the universe began as single node event, in effect an initial "tear" in the bulk, which then grew, like a small rip in a fabric.
4. *Why did the universe initially expand so fast?* Physicists who extrapolated the visible universe back to the big bang were puzzled why it initially expanded much faster than the speed of light allows. This brief initial period of fantastic expansion is called *inflation*. Various theories struggle to explain both why inflation occurred and why it stopped. In this model inflation could have been the chain reaction that followed the initial rip in the bulk.

Suppose the initial event was a node that somehow "moved" or separated to give a maximum frequency electro-magnetic wave (Figure 7b). This would have left a small "hole" in the bulk. The force of this split could separate other grid nodes in the same way in a stupendous chain reaction, like a nuclear bomb but much greater. Inflation would then be when *space divided to create light*, loosely speaking. No black hole would occur as black holes require space, and here space itself is exploding.

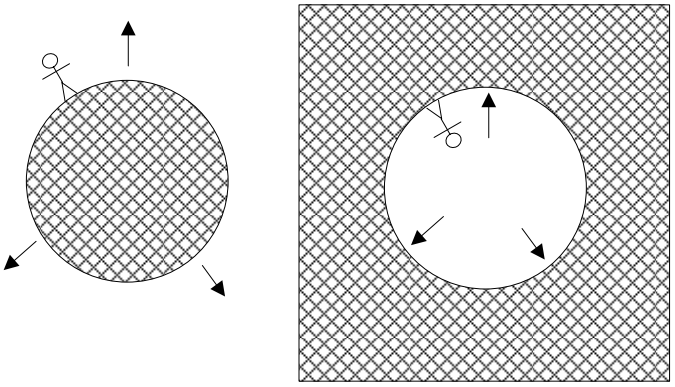

Figure 12a. The Big Bang, 12b. The Big Bubble

What then could stop this inflation? The expansion of the bubble adds new points to what we call space, which dilutes waves moving through it. This dilution is why cosmic background radiation that began as white hot radiation at the dawn of time is now "cold". Inflation would stop as the waves that caused the chain reaction diluted, and were no longer strong enough to split what we call space, though the bubble continued to expand at light speed.

This model fits the Hartle-Hawkin no-boundary theory, that the big bang began with four dimensions of space, one of which somehow became the dimension of time [28]. It also suggests that *all* the free information of our universe was created during the initial inflation chain reaction. This supports the idea that the total information in the universe is constant [29], as it came from an event that will never repeat for our universe.

Synchronizing space

In passing information in any network synchronization is critical. If a transmitting node completes two "pass photon" events while the receiving node only completes one "receive photon" event, the second photon just disappears. When computer simulations "lose" transfers then objects can vanish for no reason.

The centralized solution

In home computers the CPU runs screen nodes in strict sequence but in the distributed processing model proposed, each node runs itself. Even with identical node capacity, in a distributed network varying

work-loads make nodes run at different rates. CPU design illustrates the problems of synchronizing dynamic processing. If a CPU asks its communication lines to retrieve data from memory, how does it know *when* the data arrives in a register? If it acts too soon, it uses garbage left over from the last call and makes an error. If it waits too long, it wastes processing cycles. Looking to check if the register data has changed is another CPU command which needs another register, which then also needs checking, giving an endless cycle.

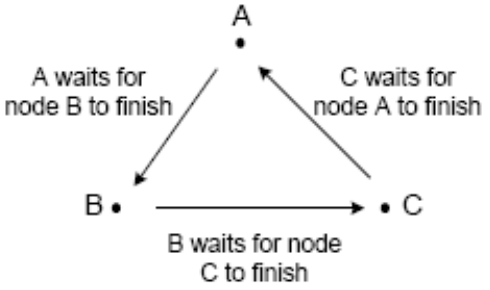

Figure 13. Node deadlock.

What our CPUs actually do is wait a certain number of clock cycles then *assume* the command is done. Hence users can "over-clock" computers to increase processing speed by reducing CPU cycle times to below the manufacturer setting, usually set too high for safety. We solve the synchrony problem by all events following a common beat, like a conductor keeping time for an orchestra. However this makes everything go at the slowest speed of the slowest component. A virtual universe that ran this way would run slower than its most overloaded node. This not only loses the gains of distributed processing but could be disastrous. If any node went too slow, the dynamic information of the universe would "leak" out of it.

The decentralized solution

In distributed dynamic processing there is no universal clock to which all nodes tick, as each node in effect has its own "clock". Every Planck volume of space is like a mini-CPU with its own cycle rate. How then to resolve transmission synchrony problems? If nodes wait until a destination node is ready to receive information this could give "deadlock", where A waits for B which is waiting for C which is waiting for A (Figure 13). A part of space could then become like a screen dead spot, unusable forever.

While early networks used fixed centralized protocols like polling, flexible protocols like Ethernet let nodes act without central control. This suggests a forward-and-forget protocol as email uses. A node channel finishing a cycle just transmits any information "package" and carries on. Like Internet packet switching, messages could then find any free route. However while ISPs have static memory to store incoming data, VR model grid nodes have no static memory. However they have neighbors to share processing with, so on receiving a transmission a node could simply pass on any unfinished processing to a neighbor. This pass-it-on protocol ensures no information is lost and needs no static data storage. It also momentarily synchronizes sender and receiver grid nodes to the same cycle phase. The light that fills space would then help to synchronize a space generated by a distributed processing grid.

Dark energy

Consider a photon of light traveling through empty space. Each node processing the photon must pass it on to the next node as soon as it completes the cycle. It must be so, or the speed of light by different equivalent routes could vary, which it does not. If the destination node has not yet finished its null processing cycle, it must still accept the photon, and pass any remaining processing to a neighbor. This pass-it-forward process repeats until a synchrony occurs. These left-over transfers "exist" briefly as energy which over the vastness of space could add up, as nodes transmit in many channels.

This links to the cosmology finding that about three quarters of our universe is an unknown "dark energy", a negative energy that somehow arises from the vastness of space to oppose gravity. Dark energy could be the accumulation of minute null processing leftovers created as light fills space. If the grid nodes that create space all cycle the same way the leftovers would have the same negative energy value. Dark energy would then not be part of the free energy of the universe, but a consequence of light synchronizing the null processing power of space.

Empty space is full

In an objective reality empty space would be simply empty, i.e. have zero energy. Yet in quantum theory: "*… space, which has so much energy, is full rather than empty.*" [30] p242. Examples include:

1. *Vacuum energy.* Physicists call the energy of empty space the energy of the vacuum. It arises because in quantum theory a point can't have a fixed energy, so space can't have exactly zero energy. Like the null calculation it is proposed to be, space averages zero energy but has a non-zero value at any instant. Empty space provides the processing that hosts all the objects of the universe.
2. *The medium of light.* How can light, which is "something", vibrate the medium of space, which is "nothing"? If space is a medium then it cannot be nothing, but if is something what is it? Empty space as processing potential and light as moving information explains how light can be a "wave" in empty space. In VR theory empty space is like a computer screen that is blank but still "on". The apparently empty points of space still process even while idle, just as an "idle" CPU still actively decides millions of times a second to do nothing.
3. *Virtual particles.* Space as null processing explains how it can spawn *virtual particles and anti-particles,* as equal cycles of opposite rotation are still null. Quantum theory predicts that these particles arise from space itself. They borrow energy from the vacuum, exist briefly, then disappear equally quickly back into it. In quantum theory clouds of virtual particles explain the *Casimir effect,* where two flat plates that are very near but not touching experience a force pushing them together. This is attributed to the "pressure" of the virtual particles of the vacuum around it, which cannot travel between the plates whose distance apart is less than their wavelength. In VR theory these "virtual" particles are as real as any other, just short lived.

That empty space is not empty has led to new ether theories:

"*The ether, the mythical substance that nineteenth-century scientists believed filled the void, is a reality, according to quantum field theory*" [32] p370.

The old ether error was to make space an object like those it contained. If space is what processes objects then it is nothing to us because we are the objects it processes, but it still does something:

"*Since 1905 when Einstein first did away with the luminiferous aether, the idea that space is filled with invisible substances has waged a vigorous comeback.*" [18] p76

The strong evidence that in our world empty space is not empty [31] suggests that it is a virtual reality.

Miscellaneous

Also consider:

1. *Moving without moving.* A constant speed observer moves in what Einstein called an inertial frame of reference, e.g. inside a car moving at 60 km/hour, apart from the world rushing by, it is *as if we were not moving at all*. The experience of constant movement is *exactly* as if we were still, *so perhaps we are*. In Figure 2 an avatar can stay at the same point on the screen yet "run" through a virtual forest, which is scrolling behind him, by bit-shifting the background. If in our world a constantly moving object bit-shifts itself through space, then it doesn't move with respect to the grid so has no experience of moving. In contrast if acceleration changes grid nodes, this can be experienced as a force. This odd idea is explored in more detail in the fifth paper of this series.
2. *The holographic principle*. Information processing requires interactions based on information transfers. A virtual reality can only register itself when information moves. If what we call the physical world appears to us by information transfers, it must be able to be represented as information crossing a boundary. The *holographic principle,* that the information in a volume of space can be encoded on its boundary surface, works in our world, e.g. it explains the behavior of black holes [33].

3. *Information conservation*. A VR that "leaks" dynamic information must eventually run down. Its fundamental "law of physics" is that the same number of dynamic choices be made before and after any interaction. A feature of our reality is the conservation of matter, charge, energy and momentum. Quantum theory adds conservation of spin, isospin, quark flavor and quark color. Yet all these laws are partial - matter is not always conserved, and quark flavor is not conserved in weak interactions. Perhaps one law rules them all: *that dynamic information is conserved*.

CONCLUSIONS

Relativity and quantum theory broke the conceptual haven of objective reality over a century ago in both cosmic and quantum fields. Since then physics has wandered a theory wilderness of higher dimensions, existence waves, quantum randomness and malleable space-time. The journey has led to amazing mathematical tools like quantum field theory, but we still don't understand why they work. Today the study of fundamental physics wanders in a mathematical desert, parched of empirical data, seeking a theory of everything vision that is turning into a theory of nothing [3]. While some say physics has gone too far in postulating what is beyond physical reality, I say it has not gone far enough, as the conceptual barrier of objective reality is preventing breakthroughs.

There is no doubt that space and time in a virtual reality behave differently from in an objective reality. Table 1 suggests that our space and time behaves more like the former than the latter. If objective reality theory was explicit, rather than just implicitly assumed, its predictions for our world would mostly fail. If the physical world as a virtual reality is evaluated then let the duck principle apply: *If it looks like a duck and quacks like a duck then it is a duck.* The argument of this paper is simply that the world is as modern physics paints it:

1. *Quantum theory* decisions are independent of this world, so perhaps are from outside it.
2. *Complex rotations* explain light, so perhaps light does rotate in an imaginary dimension.
3. *Kaluza's* extra dimension unites relativity and Maxwell's equations, so perhaps it exists.
4. *Quantum waves* exist as probabilities, so perhaps the universe they produce does too.
5. *Planck limits* on space and time suggest a discrete world, so perhaps it is.
6. *Calculus* assumes a world of infinitesimals approximates reality, so perhaps they do.
7. *Heisenberg's uncertainty principle* describes particles like waves, so perhaps they are.
8. *In Feynman's* sum over histories quantum particles travel every path, so perhaps they do.
9. *Special relativity* says our time dilates with movement load, so perhaps it can.
10. *General relativity* says our space bends and warps with mass load, so perhaps it does.
11. *Cosmic background radiation* is still here, so perhaps our universe has no centre.

For VR theory to take modern physics at face value, and its equations as literally true, is against neither physics nor science. Conversely, to be willing to use the equations of physics as tools but unwilling to accept what they imply about our reality smacks of bias – rejecting a conclusion one doesn't like. If our world behaves like a virtual reality then why is it "obviously" not so? What are the *arguments* for the world as an objective reality? What proves that it *cannot be* a virtual reality? These are valid questions that no-one is answering.

The reader can decide for themselves if the world really is a virtual reality, but would it be so bad if it were? A virtual reality is based on information but is still a reality, not a dream or imagination. All that changes is that instead of things we have choices. It is a world where one can have but not hold, use but not keep and act but not stay. No fixed Utopian "end state" is possible because at each *now* the choices inevitably "refresh". Only the journey exists. Some might find this disheartening but I do not. Indeed it

seems to me the world is pretty much like this already as coffins have no pockets. One can't possess a choice but having the choice is an even greater gift.

Table 1. Virtual properties and physical outcomes for space and time

Virtual Property	**Physical Outcome**
Dynamic information. A self-registering virtual reality (VR) exists by creating ongoing choices: a) A stable VR must conserve dynamic information in all its forms b) A self-registering VR appears as information transfer across a boundary surface	*Dynamic world.* The physical world is always and everywhere in a continuous state of flux: a) Most conservation laws are partial, so there may be a general underlying law b) The information in a space boundary can be encoded on its surface (holograph principle)
Discrete elements. Virtual realities are discrete: a) Nothing is continuous b) Space is represented by grid nodes c) Time is represented by processing cycles d) Direction is represented by node connections	*Quantization.* World elements are quantized: a) Continuity creates paradoxes/ infinities b) Space is quantized at Planck length c) Time is quantized at Planck time d) Direction may be quantized (Planck angle)
Null processing. Virtual realities best manage interactions by grid nodes mapping space: a) Space is a null processing cycle b) Null cycles can split into opposite cycles c) Null processing can transmit waves d) Constant speeds can bit-shift backgrounds but acceleration changes nodes	*Empty space is not empty.* Our space behaves like something not nothing: a) Space has a vacuum energy b) Space spawns virtual particles (Casimir effect) c) Light is a wave in the medium of space d) We don't experience constant speed but do feel acceleration
Distributed processing. Nodes share processing: a) Distributed systems scale up well b) Each node paints its own connections c) Each node cycles at its own rate d) Every node has a finite information capacity which cannot be exceeded	*Local space-time.* Space-time is local: a) The universe has scaled up well b) Each point has its own space (relativity) c) Each point has its own time (relativity) d) Finite space can hold finite information, with black holes the maximum possible
A VR presents on a surface. A 3D VR can present on a hyper-sphere surface (or brane): a) A hyper-sphere surface has no centre or edge b) Its expanding surface moves all objects apart from each other equally c) Initial vibrations will circle the universe d) The VR is on the inside of the bubble	*3D space could be a 4D surface.* A hyper-sphere surface behaves like our 3D space: a) Our universe has no centre or edge b) All the galaxies in our universe are moving away from each other equally c) Cosmic background radiation is still here d) Space may have negative curvature
Node connections create space directions. Grid architecture defines information transfer lines: a) Planar channels can define straight lines b) A node can configure a sphere of neighbor nodes around itself c) Local space makes spatial routes inexact	*Space has structure.* Node lattices behave like space, e.g. spin networks, loop quantum gravity: a) Light photons are polarized in a plane b) A point of space has a sphere of light rays that can enter/exit it (Penrose) c) Quantum object existence is spread about

Virtual existence. Virtual existence sets values orthogonal to the VR surface: a) Existence is based on circular rotations into a fourth dimension b) A moving circular function is a sine wave c) Values can rotate one way or the opposite d) The bulk which contains the virtual reality is a four dimensional space e) Virtual entities that present on a screen cannot leave its surface	*Physical existence*. Quantum and electro-magnetic fields are complex wave functions: a) Complex functions rotate into an imaginary dimension outside "real" space b) Electro-magnetic waves are sine waves c) An opposite to existence exists - anti-matter d) Relativity in 4 dimensions gives Maxwell's electro-magnetic equations (Kaluza-Klein) e) The extra dimension is not curled up in our space but wrapped around it
Time is processing: It depends on processing: a) Virtual time varies with processing load b) Different nodes can cycle time differently c) A fine sequence of states can simulate events d) An irreversible state change gives a direction to time sequences e) Reverse existence cycles reverse time f) Distributed processors synchronizing by a pass-it-on protocol have leftover transfers	*Time is relative*. It depends on context: a) Physical time varies with speed and matter b) Einstein's twin paradox is true c) Movie state sequences simulate events d) The collapse of the quantum wave function is irreversible e) Anti-matter time runs in reverse f) Dark energy may be the null processing leftovers of light synchronizing space
The big bubble. The beginning was a bubble: a) A single node event began it b) Initially there was a sphere not a point c) There was a chain reaction with other nodes d) Creating the free information of the universe e) The bubble expansion stopped inflation by diluting the vibration wavelength	*The big bang.* The beginning was a bang: a) It did not give a massive black hole b) A point singularity creates infinities c) There was an initial massive inflation d) The universe's free information is constant e) Cosmic background radiation which began as very hot is now very cold

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ANNEX A. RESPONSES TO THE PREVIOUS PAPER

Some responses to the previous paper [1] include:

1. *VR theory is just meta-physics*. Science calls untestable statements about unknowable entities outside the world meta-physical speculation, but the VR proposal is that meta-physics (outside the world) causes physics (the world). So it is also a genuine hypothesis about this world:

   "*… the hypothesis that our universe is a program running on a digital computer in another universe generates empirical predictions, and is therefore falsifiable*" [10] p1

2. *VR theory cannot be proved*. True, but objective reality as a theory is not "proved" either. Science does not prove theories - it merely rejects improbable ones, so being proven is a criterion no theory in science satisfies. Science only requires VR theory to predict empirical reality differently from OR theory, which it does (Table 1).

3. *VR theory postulates the unseen*. Being perceivable is not a requirement of science else one could argue that since we cannot see electrons they don't exist. Note that:

> "*Atomism began life as a philosophical idea that would fail virtually every contemporary test of what should be regarded as 'scientific'; yet, eventually, it became the cornerstone of physical science."* [12] p3

4. *VR theory contradicts Occam's razor*. Occam's razor is to take the simplest theory that fits the facts and doesn't multiply causes unnecessarily. A hundred years ago Occam's razor favored objective reality as a world explanation but today that has changed. When virtual particles seethe from empty space, quantum objects teleport through impassable barriers and space-time itself bends, objective reality theory no longer best fits empirical reality. Now, it is argued, VR theory is the simpler explanation, i.e. *Today Occam's razor cuts the other way*.

5. *A virtual world is a fake world.* VR theory does not contradict *realism:* The idea there is a real world "out there" generating our experiences. That our minds necessarily construct our reality does not deny a reality apart from their constructions [34].

6. *VR theory contradicts experience*. The world is "obviously" not a virtual reality, but once it was equally obvious that the sun rose and set across a flat earth. Every human age assumes they have the answers and every following age finds them wrong. Why assume we have reached the end of the line of human fallacies? The physical world seems objectively real because our senses tell us so, but are the same senses that misled us in the past now trustworthy guides?

7. *Physics equations are enough.* The equations of modern physics work but what do they mean? To declare their meaning meaningless creates a knowledge vacuum that must be filled. VR theory is compatible with all computable equations, so let those who deny it show that physics has a non-computable equation.

8. *VR theory is wrong because OR theory is true*. This argument goes:

   a. You propose the physical world is created by processing

   b. All processing is based on the physical world (assumption)

   c. So a world created by processing is a physical reality anyway.

   For example consider this dismissal of the previous paper [1] by a well known physics journal:

"*The author insists on the "virtual reality" analogy, but seems to fail to notice that virtual reality as practiced on computers deals with a physical reality based on the known laws of physics which govern electronic or other computers. … Thus we are back to physics and asking ourselves which physical laws would be governing the computer that is supporting the virtual reality framework that the writer is proposing: back to first base as they say.*"

The reviewer assumes only the physical world exists then by that assumption falsifies VR theory, i.e. used circular reasoning to "disprove" a hypothesis by assuming its antithesis! In the current feudal academic publishing system such gatekeepers can deny publishing sunlight to papers like this one [35].

REFERENCES

[1] B. Whitworth, "The physical world as a virtual reality," *CDMTCS Research Report*, vol. CDMTCS-316, http://arxiv.org/abs/0801.0337, pp. 1-17, 2007.

[2] F. Wilczek, *The Lightness of Being: Mass, Ether and the unification of forces*. New York: Basic Books, 2008.

[3] L. Smolin, *The Trouble with Physics*. New York: Houghton Mifflin Company, 2006.

[4] K. Zuse, *Calculating Space*. Cambridge Mass.: MIT, 1969.

[5] E. Fredkin, "A Computing Architecture for Physics," in *Computing Frontiers 2005*, Ischia, 2005, pp. 273-279.

[6] B. D'Espagnat, *Veiled Reality: An analysis of present-day quantum mechanical concepts*. Reading, Mass: Addison-Wesley Pub. Co., 1995.

[7] M. Tegmark, "The Mathematical Universe," in *Visions of Discovery: Shedding New Light on Physics and Cosmology*, R. Chiao, Ed. Cambridge: Cambridge Univ. Press, 2007.

[8] J. Barbour, *The end of time: The next revolution in physics*. Oxford Oxford University Press, 1999.

[9] C. E. Shannon and W. Weaver, *The Mathematical Theory of Communication*. Urbana: University of Illinois Press, 1949.

[10] G. McCabe, "Universe creation on a computer," http://arxiv.org/abs/physics/0511116, 2004.

[11] J. Mazur, *Zeno's Paradox*. London: Penguin Books, 2008.

[12] J. D. Barrow, *New theories of everything*. Oxford Oxford University Press, 2007.

[13] L. Smolin, *Three Roads to Quantum Gravity*. New York: Basic Books, 2001.

[14] S. Wolfram, *A New Kind of Science*: Wolfram Media 2002.

[15] S. Lloyd, "Universe as Quantum Computer," *arXiv:quant-ph/9912088v1* vol. 17 Dec, 1999.

[16] L. Randall, *Warped Passages: Unraveling the mysteries of the universe's higher dimensions*. New York: Harper Perennial, 2005.

[17] L. Randall and R. Sundrum, "An Alternative to Compactification," *Phys.Rev.Lett.*, vol. 83, pp. 4690-4693, 1999.

[18] B. Greene, *The Fabric of the Cosmos*. New York: Vintage Books, 2004.

[19] T. Berners-Lee, *Weaving The Web: The original design and ultimate destiny of the world wide web*. New York: Harper-Collins, 2000.

[20] P. Davies and J. R. Brown, *The Ghost in the Atom*. Cambridge: Cambridge University Press, 1999.

[21] L. Smolin, "Atoms of Space and Time," *Scientific American Special Issue, A Matter of Time*, vol. April pp. 56-65, 2006

[22] J. Ambjorn, J. Jurkiewicz, and R. Loll, "The Self-Organizing Quantum Universe," *Scientific American*, vol. 299 July, pp. 24-31, 2008.

[23] J. Case, D. S. Rajan, and A. M. Shende, "Lattice computers for approximating euclidean space " *Journal of the ACM*, vol. 48, pp. 110-144, 2001.

[24] G. P. Collins, "Computing with quantum knots," *Scientific American*, vol. April, pp. 56-63, 2006.

[25] S. Hawking and S. Penrose, *The nature of space and time*. Princeton, NJ.: Princeton University Press, 1996.

[26] S. Kauffman and L. Smolin, "A possible solution to the problem of time in quantum cosmology," *arXiv Preprint* vol. http://xxx.lanl.gov/abs/gr-qc/9703026, pp. 1-15, 1997.

[27] J. B. Hartle, "The Physics of 'Now'," *Am.J.Phys.*, vol. 73, pp. 101-109, avail at http://arxiv.org/abs/gr-qc/0403001, 2005.

[28] S. W. Hawking and J. B. Hartle, "The basis for quantum cosmology and Euclidean quantum gravity," *Phys. Rev.*, vol. D28, 1983.

[29] J. B. Davies, "Maximum information universe," *Royal Astronomical Society Monthly Notices*, vol. 186, Jan, pp. 177-183, 1979.

[30] D. Bohm, *Wholeness and the Implicate Order*. New York: Routledge and Kegan Paul, 1980.

[31] K. C. Cole, *The hole in the universe*. New York: Harcourt Inc, 2001.

[32] A. Watson, *The Quantum Quark*. Cambridge: Cambridge University Press, 2004.

[33] J. D. Bekenstein, "Information in the Holographic Universe," *Scientific American*, vol. 289, pp. 58-65, 2003.

[34] B. Whitworth "A Comparison of Human and Computer Information Processing," in *Encyclopedia of Multimedia Technology and Networking*. vol. Second Edition, M. Pagani, Ed. Hershey PA: Information Science Reference, 2009, pp. 230-239, http://brianwhitworth.com/braincomputer.pdf.

[35] B. Whitworth and R. Friedman, "Reinventing academic publishing online Part I: Rigor, Relevance and Practice," http://brianwhitworth.com/BWRF-FM-Part1.pdf, First Monday, August 2009.