

COMPUTATIONAL REALITY; A BRIEF HISTORY

INTRODUCTION

The very thought that our universe may be the result of a computational system is an idea of its time. By this I mean that it has evolved from key developments in the fields of physics, mathematics, computer technology and philosophy. In my view it is very unlikely that any substantive progress could have been made until a certain set of ducks had lined up. In this article I have attempted to place in chronological order some of the key events (or ducks) that have influenced the development of this burgeoning proposition, and also those that have helped define the paradigms, and in some sense the restrictions, upon current physics. This article also gives me the opportunity of identifying ways in which a computational model can resolve some of the fundamental questions that cannot be answered by current physics.

It is always difficult if not impossible to identify an exact time when an idea comes to fruition so the dates that I give are ball-park and the descriptions are not intended to be comprehensive, but focus on aspects that are pertinent to the objective of this essay. I will also discuss some of the qualitative results from my own research and to do this I need to define a couple of important terms. My own research suggests that from a reasonably simple CA model it is possible to create a universe in which certain patterns may be sentient beings that create their own physics based upon their interactions with other patterns, I term such beings, 'simulants'. It is also possible to consider other intelligent beings that can look into the CA from the outside, that is from outside the simulant's universe, these beings are termed, 'Simulators', and they would perceive the simulant's universe in a far different way.

540 BC – THE GREEKS AND THE IMPORTANCE OF COMPLEX DYNAMICS AND PATTERN

Most of the ancient 'atomist' ideas were based upon there being physically real objects that were stable and unchanging from which all things were made and that this constituted 'reality'. The idea that it is the pattern of 'things' created by complex dynamics, as opposed to the 'things' themselves, that constitute 'reality' dates back to Heraclitus of Ephesus (540-480BC) who argued that we are mistaken in thinking that the world consists of stable things. Instead he argued that the world is in a state of flux and that the appearance of things depended upon this dynamics for their continuity and identity. He then postulated that what needed to be explained was not change, but the

¹ I am not assuming that these simulators are responsible for creating the CA in the first place.

¹ By simple I mean in comparison to the structures that emerge from operating the CA.

emergence of stability. In essence it is this view that is supported by computational models, in that the fundamental constituent of perceived matter is 'ephemeral data', and it is the patterns of that data and the interactions between them that constitute reality.

1637 - DESCARTES

René Descartes (1) was the first philosopher to put a cogent argument together to establish two types of reality. The first being that which exists because I exist ("I think therefore I am") and the second being that which exists if I do not exist. These realities are correspondingly termed 'internal reality' and 'external' reality. Physics is our creation and the way in which we predict internal reality and what physics can say of external reality is very limited. The idea of external reality is extremely important because a computational model may give us insight into how an external reality could be structured to generate a universe like ours, something that physics as is could not do.

Descartes famous statement, 'I think therefore I exist' also highlights the importance of consciousness as the substrate for perception and hence personal acknowledgment of existence. Barring theories that argue against 'consciousness' (these are well thought out and valid arguments) I have always believed that one of the true tests of a comprehensive theory of physics is that of explaining consciousness. Some such as Penrose has postulated quantum mechanical mechanisms to account for it, but these have never been considered mainstream. One of the important aspects of a computational reality is that one can gain a greater insight into what consciousness may be and why it is perceived as such an ephemeral characteristic.

1675 - THE CALCULUS

Around 1675 Leibniz and Newton published their respective treatise on the calculus (1). One cannot underestimate the impact of the calculus on most mathematically derived subjects, including physics. However the calculus was mathematics that evolved from the idea of continuity, for it was the continuum of real numbers that lead to the concept of the infinitesimal, and it is the ability to take mathematics to this limit that is the foundation for the development of the calculus.

Calculus enables us to identify specific characteristics of patterns at any point along a continuum, so for example if a pattern changes with time we can mathematically identify the instantaneous rate of change of that pattern at any instance of time.

Calculus has a weakness when we have a discrete set of patterns; for example, moving from a solution of '0' to '1' with no intermediate solutions. At the point of change the application of calculus has no meaning.

One could consider that calculus models infinitesimally discrete systems by using continuous functions as an approximation. This may be why calculus is a very good

approximation at even quantum scales. Calculus may be such a good approximation of infinitesimally small discrete systems that we have been duped into believing that the universe is a continuum.

It took many centuries for possible cracks in this paradigm to be uncovered and for new mathematical methods to be adopted that dealt with the idea of discontinuity in the physical universe. Calculus has helped establish the idea that continuous mathematics is somehow part of the fabric of the universe and is the only way to describe it. It is ironic that the most influential and successful aspect of mathematics has also manacled the ideas in physics for centuries.

1854 - BOOLEAN LOGIC

George Boole developed Boolean logic (1) and its importance is not only as a foundation for the development of digital computers, but it embodied the way in which we perceived the universe. Boolean logic is bivalent; a proposition is either true or false, black or white, here or there and it cannot be a bit true and a bit false, grey, or here and there. It wasn't until we ventured into the quantum world that Boolean logic broke down. Developments into a computational universe approach have all been underpinned by a Boolean logic approach and we may find that other logic formalisms are required in our computational models so as to generate a perceived universe similar to our own.

1870S - HENRI POINCARÉ AND THE THREE BODY PROBLEM

By the 1870s Newton's equations of motion were well established and the ability to analyse motion was quite sophisticated. However it was Poincaré who identified that Newton's laws did not provide a general solution to the dynamics of the earth, moon and sun system. This so called, 'three body problem' (1) highlighted a general view that existed throughout physics that if there were variations in the mathematically predicted results when compared to observation, then this was likely due to measurement error or an uncontrolled outside influence; in other words, 'noise'. However Henri Poincaré noticed that within the seeming unpredictable behaviour of this three body system there were patterns of behaviour, and this led to the initial ideas of chaotic behaviour from systems that could be described mathematically, such systems are termed, 'deterministic'. A solution to the mathematics of the three, or more generally, n-body system had to wait until 1912. But Poincaré had identified that some of the fluctuations that were considered to be noise could in fact just be a fundamental characteristic of the system.

EARLY 1900S - ENTROPY

It was in the middle of the 19th century that the idea of entropy (1) was initially formalised by Rudolph Clausius. However in first years of the 20th century it was Ludwig Boltzmann who related the idea of entropy to the number of ways of rearranging a system and the amount of information that we could have of it. This was possibly the first time that a concept in physics had been related to information, and hence patterns of data. For the first time information, patterns and pure data became fundamental to the understanding of the physical universe.

1920S - QUANTUM MECHANICS AND GENERAL RELATIVITY

The development of quantum mechanics has been one of the great success stories of physics, and from a computational perspective it has set a benchmark against which any computational approach must be judged. The scale at which quantum mechanical characteristics are so accurately modelled and observed is probably not much greater than the base scale upon which a computational system would operate. Therefore it is vital that any such system is observed to generate similar quantum mechanical behaviour at the equivalent scale.

Quantum mechanics has a fundamental dependency upon the interaction of the 'observed' with the 'observer'. For me personally this indicates that the quantum mechanical behaviour that is observed in a computational system must be viewed from within the system by patterns that have the same characteristics (the simulant) and not as an external observer (the simulator).

Quantum mechanics was also a turning point in physics in that it suggests that there are limits to the knowledge that we can have about the universe at the sub-atomic scale. Some believe this to be a 'universal truth', but I believe that science should not accept such assumptions, but be pro-actively testing their validity. To that end, my research assumes that quantum mechanics is the point at which the application of continuous function mathematics to physical theories starts to fail. Such an assumption would be valid if the underlying substrate turns out to be discrete and discontinuous. This is an important motivation to those who pursue not only computational based theories, but other scientifically based alternative theories of everything.

At this point it is important to mention one of the major intrinsic characteristics of quantum mechanics and that is it is the only identifiable source of true randomness in our universe. We experience random events quite often, as anyone who plays the lottery will know. However every random event that you ever directly experience is technically 'pseudo random', meaning that either there are in fact microscopic dynamics that can be deterministically changed to make the system more or less random, or that the sequence of random outcomes to some significant level will be repeated in the future, even the lottery! Neither of these things can happen to a system that is truly

random because it can't be any more random, and it will never generate repeating patterns. True randomness has no causal link between that which creates its effect and the effect itself and this is physically illogical! Also the definition of true randomness in mathematical and computational terms always requires some sort of infinity, such as infinite time or infinite number of bits etc.

The only true randomness in the universe occurs for individual quantum level events, such as at the point of collapse of the wave-function, or at a point of de-coherence. This means that quantum theories cannot predict the resulting state of such a single quantum event, but only its probability of occurring. The problem with this situation is that quantum mechanics cannot explain the source of this true randomness, but I believe that a CA based computational model can, let me explain.

If our universe is the result of a cellular automata like computation then we reside within the computational space but this space by definition exists outside of our universe and consequently in another universe. This computational process will have deterministic rules that change the state of an individual cell, or to those existing in the computation, a quantum level event. The rules exist outside of our universe and we can never know what they are (unless we are told by the Simulators, but let's not go there) therefore from our perspective at the individual quantum event level the cause of the state change cannot be related to its effect and so we would perceive true randomness. However the fact that there are rules involved and a limited (although potentially very large) set of potential neighbourhood states mean that there would be a statistical distribution over many state changes, and this is what we see with quantum mechanics.

The seeds of quantum physics started to emerge in the early 1900s and at much the same time Albert Einstein introduced us to his special theory of relativity that dealt with non-accelerating bodies. Shortly afterwards he developed his general theory of relativity that dealt with accelerating bodies and hence a theory that had to accommodate an understanding of gravity. These two theories revolutionised the way in which we conceptualised the universe; space and time no longer existed as separate entities but were interwoven into a four dimensional space-time continuum. Later it was realised that this space-time was in fact the same physical entity as a gravitational quantum field, just like the other quantum fields, and that space-time was quantised. This does not however mean that general relativity is suggesting that space-time is discrete as in a CA model. It is more that the gravitational field is quantised, just like other fields, meaning that it has a limited number of possible states. This has meant that 'quantum fields' have become a fundamental constituent of physical reality. From a CA based viewpoint this is no great problem as the field is a representation of a set of cellular states and through the propagation of nearest neighbour interaction we can achieve action at a distance.

Einstein's theories meant that the idea of absolute space and time had to be abandoned. The idea of absolute space and absolute time are defining factors between current

physics and most, if not all CA based computational based models. The reasons for this is that computational based models suggest that relativistic space-time is a Simulant's view of their universe, when in fact from a Simulator's viewpoint space and time are separate constructs. The cellular structure of a CA is an absolute space and the fastest rate at which a cell can change state is the speed of light, which is an absolute distance and time. Movement in the CA occurs as states are transferred between these cells and the rate at which they are transferred depends upon the rate at which the cell re-processes. In my model this re-processing rate is an integer number of what I term the 'master update frequency'. This is the maximum rate at which any cell in the CA can transfer, or change state and accords with an observed 'speed of light'. The rate of processing for a given cell also depends upon its state, so it may change state more slowly or quickly depending upon its current state and that of its neighbourhood. These ideas lead to a simulant having a relativistic view of their universe, but when you view the CA from the outside space and time could be construed as absolute. Therefore if we could detect the existence of an absolute space and time then it would most certainly support the computational proposition.

Prior to Einstein's theories there was much talk of a luminiferous aether that was stationary to everything else in the universe and in the 1880s Michelson and Morley carried out a set of experiments to try to detect relative motion through this aether. The general consensus has always been that the Michelson and Morley results showed no sign of such motion when one takes into account the range of experimental error.

In the 1920s Dayton Miller carried out a similar experiment but using more sophisticated equipment and he measured an absolute velocity of 10km/s in a specific direction. However his results are now generally thought to have been within the range of experimental error given more sophisticated analysis techniques. However it will be seen later that these results are still being disputed.

In 2011 the NASA gravity probe B experiment confirmed the calculated effects of what is known as 'frame dragging'. In essence this is the effect of the earth's spin dragging on space-time causing a space-time vortex (very sci-fi) and it was an important confirmation of general relativistic ideas of space-time.

So currently there is a significant wealth of evidence for space-time and against absolute space and absolute time. However in my own computational model it is apparent that it would be impossible to measure these absolutes because we are doing the measuring from within the universe. The best that computational models can do is to explain why we would see the universe in a relativistic way and I think my own model goes a certain way toward this.

There are currently two approaches to deriving a full quantum field theory of gravity, one in string theory (more on that later), the other is quantum loop gravity, which began life around 1986. Loop gravity, as it is sometimes called, is an extremely mathematically abstract construction in which the quantum gravitational field is

created by a network of abstract objects called spinors. The spinors are quantum objects and as such have quantised states and these states are 'space'. One can imagine each spinor creating a variable bubble of quantised space. Loop quantum gravity leads to macroscopic space being envisaged as a foam of these bubbles of space. This is a similar concept to a network of nodes, each of which has a state that defines its existence and its relationship to other nodes, that is space as represented in a CA.

It is also worth noting that loop quantum gravity makes use of difference equations, as do some big bang models and thermal lattice Boltzmann methods to model gases. The importance of difference equations is that they are the discrete sibling of the differential equations that are used in physics and that assume a contiguous universe. On the other hand difference equations assume a discrete nature and exhibit complex behaviour because they have a recursive nature and show similar dynamic characteristics as CAs. The difference equation signifies in-part a move from continuous calculus to discretization.

So what does all this mean to computational based models of reality? Well personally I believe that Quantum theories and general relativity are pointing to a view that space and time, matter, energy and all of the entities that we see as physical objects are in fact ephemeral abstractions, just as they would seem to a simulant, who could not perceive that their existence is founded on pure data.

1927 - THE FIFTH SOLVAY CONFERENCE AND THE 'COPENHAGEN INTERPRETATION'.

By the time of the fifth Solvay conference (1) there were three approaches to quantum mechanics, De Broglie's 'Pilot Wave theory', Born and Heisenberg's 'Quantum Mechanics', and Schrodinger's 'Wave Mechanics'. These three theories were discussed in detail at the conference with the reasonable aim of standardising on the use of one theory in an attempt to improve communication throughout the scientific community and hence increase the efficiency of research. However the reasons for choosing the Copenhagen interpretation of quantum mechanics as the 'established interpretation' had much to do with personal preferences and internal politics as well as science. This decision meant that other interpretations were sidelined by the physics community until the 1980's.

The outcome of this meeting of the greatest physicists of their time was symptomatic of the burgeoning institutionalisation of physics. From this time on physicists, such as myself, were taught how to think by 'high priests', who maintained the 'commandments', or paradigms that structured those thought processes. Because of this restraint upon thinking, the idea that the current approach to physics may have been shown to have run its course is not one that is taken seriously by the physics community. This has reduced the number of talented physicists that 'think outside the

box' and directly affects the rate at which progress could be made in other directions, such as computational theories of everything.

1931 - GÖDEL AND THE SEARCH FOR MATHEMATICAL TRUTH

Around 1931 Kurt Gödel developed a theorem stating that no sufficiently strong, consistent, effective axiom system for arithmetic can prove its own consistency. This means that one can always find a paradox or inconsistency in all but the most trivial mathematical systems. In any given circumstance one can add another axiom to the system to remove the problem, but this just leads to yet another inconsistency.

Gödel's theorem holds true for syntactic models of reality (such as physics) that assume that the universe can be encoded into mathematical based axioms and rules that manipulate symbols. J D Barrow (ref New Theories of Everything, impossibility p223) has suggested that this enables a physical theory to be enlarged by adding new principles that force the inconsistencies and paradoxes into a part of the mathematics that has no physical manifestation, and in this case incompleteness would be very difficult, if not impossible to distinguish from incorrectness or inadequacy. In practical terms this means that as physics becomes more abstract, such as M-theory, parts of quantum mechanics and the standard model, we could be fooling ourselves into thinking that we understand more than we actually do.

1940s - CELLULAR AUTOMATA

John Von Neumann developed two dimensional cellular automata (CA) from an idea by Stanislaw Ulam. Von Neumann was interested in self-reproducing systems and developed a CA known as the 'universal constructor' that would endlessly generate identical copies of its own pattern. The importance of Von Neumann's work was that he developed the basic conceptual model of cellular automata from which other work has stemmed. There are now many types of cellular automata of varying levels of sophistication. My own research uses a recursive CA in which each cell of the CA is another CA.

1941 - DIGITAL COMPUTERS

Around 1941 Konrad Zuse developed the Z3, the first programmable binary digital computer and this opened the floodgates to our ever increasing ability to run complex and repetitive calculations. Such repetition is fundamental to investigating and visualising complex behaviour and has led to the development of the complex sciences such as chaos theory, game theory, strange attractors and general computational methods. This has opened up the development and understanding of cellular automata and added credibility to the fact that simple systems can exhibit highly complex, ordered and adaptive behaviour.

1948 - INFORMATION THEORY

Claude E Shannon revolutionised the understanding of the importance of information and applied a mathematical approach to the encoding, compression and transmission of information and secured the idea of information as bit patterns. Much of the statistical and probabilistic mathematics used in information theory came from that developed by Boltzmann and Gibbs in their work on thermodynamics. It was realised that there was a significant relationship between the idea of informational entropy and thermodynamic entropy and this laid the foundation that enabled physicists to come to understand that information is a fundamental characteristic of the physical world and needed to be incorporated into their theories. The development of information theory and its continued application to current day physics may be another indication of a data based view of reality.

MID 1900S - THE RISE OF NON-LINEARITY

Before the mid 1900s physicists used paper and pen to do their calculations. To make such calculations possible physicists would simplify their models to remove any chance of terms with high powers creeping in such as x^3 or x^5 and other complex terms. In general for many of the areas being investigated this worked fine and the disparities that occurred between actual experiments and predictions were put down to experimental error, or general 'noise' creeping in. However with the advent of computer power the physicists were able to produce mathematical models that were more refined and included the seemingly insignificant power terms. What they discovered when they carried out the complex computations was that in certain circumstances it was these non-linear terms that dominated the calculations and that the experimental error or noise they had ignored was in fact the complex behaviour of the system itself, as represented by these non-linear terms. As a consequence of this discovery much of the inherently non-linear physics that was modelled using simpler linear mathematical approximations was re-formed in terms non-linear differential equations.

From this time onwards physicists started to appreciate the role that non-linear complex dynamics played in the universe. However there is still a reluctance to accept even the possibility that the underlying substrate of the universe may be far simpler than their complex mathematical theories, and that simple rules may give rise to the complex non-linear behaviour.

1961- DETERMINISTIC CHAOS

Following on from the previous discussion, in 1961 Edward Lorenz was running non-linear models for weather prediction on a computer and noticed that the results were highly sensitive to the initial parameter settings. This sensitivity to initial conditions is a primary characteristic of what we now term 'deterministically chaotic systems'. He was one of the first scientists to specifically study the characteristics of this behaviour and laid the foundation for the basis of chaos theory.

Chaos theory and other complex sciences are not directly applied to computational models of reality but they help quantify how simple cellular automata systems can have the potential to exhibit various complex dynamic properties, including micro and macro level stability, non-linear behaviour including chaos, and self-organising and adaptive behaviours. These theories also identify some of the restrictions on the level of predictability of the dynamics of any such models and this is a major problem in making progress in developing CA based models of reality.

As I have mentioned the sensitivity to initial conditions is one aspect of complex systems that mean that one can set up a CA based system that one thinks may create, for example similar conditions to the early stages of the big bang, but after just a couple of iterations through the CA the results will be completely unpredictable at scales similar to elementary particles. This means that the initial development of such models is in some ways less scientific, because not only do we understand the impact of this unpredictability on our models, but we also realise that we need it to generate the complex universe that we see around us. This is one of the reasons that I became interested in this topic. Coming from a software engineering background I wanted to adopt a very pragmatic approach as opposed to the highly theoretical approach of many others.

1960S - CELLULAR AUTOMATA COME OF AGE

Now we are in a position where the application of cellular automata can start to be fully explored by their implementation on the ever more powerful computers. Cellular automata are a prime tool for the detailed study of complex behaviour.

Cellular automata are an excellent experimental tool for analysing complex behaviour in simple systems and currently cellular automata are seen as the best candidate for developing a computational theory of everything.

The great thing about using CAs as the substrate for our reality is that some of the imponderable abstract concepts that are created by physical theories become evidently clear with a CA paradigm and I list a few below:

- Space becomes a uniform pattern of cells with each cell being dimensionless as observed by an intelligent pattern generated within the CA (a Simulant). This cell can have a state that could be perceived as a singularity by the simulant.

- Time is measured by a change of state of the CA as measured by the simulant and this is caused by the synchronous or asynchronous updating of the CA. In my own model the rate of change of state for different cells can vary and this means that the Simulant would experience a relativistic effect during observation.
- There will be a maximum rate at which the CA can change state and this will be the maximum speed at which a state can move through space. Therefore the Simulant would observe a limit to the speed of light.
- Matter is defined as the interaction between states of cells, however there is no true physicality to matter beyond its measured interaction, everything is just data.
- The interactions between matter states are governed by CA rules that we can never know, however simulants will be able to create models of its behaviour and call it physics.
- The most likely initial conditions for the CA is to have a single cell with an invalid state that generates more states that will eventually reach a level of stability, at which point rules that govern the interactions between such states will be 'turned on'. This is similar to the 'big bang' approach.
- Quantum behaviour and the seeming randomness associated with it have already been discussed.
- The construction of quantum entangled particles can be explained by my own model in that the 'matter' states are associated with cells and it is possible for a single state to be associated with more than one cell.
- CAs can be configured so that they simulate Boolean logic gates. They can also generate rudimentary binary arithmetic. But they do not use mathematics in their rules. In essence CAs can generate the mathematics that Simulants would observe.
- From such a complex CA specific 'rules' or physical laws could emerge that would be perceived by the Simulants.

These are just a few of the concepts that come for free from a computational approach and my own model produces a more detailed universe that in many ways may be similar to our own.

1964 - QUARKS AND THE STANDARD MODEL

The quark model was independently proposed by physicists Murray Gell-Mann and George Zweig. The quarks were elementary particles that could be combined in various ways to give rise to the Hadrons that included the neutron and proton. During this time and in the following years a hotchpotch of theories were being draw together into what is now termed the Standard Model; a model that is very successful at identifying all of the particle families and the forces and interactions between them, except gravity. In the mid 1970s the Standard model received the seal of approval when quarks, a fundamental constituent of the model, were experimentally verified. Currently quarks are the smallest experimentally confirmed constituents of matter and they have no structure and are point like particles; this is similar to the dimensionless cell of data that is the fundamental constituent of a CA based model.

1965 - RICHARD FEYNMAN AND THE IMPORTANCE OF COMPUTATION.

This is more of a personal entry than all of the others that I have been discussing. For me, Richard Feynman was not only a great physicist, but he is also the one who epitomised the ideals to which every physicist should aspire. He saw himself as solver of puzzles, which he achieved by doing calculations so that he could predict how the world react around us. To him the ideas of reality were of great interest, but they had little to do with physics. He knew everything there was to know about predicting the interactions of photons, but he openly admitted he didn't know how it actually happened or what a photon was, apart from an abstract mathematical object. He treated any of the interpretations of the mathematics with a great deal of scepticism and was very open about what he didn't know. He also believed all theories had to be backed up by hard experimental verification. Unfortunately these ideals are not always evident when listening to the current media savvy physicists. There seems to be a conspiracy amongst the physicists to project the view that they really understand the mechanisms by which the universe works, and that they are looking into the eye of God. I am sure that Feynman would strongly disagree with them.

Feynman was also very involved in many areas of computation and in his book, 'The Character of Physical Law', he makes it very clear that, for example, he doesn't know what 'energy' is apart from being a parameter that is conserved across interactions. But for the purposes of this essay his important contribution was the following quote that can be found in his book, *"It always bothers me that, according to the laws as we understand them today, it takes a computing machine an infinite number of logical operations to figure out what goes on in no matter how tiny a region of space, and no matter how tiny a region of time. How can all that be going on in that tiny space? Why should it take an infinite amount of logic to figure out what one tiny piece of space/time is going to do? So I have often made the hypotheses that ultimately physics will not require a mathematical statement, that in the end the machinery*

will be revealed, and the laws will turn out to be simple, like the chequer board with all its apparent complexities".

This quote suggests that Feynman believed that our current mathematical approach to physics would not enable us to understand the mechanisms of the underlying substrate, but that the substrate may have simple rules and possibly be based on a cellular automaton (the chequer board) and that our universe emerges from the 'complexities' of the dynamics. Feynman continued his interest in this area and in the 1980s he gave a lecture entitled Simulating physics on a computer in which he gave a unbiased opinion on aspects of this question.

Throughout this article Feynman has a connection to many of the other names that will crop up, for example Feynman was a student of Wheelers and Stephen Wolfram was a student of Feynman. Also Ed Fredkin collaborated with Feynman in various areas of computation. To me this indicates that he was very interested in some of these ideas and may have helped motivate others to consider some of these ideas.

1969 - KONRAD ZUSE AND RECHNENDER RAUM

Konrad Zuse is one of the lost heroes of computing, in that he was the first engineer to develop a programmable digital computer and is considered to be a pioneer in the development of computer languages. He was also a free thinker and with his great experience of early computer technology he wrote a book entitled 'Rechnender Raum', or 'calculating space'. In this book Zuse investigated what the result would be if the known laws of physics were 'discretized' and executed on a computer. His discussion included considering aspects of the physical laws as cellular automata. Zuse was not putting forward a particular proposition, but exploring the possibilities. However it is the first serious work that considers a computational basis for external reality. In this work Zuse retained the physicists' viewpoint in that he considered that the computation would be a discretization of the current laws of physics. Now that we understand a great deal more about the sensitivity of complex systems, it is apparent that any approach that used approximations based upon our continual mathematics would not work because the minute errors due to approximation and rounding would be amplified and cause the simulation to rapidly depart from our perceived universe and on into a chaotic state. It should be noted that many physicists still use Zuse's ideas of a computational universe to discredit any such proposition, even though those of us who are interested in the paradigm have moved on from Zuse.

MID 60S TO 70S - CELLULAR AUTOMATA AND PHYSICS

During this period physicists developed the so called 'lattice gas models' to model ensembles of particles, such as those in some gases, fluids and plasmas. These models were highly accurate in simulating some of the thermodynamic behaviour that we see in such systems. In the 80's it was formally recognised that these lattice gas models were in fact a type of cellular automata (sometimes referred to as 'lattice gas automata'). This added credibility to the idea that aspects of the physical world were better described by models using discrete time and space, and that had a limited set of resulting states.

1970 - THE GAME OF LIFE

In the early 1970s a mathematician called John Conway developed a very simple two dimensional cellular automata that is known as 'life' or 'the game of life'. This is a very simple CA in that each square cell can have one of two values, one of which signifies that the cell is empty and the other that it is occupied. Whether a cell is occupied or empty depends upon four simple rules that change its value depending upon the number of occupied neighbouring cells and the cell's own state. In essence this is a survival model in that the cell either survives dies or is born depending upon how crowded its immediate neighbourhood is. One has to watch the evolution of this CA to comprehend how such a simple system can give rise to complex behaviour and emergent self organisation. There has been much research concerning this CA and many structures have been identified some of which are stable, others whose patterns have regular oscillations and yet others that move and generate other patterns. There has also been a recent report of the first pattern that can reproduce itself. When one watches the game of life unfold one can imagine that maybe the quantum world could be generated from such a system.

1980S - THE MARCH OF THE MACHINES

The development of the home PC has enabled people such as me to get involved and the continued increase in computational power means that ever larger cellular automata can be developed. However we are far from being able to run a CA that could have anywhere near the complex behaviour of our own universe, or maybe not (see later)!

LATE 1980S - NEW REALITIES

In the 1960s the USAF started to develop flight simulators; from that point on the sophistication of simulations has accelerated until we reach the current day where many of the PC games that we can buy have an amazing ability to simulate fictitious worlds with realistic physical laws. In the late 1980s, the term "virtual reality" was popularized by Jaron Lanier, one of the modern pioneers of the field. There are of course specific differences between the concepts of 'simulation' and 'virtual reality', but the important point here is that we have had a massive paradigm shift in that we can now envisage a world within a world. From the complex and commercial simulations down to the PC games in which we are able to travel through a simulated space that would seem infinite to any intelligent being within the simulation, when to us it all just fits inside an inch square memory chip or micro processor. It is important to realise that one of the basic conclusions of quantum physics is that we 'perceive' our universe from the inside, but virtual reality has opened our minds to the idea that maybe it is possible for our universe to be viewed from the outside, and that maybe, just like the games, we exist in a universe within a universe.

1980S - IT FROM BIT AND DIGITAL PHYSICS

In the 80's the great and late physicist, John Archibald Wheeler coined the phrase 'It from Bit'. Wheeler considered that it was possible that information is what sits at the core of physics and that it is hence a fundamental constituent of reality. At the lowest level of structure, the meaning and function of everything is derived from binary decisions or bits. What we view as perceived reality then becomes some immaterial sources acting in a binary fashion to interact with the binary 'us', or our equipment to produce a perceived response. Wheeler wrote, "*... every it--every particle, every field of force, even the space-time continuum itself--derives its function, its meaning, its very existence entirely--even if in some contexts indirectly--from the apparatus-elicited answers to yes-or-no questions, binary choices, _bits_.*"

This is yet another viewpoint by a great physicist and his followers that binary information may be the substrate upon which the universe exists.

1992 - FINITE NATURE TO DIGITAL MECHANICS

Professor Ed Fredkin was one, if not the first, esteemed scientist after Zuse to analyse in some detail the possibility of a computational reality. In his landmark paper entitled 'finite Nature' Fredkin proposed the 'Finite Nature Hypothesis' that states, "*Finite Nature is the assumption that, at some scale, space and time are discrete and that the number of possible states of every finite volume of space-time is finite*".

There are certain consequences to this proposition. For example, nothing would be smooth or continuous and infinitesimals would not exist in the physical universe, but

only in mathematics. Also if finite nature is true, then there are certain consequences that are independent of the scale.

Fredkin continued on from his hypothesis to outline aspects of a computational model that was in agreement in some part with aspects of mainstream physics. The description and analysis of his model became a field of study known as 'digital mechanics' or 'digital physics'. Fredkin's work, along with two collaborators, Tommaso Toffoli and Norman Margolus, has influenced many of the small group of researchers working in the field of computational theories of everything.

1994 - STRING THEORY AND BEYOND

Early ideas in string theories started in the 1960s and the objective of such theories has always been to develop a theory of particles and interactions that integrated quantum mechanics with general relativity. Over the last twenty years or so string theory morphed into super-symmetry based theories including M-theory (supported by Ed Witten) for many, a theory of this type is the only current contender for the elusive 'theory of everything'.

A vast amount of effort has been directed at string theory, super string theory and now M-Theory. But to my knowledge not one experiment has managed to confirm any specific predictions of such theories, even within the energy ranges that are now available to experimenters. This has lead Nobel laureates such as Feynman, Glashow and Gerard 't Hooft to criticise such theories as unfounded physics. For example Feynman was quoted as saying, "*string theorists don't make predictions, they make excuses.*" In 'The Road to Reality', Professor Roger Penrose says, "*but it should be made clear that there is (as yet) no observational reason to believe that string theory (in particular) is physics; although it is motivated by powerful physical aspirations*"

It seems to me that the last fifty or so years of research into string related theories is the ultimate expression of J D Barrow's assertion, that uncertainty or incorrectness is being pushed further into the abstraction of the mathematics, and this is why we are seeing no evidential validation of such theories. This is a dangerous move by physics away from the 'instrumentalist' viewpoint, that is, theory with experimental validation. Such a move could end up in an increasing spiral into pure mathematics with little benefit to our comprehension of the universe.

So far I have spent a lot of time identifying what to me are the weaknesses with current physics, but there is no denying that physics is an extremely powerful tool, and that even the theories that are abstract, but have a high level of self consistency may be telling us something about an underlying truth concerning external reality, and this is true of the string based theories. Most importantly, these theories may be indicating that near the Plank scale there is 'stuff going on' that is deterministic and predictable, but not experimentally accessible by us. A few of the other signs that are relevant to computational paradigms are discussed below:

- *String theories deal with scales that are around the Plank scale and that to other theories, including quantum mechanics, can be considered as 'dimensionless'. For string theory*

space and time are discrete at Plank scales and possibly represented as a nodal network (a possible type of CA). The Calabi-Yau space in which the string vibrates may equate to extra dimensions required by a CA model to support the observed forces and energy.

- In my model there is a direct similarity between the vibration modes of the strings and the dynamics of the lowest level nested CA. Let me explain by using a simple two dimensional view of my own model. Space in my model is represented as a two dimensional CA and we exist as patterns within this CA. To us, an individual cell is not measurable and hence dimensionless. However within each of these spatial cells there can be a set of much simpler two dimensional CAs that have very simple rules and a set of very simple states. These sub-spatial CAs may interact with each other and the 'state' of a spatial cell is a product of the state of each of the sub-spatial CAs. In my model these sub-spatial CA are similar to strings.
- *M-Theory took strings and extended them into multi-dimensional P-branes (think of strings stretched in several directions). These P-branes are seen to exist in a multidimensional universe, sometimes called 'the Bulk' and our physical universe exists on the surface of such a brane. It seems that M-Theory may be indicating that our universe exists within another universe and this is also a requirement of a computational reality.*
- String theory requires extra spatial dimensions and these are 'coiled up' and not perceivable to us. My embedded CA model can give rise to the same perception for a Simulant existing in the spatial CA.
- Both string theory and scattering use a mathematical trick of using the centre of mass frame of reference where it is assumed that the centre of mass of the system being analysed is zero. I wonder if this is saying something about the idea of absolute space and time (see later), as these absolutes exist in my CA model.
- Strings are one dimensional strands of energy. Prior to string theory 'energy' was a derived characteristic, an accounting tool and there was no meaning to the concept of 'pure energy'. String theory promotes 'pure energy' to a fundamental substrate of the universe. A string is pure energy and dependent upon its specific mode of vibration it may reflect a specific energy as in the case of a graviton or photon. My CA theory also has the concept of pure energy as a type of state of the sub-spatial CAs.

² Of which there are hundreds of thousands and this is one of the problems with string theories.

³ One can see a spatial cell as in fact a block CA with each of the sub-spatial CAs representing a block.

⁴ The number of such dimensions can vary with different theories.

1995 - THE EXPANSION OF THE INTERNET

The invention and expansion of the internet has opened up access to information that would otherwise only be available to specific groups of researchers and hopefully this situation will be improved in the next two years with the push for open access to academic research results. This availability of information has enabled amateurs, such as me to get involved, and for us all to become more aware of new developments. People such as me have an obligation to make it clear that our work is not peer reviewed or accepted as main stream science. For my part I can only state that my intentions are concerned with increasing my understanding and hopefully adding to the valid ideas in this area. Well intentioned and knowledgeable amateur scientists have a role to play in the development of ideas and I would sight Patrick Moor, and in particular Albert Einstein as two outstanding examples.

In terms of CA based models the most important feature of the internet is its potential as a distributed processing system. Any meaningful simulation of a complex universe using a CA would require vast amounts of computing resource. The good thing about processing CAs is that they are discrete and groups of cells could be batched up and calculated using the ordinary PCs that are connected to the internet. This approach may be the only way to produce meaningful models.

2003 - PROCESS PHYSICS

Process physics, as opposed to our current non-process based physics, is an idea developed by R Cahill and associates at Flinders University. In process physics the fundamental assumption is that reality is to be modelled as self-organising semantic information, that is, information that is 'internally' meaningful, using a self-referentially limited neural network model.

Cahill considers that the standard model for a stochastic neural network is similar in form to that of the quantum field descriptions in quantum chromodynamics. Re-writing the standard mathematical descriptions for quantum chromodynamics as an discrete iterative process generates a neural network of nodes where the structure of the node is unimportant but the relationships between them are self referencing and have 'meaning'. This system exhibits what is known as self organising criticality whereby patterns and behaviour emerges from the changing relationships. The structures are nested in that a node may be defined by another structure of nodes. This model is seemingly highly successful at spontaneously creating what we consider to be three dimensional space, time, and quantum behaviour, and supplies an explanation of the origins and peculiarities of gravity. Process physics requires the concept of absolute space and Cahill argues that the experiments by Miller (see earlier) have proven this point, but that they have either been ignored or misinterpreted by the physics community. Cahill's interpretation of Miller's results has been questioned by physicists and the jury is still out on the conclusions.

Process physics is not a computational model, although it could be. Its importance is as another inspiring attempt to 'think differently' about physics and the fixed paradigms that restrict current research.

2001 - ARE WE LIVING IN A COMPUTER SIMULATION

Nick Bostrom a philosopher at Oxford University wrote a paper entitled, 'Are we living in a computer simulation'. In this work Bostrom used a few logically argued assumptions to show through a mathematical approach that there was a high likelihood that we are part of a computer simulation. This idea got some air time and helped promote the computational reality concept, as well as adding another established academics view to the pot.

2002 - A NEW KIND OF SCIENCE

In 2002 Stephen Wolfram, a physicist, whose research supervisor was Richard Feynman published a book entitled 'A new kind of science'. In this book Wolfram presented a major detailed analysis of one and two dimensional cellular automata, showing that they were capable of generating many of the characteristics of complex behaviour. Wolfram also included a chapter where he postulated that our universe could be the results of a simple CA and that our physics is emergent from it. His work is a standard reference for those wanting to understand more about different types of cellular automata and their properties.

For my own part I disagree with Wolfram's insistence of using a simple CA to create a universe. Firstly what does simple mean? My own view is pragmatic and to develop something that is useful, whatever its complexity. The best way to define 'simple' in this context is to measure its complexity against that of the universe that it creates. In this case I believe that the CA would be extremely simple.

2000 ONWARDS - THE HARD PART BEGINS

This brief journey through history has now reached an important point, for in the last twenty years or so there have been no momentous events that have enabled the idea of a computational universe to be greatly extended. The reason for this is simple; now that we have some base ideas, methods and tools we need to start developing models that do more than supply anecdotal evidence of the proposition, and so far little has been accomplished. There has been some progress, notably by Ed Fredkin's continuing work on digital physics, various presentations and articles by Stephen Wolfram and also from a few other select academics.

The current situation is not surprising when one considers that from the seed of the idea from Zuse to now is only fifty years. Physics on the other hand has had over two

thousand years of development to reach its current state. So in terms of developing meaningful computational models that could generate universes that have some similarity to our physics, we are still back with the ancient Greeks. The world of physicists has in general paid scant regard to these ideas and has sometimes used very simplistic and dubious arguments to shun any further consideration. Like any large group of people with common beliefs and objectives the world of physics is institutionalised and with this comes a level of politics. The truth is that if, and it's a very big 'if', computational reality is shown to be a valid proposition then the physicists will have transferred the power of 'ultimate knowledge' to the computer scientists and therefore it is in their best interests to ignore the idea and hope that it goes away.

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