It from Bit –
Information Theory State of Art.

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05.01.2017

Content: It from Bit – Information Theory State of Art.

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Source: https://plato.stanford.edu/entries/information/index.html

History of Information

Classical philosophy

‘information’ was a technical notion associated with a theory of knowledge and ontology that originated in Plato's (427–347 BCE) theory of forms, developed in a number of his dialogues (*Phaedo, Phaedrus, Symposium, Timaeus, Republic*). Various imperfect individual horses in the physical world could be identified as horses, because they participated in the static atemporal and aspatial idea of ‘horseness’ in the world of ideas or forms.

On various occasions Aristotle mentions the fact that Plato associated ideas with numbers (Vogel 1974, pg. 139). Although formal mathematical theories about information only emerged in the 20thcentury, and one has to be careful not to interpret the Greek notion of a number in any modern sense, the idea that information was essentially a mathematical notion, dates back to classical philosophy: the form of an entity was conceived as a structure or pattern that could be described in terms of numbers. Such a form had both an ontological and an epistemological aspect: it explains the essence as well as the understandability of the object. ***The concept of information thus from the very start of philosophical reflection was already associated with epistemology, ontology and mathematics.***

Medieval philosophy

Reflection on the notion of *informatio* is taken up, under influence of Avicenna, by thinkers like Aquinas (1225–1274 CE) and Duns Scotus (1265/66–1308 CE). When Aquinas discusses the question whether angels can interact with matter he refers to the Aristotelian doctrine of hylomorphism (i.e., the theory that substance consists of matter (hylo-wood, matter) and form (morphè)). Here Aquinas translates this as the in-formation of matter (*informatio materiae*) (*Summa Theologiae,* 1a 110 2, Capurro 2009). Duns Scotus refers to *informatio* in the technical sense when he discusses Augustine's theory of vision in *De Trinitate*, XI Cap 2 par 3 (Duns Scotus, 1639, De imagine, *Ordinatio*, I, d.3, p.3).

The tension that already existed in classical philosophy between Platonic idealism(*universalia ante res*) and Aristotelian realism (*universalia in rebus*) is recaptured as the problem of universals: do universal qualities like ‘humanity’ or the idea of a horse exist apart from the individual entities that instantiate them? ***It is in the context of his rejection of universals that Ockham (c. 1287–1347 CE) introduces his well-known razor: entities should not be multiplied beyond necessity.*** Throughout their writings Aquinas and Scotus use the Latin terms *informatio* and *informare* in a technical sense, although this terminology is not used by Ockham.

Modern philosophy

Rationalism: The Cartesian notion that ideas are innate and thus a priori. This view is difficult to reconcile with the concept of experimental science.

Empiricism: Concepts are constructed in the mind a posteriori on the basis of ideas associated with sensory impressions.

Locke's reinterpretation of the notion of idea as a ‘structural placeholder’ for any entity present in the mind is an essential step in the emergence of the modern concept of information. ... opens the gate to a reconstruction of knowledge as an extensive property of an agent: more ideas implies more probable knowledge.

In the second half of the 17th century formal theory of probability is developed by researchers like Pascal (1623–1662), Fermat (1601 or 1606–1665) and Christiaan Huygens (1629–1695). For these authors, the world was essentially mechanistic and thus deterministic, probability was a quality of human knowledge caused by its imperfection. Here knowledge about the future as a degree of belief is measured in terms of probability, which in its turn is explained in terms of the number of configurations a deterministic system in the world can have.

With this new concept of knowledge empiricists laid the foundation for the later development of thermodynamics as a reduction of the secondary quality of heat to the primary qualities of bodies.

According to Kant, … the human mind can evaluate its own capability to formulate scientific judgements. Kant developed transcendental philosophy as an investigation of the necessary conditions of human knowledge.

Historical development of the meaning of the term ‘information’

‘Information’ as the process of being informed.

- This is the oldest meaning one finds in the writings of authors like Cicero (106–43 BCE) and Augustine (354–430 CE) and it is lost in the modern discourse, although the association of information with processes (i.e., computing, flowing or sending a message) still exists. In classical philosophy one could say that when I recognize a horse as such, then the ‘form’ of a horse is planted in my mind.

‘Information’ as a state of an agent,

- i.e., as the result of the process of being informed. If one teaches a pupil the theorem of Pythagoras then, after this process is completed, the student can be said to ‘have the information about the theorem of Pythagoras’. In this sense the term ‘information’ is the result of the same suspect form of substantiation of a verb (informare > informatio) as many other technical terms in philosophy (substance, consciousness, subject, object).

‘Information’ as the disposition to inform,

- i.e., as a capacity of an object to inform an agent. When the act of teaching me Pythagoras' theorem leaves me with information about this theorem, it is only natural to assume that a text in which the theorem is explained actually ‘contains’ this information. The text has the capacity to inform me when I read it.

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Building blocks of modern theories of information

- ***Information is extensive*.** Our intuition is that longer text potentially contains more information. Thus when we have two structures *A* and *B* that are mutually independent, then the total information in the combination should be the sum of both the information in *A* and *B*: $I(A \text{ and } B)=I(A)+I(B)$.
- ***Information reduces uncertainty*.** Information grows with the reduction of uncertainty it creates. When we are absolutely certain about a state of affairs we cannot receive new information about it. This suggests an association between information and probability

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Developments in philosophy of Information - Popper: Information as degree of falsifiability

- Thus it can be said that the amount of empirical information conveyed by a theory, or its *empirical content*, increases with its degree of falsifiability” (Popper 1934 [1977], pg. 113, emphasis in original).
- *The logical probability of a statement is complementary to its falsifiability:* it increases with decreasing degree of falsifiability. The logical probability 1 corresponds to the degree 0 of falsifiability and *vice versa*. (Popper 1934 [1977], p. 119, emphasis in original)
- It is possible to interpret numerical probability as applying to a subsequence (picked out from the logical probability relation) for which a *system of measurement* can be defined, on the basis of frequency estimates. (Popper 1934 [1977], pg. 119, emphasis in original)
- These issues were later developed in philosophy of science. Theory of conformation studies induction theory and the way in which evidence ‘supports’ a certain theory (Huber 2007, Other Internet Resources). Although the work of Carnap motivated important developments in both philosophy of science and philosophy of information the connection between the two disciplines seems to have been lost. There is no mention of information theory or any of the more foundational work in philosophy of information in Kuipers (2007a), but the two disciplines certainly have overlapping domains.

Source: https://plato.stanford.edu/entries/information/index.html

Shannon: Information defined in terms of probability

“The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point.”

- In two landmark papers Shannon (1948; Shannon & Weaver 1949) characterized the communication entropy of a system of messages A:
  - H(P) = −Σ(i∈A) pi log2 pi
  - Here pi is the probability of message i in A. This is exactly the formula for Gibb's entropy in physics. The use of base-2 logarithms ensures that the code length is measured in bits (binary digits). It is easily seen that the communication entropy of a system is maximal when all the messages have equal probability and thus are typical.
- The amount of information I in an individual message x is given by:
  - I(x) = −log px
- This formula, that can be interpreted as the inverse of the Boltzmann entropy, covers a number of our basic intuitions about information:
  - A message x has a certain probability p_x between 0 and 1 of occurring.
  - If p_x = 1 then $I(x)$ = 0. If we are certain to get a message it literally contains no ‘news’ at al. The lower the probability of the message is, the more information it contains. A message like “The sun will rise tomorrow” seems to contain less information than the message “Jesus was Caesar” exactly because the second statement is much less likely to be defended by anyone (although it can be found on the web).
  - If two messages x and y are unrelated then $I(x$ and $y)=I(x) + I(y)$. Information is *extensive*. The amount of information in two combined messages is equal to the sum of the amount of information in the individual messages.
- One aspect of information that Shannon's definition explicitly does not cover is the actual content of the messages interpreted as propositions. So the statement “Jesus was Caesar” and “The moon is made of green cheese” may carry the same amount of information while their meaning is totally different.

Source: https://plato.stanford.edu/entries/information/index.html

Solomonoff, Kolmogorov, Chaitin: Information as the length of a program

- **Solomonoff (1997):** Carnap's model of probability started with a long sequence of symbols that was a description of the entire universe. Through his own formal linguistic analysis, he was able to assign a priori probabilities to any possible string of symbols that might represent the universe. He formulated the notion of a universal distribution: "consider the set of all possible finite strings to be programs for a universal Turing machine U and define the probability of a string x of symbols in terms of the length of the shortest program p that outputs x on U." - Algorithmic Information Theory was invented independently somewhat later separately by Kolmogorov (1965) and Chaitin (1969). Levin (1974):
  - The information content or complexity of an object can be measured by the length of its shortest description. For instance the string: "0101010101010101010101010101010101010101010101010101010101010101“ has the short description "32 repetitions of '01'", while
  - "1100100001100001110111101110110011111010010000100101011110010110“: presumably has no simple description other than writing down the string itself.
- The **Kolmogorov complexity** of an object, such as a piece of text, is the length of the shortest computer program (in a predetermined programming language) that produces the object as output.
- An infinite binary sequence is said to be random if, for some constant c, for all n, the Kolmogorov complexity of the initial segment of length n of the sequence is at least n − c.
- **Chaitin constant** (Chaitin omega number) – Ω. or halting probability is a real number that informally represents the probability that a randomly constructed program will halt. These numbers are formed from a construction due to Gregory Chaitin. Each halting probability is a normal and transcendental real number that is not computable, which means that there is no algorithm to compute its digits. Indeed, each halting probability is Martin-Löf random, meaning there is not even any algorithm which can reliably guess its digits.
- **Algorithmic Information Theory** has gained rapid acceptance as a fundamental theory of information. The well-known introduction in Information Theory by Cover and Thomas (2006) states: "… we consider Kolmogorov complexity (i.e., AIT) to be more fundamental than Shannon entropy" (pg 3). Several authors have defended that data compression is a general principle that governs human cognition (Chater & Vitányi 2003; Wolff 2006). Hutter (2005, 2007a,b) argues that Solomonoff's formal and complete theory essentially solves the induction problem. Hutter (2007a) and Rathmanner & Hutter (2011) enumerate a plethora of classical philosophical and statistical problems around induction and claim that Solomonoff's theory solves or avoids all these problems.

Source: https://plato.stanford.edu/entries/information/index.html, Wikipedia

Open Problems in the Study of Information and Computation

- **The unification of various theories of information:**
  - Information-A, Knowledge, logic, what is conveyed in informative answers
  - Information-B, Probabilistic, information-theoretic, measured quantitatively
  - Information-C, Algorithmic, code compression, measured quantitatively
- **What is useful/meaningful information?**
- **What is an adequate logic of information?**
- **Continuous versus discrete models of nature:** The central issue is this: the most elegant models of physical systems are based on functions in continuous spaces. In such models almost all points in space carry an infinite amount of information. Yet, the cornerstone of thermodynamics is that a finite amount of space has finite entropy. What is the right way to reconcile these two views?
- **Computation versus thermodynamics:** What is a computational process from a thermodynamical point of view? What is a thermodynamical process from a computational point of view. Can a thermodynamic theory of computing serve as a theory of non-equilibrium dynamics? This problem seems to be hard because 150 years of research in thermodynamics still leaves us with a lot of conceptual unclarities in the heart of the theory of thermodynamics itself.
- **Classical information versus quantum information:** The most fundamental way to store information in nature on an atomic level involves qubits. The qubit is described by a state vector in a two-level quantum-mechanical system, which is formally equivalent to a two-dimensional vector space over the complex numbers. The exact relation between classical and quantum information is unclear.
- **Information and the theory of everything:** The notion of information seems to play a major role in the analysis of black holes (Lloyd & Ng 2004; Bekenstein 1994). Erik Verlinde (2010) has proposed a theory in which gravity is analyzed in terms of information. For the moment these models seem to be purely descriptive without any possibility of empirical verification.
- **The Church-Turing Hypothesis:** We know that a lot of formal systems are Turing equivalent (Turing machines, recursive functions, lambda calculus, combinatory logic, cellular automata, to name a few). The question is: does this equivalence define the notion of computation.
- **P versus NP?** Can every problem for which the solution can be checked efficiently also be solved efficiently by a computer

https://plato.stanford.edu/entries/information/supplement.html

- **Information and the theory of everything:**
  - **It from Bit:** Why the Quantum? It from Bit? A Participatory Universe?: Three Far-reaching, Visionary Questions from John Archibald Wheeler
  - **Erik gravity**

John Wheeler On quantum theory and information

- I have been led to think of analogies between the way a computer works and the way the universe works. The computer is built on yes-no logic. So, perhaps, is the universe. Did an electron pass through slit A or did it not? Did it cause counter B to click or counter C to click? These are the iron posts of observation. Yet one enormous difference separates the computer and the universe—chance. In principle, the output of a computer is precisely determined by the input. Chance plays no role. In the universe, by contrast, chance plays a dominant role. The laws of physics tell us only what may happen. Actual measurement tells us what is happening (or what did happen). Despite this difference, it is not unreasonable to imagine that information sits at the core of physics, just as it sits at the core of a computer. —1998

http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-02-4969-01

Guessing game

- You recall how it goes—one of the after-dinner party sent out of the living room, the others agreeing on a word, the one fated to be a questioner returning and starting his questions. “Is it a living object?” “No.” “Is it here on earth?” “Yes.” So the questions go from respondent to respondent around the room until at length the word emerges: victory if in twenty tries or less; otherwise, defeat. Then comes the moment when we are fourth to be sent from the room. We are locked out unbelievably long. On finally being readmitted, we find a smile on everyone’s face, sign of a joke or a plot. We innocently start our questions. At first the answers come quickly. Then each question begins to take longer in the answering—strange, when the answer itself is only a simple “yes” or “no.” At length, feeling hot on the trail, we ask, “Is the word ‘cloud’?” “Yes,” comes the reply, and everyone bursts out laughing. When we were out of the room, they explain, they had agreed not to agree in advance on any word at all. Each one around the circle could respond “yes” or “no” as he pleased to whatever question we put to him. But however he replied he had to have a word in mind compatible with his own reply—and with all the replies that went before. No wonder some of those decisions between “yes” and “no” proved so hard!
- — J. A. Wheeler [2]

- Wheeler proposes to delay the decision of whether to keep or to remove the beam splitter 2, until we are sure the photon passed from splitter 1 In fact, his thought experiment uses instead of beam splitters and mirrors, the deflection of light caused by the gravity of an entire galaxy.
- He concludes :
  Since we make our decision whether to measure the interference from the two paths or to determine which path was followed a billion or so years after the photon started its journey, we must conclude that our very act of measurement not only revealed the nature of the photon’s history on its way to us, but in some sense *determined* that history.
- The past history of the universe has no more validity than is assigned by the measurements we make–now!
  The delayed choice experiment is the source for Wheeler’s *law without law* and *it from bit*.

Delayed Choice Experiment

Recall the quantum experiment based on the Mach-Zehnder interferometer. Light is emitted by a source, and split by beam splitter 1 (see fig. 2). The two halves of the ray are redirected by two mirrors to meet again, and the original ray is recomposed, by beam splitter 2. The photons trigger detector B.

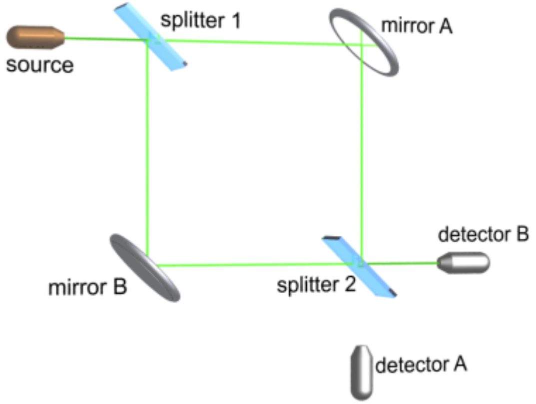

FIGURE 2. *Both ways* observation.

Now, remove the beam splitter 2. The photons will trigger with equal probability both detectors A and B (fig. 3).

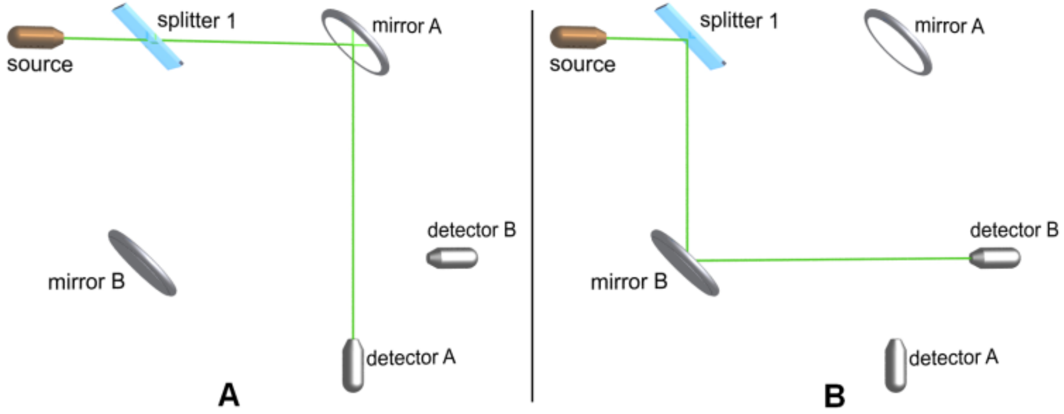

FIGURE 3. *Which-way* observation.

(Frontiers collection) Aguirre, Anthony Nicholas_ Foster, Brendan Zdon_ Merali, Zeeya (eds)-It from bit or bit from it on physics and information-Springer (2015)

Why the Quantum? It from Bit? A Participatory Universe?: Three Far-reaching, Visionary Questions from John Archibald Wheeler and How They Inspired a Quantum Experimentalist

- It turns out that very naturally the referent of quantum physics is not reality per se but, as Niels Bohr said, it is "what can be said about the world", or in modern words, it is information. Thus, if information is the most fundamental notion in quantum physics, a very natural understanding of phenomena like quantum decoherence or quantum teleportation emerges. And quantum entanglement is then nothing else than the property of subsystems of a composed quantum systems to carry information jointly, independent of space and time; and the randomness of individual quantum events is a consequence of the finiteness of information.
- The quantum is then a reflection of the fact that all we can do is make statements about the world, expressed in a discrete number of bits. The universe is participatory at least in the sense that the experimentalist by choosing the measurement apparatus, defines out of a set of mutually complementary observables which possible property of a system can manifest itself as reality and the randomness of individual events stems form the finiteness of information.
- A number of experiments will be reviewed underlining these views. This will include an entangled photon delayed choice experiment where the decision whether a photon that has passed a double slit did this as a particle or a wave is delayed not only until a time after its passage through the double slit assembly but even after it has already been registered. Thus, while the observed facts, i.e. the events registered by the detectors, are not changed, our physical picture changes depending on our choice what to measure.
- In conclusion it may very well be said that information is the irreducible kernel from which everything else flows. Then the question why nature appears quantized is simply a consequence of the fact that information itself is quantized by necessity. It might even be fair to observe that the concept that information is fundamental is very old knowledge of humanity, witness for example the beginning of gospel according to John: "In the beginning was the Word".

http://www.metanexus.net/archive/ultimate_reality/zeilinger.pdf

It from Bit from It from Bit... Nature and Nonlinear Logic

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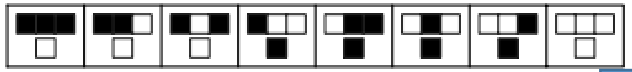
- Perhaps the most dramatic illustrations of how little we comprehend nonlinear logic arise in computer science from evolutionary computer programs. Initiated at MIT and Stanford, this sort of research is now being performed at many major universities, including MSU. Here is a seemingly straightforward example.
- A popular yardstick among computer scientists is to create an efficient program that will sort, say, a set of 100 random numbers into ascending order. To simulate evolution in creating such a program, one first uses a pseudorandom number generator to generate programs consisting of (almost) random sequences of numbers. One can then either use these programs "raw," or to speed up the process, one can retain only instructions at least marginally useful for sorting, such as comparison and exchange instructions. Thus, one begins with a population consisting of, say, 10,000 random programs, each consisting of several hundred instructions. One then runs and tests these randomly generated programs, which, as expected, do a very poor job at first. Only the "most fit," meaning any programs that show the slightest inclination for sorting, are retained. These are used to create the next generation. This can be done in two ways: First, by inserting random minor variations, corresponding to asexual mutations; second, by "mating" parent programs to create a child program, i.e., by splicing parts of programs together, hoping that useful instructions from each parent occasionally will be inherited and become concentrated. This process can be repeated thousands upon thousands of time with fast parallel processors, and eventually very efficient programs can result. (It should be mentioned in passing that this sort of research is carried out on isolated computers using nonstandard operating systems, for such programs could become dangerous viruses on the internet.)
- Some of the results were startling. Danny Hillis, who originated many aspects of these programs, sums it up vividly in his book, The Pattern on the Stone [9]:
  - I have used simulated evolution to evolve a program to solve specific sorting problems, so I know that the process works as described. In my experiments, I also favored the programs that sorted the test sequences quickly, so that faster programs were more likely to survive. This evolutionary process created very fast sorting programs. For the problems I was interested in, the programs that evolved were actually slightly faster than any of the algorithms described ...[standard algorithms].— and, in fact, they were faster at sorting numbers than any program I could have written myself. One of the interesting things about the sorting programs that evolved in my experiment is that I do not understand how they work. [my emphasis] I have carefully examined their instruction sequences, but I do not understand -4- them; I have no simpler explanation of how the programs work than the instruction sequences themselves. It may be that the programs are not understandable — that there is no way to break the operation of the program into a hierarchy of understandable parts. If this is true — if evolution can produce something as simple as a sorting program which is fundamentally incomprehensible — it does not bode well for our prospects of ever understanding the human brain.

http://www.mrtc.mdh.se/~gdc01/work/ARTICLES/2014/9-INFO-SpecialIssue/FQXi2013/13-1908-McHarris-Nonlinear-Logic.pdf

- **Physic, Math, Information:**
  - Gravity as emergent,
  - Sporadic finite Groups,
  - Leech Lattice,

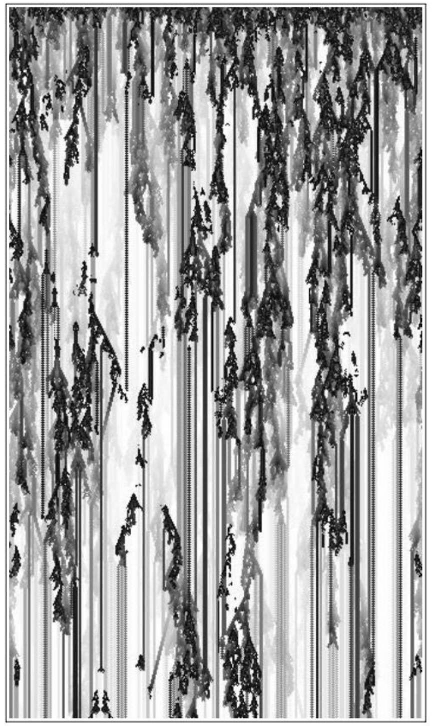


New Kind of Science

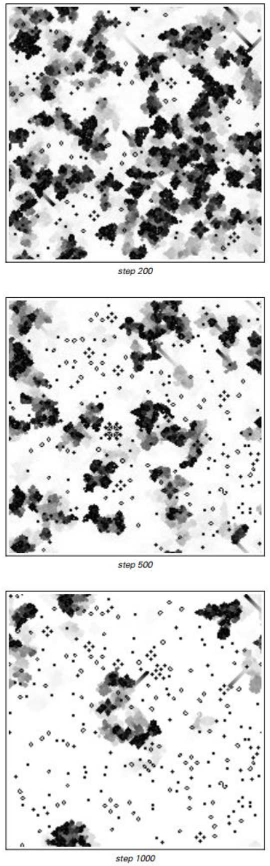
Stephen Wolfram January 15, 2002

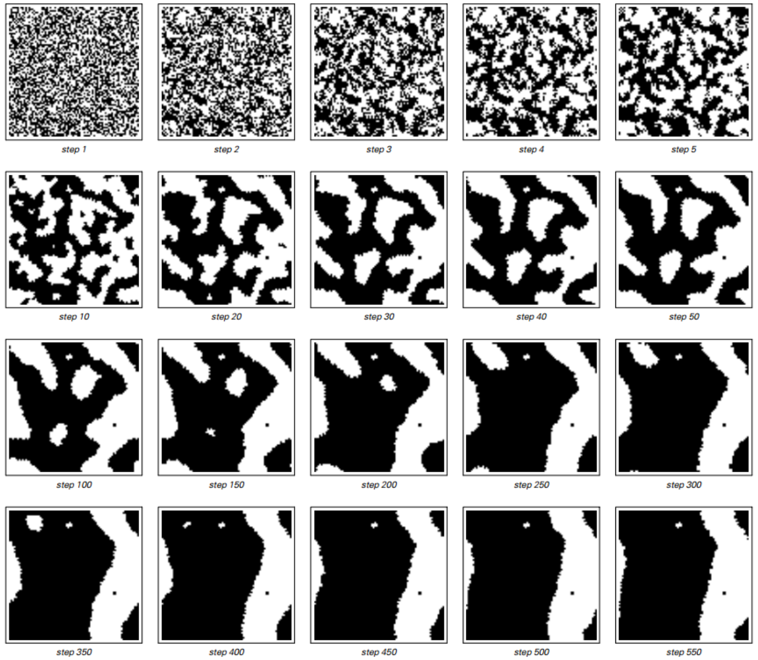
My purpose in this book is to initiate another such transformation, and to introduce a new kind of science that is based on the much more general types of rules that can be embodied in simple computer programs.

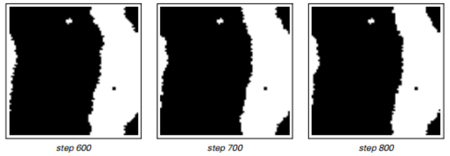
Five hundred steps in the evolution of the rule cellular automaton above. The pattern produced continues to expand on both left and right, but only the part that fits across the page is shown here. The asymmetry between the left and right-hand sides is a direct consequence of asymmetry that exists in the particular underlying cellular automaton rule used.



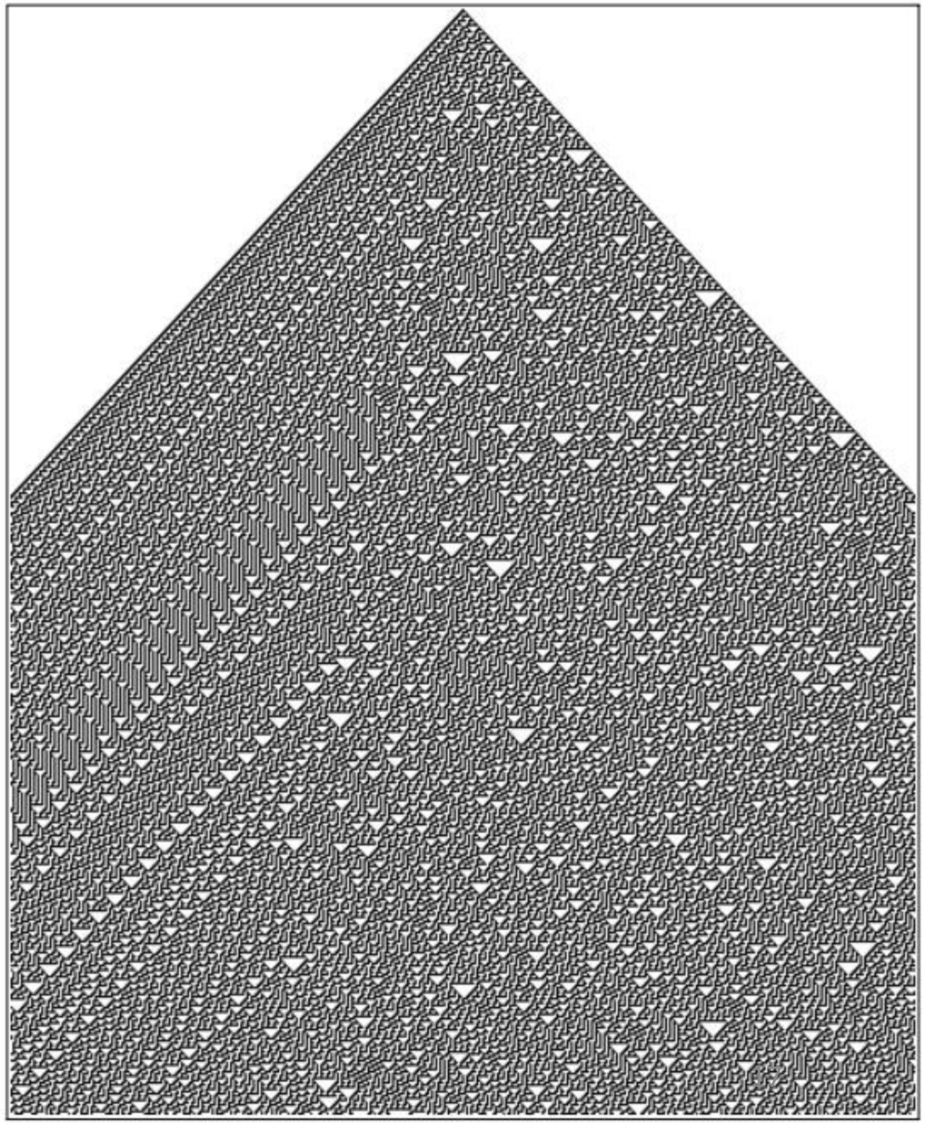
The behavior of a class 4 two-dimensional cellular automaton often known in recreational computing as the Game of Life. Localized structures that move (so-called gliders) show up as streaks in the pictures given here. The rule for this cellular automaton considers the 8 neighbors of a cell (including diagonals): if two of these neighbors are black, then the cell stays the same color as before; if three are black, then the cell becomes black; and if any other number of neighbors are black, then the cell becomes white. This rule is outer totalistic 9-neighbor code 224. The pictures on the right show cells that were black on preceding steps in progressively lighter shades of gray.







Behavior of a two-dimensional cellular automaton starting from a random initial condition. At each step, each cell looks at the total number of black cells in the 9-cell neighborhood consisting of the cell itself and the 8 cells adjacent to it (including diagonals). If this total is less than 4, then the cell becomes white on the next step, while if the total is greater than 6, it becomes black. If the total is exactly 5, then the cell becomes white, and if the total is exactly 4, then it becomes black. (The rule has totalistic code 976.) The pictures show that on a large scale, the rule leads to regions of black and white whose boundaries behave in a seemingly smooth and continuous way. Note that each picture is 80 cells across, and is effectively wrapped around so that the left neighbor of the leftmost cell is the rightmost cell, and so on.



Erik Verlinde interview

- Most people, certainly in physics, think we can describe gravity perfectly adequately using Einstein's General Relativity. But it now seems that we can also start from a microscopic formulation where there is no gravity to begin with, but you can derive it. This is called 'emergence'.
- We have other phenomena in Physics like this. Take a concept like 'temperature', for instance. We experience it every day. We can feel temperature. But, if you really think about the microscopic molecules, there's no notion of temperature there. It's something that has to do with the property of all molecules together; it's like the average energy per molecule.
- Gravity is similar. It's really something that only appears when you put many things together at a microscopic scale and then you suddenly see that certain equations arise

arXiv:1611.02269v2 [hep-th] 8 Nov 2016

Emergent Gravity and the Dark Universe

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Abstract

Recent theoretical progress indicates that spacetime and gravity emerge together from the entanglement structure of an underlying microscopic theory. These ideas are best understood in Anti-de Sitter space, where they rely on the area law for entanglement entropy. The extension to de Sitter space requires taking into account the entropy and temperature associated with the cosmological horizon. Using insights from string theory, black hole physics and quantum information theory we argue that the positive dark energy leads to a thermal volume law contribution to the entropy that overtakes the area law precisely at the cosmological horizon. Due to the competition between area and volume law entanglement the microscopic de Sitter states do not thermalise at sub-Hubble scales: they exhibit memory effects in the form of an entropy displacement caused by matter. The emergent laws of gravity contain an additional 'dark' gravitational force describing the 'elastic' response due to the entropy displacement. We derive an estimate of the strength of this extra force in terms of the baryonic mass, Newton's constant and the Hubble acceleration scale $a_0 = cH_0$, and provide evidence for the fact that this additional 'dark gravity force' explains the observed phenomena in galaxies and clusters currently attributed to dark matter.

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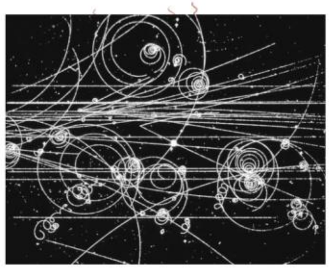
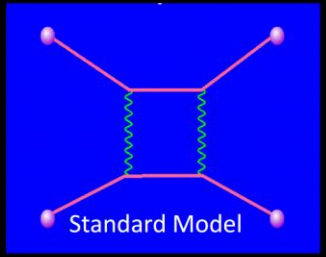
Reduction

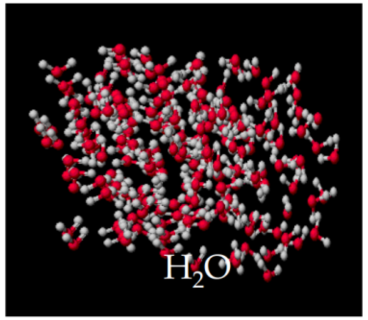


Garbage



Beauty

Emergence



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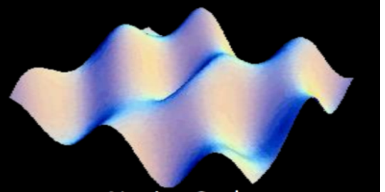
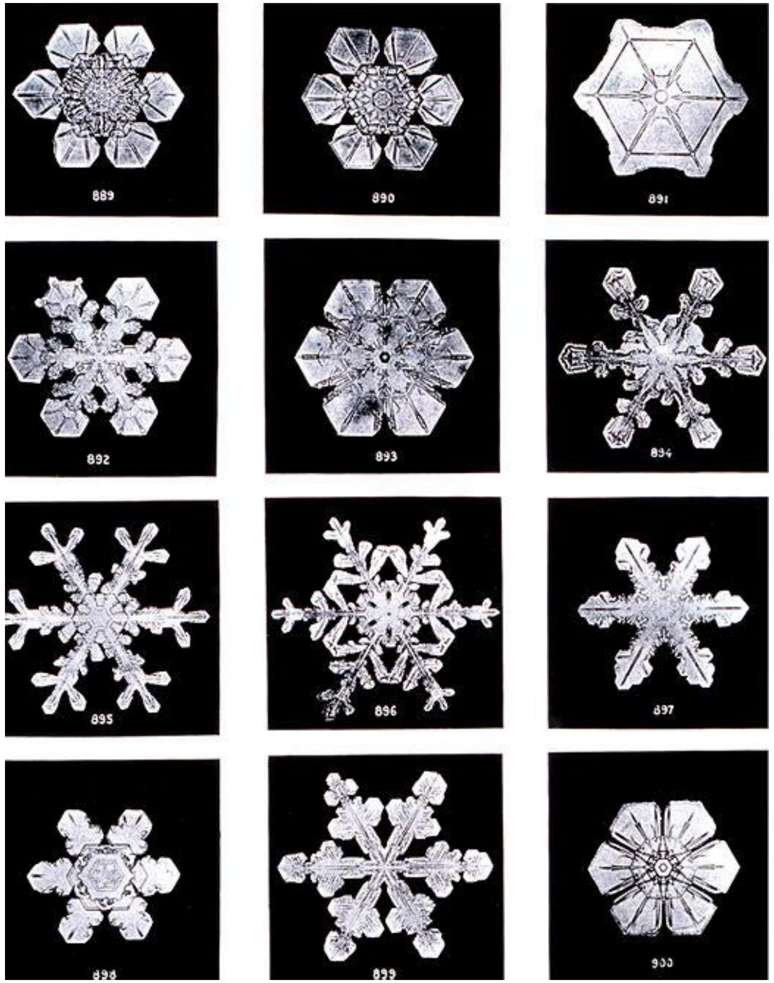


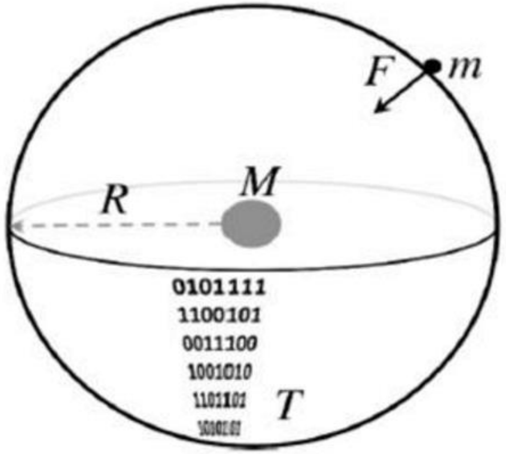
Navier-Stokes
Hydrodynamics

Beauty



Suy định luật Newton; Không cần năng lượng tối

- Ý tưởng chính ở đây là : theo nguyên lý toàn ảnh (holographic principle) thì thông tin điều khiển các hiện tượng vật lý, thông tin xác định vị trí mà ta gán cho hạt. Mọi thông tin có thể phân theo « bit ».Bản thân thông tin có bậc tự do riêng (own degree of freedom) mà chúng ta có thể nối liên với năng lượng toàn phần của hệ nhờ nguyên lý phân đều (equipartition principle) năng lượng.Nhờ entropy + nguyên lý toàn ảnh mà chúng ta thu được định luật Newton.
- … Tác giả (cũng) thu được phương trình Einstein nhờ entropy +nguyên lý toàn ảnh (holographic principle) mà không nói đến vật chất tối cũng như năng lượng tối



Hình 1. Một màng toàn ảnh (screen holographic) bao bọc một phân bố khối lượng.Trên màng là thông tin về mọi thứ nằm trong biên.

Tổng khối lương M sẽ là

$$M = \frac{1}{2}\int_S T dN$$

Viết lai thế hấp dẫn qua vector Killing và áp dung định lý Stokes và hệ thức

$$\nabla^a \nabla_b = -R_a^b \xi^a$$

ta thu được khối lương là

$$M = \frac{1}{4\pi G}\int_\Sigma R_{ab} n^a \xi^b dV = 2\int_\Sigma \left(T_{ab} - \frac{1}{2} T g_{ab}\right) n^a \xi^b dV .$$

The Universe as Quantum Computer

- The inability of classical digital computers to reproduce quantum effects efficiently makes it implausible that the universe is a classical digital system such as a cellular automaton.
- However, all observed phenomena are consistent with the model in which the universe is a quantum computer, e.g., a quantum cellular automaton.
- The quantum computational model of the universe explains previously unexplained features, most importantly, the co-existence in the universe of randomness and order, and of simplicity and complexity

arXiv:1312.4455v1 [quant-ph] 16 Dec 2013

The Universe as Quantum Computer

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December 17, 2013

Abstract

This article reviews the history of digital computation, and investigates just how far the concept of computation can be taken. In particular, I address the question of whether the universe itself is in fact a giant computer, and if so, just what kind of computer it is. I will show that the universe can be regarded as a giant quantum computer. The quantum computational model of the universe explains a variety of observed phenomena not encompassed by the ordinary laws of physics. In particular, the model shows that the the quantum computational universe automatically gives rise to a mix of randomness and order, and to both simple and complex systems.

- MONSTER

people.virginia.edu/~mah7cd/Math552/**Monster.ppt**

Monster – the discover of the fourth group class that links to String theory and maybe – Emergent

- Discovery of the Monster came out of the search for new finite simple groups during the 1960s and 70s

Steps to discovering the Monster:

1. Émile Mathieu's discovery of the group of permutations M24
2. discovery of the Leech Lattice in 24 dimensions
3. J.H. Conway's discovery of Co1 (Conway's largest simple group)
4. Bernd Fischer's discovery of the Monster

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Overview of the Monster

- Largest sporadic group of the finite simple groups
- Order = $2^{46} \cdot 3^{20} \cdot 5^{9} \cdot 7^{6} \cdot 11^{2} \cdot 13^{3} \cdot 17 \cdot 19 \cdot 23 \cdot 29 \cdot 31 \cdot 41 \cdot 47 \cdot 59 \cdot 71$

  = 808017424794512875886459904961710757005754368000000000
- Smallest # of dimensions which the Monster can act nontrivially = 196,883

Griess's Construction of the Monster

- 2 cross sections of the monster: Conway's largest simple group (requiring 96,308 dimensions) and the Baby Monster

Simple group acting on the Monster splits the space into three subspaces of the following dimensions:

$$98{,}304 + 300 + 98{,}280 = 196{,}884$$

Construction (cont.d)

- 98,304 = 2^{12} * 24 = space needed for the cross-section
- 300 = 24 + 23 + 22 + …+ 2 + 1 = triangular arrangement of numbers with 24 in the first row, 23 in the second row, etc.
- 98,280 = 196,560/2 which comes from the Leech Lattice where there are 196,560 points closest to a given point and they come in 98,280 pairs

Moonshine connections

the Monster's connection with number theory

1. The j-function:

$j(q) = q^{-1} + 196{,}884q + 21{,}493{,}760q^2 + 864{,}299{,}970q^3 + 20{,}245{,}856{,}256q^4 + \ldots$

Character degrees for the Monster:

	Let,
1	$= m_1$
196,883	$= m_2$
21,296,876	$= m_3$
842,609,326	$= m_4$
18,538,750,076	$= m_5$

Let the coefficients of the j-function = j_1, j_2, j_3, j_4, j_5 respectively

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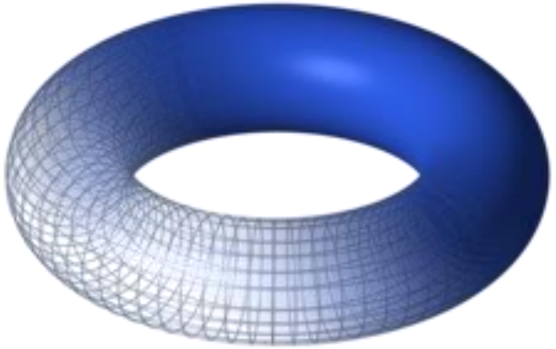
$j_2 = m_1 + m_2$

$j_3 = m_1 + m_2 + m_3$

$j_4 = m_1 + m_1 + m_2 + m_2 + m_3 + m_4$



2. J-function and Modular Theory

all prime numbers that could be used to obtain other j-functions:

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 41, 47, 59, 71

= prime numbers that factor the order of the Monster

Rationale:

modular group (allows one pair of integers to change into another) operates on the hyperbolic plane

→ surface is a sphere when the number is one of the primes above, otherwise it would be a torus, double torus, etc.

Moonshine Module: infinite dimensional space having the Monster as its symmetry group which gives rise to the j-function and mini-j-functions (Hauptmoduls)

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3. String Theory

number of dimensions for String Theory is either 10 or 26

- a path on which time-distance is always zero in a higher dimensional (> 4) space-time (Lorentzian space) yields a perpendicular Euclidean space of 2 dimensions lower

  ex. 26-dimensional Lorentzian space yields the 24-dimensional Euclidean space which contains the Leech Lattice

Leech Lattice contains a point

(0,1,2,3,4,…,23,24,70)

time distance from origin point in Lorentzian space

$$0 = 0^2 + 1^2 + 2^2 + \dots + 23^2 + 24^2 - 70^2$$

→ this point lies on a light ray through the origin

Borcherd said a string moving in space-time is only nonzero if space-time is 26-dimensional

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4. another connection with number theory

Some special properties of the number 163

a. $e^{\pi\sqrt{(163)}}$ = 262537412640768743.99999999999925 which is very close to a whole number

b. $x^2 - x + 41 = 0$ has √(163) as one of its factors

$x^2 - x + 41$ gives the prime numbers for all values of x between 1 and 40

Monster: 194 columns in characteristic table which give functions

163 are completely independent

"Understanding [the Monster's] full nature is likely to shed light on the very fabric of the universe." Mark Ronan

- LEECH LATTICE

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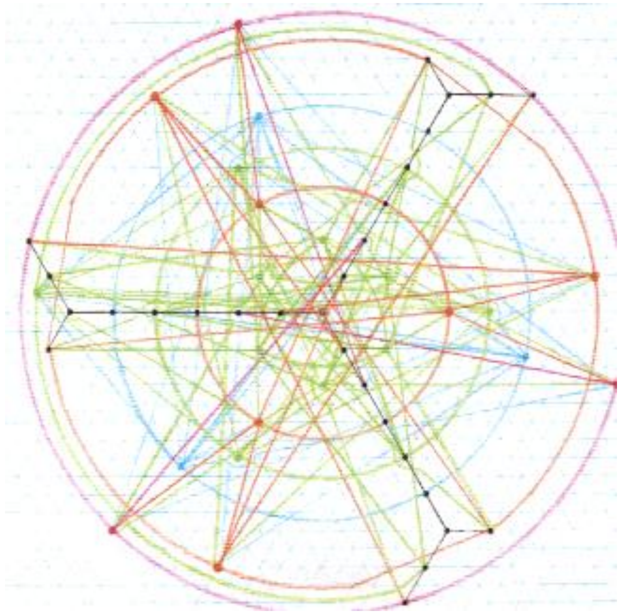
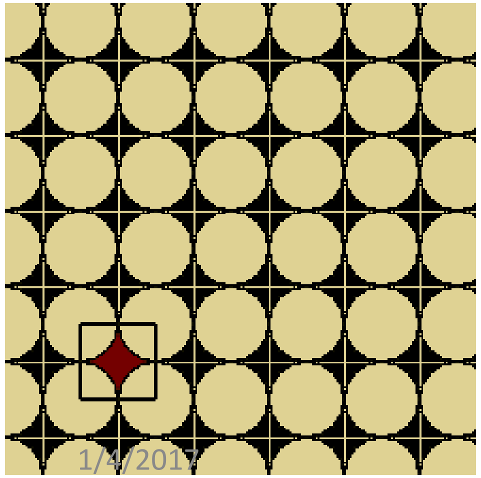


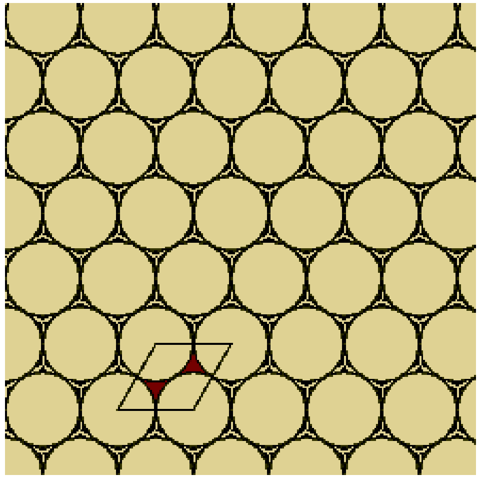
In 1964 Leech published a paper on sphere packing in eight or more dimensions. It contained a lattice packing in 24 dimensions.

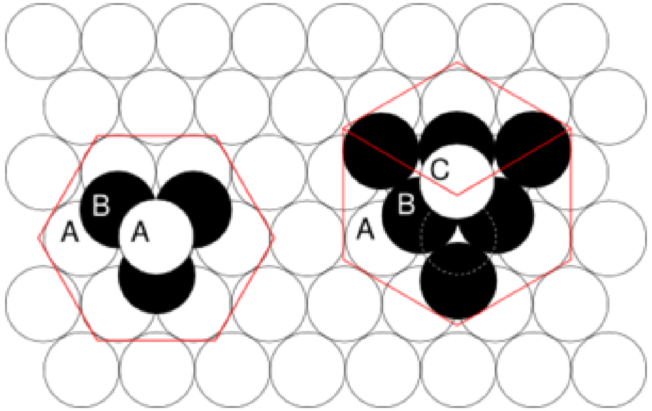
In 1965 he submitted a supplement to the paper giving a packing in 24 dimensions.

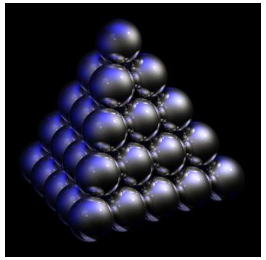
He did not have the group theory skills necessary to prove his conjectures of the symmetry of the group, so he sought the help of John Conway.

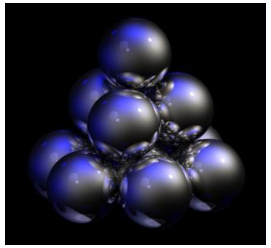
A lattice with no elements of length equal to 2, thus making it the tightest lattice packing of spheres in 24 dimensions.







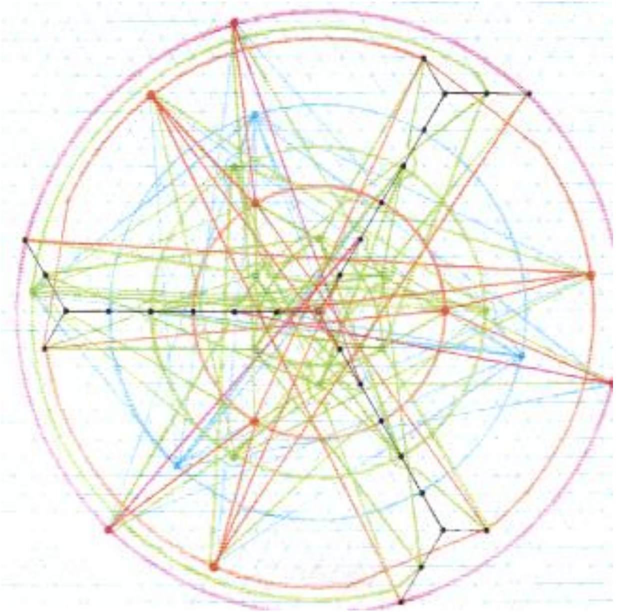




The Leech lattice

The points of the Leech lattice are the centers of spheres, each touching 196,560 others with the following list of properties:

- Unimodular = it can be generated by the columns of a certain 24x24 matrix with determinant 1
- Even = the square of the length of any vector in the leech lattice is an even integer
- The last condition = the unit balls at the points in the leech lattice do not overlap. Each is tangent to 196,560 neighbors and thus is known to be the largest number of non-overlapping 24-diemensional unit balls that can simultaneously touch a single unit ball (compare with 6 in dimension 2 as the max number of pennies which can touch a central penny).



Leech Lattice and representation of bit

- Bits are bits when they can reserve the fidelity through interaction.
- The representation must be able to cancel noise.
- Leech Lattice is the most representation (thus far) to present bit with highest density where 196,560 points are equidistant from the origin.

→ Conjecture of ***Universe digital copy***

Universe digital copy conjecture: representation of universal information

- Let's construct a universe digital copy that represent precisely the universe and call this T (Turing), now look at T:
  - T has the complexity of 1 (cannot be shorter)
  - T's code (can be in bit, qbit or wbit) should be the most optimized representation because it contains the whole universe, at the same time this coding must be intact despite whatever noises.
  - Hence T's representation if formulated in n-dimensional must have a density equal to 1.
- Now we return to the Leech Lattice to see that in the mathematical space, 24-dimension Leech Lattice is **probably** the most optimum coding that fits T.
- The conjecture goes: *Universe digital copy is represented in 24-dimensional mathematical model.*
- The next question is what differentiate T and our U and how can we construct T, knowing that it's possible at 24D. This is where we need 2 other dimensions the job is to emerge T from U and that's the emergent model

Emergent Transformation Conjecture: the math of emergent

- Theorem — Every finite simple group is isomorphic to one of the following groups:
  - A cyclic group with prime order; (Cyclic transformation)
  - An alternating group of degree at least 5; (addition transformation)
  - A simple group of Lie type, including both: (Continuous transformation)
    - the classical Lie groups, namely the simple groups related to the projective special linear, unitary, symplectic, or orthogonal transformations over a finite field;
    - the exceptional and twisted groups of Lie type (including the Tits group).
  - One of the 26 sporadic simple groups. (Not sure transformation)
- The conjecture goes: emergent transformation is from sporadic simple groups transformation.

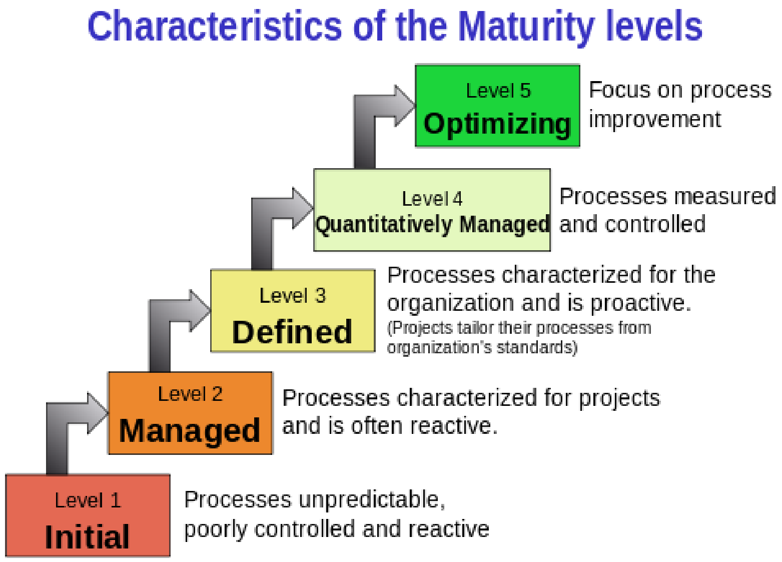
Potential applications: Deep Learning; Capability Transformation using Enterprise Architect

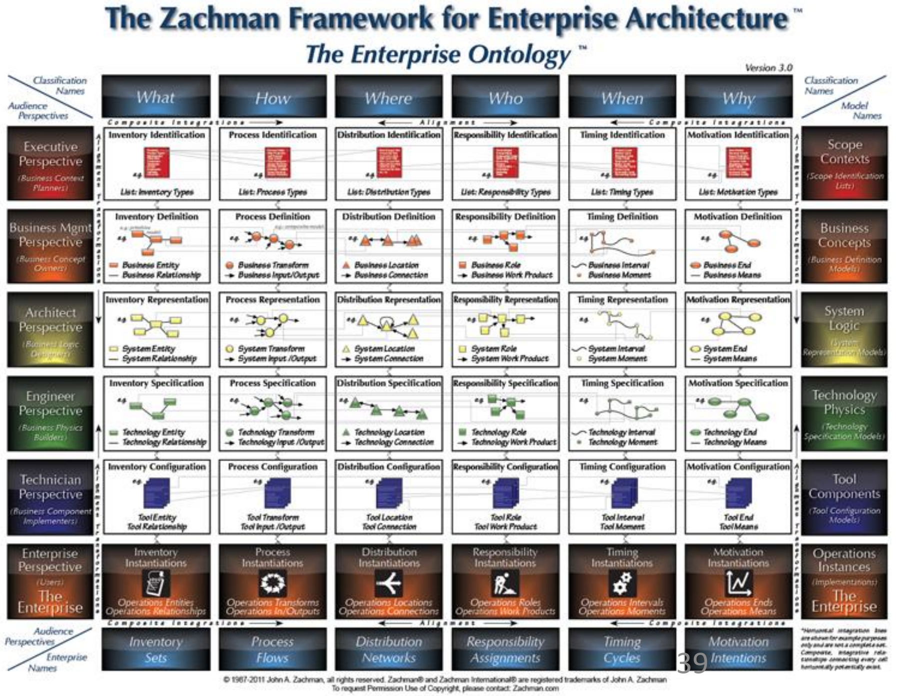
Deep learning

- There is currently no math model underlining deep learning, seems like with unlabeled data feeding in to n-layer neural network, Google can do magic like translation and voice recognition. (Refer to Cats problem from Le Viet Quoc)
- No one knows based on what math model, the optimal neural network is selected and weighted.
- It's possible that emergent math model can provide a short-cut to construct these model therefore shorten the learning process.

Capability transformation

- Sustainable development equals to capability maturing – any other shortcut is expensive
- Org Capability maturing is a transformation process that involves very complicated stakeholders and processes (enterprise architecture – enterprise ontology)
- Transforming EA/EO is an effective way to transform organization.
- Disruption equals to Emergent transformation.
- By Engineering the Emergent transformation, organization can disrupt to the next level (!?)





What's in it for us: Information science, getting ready for Industry 4.0

Information science

- It’s possible for Vietnam with lots of IT people to go deeper into Information science, forming a School (of thoughts) in this field
- It’s theory but also very closed to application
- The investment is modest
- The experts are available (overseas)
- The application are needed in many fields: AI, Cyber Security ….
- And there are many open problems to solve – opportunity to get in to the world map of science

Industry 4.0

- Emergent transformation is a possible path for Vietnam to disrupt into Industry 4.0 without blind hope
- AI, Deep Learning … are the heart of Industry 4.0
- So the research on Emergent transformation can be applied at different level:
  - Strategy: Disruptive strategic alignment
  - Process: Enterprise Architecture
  - Operation: AI, deep learning.

Conclusion

- It’s interesting time to explore Information theory
- Conjectures may turns out Truth resulting in synergy of Physics, Maths and Info.
- There are potential applications for Vietnam
- There are opportunities to research & disrupt

- Let’s discuss and drill