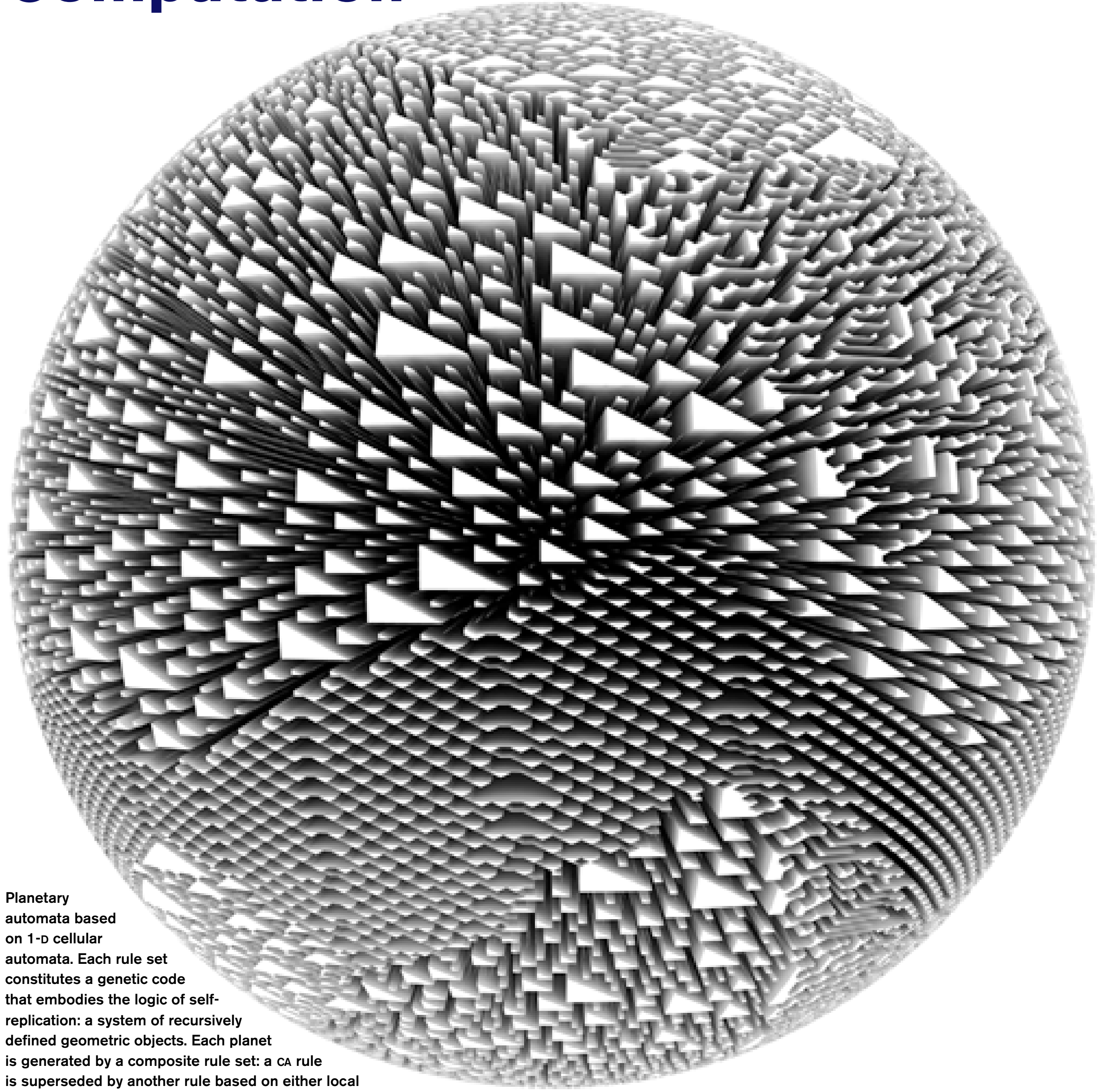
Metaphysics of Genetic Architecture and Computation



Planetary automata based on 1-D cellular automata. Each rule set constitutes a genetic code that embodies the logic of self-replication: a system of recursively defined geometric objects. Each planet is generated by a composite rule set: a CA rule is superseded by another rule based on either local conditions or random instantiation. The density of each sphere displayed here is the result of a mere 300 generations, which is exceedingly small in relation to the potentially infinite number of generations that each planet can embody. (CA programming and modelling by Kevin Sipes.)

Karl Chu ruminates on the far-reaching impact that the convergence of computation and biogenetics will have on the unfolding history of man and nature. Could the world be 'moving into the so-called Post-Human Era, which will bring forth a new kind of biomachinic mutation of organic and inorganic substances'? How can architects reconfigure the practice of their discipline in order to meet the demands of this computational and biogenetic revolution?

'All is algorithm!'

Gregory Chaitin[1]

With the dissolution of the last utopian project of Man in the name of Communism, the great spectre that once haunted Europe and the rest of the world has all but vanished, leaving in its wake an ideological vacuum that is now being filled by the tentacles of globalisation with its ecumenical ambition. As humanity has become mesmerised by the triumphant spell of capitalism, what remains less apparent in the aftermath of this dissolution is that the world is moving incipiently towards a threshold that is far more radical and fantastic than any utopic vision since the dawn of the Enlightenment. Once again, the world is witnessing the rumblings of a Promethean fire that is destined to irrupt into the universe of humanity, calling into question the nature and function of life–world relations as they so far have existed. These rumblings, stemming in large measure from the convergence of computation and biogenetics in the latter part of the 20th century, have already begun to invoke gravid visions of the unthinkable: the unmasking of the primordial veil of reality.

The evolution of life and intelligence on Earth has finally reached the point where it is now deemed possible to engender something almost out of nothing. In principle, a universe of possible worlds based on generative principles inherent within nature and the physical universe is considered to be within the realm of the computable once quantum computing systems become a reality.[2] For the first time, humankind is finally in possession of the power to change and transform the genetic constitution of biological species, which, without a doubt, has profound implications for the future of life on Earth. By bringing into the foreground the hidden reservoir of life in all its potential manifestations through the manipulation of the genetic code, the unmasking or the transgression of what could be considered the first principle of prohibition – the taking into possession of what was once presumed to be the power of God to create life – may lead to conditions that are so precarious and treacherous as to even threaten the future viability of the species, Homosapiens, on Earth. At the same time, depending on how humankind navigates into the universe of possible worlds that are about to be siphoned through computation, it could once again bring forth a poetic re-enchantment of the world, one that resonates with all the attributes of a premodern era derived, in this instance, from the intersection of the seemingly irreconcilable domains of logos and mythos. Organically interconnected to form a new plane of immanence that is digital, computation is the modern equivalent of a global alchemical system destined to transform the world into the sphere of hyper-intelligent beings.

The power of computation is already evident in the fact that in less than 70 years since the inception of the Universal Turing Machine,[3] it has ushered in the Information Revolution by giving rise to one of the most significant and now indispensable phenomenon in the history of communication: the Internet or, what could also be characterised as the universe of the Adjacent Possible. Stuart Kauffman defines the Adjacent Possible as the expansion of the networks of reaction graphs within an interactive system into the neighbourhood domain of connectivity which until then remain only in a state of pure potentiality. He suggests that: 'The Universe has not explored all possible kinds of people, legal systems, economies or other complex systems,' and that 'autonomous Agents tend to arrange work and coordination so that they are expanding into the Adjacent Possible as fast as they can get away with it.'[4]

Like every phase transition, the Internet marks a new world order by reconfiguring the planet with a virtual, albeit an interactive, matrix that is becoming increasingly spatial, intelligent and autonomous: a global self-synthesising organ bustling with neural intelligence possibly detectable from every corner of the Milky Way and beyond. It is at the level of the construction of possible worlds that the implications for architecture are most pronounced. The thesis that will be advanced in the latter part of this paper is that architecture is becoming increasingly dependent on genetic computation: the generative construction and the mutual coexistence of possible worlds within the computable domain of modal space.

Yet, what is the nature of computation that is destined to change the world, including architecture? No instrumental concept or logic of implementation since the invention of the wheel has fostered so much enthusiasm and promise as computation. Beyond the normative conception of computing machines as mere instruments for calculation, fabrication and communication, it is important to recognise the nature of the underlying ambitions of computation and its relation to architecture. As controversial and provocative as it may seem, the underlying ambitions of computation are already apparent: the embodiment of artificial life and intelligence systems either through abstract machines or through biomachinic mutation of organic and inorganic substances and, most significantly, the subsequent sublimation of physical and actual worlds into higher forms of organic intelligence by extending into the computable domain of possible worlds. At the most prosaic level, however, computation, like natural languages, deals with information in its most general form. Computation functions as manipulator of integers, graphs, programs and many other kinds of entities. But in reality, computation only manipulates strings of symbols that represent the objects.

It is not surprising that the origin of computation lies in an attempt to embody instrumental reason in an abstract machine along with the attendant drive to encode the logic of life and the world around us in all its manifestations.

It should also be pointed out that, according to the late Richard Feynman, computing systems could be constructed at the atomic scale: swarms of nanobots, each functioning in accordance to a simple set of rules, could be made to infiltrate into host organisms or environments including the human body. In its simplest form, computation is a system that processes information through a discrete sequence of steps by taking the results of its preceding stage and transforming it to the next stage in accordance with a recursive function. Such an iterative procedure based on recursion has proved to be astonishingly powerful and is classified as belonging to a class of machines having universal properties.

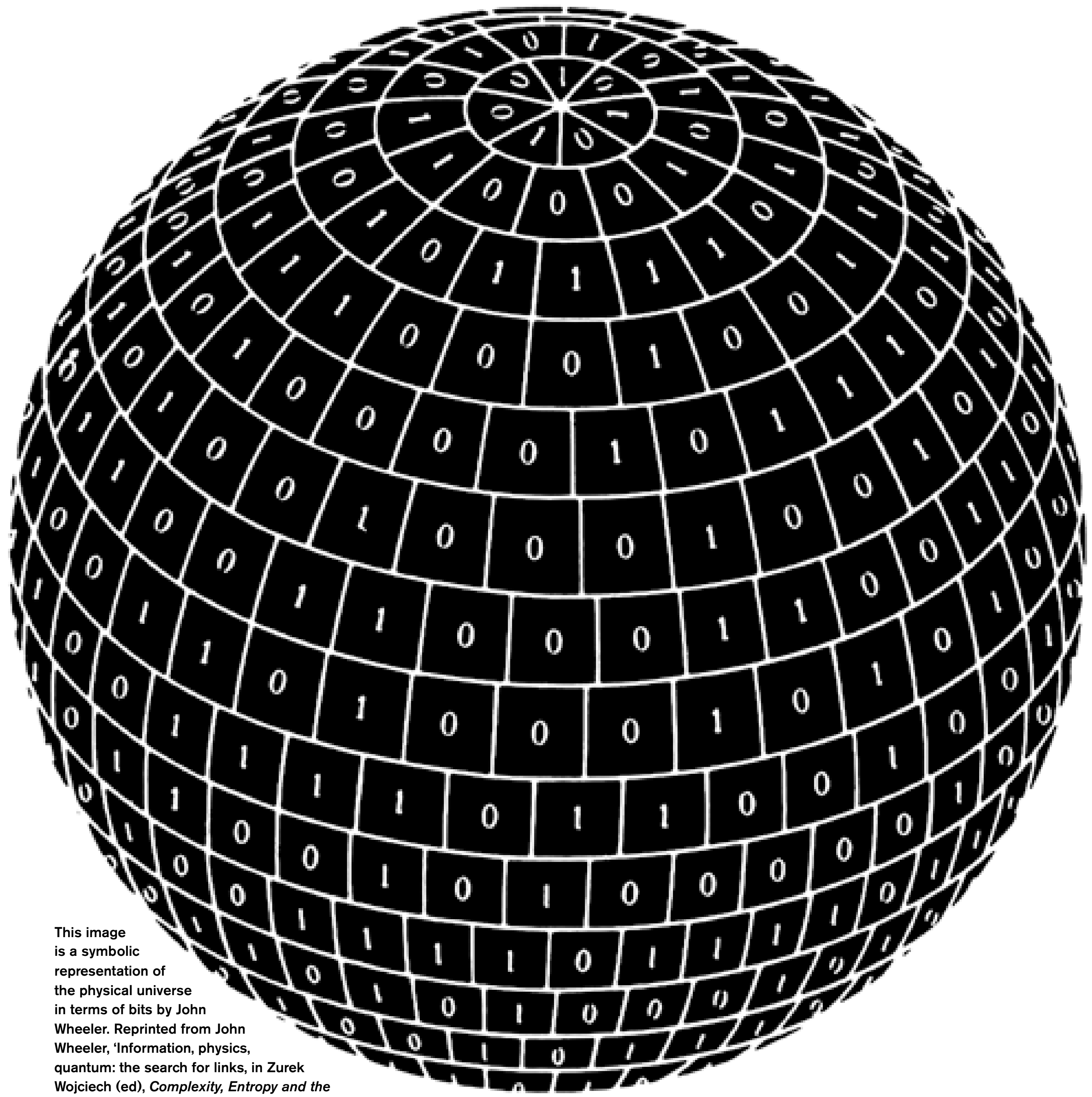
It is not surprising that the origin of computation lies in an attempt to embody instrumental reason in an abstract machine along with the attendant drive to encode the logic of life and the world around us in all its manifestations. The quest for a Universal Language[5] that could encapsulate all the attributes and functions necessary to inscribe the form and structure of all computable worlds is becoming one of the most persistent endeavours in the short history of computation. Since computation is about information processing at the most fundamental level, John Wheeler, the prominent American scientist influential to a whole generation of physicists in the latter half of the 20th century, initiated an information-theoretic conception of the world by stipulating that every item in the universe has at bottom – at a very deep bottom, in most instances – an immaterial source and explanation that is information-theoretic in origin.[6] The fact that computation is a physical process further stipulates the existence of a self-consistent logical loop: the laws of physics define the allowed mechanical operations and the possible activities of a Universal Turing Machine, which in turn determine which mathematical operations are computable and define the nature of solvable mathematics. In other words, the laws of physics generate the very mathematics that makes those laws computable. This discovery of the inextricable linkage that exists between computation and physics has led to the awareness that physical processes are in fact forms of computation, and nowhere is this understanding made more explicit than in Stephen Wolfram's formulation of the Principle of Computational Equivalence. Wolfram remarks: 'All processes, whether they are produced by human effort or occur spontaneously in nature, can be viewed as computations.'[7]

This proposition reflects a fundamental shift in the way we think about the nature of the physical universe; it is nothing short of a paradigm shift, which would not have been conceivable without an underlying thesis that enables the construction of such a worldview: the Church–Turing Thesis, as formulated by Alfonso Church and Alan Turing in the early part of the 20th century. According to Turing: 'Every "function which would naturally be regarded as computable" can be computed by the universal Turing machine.'[8]

Although the absolute veracity of the thesis cannot be decided by logical means, all attempts to give an exact analysis of the intuitive notion of an effectively calculable function have turned out to be equivalent. Each analysis offered has been proven to pick out the same class of functions, namely those that are computable by the Turing machine.

Parallel to the development of computation is the discovery of the DNA code in the early part of the 20th century, the significance of which has only begun to be realised with the completion of the Human Genome Project. Finally, with the convergence of computation and biogenetics, the world is now moving into the so-called Post-Human Era, which will bring forth a new kind of biomachinic mutation of organic and inorganic substances. Information is the currency that drives all these developments, and nowhere is this more apparent than in the words uttered by Craig Venter, the ex-CEO of Celera Corporation, which completed the human genome sequence: 'The goal is to engineer a new species from scratch.'[9]

Notwithstanding theological implications, this statement bluntly announces the unadulterated ambition of the biogenetic revolution. It is only a matter of time before the world will witness biomachinic mutation of species proliferating into every facet of what so far has been the cultural landscape of humanity. Architects take note: this is the beginning of the demise, if not the displacement, of the



This image is a symbolic representation of the physical universe in terms of bits by John Wheeler. Reprinted from John Wheeler, 'Information, physics, quantum: the search for links, in Zurek Wojciech (ed), *Complexity, Entropy and the Physics of Information (Sante Fe Institute Studies in the Sciences of Complexity Proceedings)*, Addison-Wesley Publishing Company (Reading, ma), 1989.

reign of anthropology, which has always subsumed architecture. Architecture, especially from the standpoint of its mythical inception, has always been a subset of anthropology: the expulsion of Minotaur, the beast, by entrapping it into the labyrinth built by Daedalus, the mythical architect at Knossos. The potential emancipation of architecture from anthropology is already affording us to think for the first time of a new kind of xenoarchitecture with its own autonomy and will to being. In order to break through the barrier of complacency and self-imposed ignorance on the part of the discipline, what is needed is a radicalisation of the prevailing paradigm of architecture, beyond retroactive manifestos, by developing a new concept of architecture that is adequate to the demands imposed by computation and the biogenetic revolution.

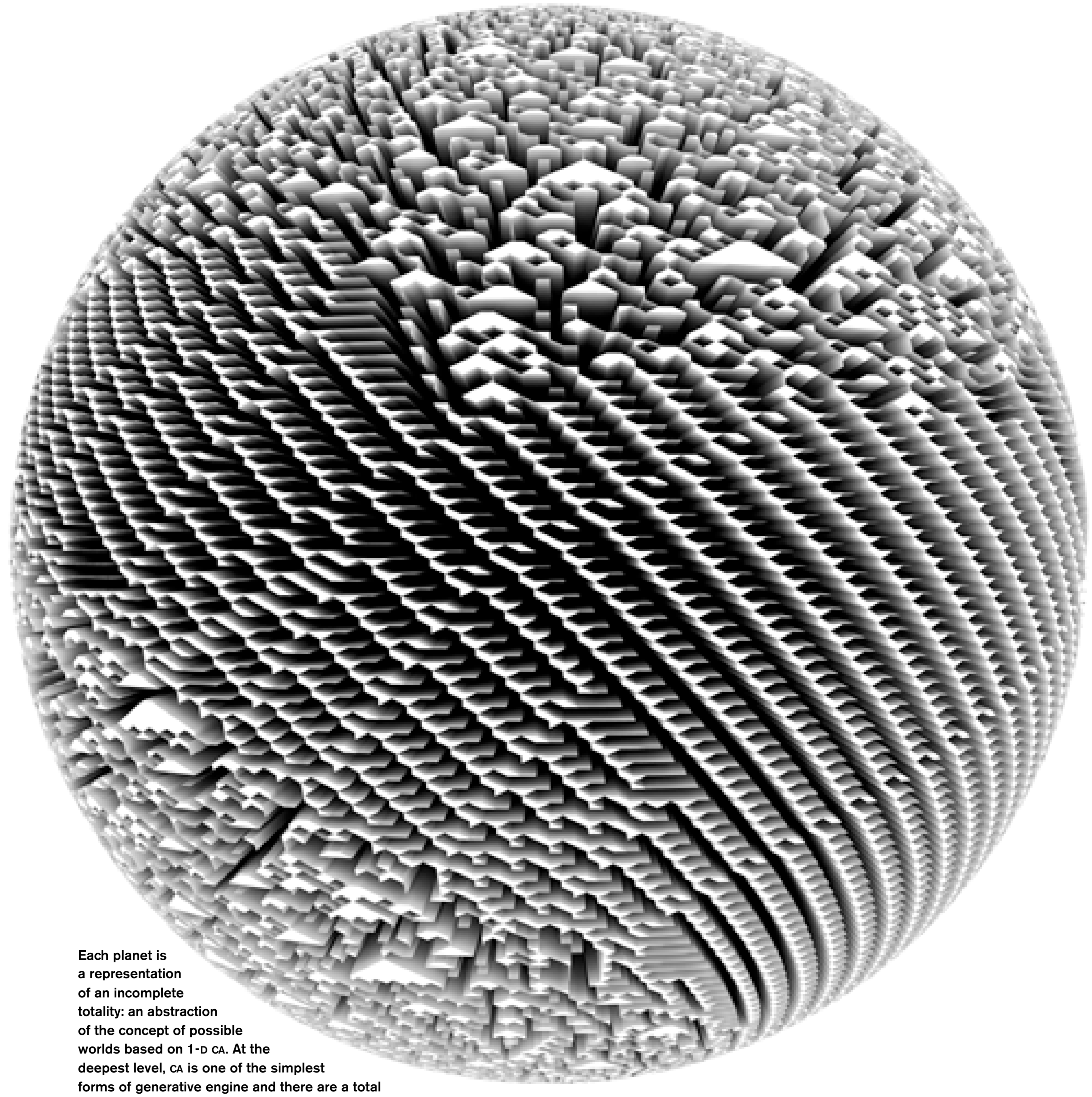
Within the contemporary landscape of architectural discourse there are two divergent trends with theoretical motivations: the morphodynamical and the morphogenetic systems approaches to the design and construction of buildings.

Even though architects have incorporated computing systems in the design and construction of buildings and environments, the phase of transmodernity that we are now in is perhaps best characterised by the use of computation still operating under the vestiges of the old paradigm. In other words, architecture has still yet to incorporate the architecture of computation into the computation of architecture. Within the contemporary landscape of architectural discourse there are two divergent trends with theoretical motivations: the morphodynamical and the morphogenetic systems approaches to the design and construction of buildings. These two systems are reminiscent of a strikingly similar problem that exists in modern biology, which is still attempting to synthesise the differences that exist between molecular biology, on the one hand, and developmental biology on the other. What is needed in architecture also is a similar synthesis of the two. After more than half a century of engagement with the Avant-Garde, the practice of architecture has become increasingly conscious of its embeddedness within the general economy of forces, relationships and the global economy. The morphodynamical approach, which has spurred two different methodological orientations in dealing with programmatic issues, is the more dominant of the two at the moment. The morphogenetic system is still more or less in its embryonic stage, even though it is by far the more fundamental and necessary since it deals with the construction of objects directly.

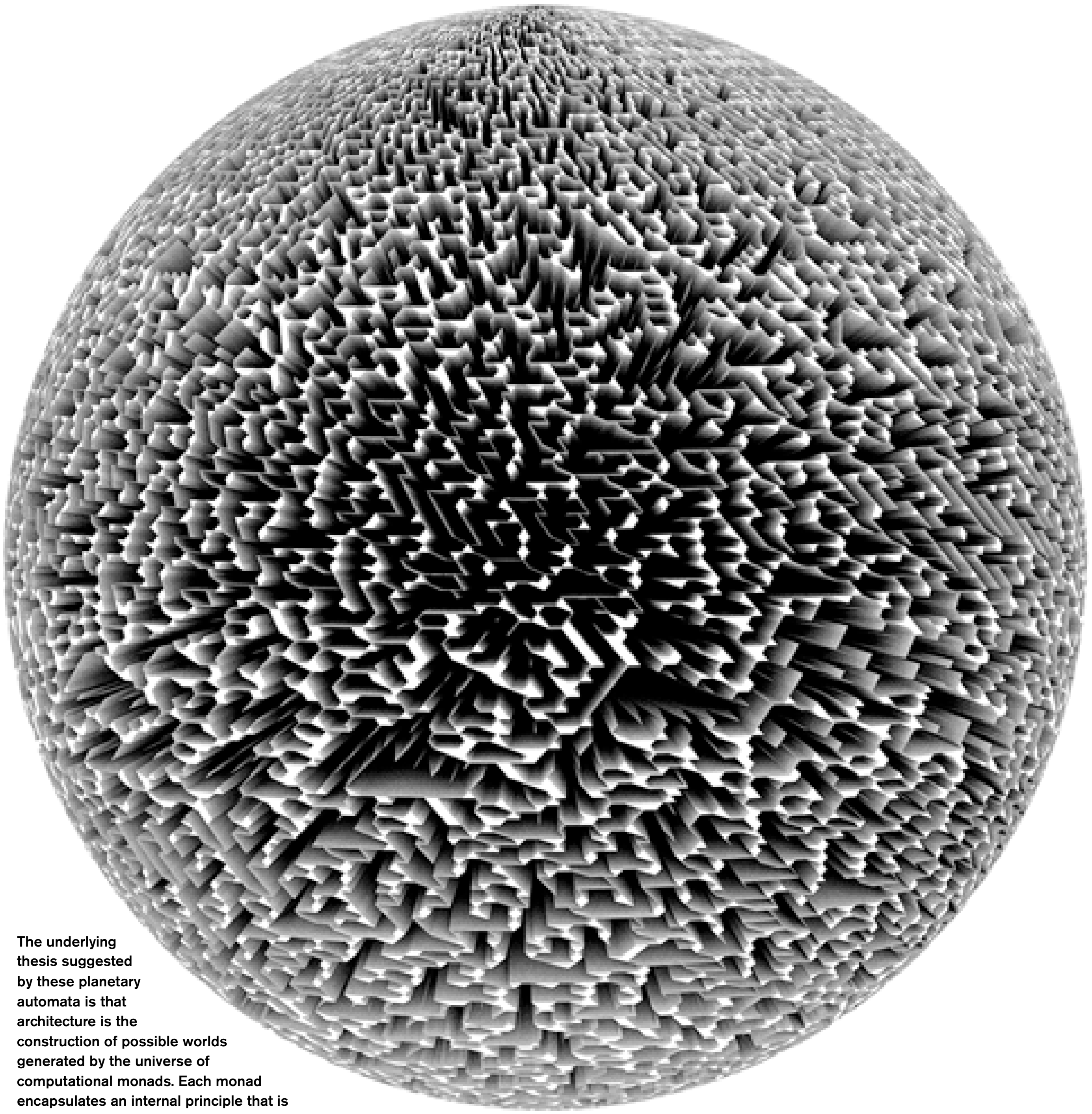
Having identified some of the salient features that are integral to dominant trends within contemporary architecture, as well as the nuanced relations that each of these trends have with regard to the phenomenon of globalisation, which is increasingly augmented and driven by the gift of Promethean fire that is now saturating the cultural universe of humanity with all forms of transgenic mutation, we are now in a position to articulate a more comprehensive theory of architecture, one that is adequate to the demands imposed by the convergence of computation and biogenetics in the so-called Post-Human Era: a monadology of genetic architecture that deals with the construction of possible worlds. As we now approach what Ray Kurzweil refers to as the Singularity,[10] the myth of matter, which underlies most theoretical and practical discussions of architecture, is about to be displaced by the myth of information. Contrary to Mies Van de Rohe's oft-quoted remark that architecture is the art of putting two bricks together, the emerging conception is that architecture is the art of putting two bits together, at least bits that are programmed to self-replicate, self-organise and self-synthesise into ever new constellations of emergent relations and ensembles.

The use of the term 'monadology' is based on the fact that genetic architecture is an extension and transformation of some of the propositions, especially those that define attributes and properties of relationships among monads, contained in Gottfried W Leibniz's *Monadology* (1714),[11] albeit without its theogony, into an architectural theory of world making. *Monadology* is one of the earliest attempts in sketching out a system of principles that generalises the nature of the world from an abstract point of view; it shares conceptual properties that are now deemed to be fundamental to the science and philosophy of computation. Even though Leibniz was impeded by the lack of conceptual and technical resources at the time,[12] his ideas nonetheless paved the way for the subsequent development of computation and, according to Gregory Chaitin, Algorithmic Information Theory[13] in the 20th century.

Leibniz's *Monadology* is arguably the earliest endeavour to propose what is now known as an open-source architecture based on the principles of philosophical genetics: the principle of generative condensation, the principle of combinatorial expansion, and the principle of the conservation of information. *Monadology* is a metaphysical treatise; Leibniz



Each planet is a representation of an incomplete totality: an abstraction of the concept of possible worlds based on 1-D CA. At the deepest level, CA is one of the simplest forms of generative engine and there are a total of 256 rules in 1-D CA, which together constitute a computational monad. Each monad therefore defines the virtual ontology of the set of possible worlds contained within a system of rules. Each sphere represents a proto-architectural universe that is potentially infinite in terms of variability and density with regard to its composition. (CA programming and modelling by Kevin Sipes.)



The underlying thesis suggested by these planetary automata is that architecture is the construction of possible worlds generated by the universe of computational monads. Each monad encapsulates an internal principle that is generative, and each generative system transmits and propagates hereditary information. Each monad is at once a self-replicating and self-organising system capable of constituting itself into a cohesive whole or a possible world: in other words, a monadology of genetic architecture.(CA programming by Chris Sandes; modelling by Christian Lange.)

defines each monad as a metaphysical point, an irreducible concept of an atomic entity that is endowed with an immaterial substance. Contrary to Leibniz and without the reference to God as the supreme creator of monads, a computational theory of monadology would instead qualify each monad as one BIT of information at the most irreducible level, and by extension a unit of a self-replicating system. It is based on this conception of a monad as a minimal unit of a self-replicating system that a monadology of genetic architecture is developed here.

Historically, genetic architecture can be seen as an extension and transformation of utopic ideas implicit within the Avant-Garde to create new worlds by drawing on new sciences and technologies. Genetics is a name coined by William Bateson in 1905 to encompass the whole of the study of heredity, but the term gene was introduced by the Danish botanist Wilhelm Johannsen, also around the same time, to account for the units within sex cells that determine the hereditary characteristics. The meanings of both terms, ‘genetics’ and ‘gene’, are sufficiently abstract and general enough to be used as concepts that have logical implications for architecture without being anchored too explicitly to biology. Implicit within the concept of genetics is the idea of the replication of heritable units based on some rule inherent within the genetic code, and embedded within the mechanism for replication is a generative function: the self-referential logic of recursion. Recursion is a function or rule that repeatedly calls itself or its preceding stage by applying the same rule successively, thereby generating a self-referential propagation of a sequence or a series of transformation. It is this logic, encoded within an internal principle, that constitutes the autonomy of the generative that lies at the heart of computation.

Even though genetic is a term derived from biology, it is used here as a generic concept based on the interconnected logic of recursion and self-replication whose philosophical underpinnings go far beyond the confines of molecular biology. It should therefore be noted that genetic architecture is neither a representation of biology nor a form of biomimesis; instead, its theoretical origins, insofar as genetic architecture is concerned, can be traced to John von Neumann’s invention of the cellular automaton and his ‘von Neumann architecture’ for self-replicating systems. From the early stages of the development of modern computing systems, von Neumann was proposing the idea of self-replication. Even though he participated in discussions leading to the development of the first electronic computer ever built – the ENIAC – von Neumann eventually came up with what is now known as the von Neumann architecture – the prototype for modern computing systems with its stored memory program. This addressed the idea of a machine that could manufacture itself: a robot that self-replicates and self-constructs copies of itself,[14] a notion that lies at the heart of biology: the essence of self-reproduction is organisation – the ability of a system to contain a complete description of itself and use that information to create new copies.

The von Neumann architecture for a self-replicating system is the ancestral and archetypical proposal, which consisted of two central elements: a Universal Computer and a Universal Constructor. The Universal Computer contains a program that directs the behaviour of the Universal Constructor, which, in turn, is used to manufacture both another Universal Computer and a Universal Constructor. Once finished, the newly manufactured Universal Computer was programmed by copying the program contained in the original Universal Computer, and program execution would then begin again. The von Neumann architecture is, therefore, a precursor to the architecture of a genetic system. AD

Notes

1 Gregory Chaitin, *Leibniz, Information, Math and Physics*, http://www.cs.auckland.ac.nz/CDMTCS/chaitin/kirchberg.pdf), 2003, p 9.
2 David Deutsch, ‘Quantum theory, the Church–Turing principle and the Universal Quantum Computer’, in *Proceedings of the Royal Society of London* A 400, 1985, p 3.
3 Alan Turing, ‘On Computable Numbers with an Application to the Entscheidungsproblem’, *Proceedings of the London Mathematical Society*, Ser 2, Vol 42, 1936. Alan Turing developed the Universal Turing Machine, an abstract machine in the logical sense of the term, in response to David Hilbert’s call for the resolution of the decision problem, or, Entscheidungsproblem, in mathematics.
4 Stuart Kauffman, *Investigations*, Oxford University Press (New York), 2000, pp 142–4. Kauffman’s concept of the Adjacent Possible was applied in the context of his investigations into the origin of life based on autocatalytic systems, which are derived from random interactions of nodes within Boolean networks. See http://www.paulagordon.com/shows/kauffman/.
5 Paolo Rossi, *Logic and the Art of Memory: The Quest for a Universal Language*, University of Chicago Press (Chicago, IL), 2000, pp 145–94.
6 John Wheeler, ‘Information, physics, quantum: the search for links’, in Zurek Wojciech (ed) *Complexity, Entropy, and the Physics of Information (Santa Fe Institute Studies in the Sciences of Complexity Proceedings)*, Vol VIII, Addison-Wesley (Reading, MA), 1989, p 5.
7 Stephen Wolfram, *A New Kind of Science*, Wolfram Research (Champaign, IL), 2002, p 41.
8 Alan Turing, op cit. Note: Apart from the analyses defined in terms of lambda-definability by A Church and recursiveness, there are analyses in terms of register machines by JP Shepherdson and HE Sturgis, EL Post’s canonical and normal systems, combinatory definability by M Schönfinkel and HB Curry, Markov algorithms, and Gödel’s notion of reckonability.
9 Craig Venter, ‘Supermicrobe Man’, *Wired*, No 10, 12 December 2002, p 191.
10 Ray Kurzweil, ‘The Singularity’, in John Brockman, *The New Humanists: Science At the Edge*, Barnes & Noble (New York), 2003, pp 215–32.
11 GW Leibniz and Nicholas Rescher, *GW Leibniz’s Monadology: An Edition for Students*, University of Pittsburgh Press, 1991.
12 Martin Davis, *The Universal Computer: The Road From Leibniz to Turing*, WW Norton & Company (New York), 2000, pp 180–7.
13 Chaitlin, op cit.
14 William Poundstone, *The Recursive Universe: Cosmic Complexity and the Limits of Scientific Knowledge*, Contemporary Books, Inc (Canada), 1985. See also: http://www.zyvex.com/nanotech/selfRepJBIS.html#vonNeumannArchitecture.