III-29. Representation of Order with Room for Doubt

Mahendra Kumar Jain: The Quarterly Review of Biology Vol. 78, June, 2003, p. 203-207. A Review of: **A New Kind of Science by** Stephen Wolfram: Champaign, (Illinois): Wolfram Research.

Author claims that this book will be the foundation of "a new kind of science." It is possibly justifiable as a claim in the form of a 1200-page advertisement about the enthusiasm of the author. Whether it receives a critical scrutiny of readers or not, I am sure it will find a place in most libraries. The book is "heavy" on hype and weak on guiding readers through the conceptual foundations. In any case, it is a kind of mix from which myths of marketing successes are made. The book is about generating patterns. Wolfram's perception is that these patterns, derived from defined rules, help him "see" the origins of the seminal issues: patterns in biology, laws of thermodynamics, Godel's incompleteness theorem, free will, and much more. The insights are certainly about representation of reality and its potential. That is what science is about. The idea of representation to extract the potential of reality is not new. Also, all methods potentially contribute, especially if we do not know what we are looking for.

Thought is about processing the perceived patterns of matter, energy, and information. History of human thought is about plights and platitudes for the representation of parts of perceived reality. Since the dawn of the Stone Age, almost a million years ago, "New Age" of human expressions has appeared many times over. Often, each age and "new order" coincides with the arrival of new technologies. Wider dissemination of technologies provides ever more ways of representing human concerns and insights. Useful representations enhance valid perceptions of shared knowledge to facilitate transition of thoughts into words and actions to address the concerns. In the process we discover Gods of things - big and small. With our zeal the better mousetrap is hailed revolutionary. But in the end, imageries and its products do facilitate perceptions of shared concerns.

Having said that, the work behind this volume and its antecedents are promising. Its conceptual core is based on the premise of Rule 110 of the Cellular Automata formalism for modeling the behavior of defined entities in a matrix. For obvious reasons, the use of computation to explore this conceptual space has grown during the last 30 years. Two key developments are critical here: Cheaper and more accessible computing power, and the realization that the traditional modeling methods have reached an asymptotic limit. Yet, from the book one would not gather that the ideas and conceptual framework have been around for centuries. They are also intrinsic in works going back several millennia.[1]

The computer-aided approach of Wolfram, at a simplistic level, is about the use of certain algorithms (available on several web sites) to visualize evolution of the behavior (patterns in a matrix) of defined bits and pieces. The approach bypasses the limitations of the more traditional analytical approaches where the equations are coded to harness the computer as a workhorse. The criteria and relations for the computing operations are built into the properties of the pieces and the programs. Computers can faithfully and reliably carry out thousands of such transformations (steps of operation within the program). The end results are remarkably enticing sets of visuals - a matrix with a mix of short and long-range order and disorder. Beyond this readers are on their own for finding the real world significance of what they started with and represented with the rules of their choosing. For example, the matrix may relate to distribution in space, or to the evolution of the patterns in time. To be fair, this theme, and the limitations that follow, apply to all tools of representation, including pottery, alphabets, brushstrokes, numbers, and a myriad of ideas about charting a rational course through the chaos of the observed and perceived reality. After all, if the defined pieces are based on reality, the potential lies in the abstract or what follows from the pieces. From there on it is the game of exploration limited by the level of observer-observed interactions. On one range of the scale it may lead to paradoxes and contradictions, and on the other to a valid perception of the "entire" reality.

How do we learn to realize the potential of a conceptual development? It happens very slowly. In the process, the representations often deteriorate into mere conventions and rituals. For example, consider the fact that zero was conceptualized in the Ganga Valley of North India about 5000 years ago. Then as now, it represents "nothing." But the conceptual node for this abstraction lies in: nothing of something or simply nothing or absolutely nothing? About 800 years ago, the Arab traders introduced zero to Italy. Use of zero, and the derived place-based counting system, was not accepted by the Italian merchants. In fact, it was banned in Europe, possibly for the same "reasons" as the use of metric system is not accepted even now in U. S. As a few people began to see the merit of the place-based numbers, the use of ten digits (including zero) is now an almost universally accepted convention.

Yet, the conceptual significance of zero has not permeated the psyche. Consider the way birthdays are counted in U. S. and most European countries. Most people still count and express their birthdays as if the first birthday is the "zeroeth" birthday! Misperceptions of zero as "nothing of something" underlie several paradoxes that puzzled the ancient Greeks. For example, Zano's paradox results if one does not distinguish between the space as the infinite of nothing, and the universe as the finite of something. What is the difference? Universe will have a boundary – at least as far away as the light has traveled. On the other hand, space as the infinite of nothing (emptiness) does not have a boundary. Ancient Greeks carved space arbitrarily "as a place or a bowl" which is also a common dictionary definition).

In the Greek inspired thought, based on certain arbitrary criteria, the node is often set as an arbitrary zero. As the point of interaction of axes (the assumed Cartesian reality) the "origin" acts as the fulcrum for affirmation and negation. On the other hand, in the Nay "nothing" is synonymous with non-existent or emptiness of boundless space. This is a critical property that is built into definitions and starting points of the concepts and programs from which the worldviews emerge. Ad hoc modes of representation ultimately limit their utility. Representation of nodes calls for caution to entertain logical doubt and alternatives. To appreciate this line of thought, readers may also wish to mull over another related question: Can zero (nothing) be the minimum of anything? Defined criteria are used for a logical representation of the observed properties. As promulgated for several millennia[1] interpretation of the observed, and therefore of the represented entity, depends on the quality of the observer observed interaction. Confronted with something complex, novices may be tempted into thinking that the underlying mechanism must be complex as well. This has kept us in the grip of omniscience. But the insight that the behavior of simple parts can produce complex behavior is not new. With this realization most of us have come to appreciate that we can take count of the universe in terms of the 10 symbols for the representation of the numbers. Of course, it is done with a full realization that it is only a representation - albeit a useful one. Elements of this approach are also built into the Euclidean theorems. Search for the underlying simplicity has also guided the experimental sciences out of the grip of the mind-set of alchemy. We have come to define the building blocks to peer into complexity. Be warned that we have dealt with artifacts of parts as well as the incomprehensible whole before. Such detours are integral part of the individual and collective thought processes. The Cyber Age dawned with the Boolean representation of the ordered universe. It is made up of only 0 (*nothing*) and 1 (*something* and *anything*). Cheaper computing power has created a tool for new ways of modeling more complex and dynamic systems. Many technologies for generating patterns have emerged. A hallmark of such methods is that beginning with a defined starting point (node); complex system emerges from relatively simple parts operated in a large number of steps with relatively simple rules. As many have pointed out before, far more information lies in the way a pattern grows and evolves during the computation. At this stage it is useful to consider the fact that the fidelity and efficiency of the biomolecular reactions is conceptually similar to the computation steps. As in biological evolution and growth, the results of the successive trials are based on the local conditions. This is akin to harnessing the wisdom of the ends, means, and paths.

Analytical representations of classical mathematics have been concerned with perfect order epitomized by equations.

Ancient Greeks were infatuated with symmetries and perfect shapes. Following such leads classical physics and engineering extracted useful constants and parameters from such conceptions. The approach has also guided modern physics, although disconnect seems to have developed on the way reconciling quantum and relativistic worlds. There is hope that someday the major questions in biology, an epitome of complexity, would succumb to such representations.

The realm of analytical deductive logic is of the perfectly ordered states: all pieces seek perfect equilibrium through steps in a defined order. Also, the rules do not change during the change of the state of order. But the real world is neither perfectly ordered, nor is it in a state of perfect disorder. In fact, such extremes hardly ever exist. For example, as a basis for the interaction of the matter with energy, the chaos lies at the conceptual foundations of thermodynamics. The Boltzman distribution of the states along the energy coordinates also follow from the chaos in the gases. In other words, counter to the adages of physical chemistry textbooks, even the behavior of gases can only be described in terms of local chaos. This insight also bears on the interaction of information because the Boltzman relation is key to defining entropy, which is also the basis for quantification of information. The information content of perfectly disordered state, the state with the highest entropy, is zero. So a critical concern would be if we ever start or end up at anything approaching such a zero. Since we do not have a measure of this zero node, we express only the changes in all such quantities or measures of energy and information.

In the other direction, if we have a defined end point in mind, the socioeconomic models and game theoretic approaches force convergence as a "goal." It is called the equilibrium or the steady-state assumption. Beginning with relaxation of a perturbation, the path to a solution, as well as the goal, is built into the starting assumptions, such as the homogenized global conditions at the start and the equilibrium conditions at the end. Following the earlier leads, Wolfram has championed the use of the method that has come to be known as "cellular automata." A good part of the book discusses what follows from a very narrow slice of this world. Illustrations in the volume tell only the end result. Like the fractal representations for the search of order in apparent chaos, this genre of programs explore the balance between the extremes of order and disorder. Utility of such models lies in the fact that often the patterns converge to an order or diverge into a disorder.

The term chaos is useful to describe the real world complexity. It is often defined as the order interspersed with disorder, and vice versa. Although equations have provided insights into the chaotic world, a satisfactory intuitive and analytical grasp of such reality has not emerged. Traditional biology has celebrated the theme of chaotic order in complex forms (shell) and functions (symmetries, lifecycles). In the early stages, inferences from analytical approaches are intrinsically limited. However, the problem is addressed as more suitable representations of the whole emerge. Yet, a synthesis of remarkable simplicity has emerged at the level of the genes, protein structure, and function. Of course, many more complex systems and behaviors remain to be discerned, understood, and exploited.

Complex phenomena emerging from simple rules are widely recognized. It is the basis on which the universe is built with only 92 building blocks. In fact, much of the biomass is based on 10 elements. Even after 50 years, it is mind-boggling to me that coding of the genetic information ultimately depends on the hydrogen-bonding between the base pairs in DNA. Self-organization of simple amphiphiles into membranes is possibly the first step toward evolution of the cell as building block for all life forms. Although the building blocks are now reasonably well understood, the unresolved other half of the genetic information is still unresolved as the problem of protein folding. The problem of emergence is also impressive from another perspective. The human organism starts with about 100 million specification in the genome that code for less than 30,000 specific functions. Yet, a developed brain can deal with information that would require millions of times more computer codes.

There has been considerable hype, hubris, and enthusiasm about the patterns of chaos produced through a variety of formalisms including the Wolfram's work. Without dwelling into such superficialities, or going into the underlying specifics, deeper concerns remain to be addressed about what such methods represent in terms of the formal thought. Current mathematics has the limitation of working within a rather strict set of rules. To assure validity, the trajectories of the assumptions, hypotheses and solutions are to be spelled out. Proofs have to be checked to assure that the logic space is unequivocally defined the way one intended to do in the first place. The process can be daunting, tedious, and time consuming. The devil often lurks in the details. For example, in full recognition of the limitation of human mind, and tribute to the scrutiny by the peers, the hidden assumptions in the Euclidean proofs continued to be discovered until the 20th century. The modern version of this representation is vastly different than what Euclid articulated and what has been taught to school children for the last 2200 years.

Cellular Automata and related methods for modeling patterns circumvent many of the problems of classical mathematics through computation tricks. It is too early to judge the liabilities of the method. Admittedly the whole process is reality based. The search trajectory does not suffer from the vagaries of the human perception. Still, one has to worry about what is built into the assumptions and definitions (starting points, nodes). Charting the logic space, built into the assumptions of the properties and the relations, is a slow process. Even the significance of the universals lies in the practice, just as "the proof of the pudding is in the eating."

Much of the deeper significance of the work of Wolfram lies in the fine print or what is not explicitly stated. In my opinion, it lies in the logic space of Rule 110 and some other related rules. The "programs" explored by Wolfram show that "simplicity begets complexity." The key finding goes well beyond reproducing pigmentation patterns of zebra or leopard stripes. Most classes of automaton converge into discernible ordered patterns, or fall off into abyss of randomness. Beyond these, Wolfram has identified the patterns produced by repeated application of the same rules to the Class 4 automaton that do not repeat themselves. The resulting pattern is neither regular nor completely random. It has some order, but the pattern is never predictable even when carried through a very large number of iterations. In short, the overall pattern is random by the statistical criteria, yet the pattern has some discernible order and trend. The result is surprising for a repetitive and deterministic process. Most of the ordinary mathematical criteria appear to have been adequately considered and characterized by Wolfram.[2]

To recapitulate, surprising though it is, the results are not unexpected. Wolfram's insight should be useful for the understanding of the emergence of hierarchies, and also of the properties and behaviors that emerge from a hierarchy. The search through a thought process is guided by the belief that simple solutions can be found to complex problems. If the past is any guide, the cellular automata are not going to be the last method we will ever look for representing the worlds of our concerns. Strength of the cellular automata method lies in the fact that it builds on efficient use of the computing power for the evolutionary search. Many issues remain unresolved, and claims require close and careful scrutiny. Does nature follow the programs outlined by Wolfram? Are these unique solutions? Which ones are consistent with the yet undefined rules and assumptions? Do the rules have any relationship to the underlying reality? More to the point of representation, we described the universe with simple rules. Extrapolations and predictions built into the assumptions also follow from useful models. The approach is not conducive to, but it may even facilitate, the structure function search for the *why* and *how*. In the end, reality lies well beyond any representation. Only our perceptions fill the inevitable gaps.

Links to the ideas in the background:

1. See www.hira-pub.org for many of the ancient and modern ideas related to the representation of reality.

2. In a very readable essay, from the mathematical and computer science perspectives, Ray Kurzweil has examined and discussed validity of many of the Wolfram's claims.
http://www.kurzweilai.net/articles/art0464.html?printable=1

Against Gods and Humbug

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