Paradigms, Programs and Paragons

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In 1951, von Neumann considered that it might be possible to create computer languages that constituted both the program and the data.[1] These were immediately recognized to be self-replicating programs. [2] In fact, along similar lines, more than one mathematician, computer scientist or physicist has since considered the amount of information one would need to construct an android capable of replicating itself.[3]

Out of this consideration to develop self-replicating programming, von Neumann and Stanislow Ulam collaborated on an idea that the state of a datum in a larger community of data could be made subject to logical operations performed on the community of data. Their work in this area gave birth to cellular automata a field of study that deals with the dynamics of the interaction between states of affairs both as theoretical mathematical concepts and also as correspondences that serve to model various social and physical processes. [4]

Automata data (the words "data" and "elements" are used interchangeably) can be mapped out in any number of dimensions beginning with one. [5] In a two-dimensional space, we can picture the automata as resembling a graph paper or checkerboard, and the elements upon the squares resembling marks or checkers moved according to a set of rules.[6] The rules that apply to the elements are associated with the proximity of neighboring elements in the immediate vicinity. The rule as applied to each element determines whether the element's future either remaining in play or being summarily removed. For example, assume that you have two checkerboards side by side: one an empty checkerboard and one that has a complement of checkers arranged in an arbitrary configuration. A rule might be that if the checker upon which you place your finger has a neighboring checker in an adjoining square, and then place a checker on the second checkerboard in the corresponding location. If no adjacent neighbor exists, then do not place a checker in the corresponding location. If we repeat this process at each square on the checkerboard until we have traveled each of the 64 squares to the end, we might see that the second checkerboard has a pattern checkers in different positions then they originally were in the first checkerboard. Now if we wipe the first checkerboard clean, and repeat the procedure on the second checkerboard, moving the pieces in reverse, to the first checkerboard, we would again likely see a change in the structure of the pieces and the checkerboard as seen as a whole.

Now, by going back and forth in this manner, and examining the pattern that emerges we would notice that one or more things eventually happen. As a first state of affairs one might observe that the pieces gradually disappear from the checkerboards and therefore any hint of a pattern vanishes. As a next possibility the pattern might eventually stabilize in one of two ways: (1) it would grow to a fixed size and simple stop there or (2) it would grow to a certain size and then retract in size and then grow again in a repetition of expansion and contraction. Finally, the pieces might exhibit a growth pattern until they were to run out of checkerboard space.

In a slightly more formal presentation than that provided above, John Conway created what he dubbed the Game of Life. These cellular automata involved the creation and annihilation of points that were arranged on a checkerboard like pattern, what mathematicians refer to as a two-dimensional array or lattice. The transition rules were formed from the central point and its relationship with any combination of points in the eight adjoining neighbors. The number of possible rules for a point that has just two states and 8 surrounds are 2 to the power 8 or 256. Conway studied the effect of the following rule: (1) if an empty space exists whose immediate neighborhood contains exactly three points, it would be filled by a new point; and (2) if a point has in its immediate neighborhood two or three points, it would remain on the board; (3) if the immediate neighborhood of a point contains four or more points, the point would be removed.

What Conway found for various initial arrangements of arbitrary points, was not at first surprising, that in some cases the points disappeared after a few moves, and in other cases the points stabilized. It was surprising that in some cases, a certain rule coupled with an initial configuration produced spontaneous exploding self-contained stable patterns that seemed to move from their origin. These patterns were often compared to self- propelled gliders or spaceships the gravity of centers of which remained in tact as the data moved itself across the lattice-like arrangement of squares. Self-contained stable growths do not depend on lattice-like arrays, but could be created from any number of conceivable arrangements of points in one, two or n-dimensional space. [7]

In an illustration of the last point, that these kinds of automata can be configured in different spaces, Zoologist Richard Dawkins created a Biomorph Seed instilling it with very simple reproductive properties. [8] The properties included “genes” that were directed to the growth of a line, from an initial vertical line, to a branch resembling a twig, having sub branches at certain allowed angles. The first few generations looked much like a forked twig followed by forked twigs having forked twig appendages. By further imposing rules that would mimic genetic variability he created a society of biomorphs, each basically differing in the fact that a mutation in one gene occurred. In Dawkin’s Biomorph Land, brave new worlds were created, fortunately only in the information-theoretic memory of a computer.

Models of dynamic processes have proved useful in exploring the behavior of natural and artificial systems. It is instructive to draw our attention to how our rules of transformation apply to these classes of models, because in many respects the artificial behaviors of dynamic processes parallel natural systems. For example, classes of dynamic processes called cellular automata resemble patterns of biological self-reproduction.

Every elemental atom and molecules of all ilk, represent the intrinsic artifacts of our Universe. Biological cells being organizations of molecules fit within this intrinsic group of natural things. At the physical level, a cell contains structure and organization that serves to carry out mechanical, electronic, chemical, and ultimately what we generally refer to as biological functions. Devices such as computers have analogous physical and organizational analogs at the level of the their physical makeup, but they are human engineered products, and ultimately depend on our interpretation of symbols to carry out human intentioned objectives. Except at the level of human consciousness expressing itself through language, other biological forms do not depend on symbols to carry out natural processes. We may attribute for purposes of analysis how a biological structure organizes itself, as for example as a genetic code, but the organization or code comprises a product of our imagination and the meaning we assign such matters. The cell and its inherent patterns of activities have objective, observer independent existence and function independent of our observation. However, at the level of human observation, there exist strong resemblances among the DNA, human and artificial language patterns to the extent that each offers possibilities for analysis using methods of automata-theoretic. [9]

Obviously, cellular automata does not represent anything, unless we give meaning to its rules and states as represented by the symbols we choose (points, lines, zeros, ones, or special indicators). They are observer-dependent, that is, ontologically subjective artifacts, to which we ascribe relative meaning in virtue of their function (what they do and what purpose they serve). We assign function based upon the goals with which we are concerned. Until we assign meaning, anyone of countless examples of automata amount to nothing, except to demonstrate that we can create novel numerical, spatial and temporal sequences. One might reasonably ask what point do we serve in all of this? Without digressing into a treatise on cellular automata, these patterns seem to imitate a large variety of human activity from the emergence of life forms to languages, both formal and natural. This field also has utility, for exploring the theoretical affects of social policy, such as the racial integration of urban housing and rodent populations. Stephen Wolfram, a Princeton University scientist who has studied cellular automata for most of his career, says, "…there are examples all over physics and biology of systems that look like that, that grow in exactly that way: crystal growth, for example, cell growth in embryos, the organization of cells in the brain, and so on. The important thing is that the mathematical features of cellular automata are the same mathematical features that are giving rise to complexity in a lot of the world's physical systems." [10]

Chess, Games and Automata

The manner in which games such as GO or chess unfold may be considered as examples of automata-theoretic processes. Chess, a game with which most of us have some familiarity, consists of the *three kinds of objects* referred to earlier: (i) physical components, two-dimensional board having 64 squares and 32 chess pieces; (ii) Rule II *rules* for moving the pieces of the game, and (iii) content upon which the rules operate. The board and the chess pieces are concrete, tangible articles, which through our understanding of the game imply certain qualities and permissible movements. The board can be viewed as matrix in two dimensions. The state of the game exists in the move-to-move configuration of the chess pieces on the chessboard.

The Rule I rule deals with the somewhat trivial fact that the chess pieces, as physical bodies, are subject to the laws of physics. This fact bears no significance to the game of chess. What may be true about games such as chess and other human creations, such as programs, may not hold in biological inventions, whose essential organizational development depends heavily on certain physiological properties. In altered biological artifacts such as those that are manipulated, the rules in play may be both Rule I and Rule II. Finally, the rules that govern the playing of the game exist largely as a set of conventions the players memorize and to which they agree to be bound. Such rules would be analogous to the rules enforcing a contract, a positive law or the claims in a patent.

The matter of physical substance stands to the chess pieces and the game boards as the process stands to the physical movement of the pieces in accordance with the rules of the game. The process or the rules transform the chessboard in transitioning a piece from one square to another. The state of the board before a move and after a move defines the transition, and each transition describes a particular state of the board or its content.
Similarly, a computer embodies the physical device that supports a content that resides in the electronic state of the computer. The state arrives through transitions that occur according to certain rules, which we call a program.

We might imagine a game of chess being played, not on a two dimensional board, but a one-dimensional board. Such a one-dimensional view corresponds to a list or in mathematical terms, a vector. In this configuration, the pieces would be lined up end to end on opposing adjacent squares. At the start of the game, separating the squares containing chess pieces would be thirty-two squares vacant and in line. Playing the game by the same rules that a familiar two-dimensional game uses would require that the players map the two-dimensional squares to the one-dimensional vector. Although the game would be more difficult to play because of the requirement to envision matters not in two dimensions, but a rather complicated one-dimensional arrangement, the generality of the game remains in tact. If we visualize how a game might proceed, we finally get to an accurate impression of how a computer proceeds. It considers a location where a particular data element exists; it applies a rule according to a program instruction, transforms the state, and moves on to the next sequence. The location, the transform and the content are embodied in the substance, the rule and the electronic state of the computer.[11]

Let us examine the significance of Rule II rules, not only as applied to games, such as chess, but to the larger institution of law. As Ronald Dworkin observed, the game of chess comprises an autonomous institution.[12] If we presume that the institution of laws (legislative or agency) conform to this metaphor, it implies that: *no one can claim an institutional right by appealing to a general morality, because the rules of the game, i.e., Rule II determine all that exists in determining one's rights.* There can be no situations where someone says, “Permit me to make this move because in fairness I have the higher moral ground, or that I have earned that right”.

Any extant rights are established by the conventions made explicit in the Rule II rulebook. Whether, baseball, football or poker, all rigidly played games subscribe to similar conventions. If what one desires to do cannot be found in the rulebook, an appeal to authority will be ineffective. Dworkin of course, is speaking about what I have termed Rule II regulatory.

When we deal with computer programs, the rulebook can be refined and corrected if it does not operate in the manner intended. In artifacts such as computers most programming changes are reversible. However, once we alter the programming mechanism in a natural artifact, we may not be able to return to the past, such that the rulebook may have been immutably revised. We will return to this consideration later in the book, for it has an implication for what we should consider in respect to developing life form technologies.

The fact that cellular automata reflects the universal feature of artificial and natural machines permits us to analyze them as like kind in respect to various problems and directions being taken in intellectual property law and practice. *For example, some modes of intellectual property protection focus on the physical, other focus on the constitutive rules and yet other focus on the content*.

Collective Intentionality

We previously discussed how we assign function to the objects of our reality, but we have not discussed collective intentionality as a concept. In simple terms this element accounts for the collective "we" that seems required in order for "us" to believe mutually in a world of objects and social conventions. Theories abound how "I and we" form mutual beliefs and reach mutual assent on a great number of things in a society. As it happens, we mutually accept things from the fact that television comes from a transmission of a broadcast from some distant studio, to that fact that a contract exists to establish rights, duties and obligations. Just about anything that we can think of in our day-to-day routine can be assumed constitutes a mutually shared notion with others in our community. This does not mean that we believe in the same deity or that everyone believes in the sanctity of marriage. It does mean people living in the same culture will acknowledge the existence of similar states of affairs.

I do not intend to digress into an analysis into the various competing schools of philosophy why collective intentionality exists. However, I will boldly accept that it has been well established that such a phenomenon exists. When we combine collective intentionality, the assignment of function and Rule II constitutive rules, we satisfactorily explain institutional reality.

Let me summarize where I have been and what I have concluded thus far. Social behavior may be viewed as process acting upon artificial and natural processes, states of affairs and artifacts. Society creates rules, which create institutions that administrate, regulate and adjudicate its behavior. Some of these rules actually create the very technology, such as machines, processes, games and computers that affects our lives. Depending on the rules chosen to transition a state of affairs, a state of affairs over many transitions may exhibit patterns that proliferate, extinguish or become steady state.

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[1] J. Von Neumann, The General and Logical Theory of Automata, In Collected works, ed. A.H. Taub, vol 5, pp. 288-328. New York: Pergamon (1956).

[2] J. von Neuman, Theory of Self-Reproducing Automata, University of Ill. Press, Urbana, IL, (1966).

[3] See, Marcel J.E. Golay, Reflections of a Communications Engineer, Analytical Chemistry Vol. 33, No. 7, June 1961.

[4] http://mathworld.wolfram.com/CellularAutomaton.html

[5] M.J.E. Golay devised a scheme utilizing an hexagonal array of points in a method that provided a topological metric used for two dimensional objects. See, Golay, M.J.E., Hexagonal Parallel Pattern Transformations, IEEE Trans. On Computers, C-18, #8, 733-740, August 1969.

[6] John Horton Conway described this type of automata, which he called “Life” in the October issue of Scientific American. Martin Gardner brought these to light in a series of articles, which he published on the subject. See, Gardner, M., Wheels, Life and Other Mathematical Amusements, Freeman, San Francisco, 1983.

[7] M. Golay, J. Carvalko, and K. Preston investigated initial configurations that produced a spontaneous cancerous growth utilizing an hexagonal matrix of points. Research Image, Perkin-Elmer Inc. Vol. 6, No. 1, Jan. 1971.

[8] See, artificial Life-II, C. Langton, et al, eds. Addison-Wesley, Redwood city CA, 1992; Also see, Dawkins, R. The Blind Watchmaker, Longman, London, 1986.

[9] John L. Casti, Reality Rules, Picturing the World in Mathematics, The Fundamentals, p. 195, John Wiley & Sons, (1992).

[10] E. Regis, Who’s Got Einstein’s Office?, Addison-Wesley, (1987). See, http://www.stephenwolfram.com/about-sw/interviews/87-einstein/text.html

[11] A.M. Turing, postulated a machine that reads one cell on a linear tape and based upon the symbol on the tape moves the tape left or right and reads again.

[12] R. Dworkin, Taking Rights Seriously, p. 101, Harvard University Press, (1977). Dworkins reference to chess provides perhaps the most cogent argument for consideration of Rule II as having regulatory significance.