Complexity Theory:
Simplifying Life for Organizational Theorists

Introduction

The fact that so many metaphors are used in interpreting organizations is evidence enough that analyzing an organization is not child's play. A majority of the paradigms used so far have each been successful in explaining particular aspects of the behavior of organizations. Few have the inherent ability to decipher the complicated behavior observed over varied lengths of time. Especially when time is an important factor in the current world, there is a need for new paradigms and metaphors that (ideally) single-handedly help unravel the underlying principles and thereby provide tools for not only explaining, but also predicting the courses that organizations take over their life cycles.

So what is a paradigm, and what is a metaphor? According to Kuhn, a paradigm can be looked at broadly in three senses of the term: (1) as a complete view of reality, or way of seeing; (2) as relating to the social organization of science in terms of schools of thought connected with particular kinds of scientific achievements; and (3) as relating to the concrete use of specific kinds of tools and texts for the process of scientific puzzle solving. Organization theorists often approach their subject from a frame of reference based upon certain assumptions that are taken-for-granted [1]. Depending on the metaphors developed through these schools of thought, they interpret various activities of an organization. These metaphors are then interpreted by others, including "hands-on" managers, in the hope of predicting something about the future, which Morgan calls the "puzzle solving" level. Figure 1 gives a graphical description of the scenario envisioned by Morgan.

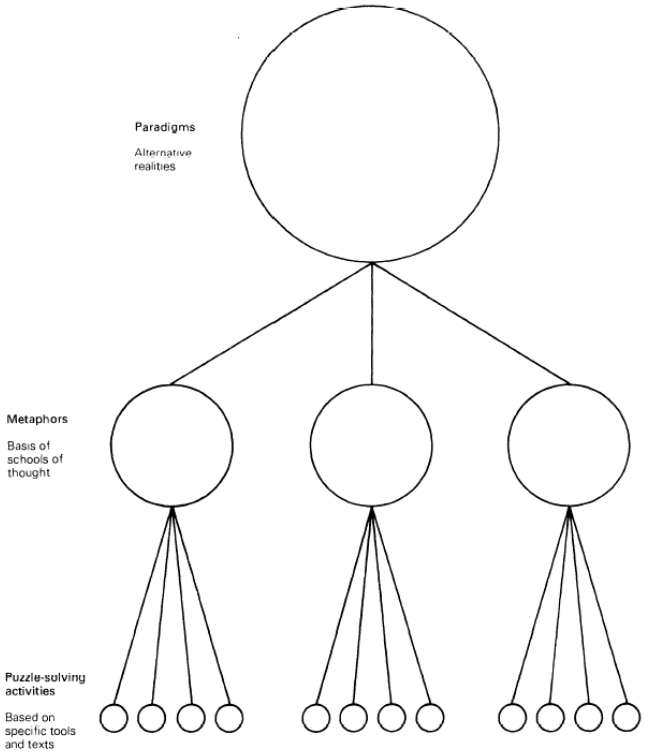


Figure 1. Paradigms, metaphors, and puzzle solving: three concepts for understanding the nature and organization of social science.

In his book *Images of Organization*, Morgan interprets numerous attributes of organizations, and their behavior, through different metaphors. While all these explanations are of high quality in the conditional interpretations, they are not of great use when they stand independently. And worse, the organization is not a linear combination of the functions described by these metaphors. The search is on for a paradigm that accepts the convoluted nature of entities and proceeds from there. Enter Chaos theory, a relatively young branch of science that does exactly the same and goes about simplifying the problems at hand while accepting that a perfect solution might not be available.

Chaos and Complexity Theories

Chaos theory was initially developed to explain some of the complicated interactions between entities in Physics and was extended successfully to explain a different interpretation of evolution before it came into the notice of social scientists. It focuses on intensely non-linear systems which can be termed to be mathematically deterministic, but cannot be solved. The systems are stable, but are not repetitive: small changes in the independent variables may bring about variedly different changes in the output variables.

Complexity Theory (CT), whose roots lie in Chaos theory, assumes a more pacifying approach in that it takes systems to be more stable and predictable compared to Chaotic systems. It states that "order emerges naturally because of unpredictable interaction—interaction is the vehicle by which this occurs and unpredictability is the stimulus that promotes novelty" [2]. CT is further extended to suit social science's requirements; combining Systems Theory with CT lead to the development of Complex Adaptive Systems (CAS), which assume that "coherence under change is the central enigma" [*].

The principal conditions for the full applicability of CT include: (1) non-linearity, (2) iteration and (3) sensitivity to initial conditions [3]. This is fulfilled clearly by organizations in general. Furthermore, concepts of CT like (Lorenz) attractors, bifurcation points, etc. (refer to appendix A) can be handy in explaining phenomena like innovation and technological cycles as well as the stability observed in organizations. Organizations "make" important decisions regarding the direction they choose to go in at the Edge of Chaos, an important phase in the organization's history. It is interesting to note that there are relatively few states that organizations settle down in as compared to the possible states they could have landed themselves in had they taken random decisions. As opposed to blind natural selection suggested by Darwin's Theory of Evolution, Stuart Kauffman's observation was extended to social systems by Russ Marion to state that the number of groups that emerge in a social system is a square root, exponential function of the number of people in that system [2]. This phenomenon, which he called *Autocatalysis*, can also be applied on a micro-scale in modeling change programs in organizations, especially those which are developed bottoms-up. Autocatalysis is a process in which events cyclically catalyze other events, thus leading to complicated, yet stable phenomena. In fact, the emergence of new configurations can be attributed to the fact that an event might be part of two or more autocatalytic chains, and

hence depending on the "input" variables, i.e. the initial conditions, different equilibriums might be attained.

CT is extremely versatile and hence can be applied in conjunction with other metaphors for interpreting organizations whose complex behavior was otherwise assumed to be outside the scope of the interpretation. In addition, it offers analytical models to understand the multifarious behavior of intangible variables associated with organizations.

Organization as a CAS

The umpteen features of Complex Adaptive Systems (CAS) can be selectively applied to explain the corresponding characteristics of organizations in different contexts. Attractors, as defined by CT, can be associated with stable configurations of organizations during its life cycle. As and when the environment changes, there can be specific roles where the organization can see itself fill-in, and decisions made at this stage depend on the environmental factors. These stages can be correlated to bifurcation points in CT, and it is crucial for an organization to know when it is at such a point, and if possible predict the arrival of such stages and be fully prepared. Inside an organization, innovation can also be explained based on the analogy of the attractors and bifurcation points. While incremental innovation is explained by the organization's gradual "climb" to a bifurcation point, radical innovation can be said to occur when the system jumps to a contiguous stage by virtue of the new technology or processes developed.

It is inherently assumed in CAS that systems are stable and that they arrive at their state of stability by adapting to the environment. This occurs primarily through "learning" about, and from, the other side of the boundary. More importantly, CAS provides for dynamic changes in the organization while it is adapting. Assuming that the organization is stable and indifferent to change while it adapts and predicting changes in quanta after the change period is not perfectly true. The "real-time" nature of change and the associated autocatalysis is captured well by CAS.

Homeostasis is the maintenance of an internal state that is distinct from the external environment and is defended against changes through continuous feedback mechanisms. This concept of order and stability in CT can be used in modeling the governments' protecting some organizations when observing the scenario on a macro level. The intra-organizational dynamics involving change of plans and strategies to meet a particular goal of overwhelming importance is an example of homeostasis within an organization.

CAS have the ability to process information. The greater the ability of a system to process increased amounts of information and turn it into knowledge, the closer to the edge of chaos the system can evolve. This evolution to higher effectiveness occurs because the edge of chaos is the most active and creative context possible for all subsystems of an organization, and their interactions. Self-organization emerges naturally in all CAS. As a system evolves to the edge of chaos, self-organization becomes stronger.

In the real world, self-directed teams are apt examples of such situations where self-organization and creativity go harmoniously hand in hand [4].

Given the basic principles fundamental to CT and CAS, it can be opined that "tinting" the spectacles of other metaphors with CT and CAS and combining the perspectives to get the real picture is a step forward in understanding organizational behavior. Accepting the prevalence of non-linearity and modeling the system based on it, instead of assuming it away, could be the way for future of organizational theory. Some events are predicted, others are "retrodicted"…explaining an event after it has occurred is rarely of interest to today's forward-looking society. Instead, more tools are required to help develop comprehensive models that at least give us an idea of the future and warn us of impending dangers ahead. To augment the arguments proposed supporting CT and CAS, the University of Michigan would be used as an example in elucidating the applications of these concepts from hereon in the essay.

CAS and Open Systems Theory

The perspective of CT about environmental interactions and awareness is strikingly similar to that offered by Systems Theory. Systems theory assumes three states—organized simplicity, organized complexity, and chaos. Analogous to these states are the three suggested by CT—stability, Edge of Chaos and, Chaos [2]. The major difference lies in the fact that the definitions provided by CT are far more inclusive of other considerations than those of Systems Theory. Open Systems Theory perceives organizations to be immensely dependent on the environmental alterations and hence stresses upon increasing awareness, the ability to classify and assign meaning to events or objects. CT additionally concentrates on the internal causes of those environmental changes and their implications on building the awareness necessary for stability. In other words, CT gives scope for observing recursive changes caused due to the interaction of sub-processes on the environment and vice-versa.

The Open Systems Theory metaphor proposed by Morgan develops the idea that improvement of an organization is based on how the requirements of the constituents are being satisfied. While this is acceptable for analysis and retrodiction, there is not sufficient framework for going into the predictive mode through this metaphoric approach. The mathematical framework provided by CAS provides a robust launch pad for predicting the growth of organizations if used appropriately. Simplifying organizational interactions to mathematical equations gives decision makers the power to foresee the effects of not catering, partially or fully, to the requirements of particular subsections. In fact this can be used by organizations incorporating concepts of lean manufacturing to eliminate the struggling and improve the straggling departments.

From the contingency point of view, "organizational slack" is essential for the organization to be prepared for dealing with uncertainty and sudden opportunity. From the CT viewpoint, slack is a source of organizational robustness and hence an opportunity for promoting stability, and change as well. Slack is critical at the Edge of Chaos, when

the organization has the best opportunity to either break the barrier and move on to a contiguous state, or revert back to its original state. During this period, differentiation is of great importance. Horizontal differentiation exists to break tasks into manageable pieces, while vertical differentiation results from the need to coordinate the roles needed to deal with the environment. Managers could best utilize their time by enabling the process (of differentiation), by seeing that it does not degenerate into factionalism and personal attacks, that the conflict doesn't stagnate in defensive posturing. The process should remain dynamic, positive, and focused on resolution [2].

An interesting extension to the Open Systems Theory's propositions is the concept of *resonance*. Resonance here refers to the interaction between attractors and the environment, and the corresponding effect of "familiarity" with the environment. Marion suggests that a bit of the environment is made part of the organization. In today's world of cost cutting, mergers and takeovers can be seen to follow the logic proposed by the principle of resonance. Thus, it is clear that CT harmoniously enhances the applicability of the Open Systems Theory metaphor in viewing an organization.

U of M: a Complex Open System

Defining the boundary of a university is a very tough task. Particularly in the case of the University of Michigan, where enrolment is high from across the globe, and people "walk" into the system from nooks and corners, the boundary plays a vital role in defining the key processes and analyzing them further. Taking the geographical boundary is not always the best option since there is close interaction with its other two campuses at Dearborn and Flint where similar standards are maintained. Differentiating the campuses is however justified bearing the community being served in mind. For example, the Dearborn campus primarily serves working people employed in the automotive industry who are keen in applying their skills in their job as soon as they find out something new. It is thus a challenge to keep up with and cater to their demands. On the other hand, the Ann Arbor campus predominantly serves a relatively less "experienced" community and concentrates more on imparting basic skills, which might not be all that practicable. Due to constraints on information-gathering and personal experience, the rest of the essay refers to the Ann Arbor campus of the University of Michigan unless specified otherwise.

The large community at Ann Arbor consists of a multiplicity of cultures whose diverse interests and backgrounds exorbitantly increase the possibility of surrounding enviroment(s) affecting them. The multi-ethnic culture at the campus is sensitive to many happenings around the world. So what might have been considered a "latent" environment might suddenly turn active, and hence the interactions with this environment would also add to the scope of complexity of the University. Substantive interactions might be stimulated by events on the political horizon, sporting arenas and even on internal turbulence. Decisions made by the University are bound to have an immense impact on the environment; an increase in tuition raises commotion in the tuition-payer's community (which falls both inside and outside the system boundary), which in turn

tends to cause mayhem in the organization as such. Considerable effort has then to be diverted into consoling the organization and cajoling it into normalcy again. On the brighter side, the behavior meted out to current students might pay off grandly when they return to invest in the University as alumni. This is a perfect example of the system influencing its own environment, a key concept of CAS.

Sometimes, the environment is completely out of control for the system. In the event of the latest political happenings, and the resulting repercussions, the University has to just alter its method of operation. In addition, it might have to justify these alterations without the freedom of revealing the logic behind the operations to the challengers, who could be from either side of the system boundary. For example, rejections in granting an entry permit to a prospective student yet to enter the country, or to a current student on a visit during a break would have to be handled by the University administratively, and then the corresponding actions have to be justified. Justification might be a tough task as it may involve interested parties who are part of the system currently.

The management of the University is there to provide for the needs of the sub-units while following certain stipulations, especially on budget and ethics. Inability to cater to the requirements of communities, or selectively meeting a few of the requirements draws avoidable criticism from both the system and the environment. The delicate line of balance has to be drawn and impeccably followed for optimal performance. Inter-departmental issues have to be dealt with tactfully and priorities must be decided in allocating funds to departments. In managing at the micro-level, intra-departmental issues are of a different order of magnitude, and require more personal attention using case-specific strategies. Modeling this is possible now, given the flexibility provided by CAS.

The University is eternally under pressure to expand its services given its fantastic reputation and the quality of services offered. This sometimes may lead to the University taking over a facility, like a college, and using that place as a base. This originally "foreign" place part of the environment becomes a part of the system, a lucid example of resonance. For resonance, or for that matter, any expansion to take place, the University must maintain an "inventory" of resources. When some expansions are specific to a specific length of time, like summer camps, there should be enough organizational slack to do the needful.

Developing mathematical models for such complex systems is a tough job, but when done faithfully, they give us a comprehensive understanding of the phenomena. But for developing an exhaustive model for the system under consideration, a lot more aspects need to be considered viewed under other metaphors.

The "Brain" in Organizations and "Innovation"

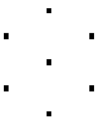
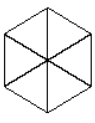
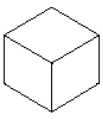
In his book *Images of Organization*, Morgan views the organization under the “Brain” metaphor wherein he concentrates on the holistic aspects and the characteristics of “learning organizations”. Although the approach is thorough theoretically, not much can be detailed about methodologies that can be used in modeling under this metaphor as such. Noting that this perspective is inherent in CAS, it is possible to utilize some

concepts propagated by CT and combine them with the "Brain" metaphor in analyzing organizations.

CT has been successfully used in modeling knowledge management, considered one of the last untapped sources of competitive advantage in business and functioning alike. Knowledge is the product of natural innovative schemes inherent to all living systems. Creating conditions where innovation thrives is sufficient, according to some, for the evolution of knowledge to naturally follow. Followers of Organizational Learning, known as organolearners, see a difference between what individuals know and knowledge held collectively by groups of individuals—individual learning leads to individual knowledge; Organizational Learning leads to collective knowledge [5]. This collective knowledge is rarely the sum of the knowledge of the individuals in the organization. It is more so a non-linear combination of the individuals' knowledge and is hence much more tough to deal with than when functioning under the linearity assumption.

It can be seen that the "Brain" metaphor goes hand in hand with innovation. An organization is its current state as a result of the innovation it has incorporated in itself based on the feedback it gets. Innovation is conceived as a means of changing an organization, either as a response to changes in the external environment or as a preemptive action to influence the environment. There are many variables involved in the process of innovation, be it banally incremental or breathtakingly radical. Research suggests that complexity is more positively related to innovation in turbulent than in stable environments. Innovation is a complex construct, however, and innovation theories including only two or three variables have limited predictive ability [6]. Structural complexity of organizations has been demonstrated to be positively associated with innovation. A greater variety of specialists, with more depth of knowledge, provides a more diversified knowledge base and increases cross-fertilization of ideas, both of which result in more innovation. Damanpour has suggested that an increase in structural

Figure 2 Elements of a learning organization in a periodic chart

Element	**Gather**	**Repeat**	**Share**	**Transform**
Complex adaptive systems	Fixed point	Repetitive	Complex	Chaotic
Information	Data	Information (connected data)	Knowledge (connected information)	System and pattern principles (connected knowledge)
Organization	Authoritarian (e.g. monarchy)	Hierarchical (e.g. bureaucracy)	Holarchical (e.g. democracy)	Intentional and evolutionary (e.g. cosmocracy)
Patterns of communication				
	Points	Lines	Hexagon	Cube

complexity and size are positively related to innovation while not-for-profit nature and administrative (as opposed to technical) nature of organizations is not positively related to innovation. Measuring innovation based on the rate of adoption of innovations, which is often operationalized by the number of innovations adopted within a certain period of time, he statistically modeled and showed the aforementioned results.

Complex Brain and Innovation in the U of M

The University of Michigan, an open system as described earlier, is subject to a variety of stresses in different forms at any point of time. People outside the realm of the university more often than not consider the University a single entity and hence the management has to respond to people's calls keeping in mind their holistic outlook. In the University, the hierarchy of departments and corresponding labs are viewed at different holistic levels.

Irrespective of how it is envisioned, the University's main task is to adapt to the changing environment and maintain the state of order for lengths of time. *Hoemeostasis*, the property of CAS maintaining their current state through real-time adaptation to environmental factors, is one of the major functions of the University and its constituents. Preserving heritage, especially with such ancient and reputed schools around, ranks high among the tasks at hand for the administration.

Sometimes, it is required for the process of change to be maintained at the same rate of improvement. And it is in these situations where innovation is most significant. As the student population grows, and the requirements for research facilities increases, the university must not only provide new facilities, but also make sure that these new facilities are in tandem with their budget and reputation. Innovatively designing plans and allocating resources accordingly is the best way to deal with such situations.

Innovation is also crucial in designing new courses that are essential for maintaining the high ranking of the University in many disciplines. This involves observing the demands of the industry and also predicting what might be required in the near future. Coming up with ideas for receiving funding from external agencies and convincing them is another aspect that entails innovation, especially one that is logically and strategically radical.

The large population, consisting of students, researchers, faculty members, etc. among others, generates an enormous amount of data that has to be managed efficiently and quickly. For example, grades of students in examinations are to be handled carefully so that people for whom they are not intended do not access the information. In fact the security aspect of this knowledge management is a big challenge in elite universities where brains are used to detrimental effect. On the other hand, voluminous files like dozens of lectures are sometimes required to be out up on the course web pages and the corresponding updates are a huge challenge to the "knowledge managers" around in the University. Administrative data flow is a separate section altogether and is as complicated as in most other humungous organizations.

One of the aspects specific to University of Michigan is the inter-library loans in libraries, intra-state and intra-Big Ten. Knowledge sometimes has to be shared with others in the same group in all three forms, print, video-clips and electronic on-line versions. To push this already complex system towards Chaos are the different classes of services available for various categories of people (faculty, staff, graduate students, etc.). Modeling this linearly will call for more assumptions than the number of unknowns. By modeling this scenario non-linearly, it might even be possible to stochastically optimize the number of resources required. Resources may in fact include some measure for innovation and planning if it is possible to quantify them in the prevalent circumstances.

Culture

Viewing organization under the culture metaphor reveals a whole new world of ideas when compared to the mechanistic metaphor, which concentrates on the design aspects mainly [7]. By throwing light on the not-so-rational outlook of organizations, the metaphor helps unravel some interesting interactions between members of the organization, the surrounding environment and the underlying beliefs of the workforce. The Iceberg model, though easy to comprehend, is one of the tougher interpretations. To identify many parts of the iceberg, an efficient and detailed understanding of the interactions between people is required. As mentioned by Schein, in filling out the surveys and questionnaires, the interviewers must be attentive to note the possible interaction of personal prejudices and ideals in the employees' answers. A majority of these are a result of non-linear interactions between "variables", which in this case can be termed to be the disposition of the employee towards some basic notions prevalent in the organization, and more importantly, his behavioral relations with others around him. CT is bound to be a useful tool in seeing the organization through this perspective, especially if the variables can be quantified upon identification.

O'Reilly and Chatman hence proposed that organizational culture "can be thought of as the normative order, operating through informational and social influence, that guides and constrains the *behavior of people* in collectives". The course that an organization takes is thus a function of the actions of the people in there, perhaps in response to conditions outside the organization. Social psychology gives two fundamental principles that link people's interactions and their sentiments in an organization: (1) people seek balance that they nay achieve either by modifying their sentiments to correspond to them or by choosing to interact with others who hold similar beliefs; (2) People's sentiments are affected by the information to which they are exposed through interaction with others, and they may choose to interact with others to gain access to new information. Under this framework, Frank and Fahrbach have come up with a simple model for influence in the case of interaction between two people, whom they term "actors" (Appendix B). In addition to the areas that they took into consideration, there are a lot more where work could be done. They however say that "the limitation is not in the conceptualization of the relationship between the organization and its environment, but in the conceptualization of the processes through which the organizational boundary is permeated" [9].

Culture at the U of M

Culture of an organization with people from similar backgrounds is tough to analyze because of the huge variability possible in the way people adapt to others' reactions, which again depend on many other non-organizational variables. When looking at a university's culture, there are bound to be confusions and complications galore in doing the same. In the case of highly diverse universities like University of Michigan, the task is similar to taking holistic look at world cultures and trying to speculate about the resulting formation. And to further mystify the situation, the stability of the student population is close to being ephemeral, and this means that any possible modeling should be dynamic in nature allowing for inter-variable interactions. Even CT, with its strong mathematical background, finds the going tough in such scenarios.

The University is an open system, as observed earlier, and hence is subject to quick changes in the environment. Students are one of the most highly sensitive classes of society and never leave a stone unturned in gathering support for their group in the event of a controversy, where there is a clear demarcation between a majority and a minority. For example, the recent showdowns between some student groups regarding US support to Israel gained wide popularity and hence disturbed the already unstable equilibrium between students of Islamic descent and others. While such influences may be localized to departments, events like the 9/11 attacks or the ongoing Gulf War II have a resonating affect even on the students and individuals who otherwise would not have bothered to take a stance on the issue. The enthusiastic loud conversations in buses, instigatingly blatant posters and fliers, and repeated calls for pursuing specific lines are all part of the interactions that influence the culture to the extent that beliefs in the second tier of the iceberg might also be shaken every now and then.

And then, there are some University propagated issues on which the community has points of view, both individual and collective. While the majority opinion phenomenon is predominant in most cases, stances taken are more vehement at times in such issues. The affirmative action has drawn wide attention nationwide of late, and when students go outside the university to social gatherings, they are questioned about the "whole affair". It is my personal observation that since the affirmative action suit has resurfaced after the judicial hibernation, reactivity among students has been on the rise.

There are some peculiar cultural issues that are more evident in universities than elsewhere. A large proportion of the students take cross-departmental courses, that too in different schools (and colleges). The underlying culture is different at different places and this leads to confusion, and at times even frustration for the students. The grading system, workload and procedures are some of the key points inviting controversy. The last one in fact affects students, faculty and staff alike. The latest trend by departments to woo students to take courses that they offer is another aspect that is bound top have a cumulative effect on students and faculty alike. But this has been forced upon by the continued economic pinch faced by the departments in making both ends meet, given that they are expected to maintain excellent research facilities even in these times of hardship.

CT in Organizational Theory: from strength to strength

Since it has been recognized for its significant contribution to development, Organizational Theory has furnished managers with a multitude of viewpoints associated with a variety of metaphors. A significant number of these metaphors have been furnished by theorists observing phenomena around them and in other areas of research like biology and economics. Towards the later part of the twentieth century, scientific approaches started gaining favor and the search for new topics expanded to quantitative fields like physics and mathematics. Applying concepts of uncertainty has been the trend for long, but the arrival of CT strongly on the horizon has changed the scenario significantly. With CT, it is possible to incorporate a lot more variables into the system. More importantly, interactions between these variables, if at all considered so far by other metaphors, were assumed to be linear. However, in CT, there is scope for defining interactions of high orders, the only constraint being the definition of the variables!

Handling systems with order of variables higher than two gives scope for quantifying phenomena that could not have been tackled so far due to the lack of supporting techniques. CT provides adequate framework for exploring possibilities in allocating numerical attributes to human relationships. Though a tough task, this would provide some rigidity to the fluid conceptualization followed thus far by most researchers.

Having mathematical models, however approximate, is a big advantage to predict the behavior of systems under different initialization conditions. As of now, simulation seems to be the basic method of getting outputs from complex systems. Nevertheless, having a (reliable) figure in the hand will be a big advantage to decision-makers. Meticulous statistical analysis of the output from simulation eliminates most errors, thereby allowing us to reap the benefits of CT.

One of the highlights of using CT in interpreting organizational processes is that there is no need to radically change the outlook of the prevalent mindset of managers who are used to other metaphors. CT is one of those tools which enhance the metaphor when used in combination. For example, employing techniques characteristic of CT to the Brain and Culture metaphors expanded the domain of applicability of the metaphor and also pin-pointed some of the assumptions that were made in the metaphorical analysis earlier. In addition, CT identifies a few areas associated with chaos that few metaphors have touched upon so far. It definitely is an enhancement to the toolkit of Organizational Theory while also being an additional asset to it.

CT: where it is fallible

Though CAS seems to be impeccable on paper, there are a few significant limitations to the application of CAS and CT in the world today. One of the weakest points about the scientific approach promoted by CT is the high level of expertise required to initially comprehend and then apply the understanding. Due to the innate complexity of CT, people might shy away from this metaphoric outlook as compared to similar simpler

approaches. Especially on the application part where CT boasts of great abilities, convincing decision makers to accept the recommendations proposed based on CT entails a proper background being imparted to them. Sociologists who have been vital in understanding and theorizing organizations are now restricted to the description of an organization through CAS. A new breed of quantitatively strong analysts is required to follow the cue and enhance the application of the theory.

While giant strides are being made in understanding complex processes, there is immense scope for research in the field. The area has to mature quickly and deliver what it promises. Being a field that thrives on contributions from branches of science cutting across all boundaries, CT is continuously churning out theories suggesting newer areas of application. Retrodiction seems to be the most prevalent form of application currently. Advocates of the theory should now concentrate on the nitty-gritty and develop foolproof methods for social systems to make full use of this versatile (set of) tool(s).

With a strong basis in science, CT describes the scientifically oriented metaphors well. But when it comes to more "sociological" and psychological metaphors, like the Political Systems metaphor or the Instruments of domination metaphor, CT at its present level is not competent enough to explain phenomena. Though human interactions are being modeled at a very simple level, complex interactions of intangible variables like emotions are yet to be incorporated efficiently.

In its short stint in the domain of social sciences so far, CT has tended to model complex situations well. However, there is a tendency to over-complicate models of systems because there now are tools to deal with more sophisticated logic. It is paradoxical that most metaphors over-simplify phenomena by making "suitable" assumptions, complexity theorists tend to make life tough for themselves. It may be that the theory set very high ideals for the subsequent practitioners.

As science evolves, assumptions made in prior theories are questioned. In a sense, this is what makes science so rigorous and vigorous. CT questioned the assumption of previous theories that there is little disorder in the environment and the system, and hypothesized that everything settles down into "order" at regions near the attractors. The latest entrant in the role of a strong challenger to prevalent theories suggesting that "order" is the order of the day is Post Normal Science (PNS). PNS underlines a basic weakness in the theories so far and questions the postulation of order at the very beginning. How often do we find order in life? Is the order we find around us really in order, or are they transient states that have their basis more in chaos than in order? These questions are more applicable to the social sciences as they are more random and chaotic than rational systems of the pure sciences like biology and physics.

Synthesis and Analysis

Complexity Theory is another step forward by researchers in challenging established streams of thought in their pursuit of the absolute. It is one of the first theories to acknowledge the existence of a significant amount of chaos in the world around. By recognizing the stability of systems and providing models where order rules the day in

spite all the chaos around, CT caters to the need of equilibrium of systems, a basic assumption in theories galore.

In the context of social systems, CT can be applied in a variety of areas as was seen in the essay so far. There are lot more areas and metaphors where CT has been observed to make considerable enhancements in the understanding of theorists. For example, leadership is a vital characteristic in chaotic systems, but is specific to social systems since few other fields can identify leaders without ambiguity. Marion and Uhl-Bien give an interesting analysis of how terrorist group Al-Qaeda's leadership model can be explained using CT [10]. In the process, they provide models of how leadership decisions are taken under chaotic situations. Similarly, the Change metaphor is enhanced by CT's concepts which include the Edge of Chaos. The Edge of Chaos demonstrates a number of phenomena in critical decision-making at the time of change and thereby elaborates some of the change efforts that might be taken in different circumstances to mold the direction of change and preventing it from meandering away from the objective.

Organization is an organism evolving through its life. What it is at present is a result of not just its own experiences but is also a function of its ability to learn from other organizations' experiences. This aspect of the organization involving internal and external "nested loops" is efficiently modeled through the CAS approach. In developing the metaphor of the organization being an Organism, CAS propagates the idea of evolution and growth of organizations similar to the evolution and growth of organisms, thought not in the same lines as the Darwinians. The incremental growth that is advocated by the Darwinian model of evolution does not provide for the birth of "radical" organizations that are a product of breakthrough innovation rather than mere improvements over their predecessors. The success of Microsoft and Enron, who use radical management processes, though the areas of application are completely different from the other's, is proof enough that the notion of attractors explains the phenomena well.

In the process of proposing order to be the over-riding phenomena compared to chaos, CT has left behind a group of researchers who advocate the prevalence of disorder over order. The proponents of this alternative philosophy, called Post Normal Science (PNS, as mentioned earlier), insist that order is transient in long cycles of Chaos. In his article on PNS, Funtowicz compares the levels of science practiced in systems today. PNS is supposed to model systems that have high uncertainty associated with higher stakes in decisions, as visualized in Figure 3. According to him, PNS focuses on aspects of problem solving that tend to be neglected in traditional accounts of scientific practice: uncertainty, value loading, and a plurality of legitimate perspectives. PNS considers these elements as integral to science. By their inclusion in the framing of complex issues, PNS is able to provide a coherent framework for an extended participation in decision-making, based on the new tasks of quality assurance [11].

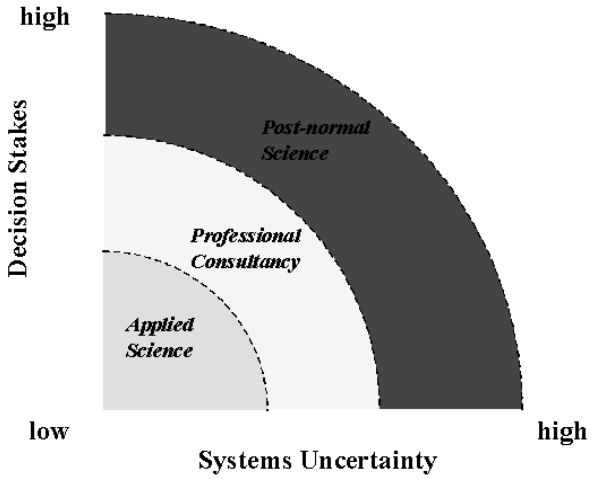


Figure 3- Phases of Scientific Application

So what is Complexity headed for in incorporating Chaos dominantly into systems? From the way things are going, it appears that the Theory of Destiny that was advocated by Asian scholars in the Middle Ages in history is set to take control of the world again. In the social systems context, the fact that organizations are enveloped in the whirlpool of Fate, where nothing is in the hands of the decision makers and all "decisions" are more so instinctive reactions to environmental and systemic changes is tough to accept at this stage, where we feel in control of the system and ourselves. It is an intriguing unanswered question, posed by some abstract minds, but to decide on the outcome depends on how we take "control" of the situation from here on. Analogous to CT, we seem to be at a bifurcation point with three attractors pulling us: present-day serenity, chaotic CT and Destiny. It will be fascinating to see how we decide our "destiny".

Appendix A

Concepts in Complexity Theory: Attractors, bifurcation points, Edge of Chaos

Edge-of-Chaos: The phrase "edge-of-chaos" refers to the idea that many complex adaptive systems, including life itself, seem to naturally evolve towards a regime that is delicately poised between order and chaos. Water, for example, exists in three phases: solid, liquid and gas. Phase transitions denote the boundaries between one phase and another. Universal computation -that is, the ability to perform general purpose computations and which is arguably an integral property of life exists between order and chaos. If the behavior of a system is too ordered, there is not enough variability or novelty to carry on an interesting calculation; if, on the other hand, the behavior of a system is too disordered, there is too much noise to sustain any calculation. Similarly, in the context of evolving natural ecologies, "edge-of-chaos" refers to how -in order to successfully adapt -evolving species should be neither too methodical nor too whimsical or carefree in their adaptive behaviors. The best exploratory strategy of an evolutionary "space" appears at a phase transition between order and disorder.

Attractors: Steady state (or equilibrium) behavior corresponds to fixed-point attractors, in which all trajectories starting from the appropriate basin-of-attraction eventually converge onto a single point. For linear dissipative dynamical systems, fixed-point attractors are the only possible type of attractor. Nonlinear systems, on the other hand, harbor a much richer spectrum of attractor types. For example, in addition to fixed-points, there may exist periodic attractors

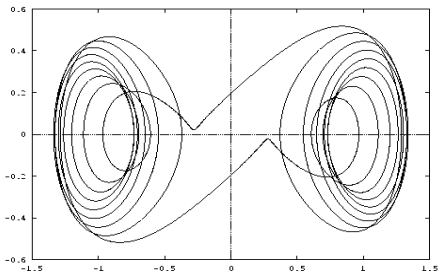


Figure A1 - Typical example of Attractor in phase-space (there are two attractors here)

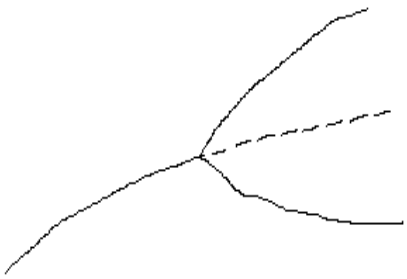


Figure A2 – A single Bifurcation

Bifurcation: The splitting into two modes of behavior of a system that previously displayed only one mode. This splitting occurs as a control parameter is continuously varied.

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