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Chaos Theory as a Meta-theoretical Perspective for IS Strategy: Discussion of the Insights and Implications

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Abstract

Development and implementation of IS strategy often takes place within a complex and uncertain socio-technical environment. Under such circumstances any predictions of the future states of an organization and organizational IS are understandably limited. We believe that Chaos Theory can provide a valuable vantage point, as well as offer a set of insights and implications, to those practitioners who are involved in the decision making process during the development and implementation of IS strategy.

Keywords: Chaos Theory, IS Strategy, Complexity, Complex Dynamic Non-Linear Deterministic Systems

Introduction

The purpose of this paper is to argue that Chaos Theory could provide a solid theoretical foundation for researching Information Systems (IS) strategy. The main argument is based on the premise that an organizational IS could be perceived as a complex non-linear dynamic system, and as such it could exhibit a pattern of behavior that is usually studied by means of Chaos Theory. To substantiate the argument, this paper proceeds as a sequence of three parts. Part 1 presents an overviews of the characteristics of non-linear dynamic systems and of the major tenets of Chaos Theory, as well as presents the argument that organizational IS can be perceived as a non-linear dynamic system. Part 2 provides a brief overview of IS strategy and inquires into the areas of IS strategy that may benefit from the insights provided by Chaos theory. Part 3 considers some of the implications of the insights that offer benefit in the area of IS strategy.

Part 1: Complex Non-Linear Dynamic Systems

Complex systems exhibit a common set of basic characteristics (Morel and Ramanujam, 1999): 1) a complex system (CS) must contain a large number of interacting parts (Simon, 1962) kept under the control of a feedback mechanism, which causes the behavior of the system to be hard to predict due to nonlinearity of the feedback-controlled type of behavior (Casti, 1994); and 2) a large number of components interacting in nonlinear fashion give rise to the emergent properties of the system, which manifest themselves in the form of the observable and empirically verifiable patterns (Morel and Ramanujam, 1999). A system is considered to be dynamic if its state or behavior changes with time in linear or non-linear fashion.

Chaos theory (CT) pertains to the study of nonlinear dynamic system (Levy, 1994) and can be defined as the *qualitative study of unstable aperiodic behavior in deterministic nonlinear dynamical systems* (Kellert, 1993). CT is the qualitative study because "in the case of nonlinear equations expressing rates of change, no general formula exists for arriving at solutions for successive points in time" (Kamminga, 1990). CT is the study of unstable behavior because the nonlinear dynamic system is "hypersensitive" to the initial conditions (Dooley and Van de Ven, 1999) and responds to even small perturbations in significant ways. Finally, the behavior is aperiodic due to the nature of the non-linear interactions of the system's variables.

Viewing any eligible system through the lens of CT theory allows us to perceive such system as consisting, fundamentally, of two components: 1) The set of unique to each system "*Initial Conditions*"; and 2) The "*Rule*" that describe the "intended trajectory" along which the states of the system lie. While two systems can have the same intended evolutionary path, due to the difference in the *Initial Conditions*, the actual evolutionary paths of any two systems may not be the same because of the exponential growth of the small errors that force the actual path of the evolving system to deviate farther and farther from the intended trajectory, defined by the *Rule*.

The dimension of a system is the number of variables that are required to describe the system at the given state. In the case of simple non-linear systems, with dimension less than three, the errors could grow indefinitely. However, feedback mechanisms of the CS (with the dimension of three or more) prevent the errors from growing to infinity. Instead, the CS can go through extremely complicated behavior where it "stretches and folds over onto itself, like a baker kneading dough" (Radzicki 1990, p. 65). When mapped on the *phase space*, which is an abstract geometrical space representing states of the system in time, behavior of a system is commonly represented in terms of an *attractor*, which is a "set of points in the phase space of a dynamical feedback system that defines its steady state motion" (Radzicki 1990, p. 64). Every attractor has a *basin of attraction* or a set of points in the space of system variables; such that initial conditions chosen in this set dynamically evolve to a particular attractor[1]. For example, if a system fluctuates aperiodically, it is said to have *strange* attractor. Strange attractors of a system could be of two kinds: *tori* attractors and *chaotic* attractors. While systems with *tori attractors* fluctuate in predictable fashion, the manner of fluctuation of systems with *chaotic attractors* is unpredictable (Radzicki, 1990). Strange attractors are called chaotic when the trajectories in the phase space, from two points very close on the attractor, diverge exponentially, thus reflecting the system's sensitive dependence on initial conditions and even small perturbations. This notion of attractors brings about the important insight that while evolutionary path of chaotic system is not predictable, the pattern of the path could be predicted (Dooley and Van de Ven, 1999). The important implication is that it allows for modeling of the overall behavior of the system.

According to CT, a given system might have multiple attractors, thus exhibiting multiple patterns of behavior. For example, it is possible for a system to transition from having a semi-stable dynamics of the *torus attractor* to the *chaotic* state. Significance of this warrants some elaboration. Behavior of the system characterized by a *torus attractor* is predictable because such attractor has a single basin of attraction. However, when a value of key parameter of such system increases and then exceeds a threshold value, it forces an outcome basin to expand into two distinct causal fields, thus forming *'butterfly' attractor*. Unlike system with *torus attractor*, a system with *butterfly attractor* may vary significantly from one state to the next. However, it is still very probable that it will wind up in one of two fairly stable, if very different outcome regions (Young and Kiel, 1994). This process of doubling of number of basins, or *bifurcation*, could safely continue up to the point of system having eight basins of attraction. However, the next bifurcation, resulting in the attractor with sixteen basins of attraction, marks the onset of chaos (Feigenbaum, 1978). Young and Kiel (1994) comment that "the remarkable thing is that this precipitous rush into an infinite number of outcome basins is universal over all natural systems so far studied. The Feigenbaum constant gives us the possibility of making a prediction of the onset of full chaos when the first few period-doubling parameters are known."

In order to argue the point that organizational IS could be looked at through the lens of CT, we follow a step-by-step approach of eligibility assessment: 1) Complexity: Since more than three variables are required to describe an organizational IS at a given state, it qualifies as being CS in terms of the number of components; 2) Non-Linearity: An organizational IS is a social system, and social systems fundamentally contain nonlinear relationships (Radzicki, 1990); 3)Occurrence of Emergent Properties: These could manifest themselves in a variety of ways in any organizational IS: as an artifact in the form of mosaic e-mail correspondence (Lee, 1994), as a system's behavior in the form of network bottlenecks, or as a social power relationships (Markus, 1983). These emergent properties do not stay fixed, however, but change with time as the organizational IS itself changes.

The change of emergent properties suggests that IS behaves as a dynamic system, for the performance of

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[1] Weisstein, E. "Basin of Attraction." From *MathWorld*--A Wolfram Web Resource. http://mathworld.wolfram.com/BasinofAttraction.html

organizational IS always fluctuates and IS itself follows a life cycle. Let us now assess whether organizational IS is a non-linear deterministic system. Consider, for example, the issues associated with the scalability of the equipment, where cause, which could be exemplified by increased bandwidth of the network or processing power, does not have a linear relationship with the effect of the system's performance. However, such non-linear relationships are still deterministic. It is so because we 'know' that the increased bandwidth must contribute to the throughput, as well as we 'know' that improved virus protection must contribute to the security of the system. New positions for help desk operator 'deterministically' relate to the improved customer support, and new software engineers are hired not because such step 'probably' results in the increased software production. All examples may exhibit different degree of cause and effect, but that the cause and effect relationships exist between them is certain and not probable. Overall, it seems reasonable to qualify organizational IS as a complex non-linear deterministic dynamic system. Therefore, the behavior of the organizational IS can legitimately be inquired into through the lens of CT.

This intent is hardly surprising, for Dooley and Van de Ven (1999) state that increasing interest of organizational scholars focused "on the notion that at times an organization may be viewed as behaving chaotically" (p.358), as well as on the "implications of chaos-that the system is deterministic and hypersensitive to small perturbations" (p.358). Some of the examples provided include works of Cheng and Van de Ven (1996), Koput (1992), Jayanthi and Sinha (1998), Dooley, Johnson and Bush (1995), Goldstein (1994), Priesmeyer (1992), Stacey (1992), and Thietart and Forgues (1995). In this paper, our goal is to apply CT to the strategy of organizational IS and, ultimately, to derive a set of insights that such application may yield. Next part of the paper is dedicated to the brief review of the topic of IS strategy.

Part 2: IS Strategy (ISS) through the lens of CT

An appropriate ISS is aimed at successfully answering two fundamentally important questions. First, how to achieve an alignment of the IS Plan with the business strategy, and, second, how to introduce IS into organizational environment. Common ground to the interests of CT and purposes of ISS is their shared interest in the long-term behavior of the systems under study. In this paper, we consider an ISS as consisting of three components: ISS formulation, ISS implementation, and ISS evaluation.

ISS Formulation via CT Lens

ISS formulation involves long-term prediction of the future state of organizational IS, by itself and in relation to the state of the organization. In terms of the achieving the alignment between an organization and its organizational IS, CT suggests that it is only achievable in short-term. Even if the two systems start from being perfectly aligned, in a long run this alignment will be lost. According to Lorenz, "two states differing by imperceptible amounts may eventually evolve into two considerably different states. If, then, there is any error whatever in observing the present state -and in any real system such errors seem inevitable-an acceptable prediction of an instantaneous state in the distant future may well be impossible" (cf. Kellert 1993, p. 12). To add an insult to injury, we must acknowledge that organization and organizational IS can never start at the point of 'differing by imperceptible amounts', rather, even the beginning states would differ significantly. Moreover, in the case of organization and organizational IS even the dynamic models of the behavior will be different. Thus, the goal of alignment of organizational IS with organization represents an attempt to align in distant future states of the two different systems with different dynamics and different starting conditions. This allows us to put forward the following proposition: *Long-term alignment between ISS and business strategy could not be achieved* (Proposition 1A).

In order to proceed with successful introduction of IS into organization, we must predict or forecast the future desired state of the organizational IS. Now, it is not problematic to create a model of the future state of organizational IS, what is problematic, however, is how to create a model of the *desired* future state. There are no tools at our disposal that can help us to predict what such state will be. In terms of CT, desired state would mean the state of the system that lies on the surface of the attractor. However, it means that we must be able to predict long-term behavior of the IS, by stating in advance what kind of attractor CS will have. Considering these points, we now put forward the following proposition: *Long-term prediction of the desired state of an organizational IS can not be achieved* (Proposition 1B).

ISS Implementation via CT Lens

ISS implementation can be considered to be the process of matching the actual state of an existing organizational IS with the intended one. This process of 'matching' is achieved by means of manipulating the behavior of the existing organizational IS. In terms of CT, process of ISS implementation concerned with the qualitative transformation of the current system's state to a new dynamical state (Young and Kiel, 1994). We know that while a system goes through the process of consecutive bifurcations prior to the region where deterministic chaos sets in, a number of natural outcomes in which system might be found changes, but internal parameters of the system stay the same. Meaning, in the pre-chaotic region the same internal configuration of the system might produce up to eight different outcomes. However, as the system enters the state of chaos, new windows of order appear which represent the emergence of entirely new organizational forms (Young and Kiel, 1994). The implications of it are obvious for ISS implementation; if what is desired is an entirely different form of organizational IS, then the process of strategy implementation must go through the chaotic stage. Accordingly, we would like to put forward following proposition: *The process of ISS implementation will have a chaotic component if the goal of the process is to obtain a qualitatively new form of organizational IS* (Proposition 2A). Consequently, the process of ISS implementation can be perceived as taking the organizational IS through the 'Order-Chaos-Order' transformation. On the other hand, if the goal of ISS implementation is to change the behavior of the organizational IS while preserving the existing structure, then the process of ISS implementation does not have to have a chaotic part. Meaning, the process of implementation might approach the edge of chaos, but never actually cross it. This scenario leads us to another proposition: *The process of ISS implementation does not have to have a chaotic component if the goal of the process is to change the system's behavior while preserving the existing structure of organizational IS* (Proposition 2B). Irrespectively of whether the goal of ISS implementation is to produce a new system or to elicit a new pattern of behavior from the existing system, the implementation process always involves change in the existing system's behavior. According to CT, the behavior of each system, as well as the change in its behavior, is unique to each system. Therefore, we are justified to put forward following proposition: *The process of ISS implementation is unique to each organization and is driven by unique to each organization set of factors that influence changes in the behavior of IS in unique way* (Proposition 2C).

ISS Evaluation via CT Lens

ISS evaluation can be perceived as consisting of two parts: Comparing the actual state of organizational IS with the intended one; and Assessing the implementation process in terms of its efficiency and effectiveness. Most of the traditional organizational evaluation programs are based on the performance against predicted goals and are developed with the assumption that the organizations represent stable and predictable systems. As a result, such programs are generic and capable of dealing only with linear subset of the behavior of CS. However, the adequate evaluation system must be able to match dynamics of the system to which it applied, as well as be able to take into consideration unique situation of the system (Eoyang and Berkas, 1999). The following two propositions, therefore, are put forward. First: *Tools and methods used in the process of ISS evaluation must be able to take into consideration linear and non-linear aspects of the dynamic system's behavior* (Proposition 3A). Second: *Tools and methods used in the process of ISS evaluation must be able to take into consideration the unique situation-specific circumstances of the system's development* (Proposition 3B).

We know that due to the gradual magnification of the inevitable errors made in defining the initial state of the system, as well as the system's sensitivity to the manipulation of the control parameters the long-term future of the system's state and behavior is unpredictable. However, it takes time for the errors to magnify. As a result, short-term future of CS is relatively predictable, because the values of the errors have not yet been magnified to the point of noticeably affecting behavior of the system. The mid-term future is less predictable because errors become large enough to affect dynamic of the system, but not to the point of altering dynamics completely. Finally, in the long-term future errors become magnified to the point of making behavior unpredictable. Because of this dynamics, evaluation of the CS must have distinct strategies for each of the time ranges. At this point, we propose that the *Evaluation of ISS must explicitly take into consideration inherent differences that exist between evaluating the short-term, mid-term, and long-term goals* (Proposition 3C). Next, we consider the implications of the insights of CT into the area of ISS.

Part 3: Implications of the insights provided by CT

ISS Formulation

While CT states that exact behavior of the system is unpredictable, even in the state of deterministic chaos behavior of the systems "is characterized by self-sustained oscillations whose period and amplitude are nonrepetitive and unpredictable, yet generated by a system devoid of randomness" (Radzicki, 1990). It is those "repetitive patterns, which often provide useful information" that ISS formulation must take into consideration (Levy 1994, p.172). Consequently, we offer the following implication: *Formulation of ISS should be process- rather than goal- oriented* (Implication 1A). Let us recall that according to CT we cannot make a long-term prediction regarding the state of the system. However, it is possible to identify general patterns of behavior. Because organization and organizational IS are complex dynamic systems, such patterns could be identified for both. As a result, it may be proposed that ISS formulation must be concerned with constant aligning of the general patterns of their respective behaviors. Consequently, we offer a following implication: *ISS formulation should propose the solution to the issue of long-term ISS-Business strategy alignment in terms of the process of aligning the behaviors of the two systems, rather than in terms of the alignment of their states* (Implication 1B).

ISS Implementation

Three components are essential for managing the behavior of chaotic system (Kiel, 1997): 1) understanding of non-linearity; 2) appreciation of the sensitivity of the system to its *Initial Conditions*; and 3) understanding of non-average behavior as a source of change. In regard to the first component, Senge (1990) and Holland (1995) argue that it is of great importance to find the "*leverages*" (Senge 1990, p.114) or "*lever points*" (Holland 1995, p.97) of the system that could be subject to *butterfly effect*. Moreover, once these lever points are found even "small targeted change may produce larger scale results compared to comprehensive change efforts that may squelch an organization's or social system's capacity for adaptive response" (Kiel, 1997). And while Holland (1995) acknowledges that its is not a trivial task to find the system's leverage points, Kiel (1997) partially addresses this issue by suggesting that the best approach is to use multiple possible levers and hope that at least some of them will work (Kiel, 1997). The second component, the system's sensitivity to the initial conditions, raises concerns regarding the effectiveness of the commonly utilized practices of benchmarking, transfer of best practices and search for prepackaged solutions. After all, CT suggests that we cannot expect that the same intervention would produce the same effect in two systems. Consequently, suggestion of Kiel (1997) that "managers identify the elements unique to their environments prior to the implementation of another jurisdiction's best practice" seems to be well warranted. Finally, the last component that is required for managing a chaotic system refers to the appreciation for a "non-average" (Prigogine and Stengers, 1984), unusual event that "pushes the boundaries of existing structures and processes and leads the way for new forms of organizational response and evolution after bifurcating events" (Kiel, 1997). Such event most likely to manifest itself in the form of an outlier, produced by a CS which behavior on the brink of change is "neither normally distributed nor regular" (Parker and Stacey 1994, p. 75). The obvious implication of this components for the managing system's behavior is clear, for it serves as an indicator and an early warning about the system behavior and structure of which is about to change. Taking into consideration the stated above, at this point we to propose a following implication: *The process of ISS implementation that aims to result in a qualitatively new form of organizational IS should start from identifying the system's unique characteristics, then proceed by means of small targeted changes, while being guided by non-average events* (Implication 2A).

The next implication that we develop would be pertinent to the management of the system that approaches the edge of chaos, but never actually crosses it. The managing of the behavior of such system is a process of controlled increase of the induced into the system gradual chaos. According to Kiel (1995), there are three ways to control chaos: 1) By altering the system's parameters in order to reduce uncertainty and increase predictability; 2) The application of small perturbations to the chaotic system to try to cause it to organize; and 3) Changing the relationship between the system and the environment. At this point, we offer a following implication: *The process of ISS implementation that aims to result in the change of the behavior of existing organizational IS could prevent entry of the system into chaotic region by either altering the internal parameters of the system, or by altering system's relationships with the environment, or by applying small perturbations to the system* (Implication 2B).

ISS Evaluation

Mapped on the time scale, motion of dynamic systems appears as continuous. However, the change that ISS intends to produce might not be continuous. Because of the inherent non-linearity, change may come in bursts, perhaps corresponding to the bifurcation points, which then are followed by long periods of the apparent lack of any activity. As a result, the process of ISS evaluation cannot rely on the existence of a smooth, linear path between beginning and the end of ISS implementation project. Consequently, such commonly used methods of evaluation as periodic sampling or end-point evaluation cannot adequately assess the unpredictable patterns of change. Eoyang and Berkas

(1999) suggest that in order to incorporate flexible and dynamic features of dynamic systems, evaluation systems should be able to capture an emerging model of causal relationships, as well as to evaluate and revise the evaluation design often, and, finally, be able to capture, preserve and learn from the unexpected system behaviors. This allows us to put forward the following implication: *Tools and methods used in the process of ISS evaluation must be able to capture an emerging model of system's causal relationships, evaluate, and revise the evaluation design often, and capture, preserve and learn from the unexpected system behaviors* (Implication 3A).

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