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Organizational information systems as seen through the lens of chaos theory.

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Abstract.
Chaos theory covers the qualitative study of unstable aperiodic behavior in deterministic non-linear dynamical systems. Organizational transformation and behavior analysis have lately been modeled after concepts from chaos theory. In this research, we use these ideas to analyze corporate IT infrastructures. The fundamental ideas of chaos theory are extracted and used to the construction of a theoretical framework. When developing a plan for an information system or implementing an information system, it is crucial to have a thorough awareness of the current state of affairs. We explore the concept of "strange attractors," or recurring patterns of behavior in information systems, organizations, and people, while taking into account the impact of both exogenous and endogenous factors. The adoption of an information systems strategy in the United Kingdom's probation service is used as a case study for the application of chaos theory ideas. It is argued that chaos theory principles provide helpful guidance in constructing a logical and relevant account of the relationships between IT infrastructure and its host enterprises.

Keywords: chaos theory, complexity, information systems strategy, interpretiveresearch, strange attractors, National Probation Service

INTRODUCTION

Because of the complexities inherent in organizations, researchers in the subject of organizational studies have sought metaphors and models to better define and explain the many social phenomena that may be seen inside them (Weick, 1998; Lamberg & Parvinen, 2003). Organizational behavior and development have been understood with the use of analogies from complexity research, such as chaos theory (Svyantek & DeShon, 1993; Cilliers, 1998; Olson & Eoyongi, 2001). The complexity of organizational behavior has an effect on IS at both the planning and execution levels. Moreover, the adoption of IS may alter the conduct of an organization in ways that may not be foreseen (Orlikowski & Hofman, 1997). Thus, it is plausible to suggest that the study of information systems in companies may benefit from drawing on the same metaphors and models utilized when examining other types of organizations.

Metaphors and models provide the basis for interpretive approaches in information systemsthat seek to draw out patterns and shed light on complex social-technical situations. Theyact as sense-making tools. They are the scaffolding (Walsham, 1995) that enables the IS researcher's audience to make sense of an interaction between IS and its organizational con-text, to view the phenomenon holistically and draw lessons that may be applicable in other sit-uations. While such models cannot be said to provide cause and effect explanations of social phenomena in information system studies, they can be seen as conceptual maps that enable the researcher's audience to navigate a situation, to view the underlying patterns and to incor-porate such patterns into their world view for reference when they encounter similar situationsin their practice or research.

Interpretive research involves both the selection of a method for carrying out the research and a model or metaphor as a framework for interpretation. Interpretive researchers in IS havetended to focus on case studies as the principal method. Whether longitudinal, historical or involving a series of snapshots, case study material provides the building blocks for the con- struction of interpretive models. Method and model are inextricably linked because the way inwhich the method is executed may be affected by the selected model. Additionally, the data col-lected within a case study may lend itself to interpretation through a particular model.

IS researchers have drawn on a variety of disciplines including sociology, philosophy and organizational studies as a source of models to act as lenses through which IS phenomenon are explained. Structuration theory has proved to be a popular model for linking individual social process and organizational social process concerning IS strategy (Walsham & Waema,1994; Jones *et al.*, 2004). Actor Network Theory has provided a model for

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examining several case studies of IS acceptance and implementation within organizations (Monteiro & Hanseth 1996). Models of power have been used to interpret IS strategy and implementation in orga- nizations (Horton, 1998; Doolin, 1998). Other interpretive studies have drawn on philoso- phers such as Heidegger and Gadamer to provide conceptual models to guide the research process and outcome (Introna, 1997; Butler, 1998). Often, in addition to drawing from other disciplines, IS researchers extend models from other disciplines and construct their own models.

The purpose of this paper is to examine the potential of chaos theory as an interpretive model for understanding the complex interactions between information systems and their orga-nizational environments. I suggest that chaos theory has potential as a sensitizing tool for iden-tifying patterns in the interactions between information systems and their environment and maysupport the identification of significant events and their effect on the life of an information sys-tem within an organization. Chaos theory differs from other interpretive models in that its ideas and concepts are firmly grounded in the reductionist world of physical sciences and can be derived from mathematical studies. This paper draws out concepts from chaos theory that might form an interpretive framework for investigating information systems in organizations. In particular, concepts around the effect of initial conditions, evolving feedback loops and strangeattractors are examined for their interpretive value.

To do this, I first introduce the principal concepts of chaos theory. The aspects of chaos the-ory of value in interpretive information systems studies are discussed. The resulting interpre- tive framework is then applied to a case study concerning the implementation of information systems strategy in the UK probation service. I suggest that interpretive application of the con-cepts of chaos theory is of value in constructing descriptions of information systems interactionin organizations.

DEFINITION OF CHAOS THEORY

Chaos theory can be defined as 'the qualitative study of unstable aperiodic behaviour in deter-ministic non-linear dynamical systems' (Kellert, 1993). It is a part of complexity theory which concerns itself with non-linear dynamic systems whose behaviour does not follow clearly pre-dictable and repeatable pathways. In linear systems, the relationship between an environmen-tal factor and system behaviour is predictable and easily modelled. As the presence of an environmental factor increases, the system behaviour changes linearly in response to it. In contrast, behaviour in chaotic systems may be perceived as unpredictable. Periods of inactivitymay be punctuated by sudden change, apparent patterns of behaviour may disappear and newpatterns unexpectedly emerge. Such behaviour emerges in complex systems. This chaotic behaviour does not indicate a lack of order. Rather, the order is difficult or impossible to describe in simple terms and requires complex narrative description.

The systems explored in chaos theory are dynamic. They respond to the environment and are often inherently unstable. Where stability occurs, it is fragile and may be disrupted by smallenvironmental changes. Chaotic systems react significantly to such changes and shift betweena number of semistable states. It is the study of this fluid behaviour that gives rise to significantinsights.

Chaotic systems do not manifest any fixed, repeatable patterns. Variables associated with the system do not repeat values, although they remain within a fixed, definable space. Such aperiodic behaviour is highly complex and permanently sensitive to small perturbations. Pat- terns emerge, persist for a while and then die off to be replaced by apparent randomness andthen the birth of new patterns. These patterns are dynamic, never exact copies and in a stateof flux.

Tsoukas (1998) suggests that chaotic systems are deterministic in that, given the initial con-ditions, there is one unique end point or goal of the system that can be mathematically derived.Small changes in the initial conditions may generate very different end points. If we consider an isolated system, in which initial conditions are determined and the system then runs to com-pletion without any further intervention, then we can clearly determine the end point. However,determinism does not imply total predictability. Thietart & Forgues (1997) argue that cause– effect links, although deterministic, cannot be repeated. Similarly, Baskerville & Smithson (1995) suggest that causal links between management directives and organizational responseshould be treated with caution.

In many systems, the complexity is magnified as there is constant intervention involving newconditions and environmental change. Such a level of complexity may be impossible to fully explain and predict with limited human understanding, and simulations would be impossible to build, given the limits of computer technology. Causality will operate in two directions such thatsystem behaviour elicits actions and actions shape system behaviour. Relationships are recur-sive and changes have multiple causes.

It should be noted that Kellert (1993) argues that chaos theory may not be deterministic, despite determinism being an element of his definition of chaos theory. Taken in conjunction with quantum mechanics, the extent of determinism supported by chaos theory is limited. As the position of a particle in a system can only be localized to a finite bounded area and not pre-cisely defined at a particular point, two identical chaotic systems with identical initial conditionsand boundaries can be in different states after a period of time. As chaos theory is, to some extent, indeterministic, its interpretive application may be justifiable.

Finally, it should be noted that Kellert's definition suggests that the study of chaos theory is principally qualitative. Chaos theory studies seek to identify patterns in behaviour over the longterm. Such holistic studies focus on qualitative changes. Chaos theory and complexity sciencecan be applied in ways that are both objective, scientific, reductionist and generalizable and that are subjective, interpretive and individualist (Griffin *et al*., 1998; Chia 1998). Hence, it maybe suggested that chaos theory may help reconcile the unpredictability and uncertainty of social and organizational systems with scientific, determinist frameworks.

Chaos theory first rose to prominence through Lorenz's work on weather patterns and then spread to other physical systems (Gleick, 1987). In organizational and managerial studies, itsuse has been both quantitative and qualitative (Ferdig, 2000; 2002). Levy (1994) applied chaostheory to explain the complex dynamics of the supply chain of a personal computer company.More qualitative studies by Griffin *et al*. (1998), Chia (1998) and Tsoukas (1998) have used chaos theory to provide frameworks for thinking about organizational theory. Gabriel (1998) used chaos theory as a basis for challenging the myth of managerial control. Byrne (1998; 2001) applied chaos and complexity concepts in an interpretive manner to analyse social policyconcerning social exclusion. Butz *et al*. (1996) apply chaos theory to understanding the dynamics of the family and engendering family change. Families are seen as organic systemswith boundaries and patterns which change in complicated ways. Anderson (1999), Boisot & Child (1999) and Frank & Fahrbach (1999) use chaos theory as part of the broader discipline of complexity theory to provide models to describe organizations as complex adaptive systems.Stacey (1993; 2002) and Lissack (1997) proposed the application of chaos theory as a basis for understanding business strategy and the generation of business strategy. Furthermore, some management practitioners have used chaos theory as a basis for catalysing organiza- tional change (Fitzgerald, 2002; Fitzgerald & van Eijnatten, 2002; Van Eijnatten & van Galen, 2002).

In information systems, Beeson & Davis (2000) identified some complexity concepts as being valuable in studying organizational change and information systems, and apply them in a general way to study the implementation of a fingerprint identification system. Ward & Dhillon(2002) applied chaos theory to the analysis of quantitative data from information strategy stud-ies. More recently, Merali (2004) explored the significance of concepts in complexity theory indescribing the network phenomenology of information systems.

This range of studies illustrates the wide applicability of complexity theory and, specifically, chaos theory, to phenomena where the interactions between many factors are such that clearcause effect relationships cannot be established, where complex interactions give rise to emer-gent behaviour and individual effects cannot be isolated. The complex interactions between actors and technology that occur in the development of information systems strategies, the implementation of IS strategies and the development of organizational change in response to information systems may be open to interpretation within a chaos theory framework. There is a need therefore to develop an interpretive framework based on chaos theory that will act asa sensitizing tool for researchers and practitioners involved with information systems in their organizational environment. The following sections explore key elements in chaos theory thatmay be used to construct an interpretive framework for studying information systems.

ELEMENTS OF THE CHAOS THEORY FRAMEWORK

At its heart, chaos theory is concerned with the initial conditions of a system and the effect of positive feedback on changes in that system (Gribbin, 2004). However, a review of organiza- tional studies literature suggests a number of key concepts that should be incorporated into aninterpretive framework based on chaos theory (Kellert, 1993; Beinhocker, 1997; Lissack, 1997;Thietart & Forgues, 1997; Chia, 1998; Gabriel, 1998; Griffin *et al*., 1998; Tsoukas, 1998; Fitzgerald, 2002). These concepts are summarized in Table 1 and considered individually in this

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section.

Domain of interaction

Any entity, including an information system, exists within a defined and bounded space. This phase space or domain of interaction encompasses all possible states that a system could bein. In interpreting an information system in an organization, the researcher should define the domain of interaction and identify its boundaries. An example of a domain of interaction mightbe an accounting system within the finance department of a major organization over its lifetime.Within that domain of interaction there is then a finite set of possible events that could occur and outcomes from those events. The domain of interaction will contain the total number of behavioural consequences of that information system. It will define the scope of the informa- tion system and the scope of its influence on the organization. The domain of interaction may be the use of an organization-wide information system within a department. Alternatively, it may be the entire internet in which the effects of one agent-based system are traced. The domain of interaction will define the possible connections between the organization and the information system. An interpretive analysis should define the organization, the nature ofthe information system or systems being studied and the relation with the organization. The effect of the information system may then be examined in terms of the selection of possible behaviours within that domain.

ITERATIONS

Cycles of repeated behaviour can be discerned throughout the history of the NPSISS.Repeated attempts to change the user interface, to provide report suites and to release the CRAMS software are clearly present in the case study. The identification of such iterative behaviour may lead to explanations of why the organizational or social behaviour follows the track of a strange attractor and is, in a sense, doomed to repeat itself. Such behaviours may only be changed when there is a catastrophic shift to a new set of strange attractors and hencea new set of iterative behaviour.

Chaos theory also contains the idea of self-similarity in which patterns of structure or behaviour are repeated at different levels of hierarchy or granularity. For example, patterns ofbehaviour concerning attempts to extract useful information from CRAMS which were seen nationally and resulted in aborted attempts to generate report suites by Bull, were also present locally where local probation services attempted to extract their own reports (NAO, 2001).

CONNECTIVITY

The nature of the social and technical networks associated with an information system is of keyimportance in supporting the feedback and amplification of initial conditions that produce cha-otic behaviours. The NPSISS business plan did not make provision for extending the networkto the Home Office Probation Unit. This may have reduced the quality of communication by thehead office with local office.

The IT strategy was run by an IS steering committee which, while having representation by chief probation officers from local services, was very much a central committee with no mech-anism for promoting acceptance and ownership of the NPSISS by local services. While the ISsteering committee approved initial systems, it had virtually no involvement in their local imple-mentation. In addition, other key decisions including purchasing the third-party reporting tool, GQL, and suspending further development of CRAMS were taken outside the committee by the Home Office.

There was no overall strategy for communicating information about the NPSISS and CRAMS. *Ad hoc* communication with chief probation officers and other probation service staff did not constitute effective communication. Lack of connectivity between the Home Office andlocal probation services could be contrasted with communication among local probation ser- vices which may have served to propagate stories and rumours about CRAMS. Local con- nectivity supported feedback and therefore the amplification of some initial attitudes about CRAMS, whether supported or unsupported. The heavy workload in CRAMS roll-out reducedthe level of communication provided.

Changes in social connectivity may affect the amplification of social messages concerning IS usage and implementation, and hence affect the effectiveness of IS implementation. In inter-preting the social effects of an

information system, it is important to understand the nature of the organizational and social networks within which it resides. Here, concepts from small worldmathematics may be of relevance (Watts, 1999).

Identifying networks of connectivity in this case study would require the identification of con-nections and conduits of information flow at a local level. Formal reports from the NAO and theNational Probation Service only identify the lack of formal communication and connectivity within the dynamic system. The informal connectivity and networks that may have contributedto the amplification of particular perceptions of CRAMS and attitudes to NPSISS would not bevisible from the analysis of formal documents. The local study (Musgrave, 2000) suggested that informal connectivity was much more significant and extensive than formal connectivity. Such informal networks would enable amplification of particular initial conditions and enable chaotic phenomena.

CONCLUSIONS

Interpretive research involves the construction of a story about events and suggests some rea-sons behind them (Walsham, 2001b). It recognizes the subjectivity of both the participants and
the researcher. The participant's statements, whether in interviews, or, as in our case study, documents from the Audit Commission and the National Probation Service, represent a sub- jective view of events and causes. The researcher also interprets these phenomena through the lens of his or her subjectivity.

This paper explores the use of chaos theory to provide conceptual scaffolding for extendingthe understanding of information systems in organizations. As a subset of complexity theory, the ideas of chaos theory are based on a view of organizations as non-linear dynamic phe- nomena in which emergent behaviour results from the interactions within complex networks ofsocial and technical agents. Such complex behaviour may not be open to linear analysis of thefactors affecting the organization as the number of factors is too complex and their interactions too involved.

The importance of theories based on complexity theory, chaos theory and non-linear dynam-ics has grown in organizational and management studies, but remains a neglected source of inspiration in information systems. This paper provides a step towards remedying this situation.I suggest that the core concepts of chaos theory may provide phenomenological support for interpreting organizational interactions involving information systems.

In treating organizations and the information systems that reside in them as non-linear sys-tems, a number of assumptions are made (Lichtenstein, 2000). Change in the system is takenas being constant. Any apparent stable state is treated as temporary. Organizations and theirinformation systems cannot be decomposed into simple elements because the complex inter-actions between processes give rise to new emergent behaviour. System elements are inter- dependent and interactions between them are non-linear such that linear causal links cannot be made. Most significantly, for an interpretive use of chaos theory, effects within non-linear systems are non-proportional. Small inputs can have large effects, and large inputs result in nosignificant change.

The use of chaos theory may provide a framework for describing and interpreting the dynamic interactions involved in the determination of IS strategy, the implementation of IS andthe use of IS over a period of time. Ideas such as initial conditions, strange attractors, edge ofchaos and bifurcations provide support for developing a coherent and meaningful story that offers valuable insights into the interactions between information systems and organizations. A study of the initial conditions within an organization at the point an information system is introduced may give some indicators as to why subsequent phenomena occurred. A search forbehavioural patterns repeated within the organization over time may be valuable, particularly when linked with shifts in organizational structure or IS usage.

Using chaos theory as an interpretive tool will be valuable in concentrating the researcher'sfocus on the dynamic progression of the information system's involvement in the organization.It will support the highlighting of organizational and individual choices made in the provision ofthe information system. It encourages the surfacing of dynamic patterns of behaviour that, once identified, may lead to new insights concerning the role and development of the infor- mation system within the organization. In particular, chaos theory emphasizes the importanceof initial influences on the development of the information system. However, chaos theoryis more concerned with the dynamic story developing over time and the social interactions involved. It may miss important elements required for a rounded interpretation such as cultureand power structures if they do not change

over the period studied.

The study to which the concepts of chaos theory have been applied involved the expensivefailure of an IS strategy in a public sector organization over a period of years. The story is welltold in the Audit Commission and Home Office reports. However, in reading the material it became apparent that chaos theory could be used as a framework to draw out significant eventsand patterns of behaviour. In particular, initial choice and conditions would affect the outcomeof the NPSISS. Repeating patterns of behaviour could be identified and examples of chaos the-ory concepts listed (Table 2). Using concepts from chaos theory helped to explore significant issues arising from the NPSISS case and helped in making sense of the progression of eventsover time. Application of chaos theory provided practical insights concerning the managementof information systems strategies, but it may not result in new theory without further work.

Any interpretation of a case study is inevitably incomplete. Incompleteness is no less anissue with a chaos theory-based interpretation. The complexity of the interactions within anorganization and with its information systems is such that only some issues will be highlighted.Within an organization, there may be many interactions, attractors, and edge of chaoseffects operating. The completeness of the picture depends on the depth of focus. As we lookfurther into the organizational phenomena, new initial conditions and attractors may emerge.Like an organizational Hubble telescope, more detailed studies of local organizations and inter-actions may reveal further organizational attractors like Hubble identifying thousands of gal-axies in what was taken to be empty space.

Some key initial conditions may be missed. In searching for patterns of behaviour, some strange attractors may be overlooked because of their complexity. An interpretation may only highlight some aspects of the whole story. Indeed, there may not be enough information to con-struct a joined-up story.

However, those initial conditions, choices and strange attractors that are identified may pro-vide useful insights into the behaviour of information systems in the organization and may sug-gest behaviours to be looked for in other future cases. Additionally, to be of value topractitioners, ideas from interpretive framework should be simply structured and clearlydefined so that the practitioner, with little time for detailed study, may easily pick up a conceptand use it as mental scaffolding.

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