ADAPTIVE INFORMATION SYSTEM DEVELOPMENT

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Abstract

Information system development (ISD) is being conducted in an increasingly turbulent and complex environment. New forms of ISD are emerging, such as open source software and agile methods but theory is needed to explain and help improve the organization of ISD. Complex Adaptive Systems (CAS) provides a novel perspective to understand and describe new forms of ISD and provide a theoretical foundation for researchers. This paper provides an overview of CAS and a review of its application to the study of organizations and to ISD. A directive approach to ISD is compared with a CAS informed approach, adaptive ISD. The CAS concept of coevolution is then used to throw light on the relationship between ISD and the enterprise in which the ISD activity takes place. The paper concludes with a research agenda for the application of CAS to ISD.

1. INTRODUCTION

In a Net-economy characterized by turbulent markets, an unpredictable environment, and rapidly developing technologies, companies need to rethink their traditional product development processes and embrace more flexible and responsive approaches (Iansiti and MacCormack 1997). Empirical studies of software development practices at international Internet software companies reveal some success factors for development in Internet time (MacCormack 2001; Baskerville and Pries-Heje 2002): the capability to deliver something working as early as possible, the ability to adapt to change (even when the project is at the later stages of development), and a stronger-than-ever emphasis on collaboration with customers throughout the project life span. Although case studies of Internet time information system development (ISD) are valuable because they help us understand what is going on in practice, they have, by themselves, limited potential for building new and more general theories of ISD.

One body of theory that might provide a basis for a broader understanding of ISD is the study of complex systems. The most well-known body for complexity research is the Santa Fe Institute, which is a gathering point for distinguished scientists and researchers from different fields who share similar interests in complex phenomena. These researchers believe there are common laws governing complex systems that can cross traditional disciplines. The approach they use to explore complexity is usually presented as the study of complex adaptive systems (CAS). CAS originated from natural sciences, such as physics and biology, and has more recently been applied to the study of organizations and organizing (Mitleton-kelly 1997; Anderson et al. 1999; Stacey 2003; Brown and Eisenhardt 1999; Haeckel 1999). Although CAS ideas have been used as the basis for agile software development by Highsmith (2000), the explicit application of CAS ideas to the field of ISD is sparse. However, it is also possible that CAS ideas are being used implicitly (and successfully) in non-traditional approaches to ISD such as open source software development.

The aim of this paper is to explore CAS theory and to consider how the IS researcher might use these ideas to investigate and build theory about ISD. To this end, section 2 provides an overview of the characteristics of CAS. Section 3 describes how CAS has been applied to organizations and considers the ontological and epistemological standing of CAS. In section 4 the application of CAS to ISD is explored with a focus on agile methods and open source software. In section 5 a view of adaptive ISD is developed and contrasted with the traditional directive approach to ISD. This is enriched by an exploration of the implications of coevolution for ISD. A summary is provided in the last section, together with a research agenda for the application of CAS to the study of IS and ISD.

2. COMPLEX ADAPTIVE SYSTEMS

Many natural and artificial systems strike us by their complexity, such as brains, immune systems, ecological cycles, financial markets, stock exchanges, and the Internet. These complex systems seem to have the ability to adapt to (and evolve in) the environments in which they are embedded. One of the key challenges for scientists is to understand these complex phenomena and describe them in a relatively simple way. With increasing complexity, this task becomes more and more demanding (Anderson 1999). Modern complexity science, especially the work of the scientists at the Santa Fe Institute, provides new ways to investigate complex phenomena, which is usually presented as the study of "complex adaptive systems" (CAS). In contrast to cybernetics, general systems theory, systems dynamics, and even chaos theory, which achieve simplicity by describing complex systems with macro level equations and abstracting away the diversity and interactions of micro level components, CAS puts the focus at lower levels, studying how individual and autonomous parts (agents) and their interactions yield emergent properties at a higher level (Stacey 2003). This bottom-up approach is considered to be the hallmark of CAS (Anderson 1999). There is no single and definitive account of CAS and related concepts, but Anderson (1999) and Stacey (2003) provide valuable introductions to CAS in the context of organization and management. From these accounts, key characteristics of CAS can be identified as: working at the edge of chaos, adaptation and autonomous agents, self-organization, and coevolution. Each of these is now considered in turn.

Working at the edge of chaos

According to cybernetics, a system seeks to stay and maintain in a stable equilibrium in order to function properly. It reaches and maintains this goal through a negative (balancing) feedback mechanism (for example, a domestic heating system). Systems dynamics introduced the idea of positive (reinforcing) feedback. One well known pattern in systems dynamics is the 'limits to success', where a reinforcing loop, such as ever increasing sales, is ultimately subject to constraint by a balancing loop, such as market saturation. CAS introduces the idea of non-linearity, where a series of positive feedbacks can push a system far away from equilibrium, sometimes into a disorderly state where no recognizable behavior patterns can be seen. According to Gell-Mann (1995), when something is in complete order or complete disorder, the effective complexity is zero: "Effective complexity can be high only in a region intermediate between total order and complete disorder.” (p. 16). A zone between order and disorder does exist, as demonstrated by many natural and artificial systems. Waldrop (1994), drawing on Langton, calls this zone “the edge of chaos”.

At the edge of chaos, a small change can either push a system into randomness or lock it into a fixed behaviour. The system shows bounded instability, stable and unstable at the same time. It is stable in the sense that the system shows patterns of behavior and the possibility space of the system’s states can be depicted using fine detail in the short term. It is unstable in the longer term in the sense that the path which the system will follow is uncertain and unpredictable - the system is in a state far from equilibrium.

When a system is at the edge of chaos, novel properties can emerge. Emergence is the appearance of a new feature, structure, or pattern of behavior at the system level which is not previously observed as part of the system’s functional characteristics. It results from the interactions of lower level individual parts. There is no plan, no blueprint at the system level for this holistic property. It emerges in a bottom-up way, but can not be reduced to and be considered independently of the properties of the parts. Emergence is the source of variety for a system. A system at the edge of chaos therefore has the potential to be creative and innovative.

Adaptation – agents with local rules

In the CAS model, the parts of a system are independent agents loosely coupled and interconnected in such a way that keeps them responsive to the change around them but not overwhelmed by the information flowing to them through their interconnectivity. Agents have their local rules, which are a package of information governing their behaviors in their interactions with other agents and with their environment. Holland calls these rules internal models while Gell-Mann terms them schemata (Gell-Mann 1995). These rules, generally, are simple, but the behaviour that results from the interactions of the agents and emerges at higher levels of the system can be strikingly complex.

Agents are responsive to the environment because these local rules describe the agents themselves and their environment, predict the future and prescribe behavior for the agents. But if an agent is always following a fixed set of rules to interact with others and the environment no matter what happens around it, such an agent has no ability to be adaptive. Agents are adaptive to the environment because they can have several set of competing local rules and these rules are subject to variation. Rules can evolve faster than agents themselves. They evolve “with a general tendency to favor better description and prediction as well as behavior conforming more or less to the selection pressures in the real world”(Gell-Mann 1995, p.17).

Self-organization

Self-organization is the ability of a system to evolve into an organized form without external pressure. The constraints on form are internal to the system, resulting from the interactions among the individual parts at the lower level but independent of the physical nature of those individuals. A self-organized system moves from a large region of state space (the total number of behavioral combinations available to the system) to a persistent smaller one (called an attractor). This process is under the control of the system itself. Generally, a self-organized system is dissipative which means it needs energy to flow into and within the system in order to move from one attractor to another.

Prigogine's work on dissipative structures shows that physical and chemical systems far from thermodynamical equilibrium tend to self-organize by exporting entropy (Prigogine and Stengers 1985). Maturana and Varela (1980) introduce "autopoiesis" to refer to autonomous systems that are self-creating, self-organizing and self-preserving. Autopoiesis is commonly applied to biological organisms and human organizations. In CAS, self-organization and emergence are keys to understand how and why complex systems can evolve from chaos and show orderly behaviors, such as the origin of life (Kauffman 1996; Holland 1998).

Coevolution

Adaptive agents tend to alter their structures or behaviors as responses to interactions with other agents and the environment. Kauffman (1996) describes this tendency as moving to higher 'fitness peaks' where agents have more chance to survive. Sometimes the alteration will cause agents to sink to 'fitness valleys', where they run the risk of becoming extinct. These peaks and valleys constitute a fitness landscape for each agent. In order to survive, an adaptive agent should continue to climb its fitness peaks and avoid valleys. All the agents are striving for fitness and seeking to avoid extinction. Each of the agents is going through their fitness landscape looking for their fitness peaks and in doing so are coevolving with other agents (the actions of each agent changes the fitness landscapes of the other agents and thus the fitness landscapes are constantly changing and deforming). In the coevolving process, those agents that are more adaptive and robust can be used as building blocks to form new and higher-level agents through recombination. Through this mechanism systems tend to develop a hierarchical structure.

The equilibrium resulting from coevolution of adaptive agents is dynamic, not static. A complex system at the edge of chaos is subject to power law dynamics (Kauffman 1993). The mathematical form of the power law is $N(s) = s^{-t}$, where N(s) is the number of events with size s and t is the exponent. The minus sign means that as s increases then N(s) falls. The implication of the power law is that large events are rare and small events are common. For example, small earthquakes happen more frequently than big ones and 80% of the wealth is controlled by 20% of the population. In CAS, small local changes are more frequently seen than large system level changes.

In summary, CAS is the study of systems that are composed of a large number of autonomous heterogeneous agents that have their own local rules and are able to adapt to their environment. Through self-organization such systems are able to reach the edge of chaos, where the CAS has the potential for creativity and innovation and the emergence of unexpected and novel system level properties.

3. CAS AND THE STUDY OF ORGANIZATIONS

CAS applications to organizations

Brown and Eisenhardt (1998) take the ideas of CAS and apply them to organizations as suggested by the subtitle of their book: "strategy as structured chaos". Brown and Eisenhardt (B&E) site the edge of chaos between structure, which they define as bureaucratic organizations attempting to run using command and control mechanisms, and chaos. At the edge of chaos "organizations never quite settle into a stable equilibrium but never quite fall apart, either" (p. 12). To compete at the edge, organizations must understand what to structure and what not to structure, to foster communication, and to capture cross-business synergies. B&E also explore the theme of time pacing and rhythm. Time pacing is an internal metronome that drives organizations according to the calendar, e.g., "creating a new product every nine months, generating 20% of annual sales from new services" (p. 167). Time pacing requires organizations to change frequently but can also stop them from changing too often or too quickly. Allied to time pacing are choreographed transitions and rhythm. Transitions are used to switch smoothly from one phase to another, such as from engineering to manufacturing. Rhythm is used by organizations to synchronize their clock with the marketplace and with the internals of their business. Time pacing is therefore not arbitrary, although Brown and Eisenhardt give no indication as to how an organization might identify and set the pace of the internal metronome.

Stacey (2003) is critical of Brown and Eisenhardt, arguing that they make loose and simplistic interpretations of CAS. Stacey argues that being at the edge of chaos is no guarantee of survival and that B&E, through their implicit use of the language of cybernetics and cognitivism, absorb CAS into traditional organizational theory. Opening this argument out further, Stacey provides a general framework for assessing the application of theory to organizations. The framework has four elements: the nature of interaction, the nature of human beings, methodology, and the focusing of attention.

Concerning *interaction*, in CAS, the nature of interaction emphasizes self-organization and emergent novelty – the system takes on a life of its own. Unfortunately, writers on organization tend to look for a few simple rules that will give rise to complex outcomes and to focus on setting a context that will enable organizations to move to the edge of chaos. This approach is reminiscent of the hunt for the silver bullet in software development – the desire to find a simple and elegant solution that will put an end to doubt and uncertainty.

With respect to the *nature of human beings*, Stacey argues that researchers have implicitly adopted cognitivist and humanist approaches. The question of human agency and the ability of humans to modify their schemata, to create and recreate meaning is side-stepped. Many researchers using CAS draw on Holland's work on emergence, but Holland is careful to restrict himself to systems with rules or laws, such as games, molecules, and scientific theories. For systems with few accepted rules, such as ethical systems and the spread of ideas, he says that "Most of the ideas developed here have relevance for such systems, but precise application to those systems will require better conjectures about the laws (if any) that govern their development" (Holland 1998, p.3). As already noted by some literature, it is difficult and not convincible to follow a straightforward mapping from generic CAS into social systems where human beings are the most important components (Mitleton-kelly 1997; Stacey 2003). Human agents in a system are affected by emotions, able to select their own individual mental purpose, impacted by power differentials among agents, and capable of systemic thinking (Stacey 1996).

From a *methodology* viewpoint, B&E (for example), see the manager as somehow separate from the situation, capable of standing outside the situation and controlling it. This view runs counter to CAS, where the manager is as much part of the situation as any other agent. At the edge of chaos there is paradox and ambiguity rather than crisis. The paradox of organizations and management are neatly summarized by Streatfield (2001):

> Are managers in control of organizations in which they work? My experience suggests this is the wrong question. The key management ability is not that of being 'in control' but the ability to participate creatively in the formation of transient meaning, which enables all o an organization's members to continue living with the anxiety generated by change. It is this meaning that creates a felt sense of order, coherence, pattern or control. The ability to participate creatively in the construction of meaning develops as managers struggle to cope with the paradox of control, using legitimate control mechanisms as tools in a wider dynamic of self-organizing communicative interaction. (p. 136)

Lastly, Stacey argues that CAS should focus our *attention* on unpredictability and diversity. The radical implications are nonlinearity, ambiguity and paradox, destruction and conflict, and the impossibility of long term planning. Similar findings are reported by Achtenhagen and Melin (2003) who consider the homogeneity/heterogeneity debate in which innovative organizations have to come to terms with paradox, trade-offs, dilemmas, and dualities. For example, empowerment and control, decentralization and centralization of units, process-based matrix organizations and hierarchical resource allocations (p. 317). The radical implications of CAS are difficult to accept for managers steeped in a tradition of being in control and able to plan and direct outcomes and the net result is a whittling away of the radical potential of CAS theory in organizations.

The ontology and epistemology of CAS in organizational research

Although it might seem self-evident and straightforward to view natural systems as CAS and thus to apply scientific method to their study, it is problematic when social phenomenon are concerned (Mitleton-kelly, 1997). Is social complexity a suitable subject for complexity theory? Can social systems be CAS? For sound research work to take place these issues must be addressed so that we "can clarify what is at issue, and help to define the proper domain of empirical inquiry" (McIntyre 1997, p. 17).

The CAS field is full of descriptive terms, such as "viruses, neurons, learning, hardwired, a forest, niches, noise, fitness, landscapes, nets and networks, basin, spin glass, etc." (Fikentscher 1998, p. 21). When applying these concepts in the field of social study, to what extent might the results produced by these terms be 'true'? According to Fikentscher (1998) the results of CAS applications have a series of decreasing plausibility ranging from: ontological conclusions drawn by using strongly convincing force of mathematical proof, through direct reasoning from structure and formal logic, down to metaphorical conclusions made by using analogy, modeling, simulation, comparison, approximation and biological metaphor (p. 47). Due to the special characteristics of social systems, the application of CAS in organizations is mainly constrained to metaphor or analogy (Church 1999) which "while evidently resonant with observations lack theoretical adequacy" (Fuller and Moran 2001, p.60).

However, the use of CAS as a metaphor is not without precedent in systems thinking. Checkland (1995) argues that the distinction between 'hard' systems thinking and 'soft' systems methodology is not about the type of problems the two approaches tackle or whether human activities are involved. Instead, the crucial distinction is that 'hard' systems thinking assumes the world to be a complex of systems while soft systems methodology makes no such assumptions, assuming only that "the process of enquiry can be organized as a system of learning" (Checkland 1995, p.53) while the best we can say about the real world is that it is problematic and messy. The ontological assumptions underlying CAS are either implicit, 'organizations actually are CAS', or explicit, 'can organizations be viewed as CAS?' From an epistemological standpoint SSM is a strongly interpretivist approach. If a similar stance were adopted with CAS then one would see CAS as a way of thinking about problem situations in order to improve organizational conversations (Streatfield, 2000) in order to build a shared understanding as a basis for collective and meaningful action.

If organizational and IS researchers are to apply CAS it is of the utmost importance that they declare the ontological and epistemological basis of their work.

4. APPLICATIONS OF COMPLEX ADAPTIVE SYSTEMS IN INFORMATION SYSTEM DEVELOPMENT

Although there is a building body of literature on the application of CAS to the field of organizational studies there is less evidence of CAS being applied in ISD. At the strategic level Peppard and Breu (2003) propose coevolution as a way of thinking about the alignment of business and IT. Of more specific relevance to ISD, the agile software development movement has consciously drawn on CAS ideas as a theoretical foundation. The association of CAS and open source software (OSS) development is less well articulated, but may prove to be a valuable example of self-organization and the implicit adoption of CAS. Agile and OSS are now considered from a CAS perspective.

Agile Software Development – pushing software development to the edge of chaos

Agile software development (ASD) emerged as a response to a rapidly changing world and the inefficiency of conventional 'rigorous' software development methodologies and practices. Termed by Highsmith (2002) as "Agile Software Development Ecosystems", a group of software development methodologies developed by experienced and recognized software development gurus share a common attribute, agility, which is "the ability to both create and respond to change in order to profit in a turbulent business environment"

(Highsmith 2002, p. 29). This family of methodologies includes Scrum, Dynamic Systems Development Method (DSDM), Crystal Methods, Feature-Driven Development (FDD), Lean Development (LD), Extreme Programming (XP) and Adaptive Software Development (ASD). The term "Ecosystems" is used to indicate that software development is more an organic than a mechanistic process. According to Highsmith (2002) it is "a holistic environment that includes three interwoven components – a 'chaordic' perspective, collaborative values and principles and a barely sufficient methodology" (p. xxiii).

In November 2001, the representatives of these methodologies convened and produced a "Manifesto for Agile Software Development" (http://agilemanifesto.org), which states:

> We are uncovering better ways of developing software by doing it and helping others do it. Through this work we have come to value:
>
> - **Individuals and interactions** over processes and tools
> - **Working software** over comprehensive documentation
> - **Customer collaboration** over contract negotiation
> - **Responding to change** over following a plan
>
> That is, while there is value in the items on the right, we value the items on the left more.

The manifesto is grounded in CAS thinking as demonstrated by Highsmith (2000), who makes explicit and clear use of CAS as the theoretical foundation of his adaptive software development methodology. The same admission was made by Kent Beck (co-inventor of *XP programming*) who claimed that CAS is "the only way to make sense of the world" (Highsmith 2002, p. 48). Using the lens of CAS, Agilists have reevaluated the software development process.

While the job satisfaction of developers in their work, customer involvement, conversation, communication and collaboration, are recognized in traditional (non-agile) methodologies, in agile approaches they are of paramount importance. This agile perspective corresponds with the emphasis in CAS given to individuals and the interactions among them - innovation and creation emerge in a bottom-up way from the rich interactions between individuals. A top-down design of structured processes and tasks can not respond to change sufficiently quickly.

According to Highsmith (2000), "In chaotic environments, success is accidental" (p. 29), a view which is echoed by CAS thinkers, who recognize that the long-term behavior of an organization can be influenced but it cannot be predicted (Stacey 2003). The reality of uncertainty and change is acknowledged in Agile methodologies and reflected in the project management approach, where projects are not managed through detailed planning, precise prediction and rigid control strategies, but through more subtle ways, "to bound, direct, nudge, or confine, but not to control", and through cultivating a culture of "emergent order" rather than "imposed order" in the project (Highsmith 2000, p.40). The positivist underpinnings of traditional project management, which assumes that reality can be understood through the identification of cause and effect relationships, give way under Agile to a sense making approach with an emphasis on continuous adapting and learning.

Agilists rely heavily on small iterative development loops (which might be as frequent as every 20 to 30 days) and continuous testing and refactoring of each small update. They emphasize small releases at the end of each development loop instead of a "Big Bang" delivery at the end of a project (Highsmith 2002). This micro-iterative approach corresponds to power law dynamics of a system at the edge of chaos, where many small changes happen more frequently than big ones.

Open Source Software Development – evolving to the edge of chaos

The origin of Open Source software development can be dated back to the "hacker cultures" of the 1960s and 1970s and the Free Software Foundation in 1985 by Richard Stallman who invented the "General Public License" (so-called "copyleft") to guarantee the openness of software source code. His idea was incorporated and improved by Bruce Perens, Eric Raymond and other prominent hackers who founded the "open source" movement in 1998 (von Krogh and von Hippel 2003). The philosophical assumption behind the open source movement is simple: "when programmers are allowed to work freely on the source code of a program, this will inevitably be improved because collaboration helps to correct errors and enables adaptation to different needs and hardware platforms" (Bonaccorsi and Rossi 2003, p 1244). Open Source software (OSS) development has proved to be an efficient way to develop software systems as evidenced by the success of Linux operating system and the Apache Internet server. A CAS lens on the OSS movement provides a way of understanding this success.

OSS developers are highly independent and heterogeneous. They are distributed around the world and have diverse curricula, interests and intentions. However, these developers are connected via the Internet by means of mailing lists, forums, instant messaging, and so on and can therefore interact. The organization of a OSS project is highly dynamic; it is not static but neither is it random. Developers can join or leave the project, but a group of core contributors exist and highly commit to the project. From a CAS viewpoint, the open source project is at the edge of chaos, a state full of creativity with the potential for generating surprises.

OSS projects are commonly thought to originate in a bottom up way, "…the hierarchically organized and top down planned structure adopted in all productive processes is abandoned in favor of a new kind of bottom up structure, which is non-coercive and largely decentralized" (Bonaccorsi and Rossi 2003, p. 1244). This self-organizing phenomenon is a typical feature of OSS projects. Fuggetta (2003) argues that these distributive and collaborative features are not exclusive to OSS projects; commercial software development initiatives, such as in Microsoft, use the same approach. However, Fuggetta didn't go further to analyze the deeper differences between these superficially similar collaborative models. In commercial software development, collaboration is an imposed property of the development process: it is planned and implemented in a top-down way. This is different from OSS projects, where collaboration emerges in a self-organizing, bottom-up way through the interactions between independent developers.

However, it would be wrong to assume that OSS projects rely entirely on a single level of bottom-up self-organization. With Linux, developers work in groups on different parts of the kernel, with each group led by a 'maintainer' who reviews the code and checks quality. Once the maintainer is satisfied with the code it is passed on to one of the developers at the top of the hierarchy: Linus Torvalds or Andrew Morton. These two maintain the development and production versions of the kernel. There is indeed self-organization present in OSS but there is also coordination from higher levels of a hierarchy of CAS. It is important that neither OSS nor CAS be trivialized as a simple bottom-up self-organizing process. If this were true OSS projects would indeed be chaotic. The study of OSS provides the researcher with a potentially rich and subtle illustration of CAS principles.

5. ADAPTIVE INFORMATION SYSTEMS DEVELOPMENT

Directive versus Adaptive ISD

The theoretical foundations of traditional development methodologies can be found in systems theory, especially cybernetics, which focuses on the macro level of the system, supposing that the entities, such as developers, in a system are homogeneous and the goal of ISD is to move the organization to a stable equilibrium. Traditional system development methodologies put focus on planning the development process carefully and in detail, predicting the possible scenarios or errors that could arise, and addressing the issues as early in the development process as possible. The round trip paradigm uses negative feedback to regulate the progress and the state of the development, diminishing the gap between the expectation and the actual status of the development to keep the development making progress to pre-defined goals. Thus, traditional methodologies treat surprises happening to the project as unwelcome disturbance and try to damp them and reduce their effects on the project, without understanding that surprises are an important and valuable aspect of a complex system. A traditional approach will also tend to damp out any internal impetus for creativity and novelty, which are needed in an ever changing environment. It is possible for prototyping and RAD to be used in a traditional way in ISD, as a more sophisticated way of achieving a rigid set of goals. We label this approach to ISD as 'directive'. In contrast to traditional methodologies, an adaptive methodology grounded in CAS should be flexible, contingent, nondeterministic, focus on individuals and the interactions between them, and absorb and even create change. Table 1 contrasts the characteristics of traditional ISD and those of an adaptive ISD.

Coevolution and ISD

A central theme of CAS is coevolution, a theme that has attracted considerable interest in the organizational theory literature (see Lewin et al. 1999 for an introduction). If a business enterprise is to be viewed as a CAS then it must itself be an emergent behaviour that results from interactions between lower level systems. This line of reasoning suggests that ISD and core business activities might be seen as CAS that will interact and coevolve.

	Directive ISD	**Adaptive ISD**
Theoretical foundation	Cybernetics	Complex adaptive systems
Organization	Structure/bureaucracy	Edge of chaos
Role of planning	Directive: to steer the ISD project to a stable and predefined equilibrium	Adaptive: to guide the ISD project to achieve a broader goal
Response to change	Avoid change by closing the gap between the expectation and the reality (negative feedback)	Reinforce small changes and new attractors, exploit emergent properties to move the development toward new equilibriums
Exceptions	Exceptions are to be designed out in the search for a perfect solution	Exceptions are the norm in an ever-changing, complex, and imperfect world
Definition of project success	The planned result is achieved on time, on budget	Project mission met
Lifecycle	Waterfall or designed iterative (RAD)	Multiple paths and testing of speculations through micro-iterations
Assumption about IS developers	Homogeneous and interchangeable parts in the process	Heterogeneous, adaptive agents with their own internal models and individual competences
Team dynamic and creativity	Limited dynamics, creativity can be stifled by structure	Unlimited during iterations, creativity and speculation encouraged
Relationship with environment	A spectrum ranging from under-responsive (project driven) to over-responsive (environment driven)	Coevolving
Structure of collaboration	Pre-defined	Emergent, self-organized
Time pacing	Fixed to a project plan	Geared to an internal metronome
Rhythm	Driven by the project environment (danger of changing too quickly) or driven by the internal structure of the project (changing too slowly)	The internal metronome is synchronized with the market (environment)
Transition	Troublesome gaps between the real work of analysis, design, testing, etc.	The real work is in the gaps, e.g., the transition from testing to production

Table 1: Directive ISD versus Adaptive ISD

In Table 2 we construct a matrix of the organization of the core business and the organization of ISD, various combinations of which might exist in an enterprise. Following Brown and Eisenhardt (1999) the organization of business and ISD are characterized as structure, at the edge of chaos, or in chaos. According to B&E, an organization characterized by structure is a rule-following bureaucracy with a rigid structure of tightly choreographed processes and formal communication channels (p. 12). By contrast, too little structure is typified by a rule-breaking culture in which individual decision-making is taken to extremes, where people don't know what is expected of them and what they are supposed to do and random and unfocused flows of information tip the system into chaos. At the edge of chaos there is just enough structure and focused, real-time communication.

This gives rise to nine archetypal relationships between business and ISD. Only one of these, (5), reflects CAS, i.e., the coevolution of systems at the edge of chaos. The remaining eight cells suggest combinations that will interact but will not evolve in a strict CAS sense unless there is development in one or both organizations. Some combinations are of particular interest. Combination (2) highlights the potential for ISD to act as a transformative change agent and (4) highlights how ISD might restrict the development of the enterprise.

		Information System Development (ISD)		
		Structure/directive	*Edge of Chaos/adaptive*	*Chaos/chaotic*
Core business	*Structure*	1 Ossification and eroding of competitiveness in the marketplace. Organizational development of the entire enterprise is required	2 ISD as transformative change agent, helping to push the business/enterprise to the edge of chaos	3 High cultural mismatch - ISD is ineffectual and viewed by the business as a maverick.
	Edge of Chaos	4 ISD acts as a brake on the adaptive capability of the business. The ISD organization needs to be pushed toward the edge of chaos	5 Coevolution of the business and ISD – the emergent enterprise is at the edge of chaos	6 ISD contributes to pushing the business beyond the edge of chaos. The ISD organization needs to be reined in so that it is at the edge
	Chaos	7 High cultural mismatch – ISD is ineffectual as the ISD structures are not meaningful to the business	8 ISD as a stabilizing influence on the business, pulling it back from the edge of chaos	9 Chaos – the enterprise is gambling on emergence

Table 2: Coevolution of core business and ISD

6. SUMMARY - A RESEARCH AGENDA FOR IS/ISD

The use of CAS as a theoretical foundation for an adaptive approach to ISD has been explored in the paper. The ideas of CAS have been presented in the general context of organizational theory and more specifically in the agile and open source arenas. The insights gained from this analysis have been used to contrast a traditional directive approach to ISD with an adaptive ISD methodology. Further, the coevolution of the ISD organization with the business organization was considered providing fresh insight into the role of ISD. However, the acid test of the value of CAS is whether it allows us to study IS/ISD from a new perspective and thereby generate novel and interesting – and researchable - questions about IS/ISD.

Firstly, the theory of CAS needs to be explored and its applicability to human systems and ISD in particular reflected on critically. What is the ontological and epistemological status of CAS? Are ISD projects 'really' CAS or is CAS better used as a metaphor? Issues such as human agency need to be addressed here, possibly through established ideas such as Giddens' structuration theory (1984).

Secondly, researchers can use CAS to inform the way in which ISD projects are organized, managed, and controlled. What might constitute sufficient structure as opposed to too much or too little? How would we know if an organization was on the edge of chaos? What is the role of the project manager? According to CAS the project manager should guide and 'nudge' rather than seek to control; the project manager should also be able to embrace paradox and uncertainty. This line of enquiry suggests the use of case studies to explore what is happening in practice (particularly in the agile methods and OSS arenas) and possibly the use of action research to make interventions according to CAS principles.

Thirdly, the relationship of ISD, the host enterprise, and the wider environment can be explored using CAS (table 2). The idea of coevolution and transforming fitness landscapes provides a rich seam of research, particularly with regard to questions about the pacing and internal rhythm of ISD activities. The principles of coevolution would also be valuable in the area of inter-organizational systems (IOS), where the role of IOS can be recast as one of promoting coevolution of partnering organizations.

Fourthly, the role of technology might be investigated. CAS lends itself to computer simulation and could be extended to simulation of ISD, such as the conditions for emergence of OSS. Further, there is a potential for computer systems to become CAS in their own right and thus coevolve with the organization without the mediating role of the ISD organization. CAS may also have valuable insights about how to organize for emergent IS through interoperability, covering areas such as middleware, enterprise application integration, grid computing, and web service enabled components.

Fifthly, since CAS are dissipative structures that must import energy to evolve and survive. A major form of energy is information and therefore it is likely that CAS can contribute to information theory and give fresh insight into the role of IS in organizations (as opposed to the process of ISD).

Taken together, the above avenues of research provide the possibility of an integrated and coherent theory of IS, IS development, and IT. However, the adoption of CAS does not mean that the rich heritage of work in systems theory in the IS discipline need be discarded. For example, soft systems may have a role to play in helping surface agents' schemata and support the process of articulation of a vision for ISD projects. Some CAS critics, such as Stacey (2003), have taken an arguably superficial view of cybernetics. Beer's (1981) work on the viable system model has many insights about the relationship of systems with their environment, about hierarchies of system and emergence, and about the relationship between command and control and autonomy. The viable system model could be used, for example, to theorize more formally about the degree of structure needed for an organization to be at the edge of chaos.

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