Complexity and Dynamism in the Information Systems Domain

Yasmin Merali, Warwick Business School, The University of Warwick, Coventry, CV4 7AL, UK; E-mail: Yasmin.Merali@warwick.ac.uk

ABSTRACT

This paper argues that the emergence of the network economy and network society extends the boundary of the Information Systems (IS) domain, and that complexity science offers the apposite concepts and tools for incorporation into a General Conceptual Framework (GCF) and Methodological Base (MB) for IS. The paper is structured in the following way. The next section outlines the imperative for a paradigm shift –from dealing with IS as discrete systems to dealing with IS as components of the interconnected world. Section 2 outlines the complexity science concepts for articulating the dynamism, adaptation and co-evolution observed in the interconnected world, and Section 3 discusses the way in which the complexity science concepts connect with existing philosophical movements in the IS domain, and reflects on how they may contribute to the development of a GCF and MB for IS.

1. INTRODUCTION

The IS and IT landscape is characterised by network dominance and increasing complexity. As shown elsewhere (Merali and McKelvey, 2006), the network motif is one that we can see at play at many different levels in the evolution of the IS field, for example,

- the potency of discrete advances in hardware and software capabilities to generate significant change in business and society is realised through the mobilisation of network effects;
- technological advances escalate the potency of network effects by continually enhancing the connectivity and bandwidth of networks;
- the growth of IT-enabled socio-economic networks is accompanied by globalisation and an increase in the number and heterogeneity of players who can affect the dynamics of networks.

Recent work on small world and scale-free networks (Newman, Barabási & Watts, 2006) shows that small changes in network connectivity can bring about major, almost costless changes in the characteristics and behaviour of the socio-economic players and milieu. The net effect of this is a perception that individuals and organisations have to deal with a world that is increasingly dynamical, complex, and uncertain, and that their actions may have unintended consequences that impact on other parts of the world.

The network form of organising is the signature of the internet-enabled transformation of economics and society. Management literature has shifted from focusing solely on the firm as a unit of organisation to focusing on networks of firms, from considerations of industry-specific value systems to considerations of networks of value systems, and from the concept of discrete industry structures to the concept of ecologies. The labels "network economy" and "network society" (Castells, 1996) have become integrated into the management lexicon. In the strategy literature the network economy is characterised by competition in high-velocity environments, speed of technological change and uncertainty (Eisenhardt, 1990. Organisations, needing to shape and redefine their own competitive arena are confronted with the need to continually innovate (Hayton, 2005). This brings with it the challenges of working towards radical and incremental innovation, whilst dealing with resource constraints to achieve an efficacious balance of risk and return. From the IS perspective, an interconnected world that is comprised of technologically mediated networks of networks can be conceptualised as

- a complex multidimensional network which
- connects a diversity of agents (individuals, groups, institutions, nations, computers, software components etc.) through
- multiple and diverse communication channels

IS and IT underpin the realisation of this networked world. Strategy, OD and IS research have converged on issues of connectivity, co-ordination, competition and collaboration, learning and transformation at multiple levels of analysis in the networked world.

These developments have two important consequences for IS scholarship and methodology development: IS methodologies need to offer the requisite ontological and epistemological constructs for enabling us to

- deal explicitly with dynamism, complexity and continuous change, and
- engage with the trans-disciplinary discourse

characteristic of the emergent networked world, in which many heterogeneous components (social, institutional, technological and informational) are connected in a dynamic fashion.

Complexity science is viewed as a source of concepts for enabling the trans-disciplinary exploration of complex organisation in the networked world, and for explaining the dynamics of networked systems at different levels of description ranging from the micro- to the macro. It offers a powerful set of methods for explaining non-linear, emergent behaviour in complex systems (Anderson, 1996, Merali, 2004 have overviews for OD and IS). There are three special issues dedicated to applications of complexity theory[1], [2], [3] in the IS domain.

The systemic level IS capabilities underpinned by the network form of organisation that are of particular interest in the "New Economy" include:

- intelligence (sensing internal and external contextual characteristics, developing representations of the environment and formulating and implementing appropriate strategies and responses).
- coordination (particularly dynamic co-ordination and recombination of distributed resources, processes and capacity to act),
- robustness (the ability to reconfigure, self-repair and renew, and to maintain integrity in the face of changes in and attacks from the environment),
- efficiency (of co-ordination, transaction and resource development within and across organisational boundaries, and
- flexibility (adaptive capability and transformational capacity).

The next section highlights concepts from complexity theory for articulating IS phenomenology and dynamics of the networked world.

2. COMPLEXITY CONCEPTS

2.1 Complex Systems and the Network Form of Organising

Complex systems are non-linear systems, composed of many (often heterogeneous) partially connected components that interact with each other through a diversity of feedback loops. Their complexity derives from the partially connected nature and the nonlinear dynamics which make the behaviour of these systems difficult to predict (Casti, 1997). The non-linearity of these systems means that small changes in inputs can have dramatic and unexpected effects on outputs, affording possibilities ***both**, for maintaining the steady state **and** for transformation*: small changes in topology can make a big difference to what is possible and what is not. The particular network dynamics and possibilities for adaptation and transformation of the network at any given time are emergent manifestations of the non-linear interactions in the particular network context. The context may support a heterogeneous combination of:

- types of links
- properties of the nodes
- types of information and knowledge flows through the links
- types of information and knowledge content and processes of nodes
- degree of connectivity and density of connections in the network
- patterns of connectivity.

The language of complexity science allows us to use network dynamics as the explanatory mechanism for linking micro-level diversity with the emergence of coherent macro-level phenomenology of the networked world.

2.2 Complexity Concepts and Networks

Complex adaptive systems (CAS), *emergence, self-organisation* and *co-evolution* in complex systems are complexity concepts developed the most in organisational literature, and are of particular interest to us in our project of developing a GCF for extending the IS domain into the management field.

The concept of CAS (open, dynamical systems that adapt and evolve in the process of interacting with their environments) serves to characterise the phenomenology of IS in the networked world (Merali, 2004). CAS are non-linear systems embodying self-organisation and emergence and have the potential (capacity) for adaptation *and* transformation.

The pattern of interactions that underpins the dynamics of CAS is explained in terms of the network of interconnections. A CAS is made up of multiple, interconnected components ("agents"). The resulting network connectivity allows for the generation of feedback loops.

A system regulated by negative feedback loops would characteristically display stability, whilst a system dominated by positive feedback loops would be subject to the "runaway" escalation of a particular trajectory. CAS embody the potential for simultaneous existence of *both* negative *and* positive feedback loops. Hence a diversity of feedback cycles may be interlinked in a variety of ways, with different consequences. – The interlinked cycles may maintain a homeostatic organisation (as in the Maturana and Varela's 1973 account of autopoietic organisation of stable living organisms) or they may spontaneously generate new, more complex forms of organisation under certain critical conditions (Prigogine, 1987; Langton, 1991; Kauffman, 1993).

Emergence refers to the phenomenon whereby the macroscopic properties of the system arise from the microscopic properties (interactions, relationships, structures and behaviours) and heterogeneity of its constituents. The emergent macroscopic "whole" displays a set of properties that is distinct from those displayed by any subset of its individual constituents and their interactions.

At the microscopic level, the behaviour of an individual constituent is contingent on the precise state of that constituent and conditions in its local environment *at that instant*. For constituents on the boundary of the system, the local environment will constitute "internal" and "external" components. The collective behaviour of the individual constituents at the microscopic level will manifest itself as the behaviour of the "whole system" visible at the macroscopic level.

Self-organisation is the ability of complex systems to spontaneously generate new internal structures and forms of behaviour. This *generative* aspect takes the complex systems concept of self-organisation beyond the early cybernetics concept of self-organisation which focused on the self-regulatory and control aspects of organisation. In the self-organisation process, the components *spontaneously* re-orientate and restructure their relationships with neighbouring components giving rise to the emergence of structures that embody an increased level of internal complexity. The constituents are partially connected: the behaviour of each one depends on the behaviour or state of some subset of all the others in the system. Each acts on local information only derived from the others with which it is connected. Thus the *system* self organises: no single component dictates the collective behaviour of the system. Network connectivity is critical in defining and maintaining the ordered state, with most components receiving inputs from only a few of the other components so that change can be isolated to local neighbourhoods. Self-organisation is not the result of a priori design, it surfaces from the interaction of system and the environment and the local interactions between the systems components.

The existence and persistence of the system is thus a relational phenomenon, predicated on the relationship of the constituents of the system to each other and to constituents of the environment in continuous time. Local, contingent, neighbourhood interactions and adjustments at the micro-level are at the same time detectable as a coherent pattern of properties constituting the "whole" system.

The classical separation of *"becoming"* from *"being"* does not advance our understanding of complex systems. In order to identify how emergent properties are produced we need to be able to access descriptions of the system at multiple scales from the micro to the macro *at the same time*. This presents us with a problem of representation in the classical mode of top-down refinement. Typically, complex systems representations are either developed as mathematical models or as computer simulations.

At the micro-level, system and environment components interact in a contiguous space, and, depending on the nature of particular relationships, can to a lesser or greater degree be considered to be mutually effective. Thus the dynamic definition of a system is contingent on the dynamic definition of its environment, and system constituents are an integral part of the landscape in which they exist. The concepts of systems adaptation and evolution are thus extended to the dynamics of the ecosystem within which systems are situated and thus to *co-evolution* of system and environment.

These characteristics require us to redefine the way that boundaries are conceptualized: from the classical view of fixed boundaries, towards a more dynamic view of boundaries as relative and relational phenomena, linking system and environmental elements through differential coupling.

The emergence of the macro level phenomenology from micro level interactions and the mutually defining relationship between the system and its environment are defining characteristics of our information network dynamics. The question of how to deal with boundaries in this context remains a non-trivial one.

To summarise, CAS are sensitive to initial conditions and hence embody path dependency, in the sense that history matters. However the heterogeneity of network nodes (i.e. we can have nodes that are defined by different sets of characteristics) and their connectedness (i.e. not all nodes are connected to the same number of other nodes) coupled with the possibility of dynamically reconfiguring network topology (by activating/deactivating links, and/or adding/removing nodes) affords a level of micro-diversity and a combinatorial potential that makes it impossible to predict with any certainty the future state of the macro-level system.

In face of this escalating computational complexity and mathematical intractability, complexity science offers agent-based modelling as a way to explore the possibilities and characteristics of the unfolding dynamics of complex adaptive systems. The next paragraphs highlight the characteristics of the agent-based approach that are useful for looking at the network dynamics of the interconnected world, suggesting the need to develop conceptual frameworks for defining the parameters to be modelled.

2.3 Agent Based Modeling and Multi-Scale Descriptions

Agent-based computational modeling has features that are particularly relevant when studying socially embedded systems, and it is displacing conventional mathematical theorizing approaches (Carley, 1995, Axtell, 2000).

It is possible to model diverse agents, capable of acting with local information and noisy pay-offs (Axtell 2000). Genetic algorithms (Holland, 1998) provide the means to explore adaptive behaviour, learning, evolution and fitness in dynamic landscapes. Running such models furnishes us with an *entire* dynamical history of the process under study. This is important when exploring processes of emergence and self-organisation in complex adaptive systems. Complex systems have many degrees of freedom, with many elements that are partially but not completely independent, with ambiguous system-environment relationships. There is a greater diversity of local behaviours than there is of global outcomes. In order to achieve an effective representation of the dynamics of the processes connecting the local (micro-level) and global (macro-level) characteristics we need to develop a multi-scale description of complex systems, and agent-based modeling provides a mechanism for doing so.

For social systems the specification of the components (agents) for the construction of agent based models is itself often a challenging prospect. With the escalation of available computational power it will be possible to build models with a million agents of reasonable complexity.

The diversity of social relationships and the idiosyncrasy of individuals makes it difficult to develop models that are both, sophisticated enough to capture the essential features of the social interactions and characteristics, and simple enough to make visible the dynamics of the system. The difficulty lies in identifying what constitutes the requisite set of attributes for defining social systems – and *this* is a matter that necessitates a discourse with the sciences of sociology, philosophy and psychology amongst others (Merali 2004).

From a methodological perspective, we need ontological and epistemological frameworks to guide the utilisation of complexity concepts in studying and dealing with social systems. However the science of complexity does not offer the requisite frameworks, nor do the social sciences. Turning to philosophy and the social sciences we find that there are a number of existing philosophical perspectives that we may be able to draw on in order to explore the possibility of developing the requisite frameworks

3. PHILOSOPHICAL OPENINGS

Our exploration of complexity concepts brings us to some openings that invite a further investigation of several philosophical positions, and these are highlighted below for future speculation.

To assimilate and accommodate the phenomenology of emergence and CAS we need to identify a philosophical position that enables us to deal with

- inseparability of *being* from *becoming*
- "fluidity" between system and context,
- *potentiality* of the emergent system and its constituents given that emergent phenomena are non-deterministic, path-dependent and context sensitive, and
- assimilation of the present and persistent with the possible and transient.

Heidegger's *Being in Time* (Heidegger, 1962) offers us a number of enabling concepts for this endeavour. Heidegger's *Dasein* (*being-there*, or *being-in-the-world)* gives us the articulation of individual and collective *being* and its relationship with past, present and future time.

Dasein (*being-there* or *being-in-the-world)* is the wholeness of being that includes the context and assimilates objects of the world into itself. This is an affirmation of *Dasein* in the present. However *Dasein* in the present is in, and open to, a space of *possibilities* of the (collective) world (this is articulated in Heidegger's concept of *clearing*) and it is pressing *forward* into the possibilities (of the future). This pressing forward has a general direction (Heidegger's *towards-which* or *for-the-sake-of-which*), but no specific conscious goal – as Dreyfus (1987) puts it,

Dasein is simply oriented toward the future, doing something now in order to be in a position to do something else later on, and all this makes sense as oriented towards something that the person is finally up to but need not have, probably cannot have, in mind.

So, *Dasein* embodies the past, present and future: The "pressing into the future" of *Dasein* in the *past* is the passage into *Dasein* in the *present* which is already pressing into *Dasein* in the *future*.

In attempting to locate complexity concepts in relation to the map of established philosophical positions, Heidegger's existential phenomenology offers a promising starting point for our ontological framework: the notion of *Dasein* articulates the qualities of emergence (in the unfolding of *Dasein*), the contiguity of *being* with *becoming,* and the spontaneous organisation of *being* (incorporating the context, assimilating objects in the environment into dynamics of being).

Turning to the social sciences, we find that Critical Realism (Bhaskar, 1986) also articulates path dependency, emergence and transformation in social systems: it does so in terms of *causal mechanisms*, tracing the emergence of the experienced world from the existence of possibilities in the actual world, realised through generative mechanisms of the real world. In *Complexity theory and the social sciences* David Byrne develops the proposition (Reed and Harvey, 1992), that Critical Realism constitutes the philosophical ontology complementing complexity as the scientific ontology.

With regard to the epistemological dimension, defining and studying the being of particular complex systems-in-the-world, presents us with another problem. The moment we speak of being, it is interpreted (Eco, 1997). Interpretations are grounded in the system of interpretation or perspective of those who generate them. It is therefore possible to generate a diversity of interpretations from the observation or experience of any particular event or state of affairs. Similarly, the possibilities of being are transcendental, extending beyond articulated experience existence and imagination of any person. We are thus confronted with the problem of appreciating the potential (of being) beyond articulated accounts, representations or speculations about the past, present or future.

The problem of exposing that which lies behind and beyond language-based interpretations and descriptions of the world constitutes an opening for the exploration of Derrida's deconstructionist (Derrida, 1978) philosophy. This opening is explored in Paul Cilliers' Complexity and Postmodernism. Cilliers draws on Derrida to develop an excellent exposition of the parallels between the complexity of language systems (and the possibilities of meaning emerging from the relationship between language-based descriptions of the world and the world itself) and connectionist accounts of the complexity of social systems.

To summarise, whilst the science of complexity does not directly offer us ontological and epistemological frameworks for the application of complexity to social systems, complexity concepts resonate very strongly with several existing philosophical movements, highlighting a number of openings for future investigation in the development of GCF and MB for IS.

4. POSITIONING IS IN THE MANAGEMENT FIELD

The exposition of the information network-in-use in this paper accentuates the existence of the information network as an integral, constitutive element of the network society and economy. The information network both, serves, and shapes the networked world.

As illustrated above, conceptualising the networked world as a CAS transcends the traditional boundaries between disciplines in the management field. This has two important implications for future IS research:

- the travail of IS in the interconnected world is a trans-disciplinary one, and demands the active development of a discourse with the other disciplines. The adoption of complexity science concepts would speak for a discourse not only across the management field, but also across the natural and human sciences
- the centrality of IS in the network economy and society places the IS domain at the heart of the management field, and we should, as a discipline, re-cognise our responsibilities for informing the discourse pertaining to information networks-in-use in other management disciplines.

5. CONCLUSION

To summarise, this paper has shown that the complexity and dynamics of systems are not readily treated with traditional research approaches that simplify the world with high level generalisations predicated on macro-level observations of structural persistence and assumptions of Gaussian statistics. Complexity science furnishes us with the concepts and tools for building multi-level representations of the world and for making sense of the dynamics of emergence. The dynamics of emergence is predicated on micro-diversity, and fine grained representations are essentially descriptive models of the detailed complexity of the world and its dynamics. Thus it is through exploratory modelling that we discover how the complex world works, and how macro-level properties and behaviours of systems emerge from micro-level diversity and dynamics. Consequently, modelling is the principal research tool for complex systems, and sensemaking is a legitimate research goal. This implies a significant shift in the established thinking about what constitutes knowledge and how it is best obtained. This is the challenge for traditional research and in particular for the hypothetico-deductive school.

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ENDNOTES

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