THEORY OF DEFERRED ACTION: AGENT-BASED SIMULATION MODEL FOR DESIGNING COMPLEX ADAPTIVE SYSTEMS

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Abstract

Deferred action is the axiom that agents act in emergent organisation to achieve predetermined goals. Enabling deferred action in designed artificial complex adaptive systems like business organisations and IS is problematical. Emergence is an intractable problem for designers because it cannot be predicted. We develop proof-of-concept, conceptual proto-agent model, of emergent organisation and emergent IS to understand better design principles to enable deferred action as a mechanism for coping with emergence in artefacts. We focus on understanding the effect of emergence when designing artificial complex adaptive systems by developing an exploratory proto-agent model and evaluate its suitability for implementation as agent-based simulation.

Keywords: Design Science, Agent-based simulation, Emergent information systems, Theory of Deferred Action.

Introduction

Business organisations, information systems (IS), and information technology (IT) systems are complex adaptive systems that exhibit emergent behaviour. Emergence is a practical design problem because predicting when it happens and its effects is impossible. To cope with emergence designers need to become comfortable with uncertainty (emergence) and design artefacts with emergent properties.

There is explanatory research on emergence in IS (Baskerville et al., 1992; Truex et el., 1999; Truex et al., 2000). There is also research in the related areas of 'ad hoc' IS development, 'evolutionary IS', 'adaptive IS' and 'bricolage'. Bricolage explains IT infrastructure design as drift from planned action and naively neglects the need for management control (Ciborra and Hsnseth, 2000:2). Research has drawn on complexity theory, whose central tenet is emergence, to explain IS (Kallinikos, 2006). Some of this research considers implications for IS design and development but does not address it sufficiently practically (Moser and Law, 2006). Patel (2002; 2003; 2005) suggests practical design principles for developing complex adaptive information systems.

There is similar explanatory research on emergence in organisation studies with obvious implications for organisation design. Emergent organisation is 'a theory of social organisation that does not assume that stable structures underpin organizations' (Truex et al, 1999: 117; Truex and Klein 1991). Feldman's (2000) study reveals that even routines are a source of continuous change. Feldman (2004) states that organizational structure is emergent and it effects the allocation of organizational resources. Emergent organizations experience sudden and unexpected change resulting in structures, processes, and resources becoming unstable and difficult to predict. Emergent organization affects actors' need for information (Truex et al., 1999; Patel, 2002) and results in 'emergent knowledge processes' (Truex et al. 1999; Markus, 2002; Patel, 2005).

This explanatory stream of research does not consider practical design and acknowledges that current design techniques are limited (Truex et al., 1999). Patel (2006) addresses how to design organisations, IS, and IT systems to reflect emergence. He seeks to design rationally complex adaptive systems that exhibit emergent behaviour. Since the actual emergence cannot be predicted, the problem is giving design capability to agents (organisational actors) to design in emergent environments.

Our research programme, rooted in design science, is to develop design theory and modelling techniques to design artificial complex adaptive systems (ACAS) with emergent properties. We invoke the Theory of Deferred Action because its axiom that many IS and aspects of IS *emerge* in organisations. It provides the theoretical framework to design capability for agents to act in emergent organisation. The importance of context and emergence in the related field of intelligent systems research is briefly described. Through agent modelling we aim to improve understanding on how to design ACAS. We develop an exploratory proto-agent model of emergent organisation and emergent IS suitable for later implementation as a multi-agent based simulation, and we evaluate the implementation computer language Netlogo.

Design Science and Complexity

Simon (1996) defines design science as: 'Everyone designs who devises courses of action aimed at changing existing situations into preferred ones'. It aims to create knowledge for the purpose of teleological design (Banathy, 1996). In IS research 'design research' studies algorithms, human/computer interfaces, design methodologies (including process models), and computer languages as outcomes to improve 'IT artefacts' (Hevner, et al., 2004; Vaishnavi and Kuechler, 2004/5).

Complex systems that seek to adapt are termed complex adaptive systems (Axelrod and Cohen, 2000). Complex adaptive systems (CAS) are a collection of elements that behave collectively but no single element has complete control over the behaviour of the whole system. CAS acquires information on its environment and on its own interaction with that environment. The information is structured into regularities and then condensed into a schema for acting. Adaptation of the system to its environment occurs when it changes itself and its schema when they are inappropriate. This is self-organisation in response to the information (Gell-Mann, 2004). Examples of CAS social systems are the scientific enterprise, economy, population, organisation, and IS.

Self-organisation and emergence are characteristics of CAS. The resulting behaviour of a collection of individual agents in which no one agent has complete control over the whole system is emergence. 'Complex adaptive systems regularly exhibit emergent behaviour' (North and Macal, 2007). Self-organisation is the response of CAS to random change that causes the system to become unstable. When existing order is disturbed by change stability is restored by the system self-organising without some external causative factor. Restored stability is an emergent order and results in new structure that is intrinsic to the system which is not caused by an external factor. A business organisation is self-organising if no external influences does the self-organising for it. The global IS, the World Wide Web, is a highly complex adaptive system designed by humans. Strategic IS and inter-organisational IS are also designed CAS. These are open socio-technical systems because they are affected by the environment.

Intelligent Systems and Emergence

The goal of intelligent systems research has been for many years to embody human-like intellectual capabilities within artificial machines. The purpose was to emulate the exceptionally complex and creative reasoning abilities people have. Originally, as a *simulation* of the hypothesised cognitive mechanisms thought to be employed by humans, but later, following a realisation that much of the knowledge brought to bear during decision making is inexplicable and tacit, the purpose has realigned closer to a composition of cognitive, social and behavioural elements. Context plays an important role in forging behaviour, as much as logical reasoning. Traditionally, the view has been that goal-based reasoning was sufficient to explain how people make decisions in real life. It is now clearer that plans, for instance, created a priori and out of the context in which they will be executed cannot be guaranteed to play out as expected. This is expected primarily because execution must be within the context of unpredictable social systems, i.e. with the involvement of people who are governed not just be their cognitive processing of the situation, but also, by their psychological and physiological needs (often without cognizance). Influence of situational factors can significantly draw an individual away from their neat predetermined course of action. Therefore, for a realistic account of human behaviour in social systems, the notion that "nothing goes according to plan" rings true. Internal factors (cognitive, psychological, emotional, and physiological) and external factors (environmental and social) collude to bring about an unexpected and unpredictable context within which an information system (i.e. a human decision maker) must process incoming data and information, bring to bear their knowledge and apply their skills to exhibit what an observer would consider rational behaviour. The constructivist view would have it that from this new context emerges new knowledge, and correspondingly, a new information system with different (usually better) capabilities.

One significant research programme that promotes this view of socially oriented systems has sought to model social elements of behaviour beyond the cognitive to understand motivational factors driving apparent behaviour. Clancey et al (2005) propose the BRAHMS simulation system for modelling realistic behaviour within the context of activities. The premise underlying this work is that information is selected to be processed according to the role and activity relevant at the time and such information might not be readily included in an idealised task model or abstract representation of the procedure. Processing of information is interruptible when the focus of activities changes, and emergent quantities may arise, such as improvised conversations or other unplanned interactions. The BRAHMS project aligns well with deferred systems work and confirms the connections between information systems research and developing ideas in the area of cognitive systems.

Designing IS For Emergent Organisation

Currently, data and information is understood to have stable properties that are predictable and structurable. Redefinition of information ontology is needed to design IS for emergent organisation. It is problematical to *predetermine* and *structure* information in emergent organisation.

Emergence affects data less than information. Names of customers, addresses or products manufactured do not change often. The affect on information is significant. Information is currently defined as processed data:

Data + algorithm = information (1)

For emergent organisation, we re-define information as processed data in the context of emergence:

Data + emergence + [contextual] algorithm = information (2)

In emergent organisation information is dependent on context. Its qualities are suddenness, change, uncertainty, and unpredictability. Emergent (unpredictable) organisational situations arise in the course of organisational life for which information is needed, which makes information dependent on emergence. Such information cannot be pre-specified for design purposes.

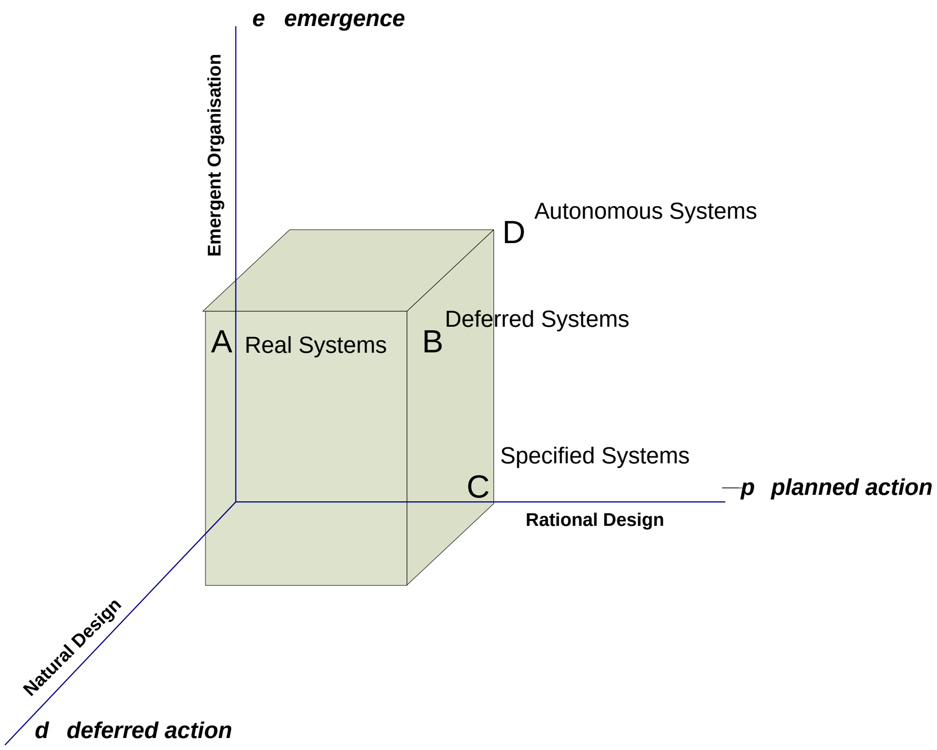
Therefore information ontology is static (1) and emergent (2), as defined above, in emergent organisation. Static elements are knowable, predictable, and specifiable for design purposes. Transaction processing systems are examples. Information required to manage a motor cycle production process can be predetermined and specified to design and develop the appropriate module for ERP systems. Emergent elements are not knowable in advance because emergent events occur suddenly and unpredictably. Information cannot be specified in advance. IS that are affected by emergence include strategic IS, decision support systems and the Web.

The Theory of Deferred Action

Though rational planning is necessary, in the context of emergence it is insufficient as the sole design dimension. Its scope is limited because agents modify their behaviour in the environment resulting in emergent organisation. The theory of deferred action provides understanding of systemic emergence to design complex adaptive systems (Patel, 2006). It is a generic artefact design theory for emergent organisations. In Gregor's (2006) terms, it is a 'theory for action and design' and therefore it informs design practice. Nomothetically, it explains and suggests effective models for organisation design, IT systems design, IS and KMS design, where emergence is a critical design factor. Here we invoke it to improve emergent IS and IT artefacts design.

Three design dimensions are postulated: planned action, emergence and deferred action, and their interrelationship constitute rational design of complex adaptive systems, as depicted in Figure 1. The theory assumes business organisations *rationally* determine goals and rationally plan to realise them. A plan is any artefact whose purpose is to construct the future such as strategic business plans or new systems design. However, the theory assumes *actual* organisational behaviour results in emergent organisation. Therefore, since rational behaviour is tempered by emergent behaviour the latter needs to be catered *actively* in the rational plan. A further assumption is that actuality is emergent and takes precedence over central plans but agents actions are constrained by the plan. Therefore, plans accommodate actuality but the teleological purpose of the system should not be deflected by the emergence.

Figure 1. Deferred Action Design Dimensions for Designing Artificial Complex Adaptive Systems



A = Real models of reality. Achieving near 1-to-1 correspondence between model and the system it models in real time. Real systems are in real-time.

B = Deferred models of reality. Imposing purposive designed structure on reality but enabling actors to shape the design in the context of real situations to achieve some future state. Deferred systems are future-oriented.

C = Static models of reality. Imposing purposive design strucuture on reality but constraining actors to behave according to it regardless of the actual situation.

D = Autonomous models of reality. Human action is replaced by actions by intelligent agents designed to achieve desired results.

Source: Adapted from Patel (2006)

Planned action

Planned action, boundedly rational design, looks at future states of systems, designing new systems and enhancing existing systems. It develops new systems futures drawing on existing knowledgebases. The innovation of a new IS draws on existing knowledgebases for developing IT systems, such as IS methodologies and design languages like UML. When planned action is not affected by emergence systems can be specified, as depicted at point B in Figure 1. These are called specified systems.

Planned action is undertaken centrally. It may be IS plans or management strategies. It is action prescribed by design and enacted *regardless* of actuality. For example, a three-year strategic plan or formal systems design for ERP systems. Planned action characterises organised action exclusively as rational act. It is useful for design problems that can be predetermined and well-structured and for solutions that can be predetermined requiring explicit and declarative knowledge. It assumes stable organisation structure and processes and negates emergence. Planned action is necessary but not sufficient for designing CAS.

Emergence

Emergence is the patterns that arise through interactions of agents, interactions between agents and IT artefacts, and agents' responses to environment. *Emergence is a becoming aspect of design*. It affects design processes and the designed systems. Agents act locally in emergent situations. So, emergence requires present, contextual, and situational aspects to be factored into design based on past histories.

To design CAS, planned action prescriptions need to cater for emergence. When planned action is affected by emergence systems cannot be completely specified. It is necessary to relate by synthesis planned action and emergence to design emergent IT artefacts, as depicted by points A and D in Figure 1. Planned action and emergence are related design dimensions when designing for emergent organisation.

Deferred action

Deferred action is the synthetic outcome of relating planned action and emergence for designing CAS. Agents undertake deferred action, within planned action, but their action is determined by and enacted in the emergent context. Thus adaptableness and self-organisation, characteristic of CAS, are facilitated as deferred action to operationalise CAS. Deferred action is necessary to design successful CAS.

Deferred action reflects emergence, space (location), and time in planned action. It contextualizes planned actions in emergent situations. Since emergence is unpredictable agents should be enabled to respond to it in particular organizational situations. Deferred action enables agents to modify an IS within the context of its use. So, systems at points A and D in Figure 1 should provide actors with deferred action capability. The IS product is conceptualized as continuous design and development process, rather than a time-bound, predetermined product.

The interrelationships among these design dimensions are detailed in Table 1 and they model designed systems in emergent *actuality*. Actuality is never sympathetic to plans. Plans are subject to systemic emergence and require an adequate embodied and situational response. In rationally designed CAS this response is deferred action.

Design Dimensions	**Description**
Planned action	Rational planning is necessary to set and achieve organisational goals, to build goal-oriented structures and processes.
Emergence	Agents' local responses to the environment create emergent situations. Emergence requires systems design and organisation design to be *continuous*.
Deferred action	Deferred action takes place within planned action in response to emergent locale. It synthesises planned action and emergence.
Synthesis of these constructs results in four system types: deferred systems (point A), specified systems (point B), autonomous systems (point C), and real systems (point D) in Figure 1. These types are also generic design types, systems types and organisation types.	

Table 1. Design Dimensions for Designing Complex Adaptive Systems

To illustrate, Google's organisation has the three design dimensions. Google has an IT infrastructure (planned action) that is 'built to build', providing the flexibility needed in emergent context. It is designed to enable further building by expansion and adaptation to market needs (emergence). Google executives realise that they are not best placed to know the emergence, so they actively enable employees to take action when they consider it appropriate (deferred action). Employees are given 10% of their time for creative work. Thus a Google employee blogger reveals how easy it was for him to write software code and have it implemented in Google's gmail application because he disliked a certain aspect of it. Google's organisation is a deferred organisation and its IT systems are deferred systems, as depicted at point A in Figure 1.

The deferred action construct is used by researchers and practitioners (Sotiropoulou and Theotokis, 2005; Stamoulis and Kanellis, 2001). Dron (2005) invokes deferred systems to design systems that have changing functionality. Elliman and Eatock (2005) developed the online E-Arbitraton-T system capable of handling workflow for *any* legal arbitration case, thus meeting the emergence criteria. They applied the deferred design decisions principle to manage the open and changing system requirements. This enabled users (agents) to make design choices rather than the system developer.

Research Methodology

We use the epistemological methodology of complexity to understand emergence, develop design constructs, design processes for designing CAS, and also to develop the proto-agent model. Researchers have applied complexity to design (Johnson et al., 2005). Zamenopoulos and Alexiou (2005) suggest that complexity can used to construct better theories of design. The Engineering and Physical Sciences Research Council fund research that seeks to 'embrace' complexity in design.

The agent-based simulation method is closely related to complexity studies. Whereas 'why', 'how' and 'what' kind of research questions are addressed by other research methods that collect data for causal inferences, agent-based model simulation addresses what-if questions and generates data to understand complex interrelationships between agents whose interactions result in emergent structures and processes. Other research methods, relying on causal inferences, address phenomena that have already happened. Non-linear research methods, like agent modelling, generate simulations of target phenomena by 'running' them into the future (simulated time) to observe what happens under differing initial conditions and variations in the environment.

We develop a conceptual design of a proto-agent model, and not a full agent model, to limit the problem description to manageable levels in order to evaluate the model. The empirical observations of our target phenomenon were described in the introduction. The initial phase of the research project involved the identification of agents, agent attributes, rules of agent behaviour, and the agents' environment. This was done through documentary and web-based search informed by the theory. The rule set for agent behaviour was derived from the bounded rationality and emergence design dimensions of the theory.

Identifying agents and representing agents and rules realistically is agent modelling (North and Macal, 2007). This search is better achieved by basing agent models on good theory. North and Macal (2007) suggest modellers answer two questions: what theory has been selected and why was this theory selected for the modelling? Our model is based on the theory of deferred action as espoused above. It is selected because it centrally recognises emergence as an ontological feature of business organisations and IT systems, it synthesises planned action with emergence, and because it predicts 'deferred action' as the response of agents to systemic emergence. The deeper rationale was elaborated above.

Basing the model on the theory has two important benefits. Theoretical inferences enable us to make general statements on designing CAS that are applicable to cases other than the one under investigation. This is powerful because it means that each case does not have to be separately investigated before we are capable of acting. The other benefit is that the obverse of generalisation is prediction. Ironically, by making generalisations prediction is made possible on the design of CAS. This is the major benefit for designing, since we want to be able to tell whether our rational designs will work in situations that have not yet been empirically tested.

From Theory to Model

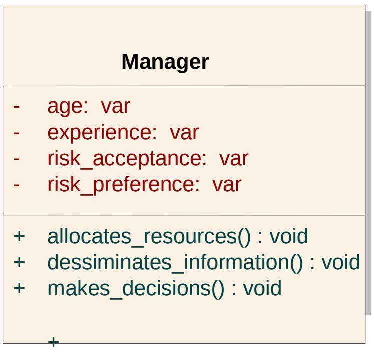
Gilbert and Troitzsch (2005) suggest simulation research questions should stem from theory and should be stated in terms of its theoretical concepts, which should form the main element of agent models. We observe this to be an operationalisation of verbal theory, such as the theory of deferred action. Our research question is: *In the context of planned action, how do agents behave in emergent organisations?* A sub question is: *How do agents fulfill informational needs in emergent organisation?* The theory predicts that some aspects of organisation work emerge and that agents will respond to emergence as 'deferred action'. It is predicted that agents design and develop their own IS using IT. The objectives of the modelling are to understand agent behaviour and satisfaction of information requirements in emergent organisation. Agent modelling will improve the theory because agent-based model simulations require precise definitions which are used for computer programme coding. This formalisation enhances the theory itself and provides inductive evidence of its veracity (Meleraba et. al., 1993; Axelrod, 1997).

Deferred Action Proto-Agent Network Model

Our modelling philosophy follows Einstein: 'Everything should be made as simple as possible, but no simpler.' The model is deliberately simple because we believe parsimony results in greater understanding. We discuss the model design decisions and modelling approximations. A model is a simplification of the target to be modelled (G/T, x). Our model is stochastic because we want to understand emergent behaviour and leverage the emergent behaviour to inform design of CAS. We used informal agent modelling techniques like hand drawn diagrams, simple text descriptions, and the formal technique UML. The modelling aim is to investigate how organisation and IT systems emerge and to understand agents behaviours and informational needs. The theory assumes organisations and IS to be socio-technical CAS, so we need to identify and define the behaviours of social agents and technical agents and other agents.

Agents are things that make choices or decisions including managers, executives, organisations and complex computer systems (North and Macal, 2007). Agents posses attributes and behaviours. The behaviour of agents is according to rules and composed of (a) evaluating its current situation, (b) executing the chosen action, and (c) evaluating the results of actions and adjusting the rules based on results. Agents have goals to focus the decision-making. Other agents should be able to identify the agent. Drawing on the theory, we have identified key agents, goals, behavioural rules, the agents' environment, and random occurrences characteristic of probability systems detailed in Table 2. We define only the goals, behavioural rules and brief descriptions. Agent attributes are to be defined later for all the agents as shown in the example in Figure 2. We have defined only simple or proto-agents, which exhibit 'minimally adaptive behaviour' (North and Macal, 2007). Proto-agents have a rule base and full-agents have a rule base and rules to change rules (Casti, 1998). We call the later meta-rules which provide adaptation by allowing routine adaptation to change over time (North and Macal, 2007). We will incrementally develop the proto-agents to full agents as the research progresses (see section of Discussion and Further Development).

Figure 2 Manager Agent Attributes and Behaviours Modelled in UML as an Object



The main elements of the model are bounded rationality (plans), emergence, and deferred action. Diversity among agents arises from differing behaviours, capabilities, resources, and positioning, and knowledge leads to emerging self-organisation and system structure. The diffused management agent is the logical consequence of emergent organisation. Since emergence is organisation-wide its management in relation to knowledge needs to be diffused in the organisation among agents (as in the case of Google employees' decision-making above).

Computational Agents	Goals; agents are driven by goals and subgoals.	Behaviour Rules Rules should be such that they create emergence Relate agents to plan agent in the rule set - Description; rules should be based on ToDA explanations of social action in emergent organisation. What does ToDA predict about how agents are expected to behave?
Plan	To create strategically beneficial future for the organisation.	Rules ?? (Yet to be formulated) Description (like shop agent) A plan has a goal and detailed prescribed actions to achieve it.
Organisation	To add value for customers. To maximise profit for shareholders	Rules Make plan for survival of organisation. If events in the environment change from planned action the organisation responds. Description Organisation is composed of people, structure, processes, IT systems, IS and KMS. Organisation is emergent. *Organising* is normal. Organisation is the collection of agents that pursue predetermined goals.
Manager	To improve efficiency of business process.	Rules Manager act on information. Manager use IS in context. Manager locally designs information (systems). Manager communicate information to other managers and process owners Manager checks the plan agent for direction. Manager monitors environment for opportunities and threats. Description A manager is someone who makes resource allocation decisions and manipulates information to improve business process efficiency.
Process owner	To complete process task.	Rules Process owners work on tasks. Process owners act on information from other process owners, managers and environment. Process owners communicate information to other process owners and managers. Description Employees, or process owners, complete task on business processes.

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Information system
What does it do? Like shop agent</td><td>To provide information on business processes.</td><td><u>Rules</u>
An IS exist in relation to manager or process owner agents.
An IS responds to its environment including other agents.
If manager agents lack information the IS creates it.
If process owner agents lack information the IS creates it.
<u>Description</u>
IS is any information or knowledge artefact created with the use of IT. IS design depends on known, specified information requirements and unknown, emergent information requirements. IS design is affected by emergence, meaning that IS exhibit emergent design. IS design requires deferred action.</td></tr>
<tr><td>Diffused management</td><td>To enable agents to locally control.</td><td><u>Rules</u>
?? (Yet to be formulated)
<u>Description</u>
Diffused management of local situations is necessary because of emergence. It caters for self-organisation and adaptive behaviour. Centralised management of local situations is ineffective in emergent organisation.</td></tr>
<tr><td colspan="3">Environment
Agents are located in the environment and connected in a network. The environment consists of business processes, predefined and processed information. Agent activation is done in the environment.

The random occurrences in the environment consist of innovation by agents, innovation by competitor agents, agents leaving, new agents with new knowledge appearing, existing agents possessing new knowledge, previously unconnected agents connecting...What are the random events in the environment? Defein toda based random events. What does toda predict to be random (not the same as emergent) Random Occurances Define random agents; events;
‘Emergent behaviour is the result of the agent behaviours and interactions within the model that are not directly specified as part of the behaviours of the agents in the model.’ (North and Macal, 2007:276). Emergence is the internally generated structure or patterns generated by agents. Structure is defined as the form of the relationships among agents.</td></tr>
</table>

Table 2. Proto-Agents Model: Agents, Goals, Rules and Environment

The agents will be represented as a small world network model. Networks will provide understanding of how networks are structured and grow and how information is communicated through networks in stable and emergent contexts. Small world networks have few nodes that are highly connected and other less connected. Networks can aid understanding of connectivity, tipping points, and flow of information propagated through the network. Networks of agents exhibit emergent behaviours and become self-sustaining. This will improve our understanding of how particular human organisation is established and becomes self-sustaining (Padgett, 2000). Following North and Macal (2007) in the network model we will address: (a) the appropriate type of connectivity for the network of agent relationships, (b) internal and external influences on the network links and relationships, and (c) the effect of network connectivity on agent and system behaviour.

Netlogo

In terms of computing, simulations are 'self-contained programs that can control their own actions based on their perceptions of their operating environment. (Huhns and Sing, 1998). The proto-agent model will be implemented in Netlogo. Here we discuss implementation issues and evaluate Netlogo.
The code will require definitions of global and patches-owned variables, specification of set-up procedures and procedures to update patches. To design the simulation we will use UML because objects in UML are akin to agents in agent modelling. We will defines agents using the class template and specify their attributes and operations (agent rules), as depicted in Figure 2. Sequence diagrams will be used to depict system dynamics and activity diagrams.

Discussion and Further Development

Our aim is to develop theoretical and practical knowledge for designing CAS. We expect to use understanding of emergence to intervene by design in CAS like business organisations and IS. We are specifically interested in the kinds of design decisions we need to make at systems level to reflect emergence in designed CAS at local level. Agents are autonomous, sociable, reactive, proactive, and they are capable of inferring and possessing knowledge and belief (G/T). Our proto-agent model will be extended incrementally to encompass these attributes as we pursue our research agenda. As managers interpret information we will code agents with knowledge and information (knowledge representation). The 'meaning' that managers attach to information, stemming from subjectivist research, will be encompassed in agents. The result will be a more sophisticated model representative of our target phenomenon. The full agent model will be used to code agents for simulation. A complex agent is adaptive, has the capability to learn and modify behaviour, and is autonomous and heterogeneous. The internal processing of agents is more sophisticated in full agent models than we have defined in the proto-agent model in Table 2.

To model the planning dimension of the theory we will develop agents that reflect organisational plans. Agents will be designed to act within the context of complex plans and be able themselves to develop complex plans. We will draw lessons from the Evolution of Societies simulation (Doron et al, 1994) which has agents capable of complex planning. In the full-agent model simulation, we expect to observe the following emergent properties: Emergent organisational structure, emergent organisational processes, emergent organisational resources, emergent Information requirements and emergent organisational knowledge. These expected results are reported in extant empirical findings and expressed as verbal theory discussed earlier. If the results of simulation, as a formalisation of verbal theory support extant empirical findings, it improves the veracity of the verbal theory (Melerba et al. 1999).

When we implement the full-agent model as a computer simulation, we expect the results to show (a) emergence and (b) deferred actions of agents (c). We expect to be able to use these results to (a) enhance our theoretical understanding of designing for emergent organisation and (b) inform the development of design techniques for designing CAS. We will compare our simulation data with the ‘target’ actual observations from emergent organisations (Doran and Gilbert, 1994). Detailed scenarios will be identified to test the simulation model. One, such scenario will require agents interacting in the context of a complete unknown. The other scenario will consist of a partial unknown, where some aspects will be known and other aspects of the situation will be uncertain. We expect some interesting emergent behaviour of the agents to result in deferred action, as predicted by the theory. These simulation run results will then be compared to actual events in our target organisation.

Conclusion

The value of simulations is its experimental capability. Hales et al., (2003) assert that multi-agent based simulations are ‘closer to an experimental science than a formal one.’ Their comment is aimed at the discipline of simulation itself. We will undertake experiments on the actual simulation model to understand the effect of various magnitudes of emergence on (a) information needs (b) IT systems. For example, in terms of organisational knowledge, we will be interested in the effect of loosing key knowledge workers to competitors.

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