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Cultivating the information systems discipline

Niek du Plooy, Sub-Editor: Information Systems

Whether by 'information system' we mean a simple bookkeeping system for a small business, or a monolithic integrated 'management information system' for a global corporation, all organisations currently need information systems in order to function effectively. The computer and business community at large have readily adopted and accepted the use of the term 'information systems', but perhaps without too much real thought being given to any more profound meaning of the term. Departments bearing that name (or something very similar) are commonly found in organisations. But can the same be said for the 'academic' use of the term, as in describing the information systems discipline? Has it been 'accepted' as a separate scientific discipline?

The term 'discipline' is often loosely applied to indicate the scientific 'field', that is, the organised 'body of knowledge' or 'domains of discourse' within which (mainly) academic activities concerning a specific topic or a number of related topics, are conducted. [3] point out that a scientific discipline has a certain paradigm associated with it, meaning that researchers in that discipline are familiar with the research topics, the research methods and the accepted ways to interpret the results in their chosen field. A discipline is further strengthened and consolidated by the educational process whereby a researcher becomes a practitioner in that discipline, initially through the pursuit of academic degrees and thereafter, through recognition amongst his/her peers. Formal study in a particular discipline results in the value sets and exemplars (the 'paradigm') of that discipline being adopted by the student, either consciously or unconsciously.

Is 'information systems' truly a recognised scientific discipline such such as this? In the past, prominent authors such as Peter Keen did not think so [15, 16]. He deplored the lack of a cumulative tradition and advocated that one be built up, asking for a clarification of the reference disciplines of this new science and a definition of its dependent variable and the building of a cumulative tradition, amongst other things. [1] however, disputed Keen's position and pointed to strong links between research and practice found in their analysis. [11] showed clearly that 'orthodoxy' exists in many aspects of information systems, i.e. in information systems methodologies as well as in other areas of information systems development. This claim was supported by [13] who, in a detailed study based on papers in scientific journals, scientific conferences and textbooks, identified seven different but complementary 'schools of thought' within the field of information systems. In a study of leading universities and leading researchers in decision support systems, [9] provide exemplars, at least for that particular sub-discipline. [5] conclude from a citation study of journal influence during the period 1981 through 1985, that the discipline of information systems has attained stability and that it is in no danger of dying. It seems therefore, that Keen's despair is unfounded and that information systems have indeed grown into a separate, identifiable discipline, even if the field is best described as a 'fragmented adhocracy' ([3]).

The existence of an established scientific community in information systems has been given formal recognition by the recent formation of the Association for Information Systems, a professional society in the tradition of scientific societies, with 1400 members in 35 countries. A recently compiled directory of information systems academics contains entries on some 4,500 researchers from more than 1,000 institutions. A number of basic University and other curricula for information systems education have been published over the years [2, 6, 18]. The most recent of these is Curriculum '95, a joint effort by the ACM, AIS, DPMA, IAIM and ICIS [10, 7]. The most popular discussion group on the Internet (ISWorldNet) devoted exclusively to information systems matters has a membership which in 1997 approached 1829 from 53 countries [14]. A well-defined scientific community therefore exists.

In addition, if the existence of sound academic scholarship is further testimony to the existence of a 'discipline', then information systems can proudly point towards a dramatic growth over the past three decades in the number of scientific journals reporting on research in this area [12]. An even more recent study on research outlets showed that, amongst twenty-seven established journals carrying articles in this field, at least three of the most highly rated top ten are devoted exclusively to the discipline.

Yet, can it be said that the information systems discipline has been conclusively defined and that the research problems and research methodologies prescribed for it have been accepted by all who consider themselves to be working in this field? A re-examination and extension of an earlier (1988) list of keywords for use in classifying information systems literature [4] includes a list of the reference disciplines of information systems, as well as lists of the external environment, the technology, the organisational environment, etc., of information systems. We could argue that this very comprehensive list of keywords (nearly 1300) and other classifications define and describe the discipline of information systems accurately and usefully. For instance, the reference disciplines were listed as:

behavioural science, computer science, decision theory, information theory, organisation theory, management theory, language theories, systems theory, research, social science, management science, artificial intelligence, economic theory, ergonomics, political science, psychology. This list reflects the interdisciplinary or pluralistic nature of information systems.

In the same vein, [19] did a study on the themes of submissions to the journal Information Systems Research and produced a list of keywords, concepts and associations that characterise the categories into which they grouped the research questions of articles submitted. This list demonstrates conclusively that the subareas of the discipline (organisational, behavioural and managerial issues) are well established and attract a large number of researchers on a long-term basis. Swanson & Ramiller conclude by observing that the discipline still exhibits the 'fragmented adhocracy' identified by Banville & Landry, and is still topically diverse and '...based on appeals to significantly different and partly incommensurate reference disciplines'.

Thus, fragmentation can have adverse effects – something that information systems researchers should be aware of. However, fragmentation of the discipline of information systems may be evident in the field for a very long time. As has been pointed out [17, 8], the discipline as a whole follows trends in information technology, and researchers tend to build their interests around new technology (e.g. the earlier interest in expert systems and decision support systems, and current interest in computer-supported co-operative work). As information technology evolves, so the research interests will follow these new directions. Although we may wish it were different, it remains a fact that information technology is still a major reference discipline of information systems, and will remain so as long as researchers struggle to separate the fundamental or common issues in different fields from the technological ones.

Clearly, then, information systems is internationally well-established as a flourishing discipline. In the Southern African context it is important that the discipline should not merely flourish but be seen to flourish. To this end, this editorial calls on academics and especially on practitioners to add your contributions, via a submission to SACJ.

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Specific Acquisition of Collective Belief Knowledge for Socially Motivated Multiagent Systems

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Abstract

Shared beliefs and knowledge are an integral part of an organisation's identity and a prerequisite for collective functioning. Multiagent systems that support or emulate cooperative problem solving in such a context cannot be constructed without the explicit acquisition and representation of such collective belief knowledge since it is this knowledge that governs coordination, problem decomposition and task allocation. These are complex issues that have a great influence on the overall effectiveness of multiagent systems. However, in much of Distributed Artificial Intelligence (DAI) research and applications, the mechanisms to deal with these issues are directly related to the data abstraction of the problem to be solved or related to the spatial, hierarchical or other structure inherent in the problem. In other words, there is no explicit knowledge acquisition process to identify knowledge for coordination, problem decomposition or task allocation as is the case with domain knowledge in other knowledge-based system development. This paper illustrates the use of congregative cognitive mapping as a technique to elicit and represent collective belief knowledge and shows that it can be used as metaknowledge for coordination, problem decomposition and task allocation. The development of a prototype multiagent system for strategic vigilance is used to illustrate the technique.

Keywords: *multiagent systems, knowledge acquisition, applications*
Computing Review Categories: *I.2.1, I.2.4, J.1*

1 Introduction

Cultures at the organisational level possess a set of collective cognitive structures. According to Sproull [28] , this set consists of recipe knowledge and social typification. Recipe knowledge is the routine performance programs and the standard operating procedures that provide people with methods of acting in particular situations. Social typification are the shared understandings which are acquired through socialization and the interaction of people with an organisation. Berger and Luckman [1] state that every institution has its own body of knowledge which supplies institutionally appropriate rules of conduct and this knowledge includes shared beliefs. Shared beliefs and values are an integral part of an organisation's identity and are a necessary prerequisite to collective functioning. Therefore, in order for a group to function, individuals must share a set of domain specific beliefs. These collective beliefs encompass more than the common beliefs held by individuals in a group and include additional aspects which may arise out of the dynamics of interaction.

When one develops a multiagent system that emulates group problem solving in a social context, such as a business or government organisation, these common, collective beliefs have to be modelled. They have to be explicitly acquired and represented. Knowledge acquisition and representation are established areas in the field of Artificial Intelligence and many useful techniques and processes have been developed that can easily be used to construct a knowledge-based system in almost any area of application. These vary from simple software engineering approaches [14, 24] to complex formal approaches [29, 12]. This is unfortunately not the case in the development of multiagent systems. While it is possible to use these techniques for acquiring and representing domain and inference knowledge, the same cannot be said for coordination, problem decomposition and task allocation knowledge. The coordination of the problem solving process, the decomposition of a problem and the subsequent allocation of tasks to agents is a fundamental problem in multiagent systems. Whether it is a centralised system with a controlling agent or a distributed problem solving system where agents negotiate, agent capabilities need to be represented. In a centralised system, the controller must have knowledge of individual capabilities in order to allocate tasks. In distributed problem solving systems, agents need to know each others' capabilities in order to establish contracts with the appropriate agents. This meta-knowledge is difficult to identify and represent especially in systems where each agent emulates a human problem solver in a social context, [20, 7] rather than in systems such as DMVT [22], Hearsay-II [15], for example, where each agent is responsible for a single sensor or for some hierarchical or data structure dependent task.

In a recent project, a medium sized manufacturing company commissioned a prototype system to support cooperative problem solving in the area of strategic vigilance. This is a typical example of collaborative problem solving at the strategic level in an organisation where important high impact decisions are made continuously in reaction to changes in the operating environment. This situation satisfies the criteria for a distributed approach [2] and the collaborative tasks can be supported and to a lesser extent automated through knowledge-based multiagent systems. Establishing an architecture for such systems is fairly straightforward since expertise is generally already functionally distributed. Acquiring domain and inference knowledge is also easily accomplished as many single agent systems have already been developed in functional areas such as marketing, manufacturing, finance and so on. The complex issue is the acquisition of coordination, problem decomposition and task allocation knowledge which has to be derived from the human process of collaboration. This paper presents the idea of congregate cognitive mapping which was used as the technique to explicitly acquire this knowledge. The next section provides a brief overview of congregate cognitive maps followed by an illustration of its use in the application.

2 Congregate Cognitive Mapping

A cognitive map is a graphic representation of a set of discursive representations made by a subject with regard to an object in the context of a particular interaction [8]. The intention of drawing a cognitive map is to describe an individual's conscious perception of reality, with sufficient detail to capture the individual's idiosyncratic world view. The use of labelled nodes and arcs in the construction of a cognitive map may give the impression that a cognitive map is just another form of semantic net. While certain types of semantic nets could also be used as cognitive maps, this is not generally the case. This issue will be discussed in more detail later. Congregate cognitive maps are combinations of individual cognitive maps connected through congregate labels [3]. The connections are minimal and the individual cognitive maps remain essentially separate, intact and idiosyncratic. Congregate labels are the public outer tags that people use to describe inner private concepts [4]. That is, each individual's actual idiosyncratic meaning for the same congregating concept, denoted by the common congregating label, arises from the label's connections within each private individual cognitive map. It must be stressed that a congregate map is not an aggregate map. An aggregate map is formed by connecting common nodes in individual maps or by overlaying common nodes from individual maps. It is the intention of this paper to show that congregate labels actually form a cognitive map of their own which can be used to represent metaknowledge in a multiagent system in which the individual cognitive maps are used to represent agent knowledge. Several interactive interview-based techniques have been developed to model the cognitive maps of domain related belief systems in management [10, 6, 19] and these have been used successfully in this research.

3 Application: A Multiagent System for Strategic Vigilance

Strategic Vigilance is the term applied to the detection of strategic issues and the further probing based on such detection [18, 13]. Strategic issues are events, developments and emerging trends in an organization's environment which may be identified as potential threats or opportunities. The task of strategic vigilance is consequently crucial to the continued competitiveness of an organization especially in turbulent and high velocity environments. The match of an organisation's internal capabilities with the opportunities and threats that exist in its environments is called its strategic posture. Unfortunately, shifts in strategic posture as a result of strategic vigilance involve the whole organization and the effects of it have to be assessed in various functional areas before changes can be implemented. This can generate a lag in the response. For most organizations, posture shifts involve a reorganization of marketing, financial, production, research and human resources plans. Since these areas are separate in most organizations, the response lag can be attributed to the actual delay in issue investigation and assessment in each functional area and also the delay that can arise due to the communication and co-ordination between these areas. Delays in response rate can allow competitors to seize profitable opportunities or strategic threats to intensify. The automation of such a system can only improve the response rate especially in cases where functional experts are not available or do not exist. Although Hewitt [17] argues that the interconnectivity and interdependence of knowledge in an organization makes it impossible to separate the knowledge of its affairs into independent modules, when one examines the reality of group decision making and intends to replicate it, a distinct compartmentalization of knowledge exists. This arises out of the distribution of assigned responsibilities in organisations which in most cases require specific expertise. In practice, the mirrored use of assigned responsibilities in multiagent systems reduces the complexity and overhead of task allocation activity [2].

The architecture of the system developed in this research is derived directly from elements of the actual human collaborative system since the design intention was to emulate the process that occurred whenever a strategic issue was discussed and solved. Each functional expert is represented by an agent and the group facilitator by a controlling agent.

Each functional expert was interviewed and the individual cognitive maps constructed. Figure 2 shows a segment of the cognitive map for the marketing expert. Link types are not shown but could be any one of various types: causal, categorization, identity, influence and inclusion. After the interviews, the principal concepts can be identified.

In some research, concepts are treated as variables [8] in others, [11], they are treated as constructs or ideas. The importance is not in the distinction but what is the operable view of the individual regarding them. The interview

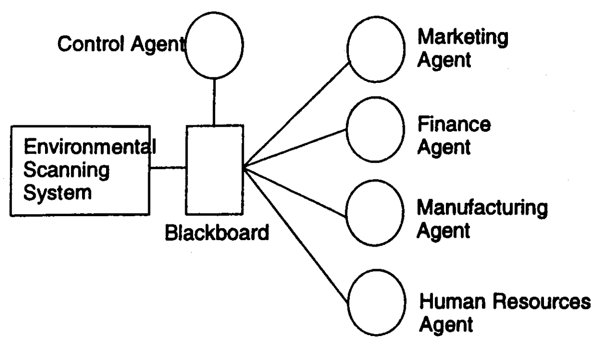

Figure 1: The System Architecture

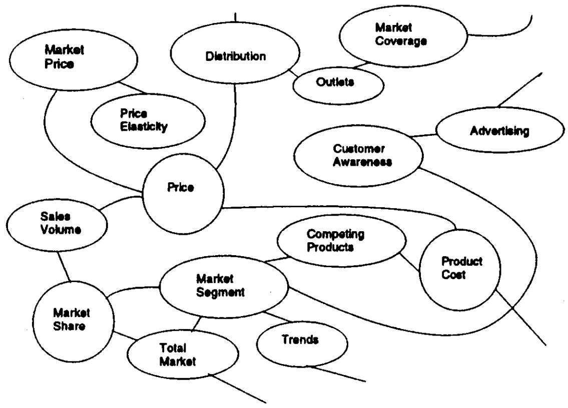

Figure 2: A Segment of an Agent Map

process and the construction of the cognitive map can be viewed as due process in Hewitt's terms except that due process takes place within action taking and decision making situations [17]. The map is presented to the individual for validation and modification. Maps can be analysed. The relative importance of concepts can be assessed through various measures. Cognitive centrality [16] measures the number of links to other concepts. Adjacency and reachability matrices of a concept measure the number of concepts directly and indirectly linked to it, respectively [23]. In addition to the above, Eden et al., [6] measure the relative path lengths between concepts . Figure 3 is an example of a congregate map. Each individual map is replaced by a silhouette and each silhouette is congregated to others by circles denoting labels.

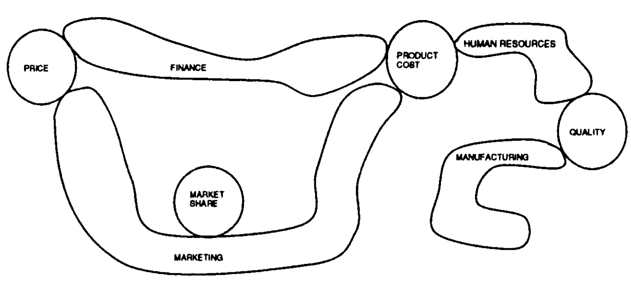

Figure 3: A Congregate Map

In this manner, the congregating labels and dominant topology stand out of the mass of individual concepts. There is always a connection from one label to another since the silhouettes can be replaced by a single link. The actual link-types that join the labels are decided by the experts collectively in a joint interview. The map that is formed by joining labels in this way is then a representation of metaknowledge that can be used by the controlling agent to manage the problem solving process. Each label is later mapped to an event in the environment such as a drop in profitability, a drop in market share, the threat of a new competitor, the threat of a substitute product etc. Spender [27] suggests that an organisation has typically only 15 labels that dominate the thinking of its members. When an event is triggered, the corresponding label and its linkages in the metaknowledge map are activated and each associated agent is sent a request to evaluate the problem with regard to the activated label. This is similar to the focused addressing used in the Contract Net [9]. Figure 4 illustrates the link relationship between the label map and the individual agent maps. When an agent receives a message, its front end processor interprets it and appropriate procedures are called much like the operation of a mace agent engine [21]. Requests for additional information and partial solution are posted on the blackboard in the conventional multiagent mode of operation.

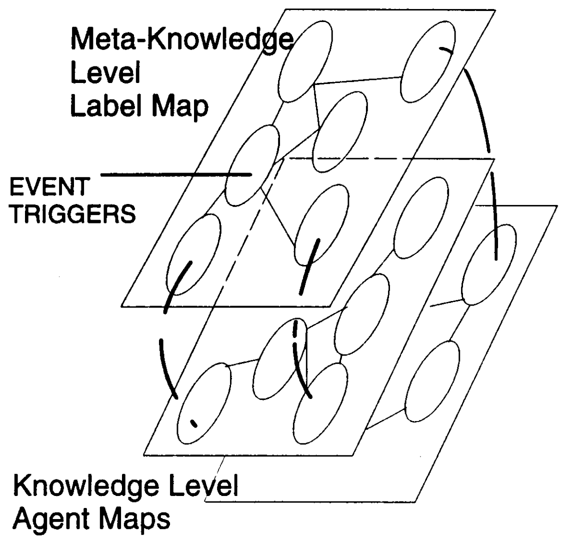

Figure 4: Knowledge Levels

4 General Issues

4.1 Label Maps as Metaknowledge

Metaknowledge for group problem solving is made up of five strategic considerations [26]. These are Goal Identification or Problem Decomposition, Distribution of Knowledge including Task Allocation, Organization of Agents, Coordination and Learning. The label map is a representation of the deepest social reality found in organisations [3]. When a label is activated by an event trigger, its connections to other labels effectively decompose the issue into components. The allocation of tasks is inherent in the structure since each label is further mapped to one or more agent maps. The architecture of the system with its assigned responsibilities together with the label map that reflects these assignments and the opportunistic event driven approach resolves many of the coordination problems inherent in multiagent systems. Conflict resolution however needs to be embedded explicitly in the controlling agent. Labels are generally mapped to more than one agent, and conflicts are common. For example, the marketing agent would lower prices to increase market share while the finance agent would increase prices to improve profitability. In real situations these conflicts are resolved by maximising the organisation's position. Theoretically, the mechanisms for accomplishing this should be embedded in the individual agent maps but these are not always explicit or procedural enough to be used for conflict resolution. In the prototype system, specific procedures were developed to evaluate conflicting proposals in terms of profitability, financial leverage, exposure and other such utility measures.

4.2 Labels and Concepts

Labels have been described as public tags to private concepts. It is sometimes difficult to distinguish between labels and concepts and indeed in many cases they are the same. Bougon [3] argues that labels are crucially important to organizations because they model the deepest reality. When using labels, he argues, 'the map is the territory'. This distinction, while it is important especially in management, can be ignored in the knowledge acquisition process if a concept exhibits sufficient cognitive centrality and if one is aware that different agents would respond differently to it. Consider two concepts Growth and Profitability. There is obviously a link between the two as confirmed by the individual cognitive maps of both the finance and the marketing expert. However, for the marketing expert the idea of market growth would influence profitability positively, while for the finance expert, the pursuit of profitability would encourage growth. There may be some relationship between the label-concept distinction and the intension-extension distinction [30]. Labels are better represented intensionally.

4.3 Semantic Nets and Cognitive Maps

Computer scientists would examine a cognitive map and argue that it is a semantic network. Management scientists would disagree and argue that the two cannot be the same since the intention and purpose for drawing them are essentially different. The latter is probably more correct since the original intention of constructing semantic networks was to model the semantics of English words [25]. Semantic networks have since been used to represent all sort of nonsemantic things [5]. The closest match between these two formalisms occurs when one views a semantic net at its epistemological level where the possibility exists for organizing knowledge into units more structured than nodes and links and where the parts of an intension can be related to the intension as a whole [5]. This is referred to as inclusion in a cognitive map [8] and is important since individuals use concepts at different levels of abstraction and often use some concepts only to specify others. The fortunate aspect of the similarity of appearance between cognitive maps and semantic nets is that one needs not invent a new implementation for cognitive maps. Trusted methods for implementing and traversing semantic networks can be used.

5 Conclusion

This paper puts forward the argument that in socially motivated multiagent systems, the knowledge that is used for coordination, problem decomposition and task allocation can be explicitly derived from the collective beliefs of the individual decision makers. The technique of constructing cognitive maps was demonstrated as a possible method of achieving this. There are a number of interesting ideas that come out of this research that could be investigated further, including teh following:

- The modelling of power relationships in multiagent systems
- The development and role of shared beliefs over time
- The automation of metaknowledge acquisition for general purpose multiagent

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- an appropriate keyword list
- a list of relevant Computing Review Categories
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- References should be listed at the end of the text in alphabetic order of the (first) author's surname, and should be cited in the text according to the Harvard. References should also be according to the Harvard method.

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Proofs of accepted papers may be sent to the author to ensure that typesetting is correct, and not for addition of new material or major amendments to the text. Corrected proofs should be returned to the production editor within three days.

Letters and Communications

Letters to the editor are welcomed. They should be signed, and should be limited to about 500 words. Announcements and communications of interest to the readership will be considered for publication in a separate section of the journal. Communications may also reflect minor research contributions. However, such communications will not be refereed and will not be deemed as fully-fledged publications for state subsidy purposes.

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Contributions in this regard will be welcomed. Views and opinions expressed in such reviews should, however, be regarded as those of the reviewer alone.

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Contents