IMPROVING COOPERATIVE MANAGEMENT
Fuzzy Modeling and Proximity Networks

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Abstract: The Internet, and perhaps of more relevance to this work, large enterprise networks are complex ICT systems of prime business importance. The effectiveness of management of any complex system is heavily dependent on understanding the functions of its components and their interactions with one another. As such, quantifying collaboration and awareness levels can play significant roles in improving the management efficiency. In most cases though, it is impossible to identify precise crisp models describing the roles, functions, and interactions of such components in a useful manner. This can in turn be related to the fact that the characterization of these concepts by human beings and managers is heavily based on the use of linguistic variables. These variables and the communication of perceptions based on them are fuzzy concepts in nature. This paper further elaborates these issues. To identify solutions, it discusses the relevant notions of soft computing and explores the ways that the utilization of fuzzy awareness modelling can help in improving cooperative management effectiveness.

1 INTRODUCTION

Provision of collaborative services requires cooperation among various entities of an organization. Associations and collaborations of humans are partially or fully dictated by their level of awareness of the ability of others to support them to fulfil their responsibilities. As such, awareness modelling and levels can play significant roles in improving the management efficiency. To facilitate collaborative services, some way to analyze cooperation levels is needed. It is well established that one of the fundamental problems in achieving robust systematic solutions to problems encountered in cooperative management environments relates to the difficulty in quantifying collaboration and awareness levels, for example see (Basker et al, 2002).

As discussed by several researchers, including (Grudin, 1994) and (Lim, 2009), associations and collaborations of humans are partially or fully dictated by their level of awareness of the ability of others to support them to fulfil their responsibilities. One of the basic difficulties in achieving robust analytical solutions in cooperative management environments relates to the difficulty in quantifying cooperation and awareness levels, for instance see (Wang and Chang, 2004). These models heavily depend on the use of intelligence. Conventional IT solutions provide some degree of artificial intelligence (AI) for processing and filtering the data. However, human interactions remain essential, as the data is often incomplete and conflicting or the information may be irrelevant to the task in hand.

Furthermore, proper implementation and utilization of AI enabled tools need to be considered. For example, (Huang et al, 2008) have shown that AI based network management systems that deal with the problems at network layer, are mostly based upon expert system techniques. From a broader point of view, the ability to handle huge amounts of information is a prerequisite for management of complex systems. These issues have been discussed in our previous works, for instance see (Shahrestani, 2008).

From a practical point of view, the assignment of the awareness levels for various entities and roles involved in a given task is more suitably achieved with the linguistic propositions and words like *minimal* or *high.* As we have shown before

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(Shahrestani, 2001), this can be related to the fact that humans prefer to think and reason qualitatively, which in turn leads to imprecise descriptions, models, and required actions. Clearly in cooperative management, the need for exploiting the tolerance for imprecision and uncertainty to achieve robustness and low solution costs is evident. This is in fact, the guiding principle of soft computing and more particularly fuzzy logic introduced by (Zadeh, 1965). In his break through work (Zadeh, 1994) introduced the calculus of fuzzy logic as a means for representing imprecise propositions (in a natural language) as non-crisp, fuzzy constraints on a variable.

This work will further discuss the utilization of fuzzy logic concepts to identify a fuzzy framework to quantify awareness levels to facilitate their implementation. In that sense, uncertainty permeates the entire management process. As we have discussed before (Shahrestani, 2003), the latter piece of information can be easily amended and handled by fuzzy logic based approaches.

The remainder of this paper is structured as follows. Section 2 establishes the background and motivations for fuzzy awareness modeling. This is further expanded in Section 3, where the design framework incorporating the agent-based cooperative management concepts are discussed. In Section 4, notions relevant to fuzzy proximity networks and execution of the design methodology through are presented. The last section presents the concluding remarks.

2 FUZZY AWARENESS MODEL

Awareness modeling is an area that has witnessed significant research to define various types of awareness and supporting awareness. In most of these works, for instance see the pioneering works (Grudin, 1994), it is argued that an individual's level of awareness is increased by insight and awareness of information about a given event or object, rather than by actually receiving that information. At any case, to be of practical value in any collaborative environment, a design methodology incorporating a reasonable approach for utilization of awareness levels is a prerequisite.

In most cases, some researchers such as (Wang and Cheng, 2004) have argued that awareness levels of an entity are altered by perception of information about a given experience or object, rather than by getting the actual information. Either way, for effective integrated management, where shared objectives and collaborations are the norm, utilization of awareness levels is a requirement. In this respect, it can be noted that in general it may be advantageous to describe the awareness levels of any role using the semantic definitions that are in fact based on the use of linguistic variables, as first discussed in (Mamdani, 1977). As stated before, it can be noted that in general human beings characterize the awareness levels of any role using the semantic definitions through the use of linguistic propositions and variables. For instance, a supervisor may characterize a technician by simply stating, "Technician D is the best in our group for upgrading a particular link." This can be easily interpreted as: within the group of people of this supervisor, D has the maximum awareness level for that particular job. Such a characterization can be conveniently modeled through utilization of fuzzy logic and fuzzy modeling.

The fuzzy modeling is based on the fuzzification of crisp values. For instance, assume that awareness level, *AL*, of a given role, for instance technician D, is defined in the crisp terms, e.g., between 0 and 4 in the form

AL (D) = a (where a is crisply defined as a member of {0, 1, 2, 3, 4}).

This is now replaced by

AL (D) is A.

where *A* is a fuzzy subset of the universe of the awareness levels of the technician role. Following on from the example above, for the most suitable technician to do the job, the technician's lowest awareness level is represented by

AL (D) is maximal.

In this sense, while *AL (D) = a,* is a particular description of the possible values of the technician's awareness level, the fuzzy set *A* represents a possibility distribution. Now, the possibility of the *linguistic variable* AL (D) is represented by a *linguistic value* as the label of the fuzzy set taking a particular (*numerical*) *value b* given by

$$\textit{Possibility}\ \{AL\ (D) = b\} = \mu_A\ (b).$$

The knowledge about AL of each role for a given task that is based on linguistic variables can act as a descriptive and flexible profile for that role. Given the semantic definitions that are actually based on the use of linguistic variables this notion of fuzzy logic is obviously more appropriate. More specifically, the fuzzy values signify a technician's AL that can be used for different purposes. The profiles can be used for identifying and ranking of suitable technicians for a given task or conversely, for a given technician it provides a means for detection of the additional knowledge that the technician needs to carry out a given task efficiently.

Furthermore, through forming of fuzzy clusters of profiles, one can establish aggregate profiles. Such aggregate profiles can be used an overall picture of the AL of the technicians within the organization. One can now characterize interactions with fuzzy-based definition of the awareness levels. These provide for the description of the complex systems and interactions using the knowledge and experience of customers, managers, and others involved using simple semantics.

3 DESIGN STRUCTURE

This work is based on the proper choice of the repositories and information as guided by the collaboration of all the individuals involved in accomplishing a common goal. This may lead to the concept of virtual awareness levels. The information repositories are mostly structured on the utilization of compound document-centric object architecture similar to those described in (Umar, 1997). Compound document architecture, made popular through Microsoft Active X/DCOM, helps express structured and unstructured knowledge in the form of documents with hyperlinks. Over the years, they have greatly evolved and are the cornerstone of web-based document systems. In this sense, the required awareness and the needed information are essentially provided using compound documents based on an object-oriented and web-based system accessible via a browser and search engines.

Given the required awareness levels for the variety of tasks in complex systems, each human role is provided with a software agent. Each agent attempts to provide the required awareness level to the human role it is serving by interaction with other agents and by search through the information base. The implementation of such a multi-agent framework needs to consider a range of intelligent techniques, such as case-based reasoning, active directories, neural networks, and appropriate rules and policies.

To improve cooperation and efficiency, each role through its agent, must be capable of determining all relevant information for the task. In other words, the task rather than the individual should dictate the relevance of information and passing them on to the human role. The information that is passed to the individuals is built upon the possible connection among various queries made by all involved individuals. In this fashion, the overall conduct in achieving the common goal can benefit from the combined awareness levels of human roles and local decisions.

As with normal practice in most human organizations, to achieve overall coherency a coordinator role is also considered. The role takes an overall view of the tasks in hand. For instance to avoid flooding any role with irrelevant or loosely relevant information, the coordinator must be able to grade the suitability of the information for the individuals in accomplishing their functions in the project. The correctness of the retrieval of such information can be defined in the context of the problem using the notion of membership in a fuzzy set around the desired keyword.

Many of the current approaches are capable of retrieving all relevant documents containing the information that is indexed by the used keywords and ranking them by some degree of relevance according to the query made by an individual. In most of these approaches, the presence or absence of the keywords in the query and the indexing terms of the documents form the basis for evaluation of the relevance of a document to the query.

It can be note that generally speaking, it is easy to combine multiple keywords within the query made by an individual as an aggregate fuzzy set using fuzzy operators. In a similar fashion, one may propose that queries from several individuals can also be based on the simplistic approach of considering them as a single query with multiple keywords.

However, as pointed out by many researchers, for instance see (Horng et al, 2008) and (Shrivanian and Lippe, 2009), basing IR systems on such approaches will have fundamental shortcomings. Among the basic deficiencies that need to be dealt with here, is the lack of ability to express the linguistic based queries made by humans in a formal way needed for machine interpretation and processing. Another and probably more fundamental problem relates to identifying suitable ways for representation and inference of concepts and the context in which they appear. In machines, the concepts need to be precisely defined, leading to lack of generalization that in turn causes the number of cases that need to be dealt with increase rapidly.

4 FUZZY PROXIMITY NETWORK SCHEME

Within a cooperative environment, an intelligent system can be built upon the collaborative nature of

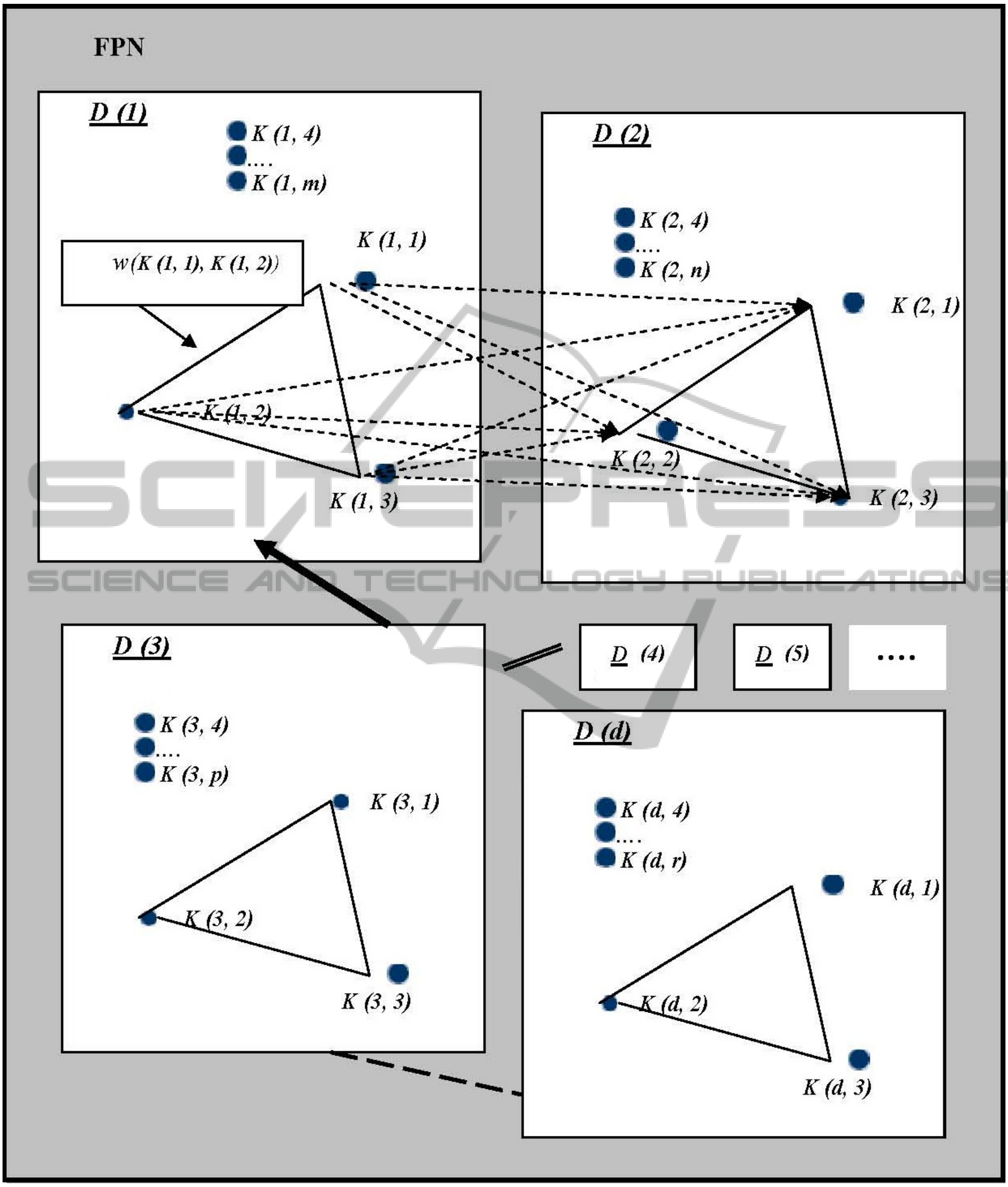

Figure 1: Formation of fuzzy proximity network (FPN).

the queries by noting the implicit connection between the individuals. One of the main applications of the awareness model of the user (or its agent) is related to the use of the awareness level terms as part of the query, resulting in an expanded query. The intelligent information system will then be able to elevate the awareness levels of the individuals by pointing to them the data set items they might have been missing otherwise.

As it will be shortly discussed, the Fuzzy Proximity Network (FPN) performs the needed aggregation. The network achieves the representation of the fuzzy awareness engine for the implementation of the multi-agent framework.

Through computation with words and the use of linguistic variables, the solutions need to manage the inherent fuzziness in human queries, representation of concepts and coordination, properly and efficiently.

To address the lack of flexibility in representing documents and queries, fuzzy systems that deal with this type of problem for individual users have also been studied and developed by several researchers. In such approaches, a fuzzy set will represent each keyword. The membership value of each piece of information or document indicates its degree of relevance to the fuzzy set denoted by the keyword. In this way, it is easy to use linguistic qualifiers for computing with words to help the information retrieval process. While this can help in indexing and the querying process, users can also employ it to provide feedback information. Such information can be used to evaluate the retrieval system and in turn for evaluation of the awareness agent.

A scheme that is based on fuzzy proximity networks in line with the work reported in (Shenoi, 1989) can be utilized to build the required intelligent system. The network is capable of providing coordination services for cooperating agents. It can also conveniently take the technicians' awareness levels and profiles into account while processing their queries. The coordinator role and its agent can evaluate and aggregate the queries from individual agents to help the cooperating agents in achieving their common goal. One important aspect of such coordination relates to connecting the cooperating agents by pointing information and documents relevant to their task, even when one agent has not asked for them. To achieve this, the system needs to be able to process queries from different cooperating users as collaborative queries. In this case, each node *i* of the fuzzy proximity network represents a keyword. The weight *w(i, j)* represents the fuzzy relevance of the two keywords at nodes *i* and *j*. Such a scheme does emphasize the keyword structures and connections, rather than focusing on the keywords themselves. The relevance between the keywords is based on the co-occurrence of a keyword or the so-called Miyamoto's measure, similar to what is reported in (Miyamoto, 1983). Stated simply, this measure implies that the more often two keywords occur simultaneously, the higher is their relevance to one another.

Consider a fuzzy proximity scheme, partially shown in Figure1. Here, as in any case of practical importance, the pieces of information are in several documents, including a document *d* denoted by *D (d)*, where the k^{th} keyword in *d* is represented by *K(d, k)*. The keywords within any given document are considered to be related to each other. For instance, keywords *K (1, 1), K (1, 2), … K (1, m)* are considered to be related, as they appear within the same document, *D (1)*. The fuzzy relevance of keywords is represented by the weight *w* between their respective nodes. For example, here the fuzzy relevance between the two keywords *K (1, 1)* and *K (1, 2)* is represented by the weight *w (K (1, 1), K (1, 2))*. In accordance with the co-occurrence concepts, if document *D (1)* refers to another piece of information in *D (2)* or is referred to by the information content of *D (3)*, then the keywords *K (2, 1), K (2, 2), … K (2, n)* as well as the keywords *K (3, 1), K (3, 2), … K (3, p)* are also considered to be related to each other, although in a weaker sense. This type of information will establish the initial setting of weights in the network model. Obviously, after this initial stage, the weights can be updated through adaptive mechanisms and supervised learning.

For each document, its characterizing attributes are calculated based on a maximum spanning tree, see (Sun, 1990). Here, as in several other applications, a spanning tree is the tree that covers a given set of nodes, i.e. keywords. The weight of the tree *W (.)*, is the sum of the weights of the branches in that tree. A maximum spanning tree is established as the tree with the maximum weight for a particular set of nodes. Given a query *Q (q)*, its maximum spanning tree weight *W (Q)*, is used as the characterizing measure of the query. The weight of the maximum spanning tree for the keywords common between *Q (q)* and a document *D (d)* divided by *W (Q)* is used to represent the characterizing attribute measure *R (.)*, of document *D (d)* with regard to *Q (q)*. These characterizing attributes calculated for all of the documents, are then used for ranking the documents with regard to their relevance to the query *Q (q)*.

In summary, each human role in a cooperative management environment is supported by a software agent that assists the process to collaboration by helping realize the right level of awareness at the right time for each collaborating role. Although conceptually one could use many different paradigms of artificial intelligence (e.g., case based reasoning, model-based reasoning, fuzzy logic etc), this paper discusses the design of an awareness agent based on fuzzy logic. It is possible to use a number of ways to involve fuzzy logic in the design of such systems, as discussed in (Shahrestani, 2005). Here, the Fuzzy Proximity Network (FPN) has provided us with a simple example that illustrates the role of fuzzy logic in the practical deployment of awareness model in any cooperative information system design.

Additionally, the previously established levels of awareness for different individuals involved in a project are used in conjunction with their queries to form a joint index set. These can be considered as the virtually combined queries from several collaborating individuals. They form the basis for the retrieval of several inter-related pieces of information that improve the awareness levels of all group members cooperating to achieve a common goal. It is worth noting that the virtual joint query is not formed through a union of the keywords used in the queries of the individuals. The joint query is rather based on reflection of combination of the keywords, structure and the supposed awareness levels of the involved individuals. They account for the connection of keywords that are linked together to form a structured concept. This is achieved by using the characterizing features based on the maximum spanning trees. Given that the information from various collaborators are being combined, the amalgamation of the keywords, rather than emphasizing on the keywords themselves, is highly beneficial.

5 CONCLUSIONS

This paper has discussed fuzzy awareness modelling as part of an efficient cooperative management design framework. In the proposed framework, higher levels of cooperation are facilitated through collaborative joint queries. These queries result in higher awareness levels for the combined roles of all individuals involved in a given task The framework is based on multiple agents, where each human role is supported by an agent. The development of multi-agent cooperative management systems is based on the notions of fuzzy logic and processing of linguistic variables. The development and implementation of an FPN for management information retrieval was used as an illustrative example.

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