Utilization of Soft Computing to Improve Cooperative Management Efficiency

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Abstract: - Provision of collaborative services requires cooperation among various entities of an organization. Furthermore, efficient management of any complex system, such as large enterprises or modern enterprise networks, depends on understanding the roles of its constituents and their interactions with one another. Interaction of humans is partially or fully dictated by their level of awareness of the capacity that others have in supporting them in fulfilling the tasks at hand. As such, awareness modelling and levels can play significant roles in improving the management efficiency. The awareness levels in human beings and managers have a fuzzy nature with linguistic variables extensively used in their characterizations and communications. Noting the underlying fuzziness, this paper explores how soft computing can be used to improve awareness modelling to achieve more effective cooperative management. This is further demonstrated through its application to an illustrative example that utilizes fuzzy proximity networks.

Keywords: **-** Soft Computing**,** Fuzzy logic, Cooperative Management, Network Management, Awareness Modelling.

1 Introduction

Successful management of any complex system or large enterprise is dependent upon cooperation amongst a number of individual and entities. To accomplish a collaborative service, cooperation amongst these entities is a must. To facilitate this, some way to describe and analyse cooperation levels leading to identification of the gaps in the support for cooperation is required. One of the basic difficulties in achieving robust analytical solutions in cooperative management environments relates to the difficulty in quantifying cooperation and awareness levels [1].

In practice, humans acting as operators, experts, managers and the like, describe these concepts in linguistic terms and analyse them qualitatively. This leads to imprecise descriptions, models, and required actions [2]. 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 [3]. Zadeh 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 [4].

In that sense, uncertainty permeates the entire management process. The information regarding the context of needed support and the type of awareness models that can be built to represent them are among crucial aspects of an efficient management system. While traditionally and in general the main components used in the definition of a context are observations or facts, the data on relevance and confidence may add precious information. The latter piece of information can be easily amended and handled by fuzzy logic based approaches [5].

This work will further discuss the utilization of soft computing and fuzzy system concepts to identify a fuzzy framework to quantify awareness levels to facilitate their implementation. As with other fuzzy systems, this framework will accept crisp measurements, as inputs and produce crisp outputs, e.g. awareness levels, while fuzzy logic operations are used internally to reach inferences for effective cooperative management.

The remainder of this paper is structured as follows. Section 2 describes our awareness model. This is further expanded to discuss fuzzy awareness in Section 3. In Section 4 the design framework that incorporates soft computing concepts is presented. The agent-based management system that utilizes the described concepts is discussed in Section 5. In Section 6, implementation of the design methodology through utilization of fuzzy proximity network notions is explained. The last section presents the concluding remarks and future works.

2 Awareness Modelling

In general, awareness relates to possession of relevant information for a given task. Normally, this information is made available to certain entities for some specific purpose. Awareness modelling is an area that has witnessed significant research to define various types of awareness and supporting awareness. In most of these works, it is argued that an individual's level of awareness is increased by perception of information about a given event or object, rather than by receiving that information [6]. 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 the recent past, the modelling of network operations and incorporation of management information has witnessed substantial growth. Commercial platforms for management of network and system tasks in organizations of different sizes and complexities are now readily available. However, without a cluster of skilled staff, operation of any typical enterprise network is not efficient. For instance, there are clear indicators showing that in telecommunication organizations automation without considering human factors can even be counter-productive [7].

The design problem is how to characterize and model the given awareness levels that are inherently fuzzy and uncertain in a global context. In this respect, it can be noted that in general it maybe advantageous to characterize the awareness levels of any role using the semantic definitions that are actually based on the use of linguistic variables [8]. For instance, a supervisor may characterize a technician by simply stating, "Technician D has a *minimal* awareness level for upgrading link A". That is the characterization is based on the use of linguistic variables, rather than on the basis of strict mathematical functions or operators. Formally, such a characterization can be conveniently modelled through utilization of fuzzy logic and fuzzy modelling. To this end, the calculus of fuzzy logic is used as a means for representing imprecise propositions that are used in a natural language as non-crisp, fuzzy constraints on a variable [3]. Some applications of fuzzy logic methodology in a network management environment are discussed in [5].

3 Fuzzy Awareness Levels

From a practical point of view, the assignment of the AL of each role for a given task is more conveniently achieved with words like *minimal* or *high.* This can be related to the fact that humans (operators, experts, managers, customers…) prefer to think and reason qualitatively, which in turn leads to imprecise descriptions, models, and required actions.

This fits almost precisely with the principles of softy computing and fuzzy quantisation leading to granulation of awareness levels. Zadeh 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 [4]. Fuzzy logic allows for the representation of imprecise descriptions and uncertainties in a logical manner.

The granulation involves the replacement of awareness level, *AL*, of a particular role, for instance technician D, 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})

by

AL (D) is A.

Where *A* is a fuzzy subset of the universe of the awareness levels of the role. For instance, the technician's lowest awareness level may be represented by

AL (D) is minimal.

Given the semantic definitions that are actually based on the use of linguistic variables this notion of fuzzy logic is obviously more appropriate. In this sense, while AL (D) = *a* is a particular characterization 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

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

The membership function μ shown in Figure 1, represents the grade of membership of *b* in *minimal* (as the technician's Awareness Level). Clearly, in comparison to trying to identify each role's levels of awareness as crisp values, this type of representation is more suitable. This is mainly related to the ill-defined (or too complex) nature of the dependencies of these levels and the knowledge required at each level on the variables that actually quantify them (e.g. contact address and activities of other people involved in interaction). Even if for some tasks such dependencies can be defined well enough, it is still advantageous to use linguistic variables to exploit the tolerance for imprecision, allowing for lower solution costs and achieving more intelligent explanations. The crisp awareness levels, for instance being between nil and four, can now be replaced fuzzy awareness levels Low, Minimal, Small, Medium and High respectively. This will help us tackle the problem of designing systems where the specified awareness levels are vague, uncertain and varying with circumstances.

The knowledge about AL of each role

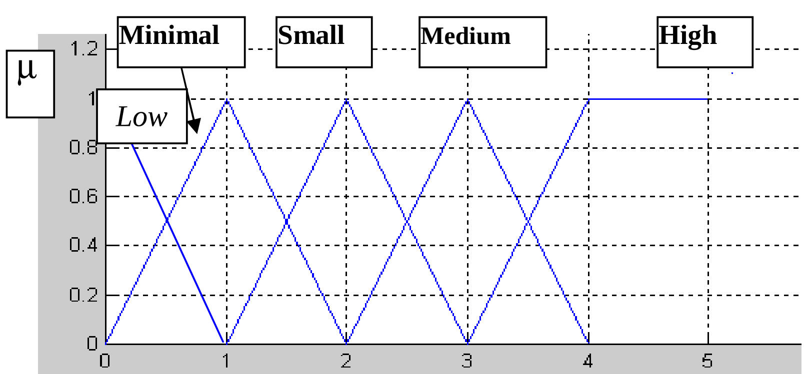

Figure 1- Awareness Level (of a Role for a Particular Task)

for a given task that is based on linguistic variables can act as a descriptive and flexible profile for that role. 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. Furthermore, the profile for a given technician provides a means for easy identification of the additional knowledge that the technician needs to carry out a given task. 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 as shown in Figure 1. This will provide for the description of the complex systems and interactions using the knowledge and experience of customers, managers, and other involved people in simple English-like rules [9]. The fuzzy-based characterization results in models that are easy to understand, use, and expand even by non-experts. Clearly, the fuzzy-based methodology offers significant benefits. In this case, an obvious advantage is related to simplification of modelling process. It can be noted that several automated approaches for classification of dynamic fuzzy models have been developed [10]. In addition, as the fuzzy systems are rule based, the system designer can focus on the actual design process. The abstract system design involves the realization of appropriate awareness levels for every interaction by designing appropriate group repositories, appropriate group communication mechanisms and tools.

4 Soft Computing Design Framework

Given the range of tasks and the required awareness levels, each human role will need to have a software agent to implement the desired awareness level for an interaction. 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 [1], [11].

This discussion assumes the use of the compound document-centric object architecture made popular through Microsoft Active X/DCOM, and OpenDoc [12]. Compound document architecture helps express structured and unstructured knowledge in the form of documents with hyperlinks. Thanks to the proliferation of the web-based applications, the benefits of compound document architecture are now evident in many areas of business. So the required awareness level is provided through compound documents (e.g., trouble-tickets) based on an object-oriented, web-based system implemented through a browser, such as Internet explorer and web-based search engines. In a collaborative environment, provided the individuals have access to proper means of communication, the collective knowledge can help in achieving the right awareness levels for the individuals. This may lead to the concept of virtual awareness levels, which 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. 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 web.

5 Agent-based Management System

This section reports on the results of applying research concepts arising in fuzzy systems and soft computing to this case. The methodology involves the access to the desired documents (e.g., trouble-tickets), rules or policies based on queries using keywords, a common mechanism for accessing knowledge over the web. While a trouble-ticket provides an artefact for sharing management information, there a number of other documents and repositories that help in diagnosing a problem and in developing an organizational knowledge-base for efficient problem management. Obviously, the situation could be vastly improved by improving the awareness of various levels by providing the appropriate knowledge or information to each role in an interaction through compound documents searched by agents against certain criteria. It may be noted that this section assumes that the required knowledge is available somewhere on the network.

To avoid bombarding an individual with irrelevant or loosely relevant information, the coordinator must be able to rank the appropriateness of the information for the individuals in achieving their functions in the project. Finding solutions for this type of problem has been the subject of extensive research. More specifically though, here we are interested in identifying ways to discover all relevant information for individuals, so that the overall conduct in achieving the common goal can benefit from their combined awareness levels and local decisions. The information that is passed to the individuals is built upon the possible connection among various queries made by all involved individuals. For example, the agent of the change manager could check the concerns of all users by extracting relevant service agreements of all relevant users, and comparing them.

In a cooperative management environment the retrieval of information from knowledge-bases is typically achieved through utilization of keywords and unstructured phrases. However, users of the World Wide Web know the shortcomings of such a system, primarily because the same keyword could be used for different meanings in different contexts. Hence many of the retrieved information could be useless. For instance, consider a query with regard to *heavy traffic*. Obviously, there is no clear boundary that can be used to distinguish between *heavy traffic* and *not-heavy traffic*. Here, the problem is related to lack of specificity. Additionally, the level of traffic that is considered as *heavy traffic* on a particular link is not necessarily labelled as such on another link. Moreover, the term *heavy traffic* may be used in contexts other than those related to the *link traffic*, e.g., the technicians are late due to *heavy traffic*. In this case, the problem is related to the vagueness of the meaning and ambiguity in the language. We define the correctness of the retrieval of such information 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. However, there are some serious problems with these approaches. 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.

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, for example see [9], [13] and references therein. 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.

To take the inexact matching of keywords into consideration, these ideas have been expanded to incorporate fuzzy thesaurus [14], [15]. Note that it is trivial 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. Although in some simple cases simple fuzzification of numerical terms can address the problem, the general solution needs to be based on fuzzification and processing of concepts. 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. As it will be shown in the next section, 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.

6 Organization of Awareness Levels through FPN

Within a cooperative environment, an intelligent system can be built upon the collaborative nature of the queries by noting the implicit connection between the individuals. The system should be capable of taking into account the individuality of different users; e.g. different people will generally use different keywords for the same query. Therefore, the emphasis should be on concepts, structure and connection of keywords as well the behaviour and awareness levels of the individuals using those keywords. 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.

A scheme that is based on fuzzy proximity networks [16] 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 [17]. Stated simply, this measure implies that the more often two keywords occur simultaneously, the higher is their relevance to one another.

Consider the scheme, depicted in its essential form in Figure 2. Here, as in any case of practical importance, the pieces of

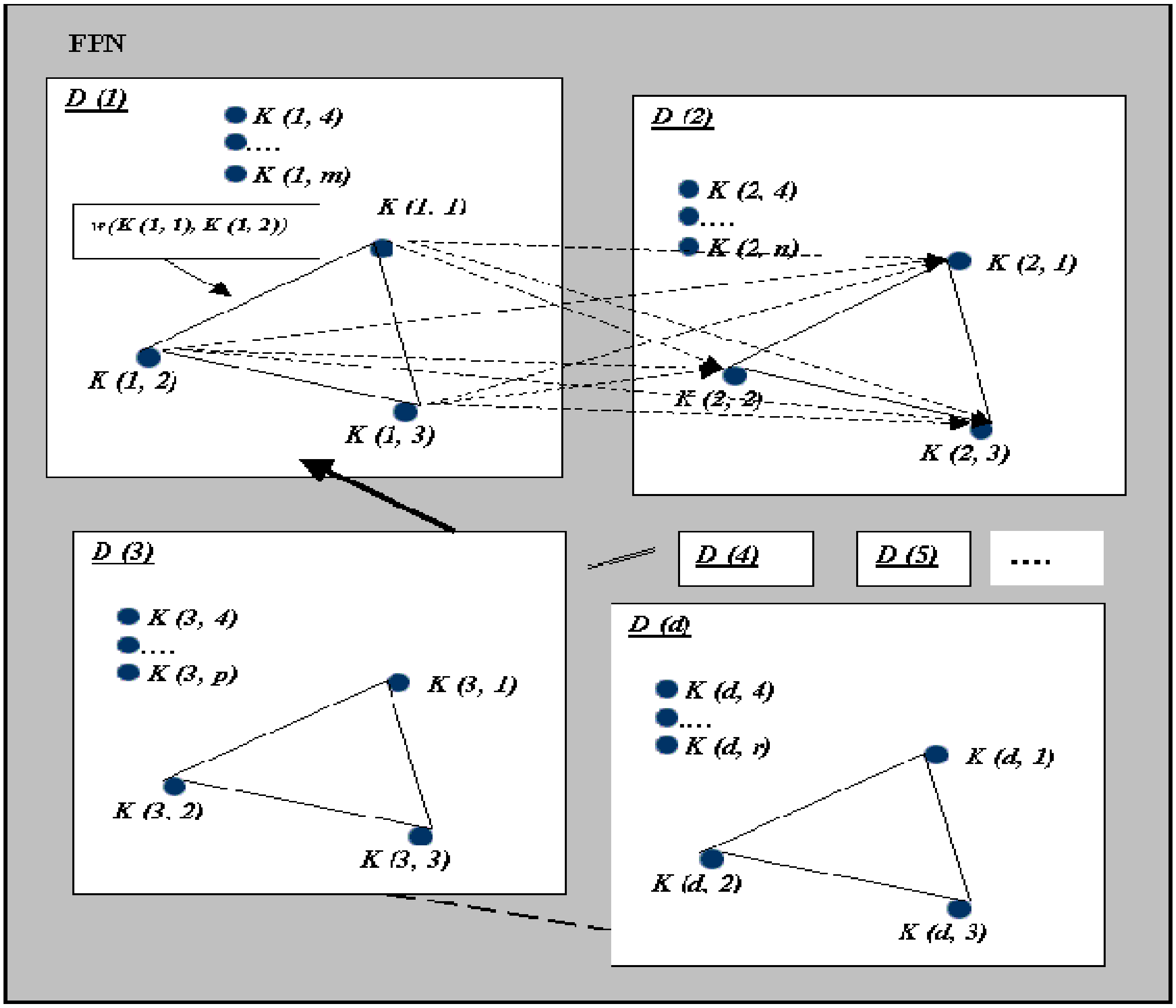

Figure 2- FPN Formation

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 [18]. 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)*.

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 are considered as the (virtual) 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. Note that the (virtual) joint query is not formed through a union of the keywords used in the queries of the individuals. It is rather based on consideration of structure and combination of the keywords and the assumed awareness levels of the individuals. This is achieved by using the characterizing attributes based on the maximum spanning trees. They account for the connection of keywords that are linked together to form a structured concept. The combination of the keywords, rather than emphasizing on the keywords themselves, is highly advantageous here as the information from various collaborators is being combined.

In summary, Figure 3 shows that each human role in a cooperative management environment is supported by a software agent that assists the process to collaboration by helping realise 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 [19]. 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.

7 Conclusions

This paper has presented how the classification and modelling of human roles and analysis of some representative scenarios could lead to identification of gaps (awareness modelling) in the existing collaborative environments. The awareness model states that a cooperative business process can be enhanced by providing the right awareness level at the right time to each human role. This can be achieved through the cooperation of human roles and their software agents.

Hence we have proposed a cooperative management design framework based on multiple agents, each human role being supported by an agent. This paper has explored the use of fuzzy logic for the development of this multi-agent cooperative management system where each agent uses some fuzzy processing to achieve the desired awareness levels for each human role in the cooperative management process. The idea was illustrated using a simple example (with Fuzzy Proximity Networks) of matching keywords for the retrieval of management information from the organizational knowledge-base, an important constituent of the modern cooperative management environment. The ideas discussed in this paper are extendable to many application areas in addition to those in network and systems management. More research is needed for this purpose.

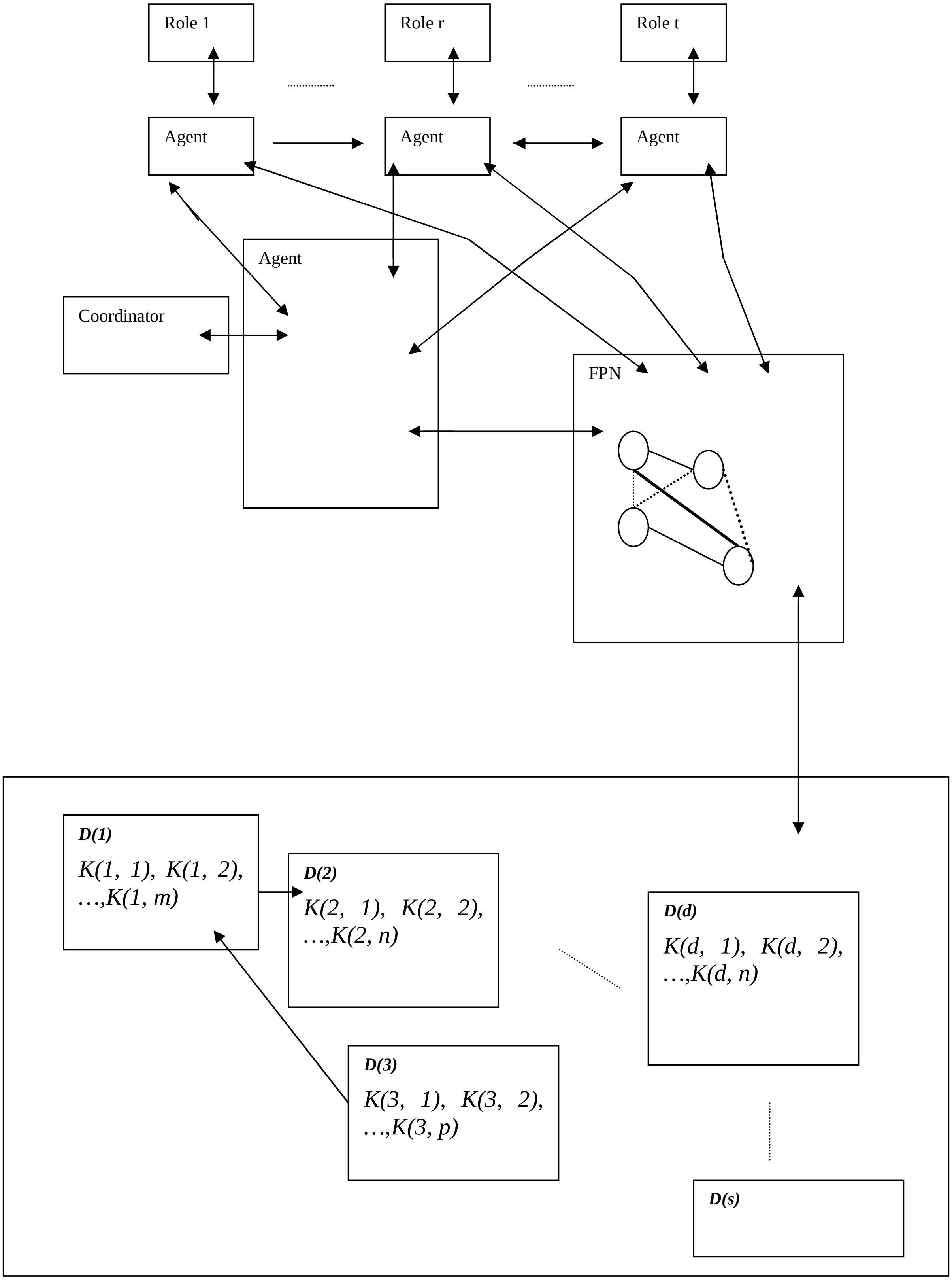

Figure 3- FPN incorporation to enhance awareness levels based on Fuzzy Proximity Network (FPN)

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