Fuzzy Modeling of Cooperative Service Management

Pradeep Ray [1] and Seyed A. Shahrestani [2]

[1] School of Information Systems Technology and Management
University of New South Wales, Sydney, NSW 2052, Australia
p.ray@unsw.edu.au

[2] School of Mechatronic, Computer, and Electrical Engineering
University of Western Sydney, Nepean, Bldg. X
PO Box 10, Kingswood NSW 2747, Australia
seyed@ieee.org

Abstract. Cooperative service management is concerned with the development, deployment, and operation on network based services involving the cooperation of a number of human/organizational entities. One of the prerequisites for efficient management of these complex systems is related to understanding of the roles of humans and the ways they interact with each other. This paper presents a new methodology for cooperative service management based on Computer Supported Cooperative Work techniques. The methodology is founded on the identification and modeling of human roles and their knowledge regarding their interactions with other people involved. The modeling is based on the notion of fuzzy sets that will readily furnish for the use of linguistic values. This is aimed at unveiling of the deficiencies in the existing collaborative support tools with a view to developing more effective cooperative service applications. The idea has been illustrated with a case study in a large telecom.

1 Introduction

Cooperative service management formalizes the need for cooperation amongst a number of individual and organizational entities to fulfil a collaborative service. The present trend towards downsizing of organizations, and out-sourcing of many aspects of a business, underscores the growing need for cooperative service management. One of the major questions facing the management is how to utilize the emerging Information Technology (IT) tools and techniques to facilitate cooperation to achieve better service levels [5]. The major hindrance to solving this problem is the lack of a mechanism to measure cooperation. This is partly due to the fact that cooperation level is a „fuzzy“ concept. It defies any attempt of precise measure and specification.

This paper explores some concepts emerging from the area of Computer Supported Cooperative Work (CSCW) to define a fuzzy framework for the measurement of cooperation levels in order to identify gaps in available support for processes in cooperative service management. The fuzzy logic is used to translate these fuzzy measures into the design of IT solutions for effective service management. Although this framework is applicable in a variety of businesses, for example see [1] and [11],

C. Linnhoff-Popien and H.-G. Hegering (Eds.): USM 2000, LNCS 1890, pp. 232-243, 2000.

this paper illustrates these concepts using a telecommunication network management service.

The remainder of this paper is structured as follows. The next section gives a brief overview of the CSCW methodology for cooperative service management. This is followed by a case study illustration of this methodology through its application to a large telecom organization. This is followed by an illustration of a conceptual framework for systematic analysis of the data gathered from that organization, using awareness levels. This leads to a fuzzy modeling of awareness for cooperative service management. The last section gives the conclusions and outlines future work.

2 Methodology

The aim of Computer Supported Cooperative Work (CSCW) is to facilitate cooperative activity among several interacting groups of people to achieve their common goals [5]. With contributions from diverse areas such as computer science, sociology, psychology, and organizational studies, research approaches in this area widely vary. For example, sociological studies in CSCW pay a great deal of attention to the detail of human interactions whereas computer science strives for abstraction [3]. Most of the reported work in the field of network management has adopted abstraction techniques taken from computer science.

In this paper we use CSCW techniques, analyzing practical scenarios based on concepts, such as roles, interactions, artifacts and tools in a real application environment [13]. We have borrowed some of the concepts from the area of participative design processes of information systems [12]. This analysis involves a top down analysis of the cooperative system under study in the following stages:

- Overall System Study
  - The overall „big picture“ of the system including the major human roles, activities and the environment.
- Logical Components Identification
  - Roles and Tasks: human roles and their major tasks.
  - Activities and Interactions: this describes the dynamics of real life processes.
  - Tools and Artifacts: some frequently used software, hardware and information structures in the system.
- Process Study
  - The study of some sample scenarios in terms of the identified roles and their interactions. This study would reveal certain generic process sequences that have a strong bearing on the efficiency of the process.
- Defining Collaborative Service Requirements
  - Repositories: application services using data stores and associated processes.
  - Communication Interfaces: mechanisms to access repositories, such as synchronous, asynchronous, remote conference, local meeting etc.
- Analysis
  - Matching of scenarios to collaborative services (tools and group communication interfaces)

- Identification of gaps in available collaborative services on the basis of user satisfaction levels
- Analysis of the above information using abstract parameters, such as human role awareness levels. Different human roles can be assigned awareness levels based on the awareness (knowledge) they have about the work, people and organization. This will lead to a conceptual design for a cooperative service management system based on required awareness levels.

The subsequent sections of this paper illustrate our CSCW based methodology in the help-desk based trouble-ticketing environment of a large telecommunication organization.

3 Modeling of Telecommunication Service Management

During the recent past, the abstraction and modeling of network operations and management information/protocols have witnessed substantial progress. Integrated management platforms that can address network and systems tasks in an organization are now commercially available [13]. However, without a group of skilled personnel, the satisfactory operation of a typical enterprise network is not possible. Some recent studies have clearly shown that automation without considering human factors can be counter-productive [14]. Such indications have triggered further research in this area initiated by some leading international telecommunications organizations.

The cooperation amongst experts/operators within and across organizations (e.g. user, software developer, equipment vendor etc) is a prerequisite for solving problems in the management of networked service [6]. The level of cooperation among the people, who take up the various roles needed to achieve a solution, has a significant impact on the level of satisfaction felt by the users of the services. In the general CSCW framework, the term awareness level (AL) is used to correlate with such a measure of human cooperation.

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 [9]. For instance, a supervisor may characterize a technician by simply stating that „Technician D has a *minimal* awareness level for upgrading link A“. Formally, such a characterization can be conveniently modeled through utilization of fuzzy logic and fuzzy modeling. 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 [15]. Application of fuzzy logic in a network management application is discussed in [8].

4 Results of a Telecom Organization Study

This section illustrates our study based on the methodology described in Section 3. It starts with a description of the management process and major problems in the management environment under study. We then identify various human roles in the process. This is followed by a brief summary of group support systems available in the organization under study. Finally, we present a sample scenario. We studied a number of scenarios to arrive at a summary of requirements for a cooperative network management system [13].

4.1 Management Process

Trouble ticketing is a help-desk based network management application. In this case, management personnel cooperate to manage a problem using various network elements. A customer encountering a problem reports it to the help-desk. The help-desk operator then assigns a trouble ticket to the problem and refers it to an appropriate person who tries to solve the problem. If the technical person is not able to solve problem within some stipulated time, he/she escalates the alarm (i.e. calls the expert) [6].

4.2 Roles and Tasks

A trouble-ticketing environment in a large organization may embrace a large number of roles. Our example scenario, described below, involves Change Management with following human roles:

The *Change Manager* (G) is responsible (on behalf of the telecom organization under study) for successful operation of the given network changes in the given set of user organizations.

The *Technician* (D) at the Network Management Centre is responsible for the technical aspects of this change.

The *Test Coordinator* (C) assists the NMC technician with systems changes and testing in remote locations.

The *Operator* (A) at the Help-Desk is responsible for procedural communication amongst all concerned parties, and updating the repository available for this purpose.

The *User*(s) (U) represent contact persons in the user organizations where the network/systems change is being undertaken.

4.3 Collaborative Services

This telecom organization uses a number of tools and artifacts along with the help-desk systems. T1 to T9 represent different types of management tools (e.g., LAN analyzers, management platform etc) available for supporting these business processes. Group communication mechanisms depend on the nature of the collaborative task [5]. C1 to C9 represent different combinations of communication tools (e.g. email, fax, mobile phone, pager etc) available to support the trouble-ticketing business process.

The described communication mechanisms and collaborative tools/artifacts are indispensable parts for supporting group cooperation amongst network management personnel in the organization under study.

4.4 Example Scenario

In this study, we examined a number of real-life scenarios. These are based on the problems in a trouble-ticketing environment in a large typical organization, as reported by the employees. This section illustrates our study with a process diagram and observations for a typical change management scenario. Each interaction is characterized within brackets with roles and interaction types shown in Fig.1. The scenario is as follows.

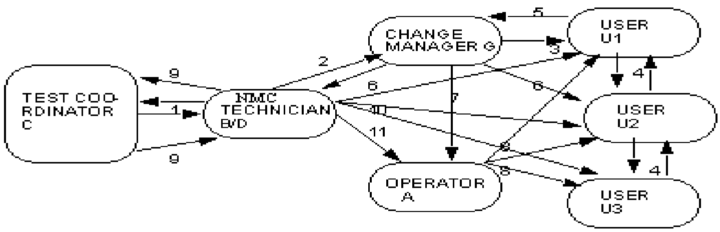

Fig. 1. Process Diagram of the Example Scenario

The existing 2 Mbps Sydney to Perth wide area link needs to be upgraded to a higher version NTU. For this an outage of 30 minutes is required. This involves the following interactions (Fig. 1) amongst the roles defined in the previous section.

1. NMC Technician discusses a suitable time with a remote Test Coordinator
2. NMC Technician/Expert submits the change request with proposed time and user impact statement to Change Manager
3. Change Manager takes up with the affected Users
4. Related Users discuss impact and examine proposed time
5. User resubmits request to Change Manager with possibly an altered schedule
6. Change Manager issues Permit to Work to all concerned
7. Help-Desk Operator is notified by Change Manager before start of the work
8. Help-Desk Operator alerts Users regarding start of work
9. Work coordination between the local and the remote sites
10. Check if OK
11. Help-desk Operator notified of completion of work.

The existing automated tools do not support the majority of the interactions and artifacts. A number of interactions require cooperation of multiple human roles simultaneously. Table 1 describes the available automated support for some of the interactions listed above.

While collaborative tools and communication mechanisms are classified according to the list in Section 4.4 and 4.5, a user satisfaction level is recorded on a scale of zero to ten (10 highest) on the basis of user interviews in the organization under study. We have also recorded what the users believe is the more appropriate communication mechanism. Having recorded the performance of each interaction, it is now necessary to analyze the scenario from the perspective of cooperative service management.

Table 1. Collaborative Service Evaluation

Interaction Number	Tool Used	Communication Mechanism (Now)	Satisfaction Level	Suggested Communication
2	T5 (Change Management)	C5 (Email)	3	C2 (Synchronous)
3	T5	C5, C1 (Face to Face)	3	C2
4 & 5	T5	C10 (Telephone)	3	C2
6	T3 (CISCO Works)	C5	2	C5

5 Cooperation Analysis

5.1 Awareness Model

As shown in Fig. 2, we model all interactions in terms of required and available awareness levels. This is then correlated to user satisfaction levels. If there is a relation between awareness and satisfaction levels, one can arrive at a design specification based on this parameter. Since this is a new experimental model, it is usually necessary to try a number of awareness related parameters, before one or a combination is found useful in the task domain.

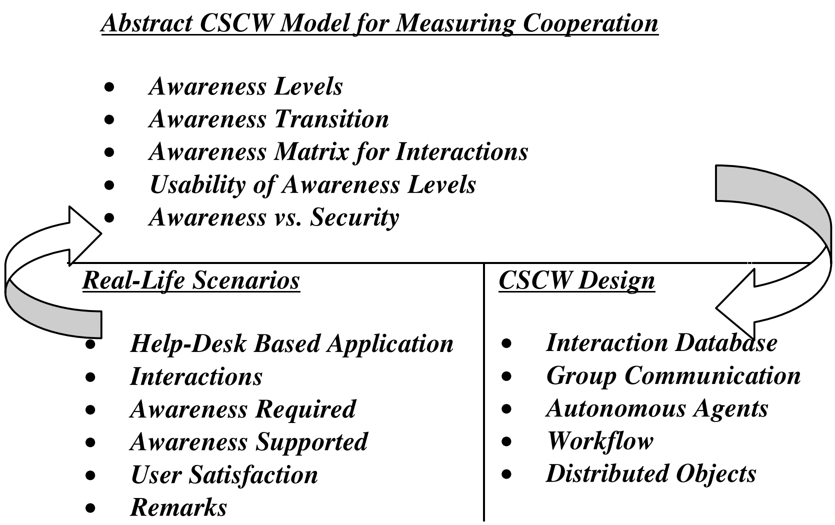

Fig. 2. Awareness Model

Process knowledge consists of task knowledge and context knowledge. While task knowledge relates to the specification, design and performance of the task, context knowledge relates to the rest of the process knowledge including relationships between various roles, tasks, and the environment of the task. It is possible to characterize role awareness in terms of the required and supported process knowledge for a particular interaction. Some examples are: knowledge of involved employees and their roles in the task, knowledge of other preoccupations of these people within the department/division, knowledge of interrelationship of various tasks in the department/division, and knowledge of other activities of people concerned with the task (external to the organization).

This model is described in more detail in [13]. These are defined by using a parameter called „awareness level". This is likely to be the most important parameter to characterize awareness in an interaction. This is a topic of active research in CSCW [1]. According to this definition, the level of cooperation (in increasing order) in a particular work context can be expressed in terms of several levels of awareness as follows:

- Level 0: knowledge related to the given interaction
- Level 1: level 0 plus knowledge regarding the contact address of people involved in the interaction
- Level 2: level 1 plus knowledge regarding the contact address of all people in the interaction context
- Level 3: level 1 plus knowledge regarding the activities of people involved in the interaction
- Level 4: level 2 plus knowledge regarding the activities of all people involved in the interaction context.

It can be noted that this is an empirical model, and these levels are assigned (in different ways) depending on the type of group situation. For example, required awareness for different members of a group can be different. Since the requirement for this information varies from task to task, and interaction to interaction, people need to keep switching awareness levels.

5.2 Granulation of Awareness Level

From a practical point of view, the assignment of the AL of each role for a given task is more conveniently achieved through the use of 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 fuzzy logic and fuzzy quantization 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 [9]. Fuzzy logic allows for the representation of imprecise descriptions and uncertainties in a logical manner [16].

The granulation basically involves the replacement of awareness level (AL), or constraints, of a particular role (e.g. technician D) defined in the previous section to be of the form

$$AL(D) = a \quad \text{(where } a \text{ is crisply defined as a member of } \{0, 1, 2, 3, 4\}) \qquad \textbf{(1)}$$

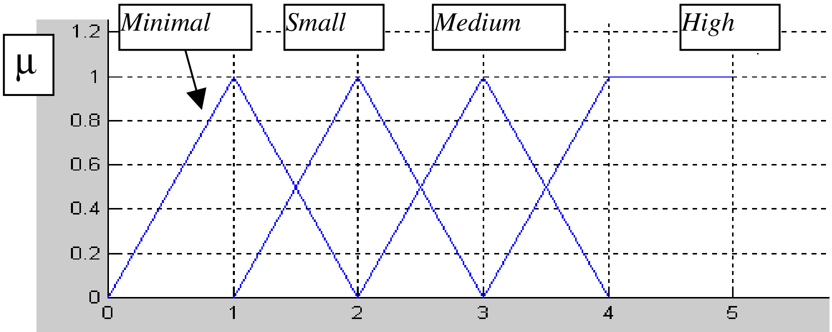

Fig. 3. Awareness Level (of a Role for a Particular Task)

by

$$\text{AL (D) is } A \quad (2)$$

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

$$\text{AL (D) is } \textit{minimal}. \quad (3)$$

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

$$\textit{Possibility}\ \{\text{AL (D)} = b\} = \mu_A\ (b). \quad (4)$$

The membership function μ shown in Fig. 3, 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.

5.3 Scenario Analysis

This section presents an analysis of the scenario described in Section 4.4, using the awareness model. The unsatisfactory interactions are:

1. NMC Technician discusses a suitable time with a remote Test Coordinator

- In this case, the manual and hence error-prone method of communication is probably the main source of dissatisfaction. Often the remote test coordinator cannot be contacted because he/she is busy at a customer site, and emails to his/her office go unanswered because he/she hardly has time to read emails. On the other hand, the customer, and the business manager is pressing hard for the change. The lack of appropriate communication mechanisms causes a mismatch between the required and supported awareness levels.

2. NMC Technician submits change request with proposed time and user impact statement to Change Manager.

- The change impact statement requires a considerable amount of context knowledge regarding user configurations. In the absence of an automated facility, the NMC technician is not likely to have the information regarding the User activities and needs. As such, this person shows only a *small* level of awareness with regard to existing artifacts and tools. In order to be effective though, this person should at least possess a *medium* level of awareness. Note that on the basis of crisply defined awareness levels, as in Section 5.1, this is stated as: the NMC Technician is only at level 1 of awareness with existing artifacts (to be effective he/she should be at level 3). Obviously, the use of linguistic variables such as *minimal* and *medium* results in statements, which are closer to human way of thinking. Also it can be noted that appropriate repositories to support information at this level can achieve the required level of awareness.

3. Change Manager takes up with the affected Users.

- While the User need not be at a higher level of awareness, the Change Manager needs to have an adequate level of awareness through appropriate repositories (non-existent in this case). Users are totally unaware of the overall system

4. Related Users discuss impact and examine the proposed time

- For this interaction to be successful, all Users need to have a reasonably high level of awareness about their own system and requirements. The coordinating User knows a little more than the others. This requires adequate group communication mechanisms and repositories to allow for all Users to interact effectively.

5. User resubmits request to Change Manager with possibly an altered schedule

- Due to the lack of adequate level of knowledge, Users may have taken invalid assumptions. The Change Manager is also unable to help in this situation. This can waste substantial amounts of time for all concerned.

6. Change Manager issues Permit to Work to all concerned

- The lack of awareness on the part of Change Manager may lead to missing some parties concerned with the work. Also some Users may not appreciate the need for responding within the stipulated time. All of this may cause substantial damage to the organization’s interests.

Table 2 summarizes part of the results for some of the required interactions based on the crisply defined awareness levels defined in Section 5.1. This table shows that many of the interactions have a low user satisfaction level due to the gap between the required and actually supported awareness. We observed this result in all of the scenarios. More research is required to check the validity of this point for all types of organizations. However, this illustrates the process of cooperation analysis.

Table 2. Awareness Matrix for the Scenario

Interaction	Awareness Required	Awareness Supported	User Satisfaction level
2	3-2	1-2	3
3	4-1	3-0	3
4	3-3	1-0	3
5	3-4	1-3	3
6	4-3	3-1	2

An alternative way for characterization of the interactions can be based on fuzzy-based definition of the awareness levels as discussed in Section 5.2. 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 [7]. The fuzzy-based characterization results in models that are easy to understand, use, and expand even by non-experts. As an example, Table 3 presents the Awareness matrix displayed in Table 2 using linguistic values. While the two tables convey similar information, the fuzzy-based methodology offers significant benefits. In this case, an obvious advantage is related to simplification of modeling process. It can be noted that several automated approaches for classification of dynamic fuzzy models have been developed [4]. In addition, as the fuzzy systems are rule based, the system designer can focus on the actual design process.

Table 3. Awareness Matrix for the Scenario (Granulated Awareness Levels)

Interaction	Awareness Required	Awareness Supported	User Satisfaction level
2	Medium-Small	Small-Medium	3
3	High-Small	Medium-Minimal	3
4	Medium- Medium	Medium-Minimal	3
5	Medium-High	Small-Medium	3
6	High-Medium	Medium- Small	2

The abstract system design specification for the required system boils down to supporting the required awareness levels for every interaction in an activity. This could be realized by having designing appropriate group repositories, appropriate group communication mechanisms and tools. The technologies to implement them use a combination of GroupWare, workflow, intelligent agents, and a distributed object-computing environment. For the sake of brevity, this paper does not discuss the process of system design.

6 Concluding Remarks

This paper has presented a new methodology for successful development of cooperative service management systems. We showed how the classification and modeling of human roles and analysis of some representative scenarios could lead to identification of gaps in the existing collaborative support tools. The methodology is illustrated by its application in a large telecom organization trouble-ticketing process. Our modeling is based on the use of linguistic variables that are interpreted as the labels of some fuzzy sets. This leads to the application of fuzzy logic approaches resulting in granulation and fuzzy quantization.

Future work will involve more research in the validation of this fuzzy framework in various types of organizational processes. While in this paper fuzzy logic approaches are used for modeling of human roles, work is underway to expand them into other aspects of importance in cooperative service management. For instance, based on available people within the organization at various roles with different ALs for a given task, fuzzy inference can be used to identify the combination of people to achieve an optimum solution. This idea can be extended to many service applications in addition to those in network and systems management.

References

1. D. Benech, „Intelligent agents for system management," Proc. Distributed Systems: Operation and management (1996)
2. S. Benford, J. Bowers, L. Fahlen, J. Mariani and T. Rodden, „Supporting Cooperative Work in Virtual Environments", Computer Journal **37** (1994)
3. G. Blair and T. Rodden, „The Challenges of CSCW for Open Distributed Processing," Proc. 2nd International Conference on Open Distributed Processing (ICODP) (1993)
4. S. G. Cao and N. W. Rees, „Identification of dynamic fuzzy models," Fuzzy Sets and Systems **74** (1995)
5. J. Grudin, „Computer Supported Cooperative Work: History and Focus," IEEE Computer Magazine (1994)
6. D. Johnson, „NOC Internal Integrated Trouble Ticket System Functional Specification Wishlist", Internet RFC 1297 (1992)
7. A. Kruse, E. Schwecke, and J. Heinsohn, Uncertainty and Vagueness in Knowledge Based Systems. New York, NY: Springer-Verlag (1991)
8. L. Lewis and G. Dreo, „Extending Trouble Ticket Systems to Fault Diagnostics," IEEE Network Magazine (1993)

9. E. H. Mamdani, „Application of fuzzy logic to approximate reasoning using linguistic synthesis," IEEE Trans. Computers **26** (1977)
10. C. Muller, P. Veitch, E. H. Magill and D. G. Smith, „Emerging AI techniques for network management," Proc. IEEE GLOBECOM *'95* (1995)
11. N. Nuansri, T. S. Dillon and S. Singh, „An application of neural network and rule-based system for network management," Proc. 30th Hawaii International Conference on System Sciences (1997)
12. T. Olle, J. Hagelstein, I. MacDonald, C. Rolland, H. Sol, F. Assche and A. Verrijn-Stuart, Information Systems Methodologies: A Framework for Understanding. Addison-Wesley (1991)
13. P. Ray, M. Fry and B. Khasnabish, „A Re-Engineering Methodology for the Cooperative Management Of Enterprise Networks," Journal of Network and Systems Management Special Issue on Enterprise Network Management (1999)
14. P. Sachs, „Transforming Work: Collaboration, Learning, and Design," Communications of the ACM **38** (1995)
15. L. A. Zadeh, „Fuzzy sets," Information and Control **8** (1965)
16. L. A. Zadeh, „The role of fuzzy logic in the management of uncertainty in expert systems," Fuzzy Sets and Systems **11** (1983)