MEASURING CONSENSUS AND CONFLICT AMONG STAKEHOLDERS IN EMERGENCY RESPONSE INFORMATION SYSTEM REQUIREMENTS NEGOTIATIONS

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Abstract: This paper introduces the experimental design we developed for the analysis of asynchronous negotiations among five different stakeholders as they work towards consensus on the functional system requirements that are needed for a common emergency response information system. We present three analytical preference models to measure the evolving consensus and conflict among the stakeholders as they modify their preferences during the negotiation. We illustrate the use of these techniques for obtaining a detailed understanding of the negotiation dynamics among the stakeholders.

1. INTRODUCTION

The upstream phases of the software development process have traditionally been focused on face-to-face negotiations to elicit and define software requirements. This phase is critical to the development of quality, useable software systems [2,3,4]. Requirements elicitation and determination is difficult at best for organizations that have common goals and needs. When multiple organizations are involved at different geographic locations, the task becomes more challenging [3]. This research looks at the final phase of software requirements determination for an emergency response information system. Five stakeholders with the assistance of a neutral systems analyst negotiate asynchronously to finalize system requirements. The stakeholders, representatives of several emergency response organizations at the local and state level, understand the importance of having a system that functions as a repository and facilitates response in a rapid, efficient manner. The stakeholders wish to work together asynchronously to find a set of robust requirements for the system. Because these organizations are geographically dispersed and the stakeholders time is valuable, they will negotiate virtually using an electronic bulletin board as their "meeting room". The negotiation scenario lies in agreeing to a series of requirements that will satisfy the stakeholders interests and critical needs while staying within specified monetary constraints. The chosen requirements will then go forward for validation and implementation.

In the following section, we introduce the domain of our research, i.e., emergency response information systems. Section 3 discusses our experimental design, while the analytical preference techniques are introduced and applied in Section 4. We conclude in Section 5 and discuss future research.

2. EMERGENCY RESPONSE INFORMATION SYSTEMS

The domain of this research is emergency response. In this domain, multiple diverse stakeholders must work together effectively and efficiently to ensure critical safety guidelines are met. The development of an information system that can be used on a daily basis during non-emergency activities will ensure the emergency response personnel are familiar with the system and can transition to emergency mode smoothly [6]. Devising a set of generic critical software requirements for an emergency response information system would provide compatibility and facilitate the distribution of common systems throughout state and local organizations, thus saving money, and more importantly, perhaps saving lives.

Many small communities do not have the resources, personnel, nor the expertise to develop a set of requirements to assist them in managing their activities as they pertain to emergency response [4]. This research hopes to contribute to the development and description of a generic set of requirements that could be utilized by state and local jurisdictions. Having a set of common system requirements will be very valuable. These common requirements can assist local community representatives who might not have the resources to do intensive research towards developing an emergency response information system. Capturing event data in an automated system will facilitate effective response in a current emergency and provide traceability for detailed analysis to improve the response of subsequent events.

3. EXPERIMENTAL DESIGN

This research proposes an experiment focusing on the negotiation of requirements by stakeholders who are located in separate locations and cannot meet face to face. Using asynchronous online threaded discussions, stakeholders will negotiate to choose a set of software requirements that satisfy their needs. The stakeholders have monetary restrictions and are provided with a series of preferred ranked requirements to guide them.

A pilot experiment which involved sixty undergraduate computer science or information system students taking an upper level class in systems analysis and design. The students completed this exercise for course credit. After groups of six were randomly assigned, each student was given one of five stakeholder roles to play. The group also chose a program manager/facilitator for their group. Each team member is provided with a role description and a set of requirements that were ranked according to criticality for their role.

The subjects are informed that this first set of requirements were determined by the traditional methods of requirement elicitation such as interviews and site visits. The elicitation was completed in each organization independently without any collaboration between them. As a result of these elicitation methods, the stakeholders each have a list of critical, medium, and low priority requirements they determined with the help of the software development firm. For five days, the stakeholders negotiate asynchronously to choose a set of requirements that would fit their own and the group needs yet stay within the allocated budget. This simulates real world requirements determination as not all needs for all users can be met for any information system. Some of the needs must be placed on a list for future enhancements or omitted altogether. Stakeholders work together and negotiate to find the best set of requirements that will provide needed functionality for all users. Providing a structure to the task and specifying each step in the negotiation process provides a framework for the problem solving activity of determining the final set of requirements. The main objective of this study is to determine if the use of a task structure and specified negotiation sequence enhances the results of asynchronous negotiation towards high quality software requirements.

3.1 Research Motivation

Although global software engineering continues to grow and expand, the study of the most important phase remains mostly under studied [5]: requirements analysis rarely takes place in a distributed mode. In this early phase of the software development process software analysts travel to organizations to interview, observe, and study the current system and users. From this direct communication, which may take several iterations, a specification is written which is shared with the stakeholders [1,3,7,9]. This specification documents the design of the system. Once the specification is completed, work can be disbursed to different parts of the globe for implementation.

Modes of communication within requirements engineering have been studied by several researchers. Ocker et al. provide research on four modes of communication during the development of software requirements [8]. They looked at the effects of different combinations of modes of communication and measured how they related to quality, solution satisfaction, and process satisfaction. The four modes of communication were 1) face to face, 2) synchronous computer conferencing with 2 face to face meetings at the beginning and end of the work phase, 3) asynchronous computer conferencing, and 4) a combined group with face to face and asynchronous computer conferencing. The results of the study showed that the combined group had the highest scores in creativity, quality, and process satisfaction. The combined group also produced better requirements definitions than the groups using other communication modes.

Seldom is there enough time or money to implement all requirements requested by all stakeholders. Little research has been done on the process of selecting and prioritizing among all the possible system requirements to choose a final set that will satisfy the stakeholders needs. The costs associated with having multiple rounds of face to face visits and interviews can be prohibitive. Group discussion in a distributed collaborative environment is an option for resolution of the final priority list. Using technology to assist in this decision making process provides traceability to the process, greatly enhancing the consistency, clarity, and maintainability of the software system [1, 8].

Organizations use a variety of asynchronous tools to facilitate their development process; email is most common, along with asynchronous messaging boards for tracking documentation and for version control. On-line meeting software is a valuable tool for large and small organizations. When employees are travelling, they can keep up to date not only by participating in teleconferences, but can update their work through such technologies which are becoming ubiquitous. The use of these technologies is inherently different than face to face meetings. Nuances such as body language, facial expression, and use of language are all modified or non-existent when using technology to communicate. These non-verbal communication cues are virtually non existent in remote teams [1,5,8]. This can be advantageous, as it brings all participants to the table with equality, which can create more diverse discussions and perhaps more creative solutions to a problem [8]. Employees that are intimidated by others may participate more in an asynchronous mode.

Negotiating conflicting requirements is an important part of the requirements phase of the software engineering life cycle. Many studies have found that clear, consistent, and traceable requirements result in more robust, maintainable software systems [1,3,5,7,8]. In order to provide this quality, consistency, and traceability, conflict management between users, analysts and managers must be facilitated during this important phase of a software system.

Conflict in requirements is usually negotiated after elicitation and problem definition. Mackenzie et al. argue that this problem is better addressed at the earlier elicitation stage [7]. They propose the use of a two stage software system and process called the "wisdom process-tool" which uses cognitive mapping and design rationale techniques to prompt stakeholders to engage in negotiations

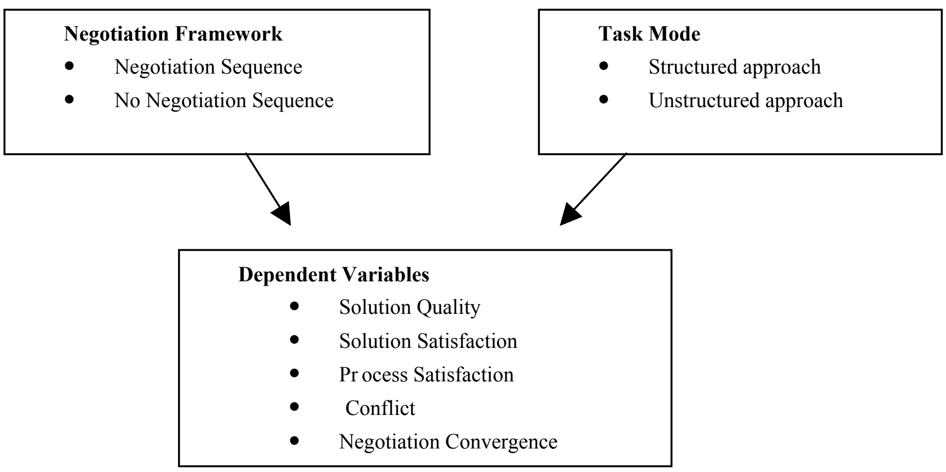

Figure 1. Conceptual experimental model

prior to the problem definition phase. The two stage process would start with an asynchronous component where preliminary issues are elicited and finish with a co-located meeting where cognitive maps are used to finalize requirements.

A study of requirements negotiation and renegotiation is described by Boehm and colleagues [3]. Using a collaborative model of software development, called the Theory-W Based Spiral approach, these authors recommend an evolutionary approach to stakeholder collaboration and negotiation to obtain software requirements that would satisfy each stakeholders "win" conditions, which means those conditions that are of particular interest to that stakeholder. This model was developed to help software engineers accommodate the changing requirements that often occurs in the early stages of the software development process.

The use of computer-mediated requirements negotiations enhance and enrich the contribution of geographically separated stakeholders, enabling important participants to have a contribution above and beyond the face to face requirement fact finding meetings.

3.2 Conceptual model

This study is designed to measure the effect of negotiation sequence and task structure on group outcome factors when negotiating in an asynchronous mode. The conceptual model of this study is shown in Figure 1. The variables are measured using post task questionnaires, expert judges, and analysis of subject generated documentation. Outcome factors to be measured are solution quality, solution satisfaction, process satisfaction, conflict, and negotiation convergence. The analysis of negotiation convergence outcomes is discussed in the following section.

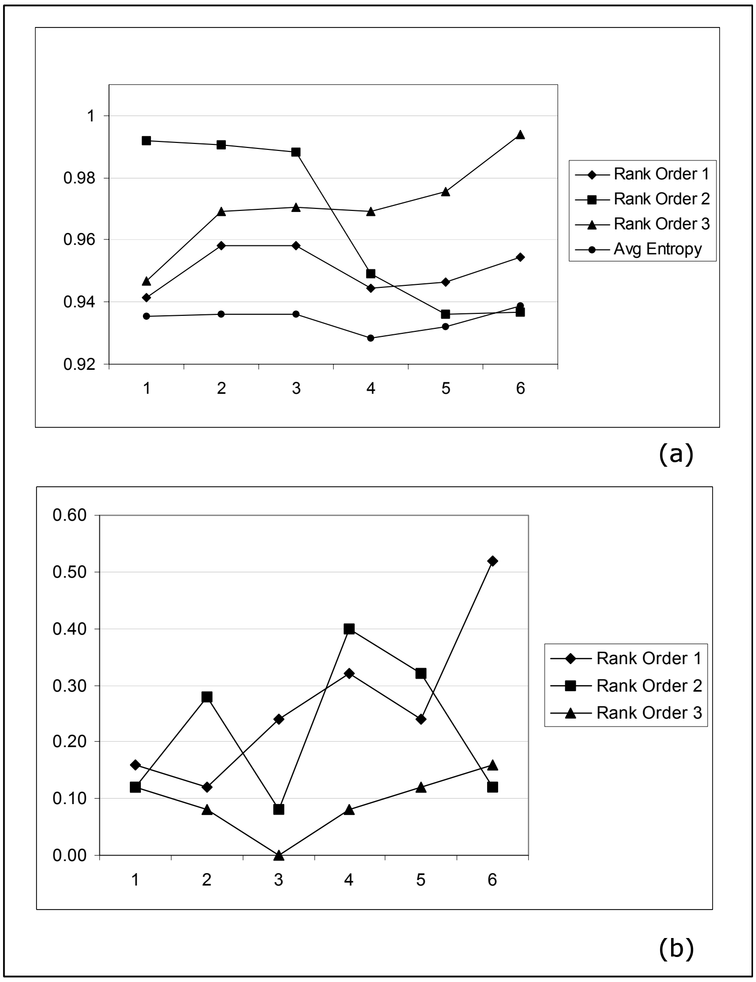

Figure 2 Rank Order Entropy (a) and Choice Agreement (b) evolution.

4. MEASURES OF CONSENSUS

Through the post-experiment questionnaires, we are able to collect qualitative data on the (perceived) conflict in the groups during the negotiation. In this section, we introduce analytical techniques which allow us to complement the qualitative analysis. Our concern here is to obtain an as detailed understanding as possible of the dynamics of the requirement preferences and rank order choices made by the individual stakeholders during the negotiation. We illustrate the application of three different analytical techniques: an approach based on an information entropy measure, a model for choice agreement and a fuzzy relational analysis method. In all three cases, we are concerned with the rank orders defined by the different stakeholders. For practical reasons, we will limit ourselves to the first, second and third rank order only.

4.1 Rank order entropy and choice agreement

The first model we apply to the analysis of the rank order information is Zeleny's entropy model for multi-criteria decision making [15]. In essence, Zeleny argues that the importance of a criterion is a function of the amount of information this criterion carries about the different decision alternatives; the most important criterion is the one that has the most 'discriminating' or different values of the alternatives. To define the discriminating power of a criterion, Zeleny makes use of Shannon's information entropy measure [10]. To apply Zeleny's model, we formally 'transform' our rank order information into a multi-criteria model as follows: the stakeholders can be viewed as the decision alternatives (implying that we have five alternatives), and the criteria as the different rank orders, from 1 to 15. We can now measure the entropy of every rank order with respect to the different stakeholders. The higher the entropy of rank order, the more the scores on that rank order are similar (the less discriminating), or the more the different stakeholders agree on that rank order. Figure 2a shows the daily evolution of the entropy for the stakeholders of Group 303 for rank orders 1, 2 and 3, and the average entropy over all alternatives. In this case, there is a higher than average agreement on the top three rank orders among the stakeholders. The entropy for the highest rank order first increases but then decreases again, while rank order 2 (resp. 3) decreases (resp. increases) continuously.

Our second technique is based on Whitworth's agreement model, which focuses on choice agreement among individuals when they have to choose one alternative among many [14]. In contrast to the cardinal entropy model above, Whitworth defines two measures of choice agreement: an individual and group agreement. The group agreement is the average individual agreement in the group, with the individual agreement defined as the

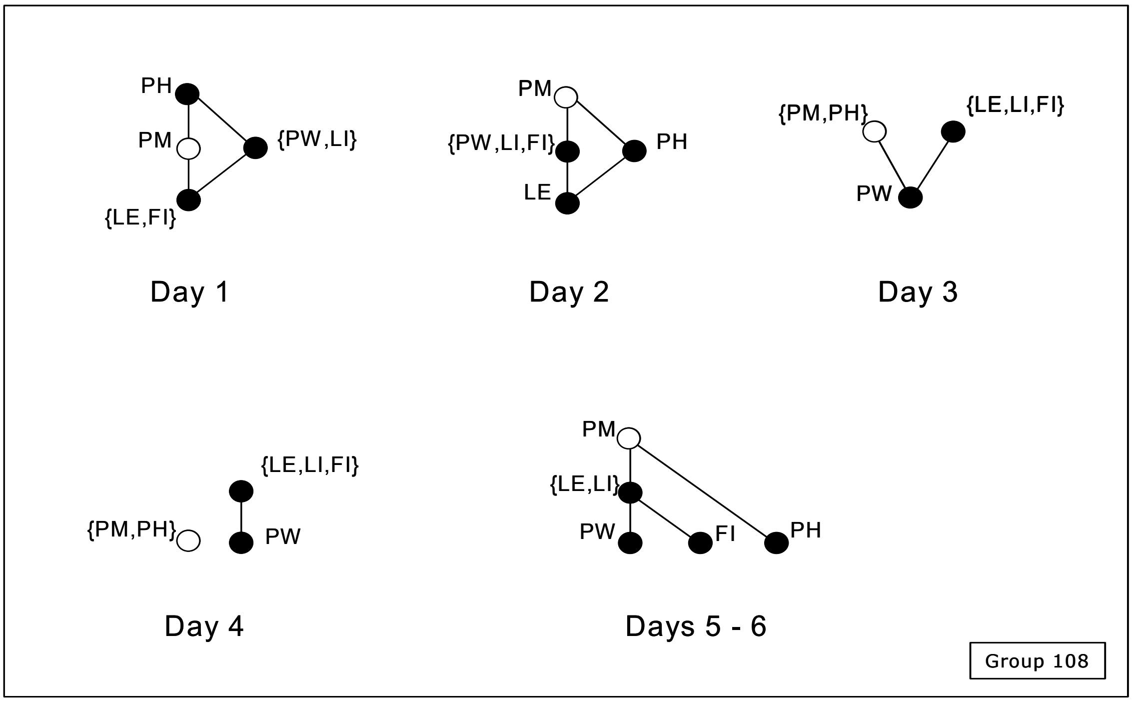

Figure 3 Relative position of the stakeholders to final consensus per day.

relative frequency with which a member's particular choice is made in the group. For instance, when all group members choose the same alternative, the individual agreement of every group member is 1, and hence so is the group agreement. Figure 2b shows the daily evolution of the group agreement for Group 303 for rank orders 1, 2 and 3. Group agreement for any rank order never exceeds 0.5, which implies that at no time more than half of the group agree on the alternative that should be ranked first, second or third. In this group, there is most agreement on the highest rank order at the end of the negotiation.

4.2 Rank order consensus

Another technique based on the interpretation of the rank order values as fuzzy relations allows us to visualize the relative position of the different stakeholders with respect to the group's consensus [13]. The diagrams in Figure 3 show the daily position of the stakeholders relative to the final group consensus on the top 3 rank orders at the end of the negotiations. The lower position a node has in the diagram, the closer the corresponding stakeholder is in agreement with the consensus. In addition to the Public Health (PH), Public Works (PW), Fire Department (FI), Law Enforcement (LE) and Liaison (LI), the diagram also shows the relative position of the Project Manager (PM). It is noteworthy that the PM in this group agrees least with the consensus that is reached in the group throughout the negotiation (in which he does not participate). Stakeholder PW is from day 3 onwards closest to the consensus; LE and FI seem to move away from consensus during the negotiation.

5. CONCLUSIONS

Requirements engineers and stakeholders commonly meet to determine the list of possible requirements for the proposed system. Seldom is there enough time or money to implement all requirements requested by the stakeholders. Little research has been done on the process of selecting and prioritizing among all the possible valid system requirements to choose a final set that will satisfy the stakeholders' needs. The techniques we have introduced in this paper allow us to gain a detailed understanding of the evolution of preferences during the negotiation process and its convergence to consensus.

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