A multidisciplinary approach to the study of distributed requirements negotiation

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Abstract

This paper addresses requirements conflicts, their resolution through negotiation and the investigation of such processes in distributed communication settings. It proposes a multi-disciplinary research approach to the study of distributed requirements negotiation. This approach builds on 'best practice' models in the research fields of requirements engineering, soft systems methodologies, study of groups with technology, negotiation behavior, group interaction analysis, and behavioral and social sciences. Preliminary results of the implementation of this approach are presented and future work is discussed.

1. Introduction

Although a relatively new field in software engineering, requirements engineering has become of increasing interest for both academics and practitioners as one of the most important, but difficult and problematic phases of software development. Numerous models of requirements processes have been proposed, and problems associated with it have been documented, but the software engineering profession is still in the process of establishing an understanding of what is involved in developing requirements.

Requirements engineering is, in essence, an ongoing process, characterized by technical, social, organizational and political issues, during which stakeholders define, understand, and most often negotiate requirements. Requirements conflicts and their negotiation as conflict resolution have become a fact of life in software development. Furthermore, the reality of distributed software development in recent years has brought about new issues that need to be addressed in requirements negotiation.

This paper proposes a multi-disciplinary approach to the study of distributed requirements negotiation. It describes the research questions and the different research fields that contribute to the development of a methodology for the study of distributed groups negotiating requirements. Section 2 discusses conflict and the role that good communication channels play in effective conflict management in Requirements Engineering. Section 3 introduces the challenges of distributed requirements negotiation and the need for empirical studies of different communication media in requirements engineering. Section 4 presents a multi-disciplinary research approach to the study of distributed requirements negotiation while section 5 briefly introduces the first stage of its implementation, a laboratory experiment. A short discussion of the laboratory findings and future investigations conclude the paper.

2. Conflict and negotiation in requirements engineering

As the elicitation and negotiation of requirements has come to be seen as a fundamental component of the software engineering processes, it has also been noted that requirements engineering is dominated by human, psychological, social and organizational factors [Goguen, 1994]. Requirements engineering is essentially a multi-disciplinary, human-centered process [Nuseibeh and Easterbrook, 2000] and requirements conflicts represent one of the biggest problems in requirements engineering. The central activity surrounding requirements becomes their negotiation [Lawrence and Gause, 2000]

Research in requirements engineering in the last decade reveals a number of sources of conflict. They include conflict between stakeholders' perceptions of the problem, conflict between the many goals of a design, conflict between suggested solution components, conflicts between stated constraints, and conflicts in resource usage [Easterbook, 1994].

In fact, occurrence of conflict is inevitable in any collaborative enterprise [Wastell, 1993]. The inherent differences between individuals' experiences, personalities and commitments make the potential for conflict inherent to any group of people. In system design, system stakeholders have their own agenda of what work needs to be done, how to divide the work, what tools to use, and how the computer system should support their work role. The system design becomes a "pluralistic, conflict-laden process", part of a complex social phenomenon [Wastell, 1993].

Although the presence of conflict and the need for negotiation of requirements has been noted as early as '77 [Ross and Schoman 1977], conflict has been regarded as destructive for a long time, and many models in software engineering either disregard its presence or concentrate on its elimination and avoidance. The study of Curtis and colleagues [Curtis, Krasner and Iscoe, 1988] pioneers a decade of research that regards conflict as productive, following Deutsch's [Deutsch, 1973] suggestion that the confrontation of divergent views can in fact produce new perspectives and more comprehensive views, leading to superior decisions. Consequently conflict was regarded as beneficial to a 'more complete' system analysis and design.

However, not many other approaches to requirements negotiation can be found in the literature, a fact that underscores the need for more studies of conflict, and of the negotiation through which they get resolved. Easterbrook [Easterbook, 1994] proposes a model and the Synoptic system for the analysis and integration of conflicting domain descriptions. The model draws on concepts from organizational behavior theory and attempts to focus more on the socio-organizational perspective of conflict. Robinson [Robinson, 1990] proposes formal models of users' desires and resolution methods, and develops automated means to promote integrative behavior during requirements specification. The design tool Oz uses integrative reasoning, which is an abstraction of integrative negotiation behavior. Boehm and his colleagues [Boehm, Rose, Horowitz and Lee 1994] develop the WinWin system, which uses the WinWin spiral process model in aiding negotiation processes during specifications. Empirical evidence on the use of WinWin has been reported. The strongest positive aspects of using the WinWin approach and system were: increasing cooperativeness, focusing participants on key issues, reducing friction and facilitating distributed collaboration. However, it was also found that the WinWin tool did not completely replace other methods of interaction and other negotiation aids were also used: while the use of WinWin tool accounted for 28% of the negotiation time, the usage of face-to-face meetings and telephone conversations accounted for 42% and 19% respectively. This fact emphasizes the need for further research in requirements engineering that investigates the use of systems that support the remaining types of communication.

2.1 Good communication: essential in dealing with conflict in requirements engineering

The consideration of the communication medium as a factor in the effectiveness of systems to support requirements negotiation is important since evidence exists that effective conflict management in requirements engineering requires effective communication with and among the system users. Curtis and colleagues [Curtis, Krasner and Iscoe, 1988] identify conflicting requirements and breakdowns in communication and coordination as two of the three major problem areas in software engineering, stressing that a good approach to conflict resolution should emphasize communication between interest

parties. Case studies [Macaulay, 1996] show that problems often occur not only from an under-consideration of the social and organizational settings, but also from failure of customers and suppliers to communicate effectively. Macaulay emphasizes that appropriate human communication mechanisms need to be established as part of the requirements process. If different interest groups do not communicate effectively with each other, each will see the other as attempting to exert power and influence unreasonably.

Face-to-face formal meetings and discussions are highly used in software projects. Group session approaches to requirements engineering such as JAD (Joint Application Design) [Wood and Silver, 1995] have become proven techniques in achieving effective decision-making. They build work groups for the task at hand and are driven by the premise that high quality decisions can be achieved when 'the right people' are in the same meeting room. They typically involve client representatives such as executive sponsor, key user representatives and designer representatives.

Case studies [Al-Rawas and Easterbrook, 1996] reveal that group meetings account for 65% of the communication channels in requirements engineering, in spite of the finding that organizational and social issues have a great influence on the effectiveness of communication activities. These aspects inhibit communication among development teams throughout the development process: not only the selection of client representatives is affected by organizational power but also the effectiveness of face-to-face meetings is as high as the ability to mediate the dominance by some members of the group. The role of the facilitator is regarded as critical in managing effective face-to-face requirements meetings [Macaulay, 1996]. While technical approaches to requirements engineering are largely concerned with formal processes for describing, representing and analyzing requirements, the human processes leading to these requirements are underinvestigated, and the issues of conflict and cooperation among participants in the requirements process have not been widely studied to the extent merited by their practical importance.

Thus direct communication modalities and any investigations of such modalities must address interpersonal dynamics and idiosyncratic differences that can get in the way of developing a complete, accurate understanding of the customer problem and potential solutions.

3. Distributed Requirements negotiation

The situation becomes more complicated in recent years as organizations move towards more globally distributed structures. A distinctive feature of requirements engineering when compared to other phases of software development is that the stakeholders belong to more than one business units, across the customer and supplier organizations. In this case, releasing relevant participants to attend meetings at remote sites has become problematic. Case studies [Al-Rawas and Easterbrook, 1996] reveal that when it comes to selecting participants for requirements engineering meetings, mangers try to strike a balance between allowing the software practitioners to talk to 'the right people' and maintaining the smooth running of the rest of the business. Such selections based on criteria other than those of requirements knowledge can undermine the entire requirements development process. It is critical that the key participants in requirements meetings play the proper roles in developing requirements regardless of their location.

Fortunately, advancements in communication technology have brought about the concept of virtual teams and a redefinition of the traditional meaning of *meetings* in distributed collaborations in software engineering. Groups no longer have to meet in the same location as new meeting technologies (group support systems) allow the relaxation of the constraints of co-location. Asynchronous forms of electronic communication such as email and bulletin boards are described as potentially helpful for requirements engineering [Sommerville and Sawyer, 1997]. Furthermore, they bring advantages to the communication of requirements, which were not thought of in traditional meetings: personality factors are less important in electronic discussions than in face-to-face, and strong personalities cannot impose their views on the requirements.

Although these advancements in computer-mediated communication make it potentially easier for the appropriate people to participate in the requirements negotiation process, studies of groups with technology provide mixed empirical evidence. On the one hand, some literature on the role of media in

human communication processes has questioned the suitability of such ‘impoverished’ media to support human negotiations [Short et al 1976, Daft and Lengel 1984]. It is then reasonable to be concerned that the difficulties of requirements engineering might be exacerbated when face-to-face communication is replaced by computer-mediated communication. On the other hand, more recent evidence [Walther 1996] exists on the beneficial effects of the less emotional computer-mediated communication (CMC). Despite the tendency of the main theories in the field to regard the less socially oriented communication as alterations of human communication, decreased personalization in CMC has the simple effect of leaving greater proportion of a group's work time for its instrumental task. In negotiation situations, as socioemotional concerns such as conflict or relationship management take time and effort away from task resolution, any mechanism that reduces the need to expend effort in these directions should enhance the efficiency of group's effort.

The requirements engineering community however is lacking an understanding of real-time requirements negotiation meetings at a distance and, in particular, insights into any changes that technology may bring to the group performance and behavior. From a socio-psychological perspective it is important to investigate the group's task vs. emotionally oriented behavior, in particular whether stakeholders with different (conflicting) requirements manage conflict differently when physically separated or co-located. This emphasizes the need for empirical investigations to understand the opportunities and constraints that multimedia meeting systems bring to the field of synchronous distributed requirements negotiations. Requirements engineering needs systematic methods for the study of the social and psychological significance of communication technology in requirements negotiation.

The remaining of the paper presents a multi-disciplinary research approach that uses empirical methods in the study of group work in distributed requirements negotiation.

4. A multidisciplinary research framework

The development of this framework was guided by research questions such as: What is conflict in requirements engineering? Who are the actors in conflict? What is the context in which conflict develops? What type of negotiation behavior is relevant to investigate in requirements engineering? What is the evidence on groups with technology? How to investigate the group's task vs. emotionally oriented behavior? What are the available empirical methods of behavioral sciences for the study of group work in distributed requirements negotiation?

The framework (**Figure 1**) builds upon the areas of study of requirements engineering, soft systems methodologies, study of groups with technology, negotiation behavior, group interaction analysis, and behavioral and social sciences. 'Best practice' models from these research fields provide frameworks useful in addressing these research questions.

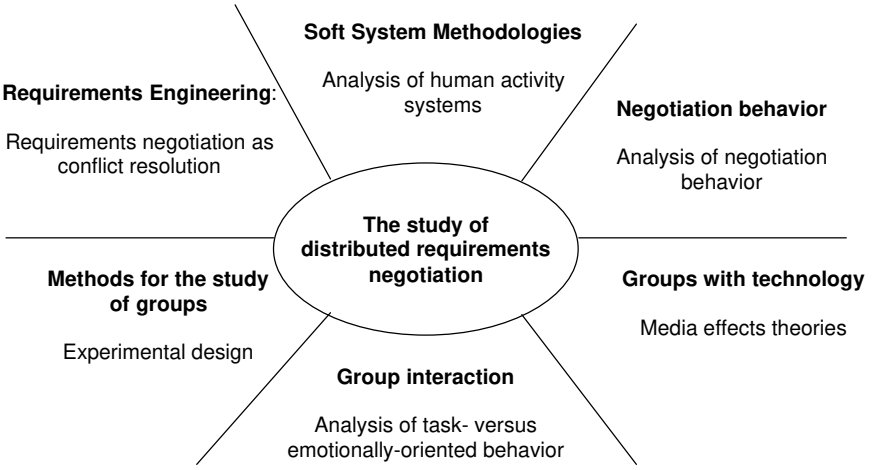

Figure 1. A multi-disciplinary research framework: 'best practice' models from literature

Each of the research questions outlined above is presented next together with a brief description of the contributions brought by these research fields.

4.1 Requirements Engineering

Q: What is conflict in requirements engineering?

Requirements represent the interests of a wide range of stakeholders of the system. This makes them to be nearly always in conflict and a critical aspect of managing requirements is making tradeoffs among them [Lawrence and Gause, 2000]

Part of the problem in dealing with conflict however is that conflict is not easy to define although examples of it exist in the literature. Easterbrook [Easterbook, 1994] defines conflict as arising because of differences between the goals and desires of participants in the system development process and discusses the case of cognitive conflicts in the design of a library system where two librarians have different views of the library. Robinson [Robinson, 1990] gives an example of user involvement and resistance in defining requirements for a university admission system. The analyst and the system user negotiate the requirements for the system; at issue is the amount of computer time in which the system user must engage. While the analyst supports typical goals of an automated filing system, the user desires to work away from a computer at a variety of tasks. Perceiving the specified system as conflicting with her objectives, the user negotiates for a card file that would complement the automated system.

Conflicts between stated constraints are another source of compromises in requirements engineering. A major constraint that is difficult to manage is that of project cost, that brings the need to fit the requirements within the project cost [Gabb, 2000][Hooks, 2000].

4.2 Soft System Methodologies

Q: Who are the actors in conflict? What is the context in which conflict develops?

It is important that requirements engineering considers organizational issues such as stakeholders' work roles, power structures, obligations and responsibilities. Soft System Methodology (SSM) [Checkland, 1999] is particularly relevant in addressing organizational requirements, in identifying the roles and expertise involved in the system definition. SSM is a framework for the analysis of systems with human and social components, and has been widely applied to difficult problem areas (Wilson, 1984). It is developed to tackle 'soft', ill-defined situations in *human activity systems*, which are "generally describing humans undertaking purposeful activity such as man-machine systems, industrial activity, political systems" (Wilson 1984, pg. 25), and with the aspect of multiple perceptions that are possible and legitimate in human activity systems. As the context in which requirements engineering takes place is usually a human activity system, and the problem owners are people [Nuseibeh and Easterbrook, 2000], SSM is particularly useful in analyzing what people and *roles* are involved in the system and how they perceive and understand the world around them.

4.3 Negotiation behavior

Q: What negotiation behavior is relevant to investigate in requirements engineering?

Negotiation is defined as a method of decision making when two or more parties' interests are opposed. Opposed interests means that the parties' differing needs lead them to incompatible preferences among the alternatives under consideration.

Negotiation behavior models have been developed [Pruitt, 1981] both for distributive and integrative negotiation. Distributive behavior reflects the situation "your loss is my gain" and typically involves only one issue. A situation in which multiple issues are considered at the same time and it is possible for all parties to gain from varying values of issues is characterized as integrative bargaining [Pruitt 1981]. It consists of incorporation of opposing proposals, communication of goals and constraints, as well as searching through extreme alternatives and multiple issues.

Requirements engineering is an area that benefits from the study of integrative negotiation, since group session approaches [Macaulay 1996] strive to ensure that the views of all stakeholders are

considered and to achieve a mutual agreement of requirements and their priority in system development. Different stakeholders may assign a different priority to the same requirement, based on the goals they strive for in system's operational environment. This may reflect real needs, different stakeholder perceptions or divergent interests. Negotiating requirement priority classifications such as 'essential', 'useful' or 'desirable' may involve compromises [Sommerville and Sawyer 1997] buy may help find creative ways to reconcile different goals and provide greater joint benefits.

4.4 Groups with technology

Q: What is the evidence on groups with technology?

The study of groups has been the interest of social psychologists for a long time, as groups are believed to exhibit performances that their individual members, acting alone, might never manifest. This fueled the continued interest in groups as potential for improving task performance. Furthermore, a large body of research has been dedicated to the design of group support systems to improve group task performance.

Although the literature on computer-supported cooperative work is rich in theoretical and empirical research regarding the design and use of group support systems, much of this work has been about computers in groups from a technological development perspective. However, we are still building an understanding of phenomena in groups with computers [McGrath, 1984]. The latter approach emphasizes, from a group perspective, the effects that technology has on the behavior of groups, on ways in which groups adapt and use technology. The contributions of McGrath and colleagues [McGrath and Hollingshead, 1994] provide a framework of theoretical approaches to the study of groups with technology and empirical evidence of impacts of technology on group work. For instance, media effects theories that dominated the research in this field such as Social presence theory [Short, Williams and Christie, 1976] and Media richness theory [Daft and Lengel 1984] have been developed and focus on matching group performance with the communication medium. They deal with how the potential amount and content of communication differs for various communication media and discuss the favorable and adverse effects of restrictions of communication modalities on the work of groups. Later contributions [McGrath and Hollingshead, 1994] propose a task-media fit where communication media are arranged in decreasing order of effectiveness for negotiation situations: face-to-face meetings, video systems, audio systems and computer (text-based) systems. Negotiation situations and interpersonal relationships are considered the primary testing grounds for media effects on group work.

These theories of media effects provide both a framework for formulating hypotheses in the study of media effects in requirements negotiation and the conceptual domain from which we draw ideas that seem likely to give meaning to our results

4.5 Group interaction

Q: How to investigate the group's task vs. emotionally oriented behavior?

Group interaction process is at the heart of models for the study of groups [McGrath, 1984]. Understanding the interaction of group members is considered an important step in studying and getting insights into groups as task performance systems. In this direction, the observation and analysis of the dynamics of group interaction have been the topic of researchers over the last forty years. Two fundamental processes that underlie the interaction of problem solving groups -- task-oriented and socio-emotionally oriented processes -- represent a common theme among major theories of group dynamics (e.g. [Bales and Cohen, 1979]). Investigating these processes in distributed requirements negotiation complements the evidence on group performance and allows the researcher to seek an understanding of ways that the media effects on group interaction processes may influence the effects on the task-related outcomes. SYMLOG methodology [Bales and Cohen, 1979] provides not only a framework for the observation, coding and analysis of group dynamics but also models for the graphical representation of groups' task-oriented and socio-emotionally oriented processes.

4.6 Methods for the study of groups

Q: What are the available empirical methods of behavioral sciences for the study of group work in distributed requirements negotiation?

McGrath's [McGrath, 1984] research method circumplex (figure 2) provides a framework for the classification of methods in behavioral sciences. Each method is regarded as offering potential opportunities not available by other means, but also as having inherent limitations. Although the goal is to maximize three criteria:

a. *generalizability* of the evidence over the populations of actors,
b. *precision* of measurement of the behaviors that are being studied,
c. *realism* of the situation or context within which the evidence is gathered,

this is, in principle, not possible: any one method is limited in what it can achieve. Figure 2 shows where each of the desired features is at its maximum.

Thus the central theme at the strategic level is that all methods represent opportunities for the study of groups but all have limitations, that different flaws of various methods can be offset by the strengths of other methods. The use of multiple methods, *triangulation*, becomes an essential requirement in optimizing research effectiveness. It is about using more than one method in gaining confidence that the study results have to do with the phenomena under study and not just with the methods used.

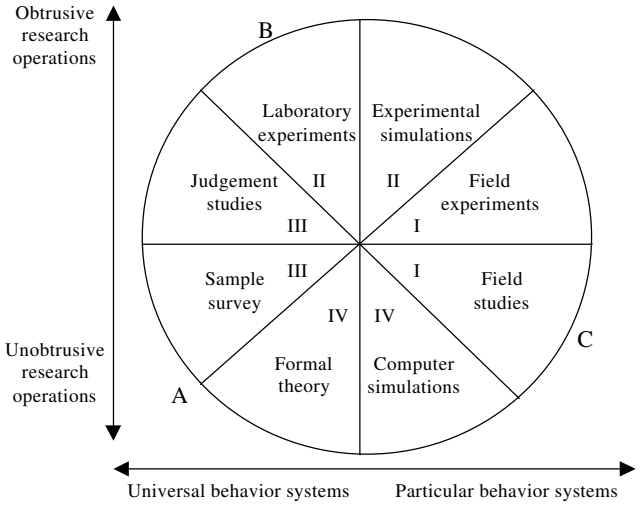

Figure 2. **Research strategies in behavioral and social sciences** [McGrath 1984]

Among these methods, the method of laboratory experiments has been the most commonly used in investigating the effects of media on negotiations along the years. Although it has been criticized for losing in realism by investigating the phenomenon in the laboratory and not in real settings, there is a good reason for favoring laboratory experiments over other methods such as field studies for instance [McGrath, 1984]: conflict management and negotiation situations are recognized as complex human tasks and careful observation of their intimate details is often inaccessible in field settings. Experimental methods (a) make possible the careful observation and precise manipulation of independent variables (e.g. communication technology), allowing for greater certainty with respect to cause and effect, while holding constant other variables that would normally be associated with it in field settings, and (b) encouraging the researcher to try out novel conditions and strategies in a safe and exploratory environment before implementing them in the real world.

In the study of distributed requirements negotiation an experimental research strategy that investigates group performance and behavior in a laboratory experiment followed by a field experiment in the software industry enables the researcher to obtain not only the precision of measurement and control of related variables, but also a validation of laboratory findings in settings with a greater realism of context.

5. Preliminary results

This multi-disciplinary approach is currently being implemented in the investigation of distributed requirements negotiation. The first author was the principal investigator of the first part of the study, namely the laboratory experiment of which design and results are briefly mentioned here.

The laboratory experiment compared the group performance and interpersonal relationships in requirements negotiation in face-to-face meetings versus distributed settings with advanced multimedia meeting systems. The communication equipment in the distributed settings was a combination of videoconferencing and computer support. The study tested the hypothesis that the group performance in computer-mediated settings could lead to at least as good performance as in face-to-face negotiation.

The laboratory task addressed the conflict between the requirements scope and the available software development resources. The roles played by study participants were of system users and system analyst, in groups of three, mediated by one professional facilitator. The task was a requirements negotiation with integrative potential; both win-win and win-lose resolutions were possible in the task. Instruments were designed to assess the group performance (decision quality) and interpersonal relationships, negotiation models were used in gaining an understanding of the requirements negotiation behavior, and task and social-emotional behavior was observed in the interaction of all experimental groups.

Contrary to the belief that face-to-face contact increases performance, the laboratory findings suggest that groups in face-to-face meetings performed no better than the electronically mediated groups. Moreover, a particular distributed group configuration was identified that significantly improved performance across in the study and was qualitatively more conducive to requirements negotiation than face-to-face meetings. The results suggest that the electronic mediation reduced the transmission of socio-emotional cues in the interaction, thus enabling groups to have a more rational approach to conflict resolution in requirements engineering. More detailed information on the study design and results can be found in [Damian, Eberlein, Shaw and Gaines, 2000] and at http://sern.ucalgary.ca/~danah/PhD/RE_study/Group_performance.html.

6. Conclusions

This paper presented a multi-disciplinary research approach to the study of distributed requirements negotiation, approach that built on the best practice models in research fields of requirements engineering, soft systems methodologies, study of groups with technology, negotiation behavior, group interaction analysis, behavioral and social sciences. Multiple research methods from the study of groups were proposed in investigating a complex phenomenon and the findings of a laboratory experiment were briefly discussed. While these findings indicate possible effects of different communication media use in requirements negotiation, more research is needed to confirm the laboratory results. Future work includes, as the research approach prescribed in this paper, carrying out a similar but less controlled investigation in the field, to see whether there is sufficient continuity between laboratory and field setting to which we wish to generalize for a particular effect to be found in both arenas.

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8. References

Al-Rawas, A. and Easterbrook, S. (1996). Communication problems in requirements engineering: a field study, Proceedings of the First Westminster Conference on Professional Awareness in Software Engineering, London

Bales, R.F. and Cohen, S.P.(1979): SYMLOG; A Systems for the Multiple Level Observation of Groups, Collier Macmillan

Boehm, B., Rose, P., Horowitz and Lee, M.J. (1994): Software requirements negotiation and renegotiation aids: a theory-W based spiral approach, ICSE 95.

Chapanis, A. (1975): Interactive human communication, Scientific American, 232(2), 36-42

Checkland, P. (1999): Systems Thinking, Systems Practice, Wiley

Curtis, B., Krasner, H and Iscoe, N. (1988). A field study of the software design process for large systems, Comm. of the ACM, 31(11), pp. 1268-1287

Daft, R.L. and Lengel, R.K. (1984). Information richness: a new approach to managerial information processing and organizational design, Research in Organizational Behavior, 6, 191-234

Damian, E.H.D., Eberlein, A., Shaw, M.L.G. and Gaines, B.R. (2000): The effects of communication media on group performance in requirements engineering, IEEE Software, May

Deutsch, M. (1973): The Resolution of Conflict, Yale University Press

Easterbrook, S. (1994): Resolving requirements conflicts with computer-supported negotiation, in Jirotka, M. and Goguen, J. (Eds.), Requirements Engineering: Social and Technical Issues, Academic Press

Gabb, A. (2000): Comment on the Software Requirements Engineering mailing list, [SRE: 2127]

Goguen, J.A. (1994): Requirements engineering as the reconciliation of social and technical issues, in Jirotka, M. and Goguen, J. (Eds.): Requirements Engineering social and technical issues, Academic Press, pp. 165-200

Hooks, I. (2000): Comment on the Software Requirements Engineering mailing list, [SRE: 2127]

Lawrence, B. and Gause, D. (2000). Personal communication at ICRE2000.

Macaulay, L. (1996): Requirements Engineering, Springer-Verlag

McGrath, J.E. (1984): Groups: Interaction and Performance, Prentice Hall

McGrath, J.E. (1995): Methodology matters: doing research in the behavioral and social sciences, in Readings in Human-Computer Interaction: toward the year 2000, Morgan Kaufmann

McGrath, J.E. and Hollingshead, A. B. (1994) Groups interacting with technology: ideas, evidence, issues and an agenda, Sage

Nuseibeh, B. and Easterbrook, S. (2000): Requirements engineering: a roadmap, Proceedings of ICSE2000

Pruitt, D. (1981). Negotiation Behavior, Academic Press

Robinson W. N. (1990). Negotiation behavior during requirement specification, Proceedings of the 12th International Conference on Software Engineering, IEEE Computer Society Press, Nice, France, pp. 268-276

Ross, D. and Schoman, R. (1977): Structured analysis for requirements definition, IEEE Trans. on Software Engineering, January, pp. 6-15

Short, J., Williams, E. and Christie, B. (1976). The Social Psychology of Telecommunications. Wiley

Sommerville, I. and Sawyer, P. (1997): Requirements Engineering: A Good Practice, Wiley

Walther, J.B. (1996). Computer-mediated communication: impersonal, interpersonal, and hyperpersonal interaction, Communication research, 23(1), 3-43

Wastell, D.G. (1993): The social dynamics of systems development: conflict, change and organizational politics. In S.M. Easterbrook (Ed.), CSCW: Cooperation or Conflict?, Springer-Verlag

Wilson, B. (1991): Systems: Concepts, Methodologies and Applications, 2nd Ed., Wiley

Wood, J. and Silver, D. (1995): Joint Application Development, Wiley, 2nd Ed.