DOCTOR OF PHILOSOPHY

An Agenda based Multi Issue Negotiation Model

Abedin, Fahmida

Award date:
2014

Awarding institution:
Coventry University

An Agenda based Multi Issue Negotiation Model

By

Fahmida Abedin

January, 2014

Coventry University

An Agenda based Multi Issue Negotiation Model

By

Fahmida Abedin

January, 2014

A thesis submitted in partial fulfilment of the University's requirements for the Degree of Doctor of Philosophy

Acknowledgements

I would like to take this opportunity to thank all of the people who have supported me throughout this research. First to all, I wish to thank my PhD director, Professor Kuo Ming Chao who introduced me in the research field, and who has always provided his knowledge, experience, guidance and precious comments over these years. I also acknowledge my supervisor, Dr. Nick Godwin who has always helped me in all the steps that lead to this thesis. I gratefully thank him for sharing his knowledge, for his patient guidance and valuable suggestions to improve the quality of my papers, as well as this thesis. Without their constant help this work would not been possible. I am grateful for the opportunity to work with them. I would like to thank Dr. Rachid Anane for his valuable advice on the research.

I must express my gratitude and admiration to my parents, Dr. Zainal Abedin and Kaniz Fatema for their moral support. They have always been there to encourage and inspire me. I would also like to thank my brothers Fakhrul Abedin, Imrul Abedin, niece Fariha and all my close friends who have always provided me assistance. Special thanks to my sister-in-law Khaleda Jannat, mother-in-law Naznin Begum and father-in-law Mobarak Ali for their unconditional support. Finally, I want to thank my dear husband Rezwan Ahsan who has encouraged me during the period of this research and always believed that I could achieve those goals that seemed impossible to me.

Abstract

In multi-issue automated negotiation, group of agents may have different preferences and expectations on different issues. To reach an optimal negotiation outcome efficiently and effectively among a group of agents by considering their different preferences is a challenging problem in multi-issue automated negotiation. Negotiation convergence is a crucial part of the multi-issue automated negotiation process. To improve the negotiation convergence process and to minimise multi-issue negotiation complexity an agenda based approach is proposed to build a new negotiation model. The agenda based model investigates the significance of the choice of the sequence in issue-by-issue negotiation and also analyses the appropriateness of applying a preference ordering technique to generate the choice of sequence of issues. This model improves an agent's utility by providing efficient convergence and an effective equilibrium outcome. The main motivation is to construct a new model which is symmetric and Pareto-optimal. The proposed automated negotiation approach deals with multiple issues in such a way that it helps to balance the efficiency and effectiveness of the outcome.

The negotiation is an interactive and decision making process by which a joint consensus decision is made by two or more parties. An agenda based negotiation approach is proposed where agents are led to cooperate in order to achieve a global goal while trying to satisfy as best as possible individual preferences and objectives. In this model multiple agents have their own decision measure to evaluate an offer related with both independent and sequentially interlinked multiple issues. This proposed approach shows how an issue-by-issue agenda based negotiation affects the negotiation outcome and makes it easy for the agents to find a common zone. The impact of the agenda procedure along with the strategy on the outcome is illustrated by a case study. The agent's preference order is used as a base case for providing the optimal agenda-procedure combination.

In a multi-issue negotiation process, it is difficult to reach an optimal outcome when the group of agents' preferences and the relative importance of the issues are not known to each other. This research investigates the multi-issue fuzzy group decision making problem where preference information on issues associated with services or products is expressed in different formats by the agents. A fuzzy preference concept is used to order the issues in the pre-negotiation stage to improve the efficiency of the outcome. A dynamic and iterative group consensus process is developed to support the preference ordering process. Furthermore, the preferences of the decision-making agents are constructed using a multi-issue methodology allowing the agents' to take into account the preference ordering that can be used in the negotiation process, in order to help in quickening the search of a consensus between the agents. Therefore, the proposed negotiation approach consists of a multi-criteria decision making process and a cooperation-based multi-agent multi-issue negotiation protocol. The proposed negotiation protocol and strategy reach a Pareto optimal agreement on multiple issues. Experimental results illustrate that the proposed model can help to make an agreement efficiently under diverse situations of conflict scenarios.

Publications

The following is a list of papers that have been published during my PhD study.

Journal Paper:

Abedin, F., Chao, K. and Godwin, N. (2012) ‘An agenda based multi issue negotiation approach’. *Journal of Ambient Intelligence and Humanized Computing* [online] available from <http://dx.doi.org/10.1007/s12652-012-0123-1>

Conference Papers:

Abedin, F., Chao, K. and Godwin, N. (2011) ‘A fuzzy group decision making process in a multi-agent negotiation environment’. *Proceedings of the 15th International Conference on Computer Supported Cooperative Work in Design (CSCWD 2011).* held 08-10 June 2011 at Lausanne, Switzerland. IEEE, 311-318

Abedin, F., Chao, K., Godwin, N., and Arochena, H. (2009) ‘Preference Ordering in Agenda Based Multi-issue Negotiation for Service Level Agreement’. *Proceedings of the IEEE 23rd International Conference on Advanced Information Networking and Applications (AINA-09),* held 26-29 May 2009 at University of Bradford, UK. IEEE, 19-24

Table of Contents

List of Figures

List of Tables

List of Abbreviations

AI	Artificial Intelligence
AHP	Analytic Hierarchy Process
TOPSIS	Technique for Order Preference by Similarity to an Ideal Solution
VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian, means Multi criteria Optimization and Compromise Solution
OWA	Ordered Weighting Operator
FOWA	Fuzzy Ordered Weighting Operator
QGDD	Quantifier guided dominance degree
QGNDD	Quantifier guided non-dominance degree
DM	Decision Making
FMCDM	Fuzzy multi criteria decision making
CSV	Computing Services Department

List of Symbols

$i_m = \{i_1, i_2 \ldots i_n\}$	A given finite set of issues
$D^k = \{D^1, D^2 \ldots D^l\}, l >= 2$	A given finite set of decision makers
$O^k = (o^k(1),\ldots,o^k(n))$	Ordered vector
$U^k = (u_1^k,\ldots,u_n^k),\ u_i^k \in [0,1]$	Utility vector
$L = (l_1, \ , l_n)$	Linguistic term vector
$S^k = (i_{i1}^k,\ldots,i_n^k)$	Selected subset
$\mu_{R^k}(i_i, i_n) = r_{ij}^k$	Fuzzy preference relation
$c_k(i_j)$	Consensus degree of each consumer for each issue
W	Weight vector
R^c	Collective fuzzy weight preference matrix
Q	Fuzzy quantifier
b	Control the rigorousness of the consensus process
$t_k, k = 1,2 \ldots max$	Time round
γ	Controls the aggregation operator
min(i)or max(i)	Minimum or Maximum value of *i* issue
k_a	Start up value of the offer
β	Determines the time dependent tactic
w_i	Importance weights for *i* issue
U_i or G_i	Degree of satisfaction value for i issue
s_i^k	An offer received by a consumer from a supplier
c_i^k	An offer received by a supplier from a consumer
σ^a	The length of the allowed values interval for the agents
α^i	Degree of intersection between the intervals of the two agents (consumer and supplier)

Chapter 1

Introduction

Automated negotiation is an iterative process and represents a key form of interaction between autonomous agents in electronic markets. The autonomous agents play important roles in these electronic markets (Kurbel et al. 2004). The autonomous agents communicate and compromise to reach mutually beneficial agreements (Fatima et al. 2004; Fatima et al. 2005). In recent years, due to rapid expansion and adoption of electronic environments a lot of research has emerged in the area of electronic commerce and autonomous mechanisms such as automated negotiation. There has been a potential benefit of automating negotiation process in e-commerce. Negotiation is a well-known approach for resolving conflicts in human and agent societies (Abedin et al. 2009). The field of negotiation instigates from various disciplines including artificial intelligence, economics, social science, game theory and computer science. The complexity of automated negotiation has led researchers to use different theories in suggesting their automated negotiation models. With the rapid growth of e-commerce, research in group negotiation has become increasingly important and challenging since negotiations in such a context are characterised by complex negotiation search spaces, tough deadlines, very limited information about the opponents, and unpredictable negotiator preferences (Jennings et al. 2001; Lau et al. 2006; Abedin et al. 2009). This introductory chapter briefly reviews the state of the research area. It presents the problems of multi-issue negotiation, the motivations, goals and the main contributions of this thesis. Finally, the structure of the thesis is described.

1.1 Background and Motivations

Multi agent multi-issue decision-making problems arise in many real world negotiation situations since groups instead of individuals make more and more decisions in a fast changing world (Abedin et al. 2009). Researchers face numerous challenges in the design of an effective automated negotiation model, due to the complex nature of the situations in which it is to operate. There are number of assumptions that the researchers had to make in order to proceed with the mechanisms in this field. These assumptions limit the development of the existing automated negotiation for practical uses, and for meeting user requirements. Some key challenges are briefly stated below.

Designing an appropriate negotiation process is a difficult task in multi-issue automated negotiation. An appropriate negotiation process allows the negotiation agents to follow a set of plausible rules during negotiation and reach a satisfactory result. In recommending a procedure of negotiation, it is essential to construct an initial choice for the scope of the situation of the negotiation process. The environment in which a negotiation occurs determines the options accessible for the negotiating agents (Chen et al. 2005). There are some factors that are essential in a multi-issue negotiation problem. These factors are: negotiation object, information, protocol and strategy (Lomuscio and Jennings 2003; Fatima et al. 2004). The negotiation object is the issues or alternatives related to the product or service that the agents are negotiating for. Agents may bargain over a single issue associated with the service or products, but negotiations often involve groups of agents and bargaining over multiple issues (Raiffa 1982; Abedin et al. 2009). Agents need to come to agreements about products or services that are categorized by issues such as price, performance, quality, reliability, delivery time, penalties, terms and conditions, and so on. Negotiation information such as issue preferences and issue dependencies needs to be handled efficiently in order to deal with multiple issues. These issues are directly or indirectly interdependent through their evaluation functions which are also called utility functions. When utility functions need to manage a set of interdependent issues, the complexity increases.

Multiple related negotiations can be performed sequentially, or simultaneously, or based on a hybrid procedure by combining these two aspects. Sequential negotiation such as issue-by-issue procedure is computationally simpler and outcome is more traceable than simultaneous negotiation. The reason is in existing issue-by-issue negotiations the utility function can be calculated separately (Chen et al. 2005). But in real life the issues have linkages with each other. In addition, the negotiating agents cannot reveal their utility functions to the public. One major research issue is how to decide an appropriate and less complex procedure for the agents when multiple related negotiations need to be performed.

A negotiation protocol and associated strategies need to be designed effectively so that a solution or agreement can be reached which will be agreed by the group (Abedin et al. 2009). The channels of communication and the allowed protocols will provide constraints on the interactions and the strategies that can be adopted (Chen et al. 2005; Jiaxing et al. 2007). The protocol should be transparent and open to participating negotiators. The protocol can clarify the negotiation procedure during the negotiation and offer an opportunity for the negotiating agents to explore potential agreement spaces.

The context must support sufficient exchanges of information to provide for an improvement process. It must be possible to progress towards an optimal agreement or maximise social welfare or utility from the interactions. The individual concern in a negotiation will be the choice of strategy within the agreed context. One view of the choice of strategy is that the aim is to resolve the conflict between maximising private payoffs and enlarging the common benefit (negotiators may give appropriate concessions that may increase common utility) (Chen et al. 2005; Jiaxing et al. 2007). Negotiators use their own private strategies to analyse the current situation during the sequential interactions. Assuming a context in which alternating offers and counter offers are made, the strategy must determine those offers and counter offers generated during the negotiation process. The problem is to design a strategy and protocol suitable for automation that will effectively explore the possible agreement space. For these reasons, careful design of the strategy and its contextual protocol is required (Chen et al. 2005).

This research aims to investigate these issues and to propose an effective automated negotiation model by considering these factors. A generic negotiation model should be designed to assist the group of agents with diverse preferences over multiple issues, and include negotiation protocol, which allows agents to cooperatively reach consensus. The negotiation strategies should be sophisticated enough to instruct agents to make reasonable concessions and offers-counteroffers. The protocol should be flexible so that the agents can set or change essential parameters in order to improve the outcome before the negotiation ends. Issue parameters may change in each round when interdependencies between the issues exist. The proposed model should consider these characteristics. By utilising selected negotiation strategies and agreed protocol, the agents should be able to maximise their own utilities as well as the joint welfare or total utility (Chen 2006).

This research analyses an important aspect of multi-issue negotiation which influences the efficiency of the negotiation process. This aspect is the negotiation agenda. If multiple issues are involved, the agenda specifies the order in which the negotiation takes place. Negotiating over multiple issues produces complex situations and makes it difficult for the agents to reach an agreement during the negotiation phase (Abedin et al. 2009). This research will suggest a model to reduce these difficulties.

Most of the work in the multi-issue negotiation field has focused on the areas of protocol design, strategy adaptation and utility calculation in various negotiation models. However, no effort to date has been put into the problem of determining the agenda sequence of the issue preferences derived from a group preference ordering process and analysing its effect in a multi-issue negotiation group (Abedin et al. 2012). The main goal of this research is to determine how the agenda has an effective impact in multi-issue negotiation process. The effective negotiation outcome can be influenced by the two key factors: the agenda (i.e., the order of the set of issues under negotiation) and the negotiation procedure (i.e., how the issues on the agenda will be settled) (Abedin et al. 2009). So agenda based multi-issue negotiation model can play a vital role in automated negotiation if it is used effectively.

Determining the agenda sequence can be one of the most important structural aspects of multi-issue negotiation as well as a significant determinant of negotiation power and influence (Abedin et al. 2009). Agenda sequence means once the issues are decided, they are then in order. Negotiation agenda sequence can have an impact on the outcome of the process. It can either be decided before or during the actual negotiation. In the proposed system a pre-negotiation strategy is produced where the agenda sequence is determined.

Multiple issues normally generate a large and complex search space in a negotiation process. Uncertainty and conflicting preferences between the agents occur during the negotiation process which delay the negotiation timeline and maximise the search space. To improve this situation, I have used a preference ordering method which is based on a group decision-making process (Abedin et al. 2009). The proposed group decision-making process when used with issue-by-issue agenda based negotiation can reduce the negotiation delay time and the search space (Abedin et al. 2012).

Negotiation requires the management of stated preferences regarding the multiple issues which need to be captured. So the approach of this work is to first present a pre-negotiation protocol or strategy which deals with the different preference information expressed by the agents on the issues or attributes associated with the service or alternative. Each agent gives their own importance over the issues. The participating agents have no prior knowledge about the preferences over the issues of the other agents. This situation is common in e-commerce negotiations, where the number and diversity of agents is so large that an agent may not have any estimate about the preferences of any particular agent it is negotiating with (Saha and Sen 2006). This can end up with inefficient agreements. In this situation aggregated preference information can be used to reach agreements beneficial for both agents. Preference ordering methods are used to obtain the aggregated result (Abedin et al. 2009).

The agents participating in the proposed negotiation process are initially divided into users and providers. They are not in the same side regarding the preferences but form a negotiation group to reach consensus. It is very unlikely that a group of agents will share the similar opinions, particularly in the case of multi-issue decision-making problem. A group of agents faced with multiple issues related with multiple alternatives may often have conflicting preferences and the method of finding a group consensus affects the efficiency of the negotiation outcome. In a multiple-issue negotiation process it is difficult to reach an optimal outcome when the two agents' preferences and the relative importance of the issues are not known to each other and are diverse in nature (Abedin et al. 2011; Abedin et al. 2012).

A fuzzy group decision-making process can be designed to adopt the agents' preferences, reach consensus and order the issues in the pre-negotiation stage to improve the efficiency of the outcome. This fuzzy group decision-making process is developed to facilitate the agenda based multi-issue negotiation environment (Abedin et al. 2011). This research first investigates the multi-issue decision-making problem where preference information on issues associated with services or products are expressed in different formats by the agents. A fuzzy preference concept is used to order the issues in the pre-negotiation stage to improve the efficiency of the negotiation outcome. This preference ordering is used in the proposed agenda based multi-issue negotiation process. Most work done on automated negotiation has been done in the areas of protocol design, strategy computation and user utility elicitation, in various negotiation models such as bilateral negotiation (single-issue and multi-issue) and auctioning (Buffett and Spencer 2007). However, less effort to date has been put into the problem of determining agenda sequence particularly in the area of multi-issue negotiation to minimise the search space which also affects the final negotiation strategy and outcomes.

1.2 Research Aim and Objectives

The aim of this research is to introduce a framework for an agenda based model which investigates the significance of the choice of the sequence in issue-by-issue negotiation. The process of choice of sequence to be used in negotiation is based on a preference ordering technique. Therefore, this research focuses on the following objectives:

- To investigate a fuzzy preference ordering method in the pre-negotiation stage to determine the choice of sequence over multiple issues which helps a group of agents to reach a consensus over the issues and to construct a common preference sequence.

- To generate an efficient negotiation agenda for an issue-by-issue negotiation problem and investigate the impact of negotiation agenda on negotiation performance.

- To design and build an agenda negotiation model which incorporates negotiation strategy and protocol with group decision-making process.

- To analyse and evaluate the proposed model and identify its advantages.

- To test the model for its efficiency and effectiveness in using different parameters.

1.3 Expected Research Contributions

The primary contribution of this research is to develop a model for automated multi-issue negotiation by agents using a preference ordering process and to analyse its potential benefits in cooperative environments. In particular an agenda based approach which deals with agents' preferences in such negotiation. The expected contributions of this work can be summarised as follows:

- When using the issue-by-issue approach the most important question regarding multi-issue negotiation is selecting the negotiation agenda. The proposed agenda based multi-issue negotiation approach can improve the issue-by-issue negotiation convergence process; reduce the complexity and search space by taking advantage of using preference ordering method in issue-by-issue negotiation set up. Here improving the convergence process means shortening of the exchange of offers during the negotiation.

- The agents, by using this approach, will be allowed to adequately express their preferences on relative importance and their perception of interdependence about the multiple issues related to the service or goods in the given domain so that they can: assist in offer generation; evaluate incoming offers, and, negotiate within a realistic search space.

- The proposed model can use a group decision-making mechanism based on a preference ordering process which is explicit and facilitates to construct the base for developing an automated negotiation model. These preference ordering techniques can be applied to get a collective view of multiple issues to be used in negotiation. The preference ordering method will not only derive a common preference ranking from the preference information that the group of agents can provide but also generate a common position for the issues. This mechanism will help to maximise the consensus of the group preference by minimising the gap of negotiators' individual and group preference in ordering the issues and determine the issue importance weight.

- The main problem of the existing issue-by-issue negotiation models is the interdependency factor between the issues (Ito 2007; Lopez-Carmona et al. 2010; Marsa-Maestre et al. 2009; Robu et al. 2005). In the proposed model the dependencies between the issues will be measured to identify the influence the determined sequence has upon the issue-by-issue negotiation process.

- Learning in automated multi-issue negotiation is usually unsupervised because the opponent's utility is uncertain when the agent receives an offer (Jazayeriy et al. 2011). The utility represents an agent's level of satisfaction for a negotiation outcome in terms of issues. This uncertainty makes it very hard to explore the agents' actual preferences. The proposed fuzzy preference approach will help to learn the opponent's preferences and the significant choice of sequence will supervise the negotiator agents' choice of initial combination of negotiation tactics which may help to solve the case of uncertainty. This model will increases group of agents' opportunity for reaching a mutually beneficial agreement and will help to improve agent's utility by providing an effective equilibrium outcome which is a Pareto optimal solution (Abedin et al. 2012).

1.4 Structure of the Thesis

The thesis is structured into 6 chapters. The first chapter gives an introduction to the research problems, motivation, aim, objectives and contributions of the thesis.

Chapter 2 presents a comprehensive review of literature and background of automated negotiation. The first section describes the main negotiation theories and different negotiation mechanisms. Limitations of these theories are also stated. Existing approaches of automated negotiation followed by their advantages and disadvantages are discussed in the next section. This chapter also discusses the scope of agenda based negotiation approach in issue-by-issue negotiation.

Chapter 3 presents the literature and background of multi-issue group decision-making process as it is relates to the proposed method. It describes the problems of the methods and the need of a solution concept that can be used in this research to deal with group decision-making problems in pre-negotiation phase.

Chapter 4 provides an overview of the proposed automated negotiation framework. The essential components and their interactions are also given. Details of each stage of the approach are described and explained in this chapter.

Chapter 5 presents a case study on which the model is applied. A comprehensive evaluation is provided with experimental results and their analysis. Experimental results are presented to assess the performance and effectiveness of this approach. New opportunities and directions from the experimental results for the future research are also identified.

Chapter 6 draws the summary and conclusion of the thesis by reviewing and discussing the characteristics of the proposed model. The contributions and limitations of the research are provided in addition to areas for future work.

Chapter 2

Background and Related Works for Automated Negotiation

2.1 Introduction

Automated negotiation has gained increasing attention among researchers in the last decades as it resolves the conflicts between the self-interested agents who attempt to maximise their benefits through the making of concessions or compromises. Autonomous agents can play important roles in e-commerce by negotiating on behalf of buyers/sellers, consumers/suppliers, client/server or even as a mediator. An agent should be able to generate offers and counter-offers that satisfies other agents and motivates to continue the negotiation (Jazayeriy et al. 2011). The automated negotiation models differ in the way they adopt the methods and implement them. Numerous real-life negotiations do involve multiple issues, although most of the existing literature on cooperative and non-cooperative games focuses mostly on single issue negotiations (Rubinstein 1982; Lai et al. 2004). For multi-issue negotiation, different negotiation models apply different bargaining procedures such as the complete package process and the sequential process. Various approaches and methods like: game theory (Zlotkin and Rosenschein 1996; Jennings et al. 2001); argumentation (Sierra et al. 1997; Parsons et al. 2002; MrBurney et al. 2002; Rahwan et al. 2004), and, heuristic approaches (Faratin et al. 1998; Fatima et al. 2003; Lin 2003), can be applied to implement these procedures with the aim of facilitating automated negotiation in e-commerce (Abedin et al. 2012). All these approaches have their advantages and disadvantages.

To design an effective and efficient automated negotiation process it is essential to take a number of elements into account. Negotiation protocols, negotiation strategies, negotiation tactics and negotiation objects are the important elements that have to be considered to deal with negotiation process (Jennings et al. 2001). In addition to these elements, the negotiator's decision-making model, which comprises the negotiation properties such as utility functions, Pareto efficiency and equilibrium, is an important mechanism in the negotiation process, since it offers the negotiator the essential information for making decisions on whether to accept the offer or not.

In this chapter, a review and evaluation on the related works for the elements of automated negotiation is presented as well as the scope of the proposed approach. This research wants to improve existing automated negotiation methods in order to assist the negotiation process conducted by a group of decision-making agents with different preferences over issues or services (Chao et al. 2003).

Section 2.2 presents the different negotiation procedures and their implementations. Section 2.3 describes and analyses the various approaches to automated negotiation. Section 2.4 discusses the properties of negotiation process while Section 2.5 and 2.6 addresses the limitation and scope of different negotiation procedures. The scope of issue-by-issue negotiation procedure in identified in Section 2.7. Section 2.8 discusses the related work of agenda based negotiation. Finally, the scope of agenda based negotiation will be dealt with in Section 2.9. A brief summary is given in Section 2.10.

2.2 Negotiation Procedures

The outcome of multiple-issue negotiation depends on not only strategies, but also the procedures by which the issues will be negotiated. Different procedures yield different outcomes (Dang and Huhns 2005). Agents need to decide two concerns before the negotiation: one is the kind of negotiation procedure (agenda) they will take and the other is the type of agreement implementation (Sycara and Dai 2010). The automated negotiation mechanisms can be classified into three procedures: package, separate and sequential (Inderst 2000; Gerding et al. 2000; Fatima et al. 2006). These three different negotiation procedures for multiple issue bargaining are shown in Figure 2.1 (Abedin et al. 2012). When all issues are negotiated at once then it is called package bargaining. In package procedure the agents negotiate a complete package or bundle all the issues and discuss them simultaneously (Busch and Horstmann 1997; Fatima et al. 2002; Fatima et al. 2004). This is used when the issues are interdependent. For a package deal, an offer includes a value for each issue under negotiation. For k issues, an offer is a package of k

values. This allows tradeoffs to be made between issues. Agents are allowed to either accept a complete offer or reject a complete offer (Dang and Huhns 2005). Most of the time finding equilibrium strategies for package procedure is not computationally simple. In particular, when the agents' utility functions are nonlinear, then equilibrium strategies may be hard to compute (Fatima et al. 2007).

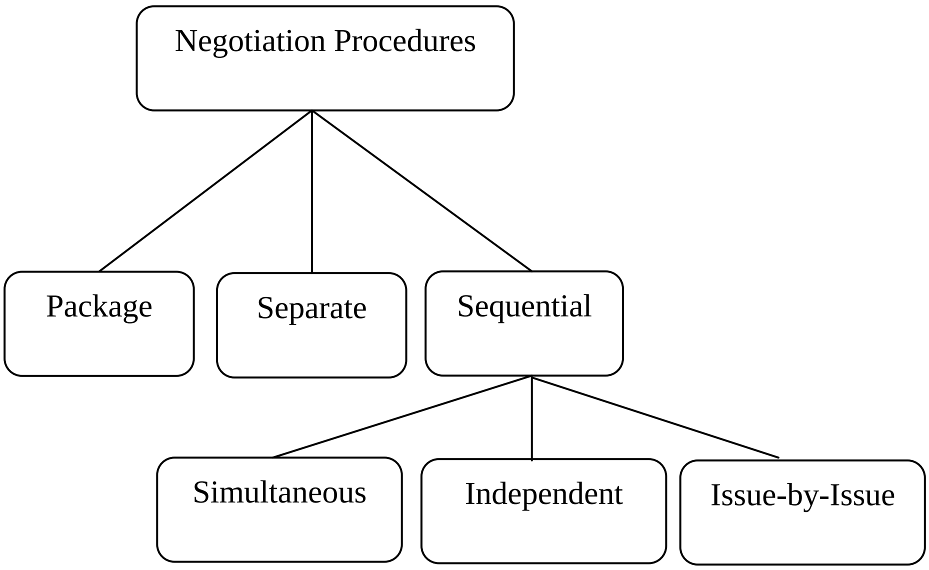

Figure 2.1 Three different negotiation procedures used in multi-issue bargaining

The other procedure is known as separate bargaining where each issue is negotiated and implemented independently. Sequential negotiation is when the agents negotiate issues sequentially. Sequential bargaining can be subdivided according to the approach taken to implementation. The distinguishing rules of these approaches specify when to get benefits from the issues which have been agreed on. The simultaneous implementation rule the agents have to wait to get the benefit until agreement is reached on all the issues (Gerding et al. 2000; Abedin et al. 2012). On the contrary, with the independent implementation rule, an agreement on an individual issue takes effect immediately, that is, the agreed-upon issues are no longer taken into account (Abedin et al. 2012). In the existing literature there is another implementation approach which settles each issue sequentially and independently of all the other issues. This is described as 'issue-by-issue' where an agreement can take place either on a subset of issues or on all of them

(Fershtman 1990; Inderst 2000; In and Serrano 2004; Dang and Huhns 2005). Although issue-by-issue negotiation minimises the complexity of the negotiation procedure, an important question that can arise is the order in which the issues are bargained (Fatima et al. 2006; Abedin et al. 2009; Fatima et al. 2006). The equilibrium result can strongly depend on the order in which the agreements are arrived at. This research focuses on issue-by-issue implementation approach which considers sequential negotiation procedure. The reason for choosing issue-by-issue sequential procedure is discussed in section 2.6.

2.3 Approaches to Automated Negotiation

Autonomous negotiating agents representing individuals or organizations and capable of reaching mutually beneficial agreements are becoming increasingly important (Lopes et al. 2008). Artificial intelligence (AI) researchers have paid some attention to automated negotiation over the last years and a number of models have been proposed in the literature (Lopes et al. 2008). The most important and most frequently applied concepts which support the implementation of a multi-issue negotiation process lead to their three-fold classification as: game theory approaches (Jennings et al. 2001; Kraus 2001; Fatima et al. 2006); argumentation approaches (Rahwan et al. 2004), and, heuristic approaches (Faratin et al. 1998; Fatima et al. 2002; Li et al. 2006). Game theory provides concepts for bargaining solutions based on mathematical analysis. However, it is restrictive in the designing of automated negotiation due to: the lack of dynamic theory; difficulty in equilibrium selection, and, the problem of hyper-rational players. An agenda based negotiation approach based on preference ordering has not been applied in an automated multi-issue group negotiation environment, though it could be useful and can be used like the other mainstream approaches if its applicability can be justified (Abedin et al. 2012).

Next section presents various essential concepts to understand the automated negotiation problem. Section 2.3.1 discusses Game theory approaches in automated negotiation. Heuristic-based approaches are analysed in Section 2.3.2. An analytical discussion is presented on argumentation-based negotiation in Section 2.3.3.

2.3.1 Game Theoretical Approaches in Automated Negotiation

Game theory provides concepts for negotiation solutions based on mathematical and economical concepts. However, it is restrictive in some respects for the design of automated negotiation. The unavailability of complete information and the intractable full rationality of the players are obstacles to the use of classic game theory to make negotiations. Nevertheless, by using Artificial Intelligent (AI) techniques to resolve the negotiation problems, these impractical assumptions seem to be unnecessary (Chou et al. 2007).

Classical game theory approaches assume that negotiating agents contain unbounded computational resources. They also assume that the agents have complete information of the outcome space. Rahwan (2004) stated that, in game-theoretical evaluations, researchers generally try to establish the most favourable strategy by analysing the communication as a game between equal participants, and looking for its equilibrium (Harsanyi 1956; Rosenschein and Zlotkin 1994; von Stengel 2002; Ateib 2010).

Rahwan (2004) further stated that the strategy determined by the classic game theory approaches can occasionally be made to be most favourable for a participant, specified the game rules, the assumed payoffs, and the aim of the participants, and assuming that the participants have no knowledge of one another not provided by introspection (Ateib 2010). It is assumed that participants behave according to the assumptions of rational-choice theory (Coleman 1990). This approach can then guide the design of the interaction method itself, and therefore help such participants to act in certain ways (Rahwan 2004).

According to Lopes et al. (2009) the majority models work with abstract problems under assumptions and often not succeed to capture the richness of detail that would be essential to effectively apply them in realistic domains. He further stated that most game theoretical models make the following restrictive assumptions: (i) the agents are rational, (ii) the set of candidate solutions is fixed and known by all the agents, and (iii) each agent knows either the other agents' payoffs for all candidate solutions or the other agents' potential attitudes toward risk and expected-utility calculations (Lopes et al. 2009). Classical negotiation models based on operational research methods or traditional game-theoretic models need to be further developed to support negotiations in realistic situations (Lau et al. 2006).

Despite of these restrictions and assumptions, the traditional game theory may give fundamental insights to process and design efficient automated negotiation protocols. These protocols have certain desirable properties (Faratin 2000). Some significant properties are described in the next section.

2.3.1.1 Advantages of Game Theory

The advantages and the desirable properties of game theory can be used to solve problems in automated negotiation in a specific situation. As game-theoretic models occasionally offer clear analysis of detailed negotiation situations and specific results regarding the optimal strategies negotiators should prefer, i.e., the strategies that maximise negotiation outcome (Lopes et al. 2008).

- **Pareto efficiency and Nash Equilibrium:** Models based on Game theory contain a number of vastly popular properties, such as Pareto efficiency and Nash Equilibrium (Sandholm 1999). Pareto efficiency occurs if there is no other allocation of utility, which can improve one negotiator's return without detriment to another negotiator (Chen et al. 2005; Jiaxing et al. 2007). The idea of an equilibrium position is that any negotiator cannot improve his return unless the others make a change in their position. Ideally the outcome of negotiation is an equilibrium agreement, if it is Pareto efficient. If a negotiation outcome is not Pareto efficient, then there is another outcome that will make at least one agent happier while keeping everyone else at least as happy (Jennings et al. 2001). The protocol should be designed to assist the agents in achieving such result. The Nash Equilibrium is a well-known kind of stability. If all agents are provided with incentives to behave in a particular way by a protocol, then that protocol is called stable.

- **Maximising social welfare:** A protocol maximises social welfare if it ensures that any outcome maximises the sum of the utilities of negotiators. For instance, if the utility of an outcome for an agent was basically defined in terms of the performance of a service that the agent obtains in the outcome, then a protocol that maximised social welfare would maximise the total amount of performance (Jennings et al. 2001).

- **Computational efficiency:** An agent can coordinate an agreement with other agents, and the refined protocol can increase searching agreement efficiently and reduce the computational overhead.

- **Simplicity:** A protocol is simple when that makes suitable strategy for a negotiation agent apparent. On the other hand, a protocol is simple when a negotiating agent can without any complexity decide the optimal strategy by using that protocol.

A desirable negotiation protocol could incorporate the above properties. An effective automated negotiation model should possess these properties. The proposed negotiation model will acquire the advantages of game theory and overcome the difficulties.

2.3.1.2 Limitations of Game Theory

The traditional game theory applies decision trees or extensive forms to explain dynamic models in complete information negotiation games. The negotiation becomes reasonably complex when multiple issues are involved. Impractical assumptions about the negotiating agents get involved in purely game theoretical based negotiation.

According to Rahwan (2004) the first assumption implies that every possible offer is evaluated by the agents with unbounded computational resources and it also has all preference information needed to execute such evaluation. In many domains, however, it may be not practical for the user to guess its complete preference information to the agent (Rahwan 2004).

The second assumption involves that agents constantly take decisions that optimise their utility and lead to equilibrium. Game theory needs this because an agent should first reason about the best possible strategy of the opponent before assuming the best response to that strategy (Rahwan 2004). But when the game is reasonably complex with multiple issues involved in realistic situations, assumptions may lead to no equilibrium or multiple equilibriums in the solution.

The traditional game theory solutions are based on some related restrictions and assumptions, in order to apply the mathematical process. The mathematical bargaining solutions depend on several axioms or a known, assumed environment that is not present in realistic cases.

Later heuristic based approaches such as evolutionary game theory came out with some solutions to solve several of the restrictions of game theoretical approaches stated above. The assumption of unbounded rationality is relaxed by the introduction of evolutionary game theory. Instead of calculating optimal strategies, games are played repeatedly and strategies are tested through a trial-and-error learning process in which players gradually find out that some strategies work better than others. But, other assumption, such as the accessibility of a preference valuation function, still exists. The representation of bounded rationality by explicitly capturing elements of the process of choice, such as limited memory, limited knowledge, approximate preferences etc are helping to overcome the limitations of game theory. The frameworks with these improvised concepts are better in describing and predicting the human behaviour in real economic and social scenarios (Rahwan 2004). The heuristic approaches are discussed in the next section.

2.3.2 Heuristic-based Approaches in Automated Negotiation

According to Brzostowski et al. (2007) the game theories assume the full rationality of the players and complete knowledge of situations. Such assumptions are relatively unrealistic and as a result the application of game theory for realistic negotiations is restricted. The agents bounded information and bounded computational power may be compensated by the ability of learning (Braun et al. 2006), reasoning and argumentation (Sierra et al. 1997; Brzostowski et al. 2007). The computational complexity of agents reasoning generates the necessity for heuristic approaches for negotiation decision-making (Brzostowski et al. 2007). A heuristic approach involve learning mechanisms like Bayesian learning (learns negotiation partner's type), Q learning, Neural Networks or Fuzzy reasoning. Evolutionary learning using a genetic algorithm can also be considered to be a heuristic approach. Q learning and Evolutionary learning search the set of potential strategies (Abedin et al. 2012).

Heuristic models offer general guidelines to assist negotiators and favourable strategies for moving toward agreement, such as strategies that guide to good (rather than optimal) outcomes (Lopes et al. 2008). Typically, they are based on informal models of interaction and negotiation from the social sciences. Heuristic models exhibit the following desirable features: (i) they are based on realistic assumptions, and (ii) they make use of reasonable computational resources to locate acceptable solutions (according to the principles of bounded rationality) (Lopes et al. 2008). Faratin, Sierra and Jennings in (Faratin 2000; Sierra et al. 1997) have used number of heuristic methods in their negotiation framework.

Brzostowski et al. (2007) evaluated some of the existing heuristic approaches. A heuristic based approach is introduced by Faratin et al. (1998) where the agents are provided with a concept of tactics and strategies. These tactics and strategies determine an offer and counter-offer in each stage of the encounter. In this approach, the negotiation agents are constrained by deadlines determining the time given to reach agreements. The time-dependent tactics calculate an offer based on the time remaining for negotiation which means that it is a function mapping a time point into the offer, either in issue space or utility space. This approach also allows for restricted level of adaptation to the behaviour of the negotiation partner. Various behavioural tactics are used to allow this adaptation. To generate negotiation offers in a more sophisticated way, negotiation strategy may be formed with different linearly combined tactics.

Faratin's model is complimented by a range of learning and reasoning approaches. The learning approaches include: Bayesian learning (Zeng and Sycara 1996), Q-learning (Cardoso and Oliveira 2000) and evolutionary computation (Matos 1998; Oliver 1996). Though, these approaches need prior knowledge obtained before entering the negotiation and such knowledge may be sometimes difficult to obtain. To overcome this, an approach of on-line learning was proposed by Hou (Hou 2000) where the agent may learn from the current encounter or it may complement its prior knowledge with the knowledge acquired from observing the partner in the current negotiation. The agent guesses the shape of the concession curve of the opponent using the regression analysis and then gets used to this forecast by making concessions that maximise its utility. Hou (2000), considered the opponent using pure tactics according to Faratin's approach (Brzostowski et al. 2007).

2.3.2.1 Limitations of Heuristic Approaches

Rahwan (2004) evaluated the heuristic approaches and mentioned that heuristic approaches do certainly overcome a lot of the limitations of game-theoretical approaches. Still, they too have a number of shortcomings (Jennings et al. 2001). According to Chen et al. (2005), it is not easy to predict in this approach exactly how the system and the ingredient agents will act. The outcomes of these models often produce sub-optimal outcomes because they assume an approximate notion of rationality and they do not explore the full space of possible outcomes.

Rahwan (2004) also stated that these models require more evaluation through simulations and empirical analysis. Like most game-theoretic approaches, heuristic approaches also assume that agents know what they want. In other words, agents have a precise and correct way of calculating the quality of the negotiation outcome (usually using numerical utility functions). But, this requirement cannot always be satisfied, in which case there is scope of alternative techniques. In most game-theoretic and heuristic automated negotiation approaches, it is mostly assumed that agents' utilities or preferences are completely characterised or known prior to the main negotiation. This is another restriction of heuristic approaches.

Also game-theoretic and heuristic approaches assume that agents' utilities or preferences are fixed. A rational agent would only adjust its preferences upon receipt of new information, and traditional automated negotiation mechanisms do not assist the exchange of such information.

For traditional game-theoretic and heuristic frameworks, computational agents can not benefit from acquiring and modifying their preferences during negotiation like the humans do during their negotiations by acquiring information, resolving uncertainties and revising preferences which are part of the negotiation process itself.

Generally in the game-theoretic and heuristic models, agents exchange proposals (i.e. potential agreements or potential deals). For example, can be a promise to purchase a good at a specified price or a value assignment to multiple issues in a multi-dimensional auction (Wurman 1999), or an alternate offer in a bargaining encounter (Larson and Sandholm 2002). Agents are not allowed to exchange any additional information other than what is expressed in the proposal itself. Agents’ preferences over proposals are assumed to be proper in the sense that they reflect the true benefit the agent receives from satisfying these preferences. Argumentation-based approaches to negotiation are introduced to overcome the above limitations by allowing agents to exchange additional information, or to argue about their beliefs and other mental attitudes during the negotiation process (Rahwan 2004).

2.3.3 Argumentation-based Approaches in Automated Negotiation

Argumentation-based models have the advantage that the negotiating agents can add information flexibly during the exchange of offers with the exchange of arguments (Jennings 2001). This permits great flexibility since, for instance, it makes possible to persuade agents to change their view of an offer during the course of negotiation (Lopes et al. 2008). Argumentation-based models allow negotiators to argue about their mental attitudes during the negotiation process. Thus, in addition to submitting proposals, negotiators can provide arguments either to justify their negotiation stance or to persuade other negotiators to change their negotiation stance (Rahwan et al. 2004;

Lopes et al. 2008). An argumentation protocol presents an agent with a communication language and the syntax that it uses (McBurney et al. 2003). The negotiating agents in the argumentation protocol incorporate a logic-based reasoning mechanism. The argumentation approach is used to assist the negotiating agents in reasoning over arguments and produce effective arguments in order to reach a satisfactory agreement (Abedin et al. 2012; Rahwan et al. 2004).

A number of works in this area have been carried out and they focus on the design of the internal mechanism of argumentation; that is how arguments are generated (Sycara 1990; Rahwan et al. 2003; Reed et al. 2003; Parsons et al. 2002), how arguments are selected (Kraus and Sycara 1998; Ramchurn et al. 2002; Amgoud and Maudet 2002) and how arguments are evaluated (Parsons et al. 1998; Sierra et al. 1997), and how the process of argumentation can resolve conflicts and achieve agreements (Jung et al. 2001; McBurney et al. 2003). Some researchers in augmentation approaches have been more interested in the design of argumentation formalism that involves modelling of the vocabulary and syntax rules for communications between participants (McBurney 2003).

2.3.3.1 Limitations of Argumentation-based Approaches

There are limitations in argumentation-based approaches; for instance Lumuscio et al. (2003) and Jenening et al. (2000) discuss two remaining challenges between internal elements and external elements. First, the agent is almost hardwired when negotiating with others. It needs to be more flexible in the rules of the argumentation protocol. Second, it needs to be specific in the transition between the underlying internal elements and external elements, for instance when is the right time to make this transition to start an argument.

Lomuscio et al. (2003), Jenening et al. (2000), Rahwan et al. (2004) also have similar views on the weaknesses of argumentation approaches and suggest improvements in developing the sets of rules that are involved in argument generation, argument selection, argument assessment, strategy generation, strategy selection and preference determination. Another difficulty the argumentation-based negotiation has is evaluating a large and complex negotiation space in complex scenarios. So there is scope for improvements in the above main negotiation approaches regarding search space, complexity and preferences determination.

2.4 Negotiation Process

Research in automated negotiation process to date has been mainly focused on the progress of negotiation protocols and strategies (Tamma et al. 2002). For example, Jennings considered that automated negotiation process mostly deal with three broad topics, they are negotiation protocols, negotiation objects and agents decision-making models (Cao et al. 2007; Jennings et al. 2001).

Recent work is mainly focused on how to construct a negotiation model, which has ability to control the whole process of negotiation, to balance conflict of interest, not on providing support to unilateral negotiator's decision-making (Cao et al. 2007). Although there are many research achievements about protocols and strategies in the field of automated negotiation nowadays, realization and real application of automated negotiation system still has a long way to go (Resinas et al. 2006; Lin 2008; Cao 2010).

To design an effective automated negotiation model it is necessary to take a number of elements into account. Negotiation protocols, negotiation strategies and negotiation utilities are the important elements in a negotiation process which have been considered to deal with automated negotiation research. According to Rosenschein and Zlotkin, (1994) the main components of an automated negotiation model can be classified in four main categories, as illustrated in Figure 2.2.

a) The negotiation protocol.
b) The negotiation strategy.
c) The negotiation mechanism (equilibrium).
d) The information state of agents.

Thus, an appropriate combination of negotiation strategy and protocol, regarding the information available, forms the negotiation mechanism which automates the negotiation process. It should be possible to move towards an optimal agreement (Chen et al. 2005) or to maximise social welfare (total utility) from the interactions.

Figure 2.2 The main components of negotiation model (Rosenschein and Zlotkin 1994)

2.4.1 Negotiation Protocol

The negotiation protocol determines the flow of messages between the negotiation agents and set the rules to govern their interaction (Cranor and Resnick 2000). It defines the possible ways the negotiation process can be led and dictates which participant can say what, and when, in the negotiation process (Fatima et al. 2004). In other words, the negotiation protocol govern how negotiations are performed and should be public, transparent, open to the participating agents who must obey it. The protocol can clarify the negotiation procedure during the negotiation and offer an opportunity for the negotiating agents to explore potential agreement spaces. For instance, the Rubinstein alternating protocol specifies (Osborne and Rubinstein 1990) that agents are allowed to send one offer in alternating turns. Basically, the negotiation protocol acts as a mechanism for the coordination and regulation of the agents that take part in the negotiation process (Sánchez-Anguix et al. 2013). The protocol should be flexible and unambiguous so that the agents can set or change essential parameters in order to improve the output before the negotiation ends. The protocol could be used for dealing with the range of issue from one to multi-issues. In multi-issue negotiation, the protocols can negotiate all the issues together or sequentially one after another. If negotiation protocols rule the exchange of proposals or arguments between the agents, the negotiation strategy is the decision-making model that agents use in order to satisfy their goals in accordance with the negotiation protocol.

2.4.2 Negotiation Strategy

Negotiation strategy is a decision-making apparatus in which a party acts within the negotiation protocol in an effort to get the best outcome of negotiation. The individual concern in a negotiation is the selection of strategy in the decided framework. By contrast with protocol, it's therefore necessarily private. One view of the choice of strategy is that the aim is to resolve the conflict between maximising private payoffs and enlarging the common benefit (Chen et al. 2005; Jiaxing et al. 2007). The negotiators may give appropriate concessions that may increase common marginal utility (Chen et al. 2005; Jiaxing et al. 2007) under the constraints they face and reach an agreement.

According to Kraus (2001) a negotiation strategy for each agent tries to guide the actions of this agent through each offer sequence by some rules and procedures. This strategy helps agents to identify the offer which that agent should propose at specific time to a specific agent. Also this strategy helps agents in accepting or rejecting the offer proposed by the opponent. The strategies can be classified into two main categories: distributive and integrative strategies. The distribution type of negotiation, aggressive bargaining, is a zero-sum game, i.e., a gain for one party, is a loss for another and generally leads to a low satisfaction level. Distributive bargaining is regarded as competitive bargaining and provides the agents with Win-Lose situation. The objectives of two parties are in fundamental conflict. In this type of negotiation the resources are constant and limited and each agent wants to maximise its share (Huang 1996). The distributive stage looks for settlements in situations where an advantage for one of the parts could be a disadvantage for any other part (Espin et al. 2007). The negotiator in this type of negotiation tries to get a higher share of the pie by various methods by equal power conditions and temporal constraints between the two participant agents (Brooks and Rose 2004). In situations where agents are characterized by high concern for their own outcomes combined with low concern for the partner's outcomes or in reverse case, a distributive strategy is the preferred strategy (Ness and Haugland 2005). In contrast to distributive bargaining, negotiators cooperate more amicably together in an integrative strategy and try to enlarge the available pie. In integrative bargaining all parties share goals and outcomes and they achieve benefits simultaneously (Linghua 1996). This type of strategy searches for advantageous solutions for both parties in a negotiation process (Espin et al. 2007). In other words, both participants look for a solution which could maximise their joint share from the pie. In contrary to distributive bargaining (which look more for Win-Lose solution), integrative negotiation seek more for Win-Win solution (Bahrammirzaee 2011). Four strategic processes for negotiation parties which are willing to use an integrative strategy have been proposed by Lewicki and Litterer (1985). According to Lewicki and Litterer, they should:

1) Understand the goal and objectives of other participants;
2) Have an open information exchange;
3) Highlight the common interests which decrease the importance of actual differences;
4) Look for solutions which satisfy mutual goals and objectives.

Negotiation parties generally achieve higher satisfaction level in integrative negotiation compare to distributive negotiation (Dzeng and Lin 2004). In negotiations where both parties pursue joint goals, and the concerns for both their own and the partner‘s outcomes are high, integrative strategy will be the preferred strategy (Ness and Haugland 2005). Given that the two sides' interests are not diametrically opposed, the atmosphere in integrative negotiations is likely to be less hostile, and less characterized by mutual suspicion and distrust, than is typically the case in distributive negotiations

(De Rue et al. 2009). Therefore, in this thesis, I will concentrate on integrative aspects of negotiation strategy.

2.4.3 Negotiation Tactics

According to the given criteria such as time, resource and behaviour, the tactics are the set of utility functions that decide the sequence of offers (Faratin et al. 1998; Faratin 2000). In other words, tactics provide the negotiators with systematic ways of making concessions. A negotiation strategy is formed by incorporating one or more strategic tactics mainly time dependent tactics, resource dependent tactics, and behaviour dependent tactics (Faratin 2000; Lau et al. 2006). The negotiation tactics are a set of functions that determine how to compute the value of each used attribute in negotiation (Romanhuki et al. 2008). These tactic functions have their own proper behaviour properties (Faratin et al. 1998).

Faratin et al. (1998) define a range of computationally tractable heuristic strategies and tactics that negotiating agents can employ to generate initial offers, evaluate proposals and offer counter proposals in multi-attribute negotiations (Kebriaei et al. 2011). The tactics are simple functions that are used to generate an offer, or counter offer, based on different criteria. A strategy is the way in which an agent changes the weights of the different tactics over time. In the negotiation model agents propose offers alternatively following their strategies. Each agent has a scoring function that is used to rate the offers received. If an agent receives an offer that has value greater than the value of the counter offer that it is ready to submit in the next step, then it accepts. Otherwise, the counter offer is submitted. The negotiation tactics include time-dependent tactics, resource-dependent tactics and behaviour-dependent tactics.

In the time-dependent tactics, an agent submits offers that change monotonically from the minimum (best) to the maximum (worst) of the deal that it can agree on, and the rate of change depends on time (Kebriaei et al. 2011). If an agent has a time deadline by which an agreement must be in place, these tactics model the fact that the agent is likely to concede more rapidly as the deadline approaches. The shape of the curve of concession, a function depending on time, is what differentiates tactics in this set (Faratin 2000; Burato 2010). Faratin et al. (1998) distinguish two families of the changing rate functions, with the rate of change being a polynomial or an exponential function of time. By varying the parameters, the functions can model that agent to be more of a Boulware or a Conceder. Bargainer is a boulware if it does not concede until close to the last moment, and a bargainer is a Conceder if it gives up quickly. Agents are capable of adjusting their behaviour during a negotiation; however, currently they do so according to time-dependent tactic functions only. Additional tactics were introduced to improve the results of the negotiations. Such tactics are behaviour-dependent or resource-dependent, taking situational factors into account. For example, an employer's agent might change its behaviour in creating offers depending on the number of employees' agents available on the marketplace. If there are many employees' agents, then the employer's agent may be less willing to make concessions quickly because other agents are waiting as potential partners if the ongoing negotiation fails (Kurbel 2004).

The resource-dependent tactics are similar to the time-dependent ones in which time are the sole considered resource. The resource-dependent tactics are similarly modelled as time-dependent tactics and may use the similar functions. The difference is that the resource-dependent tactics either, (i) have dynamic value of the maximum available resource, or (ii) make the changing rate function depend on an estimation of the amount of a particular resource.

The behaviour-dependent tactics compute the next offer based on the previous attitude of the negotiation opponent. These tactics are especially important in cooperative problem solving negotiation settings, or integrative negotiations, by allowing agents to consider the other agents' behaviour (Faratin et al. 1998). The main difference between the tactics in this family is in the type of imitation they perform (Faratin 2000; Kebriaei 2011). Here imitation entails replication of opponents' behaviour. One family imitates proportionally, another in absolute terms, and the last one computes the average of the proportions in a number of previous offers (Faratin et al. 1998; Faratin 2000). In situations in which the agent is not under a great deal of pressure to reach an agreement, it may choose to use imitative tactics to protect itself from being exploited by other agents. In this case, the counter-offer depends on the behaviour of the negotiation opponent. The imitation of others' behaviour can thus serve as a default action when an agent is uncertain about what to do next. The tactics in this family differ in which aspect of their opponent's behaviour they imitate and to what degree the opponent's behaviour is imitated (Romanhuki et al. 2008).

Negotiators may also use their own defined strategies to analyse the current situation during the sequential interactions. Assuming a context in which alternating offers and counter offers are made, the strategy must determine those offers and counter offers generated during the negotiation process (Chen et al. 2006; Jiaxing et al. 2007). The properties of negotiation strategies should be sophisticated enough to instruct negotiating agents to make reasonable concessions and counter offers. The negotiation deadline has to be involved in the real life cases, so the agents have to deal with strategy with time concern (Sandholm and Vulkan 1999). Agents may need to modify their negotiation strategies or tactics, when the market situations changes or their expectations and criteria on offer evaluations as well as counter-offer generations in order to maximise their profits (Ren 2009).

To address the shortcomings of Faratin et al. (1998) strategies, more recent literature specifically deals with uncertainty. To this end, (Brzostowski and Kowalczyk 2006) propose a strategy that performs on-line prediction of opponent behaviour, by assuming that the opponent uses a strategy that is a weighted combination of time and behaviour-dependent concession. However, their negotiation environment contains no discounting factor, and so their solution assumes that the best approach is to reach an agreement at the deadline. In negotiations where the opponent is unknown, many existing strategies attempt to model the opponent. Commonly, this involves learning either the opponent's preferences (Coehoorn and Jennings 2004; Hindriks and Tykhonov 2008; Robu et al. 2005) or classifying the opponent (Lin et al. 2008) using techniques such as Bayesian updating or kernel density estimation. However, in domains with many issues, this approach becomes computationally expensive, and may be unnecessary in automated negotiation where time constraints are based on real time rather than the number of interactions. Under such constraints, there is no benefit to limiting the number of offers exchanged; hence it may be possible for automated agents to exchange thousands of offers in order to explore the negotiation space.

2.4.4 Negotiation Utility

The utility function is a mathematical representation of an individual's preferences with respect to the possible outcomes. The utility function is used to determine how good an offer or a counter offer is. It provides the essential information for agents to decide whether an offer should be accepted or not (Chen et al. 2005). A negotiation may often involve multiple issues on which a group of agents need to agree. These issues are directly or indirectly interdependent through their complex evaluation or utility functions. Due to the complexity of utility functions it is normally infeasible for negotiating agents to learn sufficient from their interactions to fully comprehend their opponent's utility function. The preferences are usually determined by the utility functions that assigns to each possible result a level of satisfaction achieved from consuming a service or purchasing a product (Brzostowski et al. 2007). The requirement of utility function is vital because the aim of a negotiation is to get as high utility as possible (Keeny and Raiffa 1976; Luce and Raiffa 1957) assuming all other constraints such as the deadline and the knowledge about the opponent. The theory of utility function has been vastly used in multi-agent interactions for the automated agents who negotiate on behalf of their users (Braun et al. 2006; Jennings et al. 2001; Kowalczyk 2000; Kraus 2001; Rosenschein et al. 1994; Brzostowski et al. 2007). If preferences of an agent are rational in a precise sense, then a utility function can be constructed to guide the decision-making process of that agent.

During a negotiation with time constraint, a negotiation decision function is usually predefined by negotiators to express their expectations on negotiation outcomes in different rounds (Ren et al. 2012). Negotiation decision functions can be combined with negotiators' utility functions to generate offers precisely and efficiently to satisfy negotiators expectations in each round.

Much work in utility elicitation (Buffett et al. 2004; Chajewska et al. 2000; Haddawy et al. 2003) has lately focused on determining utilities of the user on whose behalf the negotiation agent works. But not much has been done to resolve the opponent's preferences. In Fatima et al. (2004)'s the multi-issue negotiation model the negotiation process is divided into several negotiations where several issues are settled together as package deal and some separately. The utility determination for those negotiations is complex. Fatima et al. (2004), Coehoorn and Jennings (2004) attempt to learn the opponent's preferences and construct counteroffers that are likely to be of interest to the opponent. This is done by making trade-offs that do not lower the agent's utility, but match more closely with the opponent's previous offers. While this method is likely to allow the negotiators to come to a deal more quickly, it is a cooperative approach and not meant to reveal information about the opponent that can be exploited (Buffett et al. 2005).

2.4.5 Negotiation Pareto Efficiency and Equilibrium

Two criteria, Pareto efficiency and equilibrium, are used to assess the quality of the agreement produced by the negotiation process. Pareto efficiency is a key criterion for measuring the degree of agreement or a useful evaluation criterion in a negotiation process (Rosenschein and Zlotkin 1994; Chen et al. 2002). In this respect, Pareto efficiency is achieved by a strategy combination that increases the payoff of one agent without reducing the payoff of another agent (Chen et al. 2002). So a solution is said to be Pareto efficient if no agent can be better off without sacrificing the other's utility (Jennings et al. 2001). If an agreement meets the requirements of the Pareto efficient concept, it means that the solution produced by the participating agents maximises the negotiation efficiency. But generating Pareto efficient solution in multi-issue bargaining is a computationally complex problem, especially when autonomous agents have incomplete information about deadlines, outside options and the opponent's preferences. For a multi-issue negotiation setting, the ideal solution is one that is Pareto efficient (Lai et al. 2006). An efficient negotiation strategy should thus be able to produce Pareto optimal solutions for multi-issue negotiation (Kalady et al. 2008). So, I can say a multi-issue negotiation model is efficient when agents reach a Pareto efficient agreement in the negotiation. If a solution complies with the concept of equilibrium, it indicates the solution is a stable one and no agent has a desire to change its decision. The strategies chosen by all players are said to be in Nash equilibrium if no player can benefit by unilaterally changing his strategy. The ultimate goal of developing an effective automated negotiation process is to generate a result that complies with the above two concepts.

2.5 Limitations in package, separate and simultaneous negotiation procedures

There are limitations in package and separate negotiation procedures when multiple inter-related issues are involved. Agent negotiation over multiple issues is often seen as the process of searching for a solution in a complex and large space. Multiple issues can be interdependent in a negotiation scenario. Evaluating the preferences of the agents over interdependent multiple issues and the offers in existing simultaneous negotiation processes require nonlinear utility functions to carry it out. The search space produced by these functions is large and complex. Depending on the negotiation mechanism such search space can be dynamic where negotiations often break down and disagreement ensues. Raiffa (1982), states that the in-bundle package procedure requires complex computations to be carried out and it has not been deeply analysed up to now (Giunta and Gatti 2006). Lai et al. (2004) also stated that finding a precise solution to the in-bundle package procedure is an intractable problem because of its large search space. Based on an incomplete information assumption, Fatima et al. (2004) discussed two procedures for multiple-issue negotiation: issue-by-issue and package deal. For two-issue negotiation, they determined the equilibrium strategy for these procedures and analysed the optimal agenda and procedure. They concluded that the package deal is the procedure that provides agents with optimal utilities for two-issue negotiation. They did not address the computational cost with increasing issue size. However, the computational cost becomes crucial when more issues are involved (Giunta and Gatti 2006). The limitations of package, separate and simultaneous procedures in multi-issue group negotiation give scope for issue-by-issue negotiation procedure implementation.

2.6 Scope in Issue-by-Issue negotiation procedure

Multi-issue automatic negotiation in groups has several aspects. In many cases, different group of agents have different preferences in relation to the multiple issues, but the same value is accepted by them both. Both sides of the negotiation want to search for a concession agreement. Multi-issue automatic group negotiation is significantly more complex than single-issue negotiation. To reduce this complexity, the issue-by-issue method can be a useful approach. But questions arise as to when or in which situations this approach is more efficient than the other procedures. The identified situations are stated below (Abedin et al. 2012):

- A negotiation consists of the participants called agents. Each agent or group of agents having their own preference or goal. Each agent has an associated amount of benefit or gain during the negotiation, called utility. Utility measures the degree of satisfaction an agent derives from the conflicting situation. The utility function is a mapping of an agent's choices into a real number. In multi-issue negotiation, the preferences of an agent about the multiple issues may be complex. A conventional way to deal with this is to characterise the preference with a utility function (a mathematical formula) and agents then make decisions based on this utility function. However, it is difficult to construct such a utility function about multiple issues, especially when one agent's preference on an issue differs from the preference of the other agents. Multi-issue negotiation may get lengthy or in some circumstances become intractable. Negotiation delay may occur when there are conflicting preferences between the agents (Lai et al. 2004).

- In multi-issue negotiation the solution space is n-dimensional (n>1), but it is 1-dimensional in single-issue negotiation. The negotiation strategy in multi-issue negotiations becomes complex, because the space is n-dimensional. Multiple issues normally form a large and complex search space (Abedin et al. 2009). The search space to consider the possible outcomes and interactions in order to identify the equilibrium solutions grows combinatorial. Uncertainty and different opinions among the agents can occur during the negotiation to find an agreement zone, which delays the negotiation timeline. Issue-by-issue negotiation can make the problem much simpler and minimise the search space.

- Resource limitation is one of the reasons to choose an issue-by-issue approach. Negotiators and the system are often constrained by: limited computational resources; lack of time, and, limited or incomplete information about opponents. This situation is usually characterized as one in which the agents have bounded rationality (Simon 1982). If negotiating all issues at the same time will not work for resource and information limitation reasons it can be expressed as saying that bounded rationality is a reason for choosing a sequential issue-by-issue approach. Resource limitations make sequential bargaining — where negotiators address the various issues in some sequence — a more realistic possibility and such bargaining tend to be the norm in practice (Kteily et al. 2013).

- Some of the research work which was mentioned earlier studied the properties of issue-by-issue negotiation and the differences between that and simultaneous negotiation. But not many have addressed the problem of agenda formation in negotiation. Fatima et al. (2003) looks at agenda selection using a mediator. The measure of utility is the time taken. Most of the research work of this area has focused on designing axioms, e.g. Nash axioms. The review in Lai et al. (2004) shows that issue-by-issue is applicable in some conditions where negotiation time is valuable, profitable or the probability of breakdown is high and the agents are heterogeneous.

- Initially, an initiator prefers an issue-by-issue approach since it has not yet obtained much information about the opponent and thus does not have enough confidence to deal with the issues in package deal or simultaneously (Soh and Li 2004).

The main current open problem of the issue-by-issue approach relates to the determination of the optimal *agenda* (i.e., the sequence of issues over which the bargaining is carried on) (Giunta and Gatti 2006). The negotiation agenda in a group negotiation can be important for the issue-by-issue procedure as it has an impact on the outcomes. The ordering of negotiation by negotiating issues in a pre-defined order or by deciding which issues to negotiate one by one, can, in some scenarios, improve the utility of the agents. Agenda based negotiation can be added as one of the main approaches in automated negotiation if its efficiency and effectiveness can be proved (Abedin et al. 2012).

2.7 Related Works in Agenda Based Negotiation

The following researchers have used an agenda approach as a part of their various negotiation procedures in different ways and some of their contributions are discussed below:

Fershtman (1990) considers a circumstance where two players bargain over two issues linearly. In his bargaining procedure the players have time preferences and their utility function is additive. Fershtman explained that the players expected bargaining outcome depend on the agenda and each player prefers an agenda to bargain the least important issue first, if that issue is the most important one for the opponent. The impact of the agenda disappears as players become more patient.

Bush and Horstmann (1997) show, if the agreements are implemented sequentially the impact of the agenda remains. In their bargaining model the easy issue is bargained first while implementing the agreements sequentially. On the other hand the hard issue is bargained first when the implementation of agreements is simultaneous.

Inderst (2000) considers a bilateral bargaining agenda which is purely endogenous and the issues are bargained simultaneously. The agenda can have an important impact on the trade-offs between the issues and this impact remains even if the players become very patient. Still multiple equilibriums can arise if at least one uncertain issue appears.

Fatima et al. (2003) have proposed a model where the order in which issues are bargained over and agreements are reached is determined endogenously. This allows the bargainers to decide which issue they will negotiate next during the process of negotiation. Negotiation delay may occur when there are conflicting preferences between the agents.

In and Serrano's (2004) work pointed out that strict issue-by-issue negotiation may increase inefficiency. Their model considers the effects of agenda restrictions on the properties of the equilibrium outcome and the outcome turns out to be Pareto-efficient when the agents are not restricted. Otherwise multiple equilibriums and delays can occur in the agreement.

Kalady et al. (2008) investigate the impact of a variety of agendas and procedures on the negotiation outcome. A negotiation strategy for both package deal and issue-by-issue negotiation procedures is defined in their work which is highly abstract as it identifies only the actions of the agents without describing either the propose or the concede strategies.

Lastly, Tiedemann (2009) explored the importance of the sequential bargaining agenda using a bilateral two-issue alternating offer model under complete information settings. In their approach the inefficient sequence emerges endogenously only when players are relatively patient and their preferences are relatively similar.

These approaches reach a Pareto efficient solution when each agent assumes the preferences of the other agents. But they do not deal with the situation where agents can manage, without prior assumption, their own and their opponents' different preferences over multiple issues (Abedin et al. 2012).

In most existing issue-by-issue researches, issues have been considered independent and their probable effects on each other have been neglected. Multiple issues may belong to one of two classes: ordered, and unordered. Ordered issues have an ordering that is common to and known by agents, though the agents may have different preferences over the issue values. So the common sequence or the order of issues over which the bargaining is carried on is called the agenda approach in this research. Conversely, unordered issues do not have a common ordering and is basically used in package or simultaneous procedures. An agenda is necessary to determine the order in which the issues will be negotiated in a sequential issue-by-issue procedure. This work has taken account of the differing importance of the issues that are significant in agenda setting. The importance is considered in terms of requirement for the issue to be settled. Different agents may have different opinions regarding the importance of the issues. This can lead to an interesting case since this allows for integrative negotiations. However, only a limited literature exists on this approach in game theory (Jennings et al. 2001). Usually, either the issues are considered of equal importance or the players are considered to have identical preferences. In Ponsati and Watson, (1997) it is assumed that preferences are additive over issues, implying that the multi-issue bargaining problem is equal to the sum of the bargaining problems over the separate issues. Fershtman (1990) considers sequential bargaining over two issues. He states that, when using Rubinstein's (1982) alternating-offers protocol for each issue in a sequential order, each player prefers an agenda in which it’s least important issue is the opponent’s most important. Particularly, it is shown that the sub game-perfect equilibrium outcome for this problem does not need to be Pareto-efficient (Ponsati and Watson 1997).

The above investigation shows that the agent not only depends on its negotiation parameters but also can be influenced by the agenda. An agenda which considers different preferences over multiple issues can play an important role in automated negotiation. Determining such an agenda based negotiation approach is the main aim of this research.

2.8 Scope in Agenda Based Negotiation

There is a need for an approach which considers the above factors and implements an agenda based sequential issue-by-issue negotiation process. Alternating-offers bargaining on multiple issues are considered a hard problem to address (Lai et al. 2004). This is mainly due to difficulties in finding computationally tractable negotiation mechanisms that produce Pareto efficient agreements. The proposed model considers the above factors and allows negotiators to deliver multiple offers to match their preferences over issues. In this way, negotiators have more chances to reach agreements.

In addition to the negotiation elements such as negotiation protocol, strategy and utility; a pre-negotiation group decision-making model is proposed in this thesis as an important part of the negotiation process since it offers the negotiators the essential preference information for making decisions on issues related to service or products. A number of exiting negotiation methods worked on issue-by-issue basis, where the utility functions can be computed independently for individual issues. However, in some cases utility needs to manage a set of interdependent issues, which is not possible in a simple issue-by-issue form designed in previous research work. A more complex form of issue-by-issue negotiation is required to solve the interdependency influence of the issues. For these reasons, effective design of negotiation strategy and its contextual protocol is required in an issue-by-issue negotiation approach. By employing the proposed negotiation strategy and an agreed protocol, the agents are able to maximise their own utilities as well as joint welfare. The proposed agenda based approach is one of the potential methods for locating equilibrium via issue-by-issue negotiation.

The outcome of single issue negotiation depends mostly on the negotiation strategies of the agents. But the outcome of multi-issue negotiation does not only depend on strategies. The main goal of this research is to design an effective model for multi-issue negotiation to illustrate that beside the strategy and the negotiation procedure, the outcome may also depend on the agenda. In this research the term, agenda, refers to the set of issues under negotiation and the order in which they are negotiated. An agenda can be defined either exogenously or endogenously (Kalady et al. 2008). If the order is decided by the agents before the issues are negotiated then the agenda is called exogenous. On the other hand, if the agents are allowed to settle on what issue they will negotiate next throughout the process of negotiation, then the agenda is called endogenous.

A number of researchers used the exogenous and endogenous agenda method to process negotiations (e.g.), Busch and Horstman 1997, Fershtman 1990, Inderst 2000, Lang and

Rosenthal 2001. Their methods focus on the selection of issues in sequential or simultaneous procedures for the agenda selection problem, which is based on splitting the multiple issues into many single issues. Some assumptions were made and simple scenarios constructed in order to carry out the mathematical calculations for issue-by-issue negotiation. Fershtman (1990) utilized the exogenous agenda to extend Rubinstein's (1982) bargaining model with complete information for splitting a single pie into multiple pies. His assumption is that both players have identical discounting factors and there is no negotiation deadline. Inderst (2000) used an endogenous agenda to carry out a similar work in a complete information negotiation. In and Serrano (2004) also introduced an endogenous unrestricted agenda to extend Rubinstein's alternative offer game. Fatima et al. (2004) presented a multi-issue endogenous agenda model to analyse the effect of deadlines and discounting factors on issue-by-issue negotiation. This protocol requires that one of the agents starts by making a combined (all issues) offer. The opposite agent can accept or reject part of the offer (one issue or some of the issues) or the complete offer. If one issue or part of an issue has been accepted then subsequently agents make offers only on the remaining issues. Negotiation ends when an agreement is reached on all of the issues or when the deadline is reached. This approach provides an effective way of solving conflicted preferences over the agendas and ordering negotiation issues.

The disadvantages of both the exogenous agenda and endogenous agenda used for the above work are the lack of flexibility and generosity (Busch et al. 1997; Fershtman 1990; Inderst 2000). The exogenous agenda can be applicable to particular scenarios where the order of negotiation issues has been confirmed. On the other hand, it may be that neither the exogenous agenda nor endogenous agenda can deal with negotiations involving complex multiple issue situations where there is difficulty in determining the order of the issues. Fatima's (2003) endogenous agenda model allows the whole set or a subset of negotiation issues to be ordered by a proposed simultaneous procedure. The efficiency of this model is not discussed by Fatima but it could be more efficient than an exogenous agenda as the negotiation can take place without the delay introduced by pre-negotiation over the order of the issues. Pre-negotiation stage in an exogenous agenda is introduced where the players have different preferences over the ordering of the issues.

According to Flamini (2007) a simultaneous procedure should be the prevailing choice; in that it both saves time and makes full use of all valuable trading opportunities across all issues. The negotiators, however, cannot deal with multiple issues at the same time due to each negotiator having different preferences among the multi-issues. In simultaneous procedures the barriers are similar to those of the traditional bargaining theory, in that they may need a learning mechanism. However, the limitation of Fatima's et al. (2003) method is the lack of a learning ability that can learn about an agent's beliefs about an opponent's intentions. Without the learning mechanism, the method may not be able to produce efficient and effective negotiating results, and a mechanism is required to re-evaluate the quality of their results for further improvement (Lau et al. 2006; Abedin et al. 2012).

The agenda based approach specifies how the issues will be settled. Agents can employ either an issue-by-issue (one-at-a-time) approach, or a packaged approach in the negotiation agenda (Fatima et al. 2004). My model has adopted the former; negotiation one issue at a time. The main reason for this is lack of knowledge about the opposing agents. As one issue is settled, the agent subsequently negotiates the other pending issues. This allows the agent to be cautious and opportunistic at the same time. For a multi-issue negotiation under incomplete information settings, the ideal solution is one that is Pareto optimal. A solution is said to be Pareto optimal if no agent can be better off without sacrificing the other's utility (Wilkes 2008). So the proposed negotiation approach should be able to generate Pareto optimal solutions for multi-issue negotiations. The majority of the existing work on multi-issue negotiations focuses on the negotiation strategy, assuming the agenda and the procedure to be predetermined (Fatima et al. 2004; Lai et al. 2004). Depending on the scenario under which the negotiation is taking place a supervised agenda procedure can have a positive impact on the outcome of the negotiation when compared to a procedure without the use of an agenda.

In the present work, this proposed model consists of issue-by-issue agenda based approach for a group of agents in a multi-issue negotiation setting. It shows how an agenda affects the outcome and makes it easy for the agents to find a common zone.

The impact of the agenda procedure along with the strategy on the outcome is illustrated in a real environment. The agent's preference order is used as a base case for providing the optimal agenda-procedure combination.

2.9 Summary

To develop an efficient automated negotiation model, selecting and integrating the most appropriate negotiation procedure and approach, negotiation elements such as protocol, strategies and utility decision functions are mostly required. This selection depends on the context of the negotiation. This research aims at improving existing automated negotiation approaches in order to facilitate the negotiation process by introducing a preference ordering technique in a group decision-making environment. The proposed agenda approach is based on mathematical methods to determine the negotiation offers. The agenda approach provides a way of using a sequential mechanism to manage the complexity of multi-issue negotiation. With such an approach, a part of the protocol is the determination of the order in which the issues will be negotiated in the resulting issue-by-issue negotiation. For multi-issue negotiations, the search space is typically complex and large, and with little *a priori* information on its structure. This research direction is to address this problem using an agenda based negotiation approach supported by a group decision-making method. This decision-making method helps to order the issues even if different agents have different preferences. It helps to reach a consensus when the preferences of the agents are diverse. The agenda based mechanism uses the result of the group decision-making method in putting the issues in order. The next chapter discusses the multi-issue group decision-making process.

In summary, this chapter deals with the main concepts of automated negotiation and the potential problems in the process of negotiation. This chapter also describes the general concept and descriptive approach of negotiation protocol, negotiation strategy, and negotiation mechanism.

Chapter 3

A Multi-Issue Fuzzy Group Decision Making Process

3.1 Introduction

Negotiation is a form of interaction among agents in which a group of agents with a desire to cooperate but with potentially conflicting interests seek to reach agreement on a set of alternatives or services (Soh and Li 2004; Abedin et al. 2012). Automated negotiation consists of such a joint decision being automatically decided by the autonomous agents. In a multi-issue negotiation process, it can be useful for agents to reflect each other's preferences for their mutual benefit. The information about the issues provided by the agents can be of a diverse nature. As every agent has their own ideas, attitudes, motivations and personality, it is quite natural to think that different agents will provide their preferences in different ways and formats. The proposed negotiation approach is regarded as decision-making under uncertainty, based on multiple issues of quantitative and qualitative nature, where the imprecise decision-makers judgements are represented as fuzzy numbers.

Group decision-making processes which resolve conflicts and involve two or more parties over multiple issues can be used as a vital part of cooperative negotiations. Not many researchers have addressed the activities of group decision-making in the negotiation stage. Currently, two schemes are used to model group decision-making: one is based on an aggregation-and-ranking procedure (Cheng 1999; Huynh and Nakamori 2005), by which the "best" alternative or service is chosen after a ranking process. The second one is based on a consensus-reaching orientated solution (Herrera 1996; Herrera-Viedma 2007). This proposed model is based on both, a consensus reaching oriented scheme which involves aggregation and ranking techniques. The consensus is also refined in that the degree of consensus is also obtained. The consensus is used to evaluate the preference ordering of the issues. The group of agents may prefer to negotiate each issue separately according to an agenda because negotiating several issues at once can be too complex (Lai 2004). The order in which the issues are negotiated in issue-by-issue negotiation is specified by the derived preference ordering.

This ordering is called the negotiation agenda. The process of ordering the issues with respect to the agents' group preferences is considered as a multi-issue group decision-making problem in this research.

A group of agents may have opposing preferences or conflicts over the issues at the beginning and then move towards agreement by a process of concession-making (Sierra 1999; Abedin et al. 2012). It is difficult to reach optimal agreements in multi-issue negotiations when the agents' preferences for the possible issues are not common knowledge. Self-interested agents often end up negotiating inefficient agreements in such situations (Saha and Sen 2007). The proposed preference ordering method in the multi-agent negotiation model can be seen as a group decision-making process which takes into account how a group of agent works together in reaching a decision. A multi-issue negotiation may result in win-win agreements if the agents have mutually non-exclusive objectives and provide a high degree of information sharing (common knowledge) between the agents. In this approach, I assume the common knowledge is explicit (e.g. preferences, utilities etc. is disclosed by fully cooperative agents). A group of agents try to learn the preferences over the issues by using a qualitative approach for decision-making rather than employ heuristics and learning mechanisms. The proposed agenda model is based on a consensus forming scheme which involves preference aggregation, negotiation protocols and negotiation strategy. The consensus is also refined in that the degree of consensus is also obtained. The consensus degree is used to evaluate the preference ordering of the issues. This chapter represents the consensus forming scheme which involves the preference ordering process.

3.2 Existing Group Decision-Making Approaches

In the existing works on multi-issue negotiation research investigations have not used any specific mechanism or preference ordering method in an agenda based negotiation process to determine and investigate the choice of the issue sequence in a group negotiation environment. Multiple attribute decision-making methods are widely used for group decision-making including qualitative and quantitative methods, such as, two dimensional strategic matrixes, Analytic Hierarchy Process (AHP) (Triantaphyllou 2005), Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS)

(Chu 2009), VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian, means Multi criteria Optimization and Compromise Solution) method (Opricovic 1998; Opricovic and Tzeng 2007), which can be used to make decision. But these methods, most of the time, cannot reflect the attitude of the majority of the decision-makers during the process of group decision-making (Abedin et al. 2011). On the contrary the proposed preference ordering approach is a hybrid method where the weight preference matrix of the issues and the aggregated group preference ordering is obtained by using Fuzzy Ordered Weighted Averaging Operator (FOWA) operator, fuzzy quantifiers and fuzzy linguistic concept under the fuzzy environment where the vagueness and subjectivity are handled with linguistic terms parameterized by fuzzy numbers (Yager 1988; Zadeh 1983) and introduces a consensus solution which reflects the maximum attitude of most decision-maker agents (Abedin et al. 2011). The two fuzzy quantifier-guided choice strategies which are applied on the weight preference matrix to determine the common sequence and importance of the issues are: quantifier guided dominance degree (QGDD) and quantifier guided non-dominance degree (QGNDD) (Chiclana 2001; Herrera-Viedma 2007).

One of the differences between the proposed fuzzy approach in the preference ordering process and those existing approaches already proposed is the use of linguistic preference relations and its application to model users' preferences and issue weights. Uncertainty factors often appear in a group decision process (Lu et al. 2007). The main two uncertainty factors involved in a group decision-making process are identified in this paper. They are the individual's preferences for the issues and the weight of the issues in the assessment. The proposed approach deals with these uncertainty factors and generate a satisfactory group decision. Consensus measurement methods are introduced into the approach to measure the degree of consensus. A decision-maker agent should express its preferences in terms of the relative importance of the issues, and one approach is to introduce issue weights. These weights may not have a clear economical significance, but their use provides the opportunity to model aspects of decision-making (the preference structure). In this research, the "importance weight" which represents the relative importance of an issue is considered as a significant aspect. The proposed preference ordering method resolves the above aspects which differ with the other existing works.

The normalized value in these methods does not depend on the evaluation unit of an issue function, where the other methods depend on the evaluation unit (Chu 2007). The traditional QGDD and QGNDD methods do not take into account the relative importance of the issues which is the issue weights and the consensus degree among the agents. For this reason the proposed fuzzy approach has been applied which takes account the above decision-making issues in a fuzzy environment. Individual preferences which are used to derive issue weight and group preference differ, therefore, the aim is to settle the differences on various issues preferences and construct a common preference ordering of multiple issues by maximising the consensus of group preference (Abedin et al. 2011).

One of the most crucial problems in many decision-making methods is the precise estimation of the pertinent data. Very often in real life decision-making applications data are imprecise and fuzzy. A decision-maker agent may encounter difficulty in quantifying and processing such linguistic statements (Carlsson 1996; Cheng 1999). Therefore, a fuzzy preference concept along with linguistic terms helps the proposed decision-making approach to deal with these problems which uses fuzzy data and methods and additionally helps to maximise the consensus degree. Several programs of research have been carried out on such problems but with a different perspective.

The main feature of the proposed approach is the integration of a Fuzzy Ordered Weighted Averaging (FOWA) method with fuzzy quantifier-guided choice strategies to effectively satisfy a group of agents' requirements. This approach tries to find a solution where the gap between the preference utility of the group and that of the individual is minimum. The derived common preference ordering sequence will support the agent negotiators efficiently to find a negotiation solution in the agenda based issue-by-issue negotiation process.

3.3 A Fuzzy Group Decision-Making Process

Even though implementation of real world negotiations is very hard, the use of soft computing can be an effective approach to automated multi-issue negotiation because of its advantage to investigate, analyse and simulate very complex issues (Sedano 2011). Use of soft computing techniques can reduce the complexity of high-dimensional negotiation to make it closer to real world negotiation (Sedano 2010). A soft computing technique such as the fuzzy approach has been employed to help to improve the effectiveness and efficiency in the proposed negotiation process.

In dealing with a decision process, the decision-maker is often faced with doubts, problems and uncertainties. In other words the use of natural language to express perception or judgment is always subjective, uncertain or vague. To resolve the vagueness, ambiguity and subjectivity of human judgment, fuzzy sets theory (Zadeh 1983) was introduced to express the linguistic terms in decision-making (DM) process. Bellman and Zadeh (1970) developed fuzzy multi-criteria decision-making (FMCDM) methodology to resolve the lack of precision in assigning importance weights of criteria and the ratings of alternatives regarding evaluation criteria. For each variable in the problem domain, an appropriate linguistic label set is chosen and used by individuals who participate in the decision-making process to express their opinions. These setting are known as the linguistic settings. Each element in a set is associated with a value indicating to what degree the element is a member of the set. This value comes within the range [0, 1], where 0 and 1, respectively, indicate the minimum and maximum degree of membership, while all the intermediate values indicate degrees of ‘‘partial” membership (Bevilacqua 2006). This approach helps decision-makers solve complex decision-making problems in a systematic, consistent and productive way (Carlsson 1996) and has been widely applied to tackle decision-making (DM) problems with multiple criteria and alternatives (Wang 2007). In short, fuzzy set theory offers a mathematically precise way of modelling vague preferences as for example when it comes to setting weights of performance scores on criteria. Simply stated, fuzzy set theory makes it possible to mathematically describe a statement like: ‘‘criterion X should have a weight of around 0.8”.

In this section, some related and extended fuzzy approaches and methods used in the proposed model will be briefly described. In the proposed approach, the agents' opinions are described by linguistic terms which can be expressed in fuzzy numbers such as those using triangular or trapezoidal membership functions, because of their simplicity and solid theoretical basis (Grzegorzewski 2005). A fuzzy quantifier (Yager 1988) and a Fuzzy Ordered Weighted Averaging (FOWA) operator are applied to aggregate the importance weights of different issues, which are later used to determine the temporary consensus solution.

3.3.1 Different Preference Formats

The proposed model allows the agents to express their preferences in a flexible way by using different information formats. Providing different individual preference formats to agents to express their individual preferences can reflect agents' true individual preferences more precisely. The information can be represented by means of preference orderings, utility functions, linguistic variables, fuzzy selected subset of all the issues and fuzzy preference relations. The information has to be made uniform (Abedin et al. 2009). Fuzzy preference relations is used as the base in my model because the use of this concept in decision-making situations to present consumer's opinion about issues, appears to be a useful tool in modelling decision processes (Abedin et al. 2009).

An agent on behalf of the group of agents collects the opinions from the consumers where each consumer expresses his/her priorities for the issues. The consumers may adjust their initial preferences according to their judgments and then present their individual preferences for group decision, which is the major and important part in the preference ordering process. The proposed approach provides a mechanism for group decision-makers to express their individual preferences in different formats based on their own attitude, motivation, personality and background (Herrera-Viedma et al. 2002; Abedin et al. 2009).

Some of the preference formats provided to the consumers in the group decision-making process is: preference ordering or ordered vector, utility vector, normal preference relation, fuzzy preference relation, fuzzy selected subset, selected subset, multiplicative preference relation (Chiclana et al. 1998). In preference ordering or ordered vector the issues are ordered from best to worse. Each issue is assigned a numerical value between [0, 1] by the consumer in utility vector format. Selected sub-set (Chiclana et al. 1998) is one of the individual preference formats where issues are selected from the basic issue set and compose a subset. In fuzzy preference relation the consumer's preference relation is described by binary fuzzy relation where the binary relation denotes the preference degree of one issue over the other issue. Often the consumers use their subjective judgments to express their preferences. Fuzzy linguistic terms that contain various degrees of preferences are used to help the consumers to express their opinions more accurately when he/she is in complex or fuzzy situation. This kind of preference are called vector of linguistic variables (Herrera et al. 1996).

In group decision-making under multiple criteria, there are a set of issues and a set of decision-makers or agents. Let $i_m = \{i_1, i_2 \ldots i_n\}$ be a given finite set of issues; $D^k = \{D^1, D^2 \ldots D^l\}$, $l >= 2$, be a given finite set of decision-makers. The decision task is to obtain the group preference ordering of the issues from issue set. It is assumed that agents (consumers and provider) can give their individual preferences directly at this stage. As the agents come from different backgrounds and have their own ideas, attitudes, motivations, and personalities, decision-makers may provide their individual preferences on issues in different formats. The following selected preference formats (Chiclana et al. 1998; Nurmi 1981; Orlovski 1978; Tanino 1990; Tsouki`as 1994; Kwok et al. 2007) are presented in the proposed model:

1. *Ordered vector*: Ordinal preference and cardinal preference are commonly used formats of individual preferences (Huber 1984; Tanino 1990). Ordinal preference can be expressed as ordered vector. The issues are ordered from the best to the worst.

2. *Utility vector*: Cardinal preference can be expressed as numerical utility vector. Each alternative is assigned a numerical value in [0, 1].

3. *Linguistic term vector*: A vector of linguistic terms is used to evaluate the issues. Here, each issue is evaluated by using a linguistic term against some criterion (Kwok et al. 2007).

4. *Selected subset*: Selected subset is one of the individual preference formats (Tanino 1990). Issues selected from basic issue set compose a subset and there is no difference among the issues in the subset. This preference expression method allows agents easily to express their individual preferences.

5. *Fuzzy selected subset*: As agents use their subjective judgments to choose issues, situations may often arise where it is difficult for them to simply choose or reject the issues. In such uncertain case, the yes/no method could not be sufficient. One alternative method is for agents to give belief levels to the selected issues to express this kind of uncertainty (Kwok et al. 2002). The belief levels belong to a set of fuzzy linguistic terms that contains various degrees of preference required by the agents. This kind of preference is called fuzzy selected subset in which each selected issue is associated with a belief level (fuzzy linguistic term). It is an extension of selected subset.

6. *Normal preference relation*: A strict preference relationship between any two-issues. For example, i_1 is preferable to i_2 (Kwok et al. 2007).

7. *Fuzzy preference relation*: Fuzzy preference relation is an extension of normal preference relation. It is the basic preference of fuzzy group decision-making and a binary relation over the set of issues, which reflects the degree to which an issue is preferred to another one (Kwok et al. 2007).

More specifically, different preference formats can be mathematically expressed as:

Ordered vector:

$O^k = \left(o^k(1),....,o^k(n)\right)$, where $o^k(.)$ is a permutation function over index set $\{1, \ldots, n\}$ of the n issues $\{ i_1, i_2 ..., i_n \}$ for agent D^k . The issues are ordered from the best to the worst in the ordered vector.

Utility vector:

$U^k = (u_1^k,....,u_n^k),\ u_i^k \in [0,1],\ 1 \le i \le n$, where u_i^k represents the utility evaluation given by agent D^k to n issues { $i_1, i_2 ..., i_n$ }.

Linguistic term vector:

Linguistic term vector on i : $L = (l_1, \ , l_n)$, where l_i represents the linguistic evaluation given to the issue i_m ={ $i_1, i_2 ..., i_n$ }.

Selected subset:

$S^k = (i_{i1}^k,....,i_{it}^k),\ 1 \le i, t \le n$, where $i_{it}^k \in [i_1....i_n],\ 1 \le i \le n$ is a selected issue.

Fuzzy selected subset:

$S^k = \{(i_{i1}^k, b_{i1}^k), ...(i_{i1}^k, b_{it}^k)\}\ 1 \le i, t \le n$, where $i_{ij}^k \in [i_1....i_n],\ 1 \le j \le n$ is a selected issue, $b_{ij}^k \in B, B$ is a set of belief level in fuzzy linguistic terms.

Normal preference:

A subset of $R^k \subseteq \{i_1....i_n\}.\{i_1....i_n\}$ satisfy certain constraints.

Fuzzy preference relation:

$\mu_{R^k} : \{i_1....i_n\}.\{i_1....i_n\} \to [0,1]$ where

$\mu_{R^k}(i_i, i_n) = r_{ij}^k$ *satisfy* $r_{ij}^k + r_{ji}^k = 1, r_{ii}^k = undefined\ \ 1 \le i \ne j \le n$.

3.3.2 Preference Uniformity

Preference uniformity is an important part in group decision-making process. The proposed approach uses this method in order to aggregate different individual preferences to reach a group agreement. Different types of preference information need to be made uniform or transformed into a common preference format to reach a group decision. The fuzzy preference relation has suitable qualities in aggregation and for generality (Abedin et al. 2009). That is the reason why the proposed approach uses the fuzzy preference relation as the base element of the uniform representation. There are various transformation functions which are used to transform preference ordering or ordered vector, utility vector, normal preference relation, selected subset and multiplicative preference relation into a fuzzy preference relation (Abedin et al. 2009).

Some of the uniformity processes (Kwok et al. 2007) used in this research is as follows:

Ordered vector to fuzzy preference relation:

Let agents D^k's preference *Ordered vector,* $O^k = (o^k(1),...,o^k(n))$. Without loss of generality, it is assumed that the smaller the number assigned to an issue in an ordered vector, the better the issue is from the viewpoint of the agent, and vice versa. For example, an ordered vector $O = (3, 1, 4, 2)$ corresponding to the issues $i_m = \{i_1, i_2 \ldots i_n\}$, means that issue i_2 is the given 1st ranking and issue i_2 the worst ranking.

Obviously, the number assigned to an issue in an ordered vector reflects the agent's preference with that issue. Therefore, it can be assumed that for a agent D^k, his/her fuzzy preference value of issue i_m over issue i_j , r_{ij}^k , depends only on the values of $o^k(i)$ and $o^k(j)$.

The following function can be used to transform the ordered vector into fuzzy preference relation (Chiclana et al 1998):

$$r_{ij}^k = \frac{1}{2}\left(1 + \frac{o^k(j)}{n-1} - \frac{o^k(i)}{n-1}\right), i, j = 1,2,.....n\ ; i \neq j \tag{3.1}$$

Utility vector to fuzzy preference relation:

The following function can be used to transform the utility vector into fuzzy preference relation:

$$r_{ij} = \begin{cases} \dfrac{\left(u_i^k\right)^2}{\left(u_i^k\right)^2 + \left(u_j^k\right)^2} & if\ \left(u_i^k, u_j^k\right) \neq (0,0)(i \neq j) \\ \dfrac{1}{2} & if\ \left(u_i^k, u_j^k\right) = (0,0)(i \neq j) \end{cases} \quad (3.2)$$

Fuzzy Selected subset to fuzzy preference relation:

The following function can be used to transform the Fuzzy Selected subset into fuzzy preference relation:

$$r_{ij} = \begin{cases} 1 & if\ i_i \in S^k,\ i_j \notin S^k \\ 0.5 & if\ i_i \in S^k,\ i_j \in S^k \quad or \quad if\ i_i \notin S^k,\ i_j \notin S^k \qquad 1 \leq i \neq j \leq n \\ 0 & if\ i_i \notin S^k,\ i_j \in S^k \end{cases} \quad (3.3)$$

Fuzzy linguistic terms to fuzzy preference relation:

The following function can be used to transform the Fuzzy linguistic terms into fuzzy preference relation:

Let fuzzy linguistic terms $b_i = (v_i, \alpha_i, \beta_i)$ and $b_j = (v_j, \alpha_j, \beta_j)$, then

$$r_{ij} = \begin{cases} \dfrac{v_i^2}{v_i^2 + v_j^2} \\ 0.5 \\ v_i \end{cases} \quad (3.4)$$

3.3.3 Group Preference Order

The agents involved in the group decision-making process may have differing importance rating associated with the issues of the alternatives. In this case these quantifier guided aggregation operators help to determine an acceptable group solution. To decide the weighting vector of Fuzzy Ordered Weighting Operator (FOWA) operator the concept of fuzzy majority is used. Fuzzy majority is a soft majority concept, which is influenced by the use of a fuzzy logic based calculus of linguistically quantified propositions. Two types of linguistic quantifiers can be distinguished: absolute and proportional. Proportional fuzzy linguistic quantifiers, such as “many, most, at least half, almost all” are used in this approach (Chiclana 2001). The semantics of a fuzzy linguistic quantifier can be captured by using fuzzy subsets of the unit interval, [0,1] for its representation (Abedin et al. 2009).

3.3.3.1 The Fuzzy Ordered Weighted Averaging (FOWA) operator

A FOWA operator of dimension *m* can be defined as a function F as follows:

$$F : [0,1]^m \rightarrow [0,1]$$

where the function associates with a weight vector $W = [w_1, w_2, ..., w_m]$, such that, $w_i \in [0,1], \sum_{i=1}^{m} w_i = 1$ and

$$F(a_1, .., a_m) = W \bullet B^T = \sum_{i=1}^{m} w_i \bullet b_i \qquad (3.5)$$

where $B = [b_1, b_2, ..., b_m]$, and each element $b_i \in B$ is the *i*th largest value in the collection $a_1, .., a_m$. The purpose is to collect the collective fuzzy weight preference matrix $R^c = (r_{ij}^c)$ from the set of individual fuzzy weight preference relations $\{R^1, ...R^l\}$ which are obtained from the normalized opinions over the issues given by the l agents, i.e.,

$$r_{ij}^c = F_Q(r_{ij}^1, ..., r_{ij}^l),\ 1 \leq i \neq j \leq m \qquad (3.6)$$

3.3.3.2 Fuzzy Qualifiers

Fuzzy quantifier Q is used to compute the weights of the FOWA operator and the weights are obtained as follows:

$$w_i = Q\left(\frac{i}{m}\right) - Q\left(\frac{i-1}{m}\right), i = 1,2,.....m \tag{3.7}$$

where Q is defined as

$$Q(x) = \begin{cases} 0 & if\ x \prec a, \\ \frac{x-a}{b-a} & if\ a \le x \le b, \\ 1 & if\ x \succ b \end{cases} \tag{3.8}$$

With $a,b,x \in [0,1]$ and $Q(x)$ indicating the degree of which the proportion x is compatible with the meaning of the quantifier it represents. The relative quantifiers "most" (0.3, 0.8), "at least half" (0, 0.5) and "as many as possible" (0.5, 1) are used in my illustrative example.

Fuzzy QGDD and QGNDD are applied to the aggregated weight preference matrix to determine the common sequence of the issues. Both are based on the use of the FOWA operators.

3.3.3.2.1 Quantifier guided dominance degree

For an issue, the quantifier-guided dominance degree QGDD is used to quantify the dominance that one issue importance has over all the others in a fuzzy majority sense as follows:

$$QGDD_i = F_Q\left(r_{ij}^c\right), 1 \le i \ne j \le m \tag{3.9}$$

3.3.3.2.2 Quantifier guided non-dominance degree

The quantifier guided non-dominance degree QGNDD is also calculated according to the following expression:

$$QGNDD_i = F_Q\left(1 - r_{ij}^c\right), 1 \leq i \neq j \leq m$$
$$where\ r_{ij}^c = \max\left\{r_{ji}^c - r_{ij}^c, 0\right\} \tag{3.10}$$

represents the degree to which one issue importance is strictly dominated by the other issue. QGNDD presents the degree in which each issue is not dominated by a fuzzy majority of the remaining issues (Abedin et al 2009).

Once the $QGDD_i$ and $QNGDD_i$ are calculated then the importance weights for each attribute is obtained. These importance weights of attributes are used further to determine the final aggregated decision matrix which represents the actual opinions or responses from the decision-makers. The temporary solution set for issues is derived by using the ranking method. One of them can be applied depends on the agents decision. Finally the temporary group ranking or group preference ordering is obtained.

The FOWA operator has the ability to aggregate linguistically expressed opinions which is collected from a group of agents. In my proposed approach, I intend to obtain the aggregated weight preference matrix of the issues. The FOWA operator along with the fuzzy quantifiers calculates the group fuzzy weight preference matrix from a set of individual preference relations considering the preferences of the majority without ignoring those of the minority. This helps to obtain a satisfactory group solution in a complex decision-making problem (Abedin et al. 2009; Abedin et al. 2011).

3.3.4 Group Consensus Measure

Group consensus is important in group decision-making. The conventional meaning of consensus is a full and common agreement; however, this is not satisfactory in many practical situations. A degree of consensus, between 0 for full disagreement to 1 for full consensus through all intermediate values, is viewed to be more appropriate. In the context of fuzzy preference relations, the concept of fuzzy majority is employed for "soft" consensus of group decision-making (Fedrizzi et al.1994; Kacprzyk et al. 1992). This soft consensus is used in stage were the temporary consensus solution is determined. A process of improving group consensus is proposed to which will help to increase the degree of group consensus.

3.3.5 A Process of Improving Group Consensus

In this section, the consensus process is presented which has the following main characteristics:

1. It is based on soft consensus criterion: a *consensus degree measure.* This measure evaluates the agreement of the agents (consumers and suppliers) and guides the consensus process. The consensus criteria are defined by comparing the individual solutions with the group solution using as comparison criterion the positions of the issues in each solution (Herrera-Viedma et al. 2002).

2. A consensus improvement process, where the consensus level is evaluated. The difficult part of this process is to find a way of making the individual converges and therefore help the agent to obtain and agree with a particular solution. To do so a consensus level can be fixed in advance. When the consensus measure reaches this level, the derived solution is the final one. If the level of consensus does not reach the satisfaction level, the process can work as an iterative process. The agents' consensus degree process also supports a feedback mechanism, which helps the decision-makers to modify their opinion or preferences to get closer to the group consensus (Abedin et al. 2011). It depends on the decision of the decision-makers whether they want to change their opinions or not. The feedback mechanism will help the decision-makers to know the direction of modifying their opinions and help the group consensus level to reach a satisfaction level.

The process is described in further details in the following subsections:

1. *Consensus degree measure:*

Each consensus parameter requires the use of a difference function, $d\ (V^k, V^c)$. To obtain the level of agreement between the individual ranking obtained for the agents D^k, $V^k = (V_1^k \ldots V_n^i)$, where V_j^k is the position of issue i_j for the k-th agent, and the group ranking $V^c = (V_1^c \ldots V_n^c)$ where V_j^c is the position of issue i_j in that group ranking.

The steps to derive the consensus degree are described below:

a) The group ranking which was obtained in the group preference ordering process is used as a temporary solution here V^c.

b) The individual ranking of the issues for the agent $\{V^k, k = 1 \ldots m\}$ are calculated.

c) The consensus degree of each consumer for each issue $c_k(i_j)$ is calculated by comparing the position of the issue in the consumer's individual solution and the group solution. A function $c_k(i_j) = c(V^k, V^c)(i_i) = f(V_j^c - V_j^k)$ is used for the comparison. I consider *f* as an increasing function and $f(x) = (a.i)^b$, $b \geq 0$, here $a = 1/(n-1)$.

$$c_k(i_j) = c(V^k, V^c)(i_j) = f\left(\left|V_j^c - V_j^i\right|\right) = \left(\frac{V_j^c - V_j^i}{n-1}\right)^b \in [0,1] \qquad (3.11)$$

The parameter b is used to control the rigorousness of the consensus process. Values of *b* near to 1 can decrease the rounds to improve the group consensus. Appropriate values for *b* are .5, .7, .9, 1.

The consensus degree of all consumers on each issues x_j can be calculated by the following equation:

$$C(i_j) = 1 - \sum_{i=1}^{n} \frac{c_i(i_j)}{n} \tag{3.12}$$

Although a mean operator is used to aggregate the consensus degree, but other operators for example OWA operator with the concept of fuzzy majority can also be used (Abedin et al. 2011).

Aggregation of the above consensus degrees on issues will be calculated by using OWA OR-LIKE operator defined by Yager and Filev (1994). It is important to do the aggregation in such a way that the consensus degree of the solution set of issues has more important weight in the aggregation process. This is the reason of using $S_{OWA\,OR\text{-}LIKE}$ operator which allows this kind of aggregation.

$$C(i) = S_{OWA\,OR\text{-}LIKE}\begin{pmatrix} C(i_s); i_s \in X_{sol}, \\ C(i_t); i_t \in X - X_{sol} \end{pmatrix} = (1-\gamma)\sum_{j=1}^{v=1}\frac{C(i_j)}{v} + \gamma.C(i_s) \tag{3.13}$$

Where v is the cardinal of the issue set and $\gamma \in [0, 1]$, is fixed before using the aggregation operator. The parameter γ controls the aggregation in such a way that if γ tends to 1 then consensus degree tends to the group solution of issues.

2. *A consensus improvement process:*

If the consensus level is not reached the required level, an improvement process along with a feedback mechanism can be applied. The consensus degree of agent's individual solution to group solution I_x^i is calculated by aggregating that agent's consensus degree in the issues. This aggregation is also done using OWA OR-LIKE operator.

$$I_x^i = S_{OWA\,OR\text{-}LIKE}\begin{pmatrix} 1-|c_i(i_s)|; i_s \in X_{sol}, \\ 1-|c_i(i_t)|; i_s \in X - X_{sol} \end{pmatrix} \tag{3.14}$$

These values are used to evaluate the agent's individual opinion. Those agents whose individual solution is furthest from the group solution are given feedback by the feedback mechanism. They are asked to consider their preferences on the issues. The agents may or may not agree to modify their opinions according to some rules given by the provider. Those who agree to change their opinions in order to obtain a higher degree of consensus can give their changed opinions and the overall group preference ordering process is applied again over the issues to get the new group ranking. The whole process works as an iterative process until the consensus degree is high enough.

The consensus process depends on the size of the set of issues and the size of the group of the agents. Therefore, when the opinions are homogeneous and these sizes are small then the convergence process is easier to obtain.

3.4 Summary

This chapter presents an approach to build a pre-negotiation protocol which includes preference ordering. This approach gives the decision-makers flexibility to express their opinions on the issues in different preference formats. The different preference formats are then transformed into a unique format which is fuzzy preference relation. Fuzzy concepts are used to aggregate the individual preferences into a group preference ordering relation. The uniformed preferences are aggregated into a collective fuzzy preference relation by adopting the ordered weighted average (OWA) operator based on the concept of fuzzy majority. Then finally to determine the global ranking of the issues, two fuzzy quantifier guided selection processes: dominance degree (QGDD) and non-dominance degree (QGNDD) are applied. An iterative consensus process is built to improve the group consensus degree. The fuzzy group decision-making process constructs a preference ordering of the issues of a service or product. This preference ordering of the issues helps to build up an agenda based negotiation process.

Chapter 4

The Proposed Model

4.1 Introduction

Multiple issues normally form a large and complex search space in a negotiation process. Uncertainty and conflicting preferences between the agents occur during the negotiation process which delay the negotiation timeline and expand the search space (Faratin et al. 2002). To improve this situation an agenda based negotiation approach based on a hybrid fuzzy preference ordering process is proposed. This process will direct the negotiating agents' search for prospective solutions that build on the individual areas of interest but move the agents towards an agreement on their common interest. This issue-by-issue agenda based negotiation can reduce the negotiation delay time and the domain of negotiations (search space) to a position that consists of feasible solutions that take account of the preferences of the participating agents.

The problem addressed in this research arises in many different contexts, in which a group of negotiators have to engage in a sequence of negotiations, where they have differing preference importance on different issues. Agents may have opposing preferences or conflicts over the issues at the beginning and then move towards agreement by a process of concession-making. The proposed model is based on a consensus forming scheme which involves preference aggregation, negotiation protocols and negotiation strategy. The consensus is also refined in that the degree of consensus is also obtained. The consensus degree is used to evaluate the preference ordering of the issues.

If the negotiators choose to negotiate sequentially, the order of the issues in which the negotiations take place will have a significant impact in the negotiation outcome. This ordering is called the negotiation agenda. The proposed negotiation approach introduces an agenda setting phase to determine the choice of sequence in issue-by-issue negotiation. The choice of sequence to be used in negotiation is based on a hybrid preference ordering method. The agenda setting can set the tone and framework for the negotiation outcomes. In this approach the issues have to be negotiated according to the order and settings specified in the agenda. The aim of this research is to investigate how the agenda-setting can be vital to the automated negotiation process. In this chapter, an agenda based negotiation model is proposed. This model incorporates the features identified in the previous chapter. The model adopts the group preference ordering concepts to solve the problems of issue-by-issue negotiation.

The conceptual framework of this model is presented in the 4.2 section of this chapter. Through a description of the components contained in the main structure of the multi-issue negotiation model, the overall picture of the model can be seen in this section. In section 4.3, the details of the agenda approach are described. The negotiation process is composed of an effective negotiation protocol and negotiation strategies. This section also contains a description of how these negotiation mechanisms in the model have been set up, so that the agents' can achieve favourable negotiation outcomes. The chapter concludes with a summary in section 4.4.

4.2 The Conceptual Framework of the Model

In this section, the conceptual framework of the proposed model is explained. There is two phases in the proposed negotiation process: pre-negotiation phase and negotiation phase. In the pre-negotiation phase, the parties identify the issue sequence for the negotiation agenda by using a preference ordering model. The negotiating parties evaluate the conflict preferences in this phase.This accelerates the negotiation process. This phase has been described in detail in chapter 3. In the second phase, the details of the negotiation process are illustrated.

In the pre-negotiation phase, a systematic approach has been proposed to solve the agents' group decision-making problem within a fuzzy multi-agent multi-issue negotiation environment. The group consensus process helps the negotiators resolve their heterogeneous opinions or preferences over issues to avoid conflict and delay during the negotiation stage. The negotiating agents are "sincerely cooperative" in the sense that they willing to effectively look for a compromise, being available, if necessary, to lose something on their private goals in order to reach the model's goal. This is a kind of "game rule" accepted by each agent, entering the group consensus process. At times a group of agents aims to gain a common global goal. On the other hand, a group of self-interested agents with different individual goals have private goals. In the proposed group decision-making process private and global goals do not necessarily concur.

When situations of coordination, conflict and/or positive cooperation take place between two different agents, a negotiation process is established. The proposed negotiation process guides the agents to work towards a global coherent solution. The negotiation process involves autonomous agents who may participate on behalf of 'buyer/consumer' and 'seller/supplier'. Preferences express agent's interest and plan in the negotiation. The natural use of preference ordering suggests a collection of either buyers/consumers or sellers/supplier getting together to provide a shared prepared position in a negotiation. The primary aspect of the position is the preferred sequence of issue negotiation. But this can be split into two by selecting a common ranking of importance and a common view on the way in which importance should be reflected in the issue's sequence (most important first or least important first). The common position can also be established on the negotiation strategy (concede or hard line) although this will only applied to cases in which there is negotiation from a group perspective.

It is also possible to consider the scenario in which there is a common population of traders who buy and sell to each other. In this case the preferences are set up to allow any negotiation between a pair of them to be carried out using an agreed consensus protocol. Given the preferred strategy the aim is to carry out this strategy in actual negotiations.

It is possible to have a pre-negotiation phase in which the protocol of the negotiation is established. There can be several structures for the pre-negotiation phase. (1) Two groups have each reached their consensus on issue preference. (2) One group has reached the issue consensus the other has not. (3) There is a single group of traders. In case (3) there is nothing to be done. In case (1) there can be a meta preference ordering associated with the parameters of the negotiation process. For this meta level the population could be assumed to be undivided and a single preference ordering can be considered. For case (2) the members of the non-coordinated group will have to carry out the pre-negotiation on an individual basis. The scope of the consensus will be different in different cases. Each variety of scenarios has their own scope of consensus. So the consensus building can be carried out for each of the cases with differing uses in the offer-counter-offer stage.

The diagram in Fig. 4.1 represents the current structure and gives an overview of the proposed model. Step 1 to step 6 are part of the fuzzy group decision-making process, described in chapter 3. On the other hand, step 7 is the agenda based negotiation approach. This step will be described in detail in section 4.3. All the steps of the model are stated below:

Step 1: Opinion Collection from Multiple Agents over Multiple Issues for Alternative or Service.

Step 2: Normalisation of Opinions or Preferences using fuzzy concepts.

Step 3: Group Preference Order.

Step 4: Temporary Issue Sequence Solution using Fuzzy Ordered Weighted Averaging Operator (FOWA), Quantifier guided dominance degree (QGDD) and Quantifier guided non-dominance degree (QGNDD) concept.

Step 5: Group Consensus Measurement.

Step 6: Consensus Improvement Process using Feedback.

Step 7: Multi-issue Agenda based Negotiation Approach.

The main steps of the proposed approach are shown in Fig. 4.1.

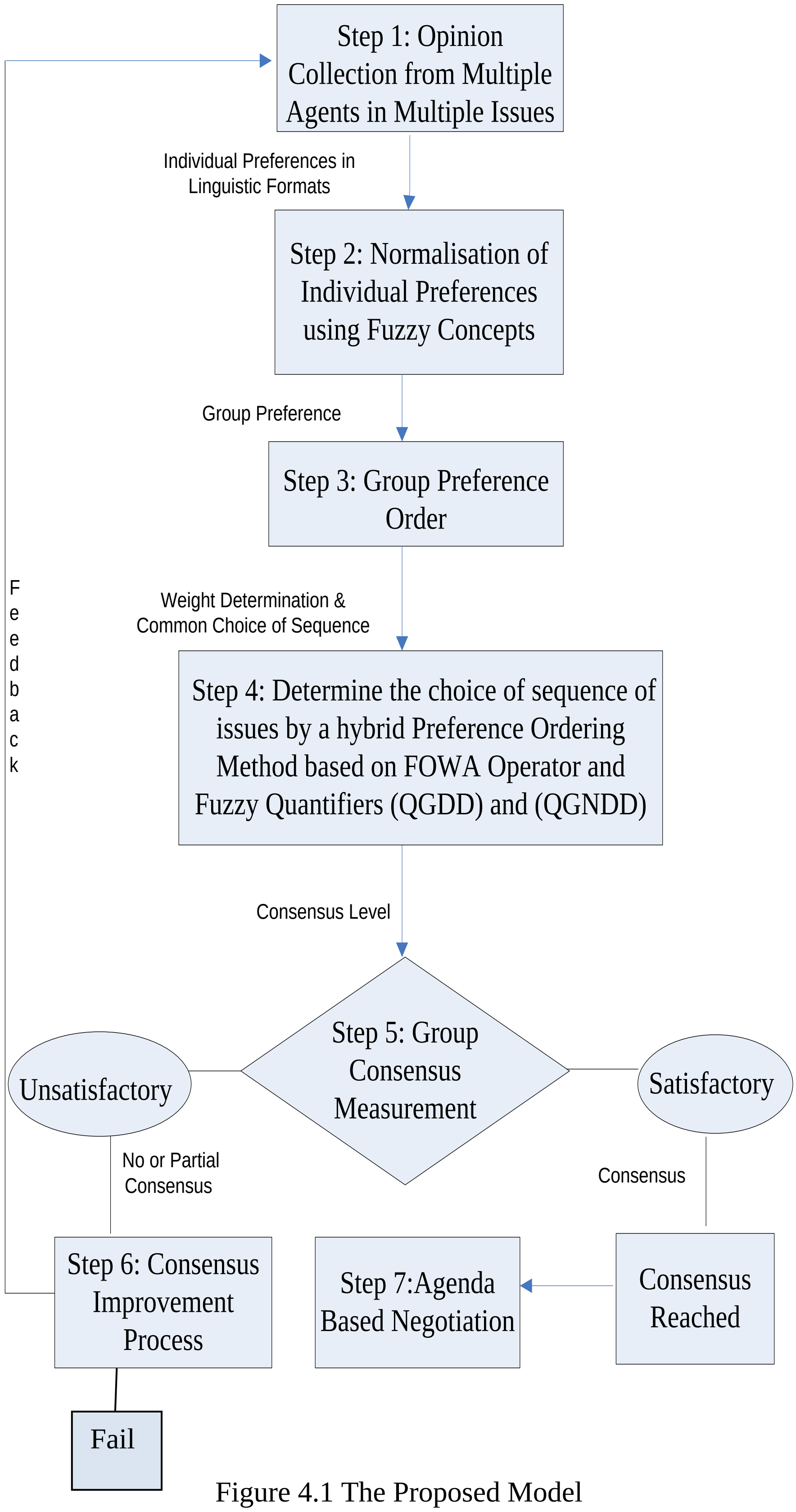

Figure 4.1 The Proposed Model

The description of each component is as follows:

Step 1: Opinion Collection from Multiple Agents over Multiple Issues for Alternative or Service:

Each decision-maker agent of a group is required to express their opinions for the issues with respect to the alternatives or services in the initial step. They also provide their priorities for the weight of the issues. The decision-makers may adjust their initial preferences according to their judgments and then present their individual preferences for a group decision which is the major part of the preference ordering process. The proposed approach provides a mechanism in chapter 3 for group decision-makers to express their individual preferences and the importance weights over various issues for the alternatives or services in different formats as well as fuzzy linguistic terms that contain various degrees of preference. Section 3.3.1 provides the different preference formats to express agents' opinions. Having information about agents' importance weights over negotiation issues can facilitate agents to produce high quality offers in the negotiation process.

Step 2: Normalisation of Opinions or Preferences using fuzzy concepts:

Different types of preference information need to be made uniform or transformed into a common preference format. The fuzzy preference relation has suitable qualities in aggregation and for generality. That is the reason why the proposed approach uses the fuzzy preference relation as the base element of the uniform representation. These transformations functions defined in section 3.3.2 from chapter 3 help the decision-maker agent to normalise their opinions more accurately when it is in complex. In this step appropriate normalisation functions for the importance weight of issues and the individual fuzzy preference for each issue must be defined to normalize the opinions. The membership functions are applied in this stage.

Step 3: Group Preference Order:

Aggregation is an essential process that has to be solved well in a group decision-making problem. The aggregation phase, which is one of the steps of the hybrid preference ordering method, determines a common group preference order. Once the individual preference information on issues is transformed into fuzzy preference relation form, then they are aggregated using defuzzification concepts described in section 3.3.3. Currently, two schemes are used to model group decision-making: one is based on aggregation-and-ranking procedure, by which the "best" alternative is chosen after a ranking process. The second one is based on a consensus reaching orientated solution. The proposed model is based on both, consensus reaching oriented scheme which involves the aggregation and ranking techniques. The degree of consensus is further obtained.

Step 4: Temporary Issue Sequence Solution using Fuzzy Ordered Weighted Averaging Operator (FOWA), Quantifier guided dominance degree (QGDD) and Quantifier guided non-dominance degree (QGNDD) Concept:

Once the group preference ordering is found, the next step is to determine and aggregate the importance weight of different issues using the Fuzzy Ordered Weighted Averaging Operator (OWA) concept. In a real situation, different group members may have different judgements when comparing the relative importance of the issues. Obviously, how the issues are used and how the priority of each issue (the weight) is processed will directly influence the ranking of these alternatives and the selection of the satisfactory group solution. That is the reason why the weights of the issues are determined and aggregated in an effective way in this model. In the approach a weight preference matrix of the issues is obtained by using this Fuzzy Ordered Weighted Averaging Operator (FOWA) operator, a fuzzy quantifier and fuzzy linguistic concept. Two fuzzy quantifier-guided choice strategies are applied on the weight preference matrix to determine the importance of the issues. The two quantifier guided choice degrees for the issues, based on the fuzzy majority concept and OWA are: quantifier guided dominance degree and quantifier guided non-dominance degree. Quantifier guided dominance degree (QGDD) is used to quantify the dominance that one issue has over all the others in a fuzzy majority sense. On the other hand, quantifier guided non-dominance degree (QGNDD) presents degree in which each issue is not dominated by a fuzzy majority of the remaining issues. One of the quantifier-guided choice strategies, either QGDD or QGNDD, is applied to the set of issues to determine the importance weights. After constructing the fuzzy aggregated group decision matrix and the aggregated weight preference matrix, the crisp values are computed for each of their elements. The temporary consensus solution is derived in this stage using the multi-issue ranking index based on the aggregated issue values. The mathematical representation of these two strategies is described in 3.3.3.1 and section 3.3.3.2 from the previous chapter.

Step 5: Group Consensus Measurement:

A soft consensus measure, which is measured in the interval [0, 1] is applied to calculate the consensus level. Instead of using complex measurement methods such as Euclidean distance, L-1 norm distance, the cosine and sine of the angle between the vectors, a simple position comparison approach is applied with the help of OWA operators to measure the consensus level. The detail processes of the consensus measurement with functions are described in section 3.3.4 and section 3.3.5.

Step 6: Consensus Improvement Process using Feedback:

A process of improving group consensus defined in section 3.3.5 is applied in this approach. This consensus process is applied to measure the degree of agreement between the group members over the issues. The consensus degree evaluates how far the group member’s individual solutions are from the group solution. A feedback mechanism is applied when the consensus level is not satisfactory. The proximity measures are used to build the feedback mechanism which helps the decision-makers to modify their opinions in order to get closer agreement between them. This is a convergent process resulting in the group solution, once the consensus degree is high enough. The next step is the initialisation of agenda based negotiation stage based on the common preference order. The proposed group decision-making process will facilitate the issue-by-issue approach.

Step 7: Multi-issue Agenda based Negotiation Approach:

In the multi-issue negotiation approach, the agents work as negotiators, jointly searching in a multi-dimensional space to find a point of agreement over multiple issues. The outcome of multi-issue negotiation not only depends on strategies, but is also influenced by the procedure by which the issues are negotiated. The proposed agenda based negotiation approach is based on the issue-by-issue procedure together with the negotiation strategies for the agents involved. The negotiation setting has the following components:

1) Issue ordering,
2) A protocol,
3) Strategies, for each agent,
4) Rules that determines when a deal has been struck and what the agreement deal is.

The complexity of utility functions for evaluating multiple negotiation issues is frequently difficult to manage as the issues form a large and complex search space. The proposed agenda approach provides a way of using a sequential mechanism to manage the complexity of multi-issue negotiation. With such an approach, a part of the protocol is the determination of the order in which the issues will be negotiated. Various orders of the negotiation issues form different agendas. The order will be decided by the agents in the approach as part of the bargaining equilibrium. The issues are ordered using the preference ordering process based on the agents' aggregated preferences which were derived in the earlier steps. Within a group of agents there is a preference ordering process for ranking the importance of the issues for the group.

To avoid having to consider all possible sequences of issues two sequences determined by the agents' preferences can be evaluated. To that the following question should be answered:

Which issue the agents want to negotiate in the beginning? Is it the most-important-first, or, the most-important-last?

It will limit to two choices and the search space is much smaller for the agenda formation.

4.3 The Proposed Agenda based Approach

The proposed agenda based approach stated in step 7 in Fig. 4.1 is described in detail in this section. The proposed negotiation mechanism consists of an agenda based negotiation protocol together with the negotiation strategies for the agents involved. The major steps of the negotiation process are shown in Fig. 4.2 which is a part of step 7 of the proposed model shown in Fig. 4.1. The essential point in the issue ordering stage is the change from agents’ preference sequence to accepting the common sequence. The issues are ordered using preference ordering process based on the agents’ aggregated preferences.

As noted previously two implementation rules are possible for any protocol. One is *sequential implementation* in which agreement on an issue is implemented as soon as it is settled; and the other is *simultaneous implementation* in which agreement is implemented only after all the issues are settled (Fatima et al. 2004). The proposed protocol uses the *sequential implementation*. The main advantage of the proposed agenda mechanism is that it minimises the complexity of the negotiation procedure, which does not require complex computation.

If each issue can be independently evaluated using the negotiators' utility functions, the agenda methods can result in a unique equilibrium solution for each issue. This is the main advantage of issue-by-issue agenda negotiation. But as in real life situations the interdependency between the issues arises. So in my issue-by-issue negotiation approach, the correlation factor between the issues is not ignored. It provides greater flexibility for the agents. For example if the price and performance issues of a software product are loosely dependent on each other then they can be correlated by quantitative mechanisms which link a pair of issues. This can be beneficial for both agents. The agents can also negotiate the issues independently in this way and the complexity will also remain simple. More details of the following issue-by-issue negotiation approach are described in section 4.3.2.1.

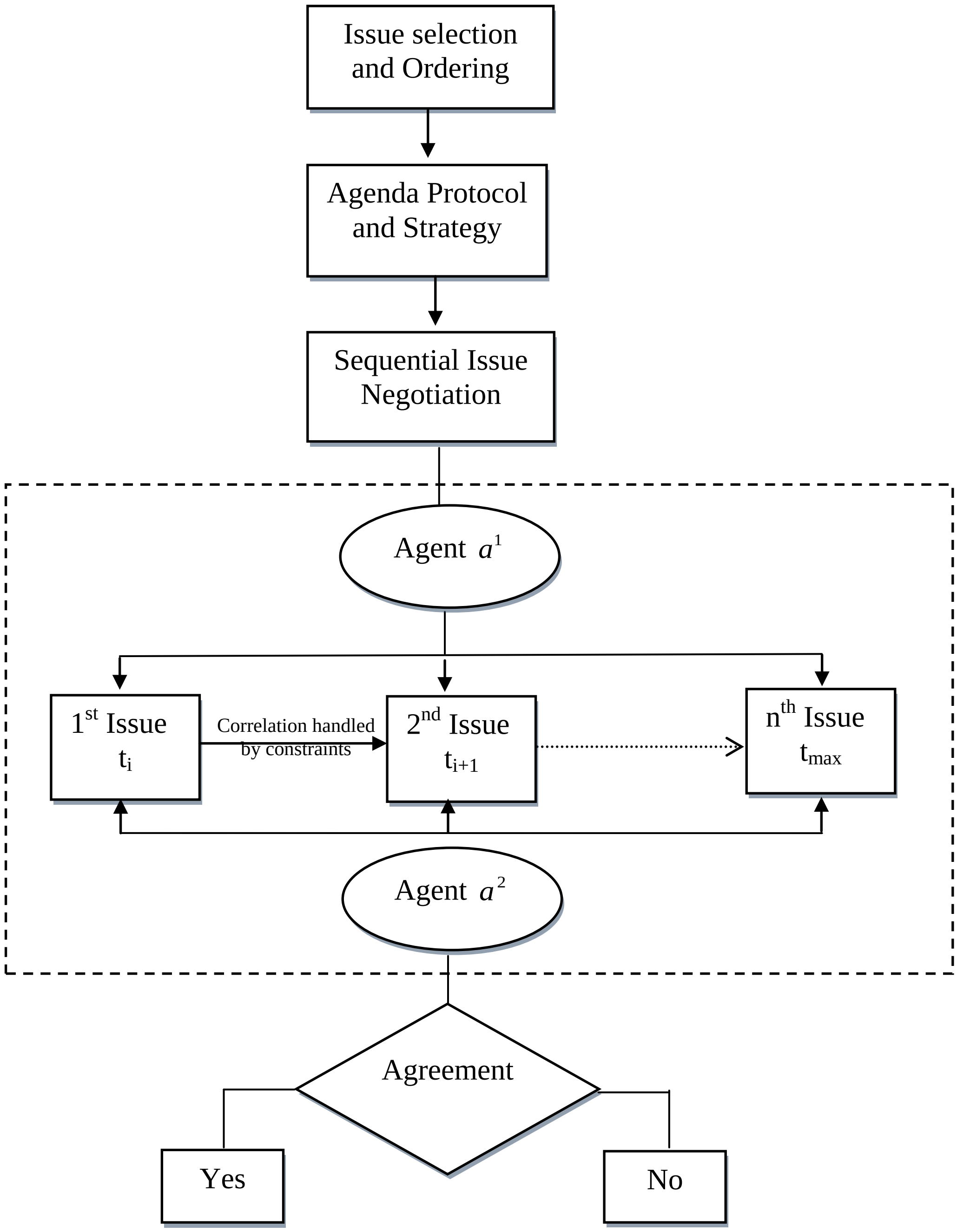

Figure 4.2 Agenda based issue- by-issue approach

4.3.1 Negotiation Parameters Set and the characteristics of the Proposed Approach

The negotiation parameters and the main characteristics of the negotiation model are shown in Table 4.1.

Table 4.1 Characteristics of the Proposed Negotiation Model

CRITERIA	
Structure	
Protocol category	Bilateral
Distribution type	Integrated model (win-win approach)
Attribute type	Multiple issues
Number of rounds	Multiple rounds (Maximum round decided by the agents)
Mediation type	Non-mediated
Access type	Closed
Process	
Automation level	Communication oriented
Orientation type	Goal oriented
Negotiation Process	Agenda based
Theoretical Basis	
Theoretical approach	Analysed by Multi utility theory
Restrictions	
Constraints	Correlation between issues handled by Constraints
Time	Time limit

4.3.1.1 Negotiation Structure

The proposed negotiation model uses a bilateral protocol in context of e-commerce. The cardinality of the negotiation is many-to-one. A group of buyer/consumer or seller/supplier can be represented by a combination of one coordinating agent.

The negotiation is done between a pair of agents. The negotiation environment refers to the scenario and settings in which the negotiation is carried out. It includes the negotiators and the negotiation object. The negotiation environment has a huge influence on carrying out the negotiation.

In automated bilateral negotiation the negotiators referred to are the two parties represented by autonomous agents. In the context of e-commerce and the negotiation scenarios, these agents can be a buyer/seller, consumer/supplier or server/client.

The negotiation object of the model is the set of multiple issues of a service or product over which agreement is to be made. For example the issues related to a software product can be: price; reliability; performance; quantity; maintenance, and so on. It is very difficult and time consuming to negotiate all the issues related to a product or service. The agents can agree on a common set of issues to negotiate on.

In a multi-issue negotiation process attaining a win-win solution is essential. This model searches for a win-win solution for the participating agents in the negotiation. Solutions where all the agents are better off are called win-win situation. And to achieve this, the best thing is to find Pareto optimal solution. This model aims to find a Pareto optimal solution. A solution is called Pareto optimal when the outcome cannot be further improved without sacrificing the agent's utility. It is hard to get one when the agents do not know the preferences of each other's.

The negotiation access type is based on closed sessions. The environment can be dynamic when some variables can change over time depending on its requirements. The impact of variations in the issue-by-issue sequence and the variations in the parameters of the individual alternate offer processes are explored in a negotiation environment.

The utility functions of the negotiation agents are modeled as private in this approach (Abedin et al. 2012).

4.3.1.2 Negotiation Process

The process of the model is agenda based, goal and communication oriented. In the proposed goal oriented negotiation the agents act on an agreed agenda which is based on their goals and objectives. The communication oriented approaches maintain the communicative procedures involved in the negotiation.

4.3.1.3 Theoretical base and restrictions

Theoretical approach

An Agenda Based negotiation approach is the core base of the model. The Multi-issue utility theory is used to compute the total utility whereas the game theoretical properties try to evaluate the outcome. These mathematically strong methods helps to find the optimal strategy between the agents based on Pareto optimality and Nash equilibrium conditions. Pareto optimality is the property that the outcome of this model aims to achieve.

Negotiation is a sequence of stages for seeking an agreement point for searching an agreement for multiple negotiation issues. One agreement point represents a point represents a point in the multiple dimensional space, where each dimension represents one negotiable issue, such as price, performance, quantity, etc. An agent has a set of options in the multidimensional space (Lai 2013). One agreement point will be decided by the agents, when the negotiation agreement is successfully made by offers and counter-offers.

The preference of an agent is modelled and analysed as a utility function representing its options in terms of the negotiation issues. The utility function can have any value from zero to one. At the start of the negotiation, the agent's offer corresponds to a utility that is close to 1 and it is expected that their opponent's offer will correspond to a utility that is near to 0. As each round passes the agents' offers will converge as they try to find a solution.

The negotiation process continues with a number of offers and counter offers. Each offer from the opponent should provide increased utility from the previous offer. Their own offers will decrease their own utility to try to accommodate the opponent's offer. Increase in the utility of the opponent's offer after each negotiation round indicates that the negotiation process is converging and the possibility of negotiation process resulting in agreement increases. If this trend does not continue and offers are received which decrease their own utility function, then an agent may decide to end the negotiation process.

A negotiation example is illustrated in Fig. 4.3, with one negotiation issue (performance) between the agents. The utility functions for the performance issue for a consumer agent and supplier agent are represented by U_c and U_s, respectively. U_c is a monotonically increasing function, and U_s is a monotonically decreasing function. P^* is an agreement value for the performance issue which belongs to the overlap of the value ranges the agent and opponent agent have.

For each issue the consumer and supplier agent have a domain where their maximum and minimum performance are the upper and lower reservation values. [P^c_{min} , P^c_{max}] are the maximum performance and minimum performance values for a consumer agent. The consumer agent will negotiate with supplier agent in the range P^c_{min} to P^c_{max}.(starting from P^c_{max}) The minimum performance and maximum performance values for a supplier agent are P^s_{min} ,and P^s_{max} respectively. The supplier will negotiate performance issue with consumer agent from P^s_{min} to P^s_{max}, (starting from P^s_{min}). Fig. 4.3 shows that the agents are able to make a deal agreement at the point P^* after number of offer-counter-offer. In this case both the consumer and supplier agent will make a favourable deal if both the agents submit honest negotiation opinions or preferences. If the supplier agent continues to submit low value offers for performance issue or if the consumer agent continues with offers of high performance value in the initial period then there are chances of no agreement or a delay on reaching the agreement point. If both agents do not reach an agreement before the deadline, they receive a utility of zero since not reaching an agreement is the worst possible outcome.

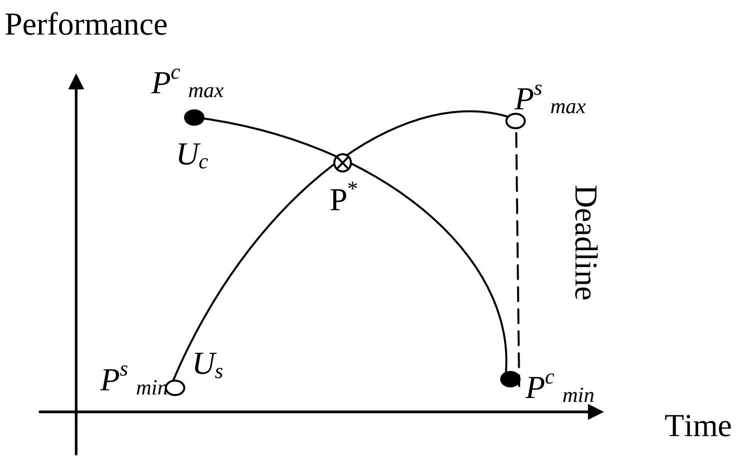

Figure 4.3 Negotiation between the agents' which shows an agreement at the point P^*

Time has huge influence on negotiation. That is why restrictions such as time limit and constraints are applied to assist the negotiation convergence towards agreement.

Constraints in the parameters of the issues

In the proposed model, I am using constraints that help the negotiation agents to decide their offers. The set of constraints that define relationships among variables and restrict the values that the issue related variable can take. For example, an agent may only accept price between [500, 1000] for a product. The limits are 500 and 1000. Not less than 500 and no more than 1000 are acceptable. This is called a hard constraint. If an agent may accept to pay more than 1000 only if the performance is greater than some given limit then this is considered to be a soft constraint. The hard constraints filter the offers and soft constraints prioritise the remaining offers. A proposal from another agent will not be accepted unless all acceptability constraints are satisfied.

Time

Time is a very important parameter in this negotiation process. In the proposed approach agents will negotiate in rounds and time is completely continuous. The agents will offer and counter offer in each negotiation round in continuous time. The agent can initiate the negotiation by sending an offer to the opponent agent over a particular issue at a particular time round. The opponent agent receives the offer and takes a decision whether to accept the offer, propose a counter-offer or withdraw the offer. This offer counter-offer takes place in a specific time round. For example, each round (t) of the negotiation may have a pair of offers offered by the participating agents. An agent who receives an offer can terminate the negotiation by either accepting the offer or by withdrawing from the negotiation after evaluating the offer even before the negotiation deadline reaches. The deadline is maximum considered time such as t_{max}. The agents usually have their expected utility range. The agents check whether the offers are in their expected utility range before they make decision to continue the negotiation by accepting the current offer or making a counter-offer. If the negotiation deadline is reached and the last offer is not acceptable to the agents then the negotiation will terminate or they can withdraw from the negotiation. The presence of a deadline encourages each agent to play a strategy that ensures the best possible agreement before the deadline is reached.

4.3.2 Negotiation Protocol

The basic negotiation steps of the negotiation protocol are shown in Fig. 4.4 which is part of step 7(Agenda based negotiation) of Fig, 4.1(The proposed model).

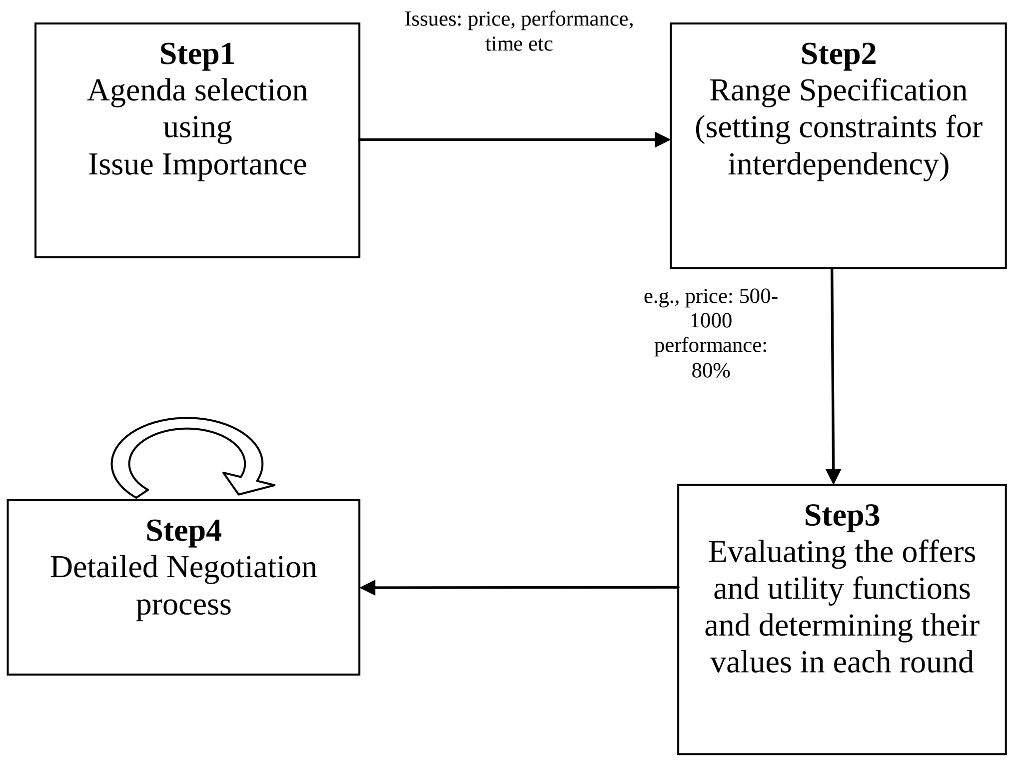

Figure 4.4 Negotiation Steps

In the first step the agenda is fixed for the agents based on the issue importance. Once the agenda is decided the constraints can be specified. The utility functions are determined to deal with the offers and counter-offers which are evaluated by the requirement criteria. The detailed negotiation process is followed next.

The proposed negotiation protocol is the set of various rules of managing the negotiation process. The negotiation protocol includes the negotiation conditions and the agents' behaviour under a specific condition. It specifies the rules of encounter between the negotiation participants. That is, the protocol defines the circumstances under which the interactions between agents take place: what deals can be made and what sequences of offers are allowed. In general, agents must reach agreement on the negotiation protocol to use before negotiation proper begins.

The negotiation process is carried out in the context of an agreed preference order for issues. An actual negotiation is between a pair of agents of opposite type. With the preference order over the issues determined, the allowed ranges for the issues are specified using constraints. Each agent has to satisfy the constraints specified by the protocol. This is because it is necessary to accept reservation values from the agents in such a way that there is always a possibility of some overlap or negotiation. The main concern is to avoid a case with no zone of agreement at the start of the negotiation process. Each agent has a reservation value for each issue which is the threshold of the offers to accept. There are aspects of the way in which information about the reservation values is managed.

At each negotiation round one agent proposes an offer first to the opponent agent. The opponent agent has three choices: accept the offer; reject the offer or propose a counter-offer. If one agent accepts the offer of the opponent agent, the negotiation terminates with an agreement. If the agent rejects the offer, the negotiation also terminates but with disagreement. On the other hand if the agent makes a counter-offer, the negotiation continues to another round. The opponent agent can now accept the proposal, reject the proposal or make a counter-offer. So the negotiation between agents ends when an agreement is reached or a disagreement occurs and the deadline is reached or one agent quits the negotiation.

Fig. 4.5 shows the choices the agents have in the negotiation stage using a protocol. This negotiation protocol is also part of step 7(Agenda based negotiation) of Fig. 4.1(The proposed model).

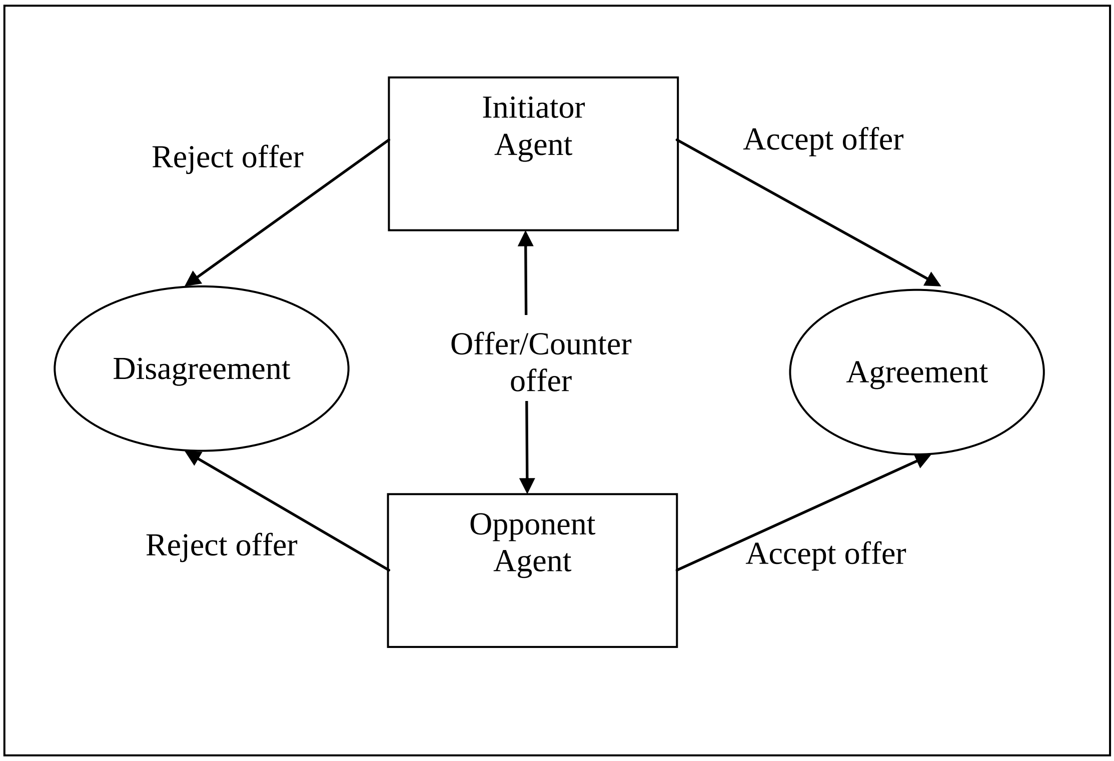

Figure 4.5 The negotiation protocol

The negotiation protocol adopts an alternating offer protocol. Negotiation between agents can end if an agreement is found or deadline is reached. It is assumed that the initiator agent makes a series of offers, $a_i^1 (i = 1,2,..,n)$ and the opponent responds with offers $a_i^2 (i = 1,2,..,n)$ sequentially. In general the offers can have more than one component so that it is possible for $a_i^1 = [a_{i1}^1],[a_{i2}^1],..[a_{in}^1]$, etc. but these are not considered for the single issue case. Each of the elements satisfies the restrictions. The first offer in the sequence of offers is from the initiator.

To generate a sequence of offers the following actions or rules are considered in the protocol:

1. How the agents produce their initial offers.

2. How the agents take action to the offers, i.e. how they generate counter-offers or reject offers, and

3. How the agents construe the offers they receive.

The first action is to produce the initial offers where a specific requirement has to be fulfilled. The second action, where the agents generate the counter-offers is based on the negotiation strategies which will be discussed in the next section. In the third action the way the offers are construed is discussed. Suppose t_{max} be the deadline for the agents a^1 and a^2. The agent a^2 receives an offer from a^1sequentially at time round $t = t_k, k = 1,2...max$ in the form of $a_i^1 = [a_{i1}^1],[a_{i2}^1],..[a_{in}^1]$ .What consequences will follow after receiving the offer and how any counter-offer will be evaluated are considered in this rule.

4.3.2.1 Agenda based issue-by-issue Negotiation Protocol

The proposed model makes the agenda sequence significant and still retains the issue-by-issue negotiation by making the constraints used as the starting point of the single issue negotiations depend on the results of the previous negotiations. This means that some approximate interdependence need to be calculated. Interdependence between issues means, an agent’s utility from an issue depend not only on the agreement that it reached but also on how the other issues are settled. Some initial constraint ranges for each of the negotiators are set first but can be varied after an issue has been negotiated. This means that the range of offers used in the negotiation is changed by the previous results but the final agreement is not fixed for these later issues. So it is necessary to consider the way in which a resulting value in one issue will influence the range of values considered for the next.

Fig. 4.6 shows the Iterative process of updating the issue parameters.

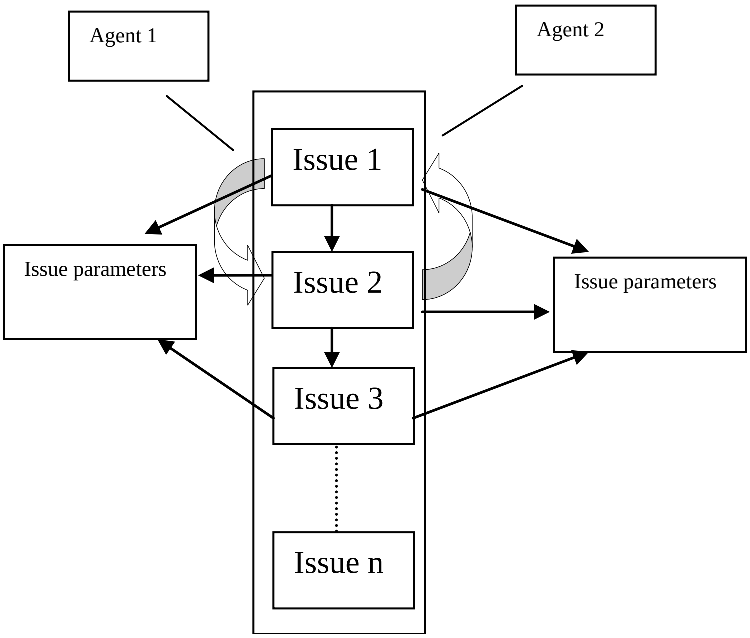

Figure 4.6 Iterative process of updating the issue parameters

For example the price agreed is near the bottom of the range for a seller this might increase the lower limit of the quantity constraint range (they need to sell more to make it worthwhile). For the whole problem it will be necessary to provide quantitative mechanisms linking the position of the result relative to the initial constraints to the change in the constraints for the other issues. In issue-by-issue negotiation there will be two participants and each will have a predetermined set of characteristics consisting of the following:

A) The list of issues i=1,2,..,n;

B) For each issue there is a [min(i),max(i)] initial range of acceptable values;

C) For each issues there is a relative weight (importance), w(i);

D) For each pair of issues (i,j) there is an influence that modifies the range of acceptable values for issue j depending on the results for issue i.

This takes the form of rules

if issue i result is below mid value then max(j) is increased/unchanged/decreased,

if issue i result is below mid value then min(j) is increased/unchanged/decreased,

if issue i result is above mid value then max(j) is increased/unchanged/decreased,
if issue i result is above mid value then min(j) is increased/unchanged/decreased,

There is also an influence in the opposite direction.

if issue j result is below mid value then max(i) is increased/unchanged/decreased,
if issue j result is below mid value then min(i) is increased/unchanged/decreased,
if issue j result is above mid value then max(i) is increased/unchanged/decreased,
if issue i result is above mid value then min(i) is increased/unchanged/decreased,

Given these directions of change there is a single formula to calculate the numerical changes in [max,min]. To find the amount by which the maxima and minima are changed the following standard calculation can be used. The target value is the mid value here.

Let max(i), min(i), $target_i$ *; max(j), min(j),* $target_j$ *be the initial values and the result be R.*

If $R<target_i$ *then change factor* $F = (target_i - R)/(target_i - min(i))$
if $R>target_i$ *then change factor* $F = (R – target_i)/(max(i) – target_i)$
if $R= target_i$ *then* $F = 0$.

The amount of increase/decrease for max(j) and/or min(j) values is $F*(max(j) - min(j))$.

It should be noted that there are combinations of the above rules that will give new max(j) < new min(j) so that the interval of allowed values for issue j is removed and the sequence of negotiations comes to an end with no agreement.

E) A value on the concession/hard-line axis that determines the response to offers in a time series of offer/counter-offer exchanges;

To evaluate the effect of negotiations between two agents, each with values for the above set of parameters, a series of alternate offer negotiations is simulated. The above parameters are sufficient to determine a utility for each bid and for the outcome of each negotiation stage.

Example for interdependencies between three issues:

For three issues (X, Y, Z) there will be six such linking calculations. This will then cover all sequences in the agenda and allow a comparison along the lines already devised. Each agent will have the maximum and minimum ranges for each issue. For example for agent a^1 and agent a^2 the ranges will be, a^1 ranges: $X[a_x , b_x]$, $Y[a_y, b_y]$, $Z[a_z , b_z]$; a^2 ranges: $X[d_x , e_x]$, $Y[d_y , e_y]$, $Z[d_z , e_z]$; The midpoint of each range for each agent is assumed as the target value for above. The interdependency factors will be considered in the negotiation by deriving linking relations between the relatively dependent issues based on the agents' consensus decisions. So the six linking relations between the three issues which consider the derived preference order can be calculated as below:

$$
\begin{aligned}
X \rightarrow Y \quad & agent\ a^1 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
& agent\ a^2 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
X \rightarrow Z \quad & agent\ a^1 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
& agent\ a^2 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
Y \rightarrow X \quad & agent\ a^1 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
& agent\ a^2 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
Y \rightarrow Z \quad & agent\ a^1 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
& agent\ a^2 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Z\ level \\
Z \rightarrow X \quad & agent\ a^1 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
& agent\ a^2 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ X\ level \\
Z \rightarrow Y \quad & agent\ a^1 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
& agent\ a^2 : above\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level \\
& \qquad below\ target \Rightarrow increase / decrease\ minimum / maximum\ Y\ level
\end{aligned}
$$

All the increases and decreases are proportional to the amount by which the agent misses their target. The calculations of the outcomes for all six agenda sequences can be calculated and the issue values can be used to determine the issue offers.

4.3.3 Negotiation Strategy

The proposed negotiation strategy is the specification of the sequence of actions (usually offers or responses) the agent plans to make during the negotiation. There will usually be several strategies that are compatible with a particular protocol, each of which may produce a very different outcome. Fig. 4.7 shows that after receiving offers from the agents the offers are sent to the negotiation strategy process. This process is part of step 7(Agenda based negotiation) of Fig. 4.1(The proposed model).

Then the offers are sent to the evaluation block. This does the analysis of the offer and calculates the degree of satisfaction of the offer; finally the decision process makes the decision. It would be acceptance, rejection or counter-offer of the current offer.

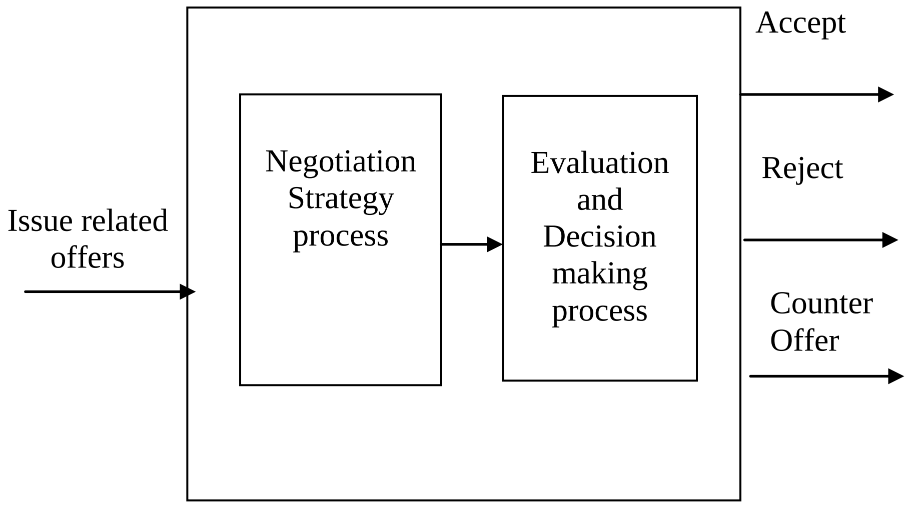

Figure 4.7 Negotiation process involving the strategy

The main goal of the proposed agenda based negotiation is to move towards possible agreements within the common area of interest in order to find the most satisfactory agreement for the group of agents. A participating agent must have a proper negotiation strategy selection method, which is based on the information available to it, in order to achieve its goal. The consequence of a negotiation depends on several factors such as: strategies used by the agents; the parameters of the strategy (for example the maximum number of rounds the agent will negotiate); the preferences of the agent, etc. The selection of the strategy and the parameters depend on the agent’s goal or need (Patel and Gupta 2006).

In the past game theory was mainly used in the negotiation process. It treats negotiation as a game and the negotiation agents are treated as players of the game. Game theory has two main drawbacks which make it unsuitable for use in the negotiation process. First is that it assumes the agent has infinite computational power and secondly it assumes all the agents have common knowledge. These limitations of the game theory were overcome by the decision functions. The decision functions produce offers based on the amount of time remaining, resource remaining or the opponent's behaviour.

Most common strategies used by the agents are: time dependent; behaviour dependent, and, resource dependent strategies (Faratin et al. 1998). The aim of the agent is to identify a zone of agreement in a given time limit. Resource and behaviour influence in the negotiation outcome are not considered in the proposed strategy as the negotiation is essentially time dependent.

A time dependent strategy is used by the agents to decide the amount of concession with respect to negotiation deadline. The closer the deadline approaches, the faster an agent compromises. By using a parameterised function as the basis of the time varying behaviour of an agent it is possible to examine the way in which different tactics influence negotiation outcomes. The agents can adopt Boulware, Conceder or linear concession tactic to decide how much they want to compromise over time. In the Boulware tactics, the agent maintains the offered value most of the time and concedes up to the reservation value when approaching the deadline (Faratin et al. 1998). The Conceder tactics are the opposite of the Boulware tactics. In this tactic agents concede much in the beginning and quickly approach the reservation value to satisfy its opponent. On the other hand, an agent with linear concession tactic reduces its offer value in an equally spaced manner. For each type of tactic there is corresponding negotiation decision function that is used to calculate the value of the next offer (Faratin et al. 1998).

In an issue-by-issue situation the decision functions can be considered separately for each issue. The negotiation decision function defines the negotiation strategy of the agents. The main aim of these strategies is to make the most of the utility under various constraints they face. In my negotiation model time is the most important factor, so the negotiation decision function modified from (Faratin et al. 1998) is defined as follow:

$$F_a(t) = k_a + (1 - k_a)(1 - \frac{t}{t_{\max} - 1})^{\beta} \tag{4.1}$$

where $F_a(t)$ is a function showing the dependence on t, k_a is a constant for the agent a which determines the value of the issues i to be offered as the first offer. There will be distinct functions for each agent but t_{max} is the deadline for both agents. The deadline puts the agents under pressure. The agents may have different time preference. Agents with different time preference may have different concession rate. The agent's value for k_a is used as the start-up value of the offer and it ranges from [0, 1]. If k_a is zero then the first offer is the minimum value for that issue. β determines the time dependent tactic type and is a concession factor. Depending on the value of β the tactics are defined: Conceder (β >1), Boulware (β <1) and Linear (β =1). The speed of the concession depends on this parameter. When β =1, it is equality concession strategy, which make the same concession range every time. With the Conceder tactic, agents make larger concessions in the early rounds and smaller at the later rounds. If the agents want to make smaller concessions in the initial rounds and larger concessions in the later rounds they can choose the Boulware tactic.

Negotiation strategy are varied by the values of β and k_a . In is Faratin's work (2000), k_a is an arbitrary value. In this work, the k_a is adapted systematically according to the sequential issues expected utility. The k_a value has been extended as a reference point for further exploration. This could also significantly reduce the search space and refine the negotiation strategies. It locates for the agents the appropriate search space for possible agreements.

Fig. 4.8 shows the time dependent concession tactics.

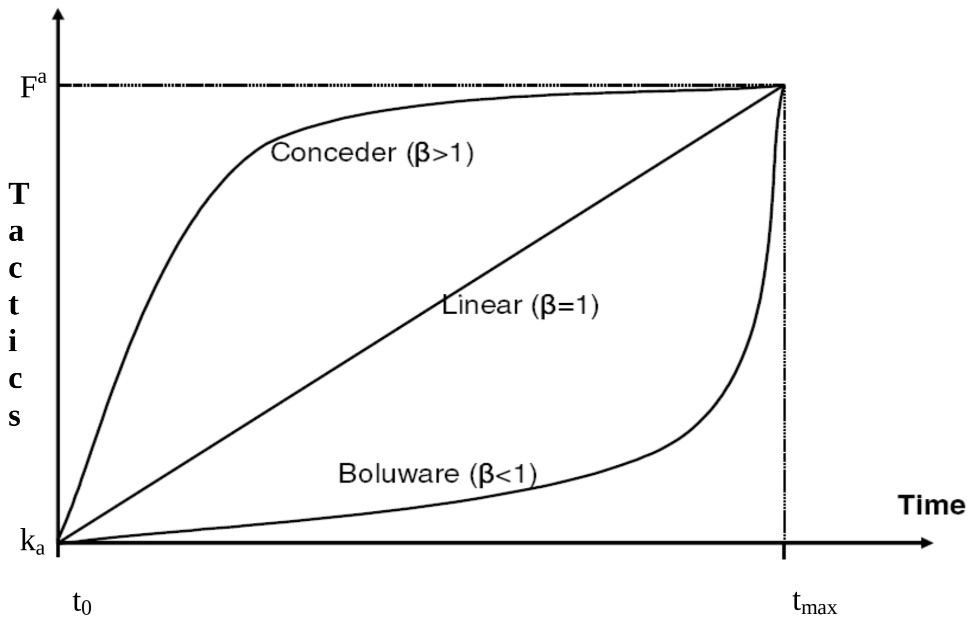

Figure 4.8 Time dependent concession tactics: conceder, linear and Boulware

Comparisons between the time dependent tactics are in Table 4.2 depending on their concession speed.

Table 4.2 Comparison between the time dependent concession tactics

Time dependent concession tactics	**Speed**	**Characteristics**
Linear	Concession uniform in remaining time	Concession is linear in the remaining time until the deadline.
Boulware	Slow concession (Conservative)	Initial offer is maintained until just before the deadline.
Conceder	Fast concession (Aggressive)	Concedes to the reservation value very quickly.

The agents can use different concession tactics and the expected time limit of the negotiation. Provided by the negotiating agent, the concession factor can be used to model the eagerness of the agent. The time when the agents want to reach to an agreement zone quickly the conceder tactic might be the right choice.

The offer proposed by an agent a^1 to the opponent agent a^2 and vice versa can be determined by using the following functions:

$$P^t_{a^1 \rightarrow a^2} = \left\{P^{a^1}_{min} + F_a(t)(P^{a^1}_{max} - P^{a^1}_{min})\right\} \tag{4.2}$$

$$P^t_{a^2 \rightarrow a^1} = \left\{P^{a^2}_{min} + (1 - F_a(t))(P^{a^2}_{max} - P^{a^2}_{min})\right\} \tag{4.3}$$

Here $P^{a^1}_{min}$, $P^{a^1}_{max}$, $P^{a^2}_{min}$ and $P^{a^2}_{max}$ are the range of the issues, a^1 is the one agent and a^2 is the opponent agent. Once the agent a^2 receives the offer, the agent evaluates it, makes a counter-offer, and replies with a degree of satisfaction with respect to the offer to the agent a^1 and the vice versa happens when a^2 receives the offer .

The degree of satisfaction function provides essential information for the evaluation of the result of the offers and counter-offers. A function which adopts a weighting technique to indicate the attitude used by the agent in evaluation solutions is used in my negotiation strategy. The utility is the total utility accruing to the two agents taking part. For example if the negotiated value for issue i is v(i) the raw utility for issue i is U(i) = (v(i) - min(i))/(max(i) - min(i)) where the max(i) and min(i) are the initial values for the issue, the total utility for an agent is the sum over i=1,2,..,n of w(i)*U(i). Adding together the two agent's results gives a utility value for the negotiation. The effort can be calculated by counting the number of offer/counter-offer steps that are taken over the set of issues in all stages of the issue-by-issue negotiation. The degree of satisfaction of both agents is derived from the following two linear functions.

The degree of satisfaction is computed as:

$$U_i\left(offer\ a^1 \rightarrow a^2\right) = \left(P^t_{a^1 \rightarrow a^2} - P^{a^1}_{min}\right) / \left(P^{a^1}_{max} - P^{a^1}_{min}\right) \quad (4.4)$$

$$U_i\left(offer\ a^2 \rightarrow a^1\right) = \left(P^{a^2}_{max} - P^t_{a^2 \rightarrow a^1}\right) / \left(P^{a^2}_{max} - P^{a^2}_{min}\right) \quad (4.5)$$

where $P^t_{a^1 \rightarrow a^2} \in \left\lfloor P^{a^1}_{max}, P^{a^1}_{min} \right\rfloor$ and $P^t_{a^2 \rightarrow a^1} \in \left\lfloor P^{a^2}_{max}, P^{a^2}_{min} \right\rfloor$

The overall outcome of the negotiation is defined as an (utility, effort) pair. Since the issues are not independent the results of negotiations will depend on the order of issues in the sequence of negotiations. The (total utility, total effort) pair for a choice of sequence will provide an evaluation of the chosen sequence. The variation in values demonstrates the importance of the choice of issue sequence.

The total utility of a set of issues can be calculated as a weighted sum of the values of each issue. The total multi-issue utility function is formulated as:

$$Total\ Utility = \sum_i^n w_i \bullet U_i\left(offer\ a^1 \rightarrow a^2\ or\ a^2 \rightarrow a^1\right) \quad (4.6)$$

Here i are the issues, w_i are the importance weights for the issues where $\sum_i^n w_i = 1$.

The importance weights for the issues are derived in the preference ordering phase. The importance weights over the negotiation issues help the agents to generate better quality offers. U_i is the degree of satisfaction value for each issue.

4.4 Summary

In this chapter, an overview of the proposed agenda based model has been provided. The model is composed of a pre-negotiation protocol, which includes preference ordering and agenda based negotiation process. The preference ordering process gives the decision-makers flexibility to express their opinions on the issues in different preference formats. The different preference formats are then transformed into a unique format which is fuzzy preference relation. Fuzzy concepts are used to aggregate the individual preferences into a group preference ordering relation. Then finally, to determine the global ranking of the issues, two fuzzy quantifier guided selection processes: dominance degree and non-dominance degree are applied. An iterative consensus process is built to improve the group consensus degree. This preference ordering of the issues helps to build up an agenda based negotiation process, which leads the agents towards an agreement in a reasonable time with an agenda sequence. So the proposed agenda negotiation process is defined by the negotiation space, which typically includes the proposed negotiation protocol (the set of the interaction rules between the agents), negotiation objectives (the range of issues to negotiate on), the agreed issue sequence and negotiation strategies (which are the sequences of actions that the agents plan to take in order to achieve their objectives).The agents must reach an agreement about the negotiation protocol before the negotiation begins and the strategy of the agents might change according to the negotiation protocol.

Effective and efficient multi-issue negotiation requires an agent to have some indication of its opponent’s issue preferences. In order to negotiate successfully in a multi-issue negotiation environment, agents need to consider each other’s agents preferences over issues and generate offers accordingly. Agents may learn about each other’s preferences over time and through interactions. As agents learn about each other’s preferences, they can provide better-targeted offers and thus enable faster negotiation (Aydoğan and Yolum 2009). The proposed agenda model addresses these crucial matters. The model specifies in which issue sequence the issues will be discussed between the two agents as well as the manner in which issue values will be processed. The proposed negotiation strategy guides the agents toward a win-win goal. The performance of the model can be evaluated by using the following performance measures: negotiation speed, effectiveness, efficiency and simplicity. The negotiation speed is a function which represents the number of negotiation rounds required for an agreement.

Chapter 5

Empirical Evaluation of the Model

5.1 Introduction

In order to analyse the effectiveness and efficiency of the proposed approach, a case study with various scenarios is adopted for use in evaluation. The main difference between the scenarios is the variation in the dependency of the issues and the changes in the parameters.

The problems that need to be investigated through a case study are: the contribution of the pre-negotiation phase, the significance of order of issues in negotiation process and the necessity of an agenda based negotiation approach in e-commerce. In a multi-issue group decision-making problem in e-commerce, multiple decision-makers are involved in making a decision. The information from multiple decision-makers can be in different formats because they would have different culture and backgrounds, and different value systems. Different opinions among the agents can occur during the actual negotiation which delays the negotiation timeline. Preference ordering in agenda based negotiation can be a technique to minimise the negotiation delay time and the search space. In the pre-negotiation phase the decision-making agents can choose their preferred formats to express their opinions. Different preference formats are uniformed in this process. Each participant agent in the group may have specific preferences and priorities as regards the negotiation agenda that conflict with others. They should firstly agree on a negotiation agenda and can negotiate the issues of concern sequentially or simultaneously. The preference ordering can be used in a pre-negotiation stage to overcome these problems.

In the case study, two negotiating agents, representing respectively a consumer and supplier, need to negotiate in order to reach a consensus over a number of issues related to a product. Each agent and issue plays a specific role in the evaluation of an offer. Both consumer and supplier agents participate in a group decision-making process, where the consumer agent collectively represents a group of decision-making agents. In the pre-negotiation situation, the decision-making agents have different preferences, but are cooperative and need to reach consensus. Each agent is concerned with maximising the social welfare of the entire process, even if this does not necessarily maximise its own utility.

Later in the actual multi-issue negotiation process, agents have opposed interests, but are cooperative and need to reach a compromise agreement. They can reach win-win agreement on issues of preference by using the common preference ordering sequence derived in the group decision-making process. Both agents want to benefit from the agreement by maximising their individual profits or utilities, but they must also try to maximise the total social welfare which is the total utility across the agents and also the consequence of the mode of agreement. In aiming to maximise their individual utilities, the system facilitate them to reach a desirable agreement only when the total utility is maximised.

The proposed automated negotiation process could be adapted in many ways. Selecting parameters for the process needs to be carried out on the basis of evidence from experiments on situations comparable to the complexity of the real world applications and current market analysis. The case study scenarios provide such situations and a basis for establishing useful settings for the parameters of the proposed process. This chapter describes the case study and provides the results after the proposed negotiation process is applied with different parameter settings. The results show that the negotiation process provides agreement points and gives an acceptable outcome. The discussions are supported by the results of a number of sets of experiments. As described in previous chapters before the exchange of offers a pre-negotiation process takes place. The outcome of the fuzzy group decision-making approach which is an integral pre-negotiation part of the overall negotiation process is also illustrated for the case study scenario. This employs the preference ordering and uses the consensus reaching concepts before making it available in the main negotiation process. Not all possible combinations of parameters for the offer exchange phase have been explored but those that appear to be the most significant have been investigated.

Brief descriptions of the background of the case study are given in section 5.2. The next section describes the negotiation process and shows the results of the agreement. The scenario involves more complex situations with dependent issues. The aim of the experiments is to evaluate the effectiveness and efficiency of the proposed negotiation approach within different scenarios and different parameter settings.

5.2 Case Study

5.2.1 The Consumer's Background

Coventry University Computing Services Department (CSV) provides centralised computing facilities to all staff and students. The Department aims to provide and support a range of information delivery; computing and telecommunications based services which will further the aims and objectives of the University and in particular enhance the educational environment for students and assist staff at all levels in fulfilling their roles and responsibilities. CSV manages a range of software purchased on behalf of the University. They have the responsibilities for providing advice on hardware and software maintenance agreements and support facility arrangements. This includes the management of services and negotiations with external suppliers. The unit also acts in an advisory capacity on the installation and upgrading services of hardware and software.

The CSV service is divided into seven distinct sections, each with their own areas of responsibility. The sections are: applications service, customer service, infrastructure service, local IT developments service, operations service, procurement and admin service, publicity and information service. The Applications Section within CSV is responsible for the implementation and support of software applications that are used across the University. This covers systems in use by staff or students. Most staffs are Analyst Programmers, but the section also includes Technical Specialists, Project Managers and Development Officers. The latter are responsible for testing, training and liaising with users. The majority of staff time goes on new systems. The remainder of the time goes on supporting existing applications. The Applications Section provides many important services and assistance to both CSV staff and University Schools in purchasing software or service. One of the main tasks is the negotiation with suppliers to ensure good deals, get services or software on reasonable price, and meet the specified requirements. They negotiated with popular hardware and software suppliers to get great educational pricing.

So the case study is about how The Applications Section Service of Computing Services department of Coventry University will offer to negotiate and communicate with the software suppliers on behalf of academic unit and deal with issues of purchasing software for the use of students and staffs. When purchasing licensed software, the software can be either for institutional or personal/individual use. Individual purchase is not considered in this case.

In this software purchasing problem, the Analyst Programmers, Technical Specialists, Project Managers and Development Officers are the key decision-makers to express their preferences over the issues related to the software services. They represent the consumer agent collectively. A range of products from software houses such as Adobe, Microsoft, SPSS are purchased after going through the deals. The issues related to the software services are basically: price, performance, quantity (number of copies), reliability, adaptability, compatibility, modifiability, availability, usability, operability, risk to break down, setup cost and time. Each decision-maker has his own ideas, attitudes, motivations and personality; it is quite natural to think that different decision-maker could express their preferences in a different way. So there is a necessity to build a flexible framework where the agents have freedom to represent their preferences in different formats. These different formats need to be uniformed and a consensus process needs to be introduced to measure the degree of consensus.

The participants in the negotiation have their own preferences over the negotiated issues, and these preferences can be formulated in its most extensive form as a multi-issue decision-making problem. To improve the decision-making environment, the preference feedback is collected from the staff of the Applications Section Service department and from the supplier they selected.

In multi-issue negotiation, the issues may or may not be correlated. The software purchase case study has interdependency between the issues. As the proposed model is an issue-by-issue approach, handling the issue dependency is a challenging task.

The preference of two agents may vary, i.e., one agent may prefer one issue over other while the other agent may prefer the opposite. Agents with different preferences need to cooperate with each other to reach agreement that is beneficial for both the agents. They may negotiate on the most important issues or least important issues related to the software service that they want to negotiate in the purchasing process. The agenda about the issues needs to be determined which will be used to negotiate with the supplier during the time of purchasing software.

5.2.2 The Supplier's Background

Coventry University has decided to purchase a large proportion of software produced by Microsoft who is a global supplier of educational software. In terms of revenues coming from software sales, the software purchase industry is clearly dominated by Microsoft, since inception. Microsoft software products are sold in largest number across the globe. Microsoft is also wants to sell Microsoft software products to University CSV department. The agreement is administered on the University's behalf by CSV. Microsoft provides a wide range of educational and retail software products which are available at reasonable prices to students and staffs.

5.2.3 Scenarios in the Negotiation

There might be different scenarios where the negotiating group of agents might negotiate with each other. One possibility is the consumers and supplier agents form a group together and express their preferences and come to a consensus. Later the interested pair of agents can start negotiating. Another possibility is the consumers' agent which consists of several coordinating agent consumers, derives their common preference agenda using the group decision-making process and then negotiates with the opponent supplier agent about the issue sequence and values. In this case supplier agent does not take part in the group preference order process. My case assumed the first scenario where both agents participate in group decision-making process and then one agent (consumer or supplier) that represents his/her group members with a collective utility function wants to negotiate a deal with the opponent agent, in order to find the best possible deal.

For this particular case study the following issues are considered to negotiate with the supplier.

- Unit Price: The University wants to purchase software at the lowest possible unit price, irrespective of how many copies of the software they require. On the other hand the supplier wants to sell the service at a higher price.
- Performance: Here performance means how fast the software or service responds to the user’s request.
- Quantity: This issue is important for both consumer and supplier in this case, as quantity will affect the price and agreement.
- Maintenance: If there is any bugs or any problems with the software how the developers or suppliers will deal with it.

The following aspects are considered in the software purchasing process.

Description of Service

The main purpose is to purchase of software for university use and to negotiation the associated issues.

Groups for Services

The staffs of the Applications Section Service of Computing Services department of Coventry University and the supplier are the groups.

Dependencies

Negotiation issues can be divided into two groups: independent issues and dependent issues. The dependencies between the issues need to be identified based on the correlation between the issues and the negotiated groups’ requirements. Based on that, the strongly related issues can be bundled together in negotiations.

Service Outputs

Purchase the software from a preferred supplier with a preferable deal from the consumer point of view. Selling the software within an acceptable price along with other issues and build a long term business relation is the main output from the supplier's side.

Disagreement Response

The aim is to reach to an agreement which is acceptable to all parties. Where a service deal fails to meet purchasing agreements they may be renegotiated or terminated and alternative recommendations may be given.

5.3 The Proposed Approach in the Case Study

To accept an offer from a software supplier, the Applications Section of Computing Services Department has to consider several issues to match user's (staffs and students) requirements such as: price; performance; quantity; and; maintenance. Since several parties are involved in this multi-issue related software purchase process, according to my approach it needs to be decided in which order the issues will be negotiated. Therefore, each section of staff (Analyst Programmers, Technical Specialists, Project Managers and Development Officers) has their own preferences in connection with its service constraints and the above issues. The supplier also has its own preferences connected to the issues. In fact, each section is referred to as a decision-maker on several of the decision criteria. Each decision-maker may have diverse opinion regarding the issues. To model this type of preferences and decision, I have used an extended multi-issue decision-making method. This method enables the decision-makers to consider this multi-issue problem at a decision level by evaluating the issues and reaching a consensus over the preference ordering of the issues.

Negotiation is the process by which a group facing conflict communicates with one another to try and come to a mutually acceptable agreement or decision and so, the university and the supplier have to negotiate. The conflict I have to resolve is to find an acceptable solution for all the parties and in particular for the university by using a particular protocol. In this context a multi-issue negotiation protocol is the best suitable for this type of problem. This type of protocol enables the Applications Section of CSV and the supplier to negotiate together. Since the negotiation is on a set of issues related to the software, the negotiation also has to deal with multiple issues. Moreover, all parties have the same objective which is to make a deal as efficiently as possible and in the best conditions. This implies the use of a negotiation protocol which encourages them to cooperate. Taking into account these aspects, an automated multi-issue negotiation in a multi-agent approach can be a useful method in the case of this decision-making process. The Applications Section of CSV is the consumer agent and the software supplier is the supplier agent in this particular scenario. Therefore, the proposed multi-issue negotiation approach consists:

- A fuzzy group decision-making process where the preferences of the agents regarding the issues are modelled.

- An agenda based multi-issue negotiation process between two protagonists after the multi-agent fuzzy process has been carried out.

The proposed automated negotiation approach will be used to negotiate the best value for the selected issues and reasonable pricing for both consumer and supplier. In the negotiation process the dependencies between the issues are also considered.

5.3.1 Negotiation Experiment

In this section a scenario, based on the case study described in section 5.2, is used to illustrate the proposed negotiation model shown in Fig. 4.1. The illustration of the overall proposed model is provided in two phases. First, the proposed fuzzy group decision-making approach for deriving the agents' common preference ordering of the issues related to software product is shown (step 1 to step 6 of Fig. 4.1). Based on the preference ordering sequence, the proposed agenda based negotiation process is shown in the second phase (step 7 of Fig. 4.1). It should be pointed out that there is more than one scenario in which the preference ordering can be used as a preliminary to a negotiation. The following case illustrates one of these scenarios.

5.3.1.1 Fuzzy Group Decision-Making Approach

A negotiation situation is considered where a group of decision-makers who represent the consumer agent negotiate over the issues for software product with Microsoft, the supplier agent. The decision-making process takes into account the preferences of the decision-makers over the multiple issues related to the software product in order to evaluate and negotiate.

As mentioned earlier the negotiation protocol is based on agenda based procedure so the first aim is to first resolve the conflicting opinions or preferences over the issues and generate a common preference sequence.

Step 1: Opinion Collection from Multiple Agents in Multiple Issues:

Individual Priority Order in Different Formats

The Analyst Programmers, Technical Specialists, Project Managers, Development Officers of the CSV department and the software supplier Microsoft form a group of decision-making agents, D^k, i = 1, 2.., 5. They are asked to express their preferences or opinions on the software issues: quantity (I_1), performance (I_2), maintenance (I_3) and price (I_4). The supplier offers the consumer group the various preference formats to express their opinions. The decision-makers can then use any one of the preference formats discussed in the section 3.3.1.

D^1 give his/her opinion in preference ordering format: an ordered vector is used by D^1 to express her/her preference on issues. These issues are ranked from the most important to the least important. In this scenario the issue I_2 is the highest rank for D^1, while issue I_4 is the lowest.

D^2 provides an opinion in terms of a utility vector: a utility value between [0, 1] is assigned to the issues by the customer D^2.

D^3 and D^4 use linguistic terms: A set of fuzzy linguistic terms are used by the decision-makers which are provided by the supplier. So the decision-maker is asked to select their priority from terms “very high”, “high”, “medium”, “low”, or “very low”. Such linguistic values can be represented using fuzzy triangular numbers. The support of the fuzzy numbers is a priority from zero to one. The following representations of the linguistic terms are used: “very high” (0.8, 1, 1), “high” (0.6, 0.75, 0.9), “medium” (0.3, 0.5, 0.7), “low” (0.045, 0.05, 0.25) and “very low” (0, 0, 0.2).

D^5, the supplier agent express his/her preference by a binary fuzzy relation which denotes the preference degree of one issue over other.

Therefore the information given by the decision-making agents can be represented as:

D^1: $O_1 = \{3, 1, 2, 4\}$

D^2: $U_2 = \{0.3, 0.7, 0.9, 0.6\}$

D^3: L_3 = {“very high”, “medium”, “low”, “very high”}

D^4: L_4 = {“medium”, “very high”, “low”, “high”}

$$D^5: P_5 = \begin{pmatrix} 0.5 & 0.6 & 0.8 & 0.5 \\ 0.4 & 0.5 & 0.6 & 0.3 \\ 0.2 & 0.4 & 0.5 & 0.1 \\ 0.5 & 0.7 & 0.9 & 0.5 \end{pmatrix}$$

Step 2: Normalisation of Individual Preferences using Fuzzy Concepts:

Transformation into a Common Preference Format

In order to aggregate individual preferences to group decision, different preference formats are standardized into a common format. Here a fuzzy preference relation is selected by the supplier as the common format. Using various transformation functions such as equation (3.1), (3.2), (3.4), the preference ordering, utility vector and linguistic vector are uniformed into fuzzy preference relation, so I have the following matrixes:

$$P_1 = \begin{pmatrix} 0.5 & 0.16 & 0.33 & 0.66 \\ 0.83 & 0.5 & 0.66 & 1 \\ 0.66 & 0.33 & 0.5 & 0.83 \\ 0.66 & 1 & 0.83 & 0.5 \end{pmatrix}$$

$$P_2 = \begin{pmatrix} 0.5 & 0.15 & 0.1 & 0.2 \\ 0.84 & 0.5 & 0.37 & 0.57 \\ 0.9 & 0.62 & 0.5 & 0.69 \\ 0.8 & 0.42 & 0.30 & 0.5 \end{pmatrix}$$

$$P_3 = \begin{pmatrix} 0 & 0.8 & 0.94 & 0.5 \\ 0.2 & 0 & 0.8 & 0.2 \\ 0.05 & 0.2 & 0 & 0.05 \\ 0.5 & 0.8 & 0.94 & 0 \end{pmatrix}$$

$$P_4 = \begin{pmatrix} 0 & 0.2 & 0.8 & 0.30 \\ 0.8 & 0 & 0.94 & 0.64 \\ 0.2 & 0.05 & 0 & 0.1 \\ 0.69 & 0.36 & 0.9 & 0 \end{pmatrix}$$

Step 3: Group Preference Order:

Collective Preference Relation

In the aggregation phase a collective preference relation $P_d = (pd_{ij})$ is obtained by means of the aggregation of all individual fuzzy preference relations $\{P_1, P_2, P_3, P_4, P_5\}$, which specifies the overall preference between every ordered pair of issues. Here $pd_{ij} \in [0, 1]$ is the individual value in the matrix, represents the degree to which one issue has over another issue. Fuzzy linguistic quantifier that represents the concept of fuzzy majority and OWA operator is used to aggregate the decision-makers' individual opinions. Fuzzy majority can be expressed by a fuzzy linguistic quantifier, such as "most", "at least half", "as many as possible" with the pairs or parameters (0.3, 0.8), (0, 0.5) and (0.5, 1) respectively. The corresponding weight vector is calculated from these quantifiers. In this scenario the "most" fuzzy quantifier and the corresponding OWA operator with the weighting vector, W = [0, 0.067, 0.33, 0.33, 0.27, 0] is used to obtain the collective fuzzy preference relation:

$$P_d = \left(pd_{ij} \right) = \begin{pmatrix} 0.5 & 0.35 & 0.67 & 0.39 \\ 0.54 & 0.5 & 0.65 & 0.38 \\ 0.22 & 0.30 & 0.5 & 0.12 \\ 0.56 & 0.52 & 0.71 & 0.5 \end{pmatrix}$$

Equation (3.5), (3.6), (3.7) and (3.8) are used to obtain the group preference matrix.

Step 4: Determine the choice of sequence of issues by a hybrid Preference Ordering Method based on FOWA Operator and Fuzzy Quantifiers:

Rank the issues using Fuzzy Concept

The next step is the selection process. In this phase the group preference about the issues is transformed into a global ranking. The fuzzy group decision-making approach uses two fuzzy quantifier-guided choice strategies to select the issues, based on the concept of fuzzy majority and OWA operator. The QGDD and QGNDD are calculated for the issues from the collective preference matrix P_d and the weighting vector W = [0.067 0.67 0.27], which is generated from the corresponding OWA operator by using equation (3.9) and (3.10). The "most" criteria has been chosen here. It may be the best choice here. Table 5.1 shows the QGDD and QGNDD of the issues acting over the collective fuzzy preference relation supplies the following values:

Table 5.1
QGDD and QGNDD of the issues

QGDD (I_1)	QGDD (I_2)	QGDD (I_3)	QGDD (I_4)
0.40	0.51	0.20	0.56
QGNDD (I_1)	QGNDD (I_2)	QGNDD (I_3)	QGNDD (I_4)
0.83	0.96	0.51	1

Here QGDD may be interpreted as the degree to which an issue dominates “most” issues when compared against “most” criteria. On the other hand, QGNDD may be interpreted as the degree to which an issue is not dominated by “most” issues when computed against “most” criteria. QGDD and QGNDD give the preference orders respectively:

Price (I_4) > Performance(I_2) > Quantity(I_1) > Maintenance (I_3)

Price (I_4) > Performance(I_2) > Quantity(I_1) > Maintenance (I_3)

When the information is consistent I got the same ordered vector of issues using QGDD and QNGDD, which are independent of the linguistic quantifier used. In this example both results came out same. On the other hand, when the information is not consistent then both can give a different ordered vector of issues. In that situation it depends on the consumer’s attitude which sequence is chosen. The QGDD reflects the positive attitude of the consumers where reward is given to as many as possible opinions. On the other hand QNGDD process is applied if the supplier decides to offend as few people as possible. That means fewer people may disagree with it. The supplier has included his/her own preference or opinion on the issues which allow the supplier to participate in the group consensus. The supplier collects the opinions and then decides the agenda which would be offered to the consumers based on the calculations he/she has done. So the following collective preference ordering is derived:

Price (I_4) > Performance(I_2) > Quantity(I_1) > Maintenance (I_3)

Step 5: Group Consensus Measurement:

A hard consensus approach has been applied to measure the consensus level. Distance between individual ranking and group ranking is required to measure the consensus. So the individual rankings are calculated using the same process as the group ranking. The individual orders of the issues are as follows:

$D^1 = \{I_4, I_2, I_3, I_1\}$

$D^2 = \{I_4, I_1, I_2, I_3\}$

$D^3 = \{I_3, I_2, I_4, I_1\}$

$D^4 = \{I_1, I_4, I_2, I_3\}$

$D^5 = \{I_2, I_4, I_1, I_3\}$

The difference between the rankings of the issues in the temporary group consensus solution and the individual solutions are calculated using the distance measurement function. The consensus degree on issues shown in Table 5.2 is calculated by equation (3.11) and (3.12) using the distance values and the dissimilarity function with different values of a parameter b (here 1 and 0.5 is used), which is in the range of [1, 0].

Table 5.2

The aggregated consensus degree of the group on each issue

	I_1	I_2	I_3	I_4
b = 1	0.72	0.78	0.78	0.83
b = 0.5	0.57	0.61	0.74	0.77

The parameter b controls the rigor of the consensus process, in such a way that values close to 1 decrease the rigor and the number of rounds to improve the consensus level. The appropriate values are from 0.5, 0.7, 0.9 and 1. These consensus degrees are used to calculate the consensus measure over the issues along with the aggregation operator OWA. Here $\gamma \in [0, 1]$ is a parameter which controls the behaviour of the aggregation operator and has to be fixed before applying in the operator. Here γ has been fixed to be 0.8. The total consensus measure is calculated by using equation (3.13) is shown in Table 5.3:

Table 5.3

The temporary consensus measure

	Consensus Measure
For γ = 0.8 and b = 1	0.87
For γ = 0.8 and b = 0.5	0.72

If the required level of consensus is selected 0.75 then using the dissimilarity function, with b = 1 value and $\gamma = 0.8$ value, the consensus process should stop in a satisfactory level because the total consensus level is above 0.75 in this case. So the temporary consensus solution will be selected as the final solution. But considering the other case where b = 0.5, the process should continue. Because the total consensus level 0.72 has not reached the required level yet.

Step 6: Consensus Improvement Process:

A consensus improvement process with a simple feedback mechanism has been used to improve the consensus level. The decision-makers are ranked according to the proximity of their individual solutions to the temporary consensus solution. Equation (3.14) is used for improvement process. The ranking is calculated by using the same consensus degree and measurement methods used before. For $\gamma = 0.8$ and b = 1, 0.5 the following proximity values shown in Table 5.4 are calculated to rank the decision-makers:

Table 5.4

Proximity values and the ranking of decision-makers

	$\gamma = 0.8$, b = 1	$\gamma = 0.8$, b =.5	Rank	Rank
D^1	0.68	0.45	3	3
D^2	0.70	0.48	2	2
D^3	0.62	0.39	4	4
D^4	0.42	0.28	5	5
D^5	0.95	0.91	1	1

These proximity values show the closeness to the consensus solution. So the higher the value is, the nearer the member of the group is from the consensus solution. Based on the above values the ranking of the members are: $\{D^5,D^2,D^1,D^3,D^4\}$.The first person to get feedback to consider his opinion will be the person with lower ranking, whose individual solution is furthest from the temporary consensus solution. A threshold value has been decided to measure how many agents will get feedback to consider their opinions regarding the issues. In this process if the proximity value is less than 0.4 Є [0, 1] then the agents are given feedback to consider their preferences associated to the services. From Table 5.4 the proximity values show that D^3 and D^4 have values less than the threshold value. So they are given feedback to consider their opinions. The new preferences from the members D^3 and D^4 are collected and the consensus process is applied again as an iterative process. After repeating all the consensus steps, the new consensus measure is calculated as Table 5.5:

Table 5.5

Updated consensus measure

	Updated Consensus Measure
For γ = 0.8 and b = 1	0.89
For γ = 0.8 and b = 0.5	0.78

The result shows that the consensus level is 0.89 and 0.78 respectively. So the consensus level has reached the required level and is quite high, so there is no need for another stage. A satisfactory consensus solution has been achieved from this convergent process. This solution is the basis for agenda based negotiations, by involving the issue weights of the agents' preferences. The numerical result shows the aspects of the proposed fuzzy decision-making approach towards multi-issue negotiation process.

5.3.1.2 Step 7: Agenda based Negotiation Approach

Automated agenda based negotiation can use the result of the above preference ordering process in order to provide an efficient negotiation. Both the supplier and the consumers may have different interests and deals. It is a very difficult and time consuming task to find a preferred deal. So a model which helps to search for their prospective deals much more quickly can be beneficial for both of them. The following scenario will show how an automated negotiation process can accommodate and benefit from agenda sequence.

The supplier initialises an agent in his/her system. This agent is provided with information of the supplier's preferences. The issues and attributes related to the software products are provided to the agents. The consumer agent is provided with information about the consumers' preferences about the multiple issues related to the software offered. The negotiation process starts between the pair of the supplier agent and the consumer agent when either of them offers a negotiation service. Multiple issues are involved in purchasing software not just the price. The issues related to software are numerous like price, performance, quantity and maintenance. It would not be practical to start negotiating on each and every issue. The agents will have differing opinions on which issues to select and in which order. To decide and to obtain a consensus process related to the selected issues are the main concerns of this research. Dealing with a product like software, both the agents wants to find the best deal regarding their own interest. A multi-issue negotiation process operates until a deal has been found or one of the parties leaves. If a deal is found satisfying both of the parties, the supplier agent and the consumer agent recommend the possible outcomes to their respective users. If the deal is suitable the consumer agent can initiate purchase of the software or can negotiate further. Both parties can be benefited by this approach since the consumer can save time and find their preferred deal and the suppliers may attract more consumers who have high probability of buying the software rather those who come to visit only. This research is to build a negotiation model which deals with multiple issues related to software acquisition. The way these issues are negotiated and how the agents come to a possible deal using a proposed agenda negotiation approach are presented with a numeric example.

The proposed protocol modelled by using the consumer-supplier scenario described above. Each agent has to satisfy the constraints specified by the protocol depending on their consensus decisions. This is because to accept reservation values from the agents in such a way so that there is always a possibility of some overlap or negotiation and also handling the interdependency between the issues if any dependency exists. The main concern is to avoid a case with no zone of agreement at the start of the negotiation process. Each agent has a reservation value for each issue which is the threshold of the offers to accept. For instance, the supplier's reservation price is the minimum price that can be accepted by the supplier. In the other hand the consumer's reservation price is the highest price that can be proposed by the consumer. So when the supplier's reservation price is lower than the consumer's reservation price, there is a possible negotiation region, which is the zone of agreement area in Fig. 5.1. If the reservation price of the consumer is lower than the one of the supplier, than there is no zone of agreement which is indicated in Fig. 5.2 (Jian and Wei 2009).

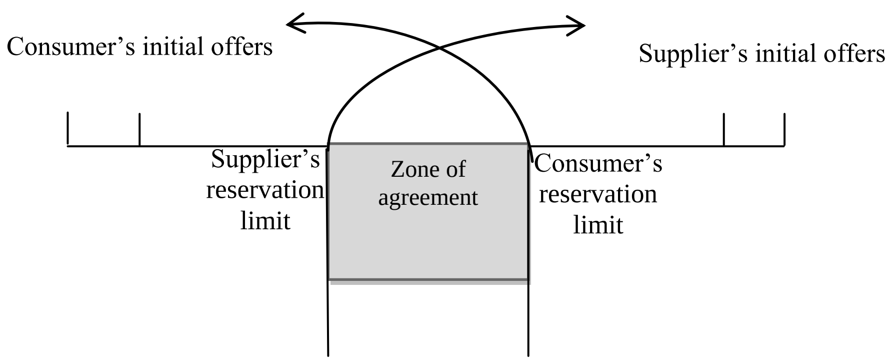

Figure 5.1 Zone of agreement

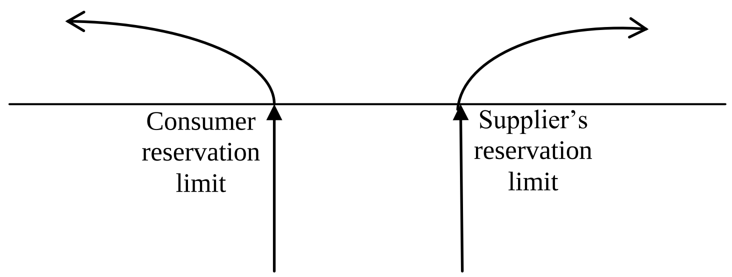

Figure 5.2 Towards no zone agreement

In my negotiation model suppose the agents a^c (consumer) and a^s (supplier) negotiate over an issue set *i* at time *t* and have respective utility functions *U* or *G*. The negotiation issues, which are determined by the agents in the pre-negotiation stage, are price (A), performance (B) and quantity (C). The maintenance issue is omitted for the actual negotiation process for simplicity. Here quantity is the number of copies requested for the software product by the agents. For this negotiation case it is assumed that the issues are independently negotiated. Selection of the agenda and to evaluate whether the selected agenda is optimal, the derived preference ordering process has been applied. The collective group ranking or preference order of the issues is also derived in the pre-negotiation protocol by using a consensus based group decision-making process. The derived preference order suggests the following agenda (ABC): price > performance > quantity.

The issues will be negotiated sequentially (issue-by-issue approach) and the sequence will be the above ordering. Before describing the process I have established a notation that covers all the issues. A negotiation process has been described in 4.3 introducing hard constraints [P_{min} , P_{max}] for each agent and each issue. An alternate offer process has been described in 4.3.3 and this is applied separately for each issue. The levels of the offers and counter offers are described in equations 4.2 and 4.3. That section also describes what are termed raw utilities in equations 4.4 and 4.5.

$s_i^{(k)}$ is an offer received by a consumer from a supplier at $t_k, k = 1,2...\max$. Here i is the issue indicator which in my case can be *pr* (price), *p* (performance), or *q* (quantity). For example the first offer which will be received by a consumer will be $s_{pr}^{(1)}$ then sequentially other values of *k* and for subsequent issues $s_p^{(k)}$ and $s_q^{(k)}$ respectively. On the other hand, $c_i^{(k)}$ is an offer received by a supplier sequentially from a consumer at times $t_k, k = 1,2...\max$. Both the consumer and supplier have some ranges concerning the issues under negotiation such as:

$$a_{pr} \leq c_{pr}^{(k)} \leq b_{pr} \quad a_p \leq c_p^{(k)} \leq b_p \quad a_q \leq c_q^{(k)} \leq b_q \tag{5.1}$$

$$d_{pr} \leq s_{pr}^{(k)} \leq e_{pr} \quad d_p \leq s_p^{(k)} \leq e_p \quad d_q \leq s_q^{(k)} \leq e_q \tag{5.2}$$

These ranges are determined in the range specification stage of the negotiation process. In the equation (5.1) and (5.2) a_{pr}, a_p, a_q and b_{pr}, b_p, b_q are the minimum and maximum of price, performance and quantity for a consumer agent, respectively. On the other hand d_{pr}, d_p, d_q and e_{pr}, e_p, e_q mean the minimum and maximum of price, performance and quantity for a supplier agent, respectively. I have used $c_{pr}^{(k)}, c_p^{(k)}, c_q^{(k)}$ and $s_{pr}^{(k)}, s_p^{(k)}, s_q^{(k)}$ to denote the target values for the agents for the issues.

Different points from these intervals are of different value for negotiating agents (Kurbel and Loutchko 2005). For convenience the utility values are considered to be in the range [0, 1]. The value of negotiation issues is represented by utility functions U_{pr}, U_p, U_q for a consumer and G_{pr}, G_p, G_q for supplier:

$$U_{pr} : [a_{pr}, b_{pr}] \rightarrow [0,1]; \quad U_p : [a_p, b_p] \rightarrow [0,1]; \quad U_q : [a_q, b_q] \rightarrow [0,1]; \quad (5.3)$$

$$G_{pr} : [d_{pr}, e_{pr}] \rightarrow [0,1]; \quad G_p : [d_p, e_p] \rightarrow [0,1]; \quad G_q : [d_q, e_q] \rightarrow [0,1]; \quad (5.4)$$

The higher is the value of a utility function for a certain value of an issue the more advantageous is this value for a negotiating agent. Different utility functions adopt different strategies, depending on the type of the issue. U_p is an increasing function for the consumers, whereas the function U_{pr} is a monotonic decreasing one. The function G_p will decrease monotonically and G_{pr} will be a monotonic increased function for the supplier.

For a specific case it is necessary to link the general values used in equations (5.3), (5.4) with the limits specified as hard and soft constraints. These constraints do not necessarily need to cover the full range of utility values allowed in (5.3) and (5.4). In Fig. 5.3, the values $Pf^{c}_{\min}$ and Pf^{c}_{opt} are respectively, the minimal performance level the consumer will accept for the software product and the optimal performance level being sought by the consumer. The optimal performance level means the highest utility score the agent is trying to gain for the performance issue.

The utility function $G_p(c^k_p)$ of a supplier can be of the form presented in Fig. 5.4. Pf^{s}_{max} is the maximal performance level the supplier can provide to the consumer for that particular software, Pf^{s}_{opt} is the performance level the supplier considers optimal for the software product.

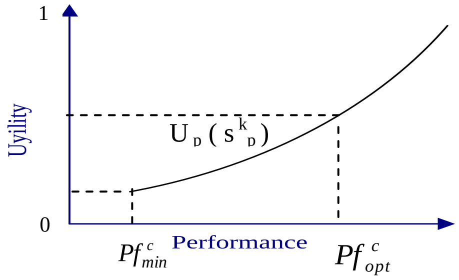

Figure 5.3 Utility function for performance used by a consumer agent

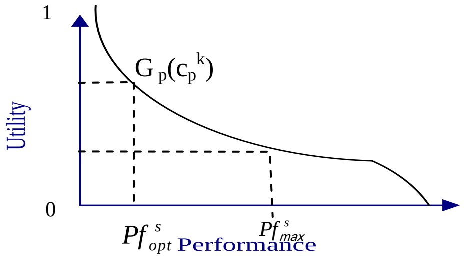

Figure 5.4 Utility function for performance used by a supplier agent

The utility function $U_{pr}(s^k_{pr})$ of a consumer can be of the form presented in Fig 5.5. Prf^c_{max} is the maximal price the consumer can offer to the supplier, Prf^c_{opt} is the price offer the consumer considers optimal for the software and targeting for. The values between this range $[Prf^c_{max}, Prf^c_{opt}]$ are the price offers which are going to be negotiated. In Fig. 5.6, the values Prf^s_{min} and Prf^s_{opt} are the minimal price the supplier will accept and the optimal price is looking for, respectively.

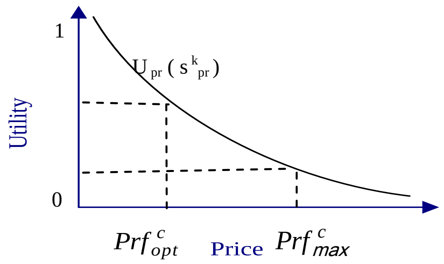

Figure 5.5 Utility function for price used by a consumer agent

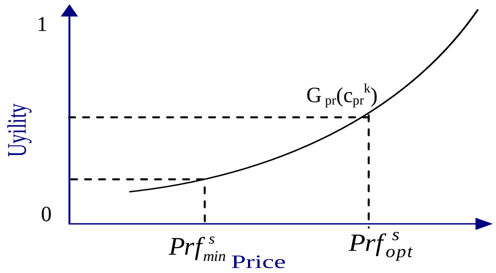

Figure 5.6 Utility function for price used by a supplier agent

The utility functions for other issues such as quantity can also be presented by utility graphs as above depending on the situation.

In my scenario each negotiation agent has different importance weights for the issues. They might also assign equal importance to each issue in my approach depending on the preferences of the agents. To reduce the complexity I have used the collective ordering of the issues derived in the pre-negotiation stage to assign the relative importance. Let $w_{pr}^{c}, w_{p}^{c}, w_{q}^{c}$ be the relative importance of price, performance and quantity respectively, for consumers, and $w_{pr}^{s}, w_{p}^{s}, w_{q}^{s}$ the relative importance of the same issues for a supplier. I assume that the following normalization relations are suitable for the approach:

$$w_{pr}^{c} + w_{p}^{c} + w_{q}^{c} = 1, \qquad w_{pr}^{s} + w_{p}^{s} + w_{q}^{s} = 1 \tag{5.5}$$

The utility values and relative importance of each issue are used to determine the total utility. A multi-issue utility function derived in equation 4.6 is used to generate the total utility of a consumer or supplier agent in my approach which is linear and will be used later to evaluate the overall outcome of the negotiation:

$$U(P) = w_{pr}^{c} U_{pr}(s_{pr}^{k}) + w_{p}^{c} U_{p}(s_{p}^{k}) + w_{q}^{c} U_{q}(s_{q}^{k}) \tag{5.6}$$

Here $U(P)$ will be the combined utility value for that particular offer.

On the other hand, the value of $c_i = c_{pr}, c_p, c_q$ received by a supplier can be evaluated by the utility function,

$$G(P) = w^s_{pr} G_{pr}(c^k_{pr}) + w^s_p G_p(c^k_p) + w^s_q G_q(c^k_q) \tag{5.7}$$

5.3.1.2.1 Negotiation Case 1: Boulware time dependent strategy with negotiation agenda (most important issue first) for Price => Performance => Quantity sequence

The behaviour a single negotiation agent adopts is a prepared protocol and strategy from the proposed negotiation approach. The consumer and supplier agents in this software purchase scenario also acts upon that. The parameters of the behaviour for this negotiation scenario are:

- The list of issues (i = 1, 2,..n) : price, performance, quantity.
- A [min(i), max(i)] initial range of acceptable values for each issue
- A relative weight (importance), w(i) for each issue and
- For each pair of issues (i, j) there is an influence that modifies the range of acceptable values for issue j depending on the results for issue i.

Before the series of offers counter-offers among the agents starts, there are number of steps that need to be performed to determine the issue parameters based on issue-by-issue sequence effect. The first step is to set up the maximum and minimum values of the issues for both consumer and supplier agent. The second step is to indicate what changes need to take place on the initial issue values depending on the sequential interdependency between the issues and to modify them according to the rules. Given these directions of change there is a need to determine a formula to calculate the numerical changes in [max, min]. This is done in step three.

Step 1: According to the agenda based model the consumer agent will start negotiating with the supplier over the issues related to the software product based on the derived preference order from the group decision-making process. The issues will be negotiated sequentially. In this negotiation case the most important issue is negotiated first. At first the agents will negotiate about the 1st issue, price per copy. To setup the allowed price interval for negotiation, which is the difference between the maximum and minimum values of the issues given by the agents, I have used two variables; the length of the allowed values interval for the agents (σ^a) and the degree of intersection (α^i) between the intervals of the two agents (consumer and supplier) ranging from 0 to 1. Here, 0 is for full overlap, 0.5 is partial overlap and 1 is for almost no overlap.

Now in the negotiation environment the lengths of the intervals (σ^a) for price issue are selected randomly from a range and the degree of intersection is assigned $\alpha^{pr} = 0.5$ for both the agents. For this experiment the consumer range (σ^c) is selected to be 500 and for the supplier (σ^s) is chosen as 650 per unit. An initial lower limit of 1000 for the consumer offers is taken. The overlap is assumed to be a fraction of the consumer range. The maximum and minimum prices of both agents are calculated using the above values:

$$Pr^{c}_{min} = 1000; Pr^{c}_{max} = min^{c} + \sigma^{c} = 1000 + 500 = 1500;$$
$$Pr^{s}_{min} = Pr^{c}_{min} + \sigma^{c} \times \alpha^{pr} = 1000 + 500 \times 0.5 = 1250;$$
$$Pr^{s}_{max} = Pr^{s}_{min} + \sigma^{s} = 1250 + 650 = 1900;$$

The maximum and minimum values for the performance and quantity issues can be calculated using the same process. For the performance issue consumer range (σ^c) is selected to be 30 and for the supplier (σ^s) is chosen as 50 per unit. The degree of intersection is assigned $\alpha^p = 0$.

$$P^{c}_{min} = 50; P^{c}_{max} = min^{c} + \sigma^{c} = 50 + 30 = 80;$$
$$P^{s}_{min} = P^{c}_{min} + \sigma^{c} \times \alpha^{p} = 50 + 30 \times 0 = 50;$$
$$P^{s}_{max} = P^{s}_{min} + \sigma^{s} = 50 + 50 = 100;$$

For the quantity issue, the difference between the agent's minimum and maximum values is also computed using two variables (σ^a) and α^q. Both σ^s and σ^c are 90 and 30 copies respectively; the degree of intersection is set to $\alpha^q = 0$.

$$Q^c_{min} = 10; Q^c_{max} = min^c + \sigma^c = 5 + 30 = 35;$$
$$Q^s_{min} = Q^c_{min} + \sigma^c \times \alpha^q = 10 + 30 \times 0 = 10;$$
$$Q^s_{max} = Q^s_{min} + \sigma^s = 10 + 90 = 100;$$

The maintenance issue is not considered in the negotiation phase as it is the least important issue for both agents. The consumer and supplier agents have different initial maximum and minimum values for price, performance and quantity issue respectively. So the initial maximum and minimum value ranges of the three issues for both the agents are:

Supplier ranges: Price [1250, 1900], Performance [50, 100], Quantity [10,100]
Consumer ranges: Price [1000, 1500], Performance [50, 80], Quantity [10, 35]

The initial reservation values (the values for the initial offer in a negotiation) for the three interdependent issues (price, performance, quantity) of the software product from both supplier and consumer agents are shown in Table 5.6. In some cases the first offer will be at the upper end of the range and in other cases the first offer is at the lower end of the range.

Table 5.6

The initial offer values of the agents for Price, Performance, Quantity for Negotiation Case 1

	Reservation offers
Supplier agent	1900, 50, 100
Consumer agent	1000, 80, 10

The interdependency factors will be considered in the negotiation by deriving linking relations between the relatively dependent pair of issues based on the agents' consensus decisions for the prior issue. In 4.3.2.1 the way in which the new ranges are to be calculated is specified. The midpoint of the range the maximum and minimum for each agent is assumed as the target value which is used in the linking constraints relations. So the initial target values are:

Price: supplier target = 1575, consumer target = 1250

Performance: supplier target = 50, consumer target = 65

Quantity: supplier target = 55, consumer target = 22

Step 2: Based on section 4.3.2.1, the six relationships between the issues can be derived for three issues which consider the sequence of the issues.

$$\begin{array}{l}
Price \rightarrow Performance \\
consumer: above\ target \Rightarrow decrease\ maximum\ Performance\ level \\
\qquad\qquad below\ target \Rightarrow increase\ minimum\ Performance\ level \\
seller: \quad above\ target \Rightarrow increase\ maximum\ Performance\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ minimum\ Performance\ level
\end{array}$$

$$\begin{array}{l}
Price \rightarrow Quantity \\
consumer: above\ target \Rightarrow decrease\ minimum\ Quantity\ level \\
\qquad\qquad below\ target \Rightarrow increase\ maximum\ Quantity\ level \\
seller: \quad above\ target \Rightarrow decrease\ minimum\ Quantity\ level \\
\qquad\qquad below\ target \Rightarrow increase\ maximum\ Quantity\ level
\end{array}$$

$$\begin{array}{l}
Performance \rightarrow Price \\
consumer: above\ target \Rightarrow increase\ minimum\ Price\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ maximum\ Price\ level \\
seller: \quad above\ target \Rightarrow increase\ minimum\ Price\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ maximum\ Price\ level
\end{array}$$

$$\begin{array}{l}
Performance \rightarrow Quantity \\
consumer: above\ target \Rightarrow increase\ minimum\ Quantity\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ maximum\ Quantity\ level \\
seller: \quad above\ target \Rightarrow increase\ minimum\ Quantity\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ maximum\ Quantity\ level
\end{array}$$

$$\begin{array}{l}
Quantity \rightarrow Price \\
consumer: above\ target \Rightarrow decrease\ maximum\ Price\ level \\
\qquad\qquad below\ target \Rightarrow increase\ maximum\ Price\ level \\
s\,eller: \quad above\ target \Rightarrow decrease\ minimum\ Price\ level \\
\qquad\qquad below\ target \Rightarrow increase\ minimum\ Price\ level
\end{array}$$

$$\begin{array}{l}
Quantity \rightarrow Performance \\
consumer: above\ target \Rightarrow increase\ minimum\ Performance\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ maximum\ Performance\ level \\
s\,eller: \quad above\ target \Rightarrow increase\ minimum\ Performance\ level \\
\qquad\qquad below\ target \Rightarrow decrease\ maximum\ Performance\ level
\end{array}$$

According to the above relationships and form of rules, for each pair of issues (i,j) there is an influence that modifies the range of acceptable values for issue j depending on the results for issue i. The following two Tables 5.7 and 5.8 derive the effect of changes the initial range of values of the both agents will have:

Table 5.7

The ranges of issues for consumer agent and the cross influences for Negotiation Case 1

Consumer			Price		Performance		Quantity	
			High	Low	High	Low	High	Low
Price	1500	Max			Stay	down	Down	Up
	1000	Min			Up	stay	Stay	Stay
Performance	80	Max	Down	Stay			Stay	down
	50	Min	Stay	Up			Up	stay
Quantity	35	Max	Stay	Up	Stay	down		
	10	Min	Down	Stay	Up	stay		

The entries in the Price High column in Table 5.7 determine the effect of results above the target for Price. The High column also shows that in this circumstance if Performance is next its max value goes down and min value stay same. Then next the max quantity will stay the same and the minimum Quantity will go down. In the Price Low column, the max performance will stay same and the min value will go up. On the other hand in the same Price Low column the max quantity will go up and the min will stay the same. The High and Low column of Performance and Quantity issues also indicates the interlink influences. The numbers on the left of the table are the initial values for the max and min for the three issues for consumer agent.

Table 5.8

The ranges of issues for supplier agent and the cross influences for Negotiation Case 1

Supplier			Price		Performance		Quantity	
			High	Low	High	Low	High	Low
Price	1900	Max			stay	Stay	Stay	stay
	1250	Min			Up	down	Down	up
Performance	100	Max	Up	Stay			Stay	down
	50	Min	Stay	Down			Up	stay
Quantity	100	Max	Stay	Up	stay	down		
	50	Min	Down	Stay	Up	stay		

Table 5.8 defines the influence the issues have between each other for the supplier agent. The High and Low column represents the above target and below target effect. For instance if Performance issue comes just after Price issue in sequence order then in the High column, max value of Performance issue will go up while min value in Low column will go down.

Step 3: The calculation of the changes in max and min following the results for an issue requires a calculation of a change factor, *F*. This is then applied in the direction determined by the tables given above. To find the amount by which the maximum and minimum values of the next sequential issues are changed, a standard calculation is performed. For instance, for (Price, Performance) ordered pair of issues for consumer agent negotiator there will be an influence in the following form.

Negotiator Consumer: Price => Performance

Let $Pr^{c}_{max} = 1500$, $Pr^{c}_{min} = 1000$, targetPrice = 1250, $P^{c}_{max} = 80$, $P^{c}_{min} = 50$, targetPerformance = 65, be the initial max, min , target values of Price and Performance issues and the result be R.

If R<targetPrice then change factor F = (targetPrice - R)/(targetPrice - Pr^{c}_{min}*)*

if R>targetPrice then change factor F = (R - targetPrice)/(Pr^{c}_{max} *- targetPrice)*

if R= targetPrice then F = 0.

The amount of increase/decrease for P^{c}_{max} *and/or* P^{c}_{min} *values is F*(*$P^{c}_{max} - P^{c}_{min}$*).*

For the next sequence,

Negotiator Consumer: Performance => Quantity

Let $P^{c}_{max} = 80$, $P^{c}_{min} = 50$, *targetPerformance = 65,* $Q^{c}_{max} = 35$, $Q^{c}_{min} = 10$, *targetQuantity = 22, be the initial max, min , target values of Performance and Quantity issues and the result be R.*

If R<targetPerformance then change factor F = (targetPerformance - R)/(targetPerformance - P^{c}_{min}*)*

if R>targetPerformance then change factor F = (R - targetPerformance)/(P^{c}_{max} *- targetPerformance)*

if R= targetPerformance then F = 0.

The amount of increase/decrease for Q^{c}_{max} *and/or* Q^{c}_{min} *values is F*(*$Q^{c}_{max} - Q^{c}_{min}$*).*

The result R is calculated using the parameter set defined in Table 5.10 and equation 4.1 and 4.3. The result R is evaluated using the above rules. After the calculations the following values [1400, 59.6, 33] for three issues Price, Performance, Quantity were derived.

R(esult)	1400	59.6	33

The following Table 5.9 has the entries that carry out the above calculations for the consumer agent for Price => Performance => Quantity sequence.

Table 5.9

Changes on the ranges of issues for consumer agent

with the new max, min and target values for Negotiation Case 1

		Price	Performance	Quantity
Consumer	Origmax	1500	80	35
	Origmin	1000	50	10
	Change	0	18	15
	Newmax	1500	62	35
	Newmin	1000	50	25
	t(arget)	1250	56	30
	t – min	250	6	5
	max – t	250	6	5
	F	0.6	0.6	0.6

In the first column of for the Price values there is no ‘change’ since this is the first issue in the sequence. The new target value for Performance and Quantity is calculated from the newmin and newmax values of the issues. The ‘change’ value for Performance and Quantity is calculated using the changing factor ‘F’ value for Price and Performance respectively. The application of the change (‘up’, ‘down’, or, ‘stay’) depends on the result of the negotiation in relation to the target.

The same process is done for the supplier agent also. The Supplier agent calculation for its 'F' and 'change' values is carried out independently for same issue sequence and is shown below in Table 5.10.

Table 5.10

Changes on the ranges of issues for supplier agent

with the new max, min and target values for Negotiation Case 1

		Price	Performance	Quantity
Supplier	Origmax	1900	100	100
	Origmin	1250	50	10
	Change	0	26.92308	4.536
	Newmax	1900	100	95.464
	Newmin	1250	23.07692	10
	t(arget)	1575	61.53846	52.732
	t – min	325	38.46154	42.732
	max – t	325	38.46154	42.732
	F	0.538462	0.0504	0.461762

Both the consumer and supplier agent have new range of maximum and minimum values for the sequential effect on the issues. These ranges of issue values will be used for the offer counter-offer negotiation process.

The parameters of the individual alternate offer processes

The impact of variations in the issue-by-issue sequence has been explored in this research with the help of the variations in the parameters of the individual alternate offer processes. For a given pair of k_a and β in equation (4.1), an agent has different strategies. In the first experiment the agents have adopted Boulware time dependent strategy in the proposed model to reach the allowable range swiftly. The parameters are specified with the values of β = 0.5, k_a = 0.2 and t_{max} = 10. In this model the initial maximum and minimum parameters of the issues for both agents are changed after the interdependency factors are considered. The following Table 5.11 shows the modified parameters for the maximum and minimum values of the Performance and Quantity issues of a software product.

Table 5.11

The modified parameters of P_{min}, P_{max} for Price => Performance => Quantity sequence

Offer Parameters	k_a	t_{max}	β	P_{min}	P_{max}
Consumer price	0.2	10	0.5	1000	1500
Supplier Price	0.2	10	0.5	1250	1900
Consumer Performance	0.2	10	0.5	50	62
Supplier Performance	0.2	10	0.5	23.07692	100
Consumer Quantity	0.2	10	0.5	25	35
Supplier Quantity	0.2	10	0.5	10	95.464

Both the supplier and consumer agent are have generated the offers in Fig. 5.7 and Fig. 5.8 using equation (4.1), (4.2) and (4.3) respectively at each round. The parameters of Table 5.11 are used to generate these offers and counter-offers for both consumer and supplier agents. These figures provide the offer process of the approach of the proposed negotiation strategy. The following Table 5.12 shows the generated offers counter-offers of the agents until the maximum time limit is reached.

Table 5.12

The sequence of offers counter-offers for consumer and supplier agent for Negotiation Case 1

	Price		Performance		Quantity	
Offers	Consumer	Supplier	Consumer	Supplier	Consumer	Supplier
1	1022.8764	1870.261	50.54903	96.48056	25.45753	91.55379
2	1047.2332	1838.597	51.1336	92.73336	25.94466	87.39053
3	1073.4014	1804.578	51.76163	88.70748	26.46803	82.91765

4	1101.8576	1767.585	52.44458	84.3296	27.03715	78.05368
5	1133.3333	1726.667	53.2	79.48718	27.66667	72.6736
6	1169.0599	1680.222	54.05744	73.99079	28.3812	66.56693
7	1211.4382	1625.13	55.07452	67.47105	29.22876	59.32329
8	1266.6667	1553.333	56.4	58.97436	30.33333	49.8832
9	1400	1380	59.6	38.46154	33	27.0928
10	1400	1380	59.6	38.46154	33	27.0928

Fig. 5.7 and Fig. 5.8 represents the offers the consumer and supplier agent generate for the Price issue with selected parameters respectively.

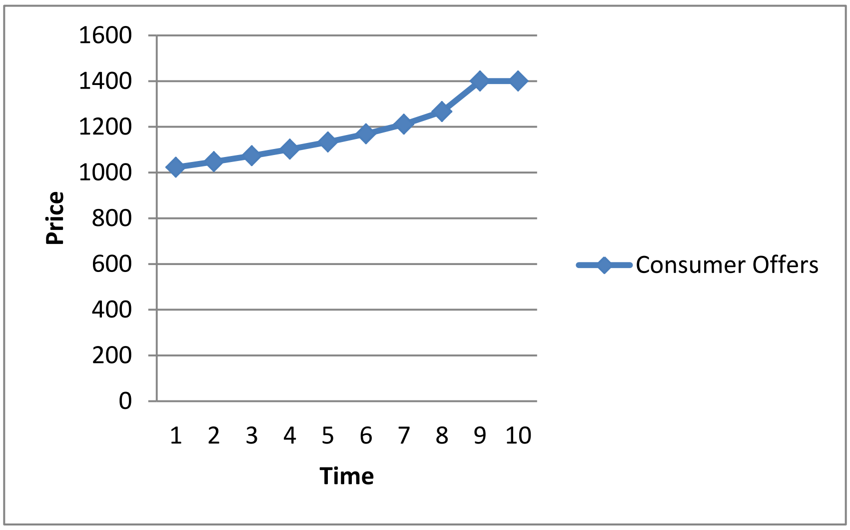

Figure 5.7 Consumer agent's offer generation for price using the Boulware concession strategy, where $Pr^{c}_{max} = 1500, Pr^{c}_{min} = 1000, k_a = 0.2, t_{max} = 10, \beta = 0.5$

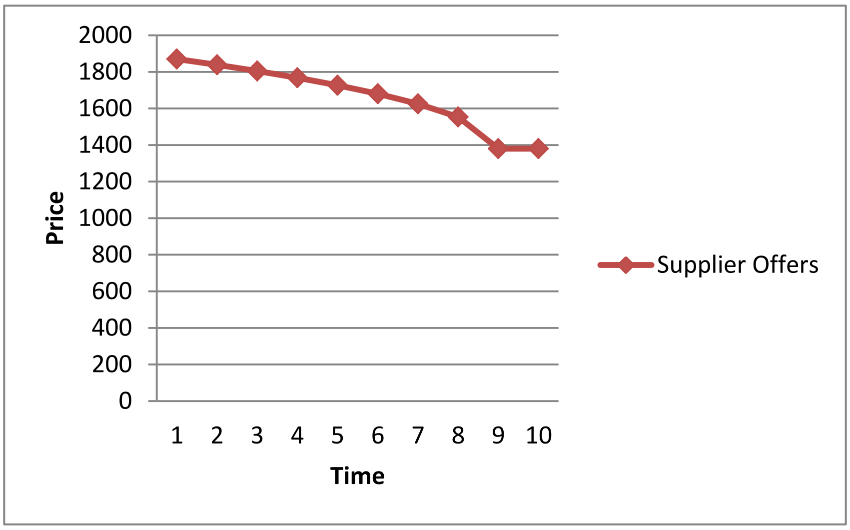

Figure 5.8 Supplier agent's offer generation for price using the Boulware concession strategy, where $Pr^{s}_{max} = 1900, Pr^{s}_{min} = 1250, k_a = 0.2, t_{max} = 10, \beta = 0.5$

The consumer gradually increases the price, whereas the supplier gradually decreases its price. Both the agents are trying to maximise their own utilities for Price issue. The two agents gradually reach to an agreement zone by using Boulware time dependent strategy which is showed in Fig. 5.9. So the acceptable price price range is [1400, 1380] for both of the agents at t = 9.

Figure 5.9 The acceptable price for both agents for Price issue
$Pr^s_{max} = 1900, Pr^s_{min} = 1200, Pr^c_{max} = 1500, Pr^c_{min} = 1000, k_a = 0.2, t_{max} = 10, \beta = 0.5$

Next the performance issue is negotiated according to the agreed preference ordering. The same negotiation process has been applied to the Performance issue. After generating the offers for the supplier and consumer about the performance of the software product, they came to an acceptable value of 59 at t=8, shown in Fig. 5.10. The final issue in the sequence is the Quantity. Fig, 5.11 shows the acceptable quantity range [27, 33] for both agents.

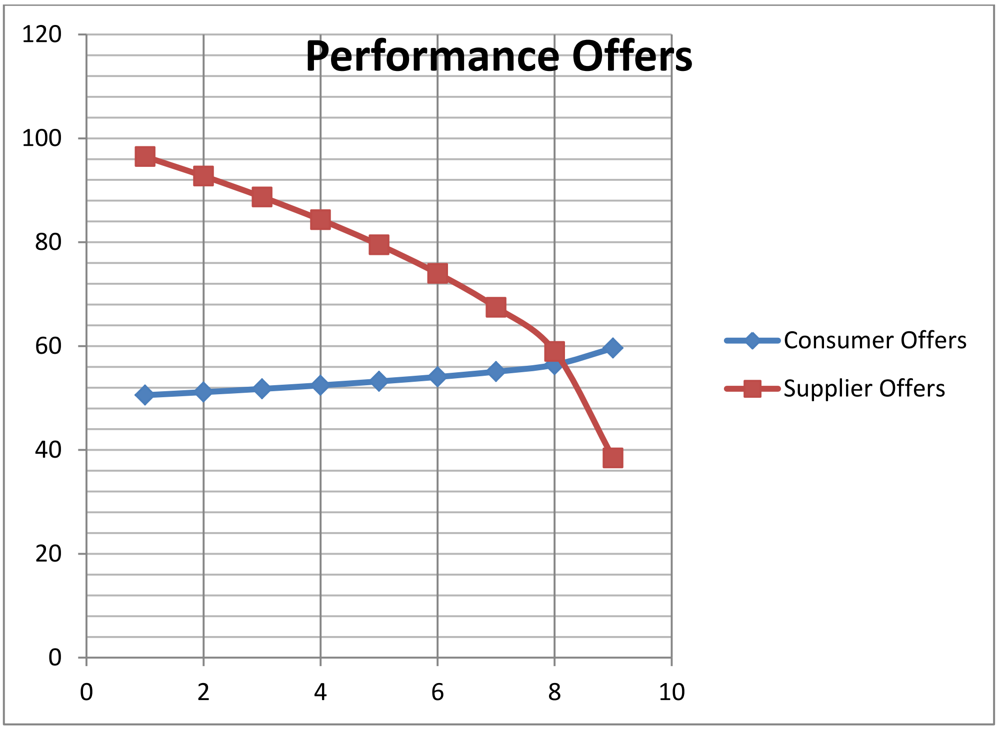

Figure 5.10 The acceptable performance for both agents for Performance issue
$P^s_{max} = 100, P^s_{min} = 23, P^c_{max} = 62, P^c_{min} = 50, k_a = 0.2, t_{max} = 10, \beta = 0.5$

Figure 5.11 The acceptable Quantity for both agents for Quantity issue
$Q^s_{max} = 95, Q^s_{min} = 10, Q^c_{max} = 35, Q^c_{min} = 25, k_a = 0.2, t_{max} = 10, \beta = 0.5$

A calculation of utility for Consumer and Supplier for each issue is carried on for this particular issue sequence. For each participant these values are added using their weightings that are independent of the issue sequence. According to the proposed approach which is described in chapter 4, if the negotiated value for issue i is v(i) the raw utility for issue i is U(i) = (v(i) - min(i))/(max(i) - min(i)) where the max(i) and min(i) are the initial or modified values for the issue. This equation is used to calculate the individual utility for each issue for both supplier and consumer agent.

The total utility for an agent is the sum over i=1,2,..,n of w(i)*U(i). Adding together the two agent's results gives a utility value for the negotiation. So the total utility is derived for both agents by applying equation (4.6) with different important weights for different issues. The importance weights of issues (price, performance, quantity) for the supplier agent is w_i^s = [0.5, 0.1, 0.4] and for the consumer is w_i^c = [0.5, 0.4, 0.1].

The Consumer utility entries are shown together with the total Customer Utility.

		Weights		Weights
Consumer	Price	0.5	Supplier	0.5
	Performance	0.4		0.1
	Quantity	0.1		0.4

Consumer	Weight	0.5	0.4	0.1	Total
	Utility	0.2	0.8	0.8	0.5

The Supplier utility values are calculated in the same process as Consumers. Using the Supplier weights; a Supplier's total utility is calculated. Finally the total of the Consumer and Supplier utility values give a joint utility value. The joint utility for each of the issue sequences is also shown.

Supplier	Utility	0.230769	0.5252	0.730881	0.460257
	Weight	0.5	0.1	0.4	Total
				Total utility	0.960257

The sequence Price-Performance-Quantity is a success as there is no 0 utility for any of the issue value. The equation 4.6 determines the above result by using the importance weights and individual utility of the issues for the determined agenda sequence.

The total utility gained by the consumer agent for all the issues is 0.5*0.2 + 0.4*0.8 + 0.1*0.8 = 0.5;

The total utility gained by the supplier agent for all the issues is 0.5*0.23 + 0.1*0.52 + 0.4*0.73 = 0.46;

So the total utility for the consumer is obtained 0.5 for which the opponent supplier gains total 0.46 utility. The overall outcome of the negotiation is defined as an (utility, effort) pair. The utility is the total utility accrueing to the two agents taking part. The effort can be calulated by counting the number of offer counter-offer steps that are taken over the set of issues.

Adding together the two agent's results gives a utility value of 0.96 for the negotiation outcome. The total number of offer counter-offer steps that are taken over the set of issues to gain this utility is 27. So for the pair of the defined agents the negotiation outcomes (utility = 0.96, effort = 27) is derived for the selected agenda.

5.3.1.2.2 Negotiation Case 2: Boulware time dependent strategy with negotiation agenda (least important issue first) for Quantity => Performance => Price sequence

This experiment is done to show that there can be a range of outcomes in multi-issue negotiation and so that the choice of agenda is important. Considering the relationship between the issues and the best sequences for the agenda is one of the main contributions of this research.

For the pair of defined agents (consumer and supplier) the (utility, effort) outcomes are determined. These outcomes are derived from each of the possible agendas. An additional variation could be introduced by changing the target values for the agents on the concession/hard-line axis.

Now to evaluate the proposed agenda based negotiation process with a selected sequential preference order and to prove the agenda effect, I am comparing the outcome of the determined agenda with other possible agendas, which means changing the possible sequences of the issues. The main concern is if different agendas give different utilities to the agents. Obviously the utility maximising agent wants to know which agenda is maximising his own utility values and is approaching to a feasible negotiation space.

In this negotiation case the issues will be negotiated is a different sequence then the negotiation case 1. The sequence will be Quantity => Performance => Price. At first the pair of agents will negotiate about the 1^{st} issue, quantity. According to the preference order quantity issue is the least important among all and price is the most important. To show that the choice of agenda is important and there is a range of outcomes when the sequence varies, the values of the issues are kept the same as case 1.

The initial maximum and minimum values for Quantity, Price and Performance issues are same for both agents as case 1. So the initial values of three issues for both the agents are:

Supplier ranges: Quantity [100, 10], Performance [50, 100], Price [1250, 1900]

Consumer ranges: Quantity [35, 10], Performance [50, 80], Price [1000, 1500]

The interdependency factors will be considered in the negotiation by deriving linking relations between the relatively dependent pair of issues based on the agents' consensus decisions. Now to consider the interdependency factors between the issues some initial constraint ranges of each of negotiators are used. The midpoint of range the maximum and minimum for each agent is assumed as the target value which is used in the linking constraints relations. So the initial target values are:

Quantity: supplier target = 55, consumer target = 22

Performance: supplier target = 50, consumer target = 65

Price: supplier target = 1575, consumer target = 1250

Only the interdependency factors which are considered in the previous negotiation case by deriving linking relations between the relatively dependent pair of issues based on the agents' consensus decisions are changed.

Quantity $\rightarrow$ *Performance*
consumer : above target $\Rightarrow$ *increase minimum Performance level*
below target $\Rightarrow$ *decrease maximum Performance level*
s eller : above target $\Rightarrow$ *increase minimum Performance level*
below target $\Rightarrow$ *decrease maximum Performance level*

Quantity $\rightarrow$ *Price*
consumer : above target $\Rightarrow$ *decrease maximum Price level*
below target $\Rightarrow$ *increase maximum Price level*
s eller : above target $\Rightarrow$ *decrease minimum Price level*
below target $\Rightarrow$ *increase minimum Price level*

Performance $\rightarrow$ *Price*
consumer : above target $\Rightarrow$ *increase minimum Price level*
below target $\Rightarrow$ *decrease maximum Price level*
seller : above target $\Rightarrow$ *increase minimum Price level*
below target $\Rightarrow$ *decrease maximum Price level*

Performance $\rightarrow$ *Quantity*
consumer : above target $\Rightarrow$ *increase minimum Quantity level*
below target $\Rightarrow$ *decrease maximum Quantity level*
seller : above target $\Rightarrow$ *increase minimum Quantity level*
below target $\Rightarrow$ *decrease maximum Quantity level*

Price $\rightarrow$ *Performance*
consumer : above target $\Rightarrow$ *decrease maximum Performance level*
below target $\Rightarrow$ *increase minimum Performance level*
seller : above target $\Rightarrow$ *increase maximum Performance level*
below target $\Rightarrow$ *decrease minimum Performance level*

Price $\rightarrow$ *Quantity*
consumer : above target $\Rightarrow$ *decrease minimum Quantity level*
below target $\Rightarrow$ *increase maximum Quantity level*
seller : above target $\Rightarrow$ *decrease minimum Quantity level*
below target $\Rightarrow$ *increase maximum Quantity level*

The above six relationships between the issues can be derived again for these three issues which consider the order of the issues. The main aim is to determine the (utility, effort) outcomes derived from the selected agenda. Among the six relationships, the $Quantity \rightarrow Performance$ and $Performance \rightarrow Price$ sequence is used for the selected issue sequence.

The following Tables 5.13 and 5.14 show the effect of changes the initial range of values of the both agents will have using the issue interdependency rules.

Table 5.13

The ranges of issues for consumer agent and the cross influences for Negotiation Case 2

Consumer			Quantity		Performance		Price	
			High	Low	High	Low	High	Low
Quantity	35	max			stay	down	stay	Up
	10	min			up	stay	down	Stay
Performance	80	max	Stay	down			down	Stay
	50	min	Up	Stay			stay	Up
Price	1500	max	Down	Up	stay	down		
	1000	min	Stay	Stay	up	stay		

So the entry in the Quantity High column determine the effect of results above the target for Quantity thus the max Performance will stay the same and the minimum Performance will go up. The column also shows that in the same circumstance if Price is next its max will go down and min will stay.

The numbers on the left of the table are the initial values for the max and min for the three issues.

Table 5.14

The ranges of issues for supplier agent and the cross influences for Negotiation Case 2

Supplier			Quantity		Performance		Price	
			High	Low	High	Low	High	Low
Quantity	100	max			stay	down	stay	Up
	10	min			up	stay	down	Stay
Performance	100	max	Stay	Down			up	Stay
	50	min	Up	Stay			stay	Down
Price	1900	max	Stay	Stay	stay	stay		
	1250	min	Down	Up	Up	down		

The calculation of the changes in the initial max and min values of the three issues are performed in the same way as case 1. The following Tables 5.15 and 5.16 have the changed entries that carry out the calculations for the consumer and supplier agent respectively for Quantity => Performance => Price sequence.

Table 5.15

Changes on the ranges of issues for consumer agent with the new max, min and target values for Negotiation Case 2

		Quantity	Performance	Price
Consumer	Origmax	35	80	1500
	Origmin	10	50	1000
	Change	0	18	33.33333
	Newmax	35	80	1466.667
	Newmin	10	68	1033.333
	t(arget)	22.5	74	1250
	t – min	12.5	6	216.6667
	max – t	12.5	6	216.6667
	F	0.6	0.066667	0.6

Table 5.16

Changes on the ranges of issues for supplier agent

with the new max, min and target values for Negotiation Case 2

Supplier	Origmax	100	100	1900
	Origmin	10	50	1250
	Change	0	27.77778	15.6
	Newmax	100	100	1900
	Newmin	10	50	1234.4
	t(arget)	55	75	1567.2
	t – min	45	25	332.8
	max – t	45	25	332.8
	F	0.555556	0.024	0.5625

Both the consumer and supplier agent have new range of maximum and minimum values for the sequential effect on the issues. These ranges of issue values will be used for the offer counter-offer negotiation process. Table 5.17 shows the modified parameters for the maximum and minimum values of the Performance and Price issues of a software product.

Table 5.17

The modified parameters of P_{min}, P_{max} for Quantity => Performance => Price sequence

Offer Parameters	k_a	t_{max}	β	P_{min}	P_{max}
Consumer price	0.2	10	.5	1033.333	1466.667
Supplier Price	0.2	10	.5	1234.4	1900
Consumer Performance	0.2	10	.5	68	80
Supplier Performance	0.2	10	.5	50	100
Consumer Quantity	0.2	10	.5	10	35
Supplier Quantity	0.2	10	.5	10	100

This negotiation scenario also adopts the Boulware time dependent tactic where the parameters are specified with the values of β = 0.5 and k_a = 0.2. The offers and counter offers for both the supplier and consumer agent are generated in using equation (4.1), (4.2) and (4.3) respectively at each round. Table 5.18 shows the offers and counter-offers for both agents.

Table 5.18

The sequence of offers counter-offers for consumer and supplier agent

	Quantity		Performance		Price	
Offers	Consumer	Supplier	Consumer	Supplier	Consumer	Supplier
1	11.14382	95.88225	68.54903	97.71236	1053.16	1869.547
2	12.36166	91.49803	69.1336	95.27668	1074.269	1837.123
3	13.67007	86.78775	69.76163	92.65986	1096.948	1802.288
4	15.09288	81.66563	70.44458	89.81424	1121.61	1764.407
5	16.66667	76	71.2	86.66667	1148.889	1722.507
6	18.45299	69.56922	72.05744	83.09401	1179.852	1674.947
7	20.57191	61.94113	73.07452	78.85618	1216.58	1618.533
8	23.33333	52	74.4	73.33333	1264.444	1545.013
9	30	28	77.6	60	1380	1367.52
10	30	28	77.6	60	1380	1367.52

Both the agents are trying to maximise their own utilities for each issue. The consumer gradually increases the quantity, whereas the supplier gradually decreases its quantity. The two agents gradually reach to an agreement zone on Quantity which is showed in Fig. 5.12. So the acceptable quantity for both of the agents at t = 9 is 30.

Figure 5.12 The acceptable Quantity for both agents for Quantity issue

$$Q^s_{max} = 100, Q^s_{min} = 10, Q^c_{max} = 35, Q^c_{min} = 10, k_a = 0.2, t_{max} = 10, \beta = 0.5$$

Next the acceptable range for performance issue is negotiated according to the agenda sequence. The last negotiation issue is price. Fig, 5.13 and Fig. 5.14 shows the acceptable performance range and Price offer for both agents.

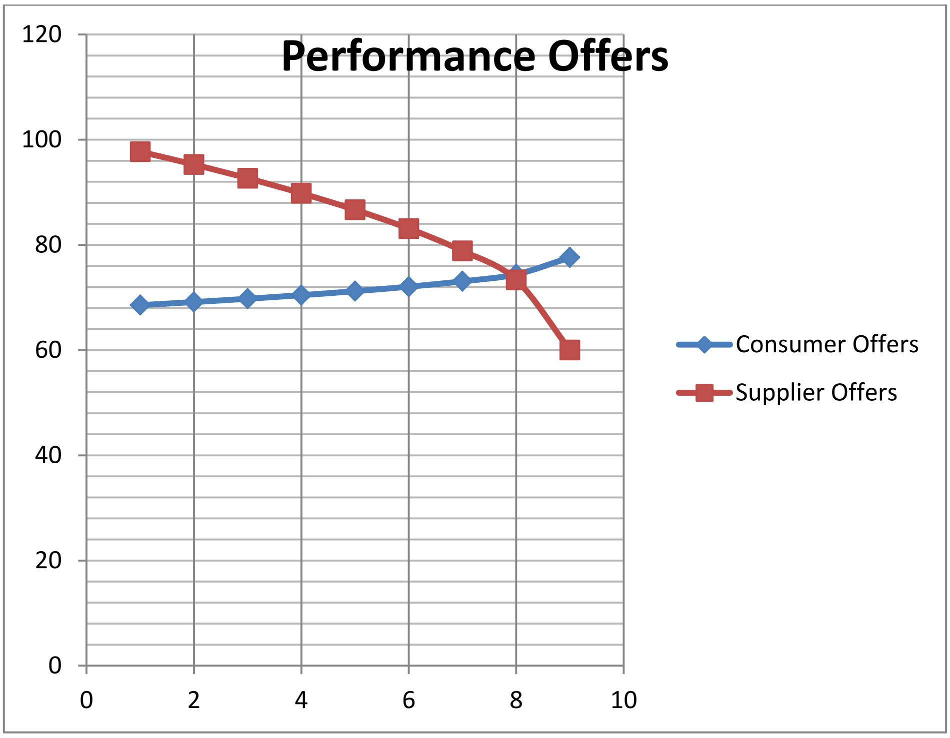

Figure 5.13 The acceptable performance for both agents for Performance issue

$P^{s}_{max} = 100, P^{s}_{min} = 50, P^{c}_{max} = 80, P^{c}_{min} = 64, k_{a} = 0.2, t_{max} = 10, \beta = 0.5$

Figure 5.14 The acceptable price for both agents for Price issue

$Pr^{s}_{max} = 1900, Pr^{s}_{min} = 1234, Pr^{c}_{max} = 1467, Pr^{c}_{min} = 1033, k_{a} = 0.2, t_{max} = 10, \beta = 0.5$

For the above accepted offer values for the issues, the individual utility is determined. The raw utility for quantity issue is 0.8 for the consumer agent and 0.40 for the supplier agent, which is derived from equation 4.4. After applying the same procedure for the performance issue the utility of [0.53, 0.1] is gained for both the agents respectively. Finally the price issue gets 0.8 utility for consumer agent and 0.5 utility for supplier agent respectively. The following results are determined by using the importance weights and the individual utility of the issues for the determined agenda sequence.

The total utility gained by the consumer agent for all the issues is 0.1*0.8 + 0.4*0.53+ 0.5*0.48 = 0.69;

The total utility gained by the supplier agent for all the issues is 0.4*0.77 + 0.1*0.51 + 0.50*0.78 = 0.75;

So the total utility for the consumer is obtained 0.69 for which the opponent supplier gains total 0.75 utility. Adding together the two agent's results gives a utility value of 1.45 for the negotiation outcome. The total number of offer counter-offer steps that are taken over the set of issues to gain this utility is 27. So for the pair of the defined agents the negotiation outcomes (utility = 1.45, effort = 27) is derived from the selected agenda (Quantity>Performance>Price). The sequence Quantity-Performance-Price is a success as there is no 0 utility for any of the issue value.

So it is shown that varying the sequence of the issues may cause different results in a multi-issue negotiation process and finding the optimal agenda is very important for an effective and successful issue-by-issue negotiation outcome. In both negotiation cases the agents have negotiated based on a particular sequence derived from the group of participating agents.

5.4 Discussion

The prospect for reaching any agreement between the consumer and the supplier depends on there being a certain degree of compatibility between the two negotiator's allowed ranges of values for the issues. An approximate match can be assumed in a relatively mature market. The example results shown in detail provide evidence that the agenda chosen makes a considerable difference to the outcomes of negotiation. The results show there is an agreement for the common preference sequence of the agents involved in the process. So an issue-by-issue procedure can achieve agreement if an optimal agenda is determined. The difference between the existing work on issue-by-issue negotiation and ours is the existing models that define the sequence of the issues endogenously during the negotiation process and in contrast, my model defines an exogenous agenda according to the agents' preferences. When multiple issues are involved in a negotiation then the outcome not only depends on the negotiation procedure but also can be influenced by the negotiation agenda. The agenda based approach directs the negotiating agents in the process of searching for prospective solutions from the individual area of interest towards an agreement from the common area of interest. It reduces the domain of negotiation solutions (search space) by considering individual issues, each in a simple to manage converging monotonic offer exchange and dealing with issues according to the preferences of the participating agents.

One of the accepted ways to measure the quality of a model is performance measure (Coehoorn and Jennings 2004; Hindriks and Tykhonov 2008). With this method, the success of a model is expressed in terms of the negotiation result (Baarslag et al. 2013).

Performance: The negotiation agreement point depends on a large number of factors. Once the allowed ranges are chosen the choice of parameters for alternate offer process normally have more effect on the rate of reaching agreement than the value of the agreement point. For the example case the efficiency of the negotiation process increases, because the agreed preference sequence of multiple issues selects an agenda combination that leads to an overall agreement. The efficiency of the negotiation process increases, because the agreed preference sequence of multiple issues eliminates lots of possible agenda combinations which do not reflect the agents' common interest. This suggests that randomly generated possible agenda combination will increase the computational time and may lead to no zone agreement space. For *n* negotiating issues there will be a total of *n!* scenarios. This *n!* gives the number of ways that the issues can be permuted. The common preference order of the agents minimises the possible ways and helps to select the optimal agenda scenario which could shorten the negotiation process. For example, consider a scenario where a consumer agent may want to negotiate the issues of a software product such as price, performance, reliability etc. with a supplier agent. The buyer agent may prefer to follow the sequence {price, reliability, performance} during the negotiation process. On the other hand, the supplier's side might prefer the order of {performance, price, reliability}. So the negotiators have conflict because the opponent has different preference list, which needs to be resolved before the offer-counter offer process starts. For this reason in the pre-negotiation phase, the group decision-making process minimises the conflict which helps to get rid of the non-optimal solutions in the later phase and both the consumer and supplier are better off. In several scenarios the joint utility of both the agents can improve by negotiating the issues in their common preferred order (Abedin et al. 2011). In section 5.3.1.2.1 Negotiation Case 1 and section 5.3.1.2.2 Negotiation Case 2, the common preference order sequence derived in the group decision-making process were assigned. Both the scenarios have achieved a negotiation success outcome with higher joint utility compare to the other issue-by-issue preference sequences. The negotiation case 3 described in A1 shows a low joint utility which does not follow a common preference agenda of the agents.

Equilibrium: If there is an agreement between agents, a stable equilibrium in the end of negotiation should be produced in order to ensure that agents do not deviate from their agreements. As the proposed negotiation process is directed with agents' own chosen preferences, there is less chance of diversion from the agreement. The results also show the stability even when there are variations in the negotiation parameters. The model equilibrium is evaluated on global optimality. In section 5.3.1.2.1 Negotiation Case 1 and section 5.3.1.2.2 Negotiation Case 2, both negotiation cases showed that agreements have been achieved in a considerable negotiation steps. In these cases the preference order derived in the pre negotiation stage helped to reach the equilibrium.

Simplicity in Negotiation Protocol: Negotiation processes that are simple and efficient are preferable to complex processes (Kraus 2001). The simplicity increases also the amount of efficiency and stability. The proposed negotiation model consists of a systematic and explicit negotiation protocol which includes group consensus on agenda and detailed negotiation on issue. Therefore, the agents do not have to guess or estimate the preferences of their opponent or their utility function. Moreover it is possible to compute the proposed simple and feasible strategy in a reasonable amount of time. Because, the agent doesn‘t need to take more time and resource to come to optimal solution. The agents use less computational and communicational resources to reach their preferred goal as the selected agenda is already based on the consensus.

Chapter 6

Conclusions and Future Research

6.1 Review of Thesis and Discussion

The fundamental problem of an automated negotiation is the dilemma faced by any negotiator to attain two conflicting goals: maximise agent's own utility and chance of reaching an agreement with an opponent at the same time. In this work on agenda based multi-issue negotiation model, the agents try to reach an agreement by resolving these conflicts while maximising their own utility.

The proposed model shows the agenda sequence can be one of the most important structural aspects of multi-issue negotiation as well as a significant determinant of negotiation power and influence in issue-by-issue negotiation. This research investigates a multi-issue preference ordering process in an agenda based multi-agent negotiation environment where preference information or opinions on multi-issues associated with the alternatives or services are expressed in linguistic formats by the agents. The preference ordering process considers the common knowledge between the agents to process the choice of sequence over the issues using a hybrid method based on Fuzzy Ordered Weighted Averaging operator and fuzzy quantifies. The aim of using this method is to investigate the common sequence of the issues and to calculate their weightings according to the group of agents' preferences in such way that a higher consensus level is achieved. In addition to this method of finding a first approximation a dynamic and iterative group consensus process is used to support and validate the group preference ordering process.

This consensus measure method helps to improve the consensus level of the group. The preference ordering impacts the agenda based negotiation process in allowing an efficient issue-by-issue procedure. So it is important to decide it before the actual negotiation taking place. In order to make an automated negotiation efficient, the agents must be able to adequately represent their importance, preferences, and interdependency about the issues along with cost functions in the given domain such that they can negotiate within a realistic search space. Automated multi-issue negotiation is usually unsupervised and the agents' final gained utility is uncertain based on a number of factors such as bargaining power, utility functions, and cooperative or uncooperative level etc. This uncertainty makes it very hard to explore the agents' preferences. The fuzzy preference approach and the significant choice of sequence help to solve this case. The agenda based negotiation approach improves the negotiation convergence process and minimises the complexity. An efficient negotiation mechanism should also be able to produce Pareto optimal solutions for multi-issue negotiation. This model improves agent's total utility by providing an effective equilibrium outcome which is a Pareto optimal solution.

6.2 Contributions Achieved

This research has achieved theoretical contribution and also contains important practical suggestion for difference preferences in group negotiations. The contributions of this work can be summarised as follows:

The proposed issue-by-issue negotiation approach in multi-issue negotiation process: the simplest negotiation takes place between two agents on a single issue. Two agents interact to settle on a value for that single issue. But most negotiation nowadays involves multiple issues. The situation becomes more complicated when the negotiators deal with multiple issues which have influence on each other. In the multi-issue negotiation the importance of the issues may vary for the agents. One agent may prefer a particular issue more important whereas the other agent may consider another issue. For example, the performance issue of a service may be the most important issue for a particular agent while the price of the service may be more important for the other agent. Realistically it is also possible to have interdependencies between the issues. In this situation, the search space for the acceptable agreement increases, which complicates the whole negotiation process. Considering the huge search space created by the issues, the most difficult challenge is to design a less complicated negotiation model to find a mutually beneficial solution for all the participated agents. Instead of blindly searching for agreements in the search space, this model will provide an agenda to find a successful consensus result. Consequently, the number of steps to reach an agreement is also important. The experimental results of the proposed model shows reasonable number of rounds are required to have an agreement in a negotiation situation.

The proposed pre-negotiation phase in multi-issue negotiation process: the proposed multi-issue agenda based negotiation has come with the solutions to deal with the above situations. The agents have sufficient knowledge about the negotiator's preferences. The model accepts different formats of preferences. The preferences can be represented in qualitative and quantitative ways. In a group negotiation, the individual preferences are transformed and aggregated using soft-computing techniques such as fuzzy membership functions, fuzzy preference relations. Considering the opponents' preferences over the issues can determine better-targeted offers counteroffers which enables quicker negotiation results. It reduces the search space and leads to more efficient negotiation. This process takes place in a pre-negotiation phase which has been introduced in this work. The pre-negotiation phase incorporates the fuzzy group decision-making process. Experimental results show the process can help the agents to gain higher consensus degree over the preferences. So the preference ordering has more acceptances among the agents.

In spite of the attention that negotiations have received as a possibility for resolving conflict of interests, both between individuals and groups, there has been very little consideration of a crucial stage in the negotiation process: the pre-negotiation phase where the preference consensus shows the willingness to actually accept an offer to negotiate. The vast majority of negotiations research assumes that two sides are already at the negotiating table (Bear 2011; Kteily et al. 2013), and subsequently investigates a number of other negotiation factors. If, however, one (or both) of the two opposing agents in a preference conflict expresses no willingness to enter into negotiations with its opponent, these other factors will matter very little. The pre-negotiation phase helps to locate if there is any possibility of reaching a consensus with the conflicting preferences over the issues. For example if the supplier realizes that it would not be able to satisfy the consumers' requirement or vice versa in a reasonable time then it is better not to waste resources to continue with the actual negotiation.

The issue-by-issue agenda based negotiation model with the interdependency factor: this research examined sequential negotiations, with issues varying in agenda sequence. In such negotiations, the most important issues can be discussed first, or after less important issues are discussed depending on the group consensus. Because both ‘important first’ and ‘important later’ orders specify the discussion of the same issues, both agendas may seem to have equal potential to influence the outcome. In contrast to other sequential issue-by-issue works, this negotiation approach considers interdependencies between the issues. Absence of issue dependencies in sequential negotiation has shown the importance of such model. The existing models define the sequence of the issues endogenously during the negotiation process and in contrast, the presented model defines an exogenous agenda according to the agents’ preferences. The proposed issue-by-issue negotiation approach is much simpler in terms of computational complexity than the existing package deal or simultaneous negotiations even though it considers the interdependency factors during the negotiation process by deriving linking relations between the relatively dependent issues.

Numerous tasks must be carried out by negotiation teams during the pre-negotiation stage to avoid unexpected outcomes. These pre-negotiation tasks such as preference collection and consensus, understanding the negotiation environment, and selecting a proper agenda may have a significant impact on performance during the negotiation, which have been largely unexplored by multi-issue multi-agent literature. The proposed model demonstrated the negotiation agenda as a crucial aspect of the negotiation process. This research initiated another important factor of negotiation which is pre-negotiation discussions or phase.

The model shows how the agenda hold the potential to influence outcomes. Moreover, unlike other relevant aspects of negotiations, such as involvement of mediator, which may be applicable in some contexts but not always, the negotiation agenda can be used across the vast majority of negotiations.

The final negotiation outcomes indicate that the agents which use the proposed model not only have more chances to reach agreements but also will be able to find agreements with best possible utilities.

6.3 Future Research

Even though the proposed system has overcome a number of problems and made a significant contribution to the area, there are aspects which can be improved in the future. This research also opens up various lines of possible future work.

The proposed protocol only allows bilateral negotiation. Bilateral negotiation can be extended in the future to support multi-lateral negotiations where each pair of agents has similar approach in between them. Auction mechanism in pre-negotiation can be introduced.

The model incorporates the concept of interdependency. It is interesting to note that a full analysis of the interdependence (over all the potential issues) relates to the possible bundling of issues. A method that will deal with those two elements is something that can be looked at and considered as future work.

Future work may further illuminate modelling dishonest behaviours in degree of satisfaction responses. Trust is also required in forming a group of agents. Therefore, using trust and reputation mechanisms can solve this problem. These mechanisms assist to reduce disagreement by interacting with potential agents with good past experiences. Exploring the model with the other strategies such as Conceder time dependent strategy, resource strategies and behaviour strategies are considered as future work.

These challenges could form the basis for further research on automated negotiation.

REFERENCES

Abedin, F., Chao, K. M., Godwin, N., and Arochena, H. (2009) ‘Preference Ordering in Agenda Based Multi-issue Negotiation for Service Level Agreement’. *Proceedings of the IEEE 23rd International Conference on Advanced Information Networking and Applications (AINA-09),* held 26-29 May 2009 at University of Bradford, UK. IEEE, 19-24

Abedin, F., Chao, K. M. and Godwin, N. (2011) ‘A fuzzy group decision making process in a multi-agent negotiation environment’. *Proceedings of the 15th International Conference on Computer Supported Cooperative Work in Design (CSCWD 2011).* held 08-10 June 2011 at Lausanne, Switzerland. IEEE, 311-318

Abedin, F., Chao, K. M. and Godwin, N. (2012) ‘An agenda based multi issue negotiation approach’. *Journal of Ambient Intelligence and Humanized Computing* [online] available from <http://dx.doi.org/10.1007/s12652-012-0123-1>

Amgoud, L. and Maudet, N. (2002) ‘Strategical considerations for argumentative agents (preliminary report)’. *In Benferhat, S. & Giunchiglia, E. (eds.), Proceedings of the 9th International Workshop on Non-Monotonic Reasoning (NMR 2002)*: Special Session on Argument, Dialogue and Decision, 399–407

Ateib, M. T. (2010) ‘Agent based negotiation in e-commerce’. In: *Proc. ITSim, IEEE Trans*., Malaysia, 861–868

Aydoğan, R., and Yolum, P. (2009) ‘Ontology-based learning for negotiation’. In *IEEE/WIC/ACM international conference on intelligent agent technology (IAT 2009)* Milan, Italy, 177–184

Baarslag, T., Hindriks, K., Hendrikx, M. and Jonker C. M. (2013) ‘Predicting the Performance of Opponent Models in Automated Negotiation’. *IEEE/WIC/ACM International Joint Conferences on Web Intelligence (WI) and Intelligent Agent Technologies (IAT).* 2, 59-66

Bac, M. and Raff, H. (1996) ‘Issue-by-issue negotiations: the role of information and time preference’. Games and Economic Behavior, 13, 125–134

Bahrammirzaee, A. (2011) Contribution in Design and Implementation of Virtual Intelligent Agents: Application in Simulation of Negotiation Process Strategies, PhD thesis, University PARIS-EST-Creteil (UPEC), France.

Bear, J. (2011) ‘Passing the buck: Incongruence between gender role and topic leads to avoidance of negotiation’. *Negotiation and conflict management research,* 4, 47-72

Bellman R. E. and Zadeh, L. A. (1970) ‘Decision-making in a fuzzy environment’. *Management Science,* 17(4), 141-164

Bevilacqua, M., Ciarapica, F. and Giacchetta, G. (2006) 'A fuzzy-QFD approach to supplier selection'. *Journal of Purchasing and Supply Management*, 14-27

Braun, P., Brzostowski, J., Kersten, G., Kim, J., Kowalczyk R., Strecker S. and Vahidov, R. (2006) 'Intelligent Decision-Making Support System: Foundation, Applications, and Challenges', *chapter e-Negotiation Systems and Software; Agents: Method, Models, and Applications.* Springer-Verlag.

Brooks, B. W. and Rose, R. L. (2004) 'A contextual model of negotiation orientation'. *Industrial Marketing Management*, 33(2), 125-133

Brzostowski, J. and Kowalczyk, R. (2006) 'Experimental evaluation of possibilistic mechanism for negotiation partners selection'. *In Proc. 2nd Int. Workshop on Rational, Robust, and Secure Negotiations in MAS*, 119-137

Brzostowski, J. and Kowalczyk, R. (2007) 'On fuzzy projection-based utility decomposition in compound multi-agent negotiations'. Proceedings of the World Congress of the International Fuzzy Systems Association. Lecture Notes in Computer Science, Springer Berlin, 4529, 757-766

Brzostowski, J., Chhetri, M. B. and Kowalczyk R. (2007) 'Three Decision-making Mechanisms to facilitate Negotiation of Service Level Agreements for Web Service Compositions'. *Proc. Joint Conference of the INFORMS Section on Group Decision and Negotiation*, 37-44

Busch, L. A. and Horstmann, I. J. (1997) 'Endogenous incomplete contracts: A Bargaining Approach'. *Games and Economic Behavior*, 19, 144-148

Busch, L. A. and Horstmann I. J. (2002) 'The game of negotiations: ordering issues and implementing agreements'. *Games and Economic Behavior*, 41, 169–191

Buffett, S., Comeau, L., Fleming, M. W. and Spencer, B. (2005) 'Monologue: A tool for negotiating exchanges of private information in e-commerce'. In *Third Annual Conference on Privacy, Security and Trust* (PST05), 79–88

Buffett, S. and Spencer, B, (2007) 'A bayesian classifier for learning opponents' preferences in multi-object automated negotiation', *Electronic Commerce Research and Applications*, 6(3), 274-284

Buffett, S., Spencer, B. (2005) 'Learning opponents' preferences in multi-object automated negotiation'. In *Proceedings of the 7th international conference on electronic commerce (ICEC2005)*, Xi'an, China, 300–305

Burato, E., (2010) Meaning Negotiation in Multiple Agent System: an Automated Reasoning Approach Ph.D. Thesis, Università degli Studi di Verona Dipartimento di Informatica, Italy.

Cao, M., Feng, Y., Wang, H., Wang, C. (2007) 'Modeling Negotiating Agent for Automated Negotiation'. *Proceedings of Sixth International Conference on Machine Learning Cybernetics*, Hong Kong, 19-22

Cao, M. (2010) 'Agent Communication Language for Automated Negotiation'. *Journal of Networks*, 5(6), 675-682

Carlsson, C. and Fuller, R. (1996) 'Fuzzy multiple criteria decision-making: Recent development'. *Fuzzy Sets and Systems* 78(2), 139-153

Cardoso, H. L. and Oliveira, E. (2000) 'Using and evaluating adaptive agents for electronic commerce negotiation.' *Proceedings of the International Joint Conference, 7th Ibero-American Conference on AI*, 96-105, London, UK. Springer-Verlag.

Chao, K. M., Younas, M., Anane, R., Tsai, C. F. and Soo, V. W. (2003) 'Degree of satisfaction in agent negotiation'. *Conference Proceedings of 2003 IEEE Conference on E-Commerce*, June 24–27, Newport Beach, California, USA, IEEE CS, 68–75

Chajewska, U., Koller, D. and Parr, R. (2000) 'Making rational decisions using adaptive utility elicitation'. In AAAI-00, 363–369, Austin, Texas, USA.

Chen, J. H. (2006) An Automated Negotiation Mechanism Based on Co-Evolutionary Processes and Game Theory, PhD thesis, Coventry University, UK.

Chen, J., Anane, R., Chao, K. M. and Godwin, N. (2002) 'Architecture of an agent-based negotiation mechanism'. *In Proc. of Int. Conf. on Distributed Computing Systems Workshops*, Vienna, Austria, 379-384

Chen, J. H., Chao, K. M., Godwin, N. and Soo, V. W. (2005) 'Combining cooperative and non-cooperative automated negotiations'. *Information Systems Frontiers*, 7(4/5), 391–404

Chen, M. K. (2002) Agendas in Multi-Issue Bargaining: When to Sweat the Small Stuff. Technical report, Harvard Department of Economics, Cambridge, November 2002

Chiclana, F., Herrera, F. and Herrera-Viedma, E. (1998) 'Integrating three representation models in fuzzy multipurpose decision making based on fuzzy preference relations.' *Fuzzy Sets and Systems*, 97, 33–48

Chiclana, F., Herrera, F. and Herrera-Viedma, E. (2001) 'Integrating multiplicative preference relations in a multipurpose decision-making model based on fuzzy preference relations'. *Fuzzy Sets and Systems*, 122, 277–291

Cheng, C. -H. (1999) 'A simple fuzzy group decision making method'. In *Proceedings IEEE International Conference Fuzzy Systems'*. 2, II-910–II-915

Chou, T. C., Fu, Li. C. and Liu, K. P. (2007) 'E-Negotiation of Dependent Multiple Issues by Using a Joint Search Strategy'. ICRA, IEEE, 1298-1303

Chu, T. C. and Lin, Y. C. (2009) 'An interval arithmetic based fuzzy TOPSIS model', Expert Syst. Appl. 36, 10870-10876

Chu, M. T., Shyu, J., Tzeng, G.-H. and Khosla, R. (2007) 'Comparison among three analytical methods for knowledge communities group-decision analysis'. *Expert Systems with Applications*, 33(4), 1011-1024

Coehoorn, R. M. and Jennings, N. R. (2004) 'Learning an opponent's preferences to make effective multi-issue negotiation trade-offs'. In *Proceedings of the 6th international conference on Electronic commerce*.

Coleman, J. S. (1990) Foundations of Social Theory. Cambridge: Belknap.

Cranor, L. F. and Resnick, P. (2000) 'Protocols for automated negotiations with buyer anonymity and seller reputations'. *Netnomics*, 2(1), 1-23

Dang, J. and Huhns, M. N. (2005) 'Coalition Deal Negotiation for Services'. *Proc. First Int',l Workshop Rational, Robust, and Secure Negotiations in Multi-Agent Systems (RRS ',05)*, 67

DeRue, D. S., Conlon, D. E., Moon, H., and Willaby, H. W. (2009) 'When is straight forwardness a liability in negotiations? The role of integrative potential and structural power'. *Journal of Applied Psychology*, 94, 1032–1047

Dzeng, R. J. and Lin, Y. C. (2004) 'Intelligent agents for supporting construction procurement negotiation', *Expert Systems with Applications*, 27, 107–119

Espin, R., Fernandez, E., Mazcorro, G. and Lecich, M.I. (2007) 'A fuzzy approach to cooperative *n*-person games'. *European Journal of Operational Research*,176, 1735–1751

Faratin, P., Sierra, C. and Jennings, N. R. (1998) 'Negotiation decision functions for autonomous agents'. *Robotics and Autonomous Systems* 24 (3-4), 159-182

Faratin, P., Sierra, C. and Jennings, N. R. (2002) 'Using similarity criteria to make trade-offs in automated negotiations'. *Artificial Intelligence*, 142(2), 205–237

Faratin, P. (2000) 'Automated Service Negotiation Between Autonomous Computational Agents' Ph.D. Dissertation, University of London, Queen Mary College, Department of Electronic Engineering.

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2002) 'Multi-issue negotiation under time constraints' In *Proceedings of the First International Conference on Autonomous Agents and Multi-Agent Systems,* Bologna, Italy, 143–150

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2003) ‘Optimal Agendas for Multi-Issue Negotiation’. In Proceedings of the second international conference on Autonomous Agents and Multi-Agent Systems (AAMAS-03), Melbourne, Australia, 129-136

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2004) ‘An agenda based framework for multi-issue negotiation’. *Artificial Intelligence Journal*, 152(1), 1- 45

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2004) ‘Optimal Negotiation of Multiple issues in incomplete Information Settings’. In *the Proceeding of the 3rd International Conference on Autonomous Agents and Multi-Agent Systems,* New York, USA, 1080–1087

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2005) ‘A Comparative Study of Game Theoretic and Evolutionary Models of Bargaining for Software Agents’. *Artificial Intelligence Review*. 23(2), 187-205

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2006) ‘Multi-issue negotiation with deadlines’. *Journal of Artificial Intelligence Research*, 27, 381-417

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2006) ‘On efficient procedures for multi-issue negotiation’. *In Proc. of the Trading Agent Design and Analysis and Agent Mediated Electronic Commerce*, 71–84

Fatima, S. S., Wooldridge, M. and Jennings, N. R. (2007) ‘An analysis of feasible solutions for multi-issue negotiation involving nonlinear utility functions’. In *Proc. of the Eight International Joint Conference on Autonomous Agents and Multi-agent Systems (AAMAS-2009),* 1041-1048

Fatima, S. S., Wooldridge, M., Jennings, N. R. (2011) ‘On optimal agendas for package deal negotiation’. In *Proceedings of the Tenth International Conference on Autonomous Agents and Multiagent Systems. International Foundation for Autonomous Agents and Multiagent System*s, 3, 1083–1084

Fatima, S. and Kattan, A. (2011) ‘Evolving optimal agendas for package deal negotiation’. In *Proceedings of the 13th annual conference on Genetic and evolutionary computation, ser. GECCO '11*. New York, NY, USA: ACM, 2011, 505-512. [online] available from <http://doi.acm.org/10.1145/2001576.2001646>

Fedrizzi, M., Kacprayk, J., Owsinski, J.W. and Zadrozny, S. (1994) ‘Consensus reaching via a GDSS with fuzzy majority and clustering of preference profiles.’ *Annals of Operations Research*, 51, 127-139

Fershtman, C. (1990) ‘The importance of the agenda in bargaining’. *Games and Economic Behavior* 2(3), 224–238

Fershtman, C. and Seidmann, D. J. (1993) ‘Deadline effects and inefficient delay in bargaining with endogenous commitment’. Journal of Economic Theory, 60(2), 306–321

Fershtman, C. (2000) ‘A note on multi-issue two-sided bargaining: bilateral procedures’. Games and Economic Behavior, 30, 216–227

Flamini, F. (2007) ‘First things first? The agenda formation problem for multi-issue committees’. *Journal of Economic Behavior & Organization*, 63(1), 138-157

Flamini, F. (2007a) ‘Best agendas in multi-issues bargaining’. *The Berkeley Electronic Journal of Theoretical Economics,* 7(1), 13

Gerding, E. H., Van Bragt, D. D. B. and La Poutre, J. A. (2000) ‘Scientific approaches and techniques for negotiation: A game theoretic and artificial intelligence perspective’. CWI Technical Report SEN-R0005, CWI, Amsterdam.

Giunta, F. D. and Gatti, N. (2006) ‘Bargaining over multiple issues in finite horizon alternating-offers protocol’ *Annals of Mathematics in Artificial Intelligence*, 47 (3–4), 251–271

Giunta, F. D. and Gatti, N. (2006) ‘Bargaining in-Bundle over Multiple Issues in Finite-Horizon Alternating-Offers Protocol’. In *Proceedings of the 9th International Symposium on Artificial Intelligence and Mathematics (AIMATH).* Fort Lauderdale, USA, January 4-6.

Grzegorzewski, P. and Mrówka, P. (2005) ‘Trapezoidal approximations of fuzzy numbers’. *Fuzzy Sets and Systems,* 153, 115-135

Haddawy, P., Ha, V., Restificar, A., Geisler, B. and Miyamoto, J. (2003) ‘Preference elicitation via theory refinement’. *Journal of Machine Learning Research,* (4)313–337

Harsanyi, J. C. (1956) ‘Approaches to the Bargaining Problem Before and After the Theory of Games: A Critical Discussion of Zeuthen’s, Hicks’, and Nash’s Theories’. *Econometrica,* 24(2), 144-157

Herrera, F., Herrera-Viedma, E. and Verdegay, J. L. (1996) ‘A model of consensus in group decision making under linguistic assessments’. *Fuzzy Sets System* 78, 73-87

Herrera-Viedma, E., Herrera, F., and Chiclana, F. (2002) ‘A consensus model for multiperson decision making with different preference structures’. *IEEE Transactions on Systems Man and Cybernetics Part A – Systems and Humans,* 32, 394–402

Herrera-Viedma, E., Chiclana, F., Herrera, F. and Alonso, S. (2007) ‘Group decision-making model with incomplete fuzzy preference relations based on additive consistency’. *IEEE Trans. On Systems, Man and Cybernetics-part B,* 37(1), 176-186

Hemaissia, M., El Fallah-Seghrouchni, A., Labreuche, C., and Mattioli., J. (2008) ‘Cooperation-based multilateral multi-issue negotiation for crisis management’. *Rational, Robust, and Secure Negotiations in Multi-Agent Systems Studies in Computational Intelligence,* 89, 81-100

Hindriks, K. V. and Tykhonov, D. (2008) ‘Opponent modelling in automated multi-issue negotiation using bayesian learning’. *In Proceedings of AAMAS’08*, 331–338

Huynh, V.-N. and Nakamori, Y. (2005) ‘A satisfactory-oriented approach to multi-expert decision-making with linguistic assessments’. *IEEE Trans. On Systems, Man and Cybernetics-part B* 35(2), 184-196

Huang, J. (1996) ‘A Quantitative Method Used in Negotiation Support Systems’. *Computers and Industrial Engineering*, 31(3/4), 821-826

Huber, G.P. (1984) ‘Issues in the design of group decision support systems’. MIS quarterly, 8 (3), 195-204

Hou, C. (2004) ‘Modelling agents behaviour in automated negotiation’. *Technical Report KMI-TR-144, Knowledge Media Institute,* The Open University, Milton Keynes, UK.

Inderst, R. (2000) ‘Multi-issue bargaining with endogenous agenda’. *Games and Economic Behavior,* 30, 64–82

In, Y. and Serrano, R. (2004) ‘Agenda restrictions in Multi-Issue Bargaining’. *Journal of Economic Behavior and Organization* 53(3), 385-399

Ito, T., Hattori H. and Klein M. (2007) ‘Multi-issue negotiation protocol for agents: Exploring nonlinear utility spaces’. In *Proc. of the 20th International Joint Conference on Artificial Intelligence (IJCAI-2007),* 1347–1352

Jazayeriy, H. et al. (2011) ‘The learning of an opponent's approximate preferences in bilateral automated negotiation’. *Journal of Theoretical and Applied Electronic Commerce Research* 6(3), 65-84

Jennings, N. R., Parsons, S., Sierra, C. and Faratin, P. (2000) ‘Automated Negotiation’ Proc. *5th Int. Conf. on the Practical Application of Intelligent Agents and Multi-Agent Systems (PAAM-2000),* Manchester, UK, 23-30

Jennings, N. R. et al. (2001) ‘Automated negotiation: prospects, methods and challenges’. *International Journal of Group Decision and Negotiation* 10(2), 199-215

Jian, G. and Wei, Z. (2009) ‘Multi-Issue Agent Automatic Negotiation Based on Fuzzy Evaluation’. *First International Workshop on Education Technology and Computer Science,* 1, 513 – 516

Jung, H., Tambe, M. and Kulkarni, S. (2001) ‘Argumentation as distributed constraint satisfaction’. In: *5th International Conference on Autonomous Agents.* ACM Press, New York, 324–331

Kacprzyk, J., Fedrizzi, M. and Nurmi, H. (1992) ‘Group decision making and consensus under fuzzy preferences and fuzzy majority.’ *Fuzzy Sets and Systems,* 49, 21-31

Kalady, S., Dev, B., Arun, A. N., Govindan V. K. and Mathew A. T. (2008) ‘Optimal agendas and procedures for n-issue negotiation: An inductive definition’. *In: MICAI 2008: 7th Mexican international conference on artificial intelligence*, Atizapán de Zaragoza, Mexico, October 27–31

Kebriaei, H., Kian, A. R. and Majd, V. J. (2011) ‘An Agent-Based System for Bilateral Contracts of Energy’. *Expert Systems with Applications,* Elsevier, 38(9), 11369–11376

Keeney, R.L. and Raiffa, H. (1976) Decisions with Multiple Objectives: Preferences and Value Tradeoffs. Wiley, New York.

Kowalczyk, R. (2000) ‘On negotiation as a distributed fuzzy constraint satisfaction problem’. *In Proceedings of the 3rd International Symposium on Soft Computing for Industry*. World Automation Congress, 631–637

Kraus, S. (2001) Strategic Negotiation in Multi-Agent Environments, MIT Press.

Kraus, S. (1997) ‘Negotiation and Cooperation in Multi-Agent Environments’. *Artificial Intelligence*, 94, 79–97

Kraus, S., Sycara, K. and Evenchik, A. (1998) ‘Reaching agreements through argumentation: a logical model and implementation’. *Artificial Intelligence*, 104(1–2), 1–69

Kteily, N., Saguy, T., Sidanius, J. and Taylor, D. M. (2013) ‘Negotiating power: Agenda ordering and the willingness to negotiate in asymmetric intergroup conflicts’. J Pers Soc Psychol. 105(6), 978-95

Kurbel, K., Loutchko, I., and Teuteberg, F. (2004) ‘FuzzyMAN: An agent-based electronic market place with a multilateral negotiation protocol’, In Lindemann et al. 62, 126-140

Kurbel K. and Loutchko, I. (2005) ‘A model for multi-lateral negotiations on an agent-based job marketplace’. *Electronic Commerce Research and Applications,* 4,187–203

Kwok, R. C., Zhou, D., Zhang, Q. and Ma, J. (2007) ‘A Fuzzy Multi-Criteria Decision Making Model for IS Student Group Project Assessment’. *Group Decision and Negotiation*, 16(1), 25-42

Kwok, R. C., Ma, J. and Zhou, D. (2002) 'Improving group decision making: A fuzzy GSS approach.' *IEEE Transactions on Systems, Man and Cybernetics – Part C: Application and Reviews*, 32(1), 54-63

Lang, K. and Rosenthal, R. W. (2001) 'Bargaining piecemeal or all at once? The Economic Journal' 111, 526–540

Lai, G. et al. (2004) 'Literature Review on Multi-attribute Negotiations'. Technical Report CMU-RI-TR-04-66, Pittsburgh, USA: Carnegie Mellon University, Robotics Institute.

Lai, Y. L. (2013) 'Analyzing strategies of mobile agents on malicious cloud platform with Agent-Based Computational Economic Approach'. *Expert Syst. Appl.* 40(7), 2615-2620

Larson, K. and Sandholm, T. (2002) 'An alternating offers bargaining model for computationally limited agents'. In Castelfranchi, C. & Johnson, L. (eds.), *Proceedings of the 1st International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS-2002)*, 135–142

Lau, R. et al. (2006) 'An Evolutionary Learning Approach for Adaptive Negotiation Agents'. *International Journal of Intelligent Systems*, 21(1), 41–72

Lewicki, R. J. and Litterer, J. A. (1985) 'Negotiation'. Homewood, IL: Richard D. Irwin.

Li, C., Giampapa, J. and Sycara, K. (2006) 'Bilateral Negotiation Decisions with Uncertain Dynamic Outside Options', *IEEE Transactions on Systems, Man, and Cybernetics (Part-C)*, 36, 31–44

Li, Jiaxing., Tsai, Chen-Fang., Chen, Y. L. J. and Chao, K. M. (2007) 'A Multi-Stage Negotiation Mechanism with Service-Oriented Implementation'. ICCS 2007: *Proceedings of the 15th International Workshops on Conceptual Structures*.

Lin, J. R. (2003) 'Automated Multi-issue Negotiations between Computational Agent in a Dynamic Environment', PhD thesis, National Taiwan University, Taiwan.

Lin K. J. (2008) 'E-Commerce Technology Back to a Prominent Future', *IEEE Internet Computing*, 12, 60-65

Lin, R., Kraus, S., Wilkenfeld, J. and Barry, J. (2008) 'Negotiating with bounded rational agents in environments with incomplete information using an automated agent'. AIJ, 172(6-7), 823–851

Linghua, H. (1996) 'A Quantitative Method Used in Negotiation Support Systems', *Computers and Industrial Engineering*, 31(3/4), 821-826

Lopes, F., Wooldridge, M. and Novais, A.Q. (2008) 'Negotiation Among Autonomous Computational Agents: Principles, Analysis and Challenges. *Artificial Intelligence Review* 29, 1-44

Lopes, F., Novais, A. Q. and Coelho, H. (2008) 'Interdisciplinary Approach to Automated Negotiation: A Preliminary Report', In *European Conference on Modelling and Simulation (ECMS-08)*, 118-122

Lopes, F., Novais, A. Q. and Coelho, H. (2008) 'Towards an Interdisciplinary Framework for Automated Negotiation'. In *E-Commerce and Web Technologies. LNCS*, 5138, 81–91. Springer, Heidelberg.

Lopes, F., Novais, A. Q. and Coelho, H. (2009) 'Bilateral Negotiation in a Multi-Agent Energy Market'. *In: Huang, D.-S., Jo, K.-H., Lee, H.-H., Kang, H.-J., Bevilacqua, V. (eds.) ICIC 2009. LNCS, Springer, Heidelberg*, 5754, 655–664

Lomuscio, A. R. and Jennings, N. R. (2003) 'A classification scheme for negotiation in electronic commerce'. *Journal of Group Decision and Negotiation*, 12(1), 31–56

Lopez-Carmona, M., Marsa-Maestre, I., Klein, M. and Ito, T. (2010) 'Addressing stability issues in mediated complex contract negotiations for constraint-based, non-monotonic utility spaces'. *Autonomous Agents and Multi-Agent Systems*, 1–51

Lu, J., Zhang, G., Ruan, D. and Wu, F. (2007) 'Multi-objective Group Decision Making: Methods, Software and Applications with Fuzzy Set Techniques', Imperial College Press, London.

Luce, D. R. and Raiffa, H. (1957), Games and Decisions. New York: John Wiley & Sons, Inc.

Marsa-Maestre, I., Lopez-Carmona, M. A., Velasco, J. R. and de la Hoz, E. (2009) 'Effective bidding and deal identification for negotiations in highly nonlinear scenarios'. In *Proc. of the Eighth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS-2009)*, 1057–1064

Matos, N., Sierra, C. and Jennings, N. R. (1998). 'Determining successful negotiation strategies: An evolutionary approach'. *Proceedings of the 3rd International Conference on Multi Agent Systems*, 182, Washington, DC, USA, IEEE Computer Society.

McBurney, P., Parsons, S. and Wooldridge, M. (2002) 'Desiderata for agent argumentation protocols'. In *Proceedings of the First International Conference on Autonomous Agents and Multiagent Systems (AAMAS-02)*, Bologna, Italy.

McBurney, P., van Eijk, R. M., Parsons, S. and Amgoud, L. (2003) 'A dialogue-game protocol for agent purchase negotiations'. *Journal of Autonomous Agents and Multi-Agent Systems*, 7(3), 235–273

Ness, H. and Haugland, S. A. (2005) ‘The evolution of governance mechanisms and negotiation strategies in fixed-duration interfirm relationships’, *Journal of Business Research,* 58(9), 1226-1239

Nurmi, H. (1981) ‘Approaches to collective decision making with fuzzy preference relations.’ *Fuzzy Sets and Systems,* 6, 249-259

Oliver, J. (1996). ‘A machine learning approach to automated negotiation and prospects for electronic commerce’ *Journal of Management Information Systems* 13 (3)*,* 83–112

Opricovic, S. (1998) ‘Multicriteria Optimization of Civil Engineering Systems’, *Faculty of Civil Engineering,* Belgrade.

Opricovic, S. and Tzeng, G. H. (2007) ‘Extended VIKOR method in comparison with outranking methods’, *European Journal of Operational Research.* 178(2), 514–529

Orlovsky, S.A. (1978) ‘Decision-making with a fuzzy preference relation.’ *Fuzzy Sets and Systems,* 1, 155-167

Osborne, M. and Rubinstein, A. (1990) ‘Bargaining and markets’. New York: Academic Press

Parsons, S., Sierra, and C., Jennings N. (1998) ‘Agents that reason and negotiate by arguing. Journal of Logic and Computation’, (3), 261-292

Parsons, S. and Wooldridge, M. and Amgoud, L. (2002) ‘An analysis of formal inter-agent dialogues’. In *Proceedings of the First International Conference on Autonomous Agents and Multiagent Systems (AAMAS-02)*. Bologna, Italy.

Patel, D. and Gupta, A. (2006) ‘An Adaptive Negotiation Strategy for Electronic Transactions’. *10th IEEE International Enterprise Distributed Object Computing Conference (EDOC'06),* 243-252

Ponsati, C. and Watson, J. (1997) Multiple-Issue Bargaining and Axiomatic Solutions. International Journal of Game Theory 26 (4), 501-524

Rahwan, I., McBurney, P. and Sonenberg, L. (2003) ‘Towards a theory of negotiation strategy (a preliminary report)’. In Parsons, S. & Gmytrasiewicz, P. (eds.), *Proceedings of the 5th Workshop on Game Theoretic and Decision Theoretic Agents (GTDT-2003),* 73–80

Rahwan, I. (2004) ‘Argumentation based negotiation’. *Knowledge Engineering Review* 18(4), 343-375

Raiffa, H. (1982), The Art and Science of Negotiation. Cambridge, MA: Harvard University Press.

Ramchurn, S. D., Jennings, N. R. and Sierra, C. (2003) ‘Persuasive negotiation for autonomous agents: a rhetorical approach’. In Reed, C., Grasso, F. & Carenini, G. (eds.), *Proceedings of the IJCAI Workshop on Computational Models of Natural Argument*. AAAI Press, 9–17

Reed, C., and Norman, T.J. (2003) ‘A roadmap of research in argument and computation. In Argumentation Machines — New Frontiers in Argument and Computation’, C. Reed and T.J. Norman, editors. Kluwer Academic Publishers, 1-13

Ren, F. (2009) ‘A Market-Based Multi-Issue Negotiation Model Considering Multiple Preferences in Dynamic E-Marketplaces’. *Proc. 12th Int. Conf. Principles of Practice in Multi-Agent Systems (PRIMA09),* 1 -16

Ren, F., Zhang, M., Fulcher, J. (2012) ‘Bilateral single-issue negotiation model considering nonlinear utility and time constraint’. *New Trends in Agent-Based Complex Automated Negotiations Studies in Computational Intelligence*, 383, 21-37

Resinas, M., Fernandez, P. and Corchuelo, R. (2006) ‘A conceptual framework for automated negotiation systems’. *Proceedings of Intelligent Data Engineering And Automated Learning - Ideal.* 4224,1250-1258

Rubinstein, A. (1982) ‘Perfect Equilibrium in a Bargaining Model’. *Econometrica* 50(1), 97-109

Robu, V., Somefun, D. J. A. and Poutre, J. L. (2005) ‘Modeling complex multi-issue negotiations using utility graphs’. In *Proc. of the Forth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS 2005),* 280–287

Rosenschein, J. S. and Zlotkin, G. (1994) ‘Rules of Encounter: Designing Conventions for Automated Negotiation Among Computers’. MIT Press.

Romanhuki, E., Fuckner, M., Enembreck, F., Ávila, B. and Scalabrin, E. (2008) ‘Improving Bilateral Negotiation with Evolutionary Learning’. In *12th International Conference on Computer Supported Cooperative Work in Design, International Conference on Computer Supported Cooperative Work in Design (CSCWD).* Beijing : IEEE PRESS. 1, 343-348

Saha, S. (2006) ‘Improving agreements in multi-issue negotiation’. *Journal of Electronic Commerce Research,* 7(1), 41–49

Saha, S. and Sen, S. (2006) ‘Negotiating efficient outcomes over multiple issues’, In *Proceedings of the fifth international conference on Autonomous Agents and Multi-Agent Systems (AAMAS-06),* Hakodate, Japan, 423-425

Saha, S. and Sen, S. (2007) ‘An efficient protocol for negotiation over multiple indivisible resources’. In *Proceedings of the 20th international joint conference on artificial intelligence (IJCAI-2007),* 1494–1499

Sandholm, T. (1999) ‘Automated Negotiation’. Communications of the ACM 42(3), 84-85

Sandholm, T. and Vulkan, N. (1999) ‘Bargaining with deadlines’, *Proceedings of the sixteenth national conference on Artificial intelligence and the eleventh Innovative applications of artificial intelligence conference innovative applications of artificial intelligence,* 44-51, July 18-22, Orlando, Florida, USA

Sánchez-Anguix, V., Valero, S., Julián, V., Botti, V. and García-Fornes, A. (2013) ‘Evolutionary-aided negotiation model for bilateral bargaining in Ambient Intelligence domains with complex utility functions’, *Information Sciences*. 222, 25-46

Sedano, J., Berzosa, A., Villar, J. R., Corchado, E. S. and de la Cal, E. (2011) ‘Optimising operational costs using Soft Computing techniques’. *Integrated Computer-Aided Engineering*, 18(4), 391-400

Sedano, J., Curiel, L., Corchado, E. S., de la Cal E. and Villar, J. R. (2010) ‘A soft computing method for detecting lifetime building thermal insulation failures’. *Integrated Computer-Aided Engineering*, 17(2), 103-115

Sierra, C. and Jennings, N. R. and Noriega, P. and Parsons, S. (1997) ‘A Framework for Argumentation-Based Negotiation’. In *Proc. Fourth Int. Workshop on Agent Theories, Architectures and Languages (ATAL-97)*, Rode Island, USA, 67-182

Sierra, C. and Jennings, N. R. and Noriega, P. and Parsons, S. (1999) ‘A service-oriented negotiation model between autonomous agents’. In *Collaboration between Human and Artificial Societies*, 201-219

Simon, H. A. (1982) Models of bounded rationality (three volumes). Cambridge, Massachusetts: MIT Press.

Soh, L. K. and Li, X. (2004) ‘Adaptive, Confidence-Based Multiagent Negotiation Strategy’. In *Proceedings of the 3rd International Joint Conference on Autonomous Agents and Multi Agent Systems (AAMAS-04)* July 19-23, New York, USA.

Sycara, K. P. (1990) ‘Persuasive argumentation in negotiation’. *Theory and Decision*, 28, 203-242

Sycara, K. and Dai, T. (2010) ‘Agent Reasoning in Negotiation’. In *D. Kilgour, C. Eden (eds.), Handbook of Group Decision and Negotiation, Springer Netherlands*, 437-451

Tamma V., Wooldridge M., Blacoe I. and Dickinson I., (2002) 'An Ontology Based Approach to Automated Negotiation', *Agent-Mediated Electronic Commerce IV. Designing Mechanisms and Systems*, 317-334

Tanino, T. (1990) 'On group decision making under fuzzy preferences.' *Multiperson Decision Making Models Using Fuzzy Sets and Possibility Theory*, J. Kacprzyk and M. Fedrizzi (Eds.), Kluwer: Dordrecht, The Netherlands, 172-185

Tiedemann, J. (2009) 'One thing at a time: Efficient agendas in multi-issue bargaining'. Discussion Paper, Sozialökonomisches Seminar der Universität Hamburg.

Triantaphyllou, E. and Baig, K. (2005) 'The impact of aggregating benefit and cost criteria in four MCDA methods'. *IEEE Transactions on Engineering Management*, 52(2), 213–226

Tsouki`as, A. (1994). 'A Qualitative Approach to Face Uncertainty in Decision Models.' *Decision Support Systems* 12, (4–5) 287–296

Von Stengel, B. (2002) 'Computing equilibria for two-person games. Chapter 45, Handbook of Game Theory', eds. R. J. Aumann and S. Hart, North-Holland, Amsterdam, 3,1723-1759

Vo, B. Q. and Padgham, L. (2007) 'Searching for joint gains in automated negotiations based on multi-criteria decision making theory'. *Proceedings of the 6th International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS)*, Hawaii, USA, May, 496-503

Wang, T. C. and Chang, T. H. (2007) 'Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment'. *Expert Systems with Applications* 33(4), 870-880

Wilkes, J. (2008) 'Utility functions, prices, and negotiation'. HP Laboratories Technical report HPL-2008-81

Wurman, P. R. (1999) 'Market Structure and Multidimensional Auction Design for Computational Economies'. PhD thesis, University of Michigan.

Yager, R. R. (1988) 'On ordered weighted averaging aggregation operators in multicriteria decision making'. *IEEE Trans. Syst., Man, Cybern*, 18, 183–190

Yager, R. R. and Filev, D. P. (1994) 'Parameterized and-like and or-like OWA operators.' *Int. J. Gen. Syst* 22, 297-316

Zadeh, L. A. (1983) 'A Computational Approach to Fuzzy Quantifiers in Natural Languages'. *Computing Mathematics Applications*. 9, 149-184

Zeng D. and Sycara, K. (1996) ‘Bayesian learning in negotiation’. In Sandip Sen, editor, *Working Notes for the AAAI Symposium on Adaptation, Co-evolution and Learning in Multiagent Systems*, 99-104, Stanford University, CA, USA.

Zlotkin, G. and Rosenschein, J. S. (1996) ‘Mechanisms for Automated Negotiation in State Oriented Domains’. *Journal of Artificial Intelligence Research (JAIR)*, 5,163-238

Appendix 1

Negotiation Case 3:

Boulware time dependent strategy with negotiation agenda for Price => Quantity => Performance sequence

The experiments results are shown below for the issue sequence Price => Quantity => Performance sequence. The parameters used for this experiment are the same as the negotiation case 1 and case 2. This experiment shows that the agenda chosen makes a considerable difference to the outcomes of negotiation.

The parameter settings for both consumer and supplier agent:

Table A1.1

The ranges of issues for consumer agent and the cross influences for Negotiation Case 3

Consumer			Price		Quantity		Performance	
			High	Low	High	Low	High	Low
Price	1500	max			down	up	stay	down
	1000	min			stay	stay	up	stay
Quantity	35	max	stay	up			stay	down
	10	min	down	stay			up	stay
Performan	80	max	down	stay	stay	down		
	50	min	stay	up	up	stay		

Table A1.2

The ranges of issues for supplier agent and the cross influences for Negotiation Case 3

Supplier			Price		Quantity		Performance	
			High	Low	High	Low	High	Low
Price	1900	max			stay	stay	stay	stay
	1250	min			down	up	up	down
Quantity	100	max	stay	up			stay	down
	10	min	down	stay			up	stay
Performar	100	max	up	stay	stay	down		
	50	min	stay	down	up	stay		

Table A1.3

The initial parameters of P_{min}, P_{max} for negotiation sequence for both agents

Offer Parameters	k_a	t_{max}	β	P_{min}	P_{max}
Consumer price	0.2	10	0.5	1000	1500
Supplier Price	0.2	10	0.5	1250	1900
Consumer Performance	0.2	10	0.5	50	80
Supplier Performance	0.2	10	0.5	50	100
Consumer Quantity	0.2	10	0.5	10	35
Supplier Quantity	0.2	10	0.5	10	100

Table A1.4

Changes on the ranges of issues for consumer agent with the new max, min and target values for Negotiation Case 3

		Price	Quantity	Performai
Consumer	origmax	1500	35	80
	origmin	1000	10	50
	change	0	15	0
	newmax	1500	35	80
	newmin	1000	0	50
	t(arget)	1250	17.5	65
	t - min	250	17.5	15
	max - t	250	17.5	15
	F	0.6	0	0

Table A1.5

Changes on the ranges of issues for supplier agent with the new max, min and target values for Negotiation Case 3

Supplier	origmax	1900	100	100
	origmin	1250	10	50
	change	0	48.46154	56.93333
	newmax	1900	148.4615	43.06667
	newmin	1250	10	50
	t(arget)	1575	79.23077	46.53333
	t - min	325	69.23077	-3.46667
	max - t	325	69.23077	-3.46667
	F	0.538462	1.138667	0

Table A1.6

The modified parameters of P_{min}, P_{max} for Price => Quantity => Performance sequence

Offer Parameters	k_a	t_{max}	β	P_{min}	P_{max}
Consumer price	0.2	10	0.5	1000	1500
Supplier Price	0.2	10	0.5	1250	1900
Consumer Performance	0.2	10	0.5	50	80
Supplier Performance	0.2	10	0.5	50	43.06667
Consumer Quantity	0.2	10	0.5	0	35
Supplier Quantity	0.2	10	0.5	10	148.4615

Table A1.7

The sequence of offers counter-offers for consumer and supplier agent for Negotiation Case 3

	Price		Quantity		Performance	
Offers	Consumer	Supplier	Consumer	Supplier	Consumer	Supplier
1	1022.876	1870.261	1.601347	142.1265	51.37258	43.38389
2	1047.233	1838.597	3.306321	135.3816	52.83399	43.72163
3	1073.401	1804.578	5.138096	128.135	54.40408	44.0845
4	1101.858	1767.585	7.130032	120.2548	56.11146	44.47909
5	1133.333	1726.667	9.333333	111.5385	58	44.91556
6	1169.06	1680.222	11.83419	101.645	60.14359	45.41096
7	1211.438	1625.13	14.80067	89.90942	62.68629	45.99861
8	1266.667	1553.333	18.66667	74.61538	66	46.76444
9	1400	1380	28	37.69231	74	48.61333
10	1400	1380	28	37.69231	74	48.61333

Figure A1.1 The acceptable price for both agents for Price issue

Figure A1.2 No agreement for both agents for Quantity issue

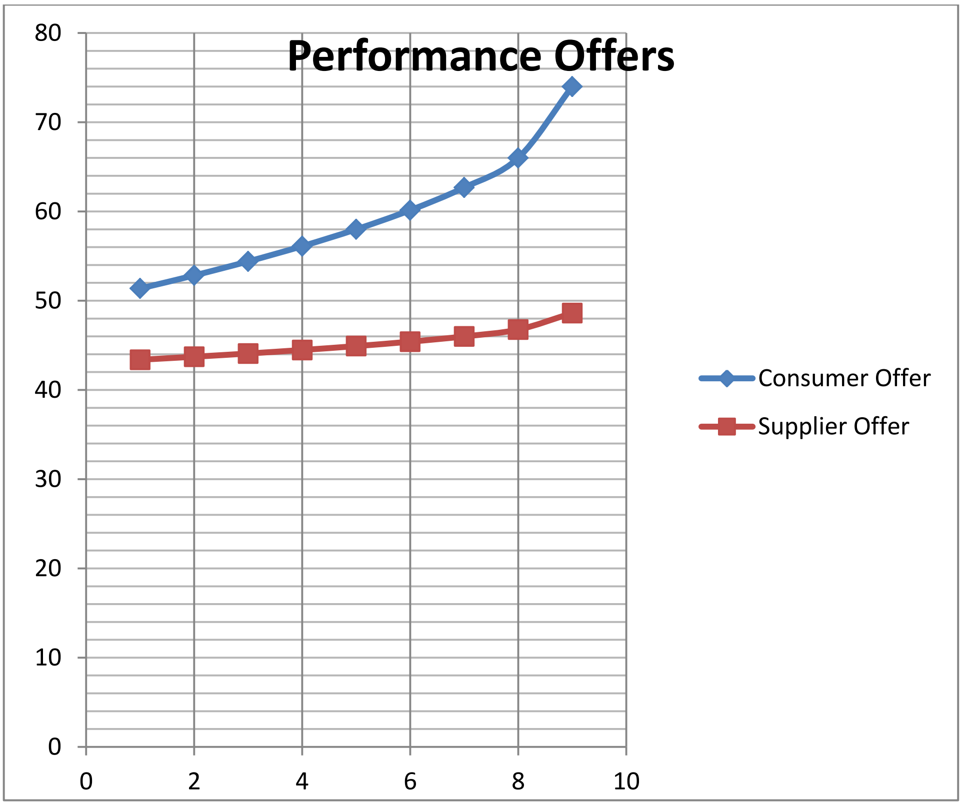

Figure A1.3 No agreement for both agents for Performance issue

The Consumer utility entries are shown together with the total Customer Utility. Fig. A1.2 and Fig. A1.3 shows that the agents have not achieved an agreement on Quantity and Performance issue in this stage. Thus the following utilities for consumer agent for Quantity and Performance issue shows 0. The total consumer utility gains 0.1.

		Weight			
Consumer	Price	0.5	Seller	0.5	
	Quantity	0.1		0.4	
	Performance	0.4		0.1	
	Weight	0.5	0.1	0.4	total
	Utility	0.2	0	0	0.1

The Supplier utility values are calculated in the same process as Consumers. Using the Supplier weights; a Supplier's total utility is calculated. Finally the total of the Consumer and Supplier utility values give a joint utility value. The joint utility for each of the issue sequences is also shown.

Supplier	Utility	0.230769	0	0	0.11
	Weight	0.5	0.4	0.1	Total
				Total utility	0.21

The sequence Price=> Quantity =>Performance is a negotiation failure in this stage as there is 0 utility for Quantity and Performance of issue value. The equation 4.6 determines the above result by using the importance weights and individual utility of the issues for the determined agenda sequence. The total utility of both agents is also low.

Appendix 2

Table A2.1

Comparison on automated negotiation approaches with my model

Approach	Author(s)	Year	Distinguishing feature(s)	Issue-by-Issue	Preference ordering in agenda based negotiation
Perfect equilibrium in a bargaining model	Ariel Rubinstein	1982	Two players have to reach an agreement on the partition of a pie of size 1. Each has to make in turn, a proposal as to how it should be divided.	No	No
The Importance of the Agenda in Bargaining	Chaim Fershman	1990	This paper discusses a multi-issue bargaining game in which the players set up an agenda and negotiate on the issues sequentially according to this agenda.	Yes	No
Deadline effects and inefficient delay in bargaining with endogenous commitment	Chaim Fershtman, Seidmann Daniel J	1993	This paper presents non stationary complete information bargaining model which exhibits delayed settlement.	No	No
Issue by issue negotiation: the role of information and time preference	Mehmet Bac, Horse Raff	1996	Many bargaining situations involve multiple issues, incomplete information. Issue by issue agenda can solve it and can arise from signalling considerations.	Yes	No
A note on Multi-issue two sided bargaining: Bilateral Procedures	Chaim Fershtman	2000	The note examines different bilateral bargaining procedures and shows different equilibrium settlements.	No	No
Multi-issue Bargaining with Endogenous Agenda	Roman Inderst	2000	The paper presents a strategic model of multi-issue bargaining with alternating offers and time preferences which allows the impact of the agenda to be analyzed plus agenda impact on outcome.	No	No
Bargaining piecemeal or all at once?	Kevin Lang, Robert W. Rosenthal	2001	Simple context of Rubinstein type offer-counteroffer structure with complete (perfect) information and where acceptance of an offer settles that issue and removes it from future bargaining.	No	No
Agendas in Multi-Issue Bargaining: When to Sweat the Small Stuff	M. Keith Chen	2002	It shows the equilibrium agenda can be produced by a straightforward algorithm which uses only ordinal information on how much each bargainers' values each issue.	No	No

The Game of Negotiations: Ordering Issue and Implementing Agreements	Lutz-Alexander Busch, Ignatius Horstmann	2002	Their two-issue bargaining model uncovers the settings in which different agenda structures are chosen in equilibrium, how the order in which issues are bargained over matters, and what impact the rules for implementing agreements have.	Yes	No
Multi-issue Negotiation Under time Constraints	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2002	The papers shows that the sequential implementation of the equilibrium agreement gives better outcome than a simultaneous implementation when agents have like, as well as conflicting time preferences.	No	No
Optimal Agendas for Multi-issue Negotiation	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2003	This paper studies the effect of combining the exogenous and endogenous agendas on the players' utilities with mediator.	Yes	No
An Agenda-based framework for Multi-issue	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2004	This paper presents an agenda-based model for multi-issue negotiation under time constraint in an incomplete information setting and orders in which issues are bargained over are reached endogenously.	No	No
Optimal Negotiation of Multiple Issues in Incomplete Information Settings	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2004	This paper analysed the process of bilateral multi-issue negotiation by fixing the protocol and varying the agenda negotiation procedure.	No	No
Agenda Restrictions in Multi-Issue Bargaining	Younghwan In, Roberto Serrano	2004	It studies a bilateral multi-issue bargaining procedure with complete information and endogenous agenda. In the procedure, proposals must be made on only one issue at a time, although the proposer can choose which issue to bring to the table.	No	No
Multi-Issue Negotiation with Deadlines	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2006	This paper studied bilateral multi-issue negotiation settings between self-interested agents in a wide range of settings. Each player has time constraints in the form of deadlines and discount factors.	No	No
On Efficient Procedures for Multi-Issue Negotiation	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2006	This paper analysed the 3 key procedures for bilateral multi-issue negotiation between self-interested agents: Package deal, Simultaneous procedure and Sequential procedure.	No	No
Improving agreement in multi issue negotiation	Sabyasachi Saha	2006	An extended protocol where self interested agents are able to explore and reach win win	No	No

			agreements without reviling its complete preferences.		
Best Agendas in Multi issue bargaining	Francesca Flamini	2007	Shows that delay affects the interplay of the forces in the bargaining game and solves the indeterminacy of equlibria. In equilibrium, players discuss the most important issue first.	Yes	No
First Things First? The Agenda Formation Problem for Multi-Issue Committees	Francesca Flamini	2007	Defines how parties should select agendas, it investigated a two-person alternating-offer model, where players differ in terms of their time preferences and valuations of the issues.	Yes	No
Optimal Agendas and procedures for N-issue negotiation: An inductive definition	Saidalavi Kalady, B. Dev, Arun A.N, V.K. Govindan, Abraham T. Mathew	2008	The impact of varying agenda and procedure on the negotiation outcome. This is done under incomplete information settings with the equilibrium strategies defined for issue by issue and package deal negotiation procedures.	Yes	No
One Thing at a Time: Efficient Agendas in Multi-Issue Bargaining	Jens Tiedemann	2009	This paper explored the importance of the bargaining agenda from two perspectives. Firstly, does a certain agenda create an efficient outcome? Secondly, by applying the ex ante perspective, how efficient is this outcome compared to those from other agendas?	Yes	No
On Optimal Agendas for package deal negotiation	Shaheen S. Fatima, Michael Wooldridge, Nicholas R. Jennings	2011	This paper analyzes bilateral multi-issue negotiation where the issues are divisible, there are time constraints in the form of deadlines and discount factors, and the agents have different preferences over the issues which are negotiated using the package deal procedure.	No	No
Evolving Optimal Agendas for Package Deal Negotiation	Shaheen S. Fatima, Ahmed Kattan	2011	This paper presents a hyper GA system to evolve optimal agendas for package deal negotiation.	No	No
Our Model	Fahmida Abedin, Kuo Ming Chao, Nick Godwin	2014	This work concentrates on the impact of agenda/procedure on the issue-by-issue negotiation outcome. The agent's preference order is used as a base case for providing the optimal agenda-procedure combination.	Yes	Yes