A Conflict Management Model for

Architectural Design Collaboration

By

Gamil M Serag-Eldin

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy in

Architecture

in the

Graduate Division

of the

University of California, Berkeley

Committee in charge:

Professor Yehuda E. Kalay, Chair

Professor Mark Anderson

Professor Lotfi Zadeh

Fall 2010

Abstract

A Conflict Management Model for Architectural Design Collaboration

by

Gamil M Serag-Eldin

Doctor of Philosophy in Architecture

University of California, Berkeley

Professor Yehuda E. Kalay, Chair

Until recently the design of a building was carried out only by an architect. The architect maintained enough knowledge of buildings, in addition to knowledge of the social, religious and other aspects of his society, that allowed him to complete a building design. The entire building project was his sole creation.

However, the design of buildings today is no longer a one-person operation, because the complexity of a large-scale design and construction exceeds the capacity of any single human's abilities. As we introduce new technologies, materials, and methodologies into building design, we draw on more and more knowledge from disciplines other than architecture and structural engineering. Designing buildings has become an exercise of multi-disciplinary teamwork.

Multi-disciplinary collaboration is a complex task. It is especially difficult when design solutions need to be shared and evaluated by participants who represent different professional views of the project. A design solution generated by one participant may satisfy certain requirements and evaluation criteria, but might be contradictory to the goals or values of another participant. The differences signify the domain-expertise each discipline possesses, which is why they were assembled for the purposes of completing the project in the first place. Conflicts among these participants are inevitable, and must be resolved to reach a comprehensive design solution.

This dissertation presents a comprehensive approach to negotiation and conflict management in architectural and building design. A primary objective of this research is to define conflict and provide analysis and understanding of its nature. Another objective is to develop a computational model of conflict management and negotiation strategies. To these ends, I developed SWAY a conceptual model that provides a set of conflict resolution algorithms that deal with situations and patterns of a conflict. The model allows designers from various disciplines to avoid conflict if possible and deal with inevitable conflicts in manners that improve the overall quality of the design. The dissertation also aims at enhancing the collaboration process among participants, which result in improving design quality and minimizing delays expenses.

Contents

Acknowledgments

I would like to extend my appreciation to my major advisor. When I thought of coming to UC Berkeley for my PhD I came to work with one person, Yehuda Kalay, on computing methods in architectural design. My deepest thanks to professor Kalay for his guidance, mentoring and support over the years. He gave me the freedom to choose my own course and yet was always there to pull me back when I wondered off on wrong directions.

Also I would like to thank my committee members who made a unique contribution to my work. Professor Mark Anderson who came in a critical time of my work, and supported me fully. Throughout my term as a graduate student, he has been a source of trusted advice.
My deepest thanks to Professor Lotfi Zadeh the founder of fuzzy logic. Professor Zadeh made me think about logic and its implementation in design from a completely different perspective than what I used to. My participation in his seminar and being involved with the BISC group added new directions to my understanding of this area of Artificial Intelligence.

My thanks to Professor Jean Pierre Protzen who supported me during my proposal writing with invaluable guidance. His work and the courses I took with him in design methods and theories were a catalyst that made the structure of my thesis crystallizes for me several years before I completed it.

The CAD Group was our research community in the architectural department. It was a friendly and helpful environment with our weekly seminar where we spent precious hours presenting and debating different ideas. Thanks to the group members Ame, Anna, whom we started the program together, Lachmi, Daniel, Gostavo, Chris, PierLuigi, Dan, Beatrice and Tim.

I should also thank the people at CMU who got me interested in CAD and taught me AI from a cognitive and computing perspectives Omar Akin, Herbert Simon, Volker Hartkof, Ulrich Flemming, Gerhard Schmitt and Ardashir Mahdawi.

A special acknowledgment to my wife and my boys who were born during my stay in Berkeley, they inspired me by just being there.
To Sayed, Zahira and to the soul of my parents.

Chapter One

1 Introduction: Why study conflict management in design?

"In the Confucian view, conflicts are disruptive of the natural peaceful order and should be resolved by amicable compromise, thereby allowing nature to follow its harmonious course. The peacemakers rule by moral example, not force of law. Litigation, in this perspective, merely continues conflict and offends nature; it does not heal."

1.1 Introduction

Can computational systems that represent architectural and engineering design help resolve conflicts among different participants in the design process when the appropriate information and capabilities are provided? The answer must be yes to certain extent, since humans have great proficiency in just doing that. Such systems should acquire the skills needed to represent and exchange participants' views, coordinate their actions, define conflicts that appear as a result of their interaction and provide a structured method to manage such conflicts.

In this dissertation I develop mechanisms for implementing a structured method for conflict management and resolution. I begin in this chapter with an overview of the nature of the design problem and the need to resolve conflicts. I continue by discussing the need of having a conflict management mechanism by describing the building design problem, its characteristics and the motivation of the work. Then I state the research objectives and approach. Last I identify the dissertation road map.

1.2 Design as a multi-disciplinary collaboration task

Buildings, temples, cities, and architecture in general throughout history reflect the greatness of civilizations. Builders held a special social status in many old civilizations, where they played the role of architect as well as physicist, chemist, astrologist, and sometimes the role of a magician. In addition to knowledge of buildings, the architect maintained knowledge of the social and religious aspects of his society. The entire building project was his sole creation.

The design of buildings today is no longer a one-person operation, because the complexity of a large-scale design and construction exceeds the capacity of any single human's abilities. As we introduce new technologies, materials, and methodologies into building design, we draw on more and more knowledge from disciplines other than architecture and structural engineering (Cuff, 1991). Designing buildings has become an exercise of multi-disciplinary teamwork.

1.2.1 The nature of multi-disciplinary teamwork

Multi-disciplinary collaboration is a complex task. It is especially difficult when design solutions need to be shared and evaluated by participants who represent different professional views of the project. A design solution generated by one participant may satisfy certain requirements and evaluation criteria, but there is no guarantee that this partial solution will satisfy evaluation criteria that are important to other participants. In fact solution that satisfies one participant's needs may conflict with another's. For example, an architect may view a floor plan as a collection of functional spaces and relationships among spaces, while a structural engineer may view the same floor plan as a collection of load elements and structural components. The differences signify the domain-expertise each discipline possesses, which is why they were assembled for the purposes of completing the project in the first place.

1.2.2 Reflections on domain-expertise

The domain expertise of different disciplines brings a new vision of the design problem. Instead of thinking from a centralized point of view we now think from distributed multi-disciplinary ones. From one main domain-expertise that has all the knowledge, to many smaller ones that posses parts of the overall knowledge. The problem set is different and consequently brings many new different aspects related to how these different domain expertises can communicate and resolve conflicts. Among these aspects are:

1.2.2.1 Multiple points of view

Since every designer comes from a different discipline and works in his specialized area it is almost impossible for him/her to have a clear vision of the overall project. The architect specialized in lighting may maximize his part of the design by choosing windows of a certain size. But this design decision affects the view that can be seen from these windows, the look of the façade and the material used for building the walls of the windows.

1.2.2.2 Judging goodness

Being specialized in certain area and not having the knowledge possessed by other disciplines hinders the ability to produce an overall good and overall acceptable design. Even if the architect was informed about the consequences of the design decision of choosing the windows she/he will not be able to judge and makes a decision that take into consideration the quality of the whole project. This quality became a distributed decision that requires knowledge that is possessed by different disciplines.

1.2.2.3 Achieving your own best

As a natural and common trend in conducting business in building design every designer wants to benefit the most to get his work approved as is for publicity, amount of work to be done and for his own ego despite any consequences. So even the designer is able to produce other acceptable solution he/she won't give it out unless he is forced to.

1.2.2.4 Communication structure

When designing a building who should start designing and who come next? Is it a linear or a parallel process, or both in a complicated pattern? When a design is done by certain participating discipline should it be presented to other participants and at what level of design? Who can override whom and under which circumstances? Do we understand others' language and presentation? All these questions simply show how communication structure is important and complicated.

1.3 Motivation

Conflicts among design participants are inevitable, and must be resolved to reach a design solution. Conflicts are often detected late in a design process, when too much effort has been invested in a specific design and there is little desire for a complete overhaul of the solution, a phenomenon that is known as 'design inertia' (Haround, 1995). So early detection and resolution of conflicts would be of great benefit to the design of buildings.

It is surprising, therefore, that although conflict has been studied by almost all the social sciences, including economics, political science, sociology and psychology, no structured method of resolving conflicts in multi-disciplinary architectural design has been developed to date.

1.3.1 Human resolve conflicts in different fields, what about architecture?

It seems reasonable to suppose that conflict management behavior does exhibit many general patterns, that the patterns of conflict in industrial relations, international relations, and interpersonal relations are not wholly different from one another. A general human-model of conflict management could, accordingly, be borrowed from these disciplines, and applied for the benefits of architectural design. Although the nature of architectural design is different from the nature of other fields, this generalized model of conflict management might be of use in resolving conflicts within the process of designing buildings. Some of this dissertation's objectives are to develop a human model for conflict management and use what is appropriate for architectural design context.

1.4 Research Objectives and Approach

As I stated at the beginning this dissertation is about how to represent conflict management problem in architectural design in a formal, domain independent way. I propose, SWAY, a framework that deals with the conflict management problem. SWAY consists of a set of algorithms for conflict resolution. It defines the basic elements of a conflict in an architecture design problem, categorizes the problem nature and applies the applicable algorithm. The unique features of SWAY include:

1. The definition of a state of conflict. It provides a general presentation of conflict issues.
2. A conceptual architecture for multiagent environment which entails several components:

    a. The participants' views and issues will be represented in the form of *agents*. Agents will represent issues of their interest, the optimal degree to which they should be satisfied, thresholds over/under which the issues will not be satisfied, and the degree of flexibility available to the agent in relaxing the requirements.
    b. A representation of the *object* of design will include information pertinent to the issues that are of interest to the agents.
    c. A *conflict management protocol (CMP)* will represent the process, informing the design participants when they should adapt or abandon certain conflict resolution methods. The *CMP* is developed by instantiating and developing from the general human-conflict model patterns that suit architecture design. This protocol will form the knowledge base of a *facilitator* that will direct the negotiation process.
    d. The explicit, quantitative representation of task interrelationships. When relationships in the design problem environment extent between tasks being worked on by separate design participants, I call them *coordination relationships*. Coordination relationships are crucial to the design and analysis of coordination mechanisms.
3. An inclusive set of algorithms that deal with all conflict states.

Like other systems, my approach is based on the *Agent* concept, which proved to be an effective means of encapsulating task-related behavior and knowledge. But unlike other approaches, I use a structured, human model of conflict management, rather than rely on distributed, agent-based conflict management, as some of the current systems do, or on strict computational approaches, such as constraint propagation, as some of the current systems advocate. Using a structured, centralized conflict management model will overcome the deadlocks characteristic of the distributed conflict management approach. The human origin of the model is expected to lend more flexibility to the conflict management process than computational approaches allow, and therefore be more suitable to the domain of architectural design.

1.5 Dissertation Road Map

This section provides pointers to the rest of the dissertation.

- In Chapter 2, I examine the background related to the research, which provide context for the dissertation. This background study covers a review of the literature of conflict management. A critical survey of research efforts and development of collaborative agent environments in architectural design and other fields, in particular those which attempted to develop conflict and negotiation models. Also I touch upon related fields namely human conflict resolutions models drawn from political science, union negotiation, economic organizations, occupational psychology and international relations; Formal models based on mathematical methods as the *Utility Theory* and *Pareto Optimality* method, Distributed Artificial Intelligence (DAI); Concurrent Engineering, since my approach depends on the notion of distribution of activities.

- In Chapter 3, I developed a general human model of conflict management and negotiation and discuss its appropriateness for being used in building design.
- In Chapter 4, I provide details about the philosophy and architecture of SWAY, a framework that supports the process and knowledge requirements for conflict resolution among different design participants. The approach provides a structured model to conflict management that defines conflict, describes an inclusive set of algorithms implemented for various conflict situations.
- In Chapter 5, the SWAY framework described in chapter 4 is illustrated through an example application.
- In Chapter 6, I summarize the main points of the dissertation and the research contributions and findings, as well as a look at possible paths of future research directions for conflict management and negotiation in building design systems.

Chapter Two

2 The research context

In this chapter I discuss briefly related research that provides a context for the dissertation. The dissertation context is related to many different areas in many different fields. I examined the historical foundations and the current approaches in negotiation and conflict management, multiagent problem solving and the coordination of agents in multiagent systems. On one hand, there is an immense amount of literature relate to the research reported here to be reviewed. On the other hand, none of this literature addresses the problem of conflict management in architectural design in a comprehensive manner. Keeping this in mind, I categorize and present the relevant areas of research below.

2.1 Negotiation and conflict management

One of the primary motivations for the dissertation research is to examine how conflict management and negotiation can be used effectively in solving conflicts among design participants while designing a building. I start with the terminology definition. The term negotiation was used in different situations with different definitions. Artificial intelligence researchers have used the term negotiation with respect to conflict resolution and avoidance (Sycara, 1988, Werkman, 1992), task allocation (Zlotkin and Roseinschein, 1989), and resource allocation (Sathi and Fox, 1989, Sycara et al., 1991). In game theory negotiation was used and examined where every participant or agent knows all relevant information about other agents (Generesereth et al., 1986, Zlotkin and Roseinschein, 1991) and under conditions where agents are hostile and completely unwilling to share private information (Sycara, 1988). Negotiation and conflict management can appear among participants using arbitrator (Sycara, 1988, Werkman, 1992), or hierarchically through certain organization (Davis and Smith, 1983, Durfee and Montgomery, 1990). Negotiation also occurs at different levels of the problem solving either in the domain or the process level.

In the following sections I look at negotiation and conflict management in several different areas and disciplines. I classified them in three categories: *Human Models*; *Formal Models*; and *Computational Models*. First I survey different *Human Models* for conflict management used in different fields as in union negotiation, corporation organization and political science. Part of my approach for this dissertation was to develop an architectural and building design model of negotiation and conflict management that resembles a human model. I set aside chapter three for developing a general human model that can be viewed as a general structure of a model for conflict management and negotiation in architectural and building design. Second I review different *Formal Models* of negotiation that are based on mathematical and organizational theories and approaches. Usually the formal models require their own problem setting driven from the need to fit the tools they use rather than the problem in hand. Third and last I review different *Computational Models* implemented according to problem context such as architectural design or problem solving methods like concurrent engineering and multiagent systems.

2.2 Human models of negotiation and conflict management

Human negotiation and conflict management models have been discussed in many different fields, in political science, union negotiation, economic organizations, occupation psychology and international relations (Pruitt 1981, Boulding 1962, Raiffa 1982). Fisher and Ury describe tactics to be used for reaching agreement in day-to-day experiences (Fisher and Ury, 1981). Expert negotiators used the techniques described mainly in human bargaining situations. Many of these techniques have useful insights that can be adjusted and borrowed for building design context. Some of the works, especially the psychological factors, are not immediately relevant. In chapter three I detailed these approaches and built a complete general human model that can be borrowed partially to the building design field.

2.3 Formal models of negotiation and conflict management

What I mean by formal models here are the models based on different mathematical methods such as the utility theory and pareto optimality method, and are developed using simple examples as the "Postman Problem" used by Zlotkin and Roseinschein 1991. Several formal models of negotiation and conflict management have been developed. (Khedro and genesereth, 1993, Zlotkin and Roseinschein, 1989, 1990). These models have some properties that are highly desirable such as the ability to reach *Pareto optimality*, or equilibrium where no agent can benefit from lying. Zlotkin and Roseinschein in their formal model of negotiation (Zlotkin and Roseinschein, 1989) provide a guarantee of the selection of a pareto-optimal, utility maximizing, solution from a set of potential solutions. However the draw back in the use of these formal solutions has been that they are computationally intractable in many situation and they often fail to capture the richness of detail that would be necessary to apply the model in a realistic domain. In this section I describe several models that have been developed.

2.3.1 Main characteristics of formal models

In formal models it is usually assumed that only two participants 'agents'[1] are involved in the negotiation process. These agents are built as 'rational' agents or so they assume. 'Rational' here means that each agent has the knowledge that allows it to understand the needs of all the participating agents in the negotiation process for every candidate

[1] I will be using the terms 'agent' and 'participant' very often all over this dissertation. I am aware that the term 'agent' may cause confusion for people coming from different disciplines as in computer science, engineering and business for example. But I find it irrelevant to my research point to try and define the term more precisely, because mainly I will be using the term 'participant' as it makes more sense to what I am researching which is the conflict management among architectural and building design participants. Meanwhile I might be using the term 'agent' as it used in different fields or where it makes more sense with clarifications.

solution. Therefore, every agent will select actions that comply with the needs of the other agents and do not hinder preferences. Usually in formal models the negotiation is viewed as a separate process used to select a solution from a set of candidate solutions. Every participant in the negotiation process selects a solution that will maximize its goals and utility, considering that all other agents will accept the selected solution.

2.3.2 Different approaches in formal models

I survey four different formal approaches that provide negotiation paradigms that deal with several issues based on different lines of thoughts. Among them are paradigms trying to reach a solution by avoiding communications among agents; guarantee an optimal solution by maximizing the local utility of each agent; planning as a constraint approach for negotiation; and finally a negotiation model for non-cooperative domains in which there may not be any benefit for cooperation.

2.3.2.1 Cooperation behavior without communication

The main objective of this approach is to avoid communication and dealing with the communication tools while it provides what they call and define as a cooperation behavior (Generesereth et al., 1986, Zlotkin and Roseinschein, 1991). This objective was achieved by defining a restricted problem domain within a specific problem set. The problem environment deals with several agents. Every agent maintains a copy of a 'payoff matrix' of the problem that will receive for every outcome generation. Every agent will decide on which decision should it take in order to reach the best payoffs. So in isolation of all other agents except of a copy of the problem matrix and with a rational behavior, agents proceed to solve the problem. They can reach a solution and an optimal one without communication. Even though this research doesn't deal directly with negotiation it is still provides a negotiation approach embedded within the problem setting. Also it provides within this problem setting different categories and types of information involved, how this information is used to negotiate the selection of the optimal solutions, and when the information required is not enough to reach a solution.

2.3.2.2 Negotiation to select pareto-optimal solutions

This approach was developed with the objective of building a negotiation paradigm that guarantees the selection of a pareto-optimal solution from a set of generated solutions (Zlotkin and Roseinschein, 1989). The problem used is the 'Postman in which two agents deliver a set of letters. The problem is not to maximize the local utilities over a set of solutions, but rather to generate solutions that maximize both global and local utilities under conditions of uncertainty and incomplete information.

2.3.2.3 Non-cooperative model

Zlotkin and Roseinschein, (1991) introduced a model called a unified negotiation protocol (UNP) in a domain in which cooperation may not be of any benefit or almost impossible. The protocol is presented in slotted-blocks domain with clear goals. Three types of situations are defined: a) cooperative, in which two agents can achieve a goal with less or equal cost than individual can; b) compromise, in which an agent has to pay more in order to achieve a goal; c) conflict, in which one of the two agent has to give up his goal to achieve the other goal a situation of no deal. In this model they show that in some conflict situation it is possible to find a partial plan that will increase both agents' relative goal achievement when all goals cannot be satisfied.

2.4 Computational approaches to conflict management

Several computational models were implemented in different fields that in one way or another have a conflict management element built into them. In this section I will categorize them according to problem context as architectural design or problem solving methods such as concurrent engineering and multiagent systems.

2.4.1 In architectural and building design

Very few models have been introduced and implemented in the architectural and building design field among these:

2.4.1.1 ICADS (Intelligent Computer-Assisted Design System) (Pohl & Myers 1994):

ICADS is one of the most sophisticated integrated collaborative building design prototype systems developed so far. It was designed to assist architects in the development, analysis, and evaluation of solutions during the early design stages. ICADS emulates the relationship between the architect and specialist consultants through the use of multiple expert systems, which it calls 'agents,' that execute concurrently in the background. Each agent has knowledge in specific domain (e.g., structural system selection, day lighting, electric lighting, noise insulation, climate control and energy conservation, space layout, and construction costs), and can evaluate solutions proposed by the (human) user, and propose solutions of its own. The agents send their conclusions to a coordination facility that identifies and resolves conflicts, with or without the interaction of the human designer. This conflict resolution is based on allowing the two conflicting agents to exchange solutions and generate alternatives, until they reach a solution. This approach doesn't usually end in reaching a common solution, because ICADS has no mechanism for analyzing and reforming design issues and preferences. It is the role of the (human) user to ultimately resolve conflicts and impose a solution.

2.4.1.2 FCDA (Federation of Collaborative Design Agents) (Khedro et al 1994):

FCDA is a system that facilitates communication among designers in A/E/C. It allows five designers and engineers (in different sites) to concurrently perform some of the design tasks and transparently exchange design information and changes via their software applications in a coordinated fashion. Although it is considered to be an agent-based model, the 'agents' in FCDA are the (human) end-users themselves. FCDA itself is, basically, an intelligent information management tool, built around a very sophisticated Facilitator, which performs a wide variety of tasks including: the intelligent routing of information based on its content; the selection of 'agents' to accomplish certain tasks; the semantic translation of different information models; support of delayed notifications and requests; dynamic discovery of information; and management of communications across the network. The FCDA system thus comprises a framework for design communication, and provides tools to present design solutions and a mechanism to exchange them. But it does not address the conflict management issues themselves, leaving them for the (human) end-users to detect and resolve.

2.4.1.3 **SEED (Software Environment to Support Early Phases in Building Design) (Flemming 1995):**

SEED is a system that employs a distributed multi-agent approach to support multi-disciplinary building design, especially in its early, exploratory phase. It uses three major agents: an architectural programming agent (SEED-Pro); a schematic layout agent (SEED-Layout); and a structure-massing agent (SEED-Config.). There are five main concepts that organize SEED: (1) functional units, (2) design units, (3) technologies, (4) design states, and (5) design spaces. In brief, design spaces comprise states, which are linked to each other by the operations required to derive one state from another. States comprise a problem, represented as functional units and a solution to that problem, represented as design units. Design units and functional units exist in one-to-one correspondence. Seed acts by creating and elaborating states comprising functional units and design units. SEED solves design problems by generating and testing design solutions, until it reaches an acceptable solution. It doesn't provide nor does it require any techniques for conflict management, since conflicts do not arise.

2.4.2 In management

2.4.2.1 **PERSUADER (Sycara, 1988).**

PERSUADER acts as a mediator between a company and a union. This is a locally cooperative domain since solution quality is a function of the utilities of independent agents. Agents are adversaries whose local goals are heavily interrelated. Agents cannot accurately predict or model the beliefs or utility values of other agents. In general, problems are over-constrained and complete goal satisfaction is impossible. The basic PERSUADER generates an initial compromise, repairs and improves a rejected compromise, and persuades the parties to change their evaluation of a compromised solution. The problem-solving methods employed are Case-based reasoning, preference analysis, and situation assessment. Case-based reasoning is used to form initial compromise proposals when suitable precedents are found; otherwise, preference analysis is applied. Once a solution is proposed, the possible responses to rejection are: (1) to persuade the agent to accept the proposal by getting the agent to change its utilities; or (2) to modify the proposal to better meet the agent's goals, although this may result in rejection by the other agent. PERSUADER differs from what I am proposing in several points. The context of PERSUADER (labor negotiations) is a different domain than design, so it doesn't deal with the characteristics of architecture design problem. It only provides a compromise strategy through mediation, so it doesn't provide a comprehensive structured method that accommodates other strategies such as reconciliation, arbitration and avoidance. PERSUADER generates counterproposals by simply changing the agent's preferences using preference analysis techniques. It is modeled by changing the weight and the utility values of goals. My proposal generates counterproposals by using the analysis of the history of negotiation recorded in the Negotiation Record.

2.4.3 In concurrent engineering

2.4.3.1 Cooperative design evaluation (Werkman, 1992).

Werkman has developed a negotiation-based approach to multi-perspective evaluation of designs. The Designer Fabricator Interpreter (DFI) system assists a human engineer by selecting and critiquing alternatives from a set of steel beam-to-column building connection designs. In DFI agents redundantly review a fixed set of alternative solutions from different perspectives rather than incrementally construct solutions with diverse expertise. To do this, the system uses a rigid representation and control structure, incorporating third party mediation and arbitration to resolve conflicts when necessary.

2.4.3.2 DICE-MIT (Distributed and Integrated Environment for Computer-aided Engineering) (Siriram et al 1992).

An architecture for building concurrent engineering systems, designed specifically to facilitate the cooperation of agents working on diverse engineering problems in an integrated project, to avoid design errors of the kind that led to the collapse of Hyatt Regency Hotel in Kansas City. DICE-MIT provides a framework for the integration of multiple computer-aided tools that will explicitly inform the design participants of potential important interactions and changes. The DICE project is ambitious in scope and tackles a number of infrastructure issues that are not examined elsewhere, such as low-level communication protocols for heterogeneous platforms and managing and storage of large amounts of data. At the same time, the project does not address some of the large conceptual issues related to conflict management that are common in a comprehensive concurrent engineering system.

2.4.4 In multiagent systems

2.4.4.1 TEAM (Lander 1994).

A framework for supporting multi-agent search and conflict management, used to implement a steam-condenser design system (STEAM) and a contract-price negotiation system (where agents negotiate over the price of artifacts). The Cooperative Experts Framework (CEF) supports cooperation between a set of full-fledged knowledge-based agents. Since conflict resolution is viewed as a knowledge-based planning process, a framework controller and knowledge-base are provided to manage the global information, to coordinate agent cooperation and to select the most effective conflict resolution strategy.

2.4.4.2 Design Fusion (Fox et al 1992)

Building upon a blackboard architecture, the Design Fusion project system maintains a shared object representation and a constraint management system. Each agent is allowed to create its own local presentation, but communicates with other agents through the shared representation (a translation and a mapping). Constraints within an agent remain in the local perspective as long as the global design does not violate the constraint. When a constraint is violated, it is posted to the global constraint management system, which builds a global constraint network. Each agent is responsible for evaluating the constraints posted on the global constraint blackboard. Obviously, conflict detection is done by individual agents, such that, as the design progresses, more constraint are posted to the global constraint management blackboard and the design narrows down.

2.5 How is my approach different?

The fundamental difference between the approach I am taking in my dissertation and these approaches is the explicit incorporation of a human conflict management model in an agent-based design environment. FCDA, ICADS, and SEED do not incorporate an explicit conflict management system. The advantage of using a structured conflict management protocol is the ability to take an impartial view of the negotiation process, which can help resolve deadlocks, which a strictly distributed approach cannot. My model will have a more pro-active role than merely passing information. It will have the ability to decide the appropriateness of proposed solutions, and to resort to progressively more stringent conflict resolution procedures.

TEAM, Design Fusion, and DICE use a computational conflict management approach, rather than the human model, which I propose to use. Their approach, which is more tractable from a computer science point of view, is also more rigid, and therefore may not be applicable to architectural design. The use of human-based conflict management protocol allows for different strategies that can be adapted to suite different design conflict situations. Likewise, Werkman's COOPERATIVE DESIGN EVALUATION system is applicable only to a narrow domain (beam-to-column connections), and Sycara's PERSUADER is designed for a different domain altogether (labor negotiations).

2.6 Summary

In this chapter I have discussed three broad areas in which conflict and conflict resolution are studied. And I have described a number of projects that have some degree of relevance to the dissertation work. It is clear that there has been a great deal of work done in different areas as conflict management, negotiation and agent coordination. However, no other work comprehensively defines a complete structured method of negotiations and conflict resolution for building design.

I have surveyed human models, formal models, and computational models of conflict management. I analyzed these models from an architectural and building design point of view.

First, *Human models*, from the social sciences, show more promise in channeling conflict situations into creative processes, but give little indication how such processes might be supported with computational tools. The main results from research in these areas is that not only is conflict inevitable in society, both within and between individuals and organizations, but that conflict has a useful role in facilitating change and producing higher quality group decisions.

The second area, *formal models*, includes areas of mathematics, decision theory and game theory. These fields are highly theoretical, and make some restrictive assumptions about, for example, the state of knowledge of the participants, and their motivations. Nevertheless, research in decision theory has developed a number of tools, which can be used to clarify the issues in decision-making. Game theory and bargaining have laid the groundwork to evaluating and understanding the use of strategies in conflict situations.

Finally, I have surveyed *computational models*, which have studied conflict. Most of these fields are extremely young, less than a decade old. The work I have covered seem to fall neatly into two camps: the AI approach, which attempts to automate completely the resolution of conflict between agents, based on mathematical approaches; and the supportive approach, in which computers are used as tools for supporting human conflict resolution, usually in a collaborative manner.

In chapter three I develop a detailed general human model to be used as the basis for my computational architectural and building design conflict management model.

Chapter Three

3 Delineating a conflict management model

"May we perhaps go so far as to say that conflict is a condition necessary for life to be possible at all? I would suggest, in any case, that all that is creativity, innovation, and development in the life of the individual, his group, and his society is due, in no small extent, to the operation of conflicts between group and group, individual and individual, emotion and emotion within one individual. This fundamental fact alone seems to me to justify the value judgment that conflict is essentially 'good' and 'desirable'."
Dahrendorf (1959)"

Conflict is found almost everywhere, and all the social sciences study it. Economists study conflict among economic organizations – firms, unions, and so on (Boulding, 1962). Political scientists focus on conflict among states in international relations (Pruitt, 1981, Raiffa, 1982). Sociologists look at conflict within and among families, racial and religious groups. Anthropologists study the conflict between cultures, and psychologists study conflict within the person. Industry looks at conflict from a CPM and scheduling matters. That includes designers where design definition was more into processing. Medical field look at conflict between the behaviors of cells and so on.

In this chapter I present a complete study of conflict based on human model. I begin with an overview of conflict occurrence, productivity, types and characteristics. Then I continue by laying down the design outlines and principles of a computational conflict management model. This model is designed and discussed in details in chapter four. Last I identify the main characteristics of the model.

3.1 Aspects of conflict with respect to design

There are several aspects of conflict that affect its resolution. Not to mention the plausibility of having or avoiding conflict itself in general and in design context. The objective of this section is to define outlines and aspects that provide boundaries for negotiation and flexibility in defining negotiation ranges among design participants.

3.1.1 Occurrence of conflict

Is conflict occurrence inevitable? Should we try to avoid it? Is conflict a negative or a positive event?

3.1.1.1 Conflict is inevitable

Conflict, it is argued, is not a random act, but a logical product of the structure of the problem solving process. Whether or not conflict in general is inevitable depends on the nature and how we view the problem solving process. Philosophers like Marx (Marx, 1947) argued that conflict is a necessary part of class awareness and social changes, "Without conflict, no progress: that is the law which civilization has followed to the present day". Dahrendorf says conflict is common in society (Dahrendorf, 1959). Every society is founded on inequalities in power and authority, resulting in the coercion of some members by others." Hall views conflict as a clash of ideologies (Hall, 1982). Ideologies are "sets of ideas, concepts, images and propositions which we use to represent to ourselves – and thus make sense of – how society works and our relationship to it." Ideologies reflect the opinions of individuals and groups.

Brehmer and Pendell have shown that although conflict within any given group may not be inevitable, it is very likely to occur: even when there are no differences in the goals, interests and motivations. Also found that conflict is a normal element of small group decision-making (Brehmer, 1976, Pendell, 1990). Dana Cuff shows an overview of architect-client design interaction that negotiation is an integrated part of it (Cuff, 1996).

3.1.1.2 Is conflict a negative or a positive event?

Even though we may admit that some conflict is positive, the word itself has a bias toward the negative. Most of the literature on conflict tended to concentrate on the negative side of conflict, on its elimination or avoidance, and it has given little attention to the positive side. We usually think of reducing conflict, not of increasing it. We think of conflict in terms of family quarrels and divorce; racial discrimination and race riots; industrial disputes and strikes; political conflict and revolutions; or international conflict and wars. Philosophers like Hegel and Marx may have defended conflict as a necessary instrument of change and progress, and socialists like Simmel and Coser may have defended it as an instrument of social integration, but this still has to be seen as a defense against common prejudice.

3.1.1.2.1 Consequences of ignoring conflict

As a common practice in existing architecture and building design process participants generally ignore conflict. Where conflicts do occur, they are likely to get ignored by the designer and be passed to other participants as long as the designer own requirements are fulfilled. In other words it is not my problem lets make it others. This process occurs mainly because of the lack of means of expressing conflict, which lead to a number of problems:

1. A single view of the design problem will dominate the design process, and will be adopted as the basis for the design concept at the cost of other participants' design views.
2. If these conflicts remain ignored it is possible that they will lead to dissatisfaction with the design process adapted.
3. If the conflicts are eventually resolved, the resolution will be carried out in a later stage during the design process. Consequently it will be carried out at an inappropriate time, causing unwanted and undesirable results.

4. Conflict between participant’s views will cause confusion during the early design phase, which will then continue throughout the design process. The participants’ understanding of the design requirements will differ, leading to further misunderstandings.
5. Participants may get frustrated and consequently withdraw from the design process.
6. Following this scenario, ignored conflicts may even lead to the breakdown of the design process.

3.1.1.2.2 Positive attributes of conflict

Literature on conflict tended to concentrate on its elimination or avoidance, but there is a growing recognition that interpersonal and inter-group conflict often serves useful functions. Research into group behavior and group decision making (Brown, 1988), (Dahrendorf, 1959), (Deutsch, 1969), (Hall, 1971) concluded that creativity, innovation, and development in the life of the individual and his group are due, to certain extent, to the operation of conflicts. In problem solving conflict can produce higher quality solutions for many reasons:

1. Exploration of the areas where participant’s views differ can lead to a much better understanding of the task domain.
2. It can help to establish group and individual identities.
3. Conflict can lead to provocation of the participant’s highest level to solve problems, which is a useful way of stretching participant’s views to limits.
4. Confrontation of divergent views can produce new perspectives and more comprehensive views, leading to superior solution.
5. Conflict can provide a clear view of the participant roles and the organization of group of design participants, which will provide a well-defined design group structure.

So far, it should be clear that conflict is not necessarily negative. The previous points present a strong argument for conflict to be carefully managed at different stages in the architectural design process. Participants are encouraged to express different views. This will ensure that the resulting design reflects different participant’s views, and does not ignore their concerns, which interfere with others views.

In conclusion, although I cannot say that conflict is inevitable for every particular situation, the structure of architectural and engineering design is such that conflict forms an integral part of it. The recognition of the positive attributes of conflict has lead to a more balanced view, which acknowledges that there are aspects of conflict, which can be both negative and positive. Rather than a consideration of its elimination and avoidance conflict proved to be necessary to the creative process of design and the research emphasis has shifted to the effective management of conflict. Conflict concerned with ideas and issues has a positive effect on the resulting decision and should not be suppressed. To designers, conflicts can be a challenge and an inspiration for innovation and a trigger for imagination and creativity. Hence, dealing with conflict must be matched with resolution methods, which do its utmost to satisfy all parties. An integrative approach should be adopted, to ensure that when divergent views arise they are incorporated into the design process. The ultimate goal should be to produce a solution, which represents all concerns.

3.1.2 Causes of conflict

This section is concerned with particular causes of conflict. I do not attempt a meticulous cover of all the potential sources of conflict, but in general conflicts occur because of three reasons, communication, structural and personal factors:

1. Communication, including insufficient exchange of information, noise, and the semantic differences that arise from selective perception and difference of background;
    - Conflicting terminology: participants coming from different fields use different terminology meaning the same thing. This produces communication problems
    - Different representation schemes: Different representation schemes in which knowledge about an issue is expressed will differ.
    - Different types of knowledge, participants are from different areas and have different types of knowledge, making it difficult to make comparisons.
2. Structural, which includes the goal compatibility of members of the group
    - Clarity and leadership style;
    - Conflicting designs, different interest of participants over a design object
    - Conflicting interpretations - descriptions of the current situation or the current requirements do not match, usually because different perspectives interpret things differently. This category corresponds to the category *Beliefs* (or "how things are"), as described by Deutsch (1973).
3. Personal factors, including individual value systems and personality characteristics

3.1.3 Aspects that increase and reduce conflict

3.1.3.1 Participants role and structure

I distinguish two key concepts, which provide measures of interdependence of the group participants. 1) Differentiation, describes the extent to which the work is divided into a large number of subtasks relative to the size of the group. 2) Specialization is the degree to which tasks can be performed by a small subset of the group. The latter is a better measure of interdependence, because, as task specialization increases, the group becomes dependent on fewer participants for the completion of each task.

The lack of clearly defined roles means that no one participant had responsibility for focusing the group's attention. Furthermore the group tends to avoid conflict and critical discussion, preferring to suppress their concern about progress. I can state that clearly defined roles reduce conflict.

3.1.3.2 More communication increases opportunities for conflict

The more communication there is between participants, the more opportunities there are for conflict. Communication is carried out for a purpose within a developing context, and it can vary in both amount and quality. Simple statement such as 'more communication will reduce conflict', or "vagueness in communication lead to conflict" have been refuted in various studies (Putnam & Poole, 1987). The inverse of this statement "the less communication there is, the fewer opportunities there are for conflict" is trivially true if conflict is a communicational activity. Also we might observe that a decrease in communication may serve to intensify a conflict.

In conclusion, conflict can be reduced by better communication, where 'better' refers not just to the pattern and the intensity of communication, but to the effectiveness of the communication.

3.1.3.3 Articulating conflict helps in its resolution

Researchers have evidence that conflicts, which are not articulated, may accumulate to produce breakdowns in decision making (Baxter, 1982). We can say that conflict cannot be resolved unless it is expressed.

These observations have lead to an interest in techniques for making conflicts explicit, which is defining the process of identifying and understanding the parameters of a conflict. This involves making the conflict explicit, recognizing the issues involved, and having individual views acknowledged by the other participants.

I identify four aspects of conflict, which are salient for delineation:

1. The strength of the disagreement;
2. The level to which the disagreement is personalized (embedded in interpersonal relationships, emotions and personalities, as opposed to being more purely concerned with task focused issues and ideas);
3. The competitiveness of the dispute; and
4. Centrality (how important the issue is for the disagreeing member and the group – this will influence how willing they are to compromise).

This last point leads me to express a note of caution. If articulation of conflict is used as a prelude to resolution, then conflicts, which should not or cannot be resolved perhaps, should not be articulated. For some conflicts, suppression may be a sensible approach if it avoids a senseless confrontation. Furthermore, too much concentration on conflict may over-emphasize its importance.

3.1.4 Temporal aspects of conflict

Many studies of conflict have ignored temporal aspects, other than recognition that a group may develop through a series of phases as time progresses. In recognition of this, I put forward a notion that any action not only takes its meaning from the context, but also from its timing. If an action is regarded as conflictive at one point, it might not be seen so at a later time.

I suggest there are three temporal types: temporal ambiguity, in that it is not clear when events will occur or recur; conflicts between temporal requirements; and insufficiency of temporal resources. These can usually be handled through scheduling, synchronization, time allocation, and by negotiating event sequences.

3.1.5 Conflicts follow a set pattern

Although many theories of conflict present a series of stages of individual conflict episodes, the empirical basis of many of these models is unclear. In most cases they simply offer frameworks for investigation of conflict rather than descriptive (or even prescriptive) models. For example, (Pondy, 1967) treats conflict as a series of episodes, with each episode including the stages: latent conflict (conditions); perceived conflict (cognition); felt conflict (affect); manifest conflict (behavior); and conflict aftermath (conditions). However, the stages are vague, and reflect an emphasis on the role of perception, and a suggestion that conflict must be perceived before it is felt.

3.2 A general model of conflict management

Different ways in which conflicts are resolved have been proposed with which to classify responses to conflict (Boulding 1962, Pruitt 1981, Raiffa 1982). In this section I am developing outlines of a conflict management model for architecture and engineering design. There are several different orientations that participant might have to conflict, based on a two dimensional space of possibilities. The two dimensions are desire to satisfy one's own concern, and desire to satisfy the other party's concern. The resulting space offers many interesting conjunctions, as shown next.

3.2.1 General model

The model can be seen in two major parts, Avoidance and Procedural Resolution:

3.2.1.1 Avoidance

The first method of ending conflicts is probably the most common, though by its very nature it is also the least noticeable. This is the method of *avoidance*. The conflict is recognized to exist, but is suppressed by one or more parties, or handled by withdrawal. The parties to the conflict simply remove themselves from one another and increase the distance between them to the point where the conflict ceases from sheer lack of contact. A man who cannot get along with his boss quits his job, or is fired. Couples who cannot get along get divorced. Avoidance always involves putting some kind of distance between the parties. It is useful where an issue is unimportant, where the potential disruption would outweigh the benefits of resolution. The distance need not only be physical, it may take the form of epistemological distance, as when two parties deliberately cultivate ignorance of each other and avoid overt communications. There are three forms of avoidance, as depicted in figure 3.1:

1. One party may simply remove himself from the field; here the avoiding party does all the work.
2. Both parties may remove themselves, though this is less likely, as once one party begins to remove himself there is little incentive for the other to move.
3. One party forcibly removes the other. This extreme form of avoidance is called *conquest*. In Conquest one party forcibly removes the other. Of course it can take place only when one party is stronger than the other.

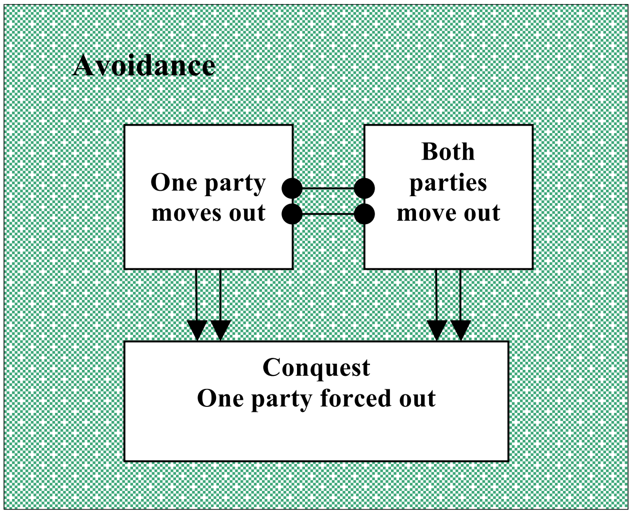


Figure 3.1 A model of avoidance

3.2.1.2 Procedural Resolution

If the parties can neither avoid nor conquer each other, some form of procedural resolution is likely. In procedural resolution, the parties have to stay together and live with each other. We may distinguish four types of procedural conflict conclusion as shown in figure 3.2:

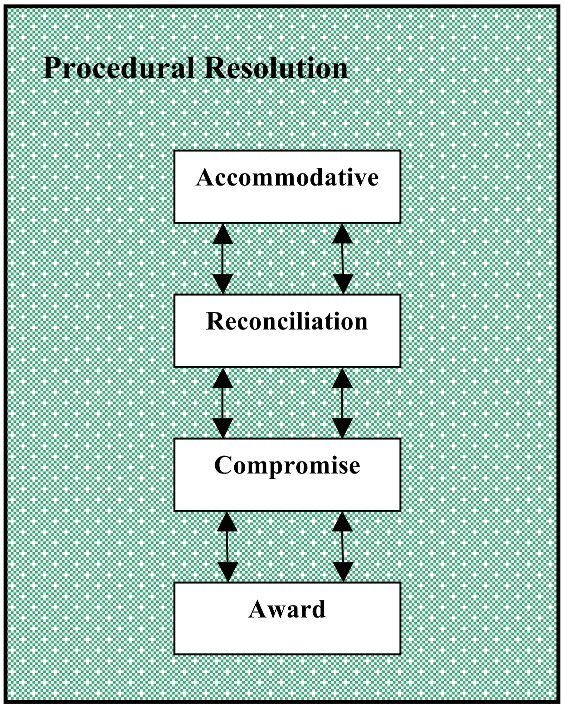


Figure 3.2 A model of procedural resolution

3.2.1.2.1 Accommodative

A party becomes self-sacrificing to appease another, and places the other's interests above their own. It is useful when issues are more important to others than to the accommodating party, where one party is losing and needs to minimize loss, or simply to build harmony.

3.2.1.2.2 Reconciliation

Reconciliation, in which both parties seek to understand their differences change their original preferences and end up with common, mutually beneficial solution, as depicted in figure 3.3. This approach is appropriate where participants' preferences and commitment are important and need to be merged rather than compromised. Reconciliation is thus the result of conversation, argumentation, discussion, or debate that leads to the modifications of preferences of the two parties. This is the condition Thomas Kuhn called 'paradigm shift' (Kuhn, 1962).

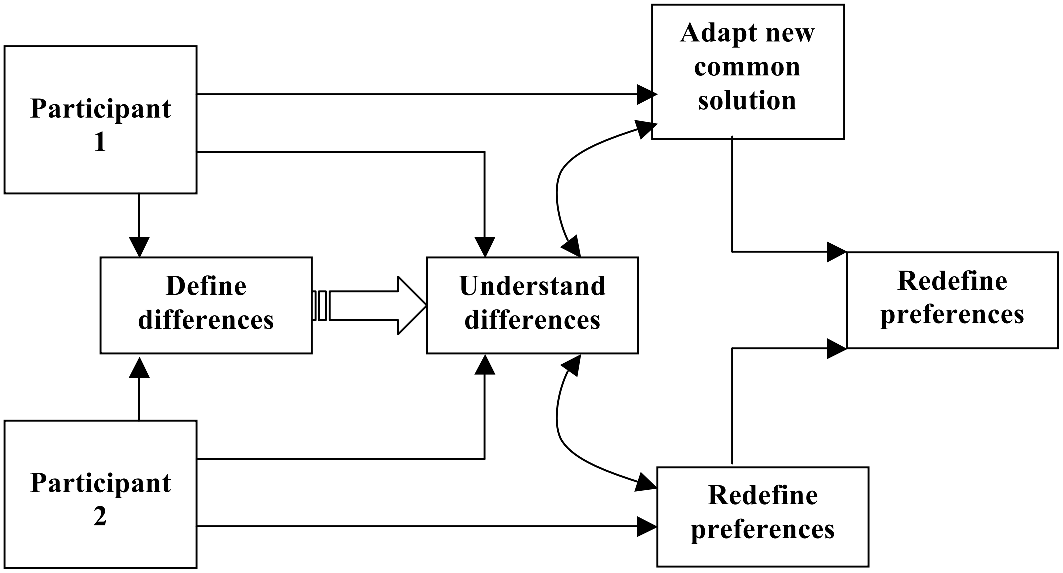


Figure 3.3 A model of reconciliation

3.2.1.2.3 Compromise

In compromise each party is willing to settle for something less than its ideal position rather than continue the conflict. Each party makes some concessions in order to reach a compromise, as depicted in figure 3.4. This is most appropriate where temporary settlement or expedient solutions are needed, especially under time pressure, or where goals are directly opposed. In compromise, a mutual settlement is reached by bargaining between the parties themselves. This form of conflict resolution is different from *reconciliation*, in that the parties reduce their original expectations rather than adopt new ones.

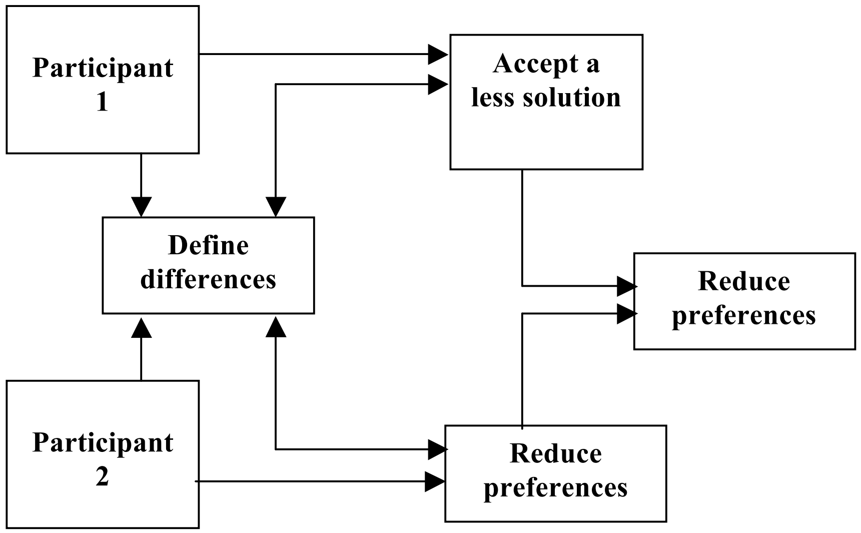


Figure 3.4 A model of compromise

3.2.1.2.4 Award

In Award situation a settlement is reached because both parties simply cannot carry out certain thinking because it would not be consistent with their position in the conflict. Both parties have agreed to accept the decision of an outside party rather than continue the conflict. The *compromise* and the *award* are essentially similar in that they both represent less than the ideal situation for each party; they differ mainly in the method of arriving at the settlement. It is clear that third parties can play a useful role. Usually third parties play two role types: the encouragement of cooperative resolution, especially by powerful and prestigious third parties; and the provision of problem-solving resources. Each of these modes is appropriate in some circumstances; the more aware participants are of the possibilities the more likely a suitable mode will be used.

3.2.1.3 Sets of procedures for Procedural-Conflict Resolution forms

To each of the four forms of procedural-conflict resolution corresponds an appropriate set of procedures, figure 3.5. None of the four forms of settlement is completely separate in practice, though there is a tendency for one form to dominate in any particular case. Frequently, however, both reconciliation and compromise occur simultaneously. Indeed, some reconciliation may be necessary before compromise is possible. Similarly, in arbitration cases, there are often elements both of reconciliation and of bargaining before the award is handed down, and the award will not be accepted unless it has been preceded by informal reconciliation and bargaining.

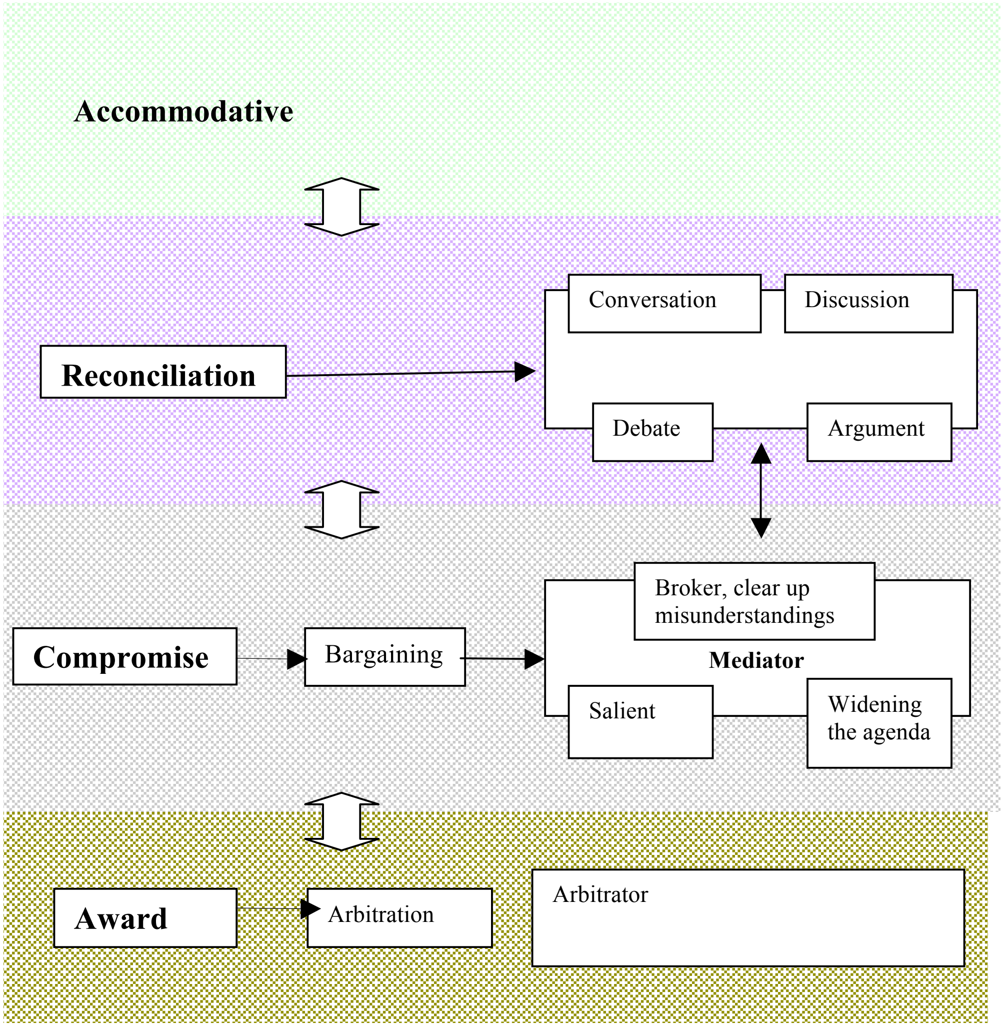


Figure 3.5 A procedures set of procedural conflict resolution

3.3 Negotiation

In the above part I introduced a general model of conflict resolution. Most of the activities in this model involve negotiation. In this section I am discussing the negotiation life cycle.

Negotiation is a complex task, it extents from the handshake between participants to signing an agreement. Negotiators bring to the bargaining table their goals and strategically share information. The complexity of negotiation stems from the difficulty in understanding all of the participants' goals, possible solutions, and their interaction. Negotiation is viewed as the actual interactions among participants that lead to mutual commitment. It starts when participants begin communicating their goals, and succeed when all participants agree to a specified contract.

3.3.1 General negotiation life cycle

The life cycle of negotiation should address steps that cover all the activities involved from detecting conflict, initiating negotiation, following the actual negotiation processes leading to success or failure of reaching an agreement. I categorize these activities into three phases: analysis, interaction design, and negotiation implementation.

3.3.2 Negotiation processes

Negotiation moves through phases with the initial phase, negotiation analysis, focusing on what participants requires and the subsequent phases, negotiation design and implementation, define how those requirements can be satisfied. During analysis, participant requirements are elicited and represented. Next designers from all sides must agree on a negotiation protocol, which will define when and how the interactions will proceed. Finally negotiators actually present their goals, recognize conflicts, generate resolutions, and commit to an agreement. However these negotiation phases do not (very often) proceed in this order. Agent models are always updated during the negotiation life cycle, when participant or negotiation protocol may change.

During the analysis phase, an agent model is created for the goals that an owner seeks to achieve, avoid, or maintain possibly under some constraints. For example an owners goal could be to maintain having an extra space in the living area to increase their satisfaction, but still fit into their budget. Such models are acquired through interaction with participants. Often the result is a formal model, such as a utility model (Zeleny, 1982).

As part of the interaction design phase, participants must agree on a negotiation protocol. A negotiation protocol defines how agents communicate through an ordered interchanged of structured information. As agents run a negotiation protocol they engage in four specific types of behavior: 1) revealing agent model 2) identifying conflict 3) searching for alternatives (including conflict resolution as discussed in previous section) 4) selecting an alternative (Pruitt, 1981).

A negotiation strategy refers to the plan by which a participant intends to interact with other participant, while using a particular negotiation protocol in an effort to achieve a desired outcome. For example participants may honestly reveal their preferences or be strategically deceitful to gain an advantage.

3.3.3 Conflict understanding

During negotiation, understanding the interactions among participant models is critical. Conflict understanding can have a significant influence on the resolution-generation approach. If only syntactic differences can be understood, then resolution generation is limited to choice among given alternatives. However, if conflict semantics are understood, then the alternatives can be decomposed and resolutions can be generated based on their restructuring. For example, price compromises for a window are possible during negotiation because agents understand the semantics of money. If the agents have a deeper understanding of window's domain, alternatives based on configurations of the window such as 'double glazing', and 'material' features can be generated.

Finally, the manner in which agents select a solution can also be critical. It can be distributed decision making – no single authority determines the final outcome. In contrast, disputants appearing in front of a judge illustrate centralized decision making. In fact, groups can switch between centralized, representative, or distributed-negotiation architectures to gain different degrees of efficiency or participation.

3.3.4 Negotiation products

Negotiation can be characterized as the search or an alternative that satisfies a set of agent models. Negotiation moves through processes of representing participant goals in agent models, detecting conflicts and other interactions among the model, generating alternative conflict resolutions, and finally creating a deal through resolution selection. Thus, agent models, alternatives, conflicts, deals, and their relationships are key negotiation products that should be tracked throughout the negotiation life cycle.

3.3.4.1 Tools of the negotiation products

In the first phase of the life cycle, negotiation analysis seeks to acquire and model individual preferences. Decision theory, and specifically utility theory, supports this phase in that it describes how to acquire and model individual preferences (Zeleny, 1982).

In the second phase of the life cycle, negotiation design seeks to define interaction protocols and strategies. Traditionally, game theory has been used for negotiation strategy design. It provides analytic techniques for modeling competitors and defining actions contingent on competitor actions. More recently, this technique has been adopted to define software agent negotiation protocols and strategies (Rosenschein and Zlotkin, 1994).

In the third phase of the life cycle, negotiation implementation seeks to reach group commitment through a series of communicative exchanges. The content of negotiations must also be addressed; this includes conflict analysis, resolution generation, argumentation, and arbitration (as mentioned earlier).

3.3.4.2 Negotiation Styles in Mediation

I mentioned a number of basic methods of conflict resolution, and categorized them as collaborative, competitive or third party. However, in organizational behavior, researchers are more concerned with behavioral approaches to conflict, and whether it can be resolved or not. Studies have shown that different people are predisposed to tackle conflict in certain ways, according to their character rather than the context of the conflict. It is useful to identify these modes, and examine the utility of each.

Each of these modes is appropriate in some circumstances; the more aware people are of the possibilities the more likely a suitable mode will be used. It is useful to compare these modes with the methods available for conflict resolution. For example, collaborative methods such as negotiation and education, while most often used in the collaborative mode, can also adopted in other modes. Education can be used to achieve conflict avoidance or accommodation by enabling participants to understand their differences better. Similarly, negotiation can assist with achieving a compromise, seeking an accommodation, or regulating competition. It is likely that successful negotiation requires at least some assertiveness and at least some co-operation from each participant. This in turn implies that each participant must have some motivation to resolve the conflict rather than avoid it.

In mediating conflicts negotiators use different styles of dispute resolution. It is important to understand different most often used styles by negotiators. The five styles of negotiation are:

3.3.4.2.1 Attack

This type of negotiator is often called an aggressive negotiator. Negotiators who tend to fight share the following characteristics:

Goals: They seek to win. The goal is victory, defined as maximizing the participant's outcome and outmaneuvering or beating opposing participant.

Character: They withhold information, "stretch" the facts, and demand one-sided gains.

3.3.4.2.2 Appease

This type of negotiator is often called a cooperative negotiator. Negotiators who tend to appease share the following characteristics:

Goals: They seek to act fairly. The goal is agreement, defined as reaching a "fair" result.

Character: They are courteous, realistic in positions, and openly share information. They also often make one-sided concessions with the expectation that the opponent is morally obligated to reciprocate.

3.3.4.2.3 Flee or attempt to evade the problem.

This kind of negotiator is often called a distracter. Negotiators who tend to flee or dither share the following characteristics:

Goals: They seek to win but are uncertain what that means. The goal is survival, defined as not losing or being beaten.

Character: They dither between three patterns: attack, appeasement and hiding/delaying/stalling. In an attack orientation the bottom line is "what can I conquer or take?" In appeasement, it is "what can we work out or create?" In dithering: "what can I avoid losing?"

3.3.4.2.4 Displace or analyze the problem.

This kind of negotiator is often called an analyst. Negotiators who tend to analyze share the following characteristics:

Goals: They seek to understand. The goal is solving the problem (often independent of the parties benefit) and increased understanding.
Character: They are thoughtful and act independent of trust. Where an appeaser cannot work with you if he or she does not trust you, and a ditherer will not trust you (even as he or she works with you). They tend to rely on objective criteria and to seek multiple options.

3.3.4.2.5 Truth seeking.

This kind of negotiator is often called an idealist. Negotiators who tend to level or seek the truth share the following characteristics:
Goals: They seek abstract truth or justice often without regard to human factors or reality. They often have a single "truth" that dominates them in spite of rational considerations.
Character: Honest, sincere, dedicated, often inflexible and idealistic.

3.3.4.3 Applying Mediation to the Process.

One reason that mediation works very well in improving the negotiation process is because it helps defuse the natural conflicts created by differences in negotiation styles. Mediation is generally set up in a structure that isolates parties from style conflicts. The parties take fixed positions prior to the mediation meeting. Then they present their sides of the conflict with minimal interruption.

The most common contemporary mediation process tends to take the style out of the process and reduces the matter to positional shifts and objective statements. It should be remembered that mediation made substantial improvements in its success rates when this basic format became the standard or common format for mediating disputes.

One of the reasons for the improved success rate of mediation when using the modern format is that negotiations that were floundering because of style conflicts in the old format had the element of style conflicts taken out or reduced by the new format.

As a mediator, by being aware of the various styles, you can seek to use the process to improve the interactions and the results. When negotiations hit a bottleneck or a seemingly impossible conflict of personality, by being aware of these issues you can aid mediation work to resolve the matter by removing the issue of style conflicts

3.4 How this model apply to architecture

Patterns of conflict in industrial relations, international relations, interpersonal relations are not wholly different from one another. The question then arises, is there a general phenomenon of conflict that applies in all of these different areas? It seems reasonable to suppose that conflict does exhibit many general patterns. Can conflict management in design be compared to conflict management in other fields?

The nature of Architectural design is different from the nature of other fields. As a discipline, it combines artistic and scientific aspects. Some of the main differences are:
Discovery: It is difficult to predict design outcomes, and designers can never evaluate a building definitively (Cuff 1991). The implication of discovery on conflict management is that it reveals differences that may not have been visible before; it may bridge formerly

perceived differences; and it may change the parties' positions as the design process unfolds, so earlier agreements may no longer be acceptable.

3.4.1 The temporary nature of collaboration

The building process is handled by architectural, structural, mechanical and engineering offices, a general contracting company, several subcontractors, product manufacturers, etc. These are basically independent task organizations, whose project-related association is temporary and short, compared to the life span of each organization individually. They join each other to form a project-related 'temporary-multi-organization' (Mohsini, 1992). While they must meet the goals of the joint project, each organization has its own long-term objectives and plans, which may not be compatible with the project goals. The individual objectives of the architectural firm, engineering firms, etc., as permanent independent organizations, aim at enhancing their name in the market, surviving the competition, etc. Once they join the temporary multi-organization, they pursue their project-dependent objectives, as well as their own independent objectives. For example, the architectural firm will propose a design that will serve the project objectives, and at the same time, serve its own independent objective of being the most attractive, noticeable part of the project. Additional luxury in materials, innovative and artistic detailing, aesthetic form design, etc. can all be means to achieve these goals. The degree to which these independent objectives are met depends on the amount of power the firm has in the multi-organization, and its ability to impose these objectives on others. This practice might lead to a situation where a participant-organization might quit the project if it is not able to meet its minimum independent objectives. As a result, a situation that needs collaboration and joint decisions might transform into achieving independent goals. If not resolved, this situation may come at the expenses of the project objectives, thus the individual objectives and ego of the participating parties in the design process influences the collaboration and the complexity of the conflict management methodology.

3.4.2 Lack of a common language

The participants in an architectural design process come from widely differing disciplines, each with its own vocabulary and professional jargon. A party may use a word or an expression to mean one thing, while another party uses the same word or expression to mean something entirely different. Alternatively, different parties may use different words or expressions to say the same thing. This can create apparent agreement or disagreement due to lack of understanding rather than real conflicting needs.

In the following chapters I will define in details and examine the general model of conflict management presented in this chapter, and adapt it to architectural design.

Chapter Four

4 Conflict management an architectural model

The presented approach is based on a framework of agents and a conflict management module. Agents representing design participants support a conflict management module called SWAY through interactions among two or a group of design agents in the course of developing a resolution for the conflict. The approach suggests that the design agents themselves can be made responsible to perform and manage various design tasks to assist SWAY in making various conflict management decisions.

The normal procedure when design agents encounter a conflict during the design process is first detect the conflict; second initiate conflict protocols for negotiation and finally follow the actual negotiation leading to a resolution of the conflict, figure 4.1.

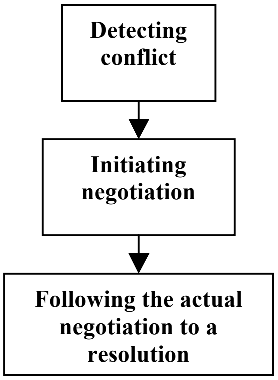


Figure 4.1 Steps to Resolve Conflict

4.1 Conflict detection

The first problem for conflict resolution is to recognize that a conflict exists. How to detect conflict is beyond the scope of this dissertation. But what is relevant here is the definition of conflict and its representation. My definition of conflict is based on interference: two participants are in conflict if the interest of one negatively affects the interest of another. Therefore, different design proposals only conflict when the differences lead to obstruction. A conflict is simply a difference that matters.

In usual design process, differences between design proposals are ignored, allowing them to develop independently. They only enter the conflict resolution process when differences between design proposals matter, to avoid efforts to resolve conflicts unnecessarily.

There are different reasons that cause a conflict as stated in chapter three. In this dissertation I am concerned with conflicts caused by conflicting designs as a result of different interest of participants over a design object. Also, Conflicting interpretations where descriptions of the current situation or the current requirements do not match, usually because different perspectives interpret things differently. This category corresponds to the category *Beliefs* or “how things are”, as described by Deutsch (Deutsch, 1973).

4.2 Issues covered and visited

A computational representation of a design environment relies on individual domain applications or agents, domain objects of artifacts being designed, and the flow of information amongst these applications and objects. Typically, domain applications represent domain expertise. Domain objects encapsulate information about the real world objects they represent. In general, a computational design environment is a collection of domain expert applications and libraries of prototypical objects. The infrastructure of communication, translators between representations, interfaces (for designer/applications/domain objects/ databases), process and configuration management mechanisms (for resource allocation and synchronization) all facilitate the coexistence of the environment players and the interactions amongst them.

As I mentioned earlier this dissertation is concerned with building a conflict management model. Figure 4.2 depicts the general components of the system underlying the covered and visited issues in this dissertation.

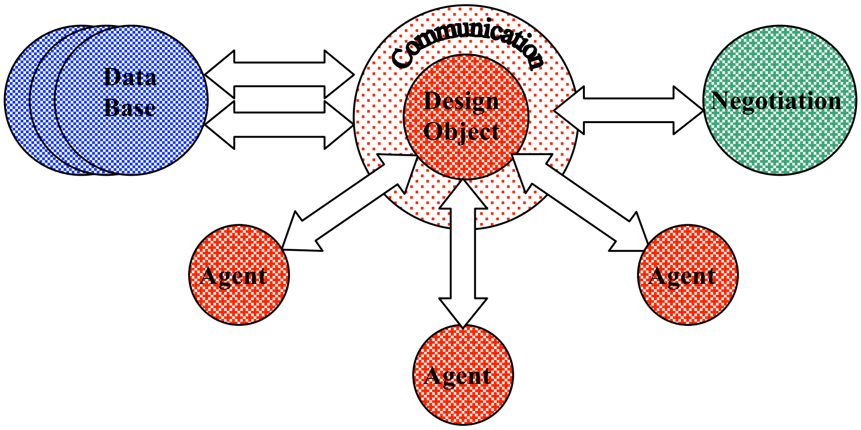


Figure 4.2 A computational representation of a design environment

4.3 Managing information

The classification of information helps to provide clean interfaces between agents and other components of the framework. Based on the information needs to be accessed and used by the framework components I distinguish three classes of information:

1) Agent level information includes the local agent negotiation strategies, evaluation criteria, and local database.
2) Shared and common information level includes Messages, Design problem specifications, coordination strategies, and solutions.
3) System information level Agent mappings, System language, Agent communication handling.

I developed the necessary parts of information for the conflict management module as described next.

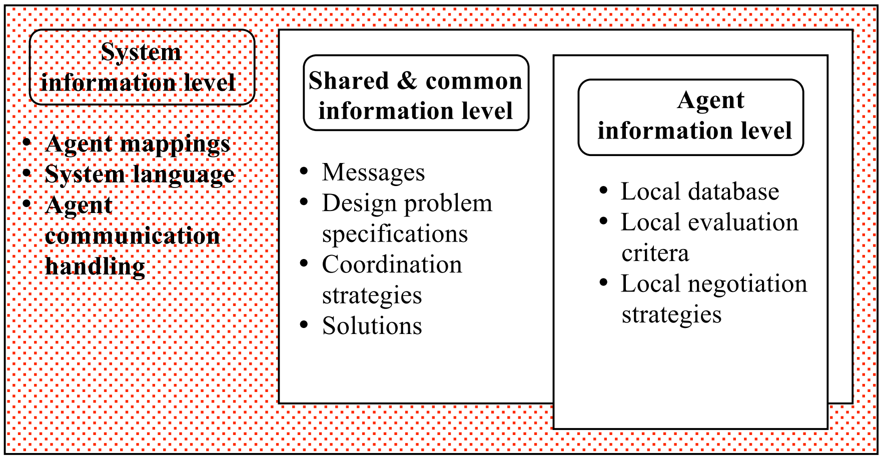

System information level
- Agent mappings
- System language
- Agent communication handling
Shared & common information level
- Messages
- Design problem specifications
- Coordination strategies
- Solutions
Agent information level
- Local database
- Local evaluation critera
- Local negotiation strategies

Figure 4.3 Classes and levels of information

4.4 Conflict management knowledge representation

The knowledge that is pertinent to the conflict method consists of: (1) the knowledge of the participating 'agents'; (2) the knowledge of the 'system facilitator'; (3) the knowledge of the conflict management module; and (4) the object data that describes the design solution. In the following, I outline each of these representations, and the links between them.

4.4.1 Representation of participants' issues and views - Agents

Each individual participant is represented through a construct, which I call 'agent[2].' Its knowledge includes the design issues it is interested in, their relative importance, and the values associated with a design solution that purports to satisfy them. This set of knowledge is called a 'view.' Each agent will be interested in a different set of issues; hence it has a different *view* of the evolving design solution than other agents.
Agents are able to communicate their views of the problem, reason from their own and other views, and generate acceptable design proposals. To do so, they convey not only the parametric value of the issues the agent is interested in, but also the *degree of*

[2] In Latin the word 'agans' means 'to act'. Accordingly, the word 'agent' is defined as the producer of an effect, an active substance, a person or thing that performs an action, or a representative. Tokoro [Tokoro 94] considers the later two meanings of the word to best describe the word use in multi-agent research, where an agent is "an individual that performs an action" and a multi-agent system is "a system composed of multiple individuals which perform actions."

satisfaction by which an agent view each issue of a solution. Each issue representation will, therefore, include the optimal degree to which it should be satisfied, the threshold below which the issue will not be satisfied, and the degree of flexibility available to the agent in relaxing the requirements. The method I am using for this representation is based on the concept of *satisfaction function*, first introduced by Rittel and Kunz [Rittel, Kunz, 1972].

Each issue that is of interest to an agent can be represented by a satisfaction curve, as depicted in Figure 4.4. The horizontal axis indicates the *parametric value* of one aspect of the design solution that is related to this issue. The vertical axis measures the *degree of satisfaction* each value elicits for this particular agent. For example, an architect-agent may be interested in a 'noise level' issue, with regard to a window design, that ranges between 40Db and 60Db. These numbers correspond to a degree of satisfaction that ranges between 80% and 100%. The optimal degree of satisfaction will be reached when noise level of the window under 40Db. The agent will not be satisfied if the noise level of the window is more than 60Db (too noisy) or less than 40Db (feel isolated). The satisfaction curves for cost and view are constructed in a similar fashion.

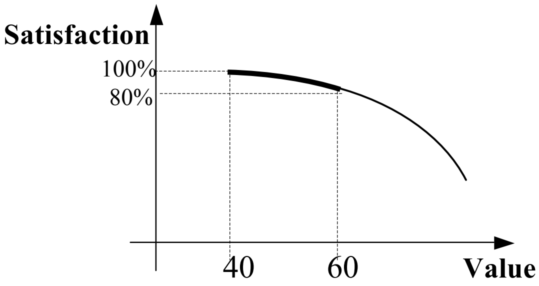


Figure 4.4 A typical satisfaction curve.

The degree of flexibility in relaxing the requirements is represented by the *slope* of the curves: the steeper the slope the more abrupt the change, which means that even a small change in the object's parametric value will result in greatly increased satisfaction or dissatisfaction. On the other hand, a shallow slope indicates a wider satisfactory latitude, which allows for more room for negotiation with other agents in case of a conflict related to this issue. If we look at the curve on Figure 4.5, moving along part A or B of the curve causes the same amount of change in satisfaction, although part A represents a greater change in the value parameter than part B does.

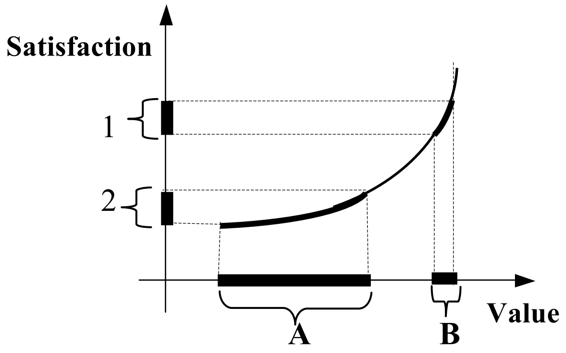


Figure 4.5 Slope as a measure of flexibility.

Each agent must set independently these satisfaction curves, which represent the subjective values of the agent with regard to the performance of the design solution. The agent's goal is to find a design solution that optimally satisfies all of the issues. This is unlikely, for there are probably incompatibilities even among the issues that are of interest to individual agent, let alone among issues of different agents. Hence, the agent will have to *prioritize* the issues of its interest, and maintains different *negotiation strategies* that it will adapt at certain points during the negotiation process, including re-prioritization of satisfying the various criteria, and its willingness to modify the satisfaction curve themselves. These strategies will form part of the agent's knowledge base.

Agents will communicate to the *Facilitator* (which is discussed next) a position stating the level of their approval of a given solution (the facilitator does not need to know how an agent arrived at this valuation). In case they are so requested by the facilitator, the agents may derive an alternative design solution from a database of such design solutions (e.g., a catalog of windows). A schema of the agent is depicted in Figure 4.6.

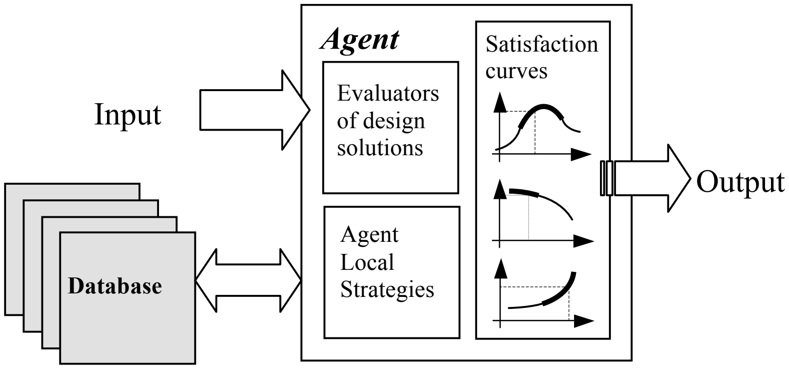


Figure 4.6 Schema of an Agent

4.4.2 Managing the process - Facilitator

The facilitator organizes the activities of the agents and informs them about proposals and counter-proposals. As depicted in Figure 4.7, it will need to maintain knowledge related to conflict resolution strategies, the issues that are of interest to each agent, and a record of the negotiation dialogue (the history of the negotiation, including the proposals, counter-proposals, agent valuations during the negotiation dialogue, and agent behavior during reconciliation, arbitration or mediation).

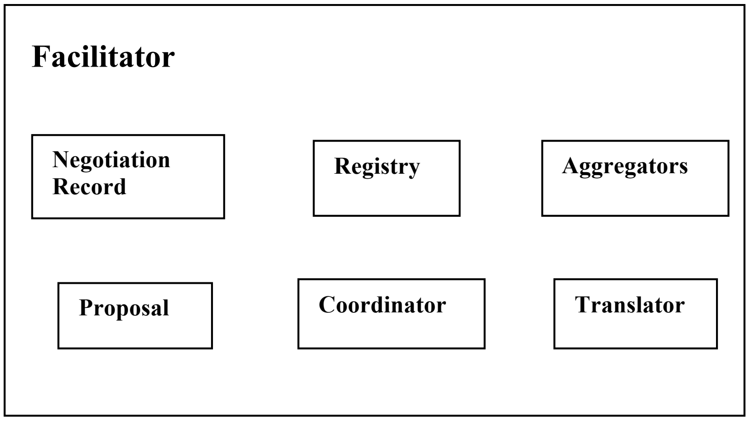


Figure 4.7 Facilitator elements

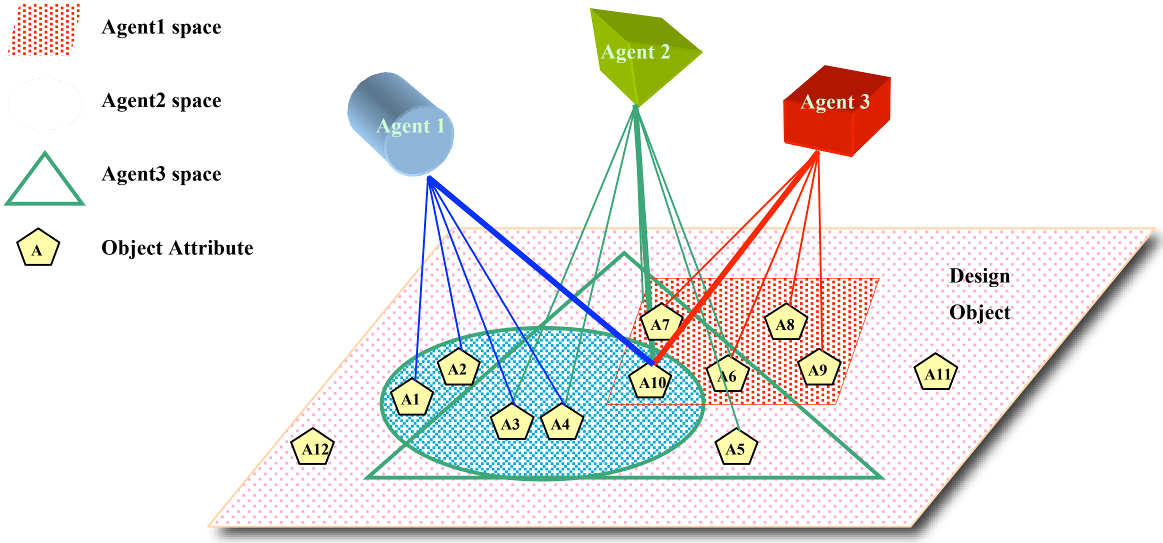


Figure 4.8 Shared object data and the links between the Object’s aspects and the Agent’s issues.

The facilitator will direct the negotiations process according to the conflict resolution model. It will be represented in the form of a protocol, which I call SWAY. The protocol provides a model and hierarchy for a structured process of conflict resolution, using the steps of *avoidance, reconciliation*, *mediation* and *arbitration* that were described earlier in the Human Model of conflict management. By determining when a deadlock condition exists, the *Facilitator* will know when to resort to another level in the conflict resolution strategy.

Coordinator

Here I am developing two simple Coordination relationships:

1.The explicit, quantitative representation of task interrelationships.

When relationships in the design problem environment extent between tasks being worked on by separate design participants, I call them *coordination relationship*. Coordination relationship is crucial to the design and analysis of coordination mechanisms. I defined several coordination relationships as hard and soft relationships. An example of a hard relationship is *enabler*. If some task A enables another task B, then A must be completed before B can begin. An example of a soft relationship is *facilitator*. If some task A facilitates a task B, then completing A before beginning work on B might cause be to take less time, or cause B to produce a higher –quality result, or both if A is not completed before work on B is started, then B can still be completed, but might take longer or produce lower quality answer than in the previous case. In other words, completing task A is not necessary for completing task B, but is helpful.

2. Postponing the resolution of a conflict:

Forcing a resolution of a conflict at this stage of the design (while other design activities come to halt until the conflict is resolved), or delaying the resolution to later stages in the design process.

4.4.3 Representing the object of discussion - Object Data (OD)

In order for the agents to judge a proposal, and for the facilitator to be able to analyze solutions and propose alternatives, the object of the negotiations needs to be represented. This shared object representation will include information about the object such as object's name, its components and their attribute values (which I call 'aspects').

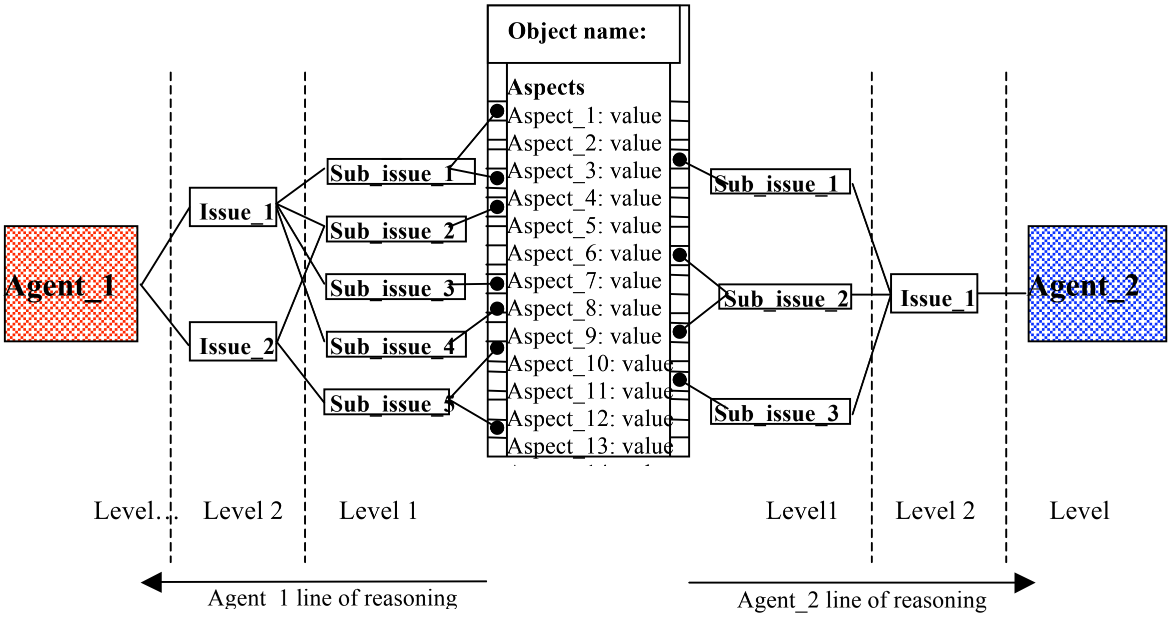


Figure 4.9 Object Data

The facilitator will maintain a list of each agent's issues and the aspects of the design solution to which they are linked. This will provide a way of relating (grouping) aspects that are common to several agents, and can be used to affect the outcome of the negotiation by causing each agent to focus on a shared issue during its proposal cycle. It can also be used to develop general explanations to all agents. Figure 4.9 depicts the shared object data and the links between it and the agents' issues

4.4.4 Conflict management protocols SWAY

SWAY is the conflict management module. It contains all the protocols for conflict resolution and methods of how to apply them. This module is discussed in details in chapter five.

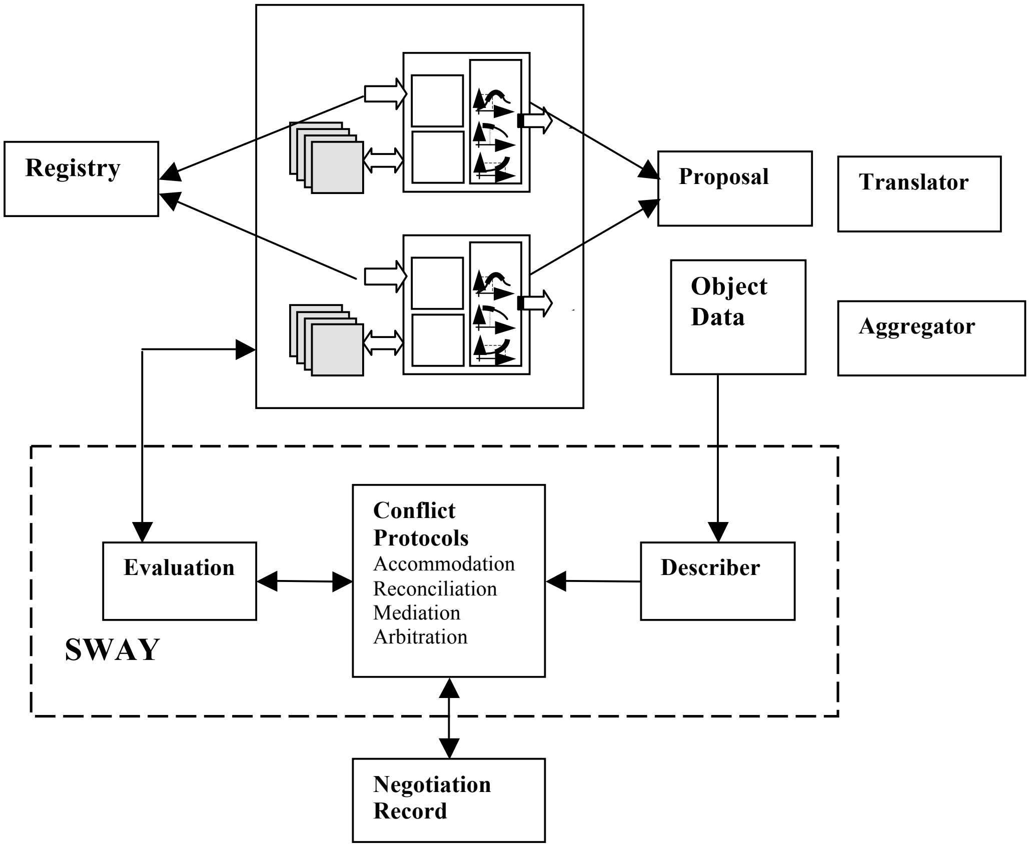


Figure 4.10 An overview of the system components

4.5 Aggregation operators

As discussed earlier in this chapter, participants present their design criteria using satisfaction curves. They negotiate their degree of satisfaction for every criterion with each other to reach a common solution. Aggregation operators are means for reasoning among participants allowing them to choose a solution from a set of objects in association with a degree of satisfaction. In this section I define a set of aggregation operators that are suitable and commonly used in design domain activities. The participants, and 'SWAY' the conflict management module will apply these aggregation operators to different criterion's satisfaction curve.

4.5.1 Definition

In a rather informal way, the aggregation problem consists in aggregating *n*-tuples of objects all belonging to a given set, into a single object of the same set. In the case of mathematical aggregation operator this set is all real numbers. In this setting, an aggregation operator is simply a function, which assigns a real number *y* to any *n*-tuple

$(x_1, x_2, x_3, \ldots\ldots, x_n)$ of real numbers:

$$S = aggreg(x_1, x_2, x_3, \ldots\ldots, x_n)$$

4.5.1.1 Function set

Since my presentation use the degree of satisfaction as a measurement, I add to the tuple the associated degree of satisfaction *y*. Then every criterion is represented as a set of n-tuples,

$$((x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots\ldots, (x_n, y_n))$$

where *x* represents the criterion value and *y* represents the correspondent degree of satisfaction.

$$S = aggreg((x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots\ldots, (x_n, y_n))$$

4.5.2 Properties

There are certain properties that every function representation should have in order to the aggregators to be able to operate properly. These properties are:

4.5.2.1 Identity

Aggregation result of a function of one member should be the same function member.

aggreg $(x) = x$

4.5.2.2 Idempotence

Also known as unanimity or agreement: If we aggregate *n* times the same value, we expect to find the initial value.

aggreg $(x_1, x_2, x_3, ..., x_n) = x$

4.5.2.3 Continuity

The function is continuous with respect to each of its variables. This property is a guaranty for certain robustness, for a certain consistency and for a non-chaotic behavior.

4.5.2.4 Monotonicity - non decreasing

The aggregators deal more precisely with a non-decreasingness with respect to each variable. I expect that if an argument increases then the final aggregation increases (or at least not decreases, remains equal).

if $(x_1, x_2, x_3, ..., x_n)$ £ $(y_1, y_2, y_3, ..., y_n)$

Aggreg $(x_1, x_2, x_3, ..., x_n)$ £ *Aggreg* $(y_1, y_2, y_3, ..., y_n)$

4.5.2.5 Boundary Conditions

Here I turn the attention to the behavior of the aggregator in the best and in the worst cases. I expect that an aggregation operator for boundary range from 0 to 100 satisfy:

aggreg (0,…,0) = 0, and

aggreg (100,…,100) = 100

These conditions define the normalization boundaries. It means that if we observe only true or completely satisfactory criteria then the total aggregation has to be also completely true or satisfactory.

4.5.2.6 Invariance

When aggregating numbers ($x_1, x_2, \ldots, x_n$) represent measurement of certain criteria, we should specify a scale in which these measurements were performed. Moreover, we may want the aggregation function *Aggreg* to respect a meaningful relation with respect to the given scale. The notion of meaningfulness is formalized as the invariance property. These conditions seem to be recurrent in all proposed definitions of an aggregation operator. All other properties may come in addition to this fundamental group. Next I present an overview of the properties we may expect from an aggregation operator.

4.5.3 Translation (*trans*)

In order for SWAY to be able to reason between two different criteria over an object we need to translate the meaning of the criteria into an object presentation. The translation operator translates the current criterion function set to the correspondent object function set. A criterion function set

$$f((x_1, y_1),(x_2, y_2),(x_3, y_3),......,(x_n, y_n))$$

matches and replaces the criterion values $(x_1, x_2, x_3, ..., x_n)$,

with corresponding object values $(o_1, o_2, o_3, ..., o_n)$ so considering

$$A = f((x_1, y_1),(x_2, y_2),(x_3, y_3),......,(x_n, y_n)) \text{ then}$$

$$trans\ A = A'$$

$$A' = f\ ((o_1, y_1),(o_2, y_2),(o_3, y_3),......,(o_n, y_n))$$

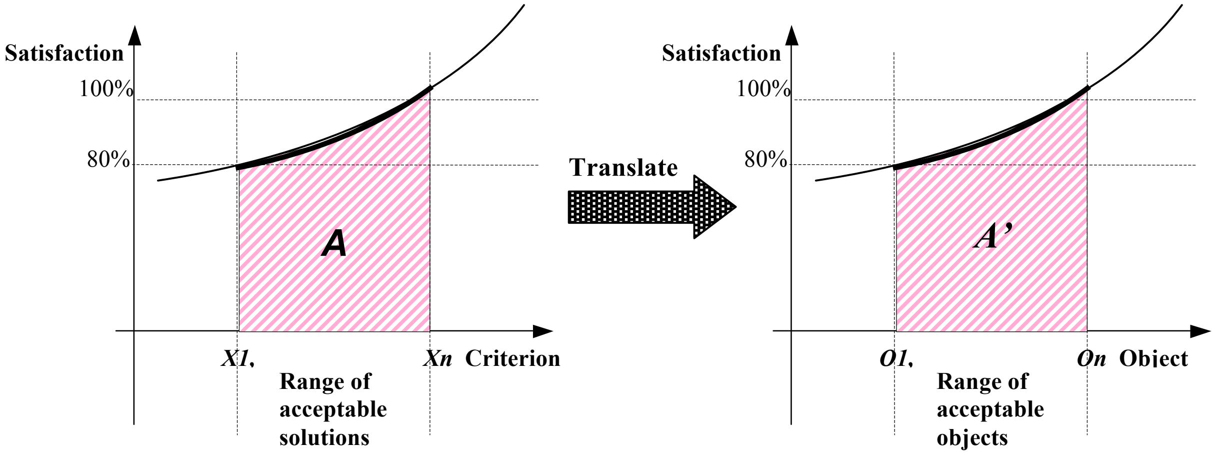


Figure 4.11 Translate criterion function set to the correspondent object function set

4.5.4 Basic aggregation operators

I present an overview of some aggregators appropriate to activities in design domains. I explain their main properties and particularities. Also I present some notable particular cases. Naturally, we should impose certain conditions on *Aggreg* to justify the name of an "aggregation operator".

The aggregators developed here are the most often used; I call them the basic ones. In this group we find the prototype of an aggregation operator, the average, the median, the minimum and the maximum, as well as some classical generalizations like the k-order. After the precedent, I formulate a new form of the classical aggregator the t-norms and the t-conorms. This new form is formulated based on a two dimensional function representing the criterion and the degree of satisfaction dimensions used in my approach. These operators do not look for a middle value, but instead they compute the intersection and union of sets. They are often used, since they can also be seen as a generalization of the logical aggregation operators: AND (t-norms) and OR (t-conorms). I present an overview of the domain, by presenting the characteristics, the advantages and disadvantages of each operator.

4.5.4.1 The arithmetic mean (aveg)

The simplest and most common way to aggregate is to use a simple arithmetic mean, also know as the average.

$$aveg(x_1, x_2, x_3, \ldots\ldots, x_n) = \frac{1}{n}\sum_{i=1}^{n} x_1$$

$$= \sum_{i=1}^{n} \frac{1}{n}.x_1$$

4.5.4.2 The median (med)

Another operator that follows the idea obtaining a middle value is the median. It consists in ordering the arguments from the smallest one to the biggest one. Then it takes the element in the middle. If the cardinality of the set of arguments is not odd then there is not a middle argument but a pair. It takes then the mean of the middle pair. This aggregation operator satisfies the boundary and the monotonicity conditions.
There exists a generalization of this operator: *the k-order statistic*, with which we can choose the element on the kth position on the ordered list, from the smallest to the biggest element.

4.5.4.3 The minimum and the maximum (min, max)

Two remarkable particular cases of the k-order statistic are the minimum and the maximum. The minimum gives the smallest value of a set, while the maximum gives the greatest one. They are aggregation operators since they satisfy the axioms of the definition.

$$\min f(x_1, x_2, x_3, \ldots\ldots, x_n) = x_1$$

$$\min_y f((x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots\ldots, (x_n, y_n)) = y_{\min}$$

$$\max f(x_1, x_2, x_3, \ldots\ldots, x_n) = x_n$$

$$\max_y f((x_1, y_1), (x_2, y_2), (x_3, y_3), \ldots\ldots, (x_n, y_n)) = y_{\max}$$

If we work in a restricted interval [*a,b*] the minimum has for absorbent element *a* and for neutral element *b*, while for the maximum it will be the opposite: *a* will be the neutral element and *b* the absorbent one.

4.5.4.4 Union of two functions (t-norm-f)

t-norm operator resemble the union (AND) operator of two sets of numbers. I redefined it to operate on two function as the criterion's functions used in this dissertation. Considering the functions of two criteria A and B, first we translate to Object function using the *trans* operator.

Trans A=A'

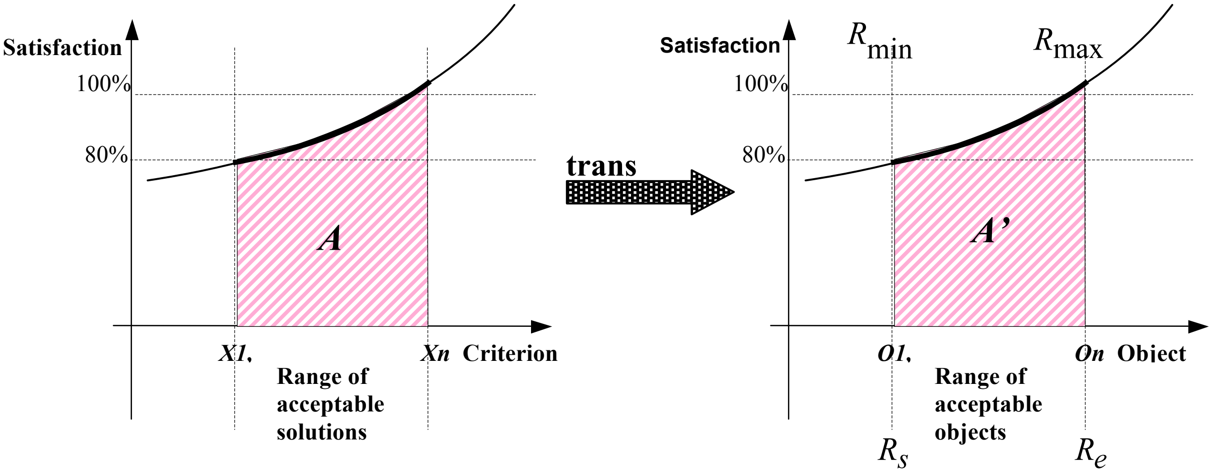


Figure 4.12 Maximum and minimum of function A

Maximum and minimum of function A

$$\max f\text{A}= R_{\max_A}$$

$$\min f\text{A}= R_{\min_A}$$

Translate the function criterion values to correspondent object value.

trans B=B'

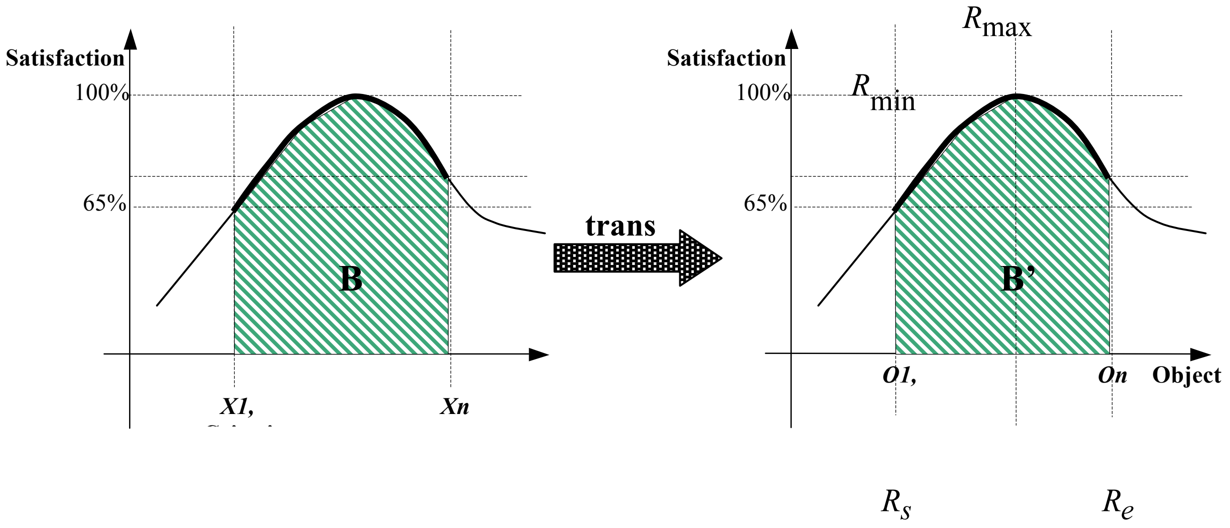


Figure 4.13 Maximum and minimum of function B

Maximum and minimum of function B

$$\max f\text{B}= R_{\max_B}$$

$$\min f\text{B}= R_{\min_B}$$

Defining the limits of range of solution for the union of function A and B

$$A \bigcup B = C$$

For fC

The lower boundary of x

$$R_{s_C} = \text{If } R_{s_A} > R_{s_B} \Rightarrow R_{s_A}$$

$$\text{Else } R_{s_B}$$

The upper boundary of x

$$R_{e_C} = \text{If } R_{e_A} > R_{e_B} \Rightarrow R_{e_A}$$

$$\text{Else } R_{e_B}$$

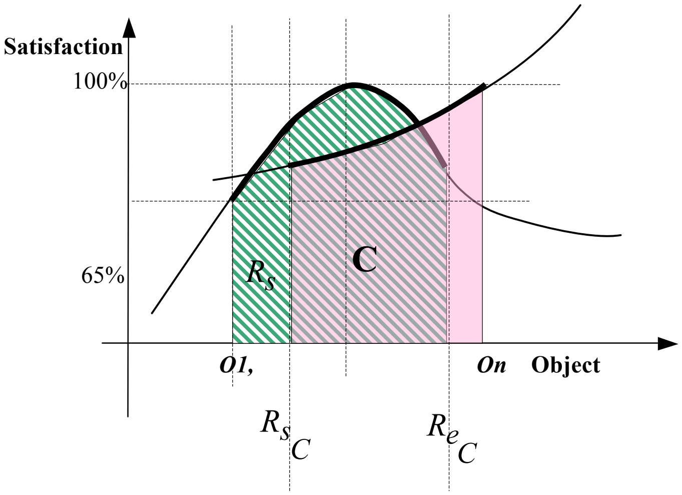


Figure 4.14 Acceptable range of solution C

The maximum and minimum of function A within the acceptable range of solution C

$$\max f\mathrm{A} = \sum_{R_{e_C}}^{R_{s_C}} R_{\max_A}$$

$$\min f\mathrm{A} = \sum_{R_{e_C}}^{R_{s_C}} R_{\min_A}$$

The maximum and minimum of function B within the acceptable range of solution C

$$\max f\mathrm{B} = \sum_{R_{e_C}}^{R_{s_C}} R_{\max B}$$

$$\min f\mathrm{B} = \sum_{R_{e_C}}^{R_{s_C}} R_{\min B}$$

The relational maximum of functions A and B within the acceptable range of solution C

$$\text{if } \sum_{R_{e_C}}^{R_{s_C}} R_{\max_A} > \sum_{R_{e_C}}^{R_{s_C}} R_{\max_B}$$

$$\max f\mathrm{A} \wedge f\mathrm{B} = \sum_{R_{e_C}}^{R_{s_C}} R_{\max_A} \wedge \text{correspond} \sum_{R_{e_C}}^{R_{s_C}} R_B$$

$$\text{else } \sum_{R_{e_C}}^{R_{s_C}} R_{\max_B} \wedge \text{correspond} \sum_{R_{e_C}}^{R_{s_C}} R_A$$

The relational minimum of functions A and B within the acceptable range of solution C

$$\text{if } \sum_{R_{e_C}}^{R_{s_C}} R_{\min_A} > \sum_{R_{e_C}}^{R_{s_C}} R_{\min_B}$$

$$\min f\mathrm{A} \wedge f\mathrm{B} = \sum_{R_{e_C}}^{R_{s_C}} R_{\min_A} \wedge \text{correspond} \sum_{R_{e_C}}^{R_{s_C}} R_B$$

$$\text{else} \sum_{R_{e_C}}^{R_{s_C}} R_{\min_B} \wedge \text{correspond} \sum_{R_{e_C}}^{R_{s_C}} R_A$$

4.6 Summary

This chapter has described a model of conflict resolution, which can be used to integrate conflicting perspectives from multiple design domains. The model was designed to provide a general framework for conflict resolution.

The model combines two methods of conflict resolution: learning and negotiation. The entire process is highly interactive, and acts to structure the elicitation of additional information concerning the conflict.

Participants present their design criteria using satisfaction curves. In this chapter I define a detailed set of aggregation operators - math of satisfaction curves - that are suitable and commonly used in design domain activities. The participants, and 'SWAY' the conflict management module will apply these aggregation operators to different criterion's satisfaction curve.

Chapter Five

5 SWAY

In this chapter I discuss SWAY the conflict management module. Sway's life cycle addresses steps that cover all the activities involved from analyzing conflict, initiating negotiation, following the actual negotiation processes leading to success or failure of reaching an agreement. I categorize these activities into three phases: the Description phase (Describer), the Negotiation phase (Negotiator) and the Evaluation phase (Evaluator), figure 5.1.

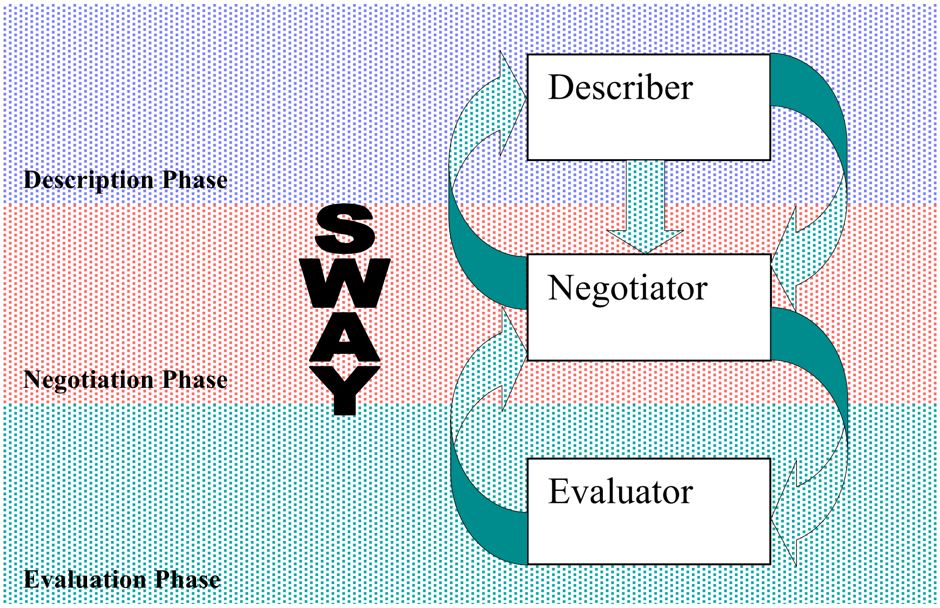


Figure 5.1 SWAY a conflict management module

5.1 Describer

The first phase of SWAY is the Description phase. The aim of this phase is to arrive at a better understanding of the conflict. This process involves obtaining knowledge needed to identify why the conflict occurred, and therefore defining the conflict type, extent and related issues. The rationale for this approach is simple: it is impossible without conflict description to apply different resolution protocols and to tell whether a conflict is real.

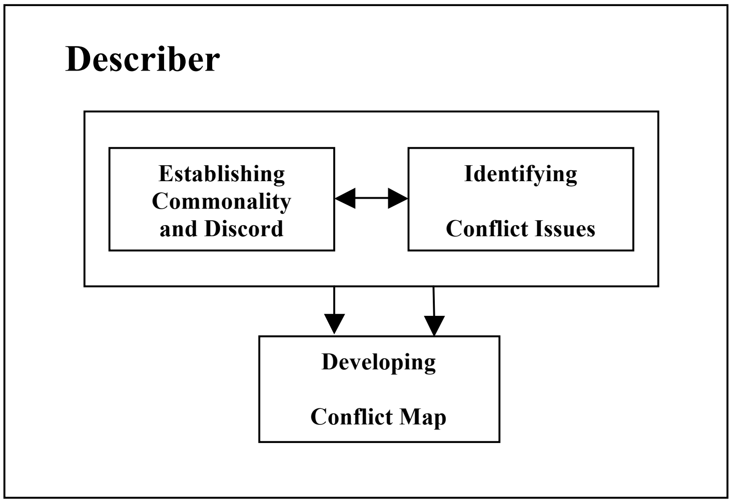

Describer
Establishing Commonality and Discord
Identifying Conflict Issues
Developing Conflict Map

Figure 5.2: Description Phase

Conflict understanding

Conflict understanding can have a significant influence on the resolution-generation approach. If only syntactic differences can be understood, then resolution generation is limited to choice among given alternatives. However, if conflict semantics are understood, then the alternatives can be decomposed and resolutions can be generated based on their restructuring. For example, price compromises for a window are possible during negotiation because agents understand the semantics of money. If the agents have a deeper understanding of window's domain, alternatives based on configurations of the window such as 'double glazing', and 'material' features can be generated.

As depicted in figure 5.2 I am defining three different components of the description phase.

5.1.1 Establishing commonality and discord

The first problem is to establish a common ground between the design proposals. This is important to set the limits of the extent of the conflict, and to provide the participants with basis for communication. The process starts with two design proposals, within which a particular part is known to conflict.

5.1.1.1 Conflict extent

To determine the extent of the conflict, the *Aspects* of the *Object Data* including the conflicting aspects of the design proposal need to be compared, as these provide a context for the conflicting aspects. Initially, this context consists of those issues in the design proposed by the participants, which are directly connected to the aspects in question. In a graphical notation, as in figure 5.3, these are the nodes connected to the aspects in question, and for a chain of inference, all the immediate antecedents and consequences are used.

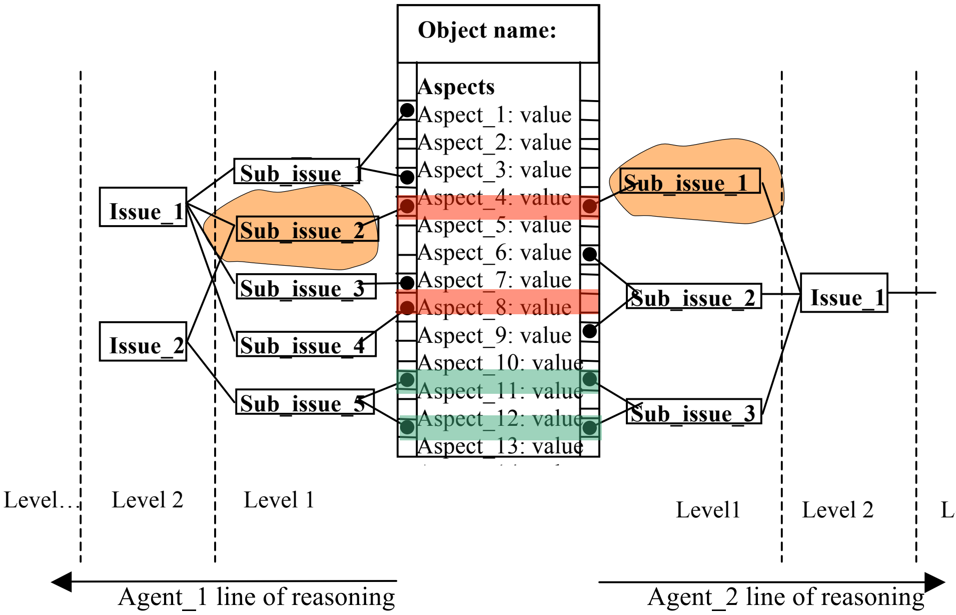


Figure 5.3 Conflicting and agreeing issues

The participants begin by identifying commonality between the *aspects* in the design proposal. Such commonality may be exact or approximate. There is an exact commonality if the aspects are agreed as sharing the same functionality; the correspondence is only approximate if the functions are similar, but differ in certain details. Other correspondences can similarly be found, and *aspect* may be involved in more than one correspondence.

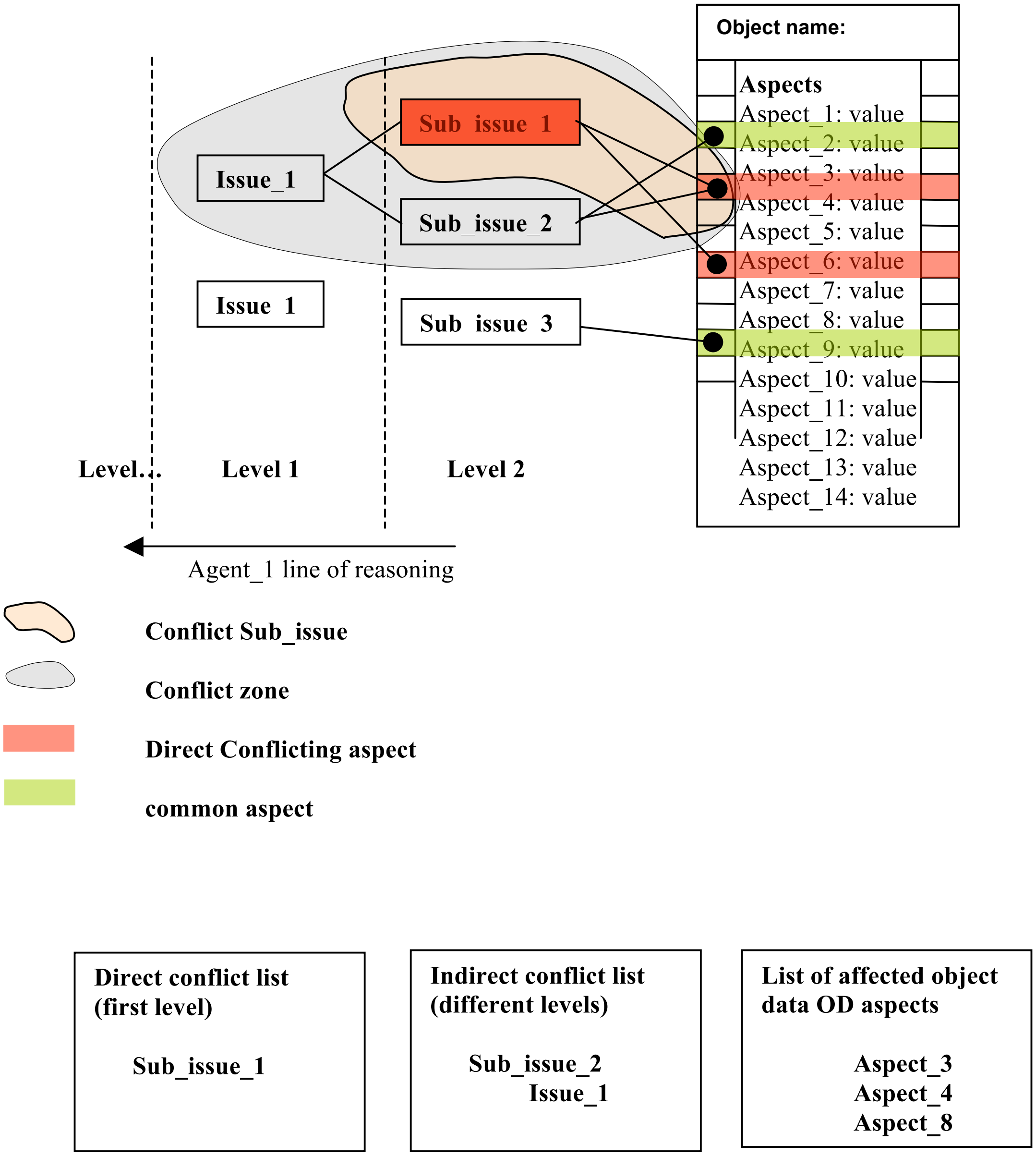


Figure 5.4 Identifying conflict and creating conflict list

As well as correspondences between single items, frequently groups of items will be linked. Where a single aspect in one proposal corresponds to a group of issues, the representations are at different levels of decomposition. This is a common problem in architecture design, as there is no standard way of deciding whether different parts of a design proposal are at the same level of abstraction. The measure of level of abstraction is a subjective one, and different designers will decompose the parts of a proposal in different orders. Such comparisons yield issues that one proposal may not have addressed, which could be usefully discussed.

Correspondences between a group of items in one description and a different group of items in another description reveal where different types of decomposition have taken place.

Finally there is the case where an item or group of items in one description has no correspondence in the other. This may be because it has been omitted, or because the role played by such an item has been filled in other ways.

The result of this stage is a list of correspondences between items in the proposals. Each correspondence may be recorded as exact or partial; but note that exact correspondences does not imply identical structure. The former indicate where there is agreement, and so restrict the area of conflict. However, where the correspondence is partial, there is still conflict to be resolved. In effect, the conflict has been broken down into its components; the initial rough description is replaced with a list of specific disparities between aspects and issues in the proposals.

5.1.2 Identifying conflict issues

For a conflict to be resolved constructively, the reasons the participants are in conflict must be ascertained. As limited for this study the reasons may vary from differences in priorities to differences in areas of concern.

Often the actual conflict is unrepresentative of the direct issues, which led to the conflict, Deutsch [1973] calls these *displaced conflicts*.

There are reasons why conflicts may appear displaced. For example, the proposals being compared might be the result of long chains of development, which are not necessarily based on the same initial assumptions and motivations.

SWAY makes use of the notion of *issues*, which are simply points that the design needs to address. They may take the form of suggested requirements, or questions that need to be resolved.

However, my approach is to elicit issues only as a response to specific conflicts. Issues are elicited as a prelude to identifying positions and as supportive arguments for proposals.

Participants raise any issues they feel other party’s proposal neglect. This to avoid having to ask participants simply to list any assumptions they made. It also avoids effort wasted discussing issues on which there is already agreement, or which are irrelevant to the current context.

5.1.3 Conflict map

The result of the description phase is a map of the conflict. It includes a list of correspondences and differences between the proposals. In other words, the original disparity between participants' proposals has been broken down into specific lists of items, which correspond, and items, which do not. Together, these comprise the *components* of the conflict.

The description phase also elicits any issues underlying the correspondences and differences, and their criteria of satisfaction.

5.1.4 Prepare for resolution

The final part of the exploration phase is the establishment of criteria by which to start possible resolutions. Objective criteria should be agreed before any resolutions are generated, to ensure that an agreement can be reached. My model treats the establishment of criteria as part of the description phase, as it involves elicitation of further information from the participants. As the measures by which participants evaluate their satisfaction, they represent the participants' goals for the resolution process. As such, these are the final part of the picture of the conflict built up by the exploration process. Issues represent the key points in the conflict; criteria show how the participants feel about these key points.

Effectively I treat issues as points that the original viewpoints left unclear, and the criteria as the clarification of these points. In most cases, the participants will agree on the criteria for an issue with little difficulty, reserving disagreements for the order of priority among criteria. However, there are issues on which participants will define opposing criteria, and in this case, both are recorded, and the dispute added to the list of items in conflict.

5.1.5 Negotiator

The result of the description phase is a map of the conflict, which can be used to guide the search for possible resolutions. The second phase is concerned with generating these resolutions. The aim is to find and propose solutions, which overcome the limitations of the original design proposal, and respond to the issues identified in the description phase. The options might be generated in a variety of ways, from directly combining elements of existing viewpoints to techniques such as mediation and arbitration. The result of the negotiation phase is a list of solutions.

5.1.5.1 Generating Resolution

The model does prescribe a particular structured method of generating resolutions. A range such methods might be usefully employed for generating solutions, depending on the components of the conflict, and the form of resolution required. Consideration of the category of the conflict components, as described in the previous section, may immediately provide one or more resolution options.

The categorization of conflicts helps to determine what form a resolution should take. For example, conflicts in terminology, once detected, can be resolved fairly simply.

Conflicting designs involve a higher level of uncertainty. Often the conflict will be the result of conflicts not tackled at earlier stages, and the issues arising out of conflicting designs will indicate the concerns that lead to them. As the description phase has broken down the original conflict into its specific components, the designs can be examined more closely.

Possible resolutions include combining the requirements underlying the designs, adapting one design to incorporate issues raised by another, or creating a totally new design which addresses the issues in new ways.

The result of this phase is a set of solutions for resolution. These will vary from the very specific (such as a particular change to a description), to entire viewpoints. Where an option is only applicable under certain conditions, these are also described as part of the option. Note that the original viewpoints could be considered as possible resolutions: one or other could be accepted unaltered, if it turns out to be a satisfactory resolution. In addition, some proposals will be candidates for combination to produce a more complete resolution, while others will be combinations, which might need to be dismantled, if only a part is needed. At this stage, the proposals have not been evaluated or compared in any way.

The protocol provides a model and hierarchy for a structured process of conflict resolution, using the steps of *avoidance, reconciliation*, *mediation* and *arbitration* that were described earlier in the Human Model of conflict management. By determining when a deadlock condition exists, the *Facilitator* will know when to resort to another level in the conflict resolution strategy. My model will not deal with *avoidance,* which will cause termination of the collaboration due to the break up of the design team.

5.1.5.1.1 Accommodative

Accommodative, a party becomes self-sacrificing to appease another, and places the other's interests above their own. It is useful when issues are more important to others than to you, where one party is losing and needs to minimize loss, or simply to build harmony.

5.1.5.1.2 Reconciliation

Reconciliation strategies: At some point during the negotiation process a proposed solution might exceed the acceptable limits of the issues of an agent. One agent has to concede or relax an issue for the negotiation to proceed. At this level the facilitator will ask an agent to apply its local negotiation strategy in order to relax constraints, or propose an alternative solution.

Mediation strategies: If the reconciliation strategy fails to resolve the conflict, the *facilitator* will resort to a mediation mode, which utilizes two mediation techniques:

1. *Issue relaxation:* Used mainly for relaxation of a key issue. The facilitator will command an agent to relax a particular issue. The goal is to force an agent to relax its key issue so that the design proposal can be approved by all the agents.
2. *Proposing alternative solution:* The facilitator suggests an alternative, previously proposed solution that was somewhat acceptable to both conflicting agents. The facilitator accomplishes this by maintaining a list of previously proposed alternatives with their stated levels of acceptability by each agent.

5.1.5.1.3 Compromise

In compromise each party is willing to settle for something less than its ideal position rather than continue the conflict. Each party makes some concessions in order to reach a compromise, as depicted in figure 5.5. This is most appropriate where temporary settlement or expedient solutions are needed, especially under time pressure, or where goals are directly opposed. In compromise, a mutual settlement is reached by bargaining between the parties themselves. This form of conflict resolution is different from *reconciliation*, in that the parties reduce their original expectations rather than adopt new ones.

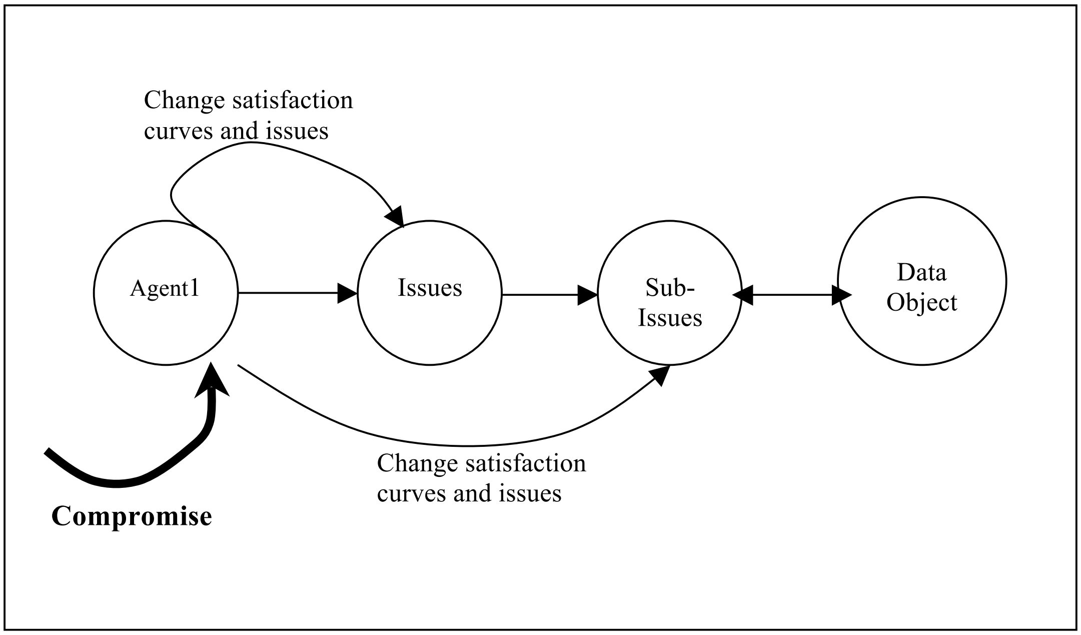

Change satisfaction curves and issues
Agent1
Issues
Sub-Issues
Data Object
Change satisfaction curves and issues
Compromise

Figure 5.5 Compromise

5.1.5.1.4 Award

Arbitration strategies: When both mediation routines fail, the *facilitator* enters into arbitration mode, which utilize two arbitration techniques:

Time limit: Setting a time limit to reach an agreement. This can be done by limiting the time for arriving at a solution after certain number of iterations. The arbitrator maintains a count of the maximum number of counterproposals. If the agent's proposals do not converge after certain number of iterations, the arbitrator may force a solution.

Force a solution: The facilitator attempts to provide a solution to the proposing and reviewing agents by analyzing each agent's proposal preference list of solution throughout past negotiation cycles from the negotiation records. Using a Trial and Error approach, the arbitrator will select a solution that it think satisfies best both agents as a last resort attempt.

5.2 Evaluator

The evaluation phase, consists of taking the design proposals for resolutions and relating them both to the map of the conflict generated in the description phase, and to each other. The aim is to evaluate the proposed solutions that best resolve the issues involved in the conflict.

The evaluation phase begins once a resolution has been generated. When participants feel that a good proposal has been generated, the evaluation phase can be initiated. The negotiation phase and the evaluative phase are kept deliberately separate, to prevent premature evaluation of the proposed solution from.

5.2.1 Relating resolutions to issues

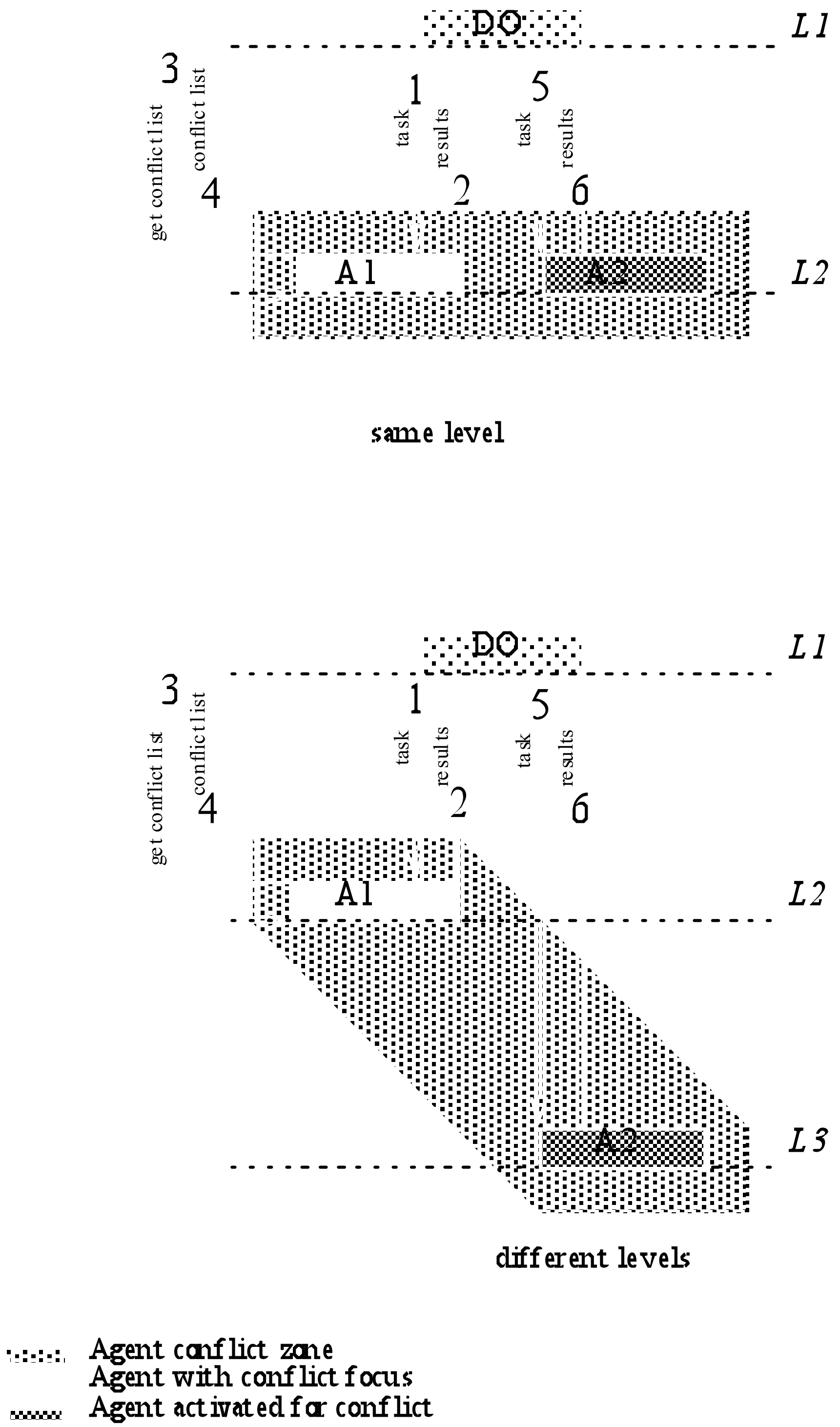
The first task is to relate the suggested resolutions to the issues underlying the conflict. This may be done by taking each proposed solution in turn and selecting the issues that it satisfies. Or by taking each issue in turn, and deciding which solution would satisfy it. Both approaches have merit, in that either may reveal additional links missed in the other. Also, the relationship may be either positive or negative, where the former indicates the suggested solution 'data object' contributes to the satisfaction of the issue, and the latter indicates it dissatisfies the issue.

5.2.2 Relating resolutions to one another

The individual resolution in a data object may interact in interesting ways. Some might usefully be combined to produce a resolution, which satisfies more issues than either individually. For other options, combination will negate some of the benefits: for example the suggestion of adding a reserve collection to the first viewpoint is not compatible with he suggestion of maintaining two types of state information, whereabouts and loan status.

5.3 Patterns of interaction

A task dependent hierarchy consists of multiple levels of agent's issues from the agent down to the leaf DO. A conflict handling session may involve ODs in the same level or in different levels. The two agents involved in the conflict constitute the conflict zone. A direct conflict handling session involves two agents one of which is the conflict focus. An indirect conflict handling session involves two agents one of which is the conflict focus. In other words, two agents may have a conflict over an attribute value of a third agent. In such a case the two agents who constitute the conflict zone are involved in an indirect conflict about a third agent attribute that is the conflict focus. Figure 5.6 shows various cases of direct and indirect conflict handling among agent's issues in the same or in different levels of a hierarchy. The various conflict cases in the figure illustrate that conflict types may require different patterns of interaction between the DO and the agents involved.



same level

different levels

Figure 5.6 Direct conflict handling for Agent issues in the same and different lev

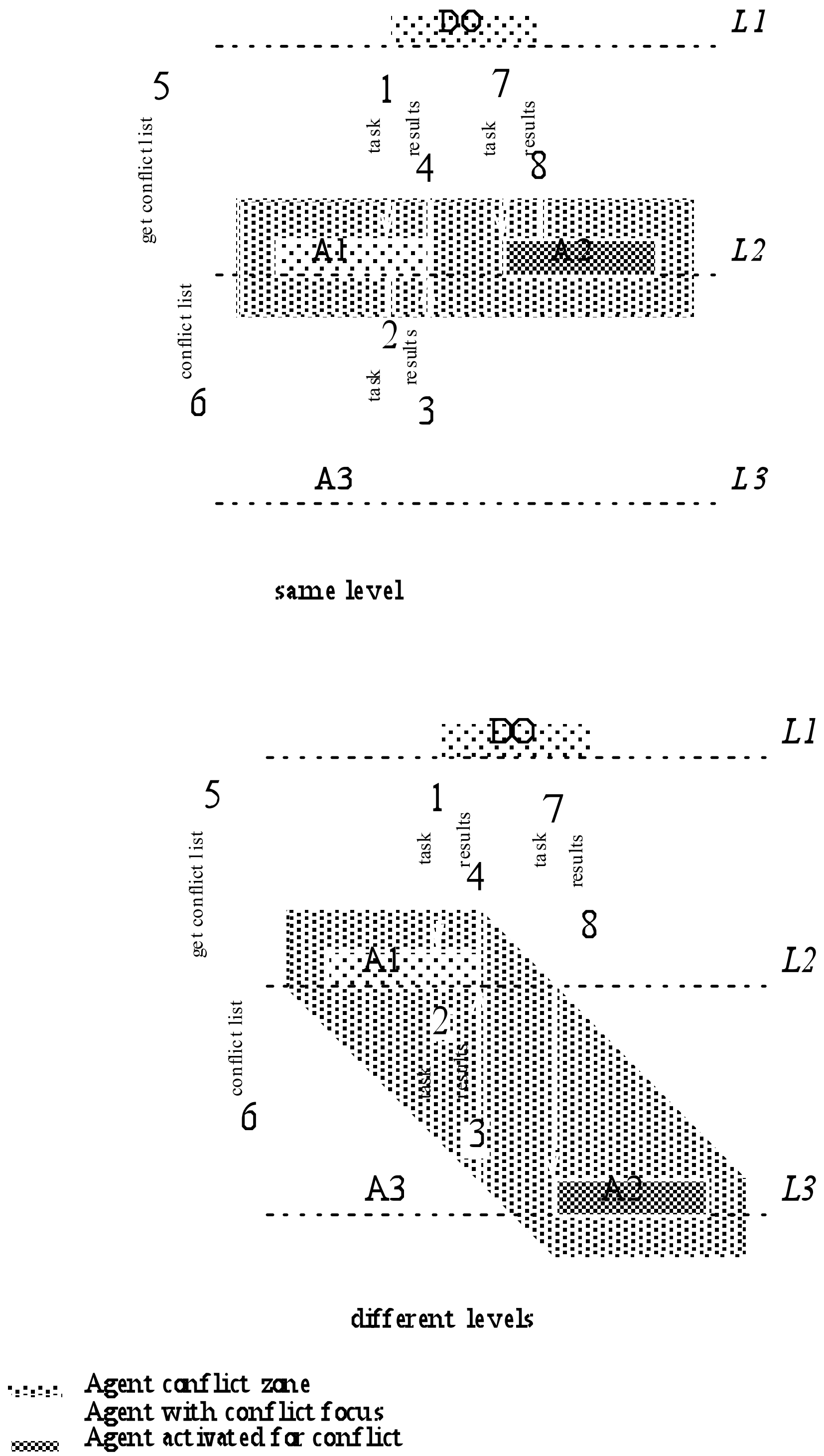


Figure 5.7 Indirect conflict handling for Agent issues in the same and different lev

5.4 Summary

This chapter has described SWAY a model of conflict resolution, which can be used to integrate conflicting perspectives from multiple design domains. In recognition of the fact that carefully managed conflict can help eliminate inaccuracy and improve the quality of the requirements specification, SWAY the multiple perspectives conflict management model encourages the expression of conflict by allowing participants to articulate their viewpoints. Expression of conflict needs to be balanced with productive resolution methods, to encourage collaboration in design and to ensure that conflicts do not become disparaging. The model described in this chapter was designed with this aim in mind.

The model consists of three phases: description of the conflict and the participants' perspectives; the negotiation phase with protocols for resolving the conflict, and the evaluation of these protocols output. During the description phase, the initial conflict is broken down into its components, represented as specific commonalities and discords between attributes in the data object. These links act as a map of the conflict to guide the later stages. In the negotiation phase, resolution takes the form of designing ways of satisfying the issues. SWAY provides protocol and hierarchy for a structured process of conflict resolution, using the steps of *avoidance, reconciliation*, *mediation* and *arbitration*. In the final phase, the resolutions generated are then compared and measured against the issues to determine the level of satisfaction. The resolution, which best satisfies the issues is chosen.

The model combines two methods of conflict resolution: learning and negotiation. Emphasis is placed on the description phase in which participants learn about other proposals by comparing them to their own, this comparison facilitates the elicitation of additional information. In fact, the final resolution is not necessarily the most important product of the negotiation process, the extra information elicited during the process, and the participant's new understanding of one another's viewpoints may be far more valuable.

Chapter Six

6 Conclusions

In this dissertation, I take an encompassing view of conflict management in multi-agent problem solving that span many different issues. In the last two decades several computational design models have been developed. In the eighties the focus was on building centralized stand-alone tools as expert systems models. Later in the nineties the focus was on building a collaborative multi-agent design environment. Such models encompass a wide range of design activities from production, generation, simulation and evaluation to generation and recommendation to production and documentation. Some models have adopted a conflict management module. Nevertheless, none of the models employ a comprehensive structured conflict management representation. This dissertation, thoroughly investigates the notion of managing conflicts in building design. Its main contribution is the development of SWAY a comprehensive structured Conflict management model that includes both conflict avoidance and conflict resolution by manipulating solution requirements for both agents in conflict until the solution is acceptable or not considered conflict.

This chapter presents conclusions from the dissertation and presents an overview of the main themes. Section 6.1 reviews the problem of conflict management that motivated the dissertation, restates the objectives, and summarizes the model, showing how it meets the objectives. Section 6.2 is a critical review of the model, while section 6.3 describes areas of further research.

6.1 Review

This section summarizes the central argument of the dissertation. I identified a number of difficulties in multi-agent systems. In addressing these difficulties, I argued that a model of conflict management is needed and set out a number of objectives for such a model. Finally, I proceeded to develop a model, which meets these objectives, based on the notion of capturing and representing multiple perspectives.

6.1.1 Objectives

This model must facilitate and encourage the collaborative aspect of conflict management. Chapter 2 set out a number of objectives for a model: the model should encourage the participation of the people whose requirements are being described; it should facilitate an exploratory approach; and it should support negotiation and conflict resolution. These objectives help ensure that the specification is representative and accessible, reflecting its role as a communication channel between participants. Additionally, tool support for the model should enable handling inconsistent and incomplete information.

6.1.2 Solution

The model presented in this dissertation meets these objectives. It is based on the capture of *perspectives* of participants. Perspectives do not necessarily correspond to participant, as one participant may use several perspectives, and a perspective might be shared by several participants.

The model concentrates on two key areas of participant's perspective elicitation of and integration of possibly conflicting perspectives. Elicitation is based on the capture of perspectives, and involves two main areas of difficulty: identifying perspectives and building the viewpoint descriptions. Integration is based on a model of conflict management, and again introduces two key problems: comparing viewpoints and resolving differences.

The problem of identifying perspectives is tackled when distinctions between perspectives are discovered. This will form an inheritance hierarchy, so that shared knowledge is inherited from a common ancestor. Descendant viewpoints represent specific areas over which perspectives disagree. The viewpoints themselves are restricted to represent only that which their participants have explicitly stated. This ensures that they remain accurate models of elicited knowledge.

The resolution process itself involves three phases, of which the initial, description phase is the most important. In this phase, participants compare the conflicting viewpoints, and identify points of correspondence and disparity between them. Issues underlying these correspondences and conflicts are elicited, in order to come to a better understanding of the conflict. During this process, some of the conflicts may disappear. In the second phase, a number of resolution options are generated, according to the types of conflict involved. The final phase involves comparing these options to one another and to the underlying issues, in order to choose the combination which best satisfies the participants.

6.2 Review

The previous section summarized the objectives of the dissertation, and the model developed to meet those objectives. I now examine the strengths and weaknesses of the model.

The multiple perspectives model SWAY provides a framework for conflict management. This covers a broad range of activities from the initial elicitation and formulation of perspectives, through to the construction and validation of an acceptable solution. Some of the activities encompassed in this range are not explicitly addressed by the model; rather the model provides the general structure. On the other hand, the model makes particular activities explicit, such as the exploration of conflict. The application of models of group interaction, negotiation and decision making to the building design process is an important feature of this dissertation, and has not been attempted before.

The model meets this need by using the capture of participants' perspectives as a driving principle. This approach modularizes elicited knowledge into recognizable perspectives, each of which is associated with a participant. These perspectives provide context for each of the statements within them. Furthermore, the integration of perspectives is explicitly supported, so that the decisions involved can be recorded and validated.

6.3 Contributions summary

This dissertation is structured around the development of a framework for conflict management environment. It makes four major contributions:

- Development of a comprehensive human model
  I developed a general human model of conflict management and negotiation and discussed its appropriateness for being used in building design.
- Development of SWAY a computational framework for decision making for conflict handling. The premise of this research is that conflict resolution and negotiation is necessary in generative collaborative multi-agent design systems in order to improve their overall usability. A computational framework for task execution, decomposition, delegation, and management for global and local decision making nodes was developed.
- Formulation of a set of algorithms for conflict management
  A set of interaction algorithms mainly for conflict handling to be used by agents during the course of handling tasks was developed. With minimal modifications this set of algorithms can be adopted for non-design decision-making environments.
- A set of aggregation operators that is suitable and commonly used in design domain activities. As participants present their design criteria using satisfaction curves. They negotiate their degree of satisfaction for every criterion with each other to reach a common solution. Aggregation operators are means for reasoning among participants allowing them to choose a solution from a set of objects in association with a degree of satisfaction. The participants, and 'SWAY' the conflict management module will apply these aggregation operators to different criterion's satisfaction curve.
- Development of a set of general and domain specific reusable patterns of interaction between agents. The developed patterns focused on conflict handling.

6.4 Future work

A conflict management model for building design encompasses a wide set of activities. There remain a number of problems with particular aspects of the model, which this dissertation has not been able to tackle in depth.

The provision of guidance, which is tackled in a rather ad hoc basis in the existing tools. For example, establishing a weight mechanism to enable participants to sort any of their attribute interest lists in respect to the degree of relevance to the task in hand. Develop a mechanism to control the number of conflict handling sessions triggered among participants linked to an aspect interest list.

There is a problem in ensuring that all relevant viewpoints take part in the resolution process. At present *Synoptic* only supports the comparison of two viewpoints. This limitation could be removed fairly easily, but this would not solve the problem of recognizing which viewpoints should participate. When a conflict is detected between two or more viewpoints there may be additional viewpoints, which have useful information to add to the resolution process, and might even provide a ready-made resolution.

The role that conflict plays also needs to be examined: it is clear that conflicts can reveal important disagreements between participants, but it is not clear how to tell which conflicts are likely to be productive and which are counter-productive. It is not even clear how to measure the productiveness of a conflict.

Finally, this thesis has barely skimmed the surface of the relation of conflict to the level of communication between participants, the level of abstraction of descriptions, and the degree to which the task is focused all need to be studied and may yield important results for the handling of conflict.

References

Boulding A. Kenneth (1962). “Conflict and Defense.” Harper and Row, New York.

Boulding A. Kenneth. Conflict and Defense. Harper and Row, New York, 1962.

Coser L. The function of social conflict. Free Press 1956.

Cuff D. (1991). “Architecture: The Story of Practice.” MIT Press, Cambridge, MA.

Dong A., Agogino A. Text analysis for constructing design representations. AID 96 prize paper. Artificial intelligence in Design, Kluwer Academic Publisher, 1996.

Fenves S., Maher M.L. Hi-Rise, Carnegie-Mellon University,1986.

Fleming U. Coyne R. LOOS : a space layout, Carnegie-Mellon University, EDRC, 1990

Fleming U. and Chien S. (1995). “Schematic Layout in SEED Environment.” *Journal of Architectural Engineering*. Vol. 1, No.4, pp.162-169.

Fleming U., "More on the representation and the generation of loosely packed arrangements of rectangles". Planning. and Design, Vol. 16, 1989.

Fox M. Et al (1992). “Design Fusion: An Architecture for Concurrent Design. *Knowledge Aided Design*. Academic Press Ltd. 1992. pp: 157-159.

Genesereth M. Software Agents. Communication ACM, 37 7 1994.

Haround, D. et al (1995). “Management of Conflict for Preliminary Engineering Design Task.” *Artificial Intelligence for Engineering Design*, Analysis and Manufacturing.

Kalay Y. Performance Based Design , UC Berkeley, Dept. of Architecture1997

Khedro T., Schultz P. The Federation of Collaborative Design Agents. Stanford University, Tech. Report#112, CIFE, 1994.

Khedro T., Schultz P. (1994). “The Federation of Collaborative Design Agents.” Tech. Report #112, CIFE, Stanford University, Stanford, CA.

Khun T. (1962). “Structures of Scientific Revolutions, University of Chicago Press, Chicago.

Konstantinos Papamichael. Building Design Advisor (BDA) project. Lawrence Berkeley National Laboratory, Building Technologies Program, 1 Cyclotron Road, Mailstop: 90-3111 Berkeley, CA 94720

Kunz W., Rittle H. (1972). “Issues as Elements of Information Systems.” DMG 5th

Anniversary report: DMG Occasional Paper No. 1. The Design Method Group, Department of Architecture, University of California, Berkeley, CA, pp.13-15.

Lander S. E. (1994). “Distributed Search and Conflict Management Among Reusable Heterogeneous Agents. Ph.D. Thesis. Graduate School of the University of Massachusetts Amherst.

Mohsini R. In Design and Prediction, Kalay Y. Editor. 1992.

Mohsini R. (1992). “On Measuring Project Performance: Some Problems of aggregation.“ In Kalay Y. Editor, *Evaluating and Predicting Design Performance*. John Wiley and Sons, New York, NY.

Pohl Y. and Myers L. Intelligent Computer-Assisted Design System. Design and Construction Institute, Cal Poly, San Luis Obispo, California, 1994.

Pohl, J. and L. Myers (1994). “A Distributed Cooperative Model for Architectural Design.” *Knowledge-Based Computer-Aided Architectural Design* (G. Carrara & Y.E.

Kalay, eds.), pp: 205-242. Elsevier Science Publishers, Amsterdam, The Netherlands.

Protzen J.P., Dehlinger H. Debate and Argumentation in planning: An Inquiry Into Appropriate Rules and Procedures. Institute of Urban and Regional Development, University of California, Berkeley. 1972.

Protzen J.P., Dehlinger H. (1972). “Debate and Argumentation in planning: An Inquiry Into Appropriate Rules and Procedures.” Institute of Urban and Regional Development, University of California, Berkeley.

Pruitt, D. G. Negotiation Behavior. Academic Press, 1981.

Pruitt, D. G. (1981). “Negotiation Behavior.” Academic Press.

Raiffa H. The Art and Science of Negotiation. Harvard University Press, 1982.

Raiffa H. (1982). “The Art and Science of Negotiation.” Harvard University Press.

Robinson W., Volkov V. Supporting the Negotiation Life Cycle. Communications of the ACM, 5 volume 43, 1998.

Rosenschein J., Zlotkin G. Mechanism for automated negotiation in state oriented domains. Journal of Artificial Intelligence Research 5, pages 163-238, 1996.

Schelling T. C., The Strategy of Conflict. Cambridge, Harvard University Press, 1960.

Schmidt, K. Modes and Mechanisms for Cooperative Work. Riso Technical Report, Riso National Laboratory, Roskilde, Denmark, 1994.

Schmidt, Kjeld: “Riding a Tiger, or Computer Supported Cooperative Work,” in *ECSCW ’91. Proceedings of the Second European Conference on Computer-Sup-ported Cooperative Work*, ed. by L. Bannon, M. Robinson and K. Schmidt, Kluwer Academic Publishers, Amsterdam, pp. 1-16, 1991.

Simmel G. Conflict. Free Press 1953.

Sriram et al (1992). “DICE: An Object Oriented Programming Environment for Communication, Coordination, and Control In Computer Aided Engineering.” In Tong C. And Sriram D., editors, Artificial Intelligence in Engineering Design (Volume III). Academic Press.

Sycara K. Argument of Persuasion in Labor Mediation. In Proceedings of the Seventh International Joint Conference on Artificial Intelligence, pages 294-296, Los Angeles, California, 1985.

Sycara K. Resolving adversarial Conflicts. Technical report. Georgia Institute of Technology, Atlanta, Georgia, 1987.

Sycara K. (1988). “Resolving Goal Conflicts via Negotiation”. In Proceedings of the Seventh National Conference on Artificial Intelligence, pp. 245-250, Saint Paul, Minnesota.

Sycara K. (1988). Resolving Goal Conflicts Via Negotiation. In Proceedings of the Ninth International Joint Conference on Artificial Intelligence, pages 245-250, Los Angeles, California.

Werkman K. (1992). “Multiple Agent Cooperation Design Evaluation Using Negotiation.” In Gero J., Editor, Artificial Intelligence in Design 92, pp.161-180. Kluwer Academic Publishers.

Wong A. and Sriram D. (1993). “Shared Workspace for Computer-Aided Collaborative Engineering. IESL, Department of Civil Engineering. MIT. Cambridge, MA.

Zeleny M. Multiple Criteria Decision Making. McGraw Hill, New York, 1982.