2

A Web-based Intelligent Collaborative System for Engineering Design

Xiaoqing (Frank) Liu and Samir Raorane

Department of Computer Science, University of Missouri-Rolla, USA

Ming C. Leu

Department of Mechanical and Aerospace Engineering
University of Missouri-Rolla, USA

Design of a modern product is often a very complicated process, which involves groups of designers, manufacturers, suppliers, and customer representatives. Conflicts are unavoidable during collaboration among multiple stakeholders, who have different objectives, requirements, and priorities. Current Web-based collaborative engineering design systems do not support collaborative conflict resolution. In this chapter, we present a Web-based intelligent system that we have developed for collaborative engineering design. It extends a collaborative solid modeling software system by adding an argumentation-based conflict resolution tool, a whiteboard, and a chat utility. We have developed an intelligent computational argumentation model to enable the management of a large scale argumentation network and resolution of conflicts based on argumentation from many participants. A Web-based collaborative engineering design system has been developed based on the above model to resolve conflicts over the Internet by enabling collaborators to select the most favored design alternative in the design argumentation from multiple perspectives. An example of collaborative design of latch mechanism for a solar car using the developed system is presented to show its effectiveness.

2.1 Introduction

Modern products are increasingly designed via collaborations that are distributed across people, organizations, and space. Because of the involvement of various disciplinary groups in decision making, numerous conflicts exist at every stage of a collaborative engineering design process [1, 2]. Decisions made by different groups may not be consistent, components may not physically fit together, and system interfaces may not be compatible. Although different tools and software support systems have been developed to facilitate collaborative engineering design [3-5], the lack of effective intelligent conflict detection and resolution capabilities still hampers effective and efficient collaborative design.

In this chapter, we present a quantitative argumentation method for collaborative engineering design. Based on the method, we have developed an intelligent Web-based collaborative engineering design system that links designers of engineering systems and facilitates effective and efficient conflict resolution among them. This system allows multiple designers to design solid models collaboratively, and facilitates resolution of conflicts effectively through argumentation.

The chapter is organized as follows. Section 2.2 reviews related work. Section 2.3 describes the architecture for a collaborative engineering design environment. Section 2.4 explains argumentation-based conflict resolution in collaborative engineering design. Section 2.5 describes the design and development of a software system implementing the described method. Section 2.6 presents an example to illustrate our method and system.

2.2 Related Work

2.2.1 Current State-of-the-art on Computer-aided Collaborative Engineering Design Systems

We will briefly review the current state-of-the-art on collaborative engineering design systems. A traditional Computer-Aided Design (CAD) system only allows a single user to do design while a collaborative CAD system allows multiple designers to work on a design together. Early research projects in collaborative CAD systems [1, 5-7] have successfully addressed some engineering design issues in collaborative environments. They were developed on local area networks, which are platform dependent, and they were not Web-enabled. It is hard to use them to support designers in locations thousands of miles away from each other to collaborate in heterogeneous platforms. There have also been research efforts toward enabling traditional CAD systems for collaborative design. For example, a Computer Supported Cooperative Work (CSCW) system [7] was developed using C++ and AutoCAD for collaborative design. It has a generic model of collaborative design. Another such system is DOME [5]. It was built by integrating existing single-user CAD systems using CORBA and C++.

The increasing power of the Internet makes collaborative CAD feasible. Recently, several Web-based CAD systems have been developed to allow multiple users from geographically distributed locations to share their design models over the Internet. They fall into three categories. The first category of Web-based CAD systems, including C-DeSS [8] and CDFMP [9], integrates Web-based multimedia tools, such as online chat and online meeting, with Web-based solid model displays so that designers from different locations can share their design ideas over the Internet. However, users cannot develop and edit their solid models online. The second category of Web-based CAD systems, including the Internet design studio [10], WCW [11], WebCAD [12], and NetFEATURE [13], allows multiple users to share their design over the Internet although multiple users can not develop their common models concurrently. The Web-based collaborative system for engineering design recently developed by us has the capabilities of both categories [14]. The third category of Web-based CAD systems, including CSM [14], CollabCAD [15], and Alibre Design [16], focuses on collaborative solid modeling.

All of the existing Web-based collaborative design systems provide very little or no support for detecting conflicts among requirements, exploring design alternatives, and identifying the best design through argumentation from multiple perspectives to resolve design conflicts. There is a clear need *to develop fundamental theoretic methodologies of conflict resolution and implement them with a Web-based collaborative engineering design system.*

2.2.2 Current State-of-the-art on Argumentation-based Conflict Resolution

Philosopher Stephen Toulmin developed a very influential model of argumentation [17] that has guided the development of software tools and systems for supporting the detection and resolution of conflicts in many knowledge domains. Argumentation is a process of arriving at conclusions through discussions and debates. Toulmin's work has promoted a more informal approach in dealing with argumentation than formal logic. In the area of engineering design, several argumentation-based conflict resolution methods and systems have been developed from Toulmin's model. The first of them, gIBIS (graphical IBIS), represents the design dialog as a graph [18]. While representing issues, positions, and arguments, gIBIS failed to support representation of goals (requirements) and outcomes. IBE [3] extended gIBIS by integrating a document editor. REMAP [19] (REpresentation and MAintenance of Process knowledge) extended gIBIS and IBE by providing the representation of goals, decisions, and design artifacts. As opposed to these systems, Sillince proposed a more general argumentation model [20]. His model is a logic model where dialogs are represented as recursive graphs and the rules of both rhetoric and logic were used to manage the dialog and to determine when the dialog has reached closure. Alexander [21] described the incorporation of Toulmin's approach into a software product (Teleologic DOORS) that represents the features of arguments in a visual hierarchy to aid the analysis of positions taken by proponents and opponents of particular design requirements. The biggest challenge with these systems is that the sizes of their argumentation networks are often too large to comprehend and therefore it is very difficult to use them to help make design decisions since they are qualitative and not computational. In addition, they cannot deal with uncertainties associated with argumentation from multiple perspectives. In a preliminary study, we developed a computational argumentation method for capturing and analyzing software design rationale [22]. Parsons and Jennings [23] proposed a framework, based upon a system of argumentation, which permits agents to negotiate to establish acceptable ways to solve problems. QuestMap [4] is a Computer Supported Collaborative

Argumentation (CSCA) tool developed to support legal argumentation by equipping the users with the language needed to construct and analyze arguments. The disadvantage of this tool is its lack of decision making capabilities. HERMES [24] was developed to aid decision makers reaching a decision, not only by efficiently structuring the discussion rationale but also by providing reasoning mechanisms that constantly update the discourse status in order to recommend the most backed-up alternative. Its disadvantage is that the weighting factor becomes very ineffective as it is not related to the entered position.

2.3 A Web-based Intelligent Collaborative Engineering Design Environment and Its Application Scenarios

A prototype Web-based intelligent collaborative system for engineering design has been developed by us. It extends a collaborative solid modeling tool from Alibre Co. [16] by adding an argumentation-based conflict resolution tool, a whiteboard, and a chat utility using a client-server architecture as shown in Figure. 2.1. On the client side, the system provides user interfaces for argumentation-based conflict resolution, whiteboards for design alternatives, and chat rooms for real-time information exchange. On the server side, it manages client communication and argumentation networks. Alibre Design is a collaborative solid modeling tool for creating 3D designs and 2D drawings. It allows engineering teams to work together concurrently over the Internet to create, visualize, review, and modify their designs and drawings.

In the collaborative design process, when a conflict is detected, an argumentation-based conflict resolution session will be initiated. A design issue concerning the conflict is raised first in the session. After multiple design alternatives are generated by the participants, arguments can be proposed by the collaborative designers to either support or oppose the design alternatives or arguments themselves. Our system can help identify the alternative that is most favored by all participants by considering all arguments to resolve the conflicts.

2.4 Argumentation-based Conflict Resolution in the Collaborative Engineering Design Environment

We have developed a computational argumentation method for collaborative engineering design based on our preliminary work on software design rationale capturing. The argumentation framework of this conflict resolution system is an extension of the informal IBIS model of argumentation using fuzzy logic. It will help achieve a consensus among stakeholders and identify the most favorable design alternative through argumentation by computing the favorability of individual design alternatives from all arguments in the argumentation network in an uncertain environment based on fuzzy logic.

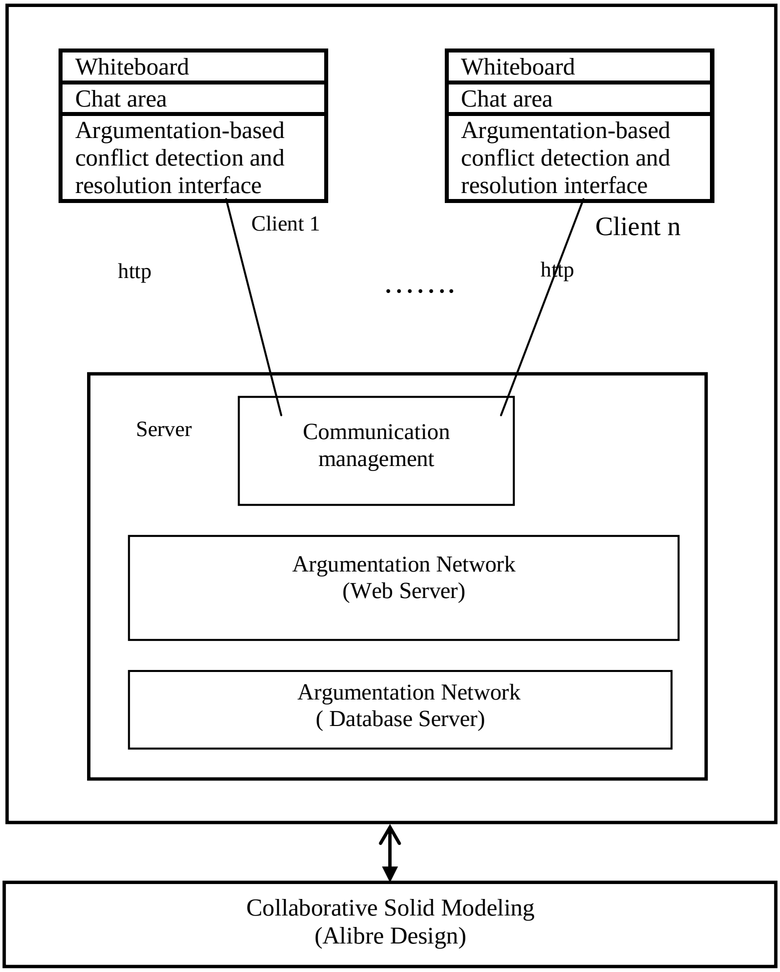

Figure 2.1. Architecture for a Web-based intelligent collaborative engineering design environment

The components of the design argumentation model for collaborative engineering design include stakeholders, requirements, conflicts, design issues, parts, alternatives, arguments, and decisions, as shown in Figure 2.2. We view collaborative design as the process of negotiating the resolution of design issues through dialogs between the stakeholders. A dialog for a given design issue is represented by the alternatives that are related to the design issue, and the arguments for or against each alternative. The resolution of a design issue is represented by a decision that selects an alternative which is most favored.

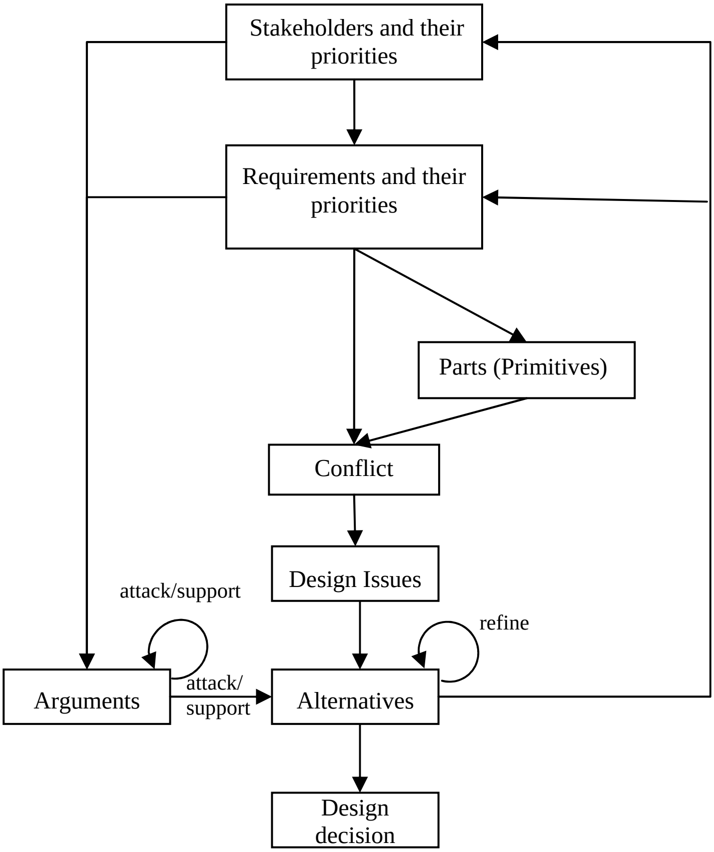

Figure 2.2. Framework for design argumentation

2.4.1 Structured Argumentation Through Dialog Graph

A design dialog for a design issue is captured as a weighted directed graph called a dialog graph [8], as shown in Figure 2.3. The nodes denoted by circles are *Positions.* A position is a statement or assertion that responds to an *issue*, which is a problem, concern, or question that requires discussion for the problem solving to proceed. The nodes denoted by rectangles are *Arguments*. Arguments are statements that support or attack Positions. Each Position may have one or more arguments that either *support* or *attack* it. Arcs represent a relationship (attack or support) from the originating argument node to the terminating argument or position node. The position node contains the name of the stakeholder posting the position and the text of the position. Each Argument node contains the name of the stakeholder posting the argument, the text of the argument and a weight value. The weight attached to an argument is the Argument Strength. It is the measure of an argument's degree of attack or support of either a position or another argument in the position dialog graph. The weight value is a real number between -1 and 1. A positive number denotes Support and a negative number denotes Attack while zero denotes Indecision. The strength of the argument is viewed as a fuzzy set and linguistic labels are used to represent the strength. It is easy to use linguistic labels, instead of real numbers, to denote the strength of an argument over another argument or a position. By doing so fuzzy inference can be used to evaluate a position. Both linguistic labels on arcs (branches) and strengths of arguments are given by participants. Since disagreements among participants are inevitable, how to objectively determine a position's overall favorability is a major research issue. A position node contains a label associated with it to give a measure of the strength of the position based on the strengths of the arguments under it. This measure represents the overall favorability of the position.

Let us use a simple example to illustrate the above concepts. Suppose that several designers in multiple locations collaborate to develop a speed reducer. They may have an *issue* of its gear design. Two design alternatives, which are represented as their *positions*, are proposed by participants. One focuses on cam and another focuses on linkage. Participants can debate about them by posting their arguments about their advantages and disadvantages to resolve their conflict. Another example will be given later to demonstrate how to apply the presented conflict resolution method.

2.4.2 Argument Reduction Through Fuzzy Inference

In Figure 2.3, we can see some arguments attached to other arguments, by a label to denote the degree of support or attack on the arc going between arguments, other than directly attached to the position. For example, A3 has Medium Attack (MA), and A1 and A5 have Strong Support (SS). Argument reduction is used to reduce the arguments which are not directly connected to the position, in order to have them directly connected to the position. For example, argument A3 which is posted as an argument that attacks argument A1, actually attacks the position P after argument reduction.

There are four General Argumentation Heuristic Rules that can be formulated as follows [2].

- General Argumentation Heuristic Rule 1: If argument B supports argument A and argument A supports position P, then argument B supports position P.
- General Argumentation Heuristic Rule 2: If argument B attacks argument A and argument A supports position P, then argument B attacks position P.
- General Argumentation Heuristic Rule 3: If argument B supports argument A and argument A attacks position P, then argument B attacks position P.
- General Argumentation Heuristic Rule 4: If argument B attacks argument A and argument A attacks position P, then argument B supports position P.

As the linguistic labels used are Strong Support (SS), Medium Support (MS), Indecisive (I), Medium Attack (MA) and Strong Attack (SA), the above four General Argumentation Heuristic Rules can be extended to obtain twenty-five Argumentation Heuristic Rules shown in Figure 2.4.

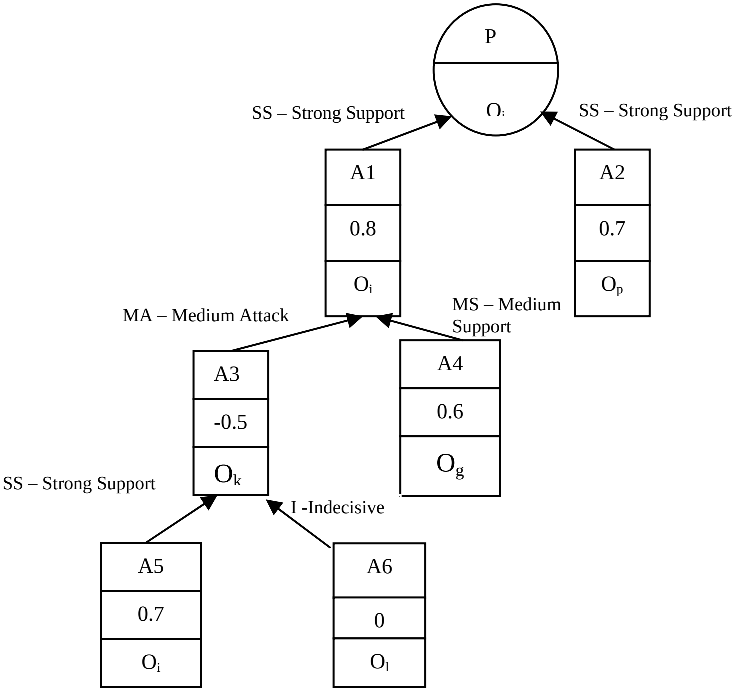

Figure 2.3. Position dialog graph

	SS	MS	I	MA	SA
SS	SS	MS	I	MA	SA
MS	MS	MS	I	MA	MA
I	I	I	I	I	I
MA	MA	MA	I	MS	MS
SA	SA	MA	I	MS	SS

SS: Strong Support   MS: Medium Support

I: Indecisive   MA: Medium Attack

SA: Strong Attack

Figure 2.4. Argumentation heuristic rules

Consider an instance where the strength of the level-1 argument is Strong Attack (SA) and that of the level-2 argument is Medium Support (MS), then the reduced strength of the level-2 argument will be Medium Attack (MA) as shown by the entry in column 3 and row 6 in Figure 2.4.

A fuzzy inference engine has been built to infer the reduced strengths of the arguments, as discussed later in this section. Using this fuzzy inference engine we can reduce a given Position Dialog Graph into one in which all the argument nodes are directly attached to the position node. Consider the example in Figure 2.3, where we have arguments occurring at level 3. The argument nodes at level 3 can be reduced and attached to the argument node at level 1. Their reduced strengths are computed using the fuzzy inference engine, as shown in Figure 2.5.

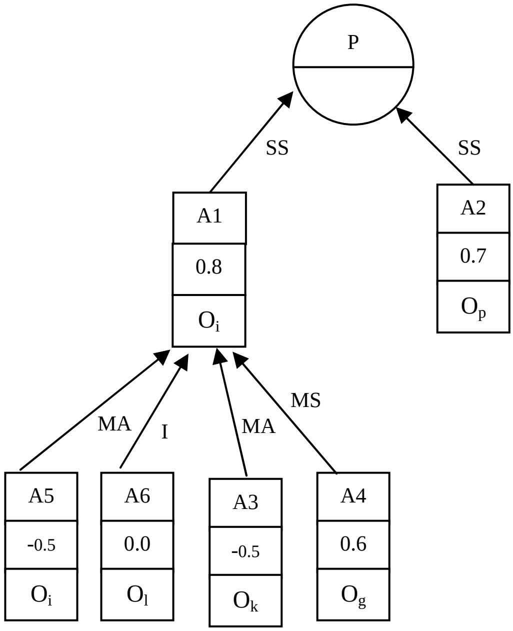

Figure 2.5. Position dialog graph after one level reduction

Now there is one level of arguments which are not directly attached to the position. Hence argument reduction has to be performed once again to have the reduced position dialog graph with all the arguments directly attached to the position. The arguments at level 2 are reduced using the fuzzy inference engine and attached directly to the position node, as shown in Figure 2.6.

In the procedure of argument reduction, the fuzzy inference engine takes in two inputs and generates one output. The inputs are the strengths of the argument to be reduced and the argument right above it. The output of the fuzzy inference engine is the strength of the argument after the argument reduction.

2.4.2.1 Linguistic Variable Through Fuzzy Membership Functions

Fuzzy membership functions are used to quantitatively characterize linguistic systems represented as fuzzy sets. The fuzzy membership function chosen for the system in our study is the piecewise linear trapezoidal function. Membership functions are defined by using a,b,c,d to denote the four vertices of the trapezoids.

Five membership functions have been defined for five fuzzy sets. The five fuzzy sets are Strong Attack (SA: a = -1, b = -1, c = -0.8, d = -0.5), Medium Attack (MA: a = -0.8, b = -0.6, c = -0.4, d = -0.2), Indecisive (I: a = -0.3, b = 0, c = 0, d = 0.3), Medium Support (MS: a = 0.2, b = 0.4, c = 0.6, d = 0.8) and Strong Support (SS: a = 0.5, b = 0.8, c = 1, d = 1). Figure 2.7 shows the five membership functions for the above five linguistic terms.

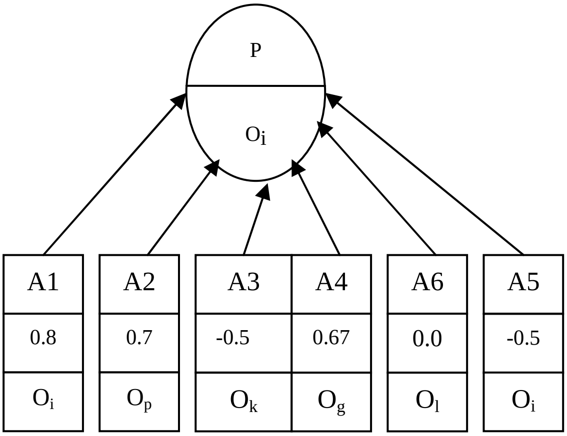

Figure 2.6. Position dialog graph after complete reduction

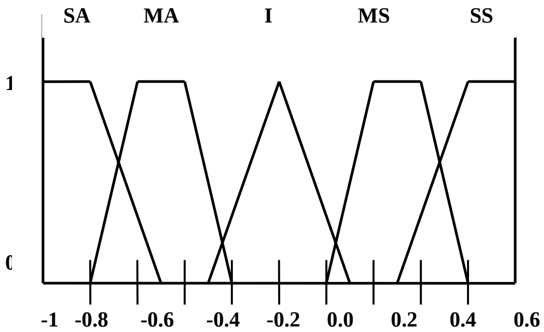

Figure 2.7. Five membership functions

2.4.2.2 Fuzzy Inference Rules

Fuzzy inference rules combine two or more input fuzzy sets and associate with them an output set. The input sets are combined by means of operators that are analogous to the usual logical conjunctives “and”, “or”, *etc*. The fuzzy rules, also known as argumentation rules, are given in Figure 2.4. The fuzzy or argumentation rules are stored and represented through the use of the Fuzzy Association Memory (FAM) matrix shown in Figure 2.8. There are two inputs X and Y for each rule.

Each input variable is one of five input sets, *i.e.*, “SS”, “MS”, “I”, “MA”, and “SA”. The output variable Z is one of five output sets which are same as the five input sets. Each FAM matrix entry is a fuzzy set that is the output of the fuzzy rule. For example, the shaded part in Figure 2.8 represents the rule: “If X is Strong Support (SS) and Y is Strong Attack (SA), then the output Z is Strong Attack (SA).”

2.4.2.3 Fuzzy System and Defuzzification

The system associated with the FAM matrix is shown in Figure 2.8. In this case we have two input variables, *X* and *Y*, each with an associated fuzzy set from SS, MS, I, MA and SA. Figure 2.7 shows the membership functions for these sets.

x \ y	SS	MS	I	MA	SA
SS	SS	MS	I	MA	SA
MS	MS	MS	I	MA	MA
I	I	I	I	I	I
MA	MA	MA	I	MS	MS
SA	SA	MA	I	MS	SS

Figure 2.8. The Fuzzy Association Memory (FAM) matrix I

The membership functions for the fuzzy sets SS, MS, I, MA and SA are denoted by F_{SS}, F_{MS}, F_I, F_{MA} and F_{SA}, respectively. A value x of the input variable *X* then has membership degrees $F_{SS}(x)$, $F_{MS}(x)$, $F_I(x)$, $F_{MA}(x)$ and $F_{SA}(x)$ in respective fuzzy sets. For example, with the trapezoidal membership functions shown in Figure 2.7 and a value x = -0.7, we would have:

$F_{SS}(-0.7) = 0.0$
$F_{MS}(-0.7) = 0.0$
$F_I(-0.7) = 0.0$
$F_{MA}(-0.7) = 0.5$
$F_{SA}(-0.7) = 0.67$

Similarly, a value y of the input variable *Y* has membership degrees $F_{SS}(y)$, $F_{MS}(y)$, $F_I(y)$, $F_{MA}(y)$ and $F_{SA}(y)$. For example, the value y = 0.6 as shown in Figure 2.9 would result in

$F_{SS}(0.6) = 0.33$
$F_{MS}(0.6) = 1.0$
$F_I(0.6) = 0.0$
$F_{MA}(0.6) = 0.0$
$F_{SA}(0.6) = 0.0$

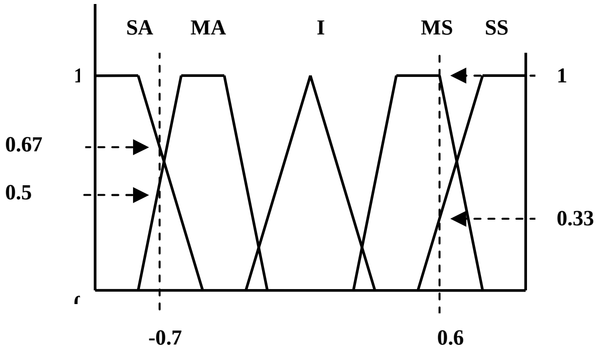

Figure 2.9. Membership degrees

Consider x = -0.7 and y = 0.6 as values of the input variables X and Y. A weight value for each entry in the FAM matrix is computed by taking the minimum value of the membership function associated with that entry. Now consider the FAM matrix entry corresponding to X as a member of the fuzzy set MA, and Y as a member of the fuzzy set SS. The weight w1 associated with the entry would be computed as:

$$\begin{aligned} w_1 &= \min\,[F_{MA}(-0.7), F_{SS}(0.6)] \\ &= \min\,[0.5, 0.33] \\ &= 0.33 \end{aligned}$$

Only those FAM matrix entries which have nonzero membership-function values for both *X* and *Y* will have nonzero weights associated with them. The shaded entries in Figure 2.10 show the four activated rules for the values in the example. In addition to w_1, there are three more non-zero weights. They are

$$\begin{aligned} w_2 &= \min\,[F_{MA}(-0.7), F_{MS}(0.6)] \\ &= \min\,[0.5, 1.0] \\ &= 0.5 \\ w_3 &= \min\,[F_{SA}(-0.7), F_{SS}(0.6)] \\ &= \min\,[0.67, 0.33] \\ &= 0.33 \\ w_4 &= \min\,[F_{SA}(-0.7), F_{MS}(0.6)] \\ &= \min\,[0.67, 1.0] \\ &= 0.67 \end{aligned}$$

The output variable *Z* also has five fuzzy sets associated with it, *i.e.* SS, MS, I, MA and SA. Specific values are assigned to these fuzzy sets, *i.e.* SS = 1, MS = 0.5, I = 0, MA = -0.5 and SA = -1. The system output is computed as follows:

$$\text{Output} = \frac{(w1.MA + w2.MA + w3.SA + w4.MA)}{w1 + w2 + w3 + w4} = -0.59$$

y \ x	SS	MS	I	MA	SA
SS	SS	MS	I	MA	SA
MS	MS	MS	I	MA	MA
I	I	I	I	I	I
MA	MA	MA	I	MS	MS
SA	SA	MA	I	MS	SS

Figure 2.10. The Fuzzy Association Memory(FAM) matrix II

2.4.3 Conflict Resolution by Computing Favorability of Positions (Design Alternatives)

The favorability of a position is a value indicating the strength of the position. It is calculated by taking the sum of the strengths of arguments obtained by performing reductions on the ones which are not directly connected to the position. Such a measure allows the participants in a design deliberation to compare positions objectively and quantitatively based upon the argument strengths.

To identify a good design concept, multiple design alternatives are usually developed and explored. These alternatives are known as positions. The designers would argue over each position by giving their arguments and respective weights. In order to resolve the conflicts, *i.e.*, to decide which is the best design alternative, the favorability is calculated for each position. The position with the highest favorability is the best design option.

At every point in the argumentation process, the designers can view the favorability values of various positions and can post their arguments accordingly. For example, a designer may observe that the favorability of a given position to which he is supporting is low. He may then decide to post a Strong Support (SS) on that position or a Strong Attack (SA) on an argument that has a Strong Attack (SA) on the position.

2.5 Design and Implementation

A Web-based intelligent collaborative engineering design system has been developed based on the above described method using Java on a client-server structure. Since whiteboard and chat utilities are commonly available for collaborative software systems today, we focus on design and implementation of intelligent argumentation for conflict resolution for the collaborative system.

The elements used for argumentation include Project, Issues, Positions and Arguments. The information has to be entered in text format, which can be viewed by every design member participating in the argumentation. If a conflicting issue has occurred in a new project, the designer has to first create a project and enter a detailed description of the project. Then he can add an issue under that project. If another conflicting issue occurs on the same project, the designer will need to retrieve the old project from the list of projects and then add an issue under the same project. Once an issue is created, the participating designers can enter their options *i.e.*, the positions to resolve the issue. The designers can then enter their opinions in the form of arguments to the positions.

At every stage in the argumentation process, the designers can view the result of the process, *i.e.*, they can view the position, it favorability, and the inputs by the other designers on the position. If the position with the highest favorability is the one the designer does not favor, he can then post an attack on that position or post a support on the position he favors (thus increasing the favorability of the position he supports).

The graphical user interface for the Web-based intelligent argumentation is shown in Figure 2.11. The Control Panel has five menu items: *Project, Issue, Position, Argument* and *Calculation/Clear*. Each menu item has submenus which perform unique actions on the respective argumentation elements.

As we discussed earlier, one of the drawbacks of the current systems developed in this field of research is that the sizes of their argumentation networks are often too large to comprehend and therefore it is very difficult to use them to help make design decisions. Hence in our system, we have represented the argumentation network in the form of a tree.

The basic argumentation elements are *project, issues, positions* and *arguments*. Project forms the root node, followed by issues, *i.e.*, the conflicting design issues that occur for a particular project. Under each issue are positions, *i.e.*, the design alternatives which address the issue. Arguments are under positions, and every argument can have any number of arguments. The tree structure is so designed that a designer at any time can work on any sub-tree of the argumentation tree. This helps the designer to concentrate on a specific part of the argumentation. The argumentation tree is not too large and as the fuzzy inference engine is used to resolve the conflicts, design decisions can be made without any difficulty.

2.6 An Application Example

UMR’s Solar Car Team, a student design team which won the competitions in the American Solar Challenge in 2001 and 2003, is confronted with many challenging issues including resolving various design conflicts. One of the tasks of the team is to design a reliable latch mechanism that holds the base frame with the body of the solar car as shown in Figure 2.12. After the design team came up with two latch mechanisms as shown in Figures 2.13 and 2.14, from which the team needs to select the better design. Some obvious pros and cons of the two designs have been identified. While design 1 (Figure 2.13) is easier to be analyzed at the detail design stage and is also easier to be manufactured than design 2 (Figure 2.14), it is harder for the components to be assembled and needs extra work for the locking system. Solid models for design 1 and design 2 and their argumentation networks have been developed collaboratively using our collaborative design system, which incorporates Alibre Design, as shown in Figure 2.15 and Figure 2.16. Their comparison using the system is shown in Figure 2.17. An argumentation network has been developed to show resolution of conflicts, as shown in Figure 2.18. The argumentation network displayed by the system is shown in Figure 2.19. The design dialog reduction is done by the inference engine in the system. The reduced argumentation tree is shown in Figure 2.20 and the final result on favorability calculation is shown in Figure 2.21. It indicates that design 2 is favored by most participants based on the argumentation since its favorability is higher than that of design 1. This result of argumentation is concurred by the UMR Solar Car Design Team.

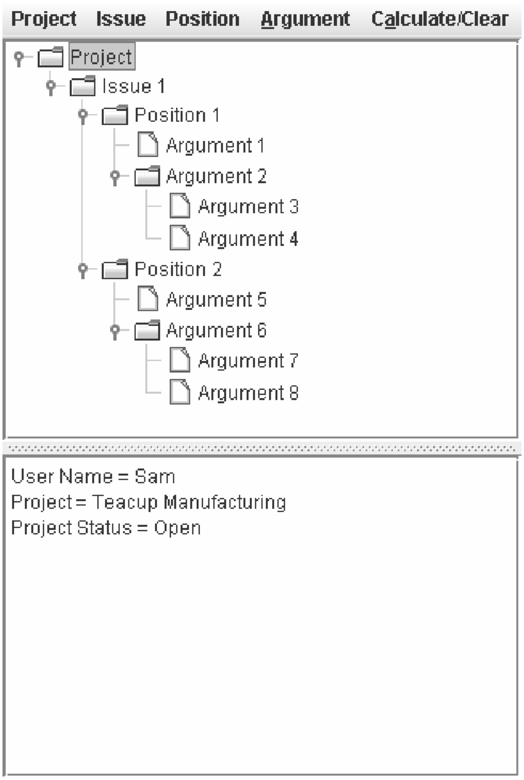

Figure 2.11. Conflict Resolution Window

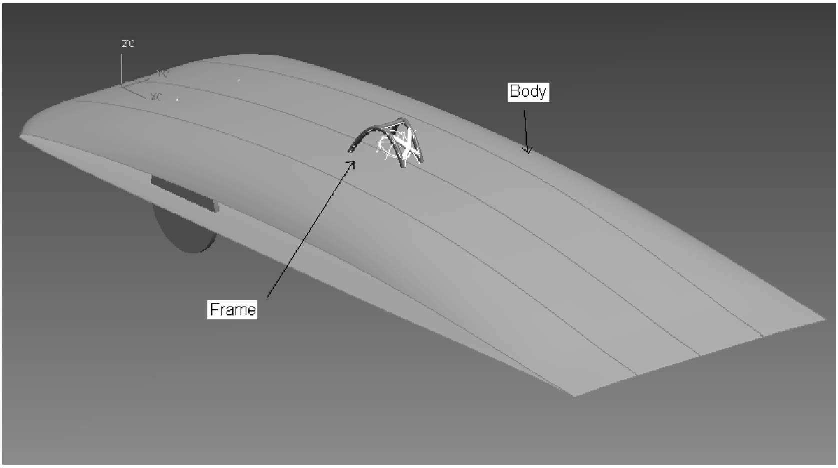

Figure 2.12. The solar car

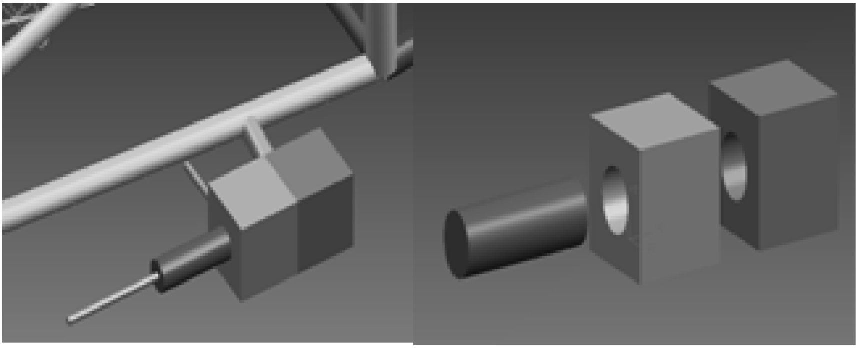

Figure 2.13. Design 1

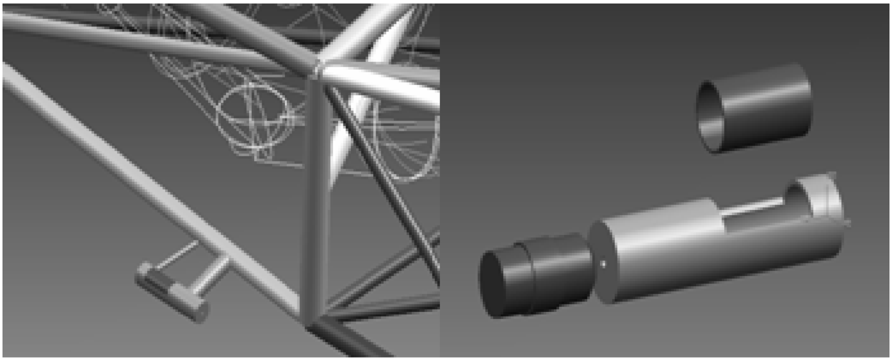

Figure 2.14. Design 2

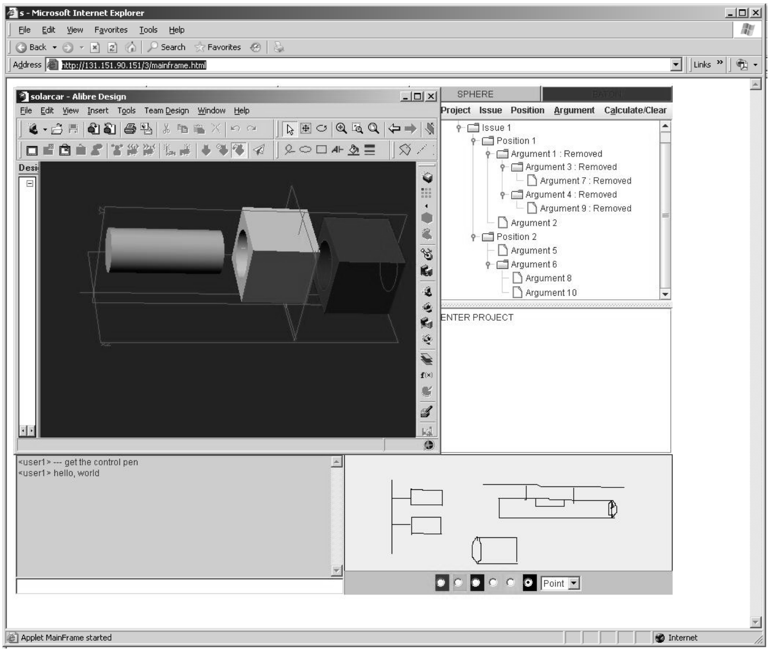

Figure 2.15. Collaborative design 1 for the Latch Mechanism

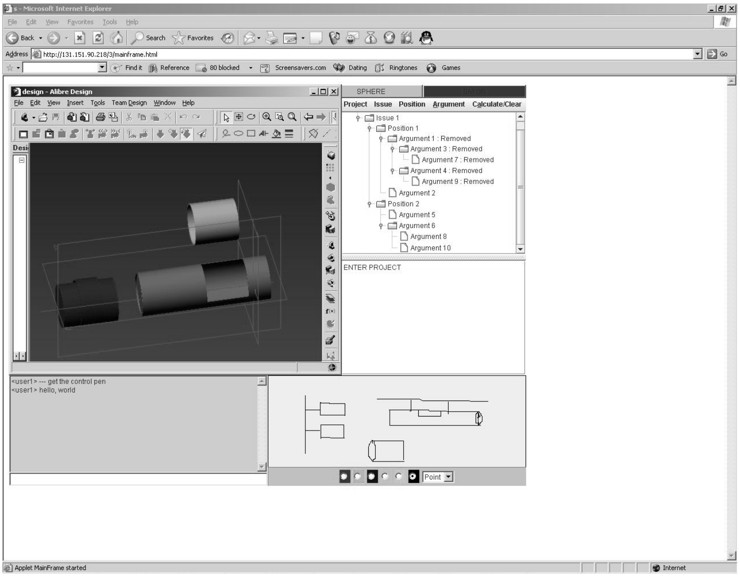

Figure 2.16. Collaborative design 2 for the Latch Mechanism

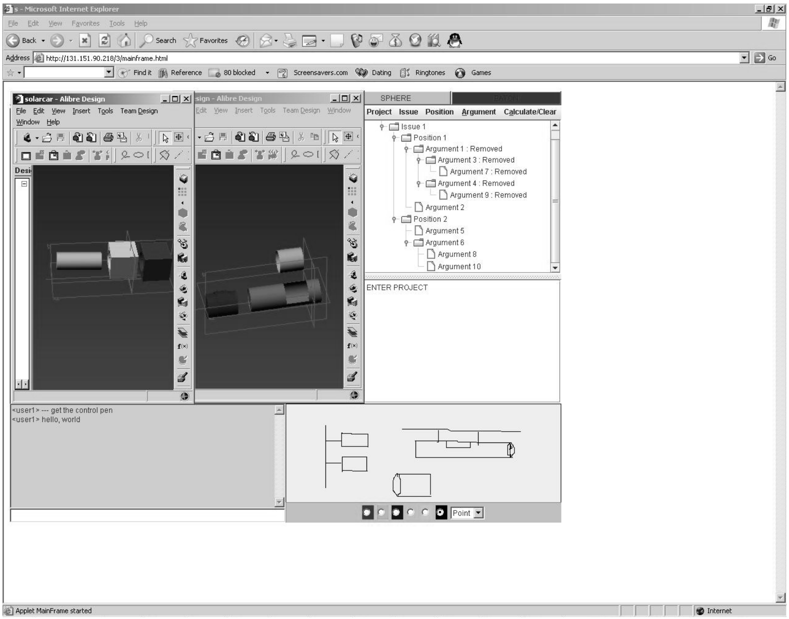

Figure 2.17. Comparisons of Design 1 and Design 2

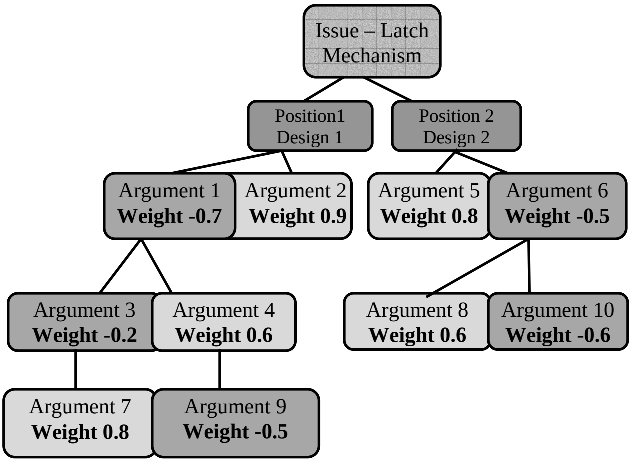

Figure 2.18. Argumentation tree

Argument 1 – The pin aligning will be a problem
Argument 2 – Design 1 is simpler and more cost-effective

Argument 3 – It is feasible to design an aligning pin and the locking can be designed easily
Argument 4 – The pin aligning is sensitive and will cause a lot of vibration
Argument 5 – A chamfer at both ends of the mating cylinder will allow smooth insertion
Argument 6 – Strength of the cylinders will depend on the material and dimensions and it is sensitive
Argument 7 – Manufacturing will be cost-effective
Argument 8 – The pin retraction will be a problem when removing the body from the frame
Argument 9 – If the two blocks are mated via a good design, then aligning will not be a problem
Argument 10 – The pin retraction should not be a problem with proper tolerance

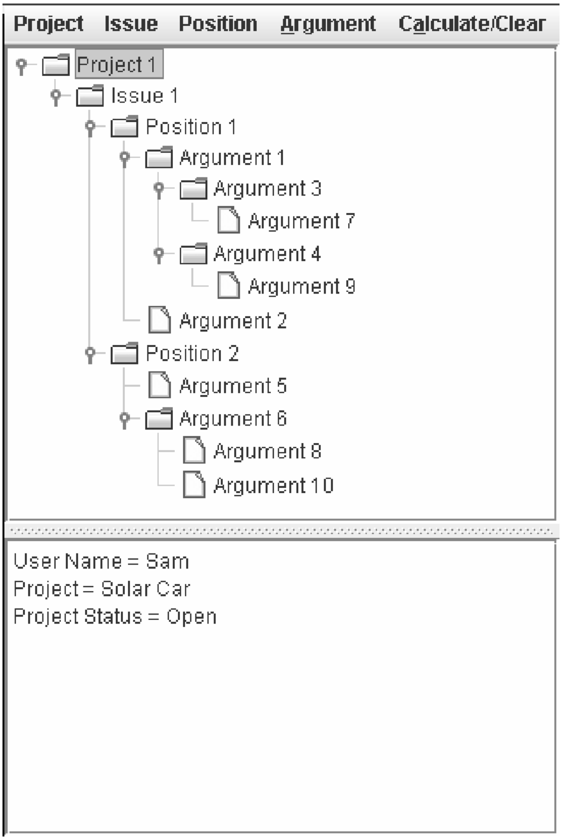

Figure 2.19. Argumentation network

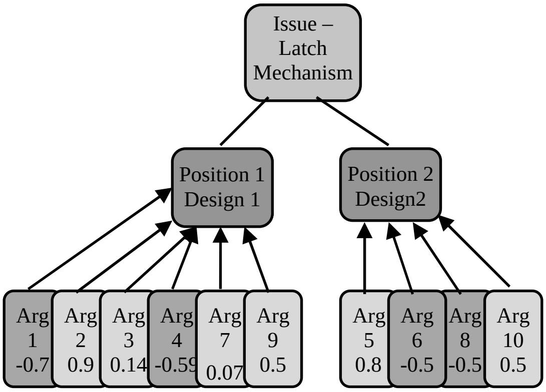

Figure 2.20. Reduced argumentation tree

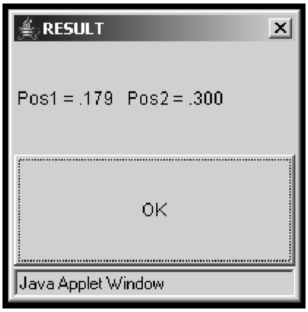

Figure 2.21. Favorabilty calculation result – solar car

2.7 Conclusions

An intelligent Web-based system has been developed using Java to facilitate collaborative engineering design by extending an existing collaborative solid modeling system to include an intelligent argumentation tool, a whiteboard, and a chat utility. It supports conflict resolution and decision making. The reduction of an argumentation hierarchy is based on fuzzy logic. The intelligent argumentation utility enhances conflict resolution capability in Web-based collaborative engineering design systems by capturing design rationale using argumentation hierarchies and providing intelligent aids to identify the most favored positions (design alternatives).

2.8 Acknowledgements

This research is supported by the Intelligent Systems Center (ISC) in the University of Missouri-Rolla. Man Zheng, Siddharth Shinde, and Yamini

Natarajan participated in and have contributed to this research project. Yan Sun has helped to edit the chapter.

2.9 References

[1] Sriram, R., 2002, *Distributed and Integrated Collaborative Engineering Design*, Sarven Publishers.

[2] Klein, M., 2003, "The dynamics of collaborative design: insights from complex systems and negotiation research," *Concurrent Engineering Research and Applications Journal*, 12(3).

[3] Lease, M., Lively, M. and Leggett, J., 1990, "Using an issue-based hypertext system to capture software life-cycle process," *Hypermedia*, 2(1).

[4] Morge, M., 2004, "Computer-supported collaborative argumentation," *CMNA IV. 4th Workshop on Computational Models of Natural Argument, ECAI 2004*, pp. 69–72.

[5] Pahng, G.-D. F., Seockhoon, B. and Wallace, D., 1998, "A Web-based collaborative design modeling environment," *Proceedings of the 7th IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (WET ICE '98)*, 17–19 June, pp. 161–167.

[6] Reddy, R., Srinivas, K., Jagannathan, V. and Karinthi, R., 1993, "Computer Support for concurrent engineering – guest editors' introduction," *IEEE Computer*, 26(1), pp. 12–16.

[7] Zhou, J. and Lin, G., 1999, "Implementation of collaborative design environment based on single user CAD systems," *Proceedings of the 3rd International Conference Knowledge-Based Intelligent Information Engineering Systems*, 31 Aug.–1 Sept., pp. 78–83.

[8] Klein, M., 1997, "Capturing geometry rationale for collaborative design enabling technologies," *Proceedings the 6th IEEE Workshops on Collaborative Enterprises*, 18–20 June, pp. 24–28.

[9] Zhang, H., Wu, H., Lu, J. and Chen, D., 2000, "Collaborative design system for performance," *Proceedings of Academia/Industry Working Conference on Research Challenges*, 27–29 April, pp. 59–63.

[10] Siddique, Z., 2004, "Internet design studio," *Proceedings of ASME 2004 Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, Sept, 2004, Salt Lake City, Utah.

[11] Wang, L., Wong, B., Shen, W. and Lang, S., 2001, "A Web-based collaborative workspace using Java 3D," *Proceedings of the 6th International Conference on Computer Supported Cooperative Work in Design*, July, pp. 77–82.

[12] Peng, S., Tang, M. and Dong, J., 2001, "Collaborative model for concurrent product design," *Proceedings of the 6th International Conference on Computer Supported Cooperative Work in Design*, 12–14 July, pp. 212–217.

[13] Lee, J. Y., Han, S. B., Kim, H. and Park, S. B., 1999, "Network-centric feature-based modeling," *Proceedings of the 7th Pacific Conference on Computer Graphics and Applications*, 5–7 Oct.

[14] Chan, S., Ng, C. and Ng, V., 1999, "Real-time collaborative design of complex objects on the Web," *Proceedings of the 1999 IEEE International Conference on Systems, Man, and Cybernetics*, 2, pp. 120–125.

[15] CollabCAD, 2005, "CollabCAD software," http://www.collabcad.com.

[16] Alibre, 2005, http://www.alibre.com.

[17] Toulmin, S. E., 1958, *The Uses of Argument*. Cambridge, UK: University Press.

[18] Conklin, J. and Begeman, M. L., 1988, "gIBIS: A hypertext tool for exploratory policy discussion," *ACM Transactions on Information Systems (TOIS)*, 6(4), pp. 303–331.

[19] Ramesh, B. and Dhar, V., 1992, "Supporting systems development by capturing deliberations during requirements engineering," *IEEE Transactions on Software Engineering*, 18(6), pp. 498–510.

[20] Sillence, J., 1997, "Intelligent argumentation systems: requirements, models, research agenda, and applications," in *Encyclopedia of Library and Information Science* (Allen Kent, Editor), Marcel Dekker, New York, pp. 176–217.

[21] Alexander, I., 2003, "Modeling argumentation: toulmin-style," Retrieved April 15, 2005. http://easyweb.easynet.co.uk/~iany/consultancy/papers.htm.

[22] Sigman, S. and Liu, X. F., 2003, "A computational argumentation methodology for capturing and analyzing design rationale arising from multiple perspectives," *Information and Software Technology*, 45, pp. 113–122.

[23] Parsons, S. and Jennings, N. R., 1996, "Negotiation through argumentation – a preliminary report," *Proceedings of the 2nd International Conference on Multi Agent Systems*, pp. 267–274.

[24] Karacapilidis, N. and Papadias, D., 1998, "HERMES: supporting argumentative discourse in multi-agent decision making," *Proceedings of the 15th National Conference on Artificial Intelligence (AAAI-98)*, Madison, WI, AAAI/MIT Press, pp. 827–832.

http://www.springer.com/978-1-84628-801-2

Collaborative Product Design and Manufacturing Methodologies and Applications
Li, W.D.; Ong, S.K.; Nee, A.Y.C.; McMahon, C.A. (Eds.)
2007, XIV, 308 p., Hardcover
ISBN: 978-1-84628-801-2