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Incorporation of Evidences into an Intelligent Computational Argumentation Network for a Web-based Collaborative Engineering Design System

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ABSTRACT

Conflicts among the stakeholders are unavoidable in the process of collaborative engineering design. Resolution of these conflicts is a challenging task. In our previous research, a web based intelligent collaborative system was developed which provides decision-making support, using computational argumentation techniques. Enhancements were done to this system to incorporate the priorities of the stakeholders and to detect arguments that self conflict. As an effort to make this system more effective and more objective in the process of decision making, we develop a method to assess the effect of evidences in the argumentation network, using Dempster-Shafer theory of evidence and fuzzy logic. One or more evidences can support or attack an argument or another evidence. Incorporation of evidences in the argumentation network makes the decision making process more objective, as the weights assigned to the arguments can be re-assessed according to the evidences associated with them.

KEYWORDS: Computational Argumentation, Evidence Based Decision Making, Dempster's Combination Rule, Conflict Resolution.

1. INTRODUCTION

Collaborative design of products has many advantages, including low development cost and time. However, with multiple stakeholders taking part in the process, there are always conflicts among them, which need to be resolved. In our previous research we have addressed this issue of conflict resolution by developing a web based intelligent system for collaborative engineering design using intelligent argumentation [1]. The decision making process takes into consideration the priority of the people taking part in argumentation depending on their roles and also detects self-conflicting arguments [2].

Evidences play a vital role in any argumentation. In Toulmin's argumentation model [4], evidences are the proofs or facts that can be associated with an argument. They can consist of statistics, quotations, reports, findings, physical evidence, or various forms of reasoning. Evidences help to reinforce the claim that a person is trying to make. For example, in a trial, a person is held guilty of a murder based on the arguments that the attorneys had during the course of the jurisdiction. Now, if there is an evidence that the weapon used for the crime does not have the finger prints of the accused, then the decision of the entire argumentation changes.

This paper is aimed at incorporating evidences into the web based intelligent collaborative system [1,2] to make the decision making process more objective and analogous to the real world scenario of argumentation. The paper is organized as follows. Section 2 presents a review of related work. Section 3 gives a brief overview of our previous research. Section 4 explains the incorporation of evidences into the system. Section 5 presents an example of the argumentation for a collaborative engineering design along with multiple levels of evidences.

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2. RELATED WORK

Philosopher Stephen Toulmin [4] developed a very influential model of argumentation that has guided the development of software tools and systems intended to support the detection and resolution of conflicts in many knowledge domains. . In the area of engineering design, several argumentation-based conflict resolution methods and systems have been developed based on Toulmin's model. The first of them, gIBIS (graphical IBIS), represents the design dialog as a graph [11]. While being capable of representing issues, positions, and arguments, gIBIS did not support representation of goals (requirements) and outcomes. IBE [12] extended gIBIS by integrating a document editor. REMAP (REpresentation and MAintenance of Process knowledge) [13] extended gIBIS and IBE by providing support for representation of goals, decisions, and design artifacts. As opposed to these systems Sillince [5] proposed a more general argumentation model. His model is a logic model where dialogs are represented as recursive graphs and both rhetoric and logic rules are used to manage the dialog and to determine when the dialog has reached closure.

Bex *et al* [6] developed a conceptual and formal framework for the analysis of reasoning with evidence about the facts of a legal case. However, this sense-making system does not do the reasoning itself, but instead helps the user make sense out of a case by structuring it. HERMES[10] is a system that aids decision makers reach 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. It is an active system, which not only captures the informal organizational memory embodied in decision making settings, but also helps the users during the decision making process.

A scalable reasoning system has been developed in [9], which represents various reasoning artifacts like arguments, evidences, hypotheses and assumptions using visualization techniques which are scalable to small devices like PDA's. Supplementing each reasoning artifact is a numerical value which represents the confidence rating of that artifact. It is similar to our work in that it represents the relationship between two artifacts as support or refute. There is also a "query" facility which helps in discovering the knowledge from the argumentation structures. The aim of their work is to facilitate visualization and foraging of data for sense-making. The system does not implement any inferential engine for decision-making.

3. MANAGEMENT OF AN INTELLIGENT ARGUMENTATION NETWORK FOR A WEB-BASED COLLABORATIVE ENGINEERING DESIGN ENVIRONMENT

We have developed a collaborative engineering design system using intelligent argumentation [1], based on the client-server architecture. On the client side, the system provides user interfaces for solid modeling, annotation, whiteboards for design alternatives, argumentation based conflict resolution, and chat rooms for real-time information exchange. On the server side, it manages client communication, concurrent access to design objects, and argumentation network. In the subsystem for conflict resolution, the dialog for a design issue is captured as a weighted directed graph called a dialog graph [8], as shown in figure 1.

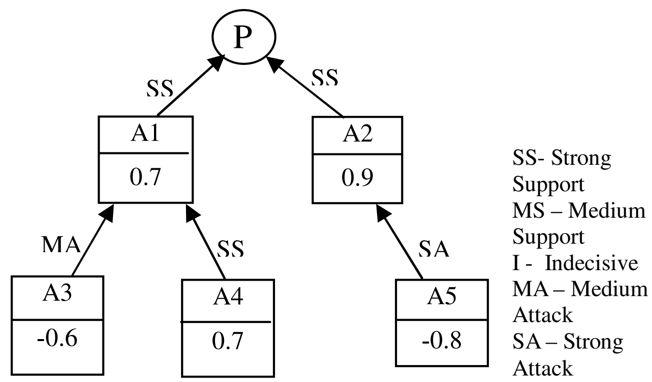

Figure 1. Argumentation Tree

The node denoted by the circles is a *Position* i.e. the design alternative and the nodes denoted by rectangles are *Arguments*. Arrows represent a relationship (attack or support) from the originating argument node to the terminating argument or position node. The weight assigned 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. 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. We use linguistic labels Strong Support, Medium Support, Indecisive, Medium Attack and Strong Attack to denote the strength of an argument. A fuzzy inference engine has been developed for argument reduction. The fuzzy inference engine has two inputs and 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 reduced strength of the argument. We reduce the complexity of the network level by level using a fuzzy inference engine to the point where every argument under a position connects to it directly. Then we compute the favorability factor of each position by summing up the weights of all these arguments. The position with the maximum favorability factor is the best design option.

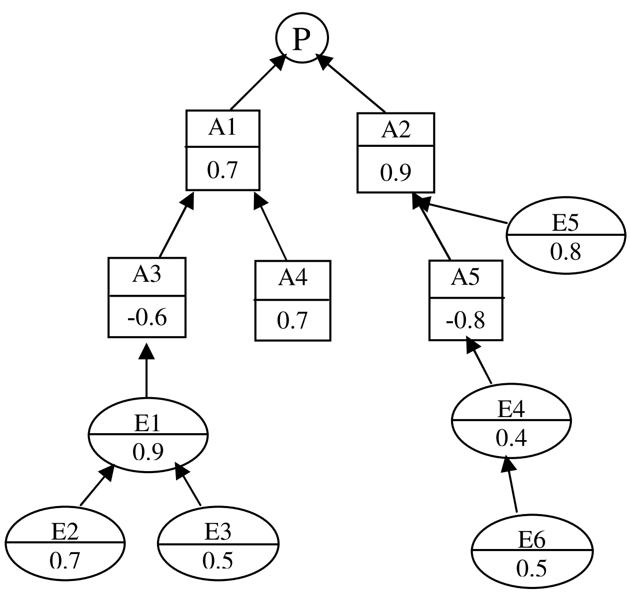

Figure 2. Argumentation Tree with Evidences

4. INCORPORATION OF EVIDENCES INTO THE ARGUMENTATION

An evidence is a fact or a proof that strengthens an argument. In any argumentation, usually the participants present various facts or figures that add more weight to their corresponding arguments. We represent these evidences in the dialog graph as ellipses, as shown in figure 2. The weight assigned to an evidence represents the degree of confidence that the participant has in that evidence, or the probability of the evidence holding true. It is a positive real number between 0 and 1. A weight closer to 1 represents a higher probability of that evidence being true.

4.1. Combining Evidences at the Same Level

The evidences at the same level are combined using Dempster's Combination Rule. Dempster's rule can be expressed as follows:

$$m(C) = \sum_{A\cap B=C} m_1(A)m_2(B) \,/\, (1-\sum_{A\cap B=\Phi} m_1(A)m_2(B))$$

where $m_1(A)$ and $m_2(B)$ are the mass functions of the evidences A and B, respectively. Mass functions represent the degree of confidence in the corresponding evidence or the probability of the evidence being true. The mass function m(C) is the result of combination of evidences A and B. The numerator is the product of the probabilities of the evidences being combined and the denominator is the normalizing factor that cancels out any degree of conflict between these evidences [7].

4.2. Propagating the Combined Evidences to Higher Level

When all the evidences at the same level have been combined using Dempster's rule, we propagate this result to the higher level using the Fuzzy Association Matrix shown in figure 3. The linguistic labels used for the strength of evidence are High (H), Medium (M) and Low (L).

	H	**M**	**L**
H	H	H	M
M	H	M	L
L	M	L	I

H-High
M-Medium
L-Low

Figure 3. Fuzzy Association Matrix for Combination of Evidences

Fuzzy membership functions are used to quantitatively characterize linguistic labels, such as low probability (L). In our previous research work, the fuzzy membership function chosen for the weight of arguments and priorities is the piecewise linear trapezoidal function. The function used for evaluating evidences is also the piecewise linear trapezoidal function with the fuzzy sets as High, Medium and Low as shown in figure 4.

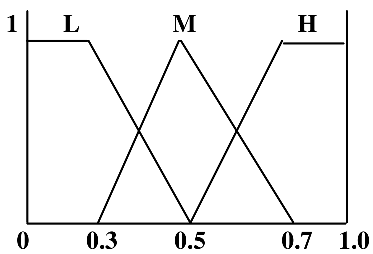

Figure 4. Fuzzy Membership Functions for Evidences

We use fuzzy rules for the propagation of the evidence weight from lower level to higher level instead of using the Dempster's Combination rule, to differentiate between the various levels of evidences. Using the Dempster's rule for all the levels would be equivalent to having all the evidences at the same level.

4.3. Re-assessment of the argument strength based on the evidence

After combining all the available evidences, the strength of the associated argument is re-assessed based on the following general heuristic rules:

General Evidence Re-assessment Heuristic Rule 1: If an argument A has supporting evidence of strength High, the strength of this argument should be significantly higher than it is.

General Evidence Re-assessment Heuristic Rule 2: If an argument A has supporting evidence of strength Medium, the strength of this argument should be moderately higher than it is.

General Evidence Re-assessment Heuristic Rule 3: If an argument A has supporting evidence of strength Low, the strength of this argument should be slightly higher than it is.

There is no notion of negative evidences here. According to Toulmin's argumentation model [4], evidences are facts or proof that support an argument being made. If a participant requires to present an evidence that is against another argument, then he/she must first present a new argument that attacks the argument for which the negative evidence needs to be presented, with appropriate weight. The evidence can then be associated with this newly added argument.

The general heuristic rules can be extended to the following fifteen Fuzzy Heuristic Rules:

	H	**M**	**L**
SS	SS	SS	SS
MS	SS	MS	MS
I	I	I	I
MA	SA	MA	MA
SA	SA	SA	SA

SS: Strong Support
MS: Medium Support
I: Indecisive
MA: Medium Attack
SA: Strong Attack
H: high priority
M: medium priority
L: low priority

Figure 5. Fuzzy Association Matrix for Combination of Evidences and Arguments

Here, the values in the columns for Medium and Low evidences are same, though the weights used for Medium and Low evidences in the fuzzy inference engine are different. This is done to make sure that the calculated weight of the arguments with evidence(s) does not become lesser than its original weight, even in the case of 'Low' strength evidence.

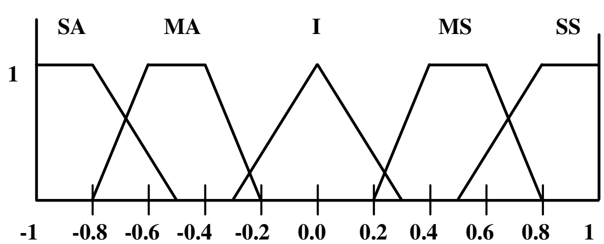

Figure 6. Fuzzy Membership Functions for Arguments

Fuzzy membership functions used for evidence remain the same as shown in figure 4. The membership functions for arguments are shown in figure 5. After re-assessing the weight of the arguments using these rules, the argumentation network is reduced using the argumentation rules in [1] and [2].

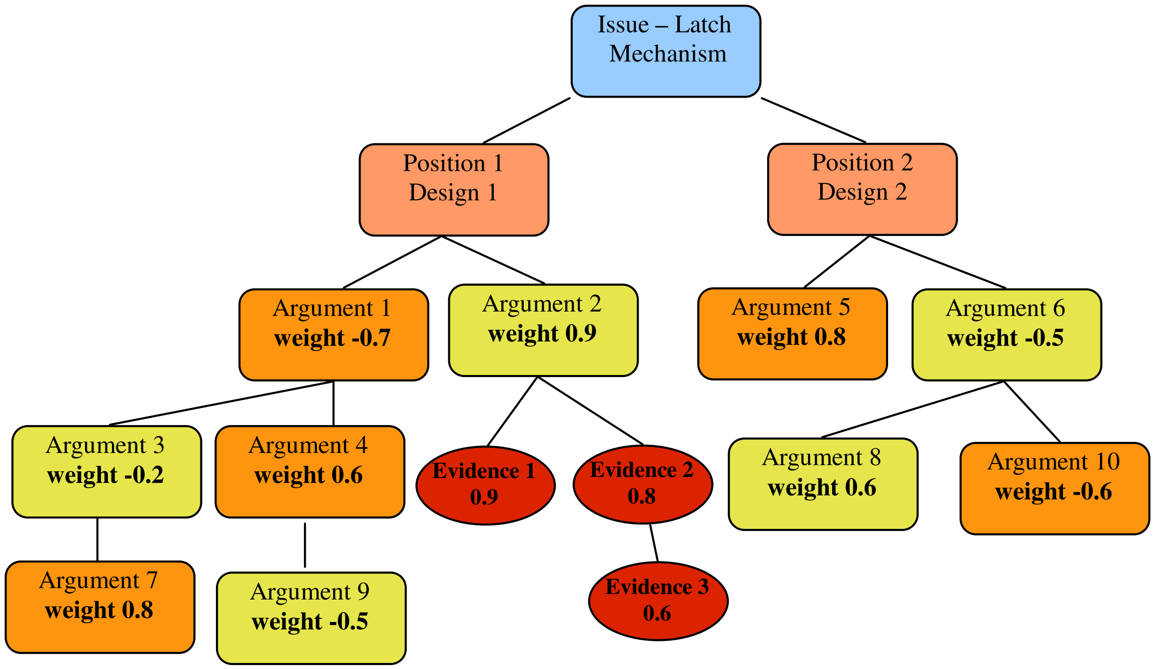

Figure 7. Argumentation Tree for Solar Car Example

Argument 1 – The pin aligning will be a problem
Argument 2 – Design 1 is simpler and cost effective
Argument 3 – It is feasible to design a pin aligning and 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 thickness and that 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 design, then aligning will not be a problem
Argument 10 – Thickness can be optimized using FEA and giving it a high safely factor

Evidence 1 – Cost of cylinder < Cost of Cubes
Evidence 2 – Machining for design 2 takes more resources
Evidence 3 – Time of production is proportional to cost of production

5. AN APPLICATION EXAMPLE

To illustrate the implementation of evidences, we have enhanced the argumentation network that was built for the design of a latch for the Solar Car team of the Missouri University of Science and Technology (previously University of Missouri – Rolla) [1]. The argumentation tree with evidences is shown in figure 7 and the design alternatives are shown in figure 8.

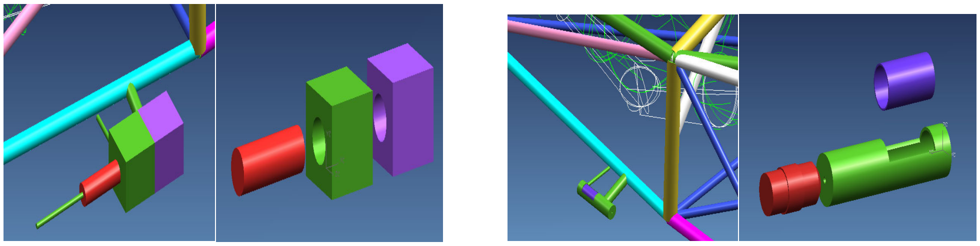

Figure 8. Solar Car Design 1 and Design 2

We need to find the combined weight of the evidences and then find the effect of this on the weight of the associated argument. To achieve this, first the weight of Evidence 3 is propagated to its higher level and the combination of the weights of Evidence 2 and Evidence 3 is calculated using the fuzzy heuristics rules and the membership functions shown in figure 3 and 4, respectively.

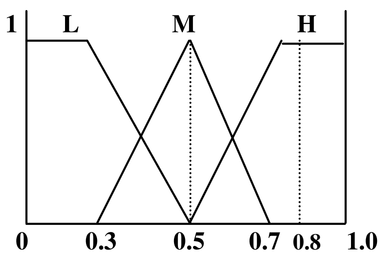

Figure 9. Membership Value for Evidence Input

The fuzzy membership values for Evidence 2 and Evidence 3 are calculated as shown in figure 9.

$E_H(0.5) = 0.0$ $E_H(0.8) = 1$
$E_M(0.5) = 1$ $E_M(0.8) = 0.0$
$E_L(0.5) = 0.0$ $E_L(0.8) = 0.0$

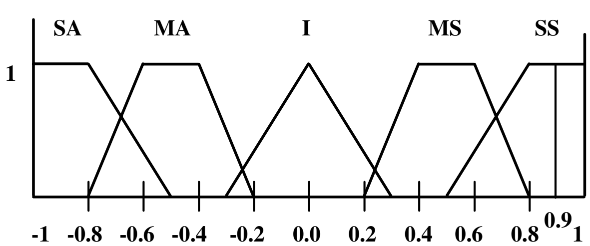

Figure 10. Membership Value for Argument Input

When we provide these as the input to the fuzzy rules in the Association Matrix in figure 3, there is only one non-zero output corresponding to the inputs

$P_M(0.5)$ and $P_H(0.8)$:
$w1 = \min [P_M(0.5) , P_H(0.8)]$
$= 1$

The output variable also has fuzzy sets associated with it i.e. H, M and L, and these have been assigned particular weights as H=0.9, M=0.5, L=0.3. The updated weight of Evidence 2 is calculated as:
$p2 = (w1 * H) / w1$
$= 0.9$

Now, since Evidence 1 and 2 are at the same level, we combine them using the Dempster's rule.
Output = (p1 * p2) / Normalizing factor
Normalizing factor = 1 – [(1-p1) * (1-p2)]
= 1 – [0.1 * 0.1]
= 0.99
output = 0.9 * 0.9 / 0.99
= 0.81

This combined effect of the evidences is then used to re-assess the associated argument i.e. Argument 2. The weights of Argument 2 and the combined weight of evidences are used as input to the corresponding fuzzy membership rules as shown in figures 9 and 10.

$F_{SS}(0.9) = 1$ $E_H(0.81) = 1$
$F_{MS}(0.9) = 0.0$ $E_M(0.81) = 0.0$
$F_I(0.9) = 0.0$ $E_L(0.81) = 0.0$
$F_{MA}(0.9) = 0.0$
$F_{SA}(0.9) = 0.0$

The only non-zero output obtained when these values are given to the fuzzy rules shown in figure 5 is

$$w2 = \min [E_H(0.81), F_{SS}(0.9)] = \min[1,1] = 1$$

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:

$$output = (w2 * SS) / w2 = 1$$

The weight of Argument 2 has increased after re-assessing it using the evidences that support it.

It should be noted that there is no restrictions on the number of evidences and the number of levels for the evidences in the argumentation network. We demonstrate the calculations for only one argument to keep the example simple. Further calculations will be carried out as earlier [1,2].

6. CONCLUSION

The main contribution of this paper is to provide the means for the participants to present any evidences that they may have, to support their arguments, in a computational argumentation network for intelligent web based collaborative engineering design system. The incorporation of evidences into the argumentation network has increased the efficiency of its conflict resolution capability. The argumentation process is more objective and is closer to the real world scenario of collaborative engineering design.

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