Intelligent Computational Argumentation for Evaluating Performance Scores in Multi-Criteria Decision Making

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ABSTRACT

Multi-Criteria decision making (MCDM), is a discipline aimed at assisting multiple stakeholders in contemplating a decision paradigm in an uncertain environment. The decision analysis to be performed involves numerous alternative positions assessed under varied criteria. A performance score is assigned for each alternative in terms of every criterion and it represents satisfaction of the criteria by that alternative. In real applications, performance scores are sometimes hard to determine and they are often subjective. We have developed an intelligent computational argumentation approach for dealing with the problem of uncertainty in resolving the subjective scores. In this approach, an argumentation tree is developed to assess a performance score for an alternative under a criterion. The argumentation takes into consideration the strength of an argument i.e. the degree of support or attack for that argument, and priorities of stakeholders. A set of fuzzy argumentation rules in a fuzzy association matrix is used to assess the indirect impact of an argument on alternatives. Aggregation of strengths of supporting and attacking; direct and indirect arguments represents a performance score of an alternative for a criterion in the decision making domain. A decision making case study for developing a mine detection simulator is used to illustrate the method.

1. INTRODUCTION

Multi-Criteria decision making techniques and models assist in the process of searching for decisions which best satisfy a magnitude of conflicting objectives in an absolute or an uncertain environment. Criterion outcomes for decision alternatives are represented through a performance chart, also called a decision matrix. The decision matrix contains performance scores of different alternatives, which represent their satisfactions for different criteria. The quality of decision is directly related to that of the performance scores. Performance scores are sometimes hard to determine. There is a wide range of different opinions about their values from different stakeholders and they might become controversial in these situations. They need an in depth analysis of different views and concerns of the stakeholders. As an example, consider a decision problem in which we have three car models from which we need to find the most favorable model in terms of cost, mileage and looks. While it is easy to find performance scores of a car model for cost and mileage, the quantitative evaluation of car models under the third criteria looks is difficult since different stakeholders may have different views about the looks of a car. A consensus may not be easily achieved in this case and a more rigorous approach is needed to find these objective scores.

To deal with the issue of uncertainty in the evaluation of performance scores, many methods make use of linguistic variables in fuzzy logic [9]. Several fuzzy logic based multi-criteria decision making methods are developed using linguistic variables for representing performance scores. They either aid in finding the most favorable alternative from among a set of various alternatives as illustrated in [4] [16] or they determine the alternative with the nearest match to an ideal solution [17]. However, these methods do not resolve the issue; that different stakeholders have different opinions about a performance score and do not help stakeholders to give objective evaluation of performance scores. Actually, many scores given by stakeholders may not be justifiable. This is why stakeholders need to provide rationales for their performance scores. In this paper, we propose to use intelligent argumentation to capture rationale of performance scores from stakeholders.

Intelligent Computational Argumentation is an effective technique for quantifying and measuring subjective factors involved in multi-criteria decision making because it stresses the need for reaching conclusions through logical reasoning. Argumentation based decision making allows stakeholders to provide arguments and justifications as a part of decision process, which in turn increases the speed of agreements being reached. Arguments are intended to support or attack other arguments or decision alternatives. Indeed, an argumentation based approach for collaborative decision making has the advantage of letting a stakeholder specify his views and beliefs along with reasons supporting the same. These reasons may lead their receivers to change their preferences. Consequently, an agreement may be more easily reached with
such approaches, when in other approaches (where stakeholder’s preferences are fixed) consensus may be more difficult to achieve.

2. RELATED WORK
For the purpose of this research, two paradigms had to be reviewed. Firstly, the existing techniques for the evaluation of subjective scores in Multi-Criteria decision making had to be studied. Secondly, various argumentation approaches for decision making developed so far had to be reviewed. The following sections provide some insight into the work already done in this regard.

Multi-Criteria decision making paradigm has been supported by many mathematical models in the past. These models evaluate performance scores for alternatives with respect to different criteria. Tsaur, Chang and Yen [16] use the fuzzy MCDM framework for evaluating airline service quality. Their implementation integrates the use of Analytic Hierarchy process (AHP) for evaluating the weights of criteria and fuzzy theory for finding out the performance scores. Wang and Lee [17] develop a fuzzy TOPSIS (Technique for Order preference by Similarity to Ideal Situation) approach based on subjective and Objective weights. They extend the Shannon’s entropy method to measure weights in MCDM. Chen, Tzeng and Ding [4] also make use of fuzzy MCDM approach to ‘Select a service provider’.

Philosopher Stephen Toulmin developed a very influential model for argumentation that has guided the development of software tools and systems intended to support the detection and resolution of conflicts in many knowledge domains. Amgoud and Prade [1] extended the argumentation framework to define mathematical models for epistemic and practical arguments. gIBIS (graphical IBIS), represents the design dialog as a graph [5]. While being capable of representing issues, positions, and arguments, gIBIS did not support representation of goals (requirements) and outcomes. IBE [8] extended gIBIS by integrating a document editor. HERMES [14] is a system that aids decision makers to reach a decision by structuring arguments and evidences together in a hierarchy. HERMES is a collaborative system which allows a real time decision making environment for participation among multiple stakeholders.

3. INTELLIGENT COMPUTATIONAL ARGUMENTATION SYSTEM
We have previously developed an intelligent computational argumentation system that allows stakeholders to determine the concerning issue, enumerate the available alternatives, and specify the arguments for those alternatives. The issue signifies a point, matter, or dispute, the decision of which is of special importance to the stakeholders. Alternative positions represent possible choices for dealing with the issue. An argument symbolizes a statement, reason, or fact for or against another argument or an alternative. The decision to be made can also be referred to as ‘Strategic Decision’.

3.1. Background
We have developed an intelligent collaborative engineering design system based on argumentation [11]. The argumentation structure is organized as a weighted directed graph also called a dialog graph [5]. The node denoted by circle is a Position or an Alternative and the nodes denoted by rectangles are Arguments. Arrows depict relationship either between two argument nodes or between an argument node and position. The relationship can be either an Attack or a Support. The strength of an argument is realized by the weight assigned to it. This weight symbolizes the degree of attack or support to an argument or position. The weight value is real number between -1 and 1. A positive weight value implies support and a negative weight value expresses attack. A weight of zero exhibits indecision. For the purpose of implementing the methodology in our current system, we let the stakeholders decide the score of an argument by discussions and reaching a general agreement. Strengths of arguments are viewed as a fuzzy set and are represented using a set of five linguistic labels. We use Strong Support, Medium Support, Indecisive, Medium Attack and Strong Attack as our linguistic labels.

A fuzzy associative matrix is developed and used alongside a fuzzy inference engine [11], which deal with reducing arguments to a single level and incorporating priority based reassessment for weights of an argument. The two approaches have been discussed in the following sections.

4. ARGUMENTATION BASED PERFORMANCE SCORE EVALUATION IN MULTI CRITERIA DECISION MAKING
Argumentation can be exclusively used for evaluating those performance scores in a multi criteria decision framework for which the objective interpretation is debatable among various stakeholders. These scores are controversial in nature and require deep analysis and rigorous discussions before they can be developed into a quantifiable value. Argumentation between stakeholders provides a logical way to figure out these subjective performance scores and the scores thus obtained represent a consensus.

4.1. Argumentation Framework For Evaluating Performance Scores
The argumentation framework for multi criteria decision making involves multiple stakeholders who establish an issue to be dealt with. Issue here symbolizes a point, the decision of which determines a matter. The issue serves as a decision problem for which various considerations are laid. The Stakeholders decide the criteria set upon which the alternatives are to be analyzed. The alternative positions are evaluated against the entire criteria set and their respective performance scores are given in the decision matrix. The argumentation framework for evaluating performance scores is illustrated in figure 1. The rectangle boxes describe the objects involved in the decision making framework whereas the tilted
rectangle boxes show the input and output associated with the system. The diamond shaped box shows the possible branching condition and the arrows exhibit the possible transition between various objects.

As can be deduced from the figure, we can make use of the argumentation system whenever the stakeholders cannot reach a consensus in deciding the performance scores. Every alternative is scored against criteria in the decision matrix. The arguments are entered in to the system by the stakeholders target a specific criterion for an alternative. The argumentation input itself consists of four inputs i.e. the name of the stake holder, the argument specification, the weight of the argument and the priority of the stakeholder. The name of the stake holder specifies the identity of the person specifying the argument. The argument is a sentence in English language which portrays the views and opinions of the stakeholder. The weight of the argument represents the degree of attack or support of that argument for that criterion.

4.2. Multi-Criteria Argumentation Tree Structure

Table 1 shows a sample decision matrix in which various alternatives are evaluated against different criterion. The scores specified in the decision matrix can be either ‘Easily Determined’ or ‘Controversial’. Figure 2 shows argumentation tree that will be developed for evaluation of subjective scores for the decision matrix in Table 1. Every criterion in Table 1 has an alternative as a child node. A detailed argumentation tree is developed for this alternative. In this way, the arguments are stated targeting this very criterion. This pin-points the arguments being stated to the highlighted matter and can extract the finer details of the concerning issue.

Table 1. Sample Decision Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Criteria2</th>
<th>Criteria3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt1</td>
<td>Easily Determined</td>
<td>Controversial</td>
</tr>
<tr>
<td>Alt2</td>
<td>Easily Determined</td>
<td>Controversial</td>
</tr>
<tr>
<td>Alt3</td>
<td>Controversial</td>
<td>Easily Determined</td>
</tr>
</tbody>
</table>

Using the above sample tree approach, we can evaluate the performance score of every alternative using the techniques of fuzzy association matrix to derive the impact of indirect arguments and aggregating the scores derived from the argumentation sub-tree with the weight of the criteria to derive the performance scores in the decision matrix.

5. CASE STUDY

As a part of our investigation, we took a project which was being implemented at the Mechanical and Aerospace Engineering Department of Missouri University of Science and Technology, Rolla. The project served as an ideal platform for us to test our proposed technique because the issue involved a decision problem which was under review of concerned research team. The issue had certain evaluation criteria which were laid down by the team members themselves. Every criterion in the criterion set had a favorability factor or weight which represented the role that criteria played in deciding the winning alternative. The nature
of the issue involved selecting the most favorable alternative from the set of underlined alternatives.

5.1. Description

The artifacts presented at the time of decision making were; the issue, the criterion set, a set of alternatives and concerned stakeholders. The subsections describe how and why the artifacts were important for decision making.

The issue deals with selecting a suitable software platform for developing a Mine Detection Training Software. The development of mine detection training tool is a research project supported by the US army. The project deals with simulating the real world conditions while detecting mines; into a system which could be used for training purposes. The stakeholders involved in the decision process are two students from the ‘Mechanical and Aerospace Engineering department’. Another stakeholder is a ‘Computer Science’ student responsible for developing the software tool. Two professors, one from Computer Science and another from Mechanical Engineering department act as stakeholders responsible for overlooking the overall software development.

As stated earlier, criterion is the attribute for which favorability of an alternative is calculated. The criterion set defined for this case study comprises of Reusability, Meeting Operational Requirements, and Meeting Project Deadline. By reusability, we mean, the amount of reuse of different functionalities that can be achieved from the previously developed system on Mine detection training tool. Meeting operational requirements implies how effectively a desired operational capability can be satisfied by an alternative. Meeting project deadline stresses on the fact, whether the project requirements can be satisfactorily achieved within the stipulated deadline which in our case was around one year.

To resolve the concerned issue, the stakeholders decided to choose Adobe Director, Adobe Flash, Open GL as the three possible alternatives.

Figure 3 summarizes the project and its three alternatives positions available. The criteria weights were calculate using the Analytic Hierarchy Process (AHP) and were as follows:-
- Reusability- 0.193,
- Meeting Operational Requirements- 0.724
- Meeting Project Deadline- 0.083

5.2. Argumentation Tree

We develop argumentation tree for each and every alternative separately. We present three figures, where each figure represents the argumentation hierarchy for one alternative derived during the case study. Rectangular boxes represent the alternatives with the name of the alternative under it. Ovals represent the criteria with their description. The arguments are specified by labels ‘A’, ‘B’, ‘C’ for alternative “Adobe flash”, “Adobe Director” and “Open GL” respectively. The box on left shows the weight of the argument whereas the box on right shows the priority of the stakeholder who specifies the argument. Once the argument has been specified, the user enters its weight. We first reassess the weights of the arguments using priority reassessment discussed in [10].Then using the techniques specified in [11], we reduce the arguments to a single level. Finally, the weighted summation of the arguments with the criteria weights helps us evaluate the final weights for the decision matrix. It is important to note here that, the aggregation method used for calculating the favorability is a weighted summation.

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Figure 3. Mine Detection System Along With Three Alternatives

Figure 4. Argumentation Tree For Adobe Flash
A1-The current system in flash does not have the functionality of dynamic allocation of particles like mine or clutter. It places them randomly.
A1.1-That is not of much importance because it still gives a new position to mine and clutter particles.
A2-Current system in flash has faster response time as compared to system in Adobe Director.
A3-The current system doesn't satisfy many of the features required for the new system like database.

A4-Adobe Flash cannot communicate with database.
A4.1-Flash doesn't support database but database support is very important and critical.
A4.1.1-The system should be able to generate evaluation reports for trainee based on previous records stored in the database.
A5-Flash doesn't create sound clips.
A5.1-We don't need sound creating features as the system has to generate sound. We can play externally recorded sound files using Adobe Flash
A6-Flash can provide good visual effects as compared to Adobe Director
A7-The developer has good knowledge in development using Flash so the system can be developed quickly
B1-We could reuse the system already developed for sound generation, as it is developed using Adobe Audition for analysis which is somehow related to Adobe Director
B1.1-The current system is better synthesized in terms of sound production and the sound produced is also instantaneous rather than discrete
B1.2-That current system has certain performance issues like slow response time
B1.3- The current system in Adobe Director has the feature of producing dynamic coloring scheme on approaching a mine. This kind of scheme is highly preferable and is not present in Adobe Flash system
B2-Adobe Director can provide more functionality as compared to the current flash system. E.g. Multiple sounds while detecting mines.
B2.1-Adobe Director can provide better visual effects as compared to flash e.g. in case of GUI’s.
B2.2- A modified version of the current system in flash can also provide the same functionality
B2.2.1-We cannot integrate code developed in other platforms with Flash, but Flash can be integrated in Adobe Director
B3-The interface provided by flash is not professional enough. It is too simple and straightforward for doing more things in future.
B4- Easily available plug-ins can help integrate the tracking system developed in C# with Adobe Director.
B4.1-Code developed in Open GL/AL can also be integrated using Adobe Director using suitable stubs.
B5- A new sound recognition algorithm is being developed in Adobe Audition which can be integrated with Adobe Director but not with Open GL or Flash (Evidence supported)
B6-If the current system is reused; the project deadline can be met easily.
B7-The developer has very little experience in development using Adobe Director.
B7.1-The developer can take help from the already developed system in Adobe Director.
C1-The tracking software already developed is coded in C#/NX5. We could reuse that and develop our system in Open GL/AL
C1.1-Open GL has C# libraries which can be used to develop the system.
C2-Because the platform used is for high end application development, it can provide good GUI and database support.

C2.1-Open GL/AL can help us generate dynamic surfaces formine detection and training which the original system in flash does not have.

C4-Open GL does not support connectivity with Adobe Audition. Adobe Audition is required for creating sound recognition algorithm.

C3-Open GL does not support connectivity with Adobe Audition. Adobe Audition is required for creating sound recognition algorithm.

C4-The time taken for developing the project using open GL will be comparatively more as the whole system would have to be developed from scratch.

C4.1-If Open GL has support for C# libraries, and then the system could be developed faster as developer is quite familiar with programming languages like C#.

C4.2-Open GL has excellent documentation that could help the developer learn the platform with ease.

C4.3-Developer has very little experience in working with Open GL platform.

For our case study, alternative B i.e. Adobe Director was the most favorable alternative amongst all the three. It catered to the reusability criteria quite well and aimed at meeting most of the desired operational requirements for the system.

6. CONCLUSION & FUTURE WORK
The main contribution of this paper is to develop an approach for evaluating performance scores in Multi-Criteria decision making using an intelligent computational argumentation network. The evaluation process requires us to identify performance scores in multi criteria decision making which are not obtained objectively and quantify the same by providing a strong rationale. In this way, deeper analysis can be achieved in reducing the uncertainty problem involved in Multi Criteria decision paradigm. As a part of our future work, we are conducting a large scale empirical analysis of the argumentation system to validate its effectiveness.

7. ACKNOWLEDGMENTS
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REFERENCES


