Multi-attribute Decision Making for Threat Analysis

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Abstract— In previous work, we have proposed an approach to automatically select information sources (such as sensors) to improve a threat analysis process based on a Bayesian network (BN). However, all relevant information for selecting information sources cannot be represented and used effectively in the BN. In particular, the implicit knowledge of a decision maker is both difficult to express and integrate in the BN. Multi-attribute decision making (MADM) is a way to simultaneously deal with multiple aspect of a decision problem. In the current work, we investigate how to use MADM to consider the expert knowledge of the decision maker, along with the suggestions by the BN.

I. Introduction And Background

At the Swedish Defence Research Agency, a situation and threat analysis support tool, Impactorium, is being developed, which helps an analyst to model, structure, fuse and visualize information. In the tool, an incoming request for information concerning a potential threat can, if complex, be turned into a detailed problem decomposition of sub-problems (that is, where sub-problems can be answered by utilizing information resources). The problem decomposition is represented with a Bayesian network (BN). By utilizing information sources to resolve sub-problems by acquiring new information, the understanding of the urgency of the threat can be better improved.

The goal of information acquisition is, in our approach, to improve the belief estimate of a threat variable in the BN. This is accomplished by assigning resources to observe other variables. In previous work [1], we proposed an information acquisition mechanism which optimizes the expected belief estimate improvements while considering the results of possible resource assignments.

However, the optimization of resource usage previously proposed is focused on acquiring the most useful information, but is ignorant of the context of the resource usage which the decision maker may possess knowledge of, including for instance the cost of using resources, the risk of losing resources, and varying complexity of using resources.

Multi-attribute decision making (MADM) methods allow the decision maker to consider multiple attributes or aspects of the decision problem. Each attribute, e.g., cost or the Bayesian network-based mechanism, results in a ranking of possible resource assignments. The rankings are weighed and combined into a joint ranking, where the top ranked resource assignment should be implemented.

For comparison, we use three different MADM methods: TOPSIS and SAW and a mixture of both. We also use two different weighing methods: AHP and entropy.

SAW (Simple additive weighting) is a common MADM technique which produces a weighted average of proposed rankings from which a final ranking is calculated.

TOPSIS (Technique for order preference by similarity to the ideal solution) ranks weighted alternatives based on the idea that the best alternative should have the shortest distance from a positive ideal solution (the best possible) and the longest distance from negative ideal solution (the worst possible).

Neither SAW nor TOPSIS specify which weighting approach should be used. In this work, we study two: entropy and AHP. The entropy approach gives more weight the attributes for which the values of the resource assignments vary greatly. For instance, if the attribute in question is cost and the cost for each resource assignment is identical (i.e., no variation in cost value), the weight will be low. AHP (Analytical Hierarchy Process) finds weights for attributes by requiring the decision maker to make pair-wise comparisons of all attributes.

II. Results

In addition to the resource assignment rankings inferred from the BN representation of the threat analysis problem, nine decision attributes were identified including cost (of using resources), resource availability (can an assignment be implemented?), and possibility of failure (the risk that an assignment will fail to make the requested observation) [2].

In our study, we compare five different approaches: SAW and TOPSIS (each with the two different weightings entropy and AHP) and a mixture of all four.

The obtained final ranking results from the five different techniques are very different as compared to ranking only based on the Bayesian network. This means that, by user interaction through MADM techniques, we could affect the final outcome the ranking of assignments.

Ideally, data from real decision making situations should be used to evaluate the results. Since that is not available, the correlation between the results of the five approaches is investigated for an example case, and the results show that the mixed method is the most stable one (because it is most similar to/correlated with the other approaches). Moreover, AHP appears more acceptable than entropy for weighting of attributes.

References

[1] R. Johansson, C. Mårtenson , “Information Acquisition Strategies for Bayesian Network-based Decision Support ” in Proceedings of the 13th International Conference on Information Fusion, 2010.
[2] A. Karami, Utilization and Comparison of Multi Attribute Decision Making Techniques to Rank Bayesian Network Options, Master thesis, University of Skövde, 2011.