An intelligent decision support system for decision making under uncertainty in distributed reasoning frameworks

Tina Comes[a] Claudine Conrado[b] Michael Hiete[a]
Michiel Kamermans[b] Gregor Pavlin[b] Niek Wijngaards[b] Frank Schultmann[a]

[a] *Institute for Industrial Production, Karlsruhe Institute of Technology (KIT),* www.kit.edu
[b] *D-CIS Lab / Thales Research & Technology Netherlands,* www.d-cis.nl

Abstract

This paper appeared at the ISCRAM 2010 [3] and presents an intelligent system facilitating better informed decision making under severe uncertainty, as often found in emergency management. The construction of decision-relevant scenarios, being plausible descriptions of a situation and its future development, is used as a rationale for collecting, organizing, filtering and processing information for decision making. The development of scenarios is geared to assessing decision alternatives, thus avoiding time-consuming analysis and processing of irrelevant information.
The scenarios are constructed in a distributed setting allowing for a flexible adaptation of reasoning (principles and processes) to the problem at hand and the information available. Each decision can be founded on a coherent set of scenarios, which was constructed using the best expertise available within a limited timeframe. Our theoretical framework is demonstrated in a distributed decision support system by orchestrating both automated systems and human experts into workflows tailored to each specific problem.

Results

Emergency management often involves *severe uncertainty*, i.e. situations in which a set of possible developments can be identified, but the likelihood of each element in the set can not be quantified [2]. In this paper, a framework is proposed to facilitate medium and longer term decision making under severe uncertainty by considering scenarios: descriptions of a situation and its possible future developments. Scenarios, being plausible, coherent and consistent are easily understandable and help overcoming cognitive biases [8]. To support decision making taking into account multiple goals and scenarios, techniques from Multi-Criteria Decision Analysis (MCDA) are used [4].

MCDA has been frequently proven useful in long(er) term emergency management as it facilitates decision making in complex situations [6]. In strategic emergency management, the decision making task is usually modelled as a choice among a small number of alternatives, making Multi-Attribute Decision Making (MADM) our preferred technique [1]. A hierarchically structured attribute tree allowing for the evaluation of alternatives is elicited from the decision makers. This structure breaks down overall-objectives (criteria) into various levels of sub-criteria and finally into measurable attributes. MADM methods, which rely on deterministic or probabilistic models, have drawbacks when applied under severe uncertainty.

This paper introduces a novel approach for the construction of scenarios based on MADM. Scenario construction is enabled in a distributed manner by using Causal Maps (CMs) [5], which represent the interdependencies between the variables relevant in a specific decision problem. Contrarily to expert systems, our framework does not encode the knowledge on how this is achieved functionally. Rather, it specifies experts (human or automated) responsible for determining the variables' possible values. Each partaking expert has associated the service(s) he/she/it can perform, describing which output information is based on what input information [7]. In this manner, our framework allows the experts to specify the variables that are *relevant* for their task and helps reducing information overload of the experts. The responsible expert can freely choose the methods to determine the (output) variable's value. Taking into

account the dependencies between the variables ensures the consistency and coherence of each scenario to a reasonable level (given that time and availability of experts is bounded). The problem of missing acceptance and trust in anonymous systems is circumvented as the scenarios are established by (human and/or artificial) experts. Altogether, our approach results in overall adaptive distributed problem solving.

Using the MADM attribute tree as starting point for scenario construction ensures that only information relevant for the decision at hand is processed. Experts can employ deterministic, probabilistic and fuzzy uncertainties as usual. Whenever experts consider multiple values to express severe uncertainty for their variables, a corresponding number of scenarios is constructed. (Otherwise adding, their single value continues the current scenario.) Eventually a set of scenarios captures uncertainty. Scenario combinatorics management is facilitated by selecting and processing only scenarios that are (sufficiently) distinguishable with respect to their values for the attributes.

To come to a robust recommendation, a twofold approach is proposed. First, a detailed analysis of all scenarios is performed, after which the scenarios with the worst, the best and a medium performance for each decision alternative are presented to the decision makers. Second, an aggregated overall performance, which encompasses the evaluations of all scenarios for each alternative, allows for overcoming overconfidence in a small range of scenarios. Decision makers can gain deeper insights into the decision situation compared to standard methods from both scenario-based reasoning and MCDA.

Our approach and its application in long(er) term emergency management are developed in close collaboration with emergency management authorities, including the Danish Emergency Management Agency (DEMA). Our research aims at tailoring this approach so that it fits best the needs of decision makers and experts.

Acknowledgements

This research has been conducted in the Diadem project, funded by the European Union under the Information and Communication Technologies (ICT) theme of the 7th Framework Programme for R&D, ref. no: 224318, www.ist-diadem.eu.

References

[1] V. Belton and T. Stewart. *Multiple Criteria Decision Analysis. An Integrated Approach*, Kluwer Academic Publishers, Boston, 2002.

[2] Y. Ben-Haim.. Robust rationality and decisions under severe uncertainty. *Journal of the Franklin Institute*, 337(2-3):171-199, 2000.

[3] T. Comes, C. Conrado, M. Hiete, M. Kamermans, G. Pavlin, and N. Wijngaards. An intelligent decision support system for decision making under uncertainty in distributed reasoning frameworks. In S. French, B. Tomaszewski and C. Zobel, editors, *Proc. of the 7th Int. Conference on Information Systems for Crisis Response and Management, ISCRAM2010*, www.iscram.org, paper 134, 2010.

[4] T. Comes, M. Hiete, N. Wijngaards and M. Kempen. Integrating Scenario-Based Reasoning into Multi-Criteria Decision Analysis. In: J. Landgren and S. Jul, editors, *Proc. of the 6th International Conference on Information Systems for Crisis Response and Management, ISCRAM2009*, 2009.

[5] G. Montibeller and V. Belton. Causal maps and the evaluation of decision options - a review. *Journal of the Operational Research Society*, 57():779-791, 2006.

[6] K. Papamichail and S. French. Design and evaluation of an intelligent decision support system for nuclear emergencies. *Decision Support Systems*, 41(1):84-111, 2005.

[7] G. Pavlin, M. Kamermans, and M. Scafes. Dynamic Process Integration Framework: Toward Efficient Information Processing in Complex Distributed Systems. *In Proc. of IDC 2009 - 3rd International Symposium on Intelligent Distributed Computing*, October 13-14, 2009,

[8] G. Wright and P. Goodwin,. Decision making and planning under low levels of predictability: Enhancing the scenario method. *International Journal of Forecasting*, 25(4):813-825, 2009.