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Information Acquisition for General Bayesian Networks with Uncertain Observations

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Abstract

In this work, we describe and evaluate an information acquisition mechanism for an intelligence analysis support system. The system uses a Bayesian network to structure intelligence requests, and the goal is to improve the belief estimate of a non-observable variable of interest based on uncertain observations.

1 Introduction

At the Swedish Defence Research Agency, we are developing an intelligence analysis support tool, *Impactorium*, which helps an intelligence analyst to model, structure, fuse and visualize information. In the tool, an incoming request for information can be turned into a detailed problem decomposition of sub-problems, which we represent using a Bayesian network (BN). However, even though the sub-problems (i.e., nodes in a BN) can be analyzed separately, the available information acquisition resources, used for observing nodes, are limited and shared. In addition, all observations are uncertain due to sensing imperfection.

The goal of information acquisition is here to improve the belief estimate of a non-observable variable of interest, i.e., the *hypothesis* variable. This is accomplished by assigning resources to other (observable) variables called *indicators*. If multiple resources are at a system's disposal, more than one resource may be used for one indicator (hence resulting in multiple observations on the same indicator). Thus, the information acquisition mechanism we propose optimizes the expected belief estimate improvements while considering the results of possible resource assignments.

2 Experiments and Analysis

Our proposed resource assignment strategy (`Hypent`) assigns the resources in such a way that the expected decrease in entropy of the hypothesis variable is maximized. We compare Hypent to a few different strategies to select a resource assignment: `Rand`, `Ex-Greedy` and `Nx-Greedy`. `Rand` assigns resources randomly to the indicators. The latter two strategies assign all resources to the single indicator with the highest entropy and the set of indicators with the highest entropy, respectively.

In our initial experiments (Johansson and Mårtenson, 2010), we used a prototype BN consisting of a hypothesis variable and four indicator variables. The performance metric used is a distance metric between the estimated probability of the hypothesis variable and the best possible one (where the true state of all indicators are known). We compare the performance of the four strategies when using one to four resources and varying the observation certainty from 50% to 95%. The strategies turn out to have similar performance from 55% to 70%, but for greater observation certainty, `Hypent` dominates the others. The disadvantage of the Hypent strategy is its comparatively long execution time (Johansson and Mårtenson, 2010).

The previous work provided a proof-of-concept indicating that `Hypent` has potential by testing it on a pre-specified prototype BN. In the current work, we make a more thorough analysis by evaluating general BNs as well as discuss pertinent design options, e.g., how to deal with multiple uncertain observations, alternative performance metrics, and related work.

3 Acknowledgement

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References

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