Report on the Dissertation Thesis

"Adaptive Testing using Bayesian Networks"

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Introduction

The goal of this short report is to provide an evaluation of the dissertation thesis, titled "Adaptive Testing using Bayesian Networks", by Ph.D. candidate Martin Plajner. The thesis is composed of a portfolio of nine scientific papers authored by the candidate, mostly co-authored with his advisor Jirka Vomlel. The portfolio is provided together with a twenty-page introduction outlining the main ideas and achievements detailed in the publications. The overall work is a nice combination of theoretical ideas, practical application of them to an important and challenging problem, and empirical validation on real scenarios and data. I think the work is mature for a public defense leading to the successful conclusion of the Ph.D. studies of the candidate. In the report we discuss with more detail the scientific relevance of this work, its relation with the state of the art in the field, the quality and strengths of the methods adopted, and the major goals achieved.

Topic Relevance

The thesis is entirely dedicated to the development of techniques for adaptive testing technologies based on Bayesian networks. The candidate's supervisor wrote a number of seminal papers on this topic, that is definitely not new in AI and educational research. Yet, the increasing importance of e-learning technologies, together with the rising attention to explainability features for modern AI technologies are making such a line of research extremely important and promising for future developments.

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Compared to, seemingly, more popular models such as neural networks, the advantages of probabilistic graphical models such as Bayesian network are clearly advocated by the candidate and new directions for an optimal exploitation of these tools derived. Having all of that in mind, the dissertation might be safely regarded as state-of-the-art research. In particular, the fundamental notion of *monotonicity* when learning the parameters of a Bayesian network in this context, considered here for ordinal discrete variables, seems to be of crucial importance for a better elicitation of adaptive models leading to more accurate student evaluations by Bayesian tools.

Proposed Methods and Achieved Goals

In the first part of his Ph.D. studies the candidate considered the practical, but not trivial, issue of gathering real data for such research studies and comparing the proposed approach based on Bayesian networks against mainstream approaches such as *Item Response theory* (IRT) and also neural network approaches. Not surprisingly, Bayesian networks have been proved by the candidate to be able to properly mix expert knowledge and statistical information in a better way than data-greedy models such as neural networks, while also providing more accurate results than simpler approaches such as IRT. Such an achievement represented an ideal starting point for a more original research pursued during the second part of the candidate Ph.D. studies. Exactly as for the first phase, such a second phase also involved the gathering of a second, this time very large, data set to be used for an extensive empirical evaluation of the proposed techniques. From a methodological point of view, the above introduce key concept of monotonicity has been first used to distinguish between models satisfying it, providing more reliable results, and the other ones. Such a from the other ones. Starting from this remark, the candidate developed a number of non-trivial EM-like procedures able to learn models providing monotonicity. The major contribution of this work is the emphasis of the role of monotonicity, something to be considered also for other domains not directly related to adaptive testing. I similarly see possible applications of the techniques for constrained optimization developed by the candidate in other domains. Even the empirical analyses included in the various publications are an important baseline for future studies in this area. The clear results about the potential of Bayesian networks compared to other methods is also an important achievement to be considered by researchers starting new investigations in the area.

Overall Evaluation

As already said in the introduction, we have an overall (very) positive opinion about the work of the candidate. The candidate has demonstrated to be able to master different aspects of the scientific research including the critical analysis of the existing technologies for a problem and their comparison, the development of new tools leading to better performances, the empirical validation on real-world data. I think **the candidate is ready to defend his work on a public Ph.D. defense**.

Finally, I would like to emphasize a number of open directions for future researches connected to the present work, this might include the use of continuous variables to model the skills for a better comparison against other models, the use of structural causal models for the implementation of stronger adaptive testing tools, the development of software tools available to the community for the easy implementation of adaptive tests, and the publication of the data used for his work in some open-access repository to improve the expansion of studies in this field.

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