Visualizing and Inspecting Bayesian Belief Models

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Abstract

Bayesian Belief Networks (BBNs) have become accepted and used widely to model uncertain reasoning and causal relationships. We have developed an interactive visualization tool (VisNet) that allows students and/or teachers to inspect BBNs. Using VisNet it is possible to experiment with concepts such as marginal probability, changes in probability, probability propagation and cause-effect relationships in BBNs using visualization techniques. ViSMod (Visualization of Bayesian Student Models), an extended version of VisNet, opens the internal representation of the student's knowledge to teachers and/or students interested in knowing more about the knowledge about them represented in the system. Both VisNet and ViSMod aim to support reflection processes in learning environments that rely on the use of Bayesian models.

Keywords: Interactive AI tools, Bayesian Belief Networks, Inspectable Student Models, and Bayesian Learner Models.

1. Introduction

Bayesian Belief Networks (BBNs) offer an intuitive mechanism to visualize causality and probabilities. Teacher and students from an introductory class on BBNs can benefit from an interactive tool that allows them to inspect any BBN as a part of a guided activity or an unsupervised one.

Concepts such as marginal probability, changes in probability, probability propagation and cause-effect relationships make more sense when they can be visualised using one or more visualization techniques. *VisNet* [Zapata-Rivera et al. 1999] lets teachers and students choose among visualization techniques such as temporal order, colour, size, proximity (closeness), link thickness, and animation to observe the effects of new evidence on a graphical representation of a BBN. Figure 1 shows a screenshot of VisNet.

By using VisNet it is possible to inspect simple and complex BBNs. For example, interesting observations can be made when one witnesses a continuous animation of the network. Using any of the available visualization techniques one can represent how probability propagation occurs in a simple network in which several causes affect a single node. A more complex network can be also inspected by focussing on a particular segment (e.g. zooming or scrolling) and trying different kinds of animation techniques such as step by step or continuous animation.

The students' reactions to changes in size, colour, and location of the nodes of a particular network can be channelled to have a profound impact in understanding the basic concepts of BBNs. Interestingly, we have asked ourselves what kinds of reactions can these tools generate on the students if the Bayesian model that is been inspected is the system's representation of the user's own cognitive state. In order to answer this question, Bayesian student models have been made available to students and teachers through the use of *ViSMod* [Greer et al., 1999, Zapata-Rivera & Greer 2000] (Visualization of Bayesian Student Models). ViSMod allows teachers and students to engage in a negotiated assessment of the student's knowledge where the Bayesian student model serves as basis for the discussion. Therefore, student modelling is seen as the result of a communication process that takes into account the system's, the teacher's and the student's point of view about different aspects of the student's learning process.

2. VisNet (Usability Study)

An initial usability study was conducted at the University of Saskatchewan. After a short explanation about cause-effect relationships and directed acyclic graphs (DAG), ten graduate students were asked to perform a sequence of tasks

to determine the efficacy of each of the visualization techniques. Some of the results found in this study are:

- Temporal order was chosen as an appropriate way to show cause-effect relationships; participants preferred size over colour to represent marginal probability.
- Combinations of techniques appear to be clearer than a single technique; participants chose size and colour as a good combination to represent marginal probability (size) and strength of a relationship (colour). For large networks, which are very sensitive to changes in size and position of the nodes, colour was chosen as a better alternative for representing marginal probability.
- Proximity of nodes proved to be an interesting and powerful way to show probability propagation and changes in probability.
- Finally, animation was useful for representing probability propagation; especially node by node animation, which was preferred because it shows both a possible sequence of Bayesian belief updating and probability propagation.

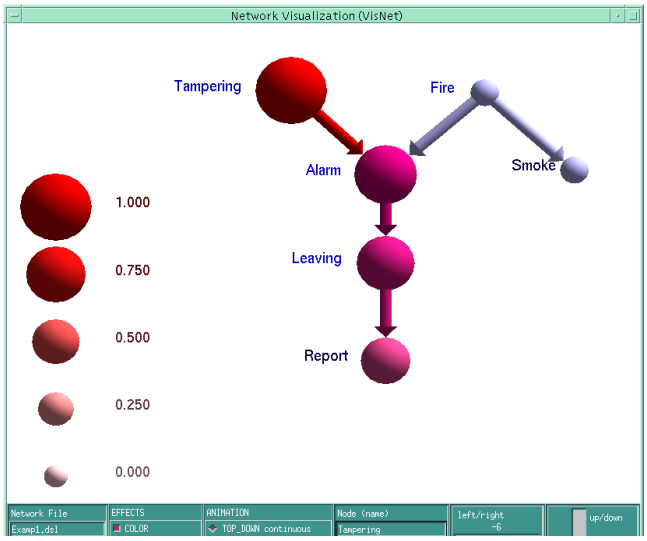

Figure 1. A screenshot of VisNet showing a popular Bayesian belief network. In this figure, size and colour are used to visualise the network after "Tampering" was observed.

3. ViSMod (Visualizing and Inspecting Bayesian Student Models)

ViSMod provides a flexible architecture in which students and teachers can create their own views of a student model by choosing nodes they want to inspect from the Bayesian network representing the student model.

By using their own views, teachers and students can select and visualize groups of nodes that are significant to them in a particular situation. For example, teachers may be interested in knowing how eager or helpful a student is, or how certain behaviour corresponds to student knowledge on a specific topic. On the other hand, students can visualize how their interests and claims are taken into account to assess their knowledge on a specific topic.

A graphical representation of student models might help teachers determine learning deficiencies on a specific topic for a student or group of students. Teachers may find this information useful when planning their teaching strategies or variations in their lesson plans. Figure 2 shows a screenshot of ViSMod. Both student beliefs and system beliefs have been associated to each of the concepts of the network. In addition, it is possible to visualise the effects of social aspects of learning on each of the concept nodes.

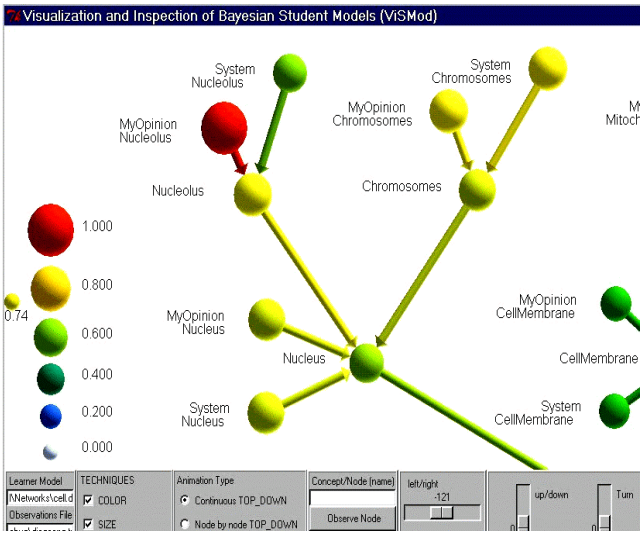

Figure 2. A screenshot of ViSMod showing a fragment of a Bayesian student model in the area of biology cell. It shows how students' and systems/teachers' opinions are taken into account to assess the overall belief of a student knowing a particular concept.

Some general characteristics of ViSMod are:

- ViSMod provides a graphical representation of the student model that makes it easier for students to understand Bayesian student models.
- ViSMod supports multiple views of the student model that makes it possible to inspect, modify and create interesting representations of the learning process.
- By allowing inspection of student models using VisNet's animation effects and the creation of what-if scenarios, ViSMod aims to support students' reflection, knowledge awareness, and refining of student models.
- Finally, ViSMod allows visualization of Bayesian student models at different levels of granularity and using several sources of evidence.

4. Supporting Negotiated Assessment and Reflection

Special interfaces have been designed to allow students and teachers to interact with the Bayesian student model. Students interacting with the model may realize what they really know and perhaps use this information to focus their learning process.

Students can agree or disagree with the information shown in the model. ViSMod aims to support a dialogue process between the student and the teacher based on the model which includes information about what the student thinks about his/her level of knowledge, the teacher's view of the student, and the system's view of the student. In addition, social aspects of learning have been included in the model in order to situate the model in a learning context that can influence the learning process directly or indirectly.

Figure 3 shows the interface students use to inspect/change their opinion about their level of knowledge on a particular concept. In this case, the node being inspected is *"MyOpinionNucleolus"*. The student believes that he/she knows this concept perfectly well. The student should explain why he/she believes so by writing the reasons in the textbox and checking any of the options that appear in the lower part of the window.

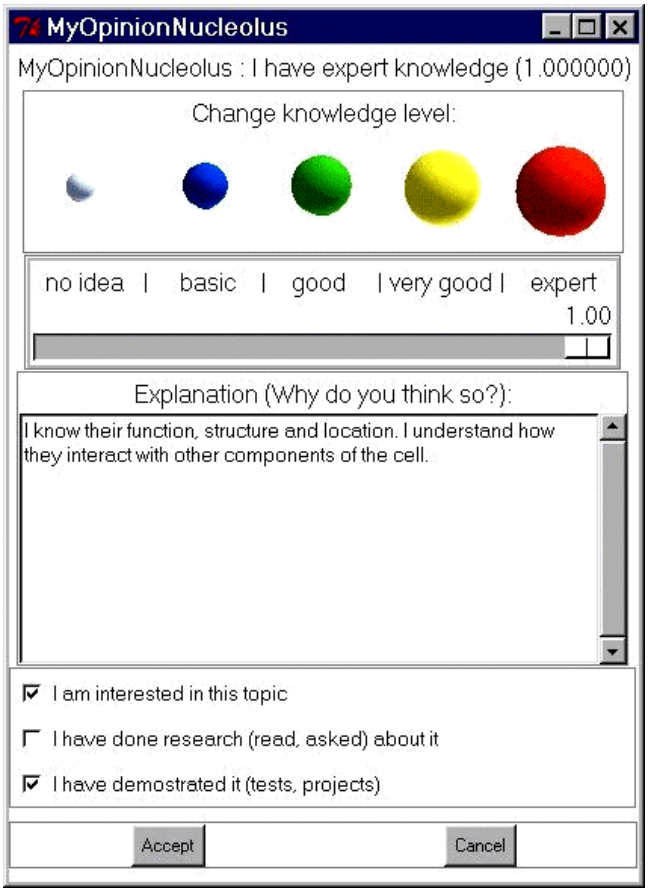

Figure 3. A screenshot of ViSMod showing a student's interface designed to help the student interact with and reflect upon the model.

5. Future Work

ViSMod will be tested in different settings. One of them is in a Colombian classroom with children working in a guided collaborative activity that involves the use of different kinds of educational software.

ViSMod will offer children the opportunity to inspect their own student model in consultation with the teacher. We hope that teachers will be able to understand how the models of students can be used as a guide to develop new activities and to assess students' skills in a more comprehensive and transparent manner.

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