Web-Based Bayesian Intelligent Tutoring Systems

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Abstract. The rapid development of the World Wide Web offers an opportunity to apply a large variety of artificial intelligence technologies in various practical applications. In this chapter, we provide a review of our recent work on developing a Web-based intelligent tutoring system for computer programming. The decision making process conducted in our intelligent system is guided by Bayesian networks, which are a proven framework for uncertainty management in artificial intelligence based on probability theory. Whereas many tutoring systems are static HTML Web pages of a class textbook or lecture notes, our intelligent system can help a student navigate through the online course materials, recommend learning goals, and generate appropriate reading sequences.

10.1 Introduction

Web-based education is currently an area of intense research and development. The benefits of Web-based education are clear: classroom independence, easy accessibility and greater flexibility [5]. Students control their own pace of study and do not depend on rigid classroom schedules. Thousands of Web-based courses and Web-based tutoring systems have been made available over the last five years [5][63]. Many Web-based tutoring systems, however, are unable to satisfy the heterogeneous needs of users [5][7]. These tutoring systems are static HTML Web pages, which act simply as copies of regular textbooks. This kind of tutoring system suffers from two major shortcomings, namely, it is neither interactive nor adaptive [5]. Many Web courses present the same learning materials to students with widely differing knowledge levels of the given subject. In fact, Brusilovsky and Maybury [6] explicitly state that an effective system must be robust enough to deal with various types of users. To resolve the traditional “one-size-fits-all” problem, it is necessary to develop systems with an ability to adapt their behavior to the goals, tasks, interests, and other features of individual users and groups of users.

In this chapter, we provide a review of our recent work [9][10][11] on developing a Bayesian Intelligent Tutoring System, called BITS. BITS can be used on stand-alone computers or as a Web-based application that delivers knowledge through the Internet. BITS is based on Bayesian networks [48] - a formal framework for uncertainty management in artificial intelligence and supports student learning. We describe the architecture of BITS and examine the role of each component in the system. In particular, we discuss how to employ Bayesian networks as an inference engine to guide the students’ learning.
processes. Moreover, we describe the features that allow BITS to be accessed via the Web. Beside Web-based tutoring systems, we also provide a comprehensive survey of related work involving Bayesian networks in various Web-based tasks.

There are two favourable features of BITS. Unlike the static tutoring systems mentioned above, BITS can assist a student in navigation through the online materials. More importantly, BITS can recommend learning goals, and generate appropriate reading sequences. For example, a student may want to learn “File I/O” without having to learn every concept discussed in the preceding materials. BITS can determine the minimum prerequisite knowledge needed in order to understand “File I/O” and display the links for these concepts in the correct learning sequence. In this way, one can address the problem of Web-based learners’ unproductive navigation, and refocus them on their study objectives by making the tutoring system adaptable to different types of learners. Thus, BITS is very useful to any work applying Bayesian networks as a model for developing adaptive Web-based learning systems for various courses. Our discussion is based on computer programming, since BITS was recently utilized in the initial computer programming course at the University of Regina.

This chapter is organized as follows. In Section 10.2, we review intelligent tutoring systems. We discuss Bayesian networks and probabilistic inference in Section 10.3. In Section 10.4, we describe the architecture of BITS, the role of each module in the system. In particular, we discuss BITS’s capability for adaptive guidance by applying the Bayesian network approach. The features that allow BITS to be accessed via the Web are provided in Section 10.5. In Section 10.6, related work is discussed. The conclusion is presented in Section 10.7.

10.2 Background Knowledge

Here, we review Intelligent Tutoring Systems. More specifically, we discuss motivations and desirable features when designing Intelligent Tutoring Systems. We then discuss the general framework of an Intelligent Tutoring System and the function for each component. Finally, we review three popular approaches applied in current Web-based Intelligent Tutoring Systems.

10.2.1 Intelligent Tutoring Systems

*Intelligent Tutoring Systems* (ITSs) form an advanced generation of traditional education systems instructing via computers, called *Computer Aided Instruction* [8]. In particular, ITSs are computer-based programs that present educational materials in a flexible and personalized way that is similar to one-to-one tutoring [5]. The basic underlying idea of ITSs is to realize that each student is unique. These systems can be used in the traditional educational setting or in distant learning courses, either operating on stand-alone computers or as applications that deliver knowledge through the Internet.

ITSs have been shown to be highly effective in increasing students’ performance and motivation levels compared with traditional instructional methods (e.g., [34], [55]). The emergence of the World Wide Web also increased the usefulness of such systems [57]. Their key feature is their ability to provide a user-adapted presentation of the teaching