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AN ADAPTIVE LEARNING, TECHNICAL INTELLIGENT TUTORING SYSTEM FOR SIGNAL-PARAMETRIC FAULT-TOLERANT SYSTEMS

In this paper, it is presented an intelligent tutoring system for signal-parametric fault-tolerant systems. The Technical Intellectual Tutoring System (TITUS) takes advantage of Bayesian networks (BNs), which are a formal framework for uncertainty management. It is discussed how it employs BNs as an inference engine to assess the students' mastery of knowledge and determine the proper pedagogical decisions for a productive learning process. In addition, it is described the architecture of TITUS and the role of each module in the system. TITUS has been tested and the experimental results are shown.

Keywords: *intelligent tutoring system, bayesian network, fault-tolerant system.*

Introduction

Intelligent tutoring systems (ITSs) are software programs that help and give support to the learning activity. They offer new ways for education, which can change the role of the human tutor or teacher, and enhance it.

These systems can be used in the normal education process or in distant learning courses as applications that deliver knowledge on standalone computers or over the internet

It is well known that students appear to learn more when personal tutoring is available; thus, a key feature that characterizes ITS from more traditional educational systems is its ability to interpret students actions to maintain an individual model of the student's reasoning and learning, also called as the students model.

This kind of interpretation, the adaptability and the assessing of students are very important features in an ITS that increases effectiveness on the teaching process. Assessment requires uncertainty reasoning and Bayesian Networks (BNs) are a very well spread and applied approach to uncertainty modeling [1-7].

This technique combines the rigorous probabilities formalism with a graphical representation and efficient inference mechanisms.

The Technical Intellectual Tutoring System (TITUS) employs an adaptive pedagogical model which uses BNs for assessing students individually [5-7]; this assessment is required for taking pedagogical actions in accordance of each student's performance. The curriculum in TITUShas been built in accordance of the signal-parametric approach for fault-tolerant systems [11].

The aim of this work is to develop and test an ITS in base of an adaptive pedagogical model that will guide, support and assist students in acquiring the necessary knowledge components for understanding the foundations of fault-tolerant systems under the signal-parametric approach for a gyroscopic sensors unit GSU.

1. General architecture of TITUS

In this section, we outline the major components of TITUS; its general architecture is given on Fig. 1.

TITUS obtains valuable information from the students, which is helpful to know what to teach, whom it teaches and how it teaches it. TITUS has been developed as a computer application; the complete lecture notes of the studying program have been included and can be accessed on demand.

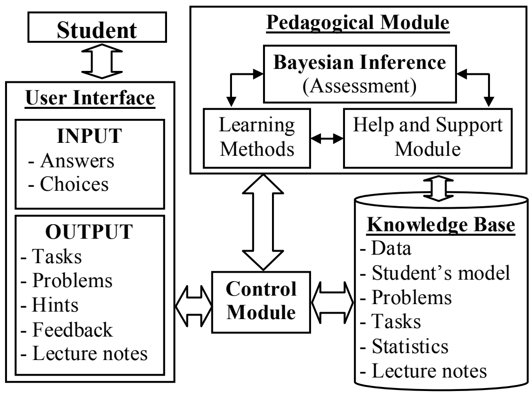

Fig. 1. General architecture of TITUS

The user interface is the environment where the student will execute his actions and attempts to solve different kinds of tasks and problems as well as it functions like a graphical support portal that can depict hints and feedbacks among other required information.

The control module is in charge to process and administrate the flow of information from and to the other blocks. The necessary pedagogical processes (outer loop and inner loop) [1-7] are involved with the learning methods block and the help and support module; here is where the pedagogical decisions or action are made in accordance to the answers of the tasks. The task analyzer; a part of the Bayesian inference block, constantly monitors the student's answers and return the proper support, i.e. hints, feedbacks, by means of the help and support module.

The knowledge base is constituted by the expert knowledge in the task domain and information that is saved while TITUS is being used by the students and required, updated and recycled as well. It also contains the complete set of knowledge components, lessons notes, tasks and problems that will be required on demand. The knowledge base records the complete state of the system as well as the student's performance, and that is how the system creates the student model.

The student model is a database that contains information about the student: the correct answers, wrong answers, attempts by task, time for answering, and other variables. This information is used to realize assessments of the student's, but also, it is used to determine the proper pedagogical actions and decisions to maintain a continuous and productive learning process; for instance, it needs to know when the student's competence exceeds the mastery threshold so it can advance the student to the next curriculum unit or difficult level, and BNs can manage this uncertainty [12].

2. Bayesian Inference

A key to aid the student to navigate through the task domain is the necessity to model the prior information he has and to keep track of his degree of mastery of each relevant knowledge component regarding to each task and BNs can help to realize that model [12, 13].

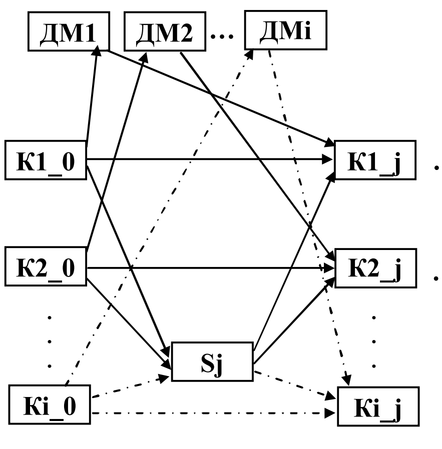

Fig. 2. Bayesian network general structure

A Bayesian network (BN) is built by nodes and directed links, where the nodes represent variables and the links represent conditional dependencies among them, a general structure of a BN applied in TITUS is depicted on Fig. 2. Let us use nodes to represent the mastery of knowledge components (Ki_j), and let each node have two values: mastered and unmastered.

Let P(Ki_j) denote the probability of mastery of the knowledge component i just after some student's answer (Sj). Let Ki_0 denote the prior probability of mastery of the knowledge component i before any answer has been done, and Ki_1 the probability of mastery after the first answer or step Sj.

Let ДМi nodes be diagnostic models that serve to monitor and influence in the posterior probabilities of each relevant knowledge component after every Sj, individually affecting posterior probabilities of degree of mastery for every knowledge component [13].

This approach assumes that each task or problem depends on individual knowledge components. That is, the set of knowledge components relevant to a task are individual cognitive processes, thus at the moment of solving a problem they can be applied independently one from another, so their posterior probability must be assessed separately.

Therefore the step analyzer assesses each relevant knowledge component in the presented task and determines the corresponding actions by activating the respective ДМi of the knowledge components either incorrectly applied or not applied at all, decreasing their probabilities more than those ones that were rightly applied. GeNIe© and SMILE library [14] were employed to model and develop the BNs in this work.

3. Pedagogical module

3.1. Learning methods block

The main responsibility of the learning methods block, also called the outer loop [4], is to decide which task the student should do next. The main design issues on this are:

– selecting a task intelligently;

– obtaining a rich set of task to select from.

In TITUS three different methods have been implemented for selecting tasks for the student. They are following mentioned in order of simplicity, with the simplest method first:

1) the outer loop assigns tasks in a fixed sequence. This approach was used to assess the prior mastery of knowledge components of the students in the task domain. Thus, the students must first solve or answer a fixed number of tasks in order to complete the initial assessment;

2) the outer loop implements a pedagogy called

"mastery learning". The curriculum is structured as a sequence of units; tasks in those units have a sequence of difficulty levels. When the student is working on a unit, the tutoring system keeps assigning task from that unit until the student has mastered the unit's knowledge components. Only then, it allows the student to proceed to the next unit;

3) the outer loop also implements a more complex pedagogy called "macroadaptation". For each task that the tutoring system can assign, it knows which knowledge components are required by the task. The tutor maintains an estimate of the student's degree of mastery for each knowledge component. When a student has completed a task and the tutor needs to select the next one, it chooses one based on the student's degree of mastery of the knowledge components in the current unit and it will always choose tasks which contain knowledge components with the lowest degrees of mastery that have not been mastered yet. In resume, the pedagogical module of the tutoring system is all about selecting tasks for the student to do.

3.2. Help and support module

Whereas the learning methods block (outer loop) is about tasks, the help and support module, also called inner loop [4], is about user interface actions or steps that are part of completing a task (solving a problem). In particular, the inner loop in the pedagogical model provides students with the following services:

– minimal feedback on a step. The tutor indicates only whether the step is correct or incorrect;

– hints on misconceptions or errors of specific knowledge components;

– error-specific feedback on an incorrect step. This information is intended to help the student to focus on which particular step or knowledge component is wrong and how to avoid making it again.

The help and support module gives only delayed hints or feedback in accordance to the student's performance and it will only give them right after the student submits the answer. It uses the step analyzer to review and assess the student's answers, these answers and every action either correct or incorrect will be stored on the student's model for its further use by the outer loop and the inner loop as well.

4. Knowledge base

The Knowledge base contains and keeps information about the student that is used by the pedagogical model in order to properly function across multiple tasks and sessions. This persistent information is often called "student model". The pedagogical model also uses other stored information about the student such as student's full name, average scores of each task, degree of mastery for each knowledge component, which tasks have been accomplished, how long the student spent for each task that has been presented, number of right answer, number of wrong answers, quantity of misused attempts for each relevant knowledge component, and session time. The knowledge base also stores the task domain lectures, the complete set of tasks and problems for being presented on the user interface. All the stored information in the knowledge base is necessary for a correct function of the tutoring system, and it can be accessed, stored and required by system's demand.

5. User interface module

A student interacts with TITUS though the user interface (UI) [10]. This interaction is partitioned into two sub-modules; an input module that receives the student's actions, and an output module that displays the necessary action that should be done (tasks), pedagogical suggestions like hints, feedbacks, lecture notes or statistics. Both sub-modules are completely correlated between them. The primary goal of the input module is to obtain information that will be stored and used to update the BNs based on the evidence or actions collected form the student.

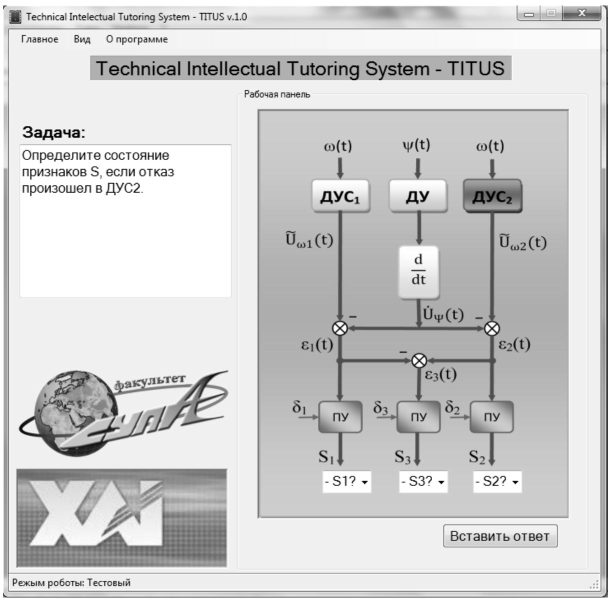

Fig. 3. A task representation in TITUS

A common representation of a task on the UI is depicted on Fig. 3, where it is possible to observe the integration of both sub-modules explained above.

Moreover, in order to provide a mechanism for selecting tasks, a set of 43 different tasks divided by difficulty and separated into three units has been developed as explained above. Some of these tasks may have more than one variant; this feature increases the set of variants of tasks up to 212 that TITUS is able to present to students.

6. Experimental results

The experimental results of evaluating TITUS were obtained by means of the analysis on 19 students' performance. The following three stages were carried out in order to evaluate the system:

1) the degree of mastery for each knowledge component on every student was firstly assessed;

2) students made use of TITUS in order to mastery the domain of knowledge;

3) final results are obtained after the students concluded the learning program.

Results for the first stage of the evaluation are shown on Fig. 4, we can observe that the degree of mastery for all knowledge components in the task domain, are under the threshold value of 0,85.

On the second stage of the evaluation, students completed a personalized curriculum of the study program and Fig. 5 shows which knowledge components were more difficult to master due to the quantity of activations in the diagnostic models counters.

Different quantity of attempts by task on Fig. 6 is the result of the adaptive algorithm in TITUS which individually assigned tasks to students accordingly to their personal performance.

From Fig. 7, it is possible to observe how students increased their probabilities of mastery on each knowledge component in the task domain after using TITUS.

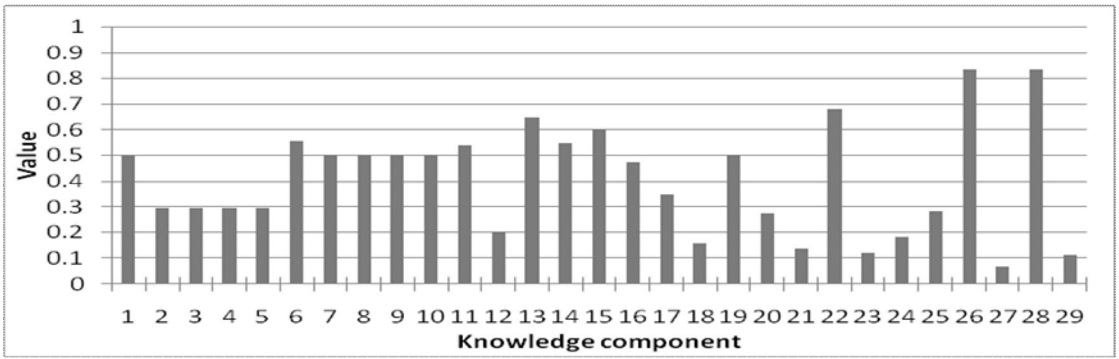

Fig. 4. Experimental results on the first stage

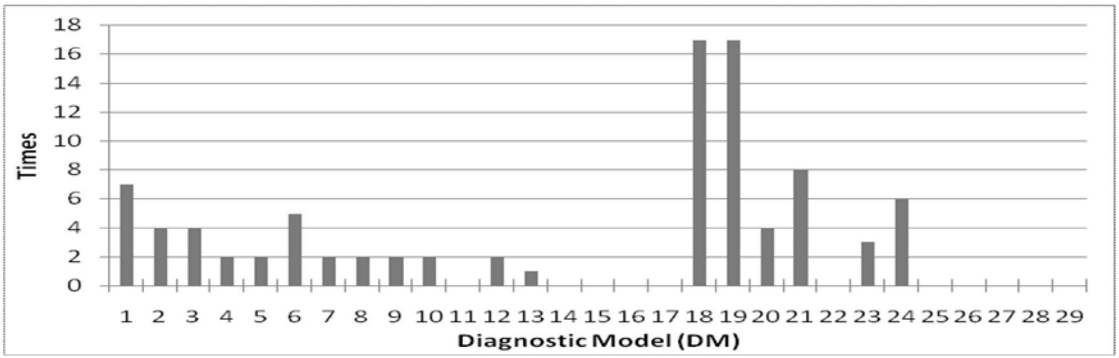

Fig. 5. Activation count for diagnostic models

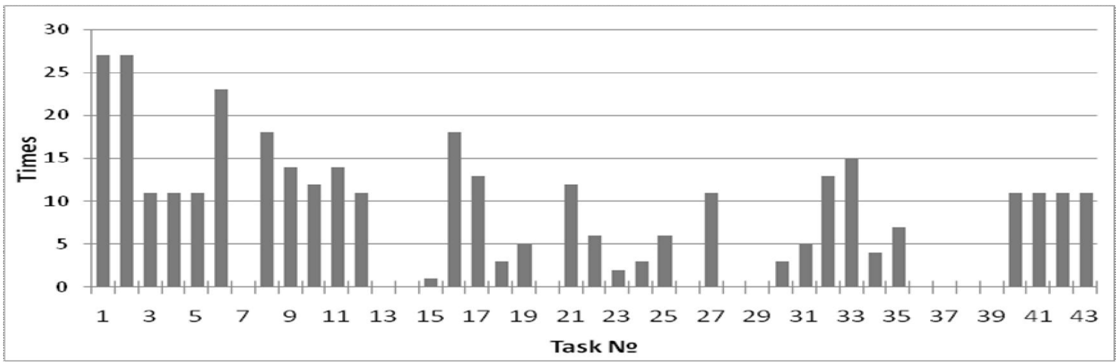

Fig. 6. Number of attempts by task

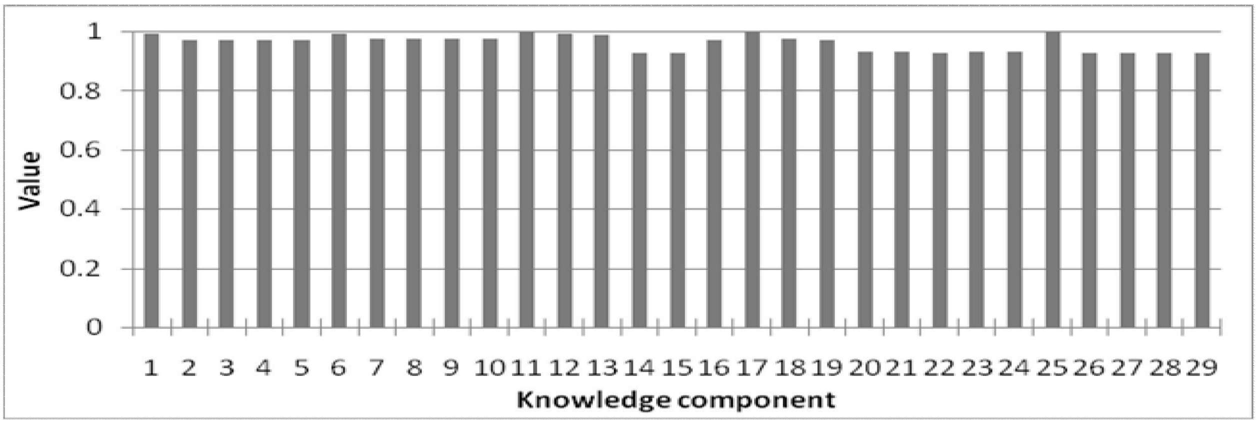

Fig. 7. Students' final results

Conclusions

This paper discusses a new architecture and approach of designing an ITS (TITUS) for signal-parametric fault-tolerant systems using Bayesian networks. The structure and the content of each component in the architecture were described. TITUS provides the learners with intelligent pedagogical support, hints and feedback. It has the ability to build a student model from each student and take pedagogical decisions based on it to actively adapt the learning process according to the student's performance. TITUS has proved to have a positive impact on students' degree of mastery of knowledge components as the results can show. Moreover it provides to students and teachers an accessible assessment tool, it is not intended to replace real tutors or teachers but support and aid the learning process. There is a long way to overcome still, and TITUS must be extended and longer evaluated, nevertheless results of its evaluation can confirm the efficacy of TITUS and show a feasible path for developing Intelligent Tutoring Systems.

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АДАПТИРУЕМАЯ ТЕХНИЧЕСКАЯ ИНТЕЛЛЕКТУАЛЬНАЯ ОБУЧАЮЩАЯ СИСТЕМА ДЛЯ СИСТЕМ ОТКАЗОУСТОЙЧИВОСТИ, КОТОРЫЕ БАЗИРУЮТСЯ НА СИГНАЛЬНО-ПАРАМЕТРИЧЕСКОМ ПОДХОДЕ

Х. П. Мартинес Бастида, А. Г. Чухрай

В данной статье рассматривается интеллектуальная обучающая система для систем отказоустойчивости, которые основываются на сигнально-параметрическом подходе. Техническая интеллектуальная обучающая система (TITUS) использует возможности Байесовских сетей (БС), которые являются формальной структурой вероятностной модели. Анализируется использование БС, как предполагаемого двигателя для помощи студентам в получении знаний и определении правильных педагогических решений для продуктивного обучающего процесса. В дополнение описывается структура TITUS и роль каждой модели в системе. TITUS была испытана, и приведены экспериментальные результаты.

Ключевые слова: интеллектуальная обучающая система, байесовская сеть, система отказоустойчивости.

АДАПТУЄМА ТЕХНІЧНА ІНТЕЛЕКТУАЛЬНА НАВЧАЛЬНА СИСТЕМА ДЛЯ СИСТЕМ ВІДМОВОСТІЙКОСТІ, ЯКІ БАЗУЮТЬСЯ НА СИГНАЛЬНО-ПАРАМЕТРИЧНОМУ ПІДХОДІ

Х. П. Мартінес Бастіда, А. Г. Чухрай

У цій статті розглядається інтелектуальна навчальна система для систем відмовостійкості, які базуються на сигнально-параметричному підході. Технічна інтелектуальна навчальна система (TITUS) використовує можливості Байєсівських мереж (БМ), які є формальною структурою ймовірнісної моделі. Аналізується використання БМ, як ймовірний двигун для допомоги студентам в отриманні знань та визначенні правильних педагогічних рішень для продуктивного навчального процесу. На додаток описується структура TITUS та роль кожної моделі у системі. TITUS було випробувано та показано експериментальні результати.

Ключові слова: інтелектуальна навчальна система, байєсівська мережа, система відмовостійкості.

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