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A LEARNING PLATFORM FOR DEVELOPERS OF FAULT-TOLERANT SYSTEMS BASED ON THE SIGNAL-PARAMETRIC APPROACH

In the presented work, a learning platform is framed. The learning platform is intended to help and give learning support to students and developers of fault-tolerant systems that are designed under the signal-parametric approach. This platform has two modules, the first module helps students and developers to understand, study and practice with a fault-tolerant system, the second module is a tutoring system, this tutor gives support in the learning process of fault-tolerant systems based on the signal- parametric approach. The tutor is able to determine the proper pedagogical actions in order to maintain a progressive and increasing learning process due to the use of Bayesian probabilistic networks.

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

Introduction

Technological systems have always been vulnerable to faults. Actuators faults reduce the performance of control systems and may even cause a complete break-down of the system. Erroneous sensor readings lead to operating points that are far from the optimal ones. Wear reduces the efficiency and performance in any mechanical device. In many fault situations, the system operation malfunction has to be handled or stopped to avoid damage to machinery or humans.

As a consequence, the detection and the handling of faults have an important role in modern systems, where many highly automated components interact or work in complex ways such that a fault in a single component may cause the malfunction of the whole system [1].

Actually, people depend on the availability and correct function of complex technological processes. Thus, software and hardware developers have the obligation of building reliable systems, but such systems lead to many challenges to overcome [2]. Many changes in technology have occurred, changing the nature of faults and failures as well, the complexity of systems, the services that they deliver, the way society uses them, and approaches [3]. Errors always happen in spite of all the efforts to eliminate faults that might cause them, so several fault tolerant mechanisms and approaches have been investigated by researchers and used in various fields of technology and applied industrial solutions [4-8]. Unfortunately, some solutions are more focused on the implementation, ignoring other development phases and this creates a dangerous gap between the implementation and the reliability of a system. Thus, there are many cases in which fault tolerant support has been undermined, decreasing gravely the systems' reliability.

Fault tolerant support should be included into every design but especially where any malfunction in the system could lead to seriously have economical lost but even worst to have lost of human lives.

This work presents a platform for learning, practicing and studying a fault-tolerant algorithm applied to a gyroscopic sensors unit (GSU). The learning platform will help students and developers to understand the basics of a fault-tolerant system under the signal-parametric approach [5, 9] while they make use of the tutor. The tutor will guide, support and assist them in acquiring the necessary knowledge components for understanding such a fault-tolerant system.

1. Description of the Learning Platform

The Learning platform presented in this work is compounded by two modules, represented on Fig. 1. Module 1 gives to students and developers a comfortable platform to study the 96 kinds of faults reported in the GSU [9].

Faults can be individually emulated for each gyroscopic sensor while the student is observing their affectations in the system in real time. Module 1 also permits students to perform a diagnosis of the GSU, this procedure helps the students to understand the implemented algorithms and how the diagnosis is carrying on, this is possible, thanks to several graphic charts, so students can dynamically observe and analyze in real time the gyroscopic sensor's signals, how they behave under different kinds of disturbances as well as the necessary processed signals to perform the diagnosis of the GSU. Students can apply any kind of the reported faults in [9] to any of the three gyroscopic sensors at any time.

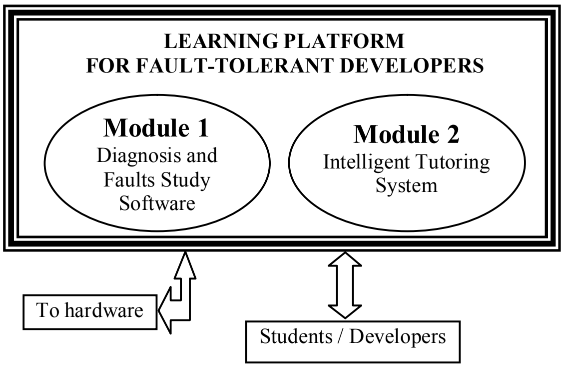

Fig. 1. Internal modular structure of the Learning Platform

The Module 2 gives learning and study support to students and developers. This module helps them to understand and learn all concepts and necessary knowledge about the theory, diagnosis algorithms and methodologies applied to the GSU. This module is a feasible tool that guides students in developing their knowledge with interactive ways, due to its graphic interface where different tasks to solve are presented to students, challenging and helping them in a continuous constructive way for constantly increasing their knowledge. Module 2 adapts and controls the flow of tasks to be solved by the students accordingly to their answers; this feature creates an individual task-learning program for each student in accordance to their own performance.

The module can perform assessments and evaluations of the performance of a group and each student individually; this characteristic may help teachers or tutors to monitor the students' performance and obtain information about their level of knowledge components that can help them to reaffirm or focus on knowledge components in which students have troubles or low proficiency. Detailed information about each build-in module in the learning platform is discussed on the following sections.

2. Module 1 – Diagnosis and Faults Study Module

A block diagram for understanding the structure of the Diagnosis and Faults Study Module (DFSM) which was recently exposed as being the Module 1 in the learning platform is depicted on Fig. 2. It can be appreciated on the diagram how the GSU is interconnected to a Personal Computer (PC) through the Control and Acquisition Data Module (CADM). GSU is conformed by two angular velocity sensors (AVS_1 and AVS_2), and one angular sensor (AS). The CADM contains a microcontroller, three Low pass filters ($LPF_{1\text{-}3}$) and the Motor control block. The PC is in charge to process the signals and depict them for studying the fault-tolerant support algorithm and emulate the faults for each gyroscopic sensor.

The analogue signals coming from the gyroscopic sensors on the GSU are digitalized by the CADM and are transmitted by a USB interface to the PC in order to be processed in real time. The CADM is also in charge to turn on and off the rotary platform in the GSU and change its velocity and direction.

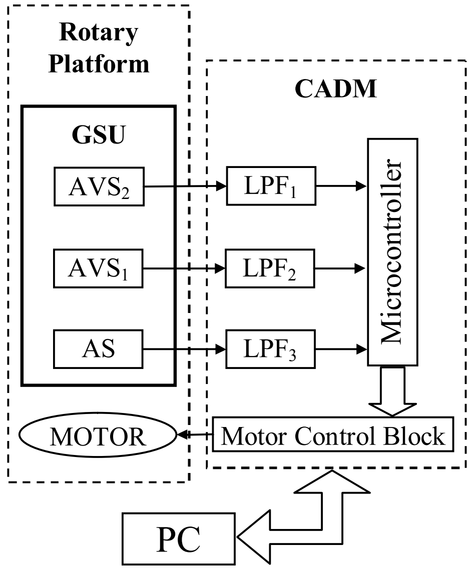

Fig. 2. Block diagram of the Diagnosis and Faults Study Module (DFSM)

Graphic interface is shown in Fig. 3, where processed signals from gyroscopic sensors are. The graphic interface of the DFSM has different controls to emulate faults in the GSU, obtain the diagnosis and apply the algorithms for recovering the system performance.

The DFSM is able to emulate a set of 32 kinds of faults for each gyroscopic sensor [9]. The student will be able to emulate a voltage drift on the range of -15V to +15V or change the value of the transfer coefficient for any of the three gyroscopic sensors independently and simultaneously.

The DFSM has been designed to work in connection with the GSU as well as in standalone mode; this is when the DFSM is not plugged to the GSU. When DFSM is working in standalone mode, the data that uses for working is data from gyroscopic sensors already saved in advance.

This feature permits students to make use of the DFSM without the necessity to be connected to the GSU. So the students can use the program anywhere and whenever they want or need for studying and practicing. Thus, the DFSS is a viable tool for supporting students in their learning process of fault tolerant systems applied to a GSU.

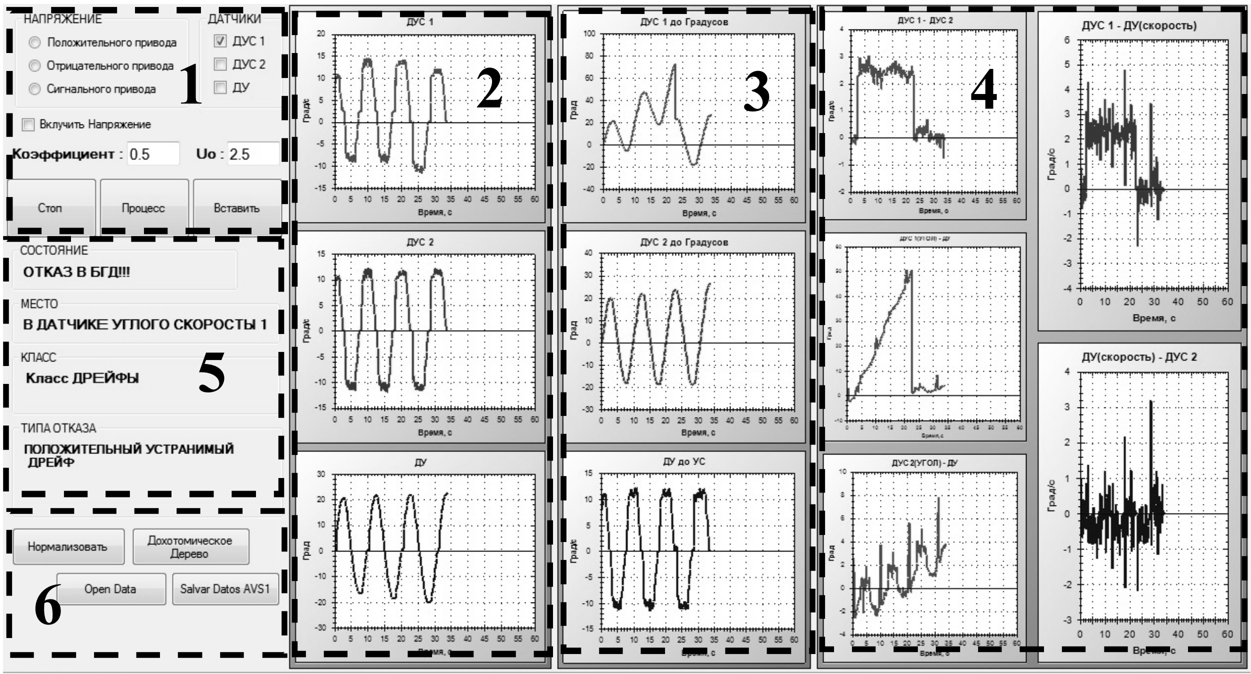

Fig. 3. Graphic interface of DFSM and its sections

The different sections on the graphic interface of DFSM depicted on Fig. 3 are described on Table 1.

Table 1

Description for sections of DFSM

Section No.	Description
1	Controls for sensor selection and parameters for emulation of faults.
2	Gyroscopic sensors' signals, from top to down, AVS_2, AVS_1 and AS.
3	Necessary conversion signals for each gyroscopic sensor.
4	Parametric signals of the system.
5	Panel for diagnosing the state of the system.
6	Data controls.

3. Module 2 – Intelligent Tutoring System

The Intelligent tutoring system (ITS) in the learning platform is a tutoring system for the education of technical knowledge, specifically for learning and studying the mathematical models and functionality of the algorithms for the diagnosis of faults for the GSU. A general architecture of the ITS is given on Fig. 4.

The ITS obtains value information from the students which is helpful for the ITS that knows what to teach, whom it teaches and how it teaches it.

The ITS has been developed as a Windows© application. The graphic interface is constantly and directly interacting with the block of learning methods, control interface, and the knowledge base.

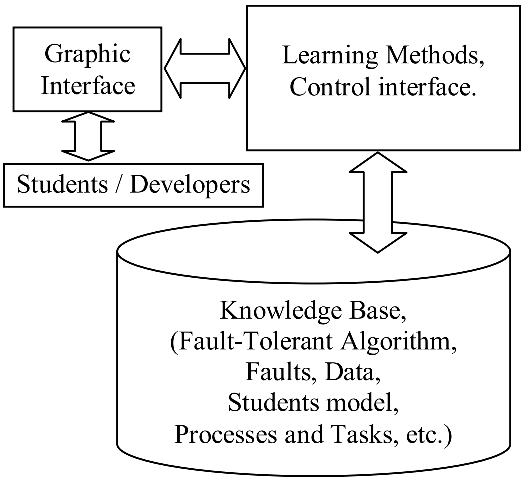

Fig. 4. General architecture of the ITS in Module 2

The Graphic interface is the environment where the student will execute his actions and attempt to solve different kinds of tasks and problems. The Learning methods and control interface block is in charge to control and administrate all the information in the ITS. It has the faculty to save or require data or any useful information into or from the knowledge database, for example; the students' models. The necessary processes and tasks are involved with the learning methods and control interface block, here is where the motor of the tutoring resides, where the knowledge inference and decisions are made.

The knowledge base is constituted by the expert knowledge in the domain and saved information that while the complex is being used by the students, are required, updated, recycled and saved. In this block, there is all theory and information about the fault-tolerant algorithm for the GSU and its diagnose as a result of several years of study on its behavior under certain working conditions [4-6, 9]. The knowledge base records the complete state of the system as well as the students' performance and that is how the system can creates the student model.

The student model is a database that contains information about the student: the correct answers, wrong answers, attempts for solving a task or step, required time for answering, and other variables more. This information will be used to realize assessments of students' performance, but also, it will be used to determine the proper pedagogical flow to maintain a continuous and increasing learning process of the relevant and necessary knowledge components.

The ITS needs assessments to drive their decision making, 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.

The "Mastery" concept is actually quite subtle. Intuitively, mastery means that the related knowledge component is known so well that the instructor and the ITS no longer need to focus on teaching it. As evidence of mastery, one intuitively expects the following:

– the knowledge component is always applied in situations where it should be applied;

– the knowledge component is never applied in situations where it should not be applied;

– when the knowledge component is applied, the application is done rapidly and without reference to external representations of the knowledge component (e.g., textbook, friend);

– the student can explain the knowledge component in general terms, and can explain why a particular application (or non-application) was justified.

The ITS does not have enough information to asses all these characteristics, so it must estimate mastery from the information that it has. Thus, the ITS should calculate only a probability of mastery, according to the given evidence, what are the chances that this student has mastered determined knowledge component?

In order to face up the assessment problem, the ITS builds and evaluates a Bayesian network [10]. Thus, the assessment problem consist of updating a set of mastery probabilities based on the student's solution process, as revealed in their step attempt histories.

A Bayesian network is built from nodes and directed links, where the nodes represent random variables and the links represent conditional dependencies among them. Let us use nodes to represent the mastery of knowledge components (Kx_y), and let each node have two values: mastered and unmastered.

In Fig. 5 is represented and example of a Bayesian network used to assess a determined task in the ITS, this example is build and evaluated with GeNIe© [11].

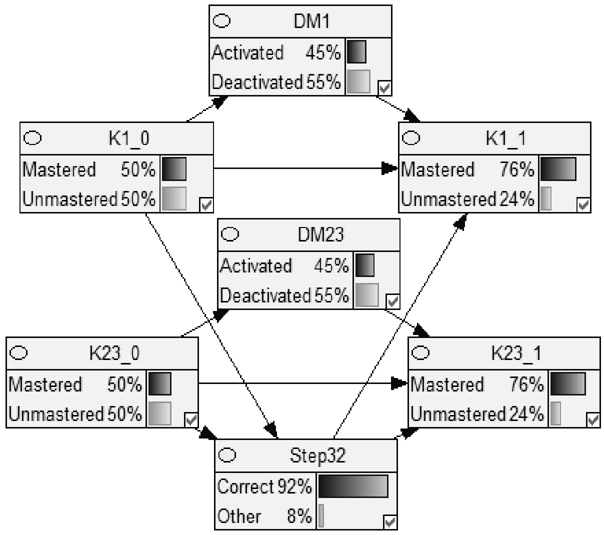

Fig. 5. Bayesian network for a task in the ITS

A knowledge component's mastery can change over time, so we use two subscripts to denote a particular mastery.

Let P(Ki_j) denote the probability of mastery of knowledge component i just after step i (Si). Let Ki_0 denote the prior probability of mastery of the knowledge component i before any steps have been done and Ki_1 the probability of mastery after the step; in order to increase uncertainty on mastery of a knowledge component before any step, the initial probability of mastery for every knowledge component is set to 0,5.

Let DMi nodes be a diagnostic model and serve to monitor and influence in the posterior probabilities of each relevant knowledge component after step Si, affecting individually posterior probabilities of mastery for every knowledge component.

The learning curriculum of the ITS consists on 43 determined tasks, separated in three units. Some of these tasks change values randomly, so this feature increases the available number of tasks over 90.

Units were determined according to the contained set of relevant knowledge components:

– **Unit 1**. Static Characteristics;

– **Unit 2.** Detection of fault and seek of place of fault;

– **Unit 3.** Determination of class and type of fault.

The complete set of knowledge components for the domain of knowledge in the ITS, has 29 relevant knowledge components and are presented on Table 2.

Table 2

Knowledge components and their description

Ki	Description
K1	Transfer coefficient for AS
K2	Minimum angle for AS
K3	Maximum angle for AS
K4	Minimum output voltage for AS
K5	Maximum output voltage for AS
K6	Transfer coefficient for AVS
K7	Minimum angle for AVS
K8	Maximum angle for AVS
K9	Minimum output voltage for AVS
K10	Maximum output voltage for AVS
K11	Class of fault "Broken"
K12	Positive power supply cable "Broken"
K13	Class of fault "Coefficient"
K14	Kind of fault "Decreased transfer coefficient"
K15	Signal cable "Broken"
K16	Negative power supply cable "Broken"
K17	Class "Drift"
K18	Unrecoverable positive "Drift"
K19	Recoverable positive "Drift"
K20	Recoverable negative "Drift"
K21	Unrecoverable negative "Drift"
K22	Reoriented transfer coefficient
K23	Characteristic equation for AS
K24	Characteristic equation for AVS
K25	Place of fault indicators
K26	Indicators state for fault in AVS2
K27	Indicators state for fault in AVS1
K28	Indicators state for fault in AS
K29	Indicators state for unknown place of fault

Some examples of the screens in the ITS are following depicted, Fig. 6 and Fig 7 give an example of tasks for Unit 1.

On Fig. 6, the student is required to select the proper static characteristic response of a gyroscopic sensor. On Fig. 7, the student must fill the boxes with the values of the static characteristics for a determined gyroscopic sensor.

Examples for Unit 2 are shown on Fig. 8 and Fig. 9. On Fig. 8, students must select the correct state of the diagnostic indicators "S" [9] according to the faulty sensor. The opposite process is required in the task depicted on Fig. 9, depending on the state of the S indicators; students must determine the faulty sensor.

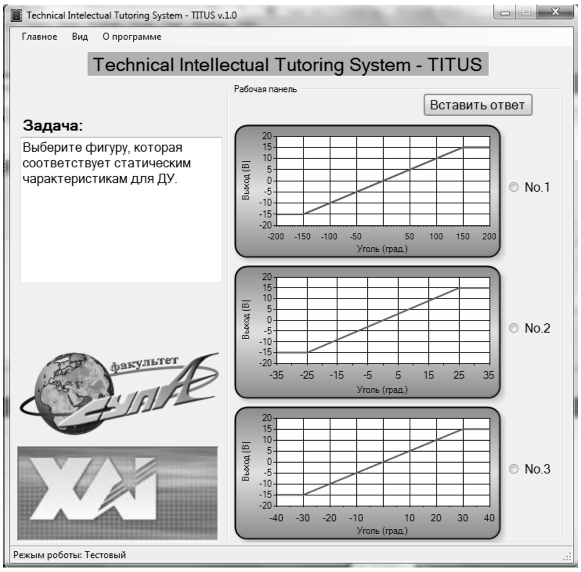

Fig. 6. Example 1 of a task in Unit 1

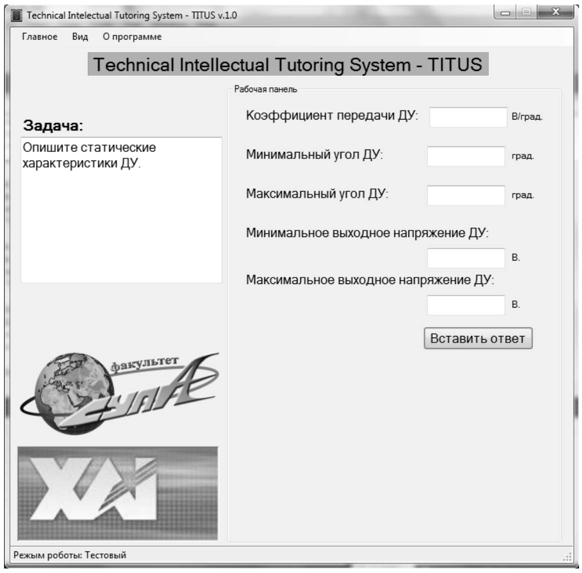

Fig. 7. Example 2 of a task in Unit 1

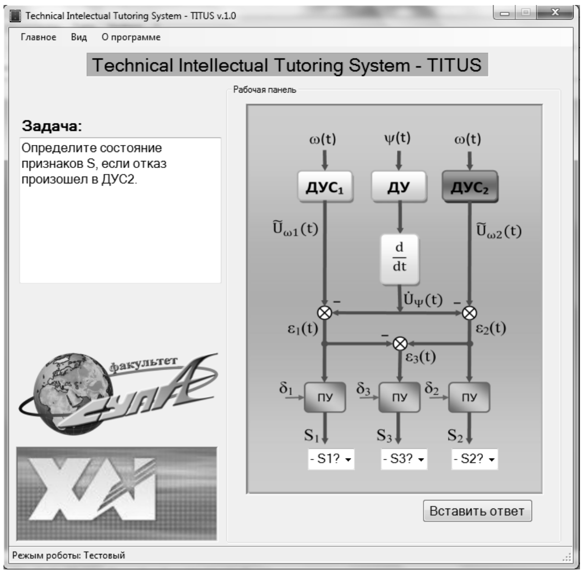

Fig. 8. Example 1 of a task in Unit 2

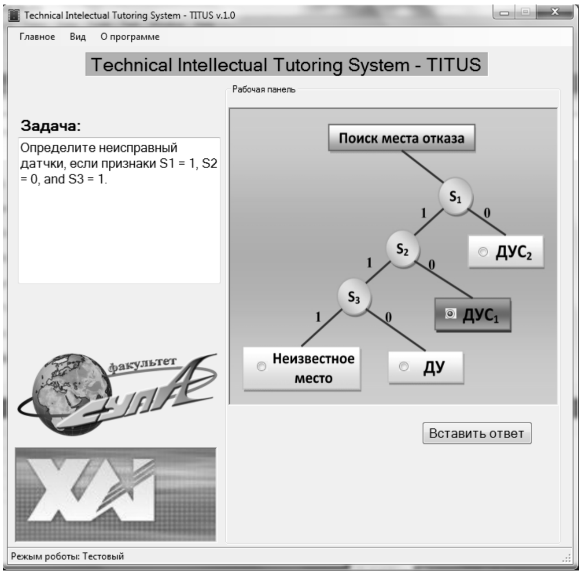

Fig. 9. Example 2 of a task in Unit 2

Finally, and example for a task in Unit 3 is depicted on Fig. 10. In the list boxes, students can select the complete set of possible kinds of classes and types of faults that have been studied and defined for the GSU. Students are required to select from the list boxes the correct class of fault and its type, accordingly to the showed figure.

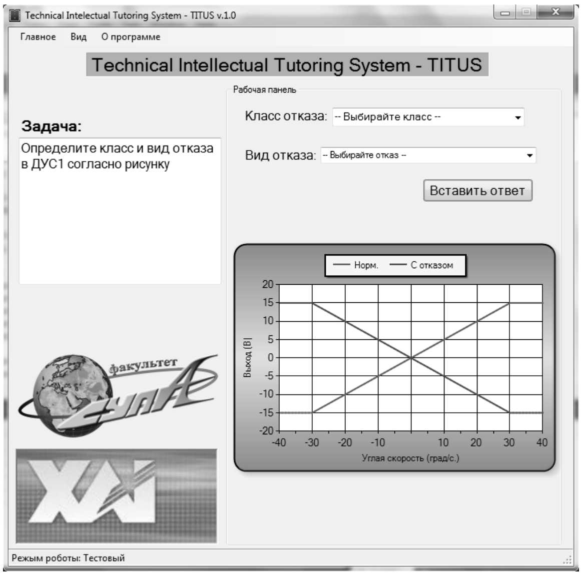

Fig. 10. Example of a task in Unit 3

Conclusions

In the present chapter a learning platform for studying a fault-tolerant algorithm for a GSU have been presented and discussed.

This learning platform is been developed with the aim to give students or developers a feasible learning support for studying the basics of a fault-tolerant system built under the signal-parametric approach; but it does not intend to replace tutors or teachers, this platform is presented as an alternative tool for practicing and studying about this kind of systems. The leaning platform also contains tools for monitoring students' progress, helping the tutors and teachers to focus on knowledge that are hardly difficult for students and adapt the learning process for better.

Due to the above reasons, this learning platform is proposed like a viable tool for supporting the students' development in the basics of fault-tolerant systems.

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ОБУЧАЮЩАЯ ПЛАТФОРМА ДЛЯ РАЗРАБОТЧИКОВ ОТКАЗОУСТОЙЧИВЫХ СИСТЕМ, БАЗИРУЮЩИХСЯ НА СИГНАЛЬНО-ПАРАМЕТРИЧЕСКОМ ПОДХОДЕ

Х. П. Мартинес Бастида, А. Г. Чухрай, Е. В. Гавриленко

В статье представлена обучающая платформа для разработчиков отказоустойчивых технических систем. Отказоустойчивость понимается в смысле применения теории глубокого диагностирования состояния технических систем и гибкого восстановления ее работоспособности. В основе платформы - два взаимодействующих модуля: первый модуль помогает студентам и разработчикам понять, изучить и практиковаться с системой отказоустойчивости, второй модуль - это обучающая система, поддерживающая процесс изучения отказоустойчивых систем, которые основываются на сигнально-параметрическом подходе. Эта система способна определить необходимые педагогические действия для того, чтобы поддерживать прогрессивный и адаптивный обучающий процесс, используя Байесовские вероятностные сети.

Ключевые слова: отказоустойчивая система, алгоритм отказоустойчивости, интеллектуальная обучающая система, Байесовская сеть.

НАВЧАЛЬНА ПЛАТФОРМА ДЛЯ РОЗРОБНИКІВ ВІДМОВОСТІЙКИХ СИСТЕМ, ЯКІ БАЗУЮТЬСЯ НА СИГНАЛЬНО-ПАРАМЕТРИЧНОМУ ПІДХОДІ

Х. П. Мартінес Бастіда, А. Г. Чухрай, О. В. Гавриленко

У цій статті представлено навчальну платформу для розробників відмовостійких технічних систем. Під відмовостійкістю мається на увазі застосування теорії глибокого діагностування стану технічних систем та глибоко відновлення її працездатності. Платформа базується на двох взаємодіючих модулях: перший модуль допомагає студентам та розробникам зрозуміти, вивчити та практикуватись з відмовостійкою системою, другий модуль - це навчальна система, що підтримує процес вивчення систем відмовостійкості, які базуються на сигнально-параметричному підході. Дана система здатна визначити необхідні педагогічні дії для того, щоб підтримувати прогресивний та адаптивний процес навчання, використовуючи Баєсовські ймовірнісні мережі.

Ключові слова: система відмовостійкості, алгоритм відмовостійкості, інтелектуальна навчальна система, Баєсова мережа.

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