ISSN 1870-4069

Intelligent Tutoring Systems based on Virtual Reality for the Electrical Domain

Miguel Pérez-Ramírez[1], Norma J. Ontiveros-Hernández[2], Carlos A. Ochoa-Ortíz[3], José A. Hernández-Aguilar[4], Benjamín E. Zayas-Pérez[1]

[1] National Institute for Electricity and Clean Energies, Cuernavaca, Mexico

[2] Tecnológico Nacional de México/Instituto Tecnológico de Zacatepec, Zacatepec de Hidalgo, Morelos, Mexico

[3]Autonomous University of Juarez City, Ciudad Juárez, Chihuahua, Mexico

[4] Autonomous University of Morelos State, Cuernavaca, Morelos, Mexico

{mperez, zayas}@iie.org.mx, norma.oh@itzacatepec.edu.mx, alberto.ochoa@uacj.mx, jose_hernandez@uaem.mx

ABSTRACT. In this paper a model to integrate the technology of tutoring systems to existing virtual reality training systems is described. The training systems are devoted to dangerous activities for energized line maintenance in the electrical domain. The systems are already in use and have impacted positively the traditional training method, which was based on classroom classes and camp training. The system augmented the availability of specialized knowledge and improved transfer of training. Nevertheless, we aim to provide further training capabilities with the salient proprieties of intelligent tutoring systems.

Keywords: Virtual reality, Intelligent tutoring systems, Training, Dangerous tasks.

1 Introduction

Power live-line maintenance refers to the work done by linemen on energized lines to carry out power restoration and to prevent power interruptions. Linemen must be well trained, since this high-risk task not only must be executed rapidly to keep time of outages as short as possible, but at the same time prevent accidents and avoid loss of human lives. Traditionally this kind of training at CFE (Spanish acronym for Federal Commission of Electricity), is accomplished through a combination of theoretical teaching at classroom and practical sessions. The former is given at job place; the latter requires workers to be moved to training camps. Although this model has been effective, there is the need to enhance training, reduce cost and provide training to a larger number of linemen. Based on previous research and application of virtual reality (VR) in the field of training [1] [2] [3], a complementary training tool was implemented. Rather than substituting the traditional method, the training tool aims to complement it and improve it, by tackling economical costs due to travel and stay expenses and making training available to a larger number of workers.

We have developed different training system devoted to maintenance of energized lines, such as ALEn^{3D} MT (for medium tension energized power lines - MTEPL), ALEn^{3D} AT (for high tension power lines [1]) and ALEn^{3D} LS (for underground power lines). We have developed also training systems for performing electrical tests to primary equipment of distribution substations (3DMaPPS) and for testing protections of distribution substations (SAMPyM3D). These VR training systems are used by CFE as tools to train high risk activities within safe virtual environments.

Even though these systems have improved the traditional training method, a new demand has arisen to integrate the well-known technology of Intelligent Tutoring Systems (ITS) to these training systems; so that, they can exhibit an intelligent and personalized behavior and they can be used to improve massive training. An ITS is conceived as a computer software designed to simulate a human tutor's behavior and guidance, but for the time being, our VR systems are only able to keep records of the progress of the students and the different courses and instructors but they do not make any decision regarding the delivery of the instructional content to specific students. Thus far, they only make sure that students learn a correct sequence of steps in a maintenance procedure (MP) and consider all the safety regulations on each step. Here we discuss about the integration of ITS technology to these systems.

The rest of the paper is organized as follows: Section 2 includes some related works. Section 3 includes the architecture of our VR training systems and how they are going to be extended to include ITS. Section 4 discuss about details of the integration of ITS. Section includes some conclusion and finally a list of references is included.

2 Related Work

Integrating the technologies of VR and ITS, is not new. This integration is approached as the building Intelligent Interactive Learning Systems (IILS) [4]. A more generic approach conceives this integration as combining artificial intelligence techniques with those of virtual environments to produce intelligent virtual environments [5]. Although putting together these two technologies in a system is considered promising, it is also considered a difficult task since sometimes is claimed that the modular structure of an ITS clashes with the interactivity and the structure of a VR system [6]. However, a classical source of IILS, even introduces Steve, an animated pedagogical tutor who inhabits a virtual environment, monitoring it and controlling it through virtual motor actions [7]. Other applications involving pedagogical agents are reported, within the firefighters' domain [8], circuit analysis [9] and even trying to influence students' affective states by using virtual agents [10]. The USA army is a pioneer in the integration of these two technologies [11], this time they are focusing the team training by using ITS based on VR. They are doing research to understand how to select a team instructional strategy, as well as finding a balance between individual and team feedback.

Despite technical burdensome that might implicate the integration of these two technologies, the combination provides exciting opportunities for the learning of complex skills. On one hand, VR provides different benefits as a learning tool, such as visualization, active learning based on interactivity and 3D navigation among others [12]; on the other hand, ITS might contribute with some degree of flexibility to adapt instruction, and thus individualize instruction [13].

Whereas the literature of ITS is rich, what is not common is to find VR training systems (VRS) devoted to maintenance to energized power lines as is the case of our training systems. We believe that it is quite viable to add some intelligence to our VRS as is argued below.

3 Architecture of the VR Training Systems

All the systems described above have the same architecture, which include the following main modules (Fig 1.):

- *VR maintenance procedures module* (VRM). This is the main module of the system; it is in charge of management of the instructional content. Maintenance procedures are delivered in terms of 3D animations complemented with environmental audios and textual and audio explanations. This module records the progress of students in two modalities. When the user is attending a classroom course, the system is connected to a database located in a web server to record information of users, courses and trainees' progress, and when the systems is used offline for self-learning, this progress is recorded in a local database.
- *Users and courses management module* (UCMM). This module allows the creation of courses where instructors can register students. It also integrates, manages and generates reports of courses, users and users' progress, which include results of practical and theoretical evaluations.
- *Licenses module* (LM). In order to permit access to the system, a user license is needed. The license management module requires user's personal information, company adscription and computer processor serial number to control access to the system.

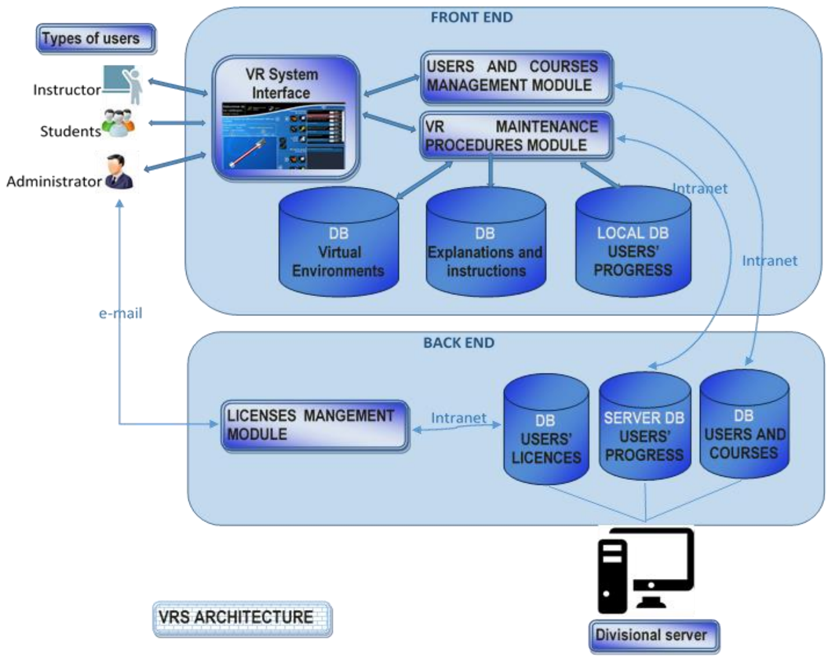

Fig. 1. Architecture of the virtual reality training systems.

3.1 Operation of the System

The operation of the systems is as follows. Once the system is installed, the trainees have to request a license, which is granted by a licenses administrator. Without license, the trainees are only able to see one maintenance procedure, just to get familiar with the system. The license is valid only for the personal computers where the system is installed. Having the license, the system is activated and the user will be able to see all the 43 maintenance procedures. The system will be able to recognize three types of users with different privileges, administrator, instructor and students. Administrators will have all the privileges to manage the system; they are usually computer science specialist who help users to install the system. There will be an administrator for each of the sixteen distribution divisions of CFE. The instructors will be able to create courses, add the student allowed to take the courses and the maintenance procedures they are going to teach on each specific course. They will use the system as a training support tools when they are training new students.

Here the VRS is connected to the CFE´s intranet so that the progress of the students is recorded in a database which can be used to generate different reports and exams. Finally, the students can use the systems in two ways, namely: a) in a classroom course programmed by the company and guided by an instructor. Here the progress of the students can be monitored by instructor and even the administrator. These courses are scheduled by the company as part of its training programs, and b) as a self-learning tool, here the students are free to learn, practice and review any maintenance procedure they wish. The progress of the student here is recorded only in a local database which cannot be monitored by the company but only by the students themselves. The student can progress to their own pace and spend the time they wish.

3.2 Functionality of the system

The functionality of the systems has three modes namely: a) learning, b) practice and c) evaluation (Fig. 2).

Fig. 2. Main menu of our VRS for electrical tests to substations.

In the learning mode, the system takes the control and teaches each MP taking the student through the whole sequence of steps which composes the MP until it is completed. The student cannot skip any step, as the intention is to learn the correct sequence, since neglecting a step or skipping it might be translated in terms of accidents. In the practice mode, the students are allowed to jump from one step into another so that they appreciate specific details of a specific step or sequence of steps.

In the evaluation mode, there are two different types of evaluation: theoretical or practical. In the theoretical evaluation, the system allows instructors to generate exams by selecting multiple choice questions from a questions database and then are marked automatically by the system once the students answered the exams.

In the practical exam, the students are required to perform a specific MP within the virtual environment (VE) but with no help provided by the system. The VE is the same for both, theoretical and practical modes. In this mode, all mistakes as well as the progress made by students are recorded in a database.

Finally, a MP is presented in two parts. In the first part, the student must select all the tools, materials and safety gear needed to perform a MP (Fig. 3). In real work tasks, this activity corresponds to a check list to make sure all the necessary equipment is ready and in working order before moving to the site where the MP will be realized. In the second part, the VRS presents the students the sequence of steps of the MP that the student has chosen (Fig. 4).

Here, we have to emphasize that the systems only present the sequences of the MP but do not take any decision on what it should delivery and when, regarding the instructional content. It lacks the intelligence owned by ITS.

Fig. 3. Selecting tools, materials and safety gear needed to perform a MP.

Fig. 4. Virtual Environment of a step of a specific MP.

4 Requirements for VRS Systems Architecture

The point here is that we want to add to our VRS some intelligence by integrating ITS technology. Even though there exist different types of ITS, it is widely accepted that an ITS provides individualized tutoring or instruction by including three components [14;15]: a) knowledge of the domain b) knowledge of the learner and c) knowledge of teacher strategies (Fig. 5).

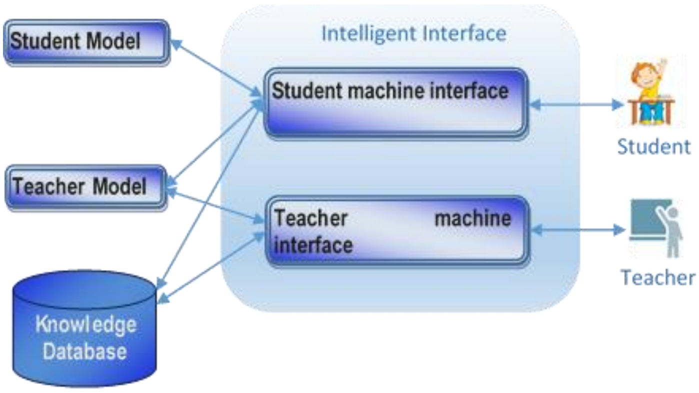

Fig. 5. Basic Structure of Intelligent Tutoring System [17].

Now personalized instruction means that the ITS must be able to do the following [15]:

- Accurately diagnose students' knowledge structures, skills, and styles.
- Diagnose using principles, rather than preprogrammed responses.
- Decide what to do next.
- Adapt instruction accordingly.
- Provide feedback.

A student learns from an ITS by providing solution to a situation or problem (Fig. 6), then the system compares the student solution with the expected one, the differences allow the ITS to update the student model and decide what kind of feedback should be delivered to the student. This is repeated until the expected solution and the one provided by the student are the same [15].

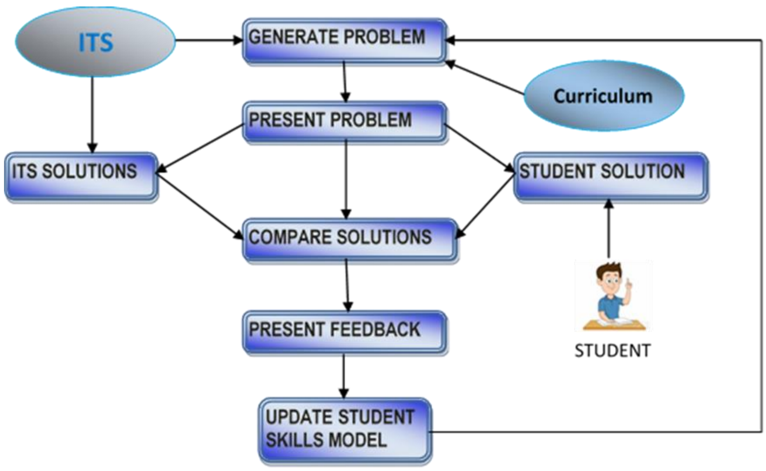

Fig. 6. How an ITS works [15].

We need to analyze and determine what changes we have to introduce in the original architecture of the VRS. In fact, analyzing our VRS, we found out that they already possess some of the components of an ITS.

1. *Knowledge of the learner*. For instance, the VRM already records the progress of the students in the users´ progress database, this is part of the ITS component, namely "knowledge of the learner". Here the VRS records different kinds of information such as the maintenance procedures (MP), that each student has learnt, but also we have more detailed information, for instance we know where each student made mistakes when

learning. The VRS also records outcomes of two types of exams, namely, a) theoretical, consisting of a list of multiple choice questions, that the VRS marks automatically, thus, here we have information of correct and incorrect answers of each student, and b) a practical exam, where the student perform a MP by his own, without any help provided by the system, here any mistake is recorded, we have records of what a student was requested to do by the system, and what the student did, wrong or correct, this recording in achieved on each step and sub step of a MP.

All this information can be helpful to know each student's academic progress, weaknesses and strengths. That is, some information already exists but it needs to be exploited.

2. *Knowledge of the domain*. We have a rich database full of knowledge of different aspects of the electrical domain on each VRS. This knowledge is stored in term of 3D animations, informative text and audio, again on each step and sub step of every MP. This knowledge came from two sources: a) specialized documents of the field and b) the expert knowledge of at least 10 experts with 20 years or more of practical experience on the field. This team of experts validated each step of each MP and they even introduced in the systems the so called "additional information," where they provided a piece of specialized knowledge, which in some cases is not described in documents, it rather came from all their years of experience in the field, that is to say, it is empirical knowledge owned by the experts.
3. *Knowledge of teacher strategies*. All the VRS were planned to follow the multidimensional approach to learning developed by Pérez and Ontiveros in 2009 [12]. The main idea in this model is to recognize that there are different factors or dimension that intervene in specific leaning processes. This includes the selection of learning theories such as Constructivism, active learning, behaviorism, and so on, providing feedback to different learning channels, even the affective aspect can be considered [16]. For the time being, the multidimensional approach is already followed by our VRS, but it is open to be enriched by integrating other elements in order to meet the requirements of an ITS. It is worth to mention that VR technology is quite flexible to create leaning contexts as has been pointed out by [12].

5 Proposed Architecture for Our VR Training Systems

Two main things need our VRS in order to get some intelligence: a) the VRS need to use the information of the student and the domain, they already posse in order to work as an ITS; and b) the integration of teaching strategies is needed. Once the VRS are complemented with these two components, they need to behave as an ITS as depicted in Fig. 6, this should still have to be programmed. Thus the new architecture of the VRS or rather Smart VRS (SVRS) would look like in Fig. 7.

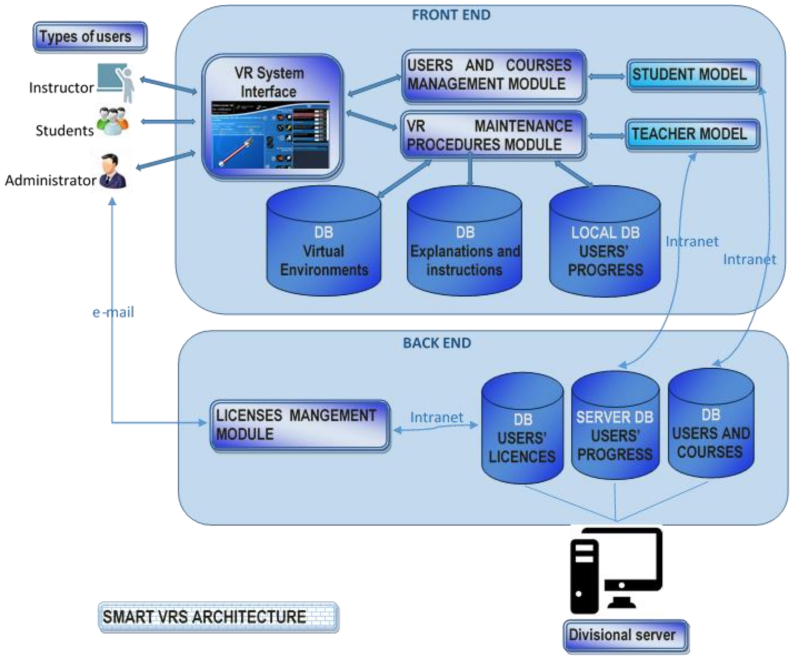

Fig. 7. Architecture of a Smart VRS.

As we can be observed, the front end and the back end of the VRS remain as they are now, the intelligence will be provided by the two new modules: the student model and the teacher model. These will operate over the data already available and will provide the strategies to exhibit an intelligent behavior when teaching. The student module might work with the data already stored in the databases, although their structure might also be modified or adapted in order to harbor any additional data required by the two new modules. There is a key fact that the teacher model needs to consider, which is relevant in the dangerous application domain, all the MP or electrical tests that they include in the domain of the VRS must be a sequence of steps. Students must learn not only the technical details of the MP but also de sequence.

We have mentioned that skipping steps magnifies the probability of accidents. For instance, a MP in energized line follows the following general structure: a) climbing up the structure (power pole), so that on each step all reference points (energized points), must be covered using isolated blankets and different kinds of covers so that the structure gets fully isolated; b) realize the objective of the MP, here again on each step the lineman must make sure that all reference points are not unnecessarily uncovered and finally, c) climbing down the structure, here all covers and isolated blankets used, are removed in the reverse order in which they were collocated in the structure, so that all the time the lineman is working on a covered (isolated) section of the energized structure. Thus, skipping a step might mean neglecting or leaving uncovered a reference point, which would be simply a suicide. This is why the sequencing is vital in all MP or electrical tests. Thus, the teacher model needs to pay attention to sequencing of MP and provide known teaching strategies so that students are able to learn effectively these dangerous tasks.

6 Conclusions

We have analyzed and presented a modified architecture for our VRS, so that they integrate ITS technology. This endeavor is technically viable since the original architecture remains and the two new modules can be integrated without great impact to the original architecture. It has been emphasized that the teacher model must care about the sequencing of MP for safety sake.

An additional benefit that we can foresee is that the proposed architecture would apply for all our VRS since they were built under the same architecture and so they work in the same way, the main difference among them is the instructional content. Elsewhere we have also explored other possible features such as introduction of animated agents [18] and affective computing [16] that together with the technology of ITS might provide solid bases to build a second generation of VRS according to the technology roadmap delineated for VR in CFE processes [19].

References

1. Stanney, K.M.: Handbook of Virtual Environments, design implementation and applications, Lawrence Erlbaum Associates Publishers, Mahwah, NJ (2002)
2. Burdea, G.C., Coiffet, P.: Virtual Reality Technology, 2nd ed., Wiley-IEEE Press, New Brunswick, NJ (2004)
3. Pérez-Ramírez, M., Zabre-Borgaro, E., Islas Pérez, E.: Prospectiva y ruta tecnológica para el uso de la tecnología de realidad virtual en los procesos de la CFE. IIE, Cuernavaca, México (2004)
4. Lopez-Garate, M., Lozano-Rodero, A., Matey, L.: An Adaptive and Customizable Feedback System for Intelligent Interactive Learning Systems. In: Proceedings of Intelligent Tutoring Systems: 9th International Conference on Intelligent Tutoring Systems, ITS 2008, Montreal, Canada (2008)
5. Luck, M., Aylett, R.: Applying artificial intelligence to virtual reality. In: Intelligent virtual environments, Applied Artificial Intelligence, 14(1):3–32 (2000)
6. Imbert, R., et al.: A Multiagent Extension for Virtual Reality Based Intelligent Tutoring Systems. In: Proceedings of the 7th IEEE International Conference on Advanced Learning Technologies, Niigata, Japan (2007)
7. Rickel, J., Johnson, W.L.: Intelligent Tutoring in Virtual Reality: A Preliminary Report. In: du Boulay, B., Mizoguchi, R. (eds.) Artificial Intelligence in Education. Proceedings of Eighth World Conference on AI in Education, Kobe, Japan, IOS Press, Amsterdam, p. 294 (1997)

8. Buche, C. et al.: MASCARET: pedagogical multi-agents systems for virtual environment for training. In: Proceedings of the International Conference on Cyberworlds, Singapore (2003)
9. Butz, B.P., Duarte, M., Miller, S.M.: An intelligent tutoring system for circuit analysis. IEEE Transactions on Education, 49(2): 216–223 (2006)
10. Frasson, C., Chalfoun, P.: Managing Learner's Affective States in Intelligent Tutoring Systems. In: Advances in Intelligent Tutoring Systems, series Studies in Computational Intelligence, vol. 308, pp. 339–358 (2010)
11. VRAC: Team Intelligent Tutoring Systems. Virtual Reality Applications Center. http://www.vrac.iastate.edu/research/team-intelligent-tutoring-systems/ Accessed 6 Mar 2017 (2017)
12. Pérez-Ramírez, M., Ontiveros-Hernández, N.J.: Virtual reality as a comprehensive training tool. In: Artificial Intelligence & Applications, Guanajuato, México: SMIA (2015)
13. Chad Lane, H., Johnson, W.L.: Intelligent Tutoring and Pedagogical Experience Manipulation in Virtual Learning Environments. In: Cohn, J., Nicholson, D., Schmorrow, J. (eds.) The PSI Handbook of Virtual Environments for Training and Education, Estport CT, Praeger Security International (2009)
14. Educause: 7 things you should know about Intelligent Tutoring Systems. https://net.educause.edu/ir/library/pdf/eli7098.pdf. Accessed 26 Feb 2017 (2017)
15. Thomas, E.: Intelligent Tutoring Systems (ITS). SDSU Dept. of Educational Technology. In: The Encyclopedia of Educational Technology. Bob Hoffman (General Editor), San Diego State University, http://www.etc.edu.cn/eet/eet/articles/tutoringsystem/start.htm. Accessed 10 Mar 2017 (2017)
16. Ontiveros-Hernández, N.J., Pérez-Ramírez, M., Hernández, Y.: Virtual Reality and Affective Computing for Improving Learning. Research in Computing Science 65, pp. 121–131 (2013)
17. Song, B. Yan, X.: Intelligent Tutoring System of Primary Mathematics Based on EGL and Web 2.0. Software Engineering 4(2):34–40 doi: 10.11648/j.se.20160402.15 (2016)
18. Hernández, Y., et al.: Designing empathetic animated agents for a b-learning training environment within electrical domain. Journal of Educational Technology & Society 19(2):116–131 (2016)
19. Pérez-Ramírez, M.: Ruta tecnológica de realidad virtual para el sector eléctrico. Komputer Sapiens 1(3): 1–16 (2011)