Adaptive and Blended Learning for Electrical Operators Training
With Virtual Reality Systems

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Abstract: Due to the danger involved in the electrical field, qualified electricians are required. Traditionally, training has been based on classroom courses and camp training, but it is costly and students need to spend a long time to develop their competences. We propose to complement traditional training with an intelligent training system composing a blended training model. The blended model enables adaptive training through a student model which represents the affective and knowledge states of the trainees. The affect is recognized taking into account a theoretical model of emotions. The knowledge of the student is updated as he interacts with the system. The instruction is presented in a virtual reality environment by an empathic agent. The virtual reality system enables practicing in a controlled and safe environment. In this paper, the general proposal for the blended training model is presented.

1 INTRODUCTION

The electrical domain requires efficient and well trained electricians because a manoeuvre badly performed can result on accidents that can injure people or damage costly equipment. However, training personnel confronts problematic situations such as the limited availability of electrical installations that trainees need for practicing in real environments, therefore the trainees have to help as assistant of electricians for a long time, and due to danger included, they first only observe the manoeuvre. This limited opportunity to practice in real environments makes training to take a long time besides being costly.

In order to advance in the solution of this problem, we are working in composing a blended learning model. A definition states that blended learning is learning that is facilitated by the effective combination of different modes of delivery, models of teaching and styles of learning, and founded on transparent communication amongst all parties involved with a course (Heinze and Procter, 2004).

In our proposal, trainees still attend classroom courses but they complement learning and practice aided by an intelligent training system. The intelligent training system integrated virtual reality systems which allow having a virtual representation of the electrical environment. The virtual reality is the electronic representation (partial or complete) of a real or fictitious environment. Such representation can include 3D graphics and/or images, has the property of being interactive and might or might not be immersive (Pérez and Ontiveros, 2009).

Another component is a trainee model representing the knowledge and affect states of the trainee. The trainee model enables adaptive training as in an intelligent tutoring system (Woolf, 2009). The trainee model is represented by Bayesian networks. On the knowledge side the model includes the topics the trainee has already learnt and the topics the trainee does not know yet. On the affect side the model includes what the trainee feels according to the OCC model (Ortony, Clore and Collins, 1988) and to the basic emotions proposed by Ekman and Friesen (1978).

The blended learning model also includes an empathic agent to be the face of the intelligent training system.

In this way, we have a blended learning model which enables adaptive and intelligent training where the individual state of trainees is considered. The training scenarios are presented as virtual environments enabling valuable practice before going to real electrical installations, and the learning is facilitate by an animated agent.

Regarding the integration of the technological pair: virtual reality and intelligent tutoring systems, it

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is not a new proposal. In the late 90s, Steve the animated agent who played the role of an instructor was representative (Johnson et al., 2000). At that time (Lane and Johnson, 2008) pointed out that there were still a number of unanswered key questions in the literature of this technological pair, some of these are: How distracting is explicit feedback? and What are the risks of stealth guidance and experience manipulation on learners with respect to confidence, self-efficacy, and help-seeking skills. Virtual reality carried out in its evolution and Burdea and Coiffet (2003) consider that training is one of the main fields for VR application.

Nowadays virtual reality technology enables developers to offer more realistic environments. Virtual environments are helpful for users to visualize how physical activities should be realized. Interactivity has improved but is still under research. Augmented reality, another strand of virtual reality is becoming more useful as training support in industry (Carson, 2015). Wagner (2015) states virtual reality will make online tutoring as common place as one-on-one tutor over the next years; he even envisages that online degrees are more affordable that the traditional ones.

An analysis of virtual reality evidences its potential for tutoring activities, since it allows the integration of features such as interactivity, visualization and audio, among others, to stimulate different human learning channels (Pérez and Ontiveros, 2009), which are propitious and helpful to enhance the learning process.

Both technologies are still under research but already mature enough to answer some of the questions posed in the past.

This paper presents our general proposal for the blended training model and describes their main components.

2 BLENDED TRAINING MODEL

Training is a strategic activity in corporations as it is recognized that the efficiency of organizations depends directly on human capital, which in turn may depend on adequate training. High productivity in part is the result of efficient training, which becomes even more valuable when there is risk of accidents that harm people. Such is the case of electrical field, which involve risk of electric shock, arc flash and other hazards for people; also there may be potential damage to equipment in electrical installations.

The training programs on the electrical field are very detailed and strict. A trainee has to accredit the classroom courses but he also must have camp practice with the close supervision of an instructor. In this traditional training method, the trainees spend a lot of time and also the training becomes costly.

With these elements, we are developing a blended training model to support traditional training as it can be seen in Figure 1. In this training model, the trainees learn through three elements: i) an instructor in classroom courses, ii) an intelligent training system and iii) camp practice.

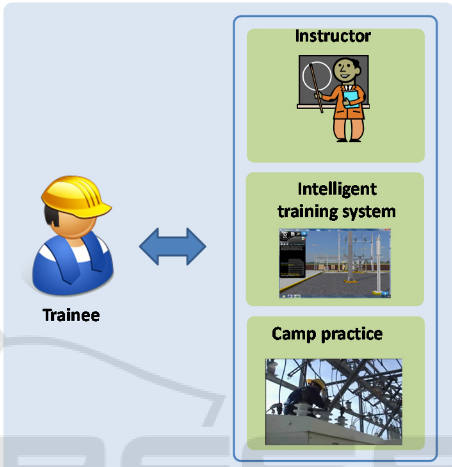

Figure 1: Blended training model.

The aim of the blended training model is to have efficient, fast and safe training, and also to reduce training costs. The base of the blended training model is the traditional training which in turn is based on a plan including theoretical lessons and practice.

In a face-to-face interaction, the instructor teaches trainees in classroom (first component). These classroom classes are supported by the intelligent training system (second component) where trainees can reinforce the theoretical topics by executing practices in a virtual environment. Separately, trainees can learn and practice with the intelligent training system as much as they want; this is in a self-learning modality.

When trainees have attended the appropriate courses they have to serve as auxiliary electricians to have camp practice (third component) in a real electrical installation.

The training course is planned by the instructor; he decides which topics will be included in the course and designs the course in the intelligent training system. In classroom, the instructor explains theoretical concepts and shares his experience in the performance of electrical manoeuvres.

This model, which supports self-learning, is looking for adaptive training, where particular trainee' needs are considered. We have established a road map with several phases to achieving such training model (Hernández and Pérez, 2014).

3 INTELLIGENT TRAINING SYSTEM

The intelligent training system is the component which allows adapting the training to particular needs of each trainee. It includes elements from intelligent tutoring systems such adaption to particular needs by means of a student model (Sottilare, 2013). Figure 2 shows a diagram of the intelligent training system.

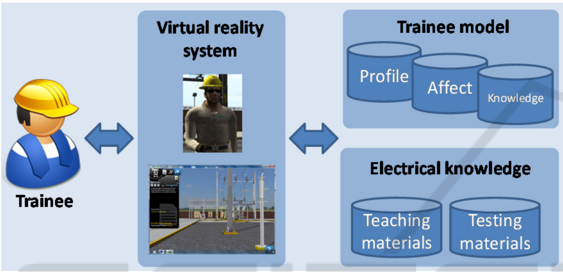

Figure 2: Intelligent training system.

Besides attending the course, trainees practice the electrical topics included in the course by using the intelligent training system with an animated agent.

A key element of this intelligent system is the trainee model that is built based on the interaction trainee-system. Also the trainee model is updated by the instructor considering the progress of the trainee in class and his performance in camp.

The trainee model represents the knowledge and affective states of trainees and their profile. The information in this model is useful for instructors to adapt the instruction in classroom, to plan the camp practice, to recommend attending other training courses or finally to grant a certification. The model can be useful to design new courses and new testing materials and even to redesign training material.

The trainee interacts with the intelligent training system via a virtual reality system. This system presents to trainees a virtual representation of the electrical environment enabling the practice before going to the real electrical installation. Also the system allows a safe training since the trainees can practice as much as they want without risk to injure them or damage costly equipment.

Depending on the specific electrical topic, the instruction and the practice in the intelligent training system can be adapted to the progress and knowledge of the trainee. In specific cases, it is difficult to adapt instruction because the electrical manoeuvre has to be performed sequentially. However, the intelligent training system can suggest to reviewing specific steps or to studying certain topics.

Another component is an empathic animated agent which uses the trainee affect to present the instruction properly. We are using the characteristics of the operators for developing the agent, such as wearing the uniform and safety helmet, among other features. We believe that by representing the tutor as an electrician, operators will accept better the training environment. Empathy is the ability to perceive, understand and experience others' emotions, in other words, to step into the shoes of another. This construct has been incorporated in animated agents with the aim to achieve credibility, social interaction and user engagement (Hone, 2006).

The knowledge about the electrical field composed by teaching and testing material are designed and developed by a team of experts.

3.1 Pedagogical Trainee Model

The pedagogical trainee model represents the trainee's knowledge about electrical topics included in the course. The model is updated when the trainee practices the electrical manoeuvres and when he solves theoretical exams. The model consists of a Bayesian network (Sucar, 2015). The Bayesian network is built when the instructor designs a course. Figure 3 shows an example of a Bayesian network for a course with five electrical topics. In turn each topic is composed by a sequence of subtopics.

The Bayesian network is composed by a node for each electrical topic included in the course. In turn, each node of the Bayesian network representing a topic is a Bayesian network composed by topics and subtopics.

Initially, the nodes representing topics have two possible values: learnt and not learnt and their probabilities are conditionally dependent on the probabilities of learning the subtopics nodes.

Course nodes also have two values: acquired and not acquired and their probabilities are conditionally dependent on the probabilities of knowing the topic and subtopics nodes.

We are working on including a node for a theoretical exam also represented by a Bayesian network composed by a number of items. The causal relationships between items and conditional probabilities for each node will be established when the exam is designed by the instructor. For the time being, we have not defined the complete structure and values of this Bayesian network. However we want to model trainee' guesses and slips on the basis of the relationships between the items and the evidence of the answers to questions. Figure 4 shows an exam with 8 items as a preliminary example.

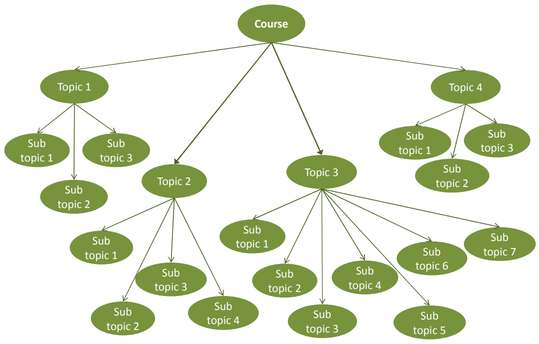

Figure 3: Bayesian network for a course.

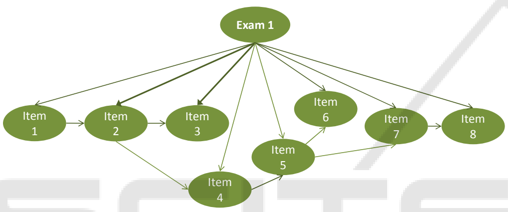

Figure 4: Initial Bayesian network for an exam.

3.2 Affective Trainee Model

The affective trainee model uses the OCC model (Ortony, Clore and Collins, 1988) to provide a causal assessment of emotions based on contextual information. The OCC model defines emotional state as the outcome of the cognitive appraisal of the current situation with respect to one's goals. The trainee model consists of a dynamic Bayesian network that probabilistically relates personality, goals and interaction events with affective states. Figure 5 shows a high level representation of the model, where each node in the network is actually a set of nodes in the detailed model. The model is based on the proposal by Conati and Mclaren (2009) and in our previous work (Hernández, Sucar and Arroyo, 2012).The dynamic Bayesian network models the dynamic nature of emotions. To infer the affective state, it considers the trainee's knowledge, personality, and the tutorial situation at that time, as well as the previous trainee affective state. The tutorial situation is defined based on the results of the trainee actions.

The trainee's appraisal of the current situation given his goal is represented by the relation between

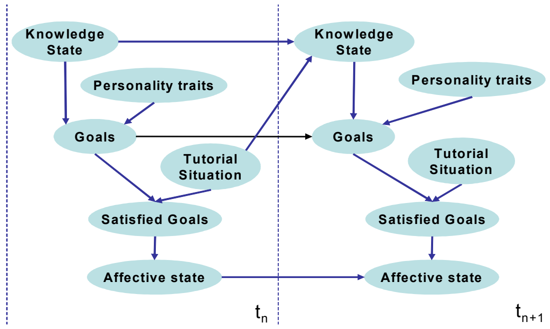

Figure 5: Dynamic Bayesian network for the affective trainee model.

the goals and the tutorial situation nodes through the satisfied goals node. The influence of the appraisal process on the trainee's affect is represented by the link between the satisfied goals node and the affective state node. From the complete set of emotions proposed by the OCC model, the affective model only includes six emotions: joy, distress, pride, shame, admiration and reproach. We use only these emotions because they are related to the events we want to evaluate: the emotions *joy* and *distress* are reactions by the individual to an event in the training session. The emotions *pride* and *shame* emerge as a consequence of the trainee's action. The emotions *admiration* and *reproach* emerge as a consequence of the tutor's action.

According to the OCC model, one's goals are fundamental to determine one's affective state, but asking the trainees to express these goals during training would be too intrusive. Consequently, the goals in our network are inferred from personality and trainee's knowledge.

3.3 Animated Agent

Training activities are presented to trainees through an animated pedagogical agent. These agents represent a major trend to have a more natural human-computer interaction (Breese and Ball, 2008, Johnson, Rickel and Lester, 2000). Animated pedagogical agents interact face to face with the students through facial expressions, gaze, emotions and deictic gestures; and cohabit with the students learning environments. Animated pedagogical agents have a significant impact on training systems as they give the impression that someone is on the other side (Sagae et al, 2012); thus the trainee perceives a very different behavior from a traditional system and more alike to human behavior. Among the behaviors of an animated pedagogical agent are those typical of intelligent tutoring systems, but there are some particular of these characters, such as demonstrations of complex tasks, observe and assist the trainee to perform their tasks, in addition to guiding trainees in virtual spaces (Wang et al, 2008).

We are using the characteristics of the operators for developing the agent, such as wearing the uniform and safety helmet, among other features. We believe that by representing the tutor as an electrician, instructors and trainees will accept the training environment. We have conducted a study to evaluate the design of the empathic agent and gather knowledge to refine it. We obtained encouraging results, as the electricians welcomed the agent (Hernández et al, 2016). The results of the study shed some light to refine the facial expressions of the agent and its overall design. Figure 6 shows two instances of the animated agent.

Figure 6: Animated pedagogical agent.

In this initial phase, the animated agent will deploy the emotions recognized in the trainee base in the OCC model as described above. The facial expressions, consequence of the emotions, adopt the theory proposed by Ekman and Friesen (1978). We are trying to accomplish an empathic behaviour in the animated agent to achieve believability and user engagement, and in turn to improve learning.

4 VIRTUAL REALITY SYSTEMS

We have developed different non immersive virtual reality systems for training. ALEn^{3D} is one of them and nowadays is a complementary training tool for medium tension live-line maintenance. In fact there are different versions of this system, all devoted to maintenance of energized lines. Thus, we have ALEn^{3D} MT for medium tension power lines, See Figure 7, ALEn^{3D} AT for high tension power lines and ALEn^{3D} LS for underground power lines.

Besides these systems we have also developed a virtual reality system for protections maintenance, see Figure 8, and substation tests. All these systems share in some degree the same architecture and functionality within different instructional domains. They keep track of trainees' progress; however we are still working on them to integrate some intelligence, so that these systems are able to keep fully records of the model of trainees and even integrate the animated agents and capability to recognise emotions among other functionalities proposed in the blended training model.

Figure 7: Virtual reality training system for medium tension live line maintenance ALEn^{3D} MT.

Figure 8: Virtual reality training system for maintenance tests to protections.

5 CONCLUSIONS

In this paper we propose a blended model for training electricians. This model includes an intelligent training providing adaptive and intelligent training since it recognizes the affect and knowledge state of trainees. The instruction is presented in a proper way by an empathic agent who is a learning companion for the trainee. The intelligent training system integrates a virtual reality system.

We have presented the characteristics of the intelligent training system as a component of the blended training model, i.e. learning and practice is part of a course; however trainees also can use the intelligent training system as distance self-training tool, practicing any topic at any time.

Even though we have added different technologies to our model and training systems in order to make them efficient, still presence of human instructors plays a decisive role. These technologies are helpful tools to support and improve training but cannot substitute instructor. As in other fields, training within the electrical field often involves high risk activities where mistakes are usually fatal.

Thus, the intelligent training system is a helpful complementary training tool which can be used to enhance the traditional training but it cannot be used instead of it.

As future work we are planning to show the trainee model to trainee as a self-evaluation tool. Self-assessment is one of the meta-cognitive skills necessary for effective learning. Trainees and students, in general, need to be able to critically assess their knowledge in order to decide what they need to study (Mitrovic and Brent, 2002). For the time being the open trainee model is used only by instructors.

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