PEDAGOGICAL SYSTEM IN VIRTUAL ENVIRONMENTS FOR HIGH-RISK SITES

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Abstract: Training at high risk sites (SEVESO sites) has many difficulties regarding potential risks, high training costs, etc. Virtual Environments for Training/Learning (VET/L) are best suited to overcome such difficulties. In this work, we have developed a collaborative VET/L where a learner with other autonomous virtual agents can work together to achieve a specific goal. We equipped this environment with an Intelligent Tutoring System, HERA, allowing to track several learners simultaneously, and to show them the consequences of their errors. HERA provides relevant feedback to learners, in real time or in a replay mode, thanks to its pedagogical model and module. This feedback depends on predefined pedagogical rules based on learners' level, their errors, the pedagogical goal, etc. In this paper, we present our system's architecture. Then, we give a detailed description of the pedagogical model, and we explain the pedagogical module functionalities.

1 INTRODUCTION

The application context of our work concerns risk management and prevention training at subcontracting companies that intervene at high risk sites. These companies aim to improve the quality of training and to reduce the number of accident causes related to human factors. Training in situ does not allow to reproduce disruptive situations that enable the acquisition of necessary skills to manage risks. Virtual Reality (VR) allows the construction of custom simulations adapted to needs (Bukhardt et al., 2006; Mellet-D'huart et al., 2005), and particularly in the area of risk prevention (Marc and Gardeux, 2007). However, few Virtual Environments (VE) take into consideration pedagogical or didactic aspects. This type of VE promotes learning by 1) allowing to better understand and analyze the learner's actions thanks to his trace and to some performance criteria; 2) providing adaptive epistemic feedback related to the learning situation; and 3) proposing an adaptive scripting by modifying the VE and the conduct of the scenario according to the behavior of the learner and to his learning evolution.

The development of such environments for human learning in the risk area gives rise to several questions: how to train learners to react to a risky or unexpected situation? How to help learners to have an idea about potential risks? How to enable a trainer to follow several learners at the same time? etc. The work presented in this paper is in the area of using the VR for training, in particular for the implementation of a pedagogy dedicated to knowledge acquisition within a collaborative work environment. Our work aims to assist trainers following learners, and to help them to analyze and understand the consequences of learners actions. This analysis will also assist learners in the debriefing and replay phase.

The feedback on learning and reflexive activities is important for the learner (Bukhardt et al., 2006). The first contribution of our work is to propose to the trainer and the learner individual activity traces, performance criteria, and especially explanations of the consequences of these activities. In addition, it aims to alert the trainer in case of difficulties encountered by a specific learner. Thus, our work intends to provide a system able to determine the task realized by each learner, detect committed errors and produced risks. The second contribution of our work is to propose adaptive pedagogical feedback learning related to the activities of each learner. The third contribution of our work is to propose a tracking system that allows to maintain the consistency between the scripting and the training objectives by generating or inhibiting certain events. Each scenario allows to learn a particular training objective or several combined objectives (e.g.

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procedure, safety standard, etc.). It consists of being able to script events in the VE related to the initial scenario, but also according to correct or erroneous actions of the learner. To propose these contributions, the scientific difficulties are 1) the lack or weakness of credible and pedagogical description languages of human activities and scripting, 2) the lack of recognition systems of learner activities in open environments such as VE, and consideration of dynamic aspects of interaction 3) the lack of generic pedagogical systems in VET/L.

To overcome these scientific difficulties, we propose a VET/L equipped with an intelligent tutoring system called HERA (Helpful agent for safEty leaRning in virtual environment). In this paper, we discuss mainly the third difficulty.

2 RELATED WORK

Several systems have been proposed in the literature that integrate pedagogy and didactic in a VE for training in order to assist the learner. Most of them are not generic and propose help (replace a learner in a task, guide him, etc.) and assistances that do not go beyond the prescribed procedure (Elliott and Leste, 1999) i.e. for a deviation or an unforeseen event, such systems do not know what to do. Some systems include a model of the didactic decision-making process allowing to produce feedback relevant to the user's knowledge (Luengo, 2005). Other systems include a generic pedagogical model that is still dependent on the trainer. These systems tend to provide a set of assistances for each erroneous situation, but it is up to the trainer to choose the most relevant among them (Buche et al., 2004). Other systems assist the learner using a set of performance criteria that are provided in a replay mode (Mellet-D'huart et al., 2005). Most of these systems penalize, disrupt, and help the learner at each time, which affects the acquisition of knowledge since the training is not progressive. In addition, although the presence of risks in several systems (Buche et al., 2004; Elliott and Leste, 1999) the concept of risk was not well enhanced in these systems.

3 OUR VIRTUAL ENVIRONMENT

In this work, we have developed a VET/L using Virtools, dedicated to knowledge acquisition. During a training session, each learner performs his training in front of a PC screen. In this environment, a learner has to conduct a collaborative work with other autonomous virtual actors. He is represented by an avatar in the VE, along with other agents with whom he is in collaboration. The learner can manipulate his avatar (displacement, changing viewpoint, etc.) using a mouse and a keyboard. To realize an action, he can click on the target object and select from the menu the action he wants (Figure1). The VE is adaptive to learners training thanks to the integration of our intelligent tutoring system HERA. In addition to HERA, the environment is equipped with an ontological knowledge-based system called COLOMBO (Amokrane et al., 2008a).

4 HERA ARCHITECTURE

HERA consists of five models representing the knowledge containers, and of five modules representing the processes that exchange, analyze, and register knowledge.

4.1 HERA Models

In addition to the pedagogical model (section 5), HERA contains the following models:

4.1.1 Activity Model

It contains a detailed description of the activity that learners must perform during the training. To this end, we have developed an activity description language called HAWAI-DL. HAWAI-DL provides a formalism to represent the hierarchical description of procedure tasks described by experts interviewed by ergonomists. In addition, it can describe "peripheral" tasks called "hyperonymous tasks". and tolerated deviations called "BTCU tasks"(Amokrane et al., 2008b; Edward et al., 2008).

4.1.2 Errors Model

It contains a generic classification of error types that may be committed by learners. This classification consists, first, of the errors classified by Hollnagel (Hollnagel, 1993). Moreover, we have added the following error types: 1) task-related errors (precondition, post-condition and constructor errors); 2) target object and action errors ; 3) role errors ; 4) subjective errors; and 5) BTCU errors. (Amokrane et al., 2008b).

4.1.3 Risks Model

It is intended to describe all the risks to which the learner's errors may give rise. It consists of the following main concepts: risk, BTCU task, hyperonymous task and environmental condition. These concepts allow to describe the causal relationships between human errors and risks as well as risks propagation using a Bayesian network. In order to define these relationships, we interpret the risk analysis scenarios realized at the INERIS [1]. (Amokrane and Lourdeaux, 2009).

4.1.4 Learner Trace

It is used to preserve the "activity trace" of the learner (what the learner has done), the errors made, the causes and consequences of the errors, as well as the risks produced.

4.2 HERA Modules

In addition to the pedagogical module (section 6), HERA contains the following modules:

- Interface module that acts as an intermediary between the exterior (VE and COLOMBO) and the other modules.
- Recognition module that determines what the learner is supposed to be doing, according to the observable actions and effects ("print trace"), the activity model and errors model, based on plan-recognition techniques.
- Learner module that produces the "activity trace"İt allows the task plan realized by the learner to be determined from among all the candidate task plans provided by the recognition module using formal approach of plan recognition (heuristics).
- Risks module that determines the risks resulting from the learner's errors and their consequences in real time according to the risks model. In addition, it calculates the probability of risks using Bayesian network.

5 PEDAGOGICAL MODEL

In addition to the four models presented previously, HERA contains a pedagogical model that allows to determine why, how and when to intervene to assist learners and to help the trainer. This model consists principally of:

5.1 Pedagogical Goal

It represents the "why" of a work session. These goals are determined according to the work environment and in situ observations and to interviews conducted by ergonomists of the Paris Descartes University and by risk analysis experts of INERIS. We distinguish several pedagogical goals such as: take into account risks by type (chemical, nuclear, etc.), take human relations into account, etc.

[1] Industrial Environment and Risk National Institute

5.2 Pedagogical Situation

In order to allow a progressive training, we define for each pedagogical goal the situations in which the learner will be involved allowing him to be evaluated during a training session. In general, pedagogical situations represent BTCU tasks, hypernymous tasks, etc. For example, in the "dangerous substances lading" scenario, if the learner does not realize the BTCU task "accompany valve", a leak may be produced. Thus, this task represents a pedagogical situation whose pedagogical goal is to "take risks into account".

5.3 Environmental Conditions

In order to allow the trainer to control a training session and to verify the knowledge acquired by a learner, we added the environmental conditions to the pedagogical model. These conditions represent the world state (states of the environment's objects). They can be the favorable pre-conditions of tasks, for example "to free a bolt", it is preferable that the "bolt be seized up". They can also be triggering conditions of a risk, for example, if the learner does not "accompany the valve", and "its spring is tired", then a leak will be triggered. On the other hand, they play a role in the triggering of risks due to learner's errors.

5.4 Learner's Level

To make the training system adaptive and personalized to the knowledge of each learner, we consider five levels of learners: novice, intermediate novice, intermediate expert, expert and very expert. The mass of knowledge to be acquired increases as the learner's level evolves. The pedagogical goals, the relevant pedagogical situations, the environmental conditions as well as the learner's level are initialized by the trainer at the beginning of a training session.

5.5 Situated, Adaptive and Pedagogical Feedback

They represent the feedback that the system provides to the learner and trainer in real time or in replay mode. We distinguish several types of feedback:

- Scale modification (enlarging some parts to get a better view, etc.).
- Reification, i.e. show the learner some concepts or abstractions in a concrete and intelligible form (emanation of colourless gas, invisible particles to naked eye, etc.).
- Restrictions to limit the learners actions, such as stop messages sent to the novice learner in real time when he commits a sever error that could lead to a risk. (Figure 1).
- Superposition of information:
  - Comments and argued explanations about the consequences of learner actions. These messages are displayed, in real time, to the learner on the VE (Figure 1) and to the trainer screen (Figure 3). The messages are displayed also in replay mode on the learner's screen, e.g. if the learner uses a wrong tool, the system displays to the learner as an explanation: "This is not the right tool".
  - Warning and attention messages sent to attract the attention of the learner, e.g. when an intermediate novice learner commits an error that causes or could cause a risk, a warning or attention message, respectively, is sent (Figure 1).

Figure 1: Object menu, Textual feedback and Performance criteria in the VE.

5.6 Situated and Adaptive Scripting

Changes and adjustments of the scripting (scenario and behaviors of virtual actors): the integration of a situated and adaptive scripting allows to adapt to the learner's profile and to the objectives of using a VE. It also allows to control and modify the scenario progress in real time, and to guide the activity and the behaviour of virtual autonomous agents in order to analyze the learner's behaviour and to enrich his learning profile. These changes correspond to:

- Triggering of risks due to learner errors in real time (Figure 2), e.g. triggering sparks if the learner uses a non-ATEX tool in an ATEX zone.
- Modifications of the scenario by sending disruptive elements in order to know the reaction of the learner in front of unforeseen situations.

5.7 Performance Criteria

To assess learners, several criteria may be used. Since our system is dedicated to SEVESO sites and to organizations interested in human relations, we have proposed the following criteria to the learner (Figure 2) and to the trainer (Figure 3):

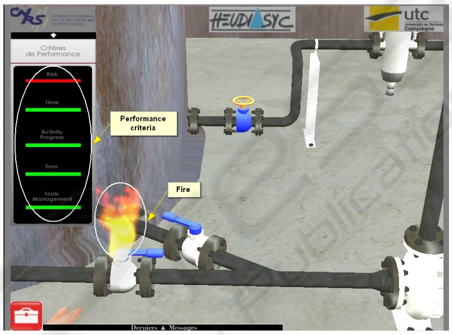

Figure 2: Fire triggering and Performance criteria.

Risk. This criterion must be respected by learners going to work in SEVESO sites, i.e. a learner must have a good level regarding this criterion to be able to work in situ without any danger. The evaluation of this criterion is based on risks severity that is calculated by the risks module.

Errors. Statistical studies have demonstrated that good operators tend to make errors before reaching the optimal solution. This assumed that the ability to detect and correct errors is a principal component of an effective solution. Based on this assumption, learners in our system, especially novices, are not penalized for each error committed, unless it persists or it was a sever error. The evaluation of this criterion can be expanded across several sessions in order to verify the evolution of the learner concerning a specific type of errors.

Productivity. It is an important aspect for industrials since it represents the amount and the quality of products.

Time. Learners must respect the constraint of time in most work situations. In the "industrial maintenance scenario", each session has a specific duration, and in other scenarios dealing with risks, the time must be respected especially when reacting to a risk situation. For example, in the scenario of "dangerous substances lading", we take into account the period spent by the learner between the

moment where a risk is triggered and the moment where the learner reacts to this unexpected situation. This criterion is calculated as follows:
TC (time criterion) = session duration / time estimated by the expert for this session.
TC = spent time to react to a risk / time estimated by the expert.

These criteria can be exploited during a training session or in replay mode, and displayed to learners and to the trainer. Performance criteria are mostly useful in replay mode allowing learners to better see the deviations they made without being disturbed during the training session. They are represented by icons that change colors depending on the severity of criteria. For example, the icon of the risk criterion is in green if there is no risk at all (probability 0), in yellow if the risk probability is small] 0, 0.3], or in red if the probability is higher than 0.6.

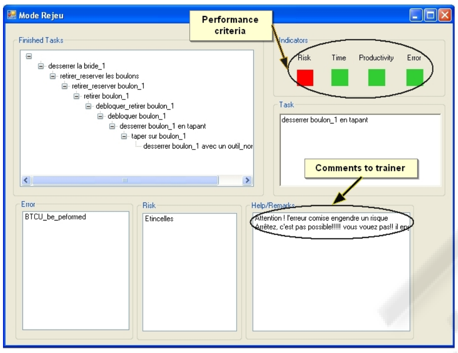

Figure 3: Trainer interface.

5.8 Pedagogical Rules

To enable our system to reason, we have defined a set of pedagogical rules allowing to determine pertinent feedback. Table 1 shows some examples of pedagogical rules. The description of these rules consists of the following concepts:

- Type of errors committed by the learner (determined by the tracking system).
- Learner's level: the choice of feedback is related to the learner's level, which allows to have an adaptive training.
- Risk probability: it is used in the cases where there are BTCU errors or omission errors of other safety-related tasks.
- Pedagogical goal and situation: for the choice of feedback, the pedagogical rules allow to select some aspects rather than others to highlight certain consequences of learners actions while maintaining a pedagogical and scenaristic coherence.

This allows to avoid overburdening the learner, i.e. to penalize him on-line only for the errors related to the selected pedagogical goals. For other errors, their consequences will be recorded in the learner's trace to be shown and explained in replay mode.

Table 1: Examples of pedagogical rules.

Pedagogical rule condition (if)					Feedback (then)	Example
Learner's level	Pedagogical goal	Erroneous task in pedagogical situations	Error type	Risk prob-ability		
Novice	Take risks into account	Yes	BTCU	< 0.7	Send an attention message	Figure 2
Expert	Take risks into account	Yes	BTCU	> 0.2	Trigger the risk	Figure 3
Novice	Take risks into account	Yes	BTCU	> 0.7	Send a stop message	Figure 2
Intermediate novice	Take risks into account	Yes	BTCU	> 0.5	Trigger the risk	Figure 3
Intermediate novice	Take risks into account	Yes	BTCU	< 0.5	Send an attention message	Figure 2
	Take risks into account	No	BTCU		Report the error without triggering risks	Figure 2
	Take into account human relations		BTCU		Let the learner continue what he is doing	

6 PEDAGOGICAL MODULE

It is the module that supports the decision of feedback to be sent to the learner. For each error message received from the learner module, this module checks the error type. If the error type is BTCU, an omission of a safety-related task, or a subjective viewpoint error, this module waits a message from the risks module to know about the produced risk and its probability. Then, it checks the learner's level, the pedagogical goal and situations selected by the trainer at the beginning of the training session. According to these data, the pedagogical module applies the relevant pedagogical rule to determine the appropriate feedback. If the feedback is in real time, it sends a message to the virtual environment and to the trainer, otherwise, it records it to be used during the replay mode.

7 CONCLUSIONS

In our work, we have developed a collaborative VET/L dedicated to industrials dealing with SEVESO sites and human relations. We have three work scenarios: pipe substitution, lading of dangerous substances, industrial maintenance. In this VET/L, a learner with other autonomous virtual agents can work together to achieve a specific goal. We equipped this envi-

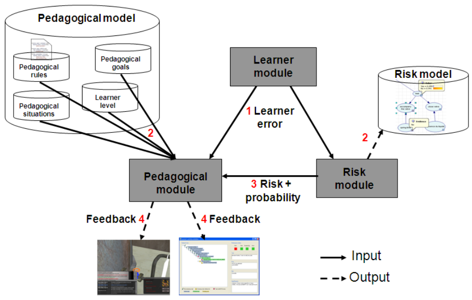

Figure 4: Data exchange between learner, pedagogical and risks modules.

ronment with an Intelligent Turning System, called HERA, allowing to track several learners simultaneously.

HERA allows to determine what the learner is doing and to detect committed errors and produced risks. Thanks to the pedagogical module and model, HERA provides the necessary feedback to help learners, to draw their attention, to warn or to stop them, and to show them the consequences of their errors; and it allows the trainer to analyze and understand the consequences of learners' actions on the organizational, technical, and human systems. HERA's pedagogical model consists mainly of a set of rules that allow to determine the appropriate feedback. These rules are based principally on the learner's level, pedagogical goals, pedagogical situations and environmental conditions.The feedback sent to learners can be in form of: 1) situated, adaptive and pedagogical feedback ; 2) situated and adaptive scripting; 3) performance criteria. Our system is personalized and adaptive to the learner's level. Thus, the feedback varies according to the learner's level in order, for example, not to disturb novices , to penalize experts, etc.

Till now, we have implemented the generic brick of our system. A preliminary evaluation has been done to validate the pedagogical model concepts used to describe the pedagogical rules. In the future we intend to:evaluate the whole system and the feedback impact over learners and trainers and mprove the system according to industrials' needs.

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