PRVIR: An Integration between an Intelligent Tutoring System and a Virtual Environment

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ABSTRACT

During the last few years, Virtual Environments (VE) have suffered a dramatic growth and improvement. The adoption of three-dimensional technologies have turned them into an appealing tool to be used in many fields. One of the fields that has adopted this new technology is education, where some ad-hoc solutions are being built for training in, for example, knee surgery, air traffic control or new skills for impaired people. However, many of these solutions are but a kind of film showing users how to do something, offering low levels of interaction. In this paper we introduce a system we have developed for training in radiological protection in a Nuclear Power Plant (NPP). In this application, the user has to perform a series of actions all over the VE, and he will do it with the aid of an Intelligent Tutoring System (ITS), which will help him carry out whatever actions he has to perform to achieve his objectives through some hints. We suggest how the integration between these two kinds of systems could be done in order to achieve a satisfactory product.

Keywords: Intelligent Tutoring System, Virtual Environment, Education, State Diagram, Training in Radiological Protection.

1. INTRODUCTION

There are plenty of reports which show that Virtual Environments are a powerful tool for teaching, mainly because of their capacity to provide believable, multisensorial, immersive environments [1], [2], [4], [5], [6], [8]. These reports suggest that the application of VEs in learning/teaching processes, be it education or training, are more beneficial for pupils than the applications of other technologies not based on VEs.

Educational Technology (ET) is the tool with which teachers and instructors may design effective educational environments. Any attempt to construct educational applications must take ET and the technology used into consideration. This is the case of VEs too, where we need to consider aspects as important as Learning Styles [3] and Teaching Techniques [7]. In our application, the aim is to teach pupils some key issues in radiological protection when working in a NPP. It was decided that building a 3D model of the NPP would be useful to teach pupils what their actions should be, since they can freely explore the whole plant, deciding what they should do in each moment, and they can repeat the whole process until they feel confident about its development.

As an important advantage, in this particular case there are some main features that make VEs the ideal way of teaching the behaviour that newcomers should have in the NPP:

- ➢ It is possible to use a simulation.

- ➢ Training in the real world is difficult and in some cases dangerous (due to radiation).

- ➢ Mistakes in the real world may be expensive and dangerous.

- ➢ Interaction with the VE is more motivating than interaction with the real situation.

- ➢ The VE will train almost as well as the real situation.

The use of an ITS is motivated mainly because of two reasons:

1. The pupil gets help when he is doing things wrongly, so he does not frustrate as easily as if he failed and had no way to know how to go on.

2. It is easier to evaluate the pupil, since the ITS can keep records of the pupil's actions and then suggest further exercises or decide to keep on with new activities.

In the next pages, we will show how the two different systems were conceived and designed and, later, integrated, and what the result of this experiment has been.

2. DESCRIPTION OF THE SYSTEM

The PRVIR project was aimed to construct an application to train the staff of a NPP in radiological protection.

The idea was to design a course that pupils could follow at home and that would prepare them for the activities they should do when working in the NPP. This course should be attractive enough in order not to bore the person doing it, so we decided to include multimedia components where relevant, and the pupil should be able to decide the rhythm at which he wanted the course to run.

With these objectives in mind, the course was given the following structure:

- ➢ Basic Concepts: the contents of this section are quite general, in order to offer the pupil a general knowledge of the subject. This section is divided in modules, and the general structure of each module is:

  - ✎ Exposition of concepts, with the following contents:

    - ☞ Introduction, where the general purpose of the module is given.

    - ☞ Explanation of the concepts, where all the concepts of that module are explained in detail. In some points, the pupil will be given the chance of optionally acquiring further knowledge about certain subjects.

    - ☞ Summary, where the pupil is told what he is supposed to have learned in that module.

In this part, the explanation of the concepts is accompanied with graphics, pictures, and animations in order to make the pupil understand all the concepts as easily as possible.

↳ Self-evaluation, where the pupil must complete some exercises in order to test the knowledge he is acquiring. For each exercise, the pupil is informed about his mistakes and he is given the chance of reviewing those parts of the module where he has had more problems.

In this part, different kinds of exercises have been used:

☞ Test-like questions.

☞ Matching elements in two columns.

☞ Gap filling with limited options.

The pupil has two different ways of completing the course:

↳ Self-controlled: The pupil will be able to choose the order in which he wants to navigate through the course.

↳ System-controlled: The system will guide the pupil through the course.

➢ Specific Concepts: this section has been planned to be very practical, and the objective is to show the user the way that some specific tasks must be done in the particular NPP in which they will be working. It has been defined in two different levels:

↳ Demonstration of how tasks must be carried out: in this level, the pupil has a range of possible activities, and he has to decide which ones he wants to learn. Once the choice is made, the system explains the task to be carried out. This is made with a film in which a narrator explains the pupil the different steps to be taken in order to perform the chosen task. At the end of the module, it must be guaranteed that the pupil has explored all the possible activities.

↳ Practice: in this level, the system shows one of the situations, and the pupil has to take the right decisions in order to perform the required task. This will be done using a VE. The system will write down the pupil's actions and will give the pupil some clues when their actions are wrong. This is where the tutoring strategy in the ITS will play an important role.

At any point of the course, the pupil has the chance of looking up words in a glossary or abandoning the course in order to continue in the same point in a future session.

As we can see, the two different parts in which the whole course is divided are quite different, so a very different treatment has to be given to each of them. In the first one, the most important thing to do is to identify which are the concepts to be taught and to design the exercises to be done in each module.

In the second one, the activities to be designed are implemented using VEs, and this involves a more complicated and hard work, since it is necessary to identify clearly the way tasks must be done, and a close collaboration must be established between the VE and the ITS, as it will be explained later.

3. THE VIRTUAL ENVIRONMENT

A VE is an application that, from the user's point of view, utilizes a three dimensional (3D) interface; and its main objective is to allow user-user and user-object interaction in a realistic way.

In the application we are describing, some of the exercises that are to be done by the pupils are set forth inside a VE, since the objective of those exercises is to let the pupil learn what is the procedure to be followed to perform certain tasks in a NPP.

The reason why we chose VEs for this exercises was that we do not only wanted pupils to learn the procedure to be followed, but we also intended their familiarization with the environment. The purpose of these exercises was their learning how to act inside the NPP in certain, very well defined, situations *before* going to the NPP, so once they were there they would know how they had to behave. The utility of VEs in a situation like this one is clear. First of all, it is not possible to do the training in the NPP, since people who have to go there occasionally usually live far from it. Besides, since some of the operations have to be performed in restricted areas, it is difficult, if not impossible, to do the training in the NPP. Furthermore, it might also be dangerous to do the training in the NPP without knowing what the correct behaviour is, and teaching it is the objective of our application.

For all these reasons, and some others, it was thought that VEs would be the ideal tool to be used for the training, and it would also be a good chance to test its suitability in this particular environment in order to see if further applicability would be possible. This is so because, in this course, no critical situations were simulated, but mere routine procedures inside the NPP.

Even though the tasks to be simulated were not inherently risky, the nature of the environment where the actions would take place in the real world seemed to suggest having a special care when designing the VE and the procedures to be simulated.

With these ideas in mind, the development of the VE was structured as follows:

➢ Static Design: in this phase we identify all the static aspects that influence the final appearance of the VE:

↳ Design of the scenario: in this step, we must identify what areas of the scenario are to be simulated. For this purpose, two kinds of visual elements were used as input: photographs of the areas and a video recording giving an overall view of the scenarios.

↳ Significant objects of the scenario: among all the elements appearing in one scenario, we must decide which ones are going to be the most significant ones in order to model them with the maximum fidelity. Most of them will be elements with which a direct interaction is required.

↳ Actors: among all the people who could be in one scenario in a determined moment, it is important to identify which ones will necessarily interact with the user, in order to include them in the simulation and, later on, identify their functions and behaviour.

➢ Dynamic Design: in this phase we identify the dynamic behaviour of all the elements appearing in the scenario. First, we have to write a script to identify perfectly how the action will take place. Then, we will have to identify how this script affects the elements of the simulation:

↳ Scenario: all the elements identified in the scenario that are static elements or elements with which there

will be no interaction at all, will not have any behaviour.

↳ Actors: in this case, it is important to identify what actions will be carried out by all the actors who appear in the simulation, specially those which will have to be performed by the actor controlled by the user. It is essential to try to assimilate all the different actions and design a small group of them, which will be carried out with all the objects, in order to be able to design an easy to use interface that, at the same time, allows us to perform a wide range of actions.

↳ Significant Objects: in the case of significant objects, it is important to know if an action performed by the user will have a visible effect that may alter the state of the VE in a way that also affects the actor controlled by the user.

Once we have identified all the elements of the scenarios and the behaviour of all the objects and actors, we have to decide some aspects that will influence the performance of the VE:

➢ First of all, we have to decide how the scenario will be designed. Since it is made of static elements, it is necessary to identify how they are to be modelled: the level of detail with which they will be constructed and if textures are going to be used in order to give them a more realistic appearance or if they will be constructed using more than one object.

➢ After that, the same procedure must be followed with objects that have some dynamic behaviour. In this case, the design is a bit more complicated, since it is necessary to identify what parts of the object will have to be moved or changed and which ones will not. Then, for each of them, it will be necessary to do the same thing we did with the elements of the scenario: decide how they will be modelled and whether they will have textures or not.

➢ The most complicated part of this task comes when we finally have to decide the structure that the actor representing the user, the *avatar*, will have. In all probability, the avatar is going to be the most complicated element we will have to model. Because of it, it must be carefully planned the level of detail with which it will be represented, since a very little detailed avatar may not result realistic, and a very detailed avatar may be difficult to manipulate, resulting in a poor performance of the VE.

There are three basic criteria we can use in order to decide what this level of detail will be:

➢ The actions that have to be performed by the avatar: if, for example, the avatar has to use a keyboard, it will probably need to have fingers, not just a ball representing the hand.

➢ Where the point of view is located: if the viewpoint of the user is situated in the eyes of the avatar, then it will not probably need to have a head, trunk or even legs, but just arm and hands. In this last case, we will need to model carefully the hands and fingers.

➢ The level of detail with which the actions must be done and seen: if it is important to be able to see in detail how an action is carried out, then we may have to divide the trunk in four pieces, instead of just one. Likewise, if it is important to see how the avatar operates with an object, then it may be necessary to model detailed hands with all the fingers' joints instead of the palm and five sticks.

Finally, since the person who will implement the 3D models will generally not be the same person who has designed them, it is of utmost importance to clearly draw and identify all the

objects that have to be modelled, indicating what elements articulate with what others and how, which ones have textures, how many polygons must each object have, etc..

4. THE INTELLIGENT TUTORING SYSTEM

The origins of the ITSs come from the field of Computer Assisted Learning. They generally provide a high level of guidance and control interactive processes in great detail. This feature is what makes them specially interesting for controlling the actions that the user is doing inside the VE.

Usually, the structure of an ITS is quite similar to the one shown in Figure 1.
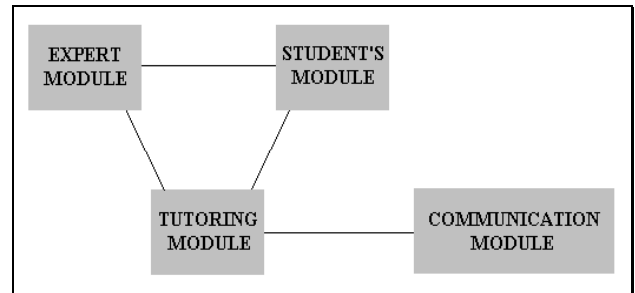

Figure 1: Structure of an Intelligent Tutoring System

The **tutoring module** contains the pedagogic knowledge and is in charge of selecting the appropriate topics to be shown in the course. Thus, this module will put forward the necessary concepts and exercises in order to let the pupil face the training in radiological protection successfully.

It also has all the strategies, rules and processes that drive the interactions between the student and the system, in order to make decisions about the informative concepts to show and the exercises that the pupil must do, along with the moment when he must be interrupted in order to correct him or make a suggestion.

In this module, two different types of exercises must be taken into consideration:

➢ The ones that are useful to evaluate the comprehension of the informative concepts that have been taught to the pupil in the first section of the course.

➢ Those related with real situations simulated in the VE, which are thought to evaluate his understanding of the process that must be followed when he is inside the NPP.

The **expert module** contains the knowledge about the subject to be taught to the student, and it is the base for the analysis of the pupil's answers. In other words, the expert module contains the information that is going to be explained in the course: all the informative concepts, which are small pieces of information in which the knowledge of the expert is divided in order to explain the subject to the pupil, and the knowledge necessary to solve the exercises.

This knowledge must be efficiently organized, so that it can be easily accessed, modified and extended.

The **student's module** keeps individualized information related to each student that is doing the course. This module is responsible for knowing what informative concepts have already been taught to the student, how many exercises he has done and the degree of success and time he has used to complete them.

It is used to evaluate the understanding of the pupil and to identify his particular way of learning, in order to let the system

adapt to this method. It is also useful to know what topics he finds more difficult to understand.

The model of the student built by this module, can also be accessed by a human tutor by means of a separated tool, the **teacher's tool**, that allows them to analyse these data and to supervise the learning process if necessary (needless to say that human tutors are still much better teachers that any computer system).

The **communication module** is in charge of the communication between the pupil who follows the course and the ITS. This module must inform the tutoring module of the actions that are performed by the pupil all along the course. This actions may be the visualization of an informative concept, the answering of an exercise in any of the forms that it may adopt, or one of the actions performed inside the VE. This idea gives us a clue about how the integration between both systems can be carried out.

This module makes possible the presentation of informative concepts and exercises in an easy to understand, intuitive way. This is essential, since an improperly designed communication module may result in a system that nobody will use, either because it is difficult to use or simply because it is ugly. A well designed communication module causes the interaction between the pupil and the system to be much more pleasant.

Each of the described modules has a very important role to play in the correct working of the intelligent tutoring system:

➢ The expert module must be designed in a way that information is easily accessible and modifiable. The way we have solved this problem is saving all the information in a relational database. The structure of this database is beyond the purpose of this paper, so no further details will be given. The basics of its functioning are:

✎ Information is divided in very small, but fully understandable informative concepts.

✎ Each of these informative concepts will point to other concepts that must be shown necessarily before or after it, inside a particular block of concepts. Each block, in turn, will point to other blocks that must be shown necessarily before or after it, in a given module.

✎ A determined group of blocks will form a module, and all the modules together will form the whole course. Each module will point to the next one inside the course.

This way, if the pupil wants to do the system-controlled course, the system will be able to decide what has to be done next, based on the student model and the dependencies among the knowledge. If, on the contrary, the student prefers to freely navigate through the course, blocks will be the smallest group of knowledge that the pupil will be able to choose, assuring that learning is not just reviewing a lot of spare informative concepts, but has still certain structure that makes sense for the student.

✎ At the end of each block, there will be a bunch of exercises related to the concepts explained in that block, so the student can test his recently acquired knowledge. There will also be an evaluation at the end of each module, where exercises from all the blocks that form that module will be chosen.

➢ The tutoring module will have the basic information about what has to be explained to the pupil, how, and when it will be appropriate to stop with informative concepts and

start with an evaluation. It also decides when the student must be stopped in order to be offered some advise about what he is doing.

➢ The student's module must be designed in a way that it collects all the relevant data necessary to make a detailed pursuit of the student's progress. To measure this progress, we need some metrics with which to compare what are the minimum and average levels for a student to pass to the next level.

➢ The communication module must make use of all the available multimedia resources in order to make the course as easy-going as possible, as long as it does not make the course be too slow, which in the end could bore the pupil.

5. INTEGRATION

This is really the key issue in the correct functioning of the system we have been describing.

It has been when describing the ITS when we have provided some clues about how this integration may be done. Now, we will explain in detail how this has been done in our system.

The information we can deduce from the former paragraphs is the following:

➢ The communication module must inform the ITS about the actions of the pupil.

➢ There are two different types of exercises from the point of view of the tutoring module. One of them is the situations simulated in the VE, and the other type encompasses all the different exercises related to the basic concepts.

What we can infer from this is that the VE will be a particular kind of exercise and that the actions performed in it must be supervised by the tutoring module. Thus, the structure of the integrated application should be the one shown in Figure 2.
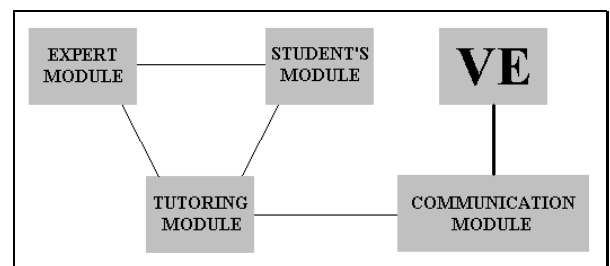

Figure 2: Integration of the ITS and the VE

Now that we have decided the general structure that the application will have, we have to decide how the tutoring module will be able to supervise the actions that take place inside the VE.

Since the steps to be followed inside the NPP are very well defined and something can't be done without doing some other actions that must be done before, everything points to the use of state diagrams, where the actions that make the state change are the actions that the pupil can do inside the VE. In some situations, there may be different possibilities, in which several actions can be performed in a not predefined order, so the state diagram may have some branches, but they will finally converge in a state from where the process will continue.

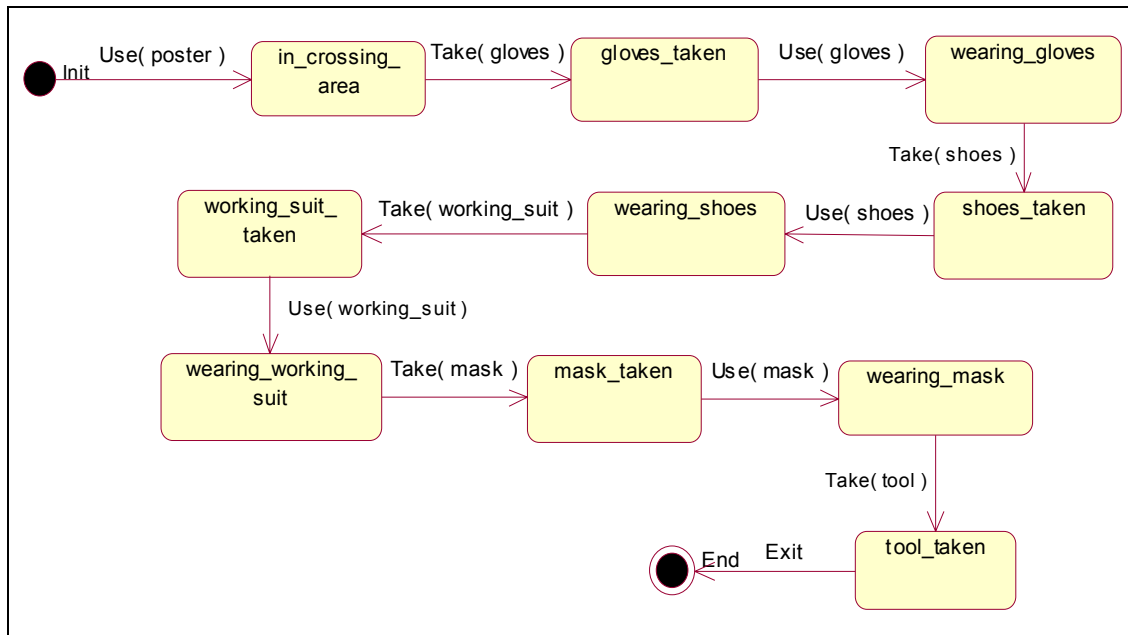The aspect of one of these state diagrams may be the one shown in Figure 3.

Figure 3: State Diagram for the VE

When this diagram is designed, the most flexible way to implement it is to design a general mechanism that is able to read the structure of the state diagram and the actions that must be done to change from one state to another. This information, as we have already done with the rest of the expert module, will be stored in a relational database (because, of course, all the information about what has to be done inside the NPP is part of the expert module). This will allow us to create or modify a state diagram using all the existing objects in the VE without having to modify the code of the application, so that if the NPP decided to change the procedure to enter the plant by changing the order of some actions, we would just have to change the information stored in the database and the application would work perfectly without any further change.

Now that we have solved this problem, there is one last problem that must be solved, which is the communication among the VE, the communication module and the tutoring module. This is a problem because there are two reasons why an action inside the VE might not be possible.

The first one, implied by the expert knowledge, because the selected action may not be the right action to be done in that moment. The second one, due to the constraints inherent in a VE, because it may not be possible to physically do the action, usually because the object is too far to be able to interact with it.

Because of these two sources of problems, when the pupil tries to do something, the procedure to be followed is:

➢ The communication module asks the VE if it is physically possible to do that action.

➢ If it is possible, then it asks the tutoring module if it is the right action to be done in that moment.

➢ The tutoring module asks the expert module if it is the right action to be done in that moment.

➢ If it is the right action, then the tutoring module tells the VE to perform the action.

➢ If it is not possible to do the action or if it is not the right action, then the communication module shows a message to the student. This message is constructed by the tutoring module, in case the action is wrong, or by the VE, if it is just not physically possible to do that action.

Once the interaction method is defined, we have but to implement what we have designed.

The design method is a bit more complicated and detailed than we have said, but this is basically the method we have followed to design the system.

The final result can be seen in Figure 4.

6. CONCLUSIONS

A little retrospective is necessary now in order to see what we have really achieved (very little), and what we still have to do (quite a lot).

First of all, since it was the main purpose of this paper, we must analyse the benefits that we have obtained with the integration of a VE and an ITS.

We think that this technology is really beneficial in the world of education, since it integrates two of the main tendencies in the world of Computer Aided Education. On the one hand, we have Intelligent Tutoring Systems, which are the main evolution of computer applications aimed to aid people in their learning process. On the other hand, we have Virtual Environments, which are increasingly used to simulate situations already known by the user, who only needs a bit more practice in order to strengthen his knowledge about a subject.

The integration between these two technologies is the next step towards the 'ideal' ITS. From the point of view of ITSs, this integration adds a new technology to all the existing ones already used by them: image, sound, video and, now, real-time, interactive simulations. From the VEs point of view, specially those aimed at the learning process, what we have done is to add a bit more intelligence to them, so now they can be used not only to practice formerly acquired knowledge, but also to teach that knowledge from beginning to end. The teaching process, also, can be adapted to fit the needs of different students. Thus the VE becomes more 'interactive', in the sense that the student has more freedom to explore different alternatives, under the supervision of an intelligent tutor that will advise them if they are getting into any trouble.

As we can see, this integration is mutually beneficial for both kinds of systems, and, over all, for the student who will use this tool, because we must not forget that pupils are the ultimate and most important objective in the career towards a more complete teaching tool.

Last, but not least, some words about the field in which this technology has been used.

Nuclear Power Plants, although secure, are a very special environment where all precautions and help are always welcome. As we have learned during the development of this project, there are certain areas where human presence is not recommendable, but from time to time it is necessary to inspect

their state. In these cases, the better the action is planned and trained, the less dangerous it is for the person who has to do it.

NPPs are environments that will be really benefited from the advance of the technology that is currently being created, because of two main reasons:

- VEs, along with ITSs, can be used to train people for their everyday work.

- VEs can be used to plan actions in the above mentioned restricted areas, so that the human presence there can be as short as possible if the action to be carried our is perfectly planned.
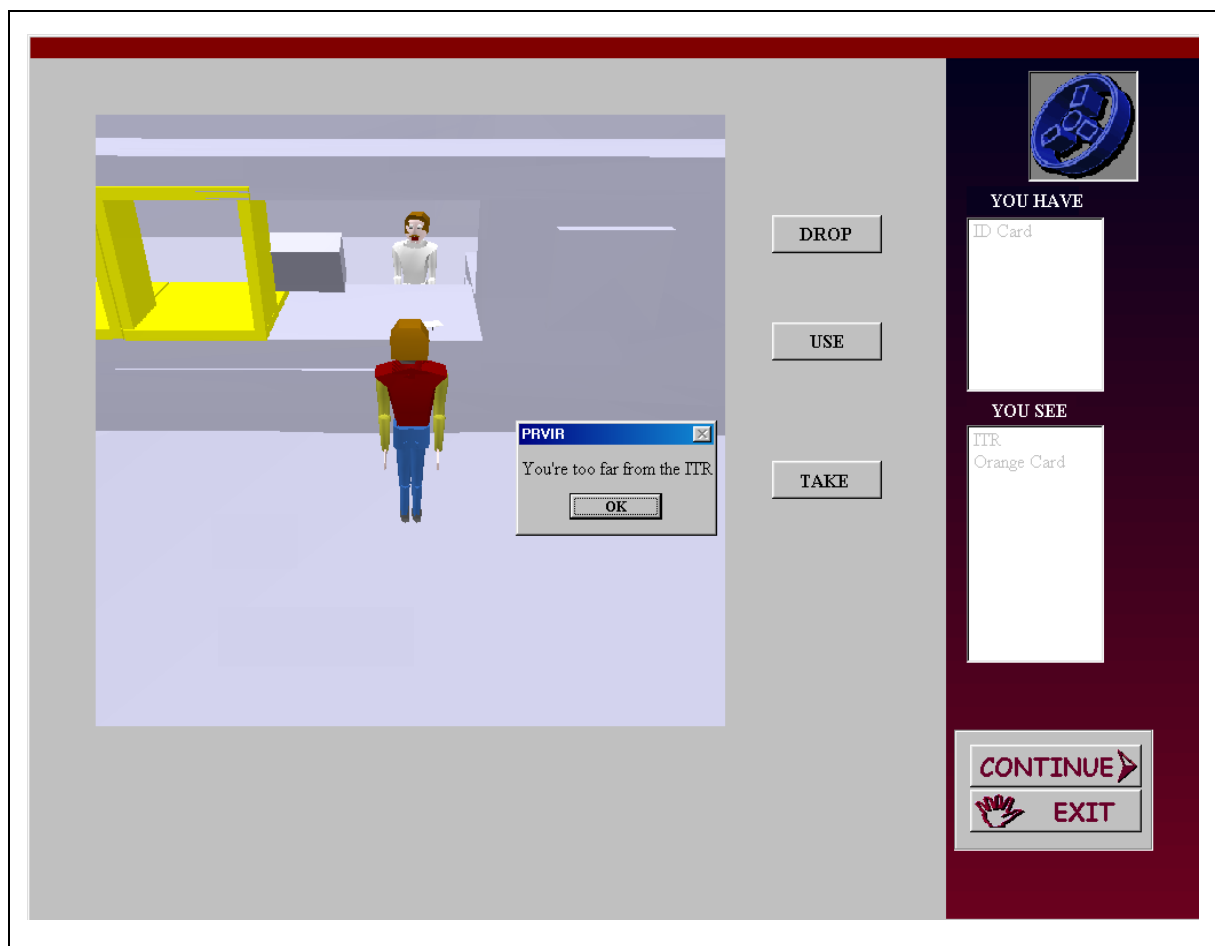

Figure 4: PRVIR Application

7. BIBLIOGRAPHY

[1] J. Bell et al. "The Investigation and Application of Virtual Reality as an Educational Tool", 1995. http://www.engin.umich.edu/labs/vriche/papers/aseepap2.html

[2] L. Casey. "Realidad Virtual". McGraw Hill, 1994.

[3] R. Felder, L. Silverman. "Learning and Teaching Styles in Engineering Education". Journal of Engineering Education, vol 78, nº 7, pp 674-681, 1988.

[4] Ch. E. Hughes, J. M. Moshell. "Shared Virtual Worlds for Education: The ExploreNet Experiment". Multimedia Systems, vol. 5, nº 2, pp. 145-154, 1997.

[5] V. S. Pantelidis. "Suggestions on When to Use and When not to Use Virtual Reality in Education", 1999. http://www.soe.ecu.edu/vr/sug.htm

[6] V. S. Pantelidis. "Virtual Reality (VR) as an Instructional Aid: A Model for Determining When to Use VR", 1997. http://www.soe.ecu.edu/vr/vredmod.htm

[7] S. Taichi. "Teaching with Technology: A Survey of Pedagogical Approaches to Interactive Computer-Based Teaching". University of Brown, 1997. http://www.cs.brown.edu/people/st/homepage/cs193.htm

[8] C. Youngblut. "Educational Uses of Virtual Reality Technology", IDE Document D-2128, Institute for Defense Analyses, 1998.