Virtual Reality as a Comprehensive Training Tool

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Abstract: Experiences on development of training systems based on non immersive Virtual Reality are described. It is discussed about factors that make VR a tool to create content and learning contexts so that instruction can be more efficient. The systems allow risk free training of highly dangerous live line maintenance procedures and keep records of trainees' progress, among other things.

Keywords: Virtual reality, training, learning process

1 Introduction

The aim of this paper is to describe the architecture followed in development of different training systems based on Virtual Reality (VR) and shows that this kind of systems allows integrating different influencing factors or dimensions of a learning process. In other words VR not only is helpful in the creation of learning content but also in the integration and creation of learning contexts.

A learning context is conceived as the sum of factors which intervene in a specific learning process. From this point of view and unlike traditional instruction which is usually considered incomplete and less efficient, we follow the comprehensive approaches to learning; where the more dimensions are integrated in a learning process the more efficient is the instruction to reach a specified learning goal.

The rest of the paper is organized as follows: Section 2 discusses about learning approaches and adopts the integration idea of the comprehensive approach. Section 3 provides a brief definition of VR, describes the architecture of the VR for training as well as a brief description of the development methodology used, a preliminary study about the efficiency of the systems, and shows evidences of the comprehensive approach in these systems. Section 4 includes some conclusions and it is followed by a list o references.

2 Learning approaches: discussion

Some authors [7] criticize the traditional instruction methods for the cognitive domain, which rely on textbooks and basic practical lessons, pointing out that they pose various limitations in assisting learners in recalling or recognizing knowledge, and developing their understandings, intellectual abilities and skills.

Intuitively, from having a group of students, all of them with different skills, we can envisage that the traditional instructional method will match the skills of a subset of the group of students, but not with the rest of the group. At most there will be some students that will be demanded different levels of extra effort to learn and get the same performance that those students in the matching group, other simply might quit.

Different approaches and theories have arisen to improve learning. Theories and methods such as conductism, constructivism and others might be included here, but from the intuition above we can observe that learning process requires a more comprehensive view so that instruction can impact learning in a broader audience.

One of the problems here is that instructional design usually does not target groups of students with the same skills; rather they are applied to a heterogeneous audience of learners each one with different skills. Thus, there are also comprehensive approaches, for instance Chen et al. [6] propose a theoretical framework based on integrative goals and principles for multimedia. Here integrative goals for instructional design [10], is based on the idea that design begins with the identification of learning goals (for instance baking a cake). Goals are sometimes conceived as objectives reflecting human performance, and sometimes as learning outcomes implying the acquired capabilities for those performances. Then integrative goals deal with a combination of several individual objectives that are to be integrated into a comprehensive learning goal.

2.1 Multidimensional approach to learning

Following the comprehensive approaches and the use of technology, when dealing with instruction, there is a variety of different dimension or factors which intervene in a learning process (Fig. 1) and that must be considered if we want to accomplish the main goal of any instruction task (knowledge transference). These dimensions can vary on different situations, some are mentioned here.

- *Learner- instructor dimensions:* Regarding the people involved, two dimensions can be identified in getting the knowledge transference goal. In case of students, this goal is to accommodate a new piece of information or a new arrangement of information into their knowledge repository within their brains. When this is achieved, learners might modify their behavior or points of view, augmenting their skills, etc. For instructors this goal should be to teach and have evidence that the knowledge has been really transferred to the brain of the students. These dimensions also involve, a perhaps just assumed, but decisive demand in order to get a combined effort to get the training goal namely, learners must really want to learn and instructors must really want to teach.
- *Instructional model dimension:* Regarding instructional model as another dimension, different have been proposed (e.g. Conductivism, Constructivism, etc.) each having

strengths and weaknesses. They all provide some truth and some approach for learning improvement (e.g. learning centered on instructors, learning centered in students, learning centered on instructor-student interaction, etc.). There might be cases where a model is used effectively that even uninterested students are involved and guided to a specific learning goal. However, depending on the instruction domain, a model or combination of models must be selected in order to make the instruction efficient.

- *Instructional domain dimension:* Instructional domain is another dimension; it is not the same football training, which is mostly a physical activity than a physics lesson which might be mostly theoretical. It is clear that each domain demands specific abilities from learners, but also determines which instructional method can be better to reach an instructional goal.
- *Learning channels dimension:* One more dimension is set up by different kinds of students according to the learning channels that they prefer when learning or that makes learning easier to them. Usually three different kinds of learners are identified according to dominant learning channel, namely auditory for those who learn better by hearing, visual for those who learn better through visualization and kinesthetic for those who learn better by manipulating objects. Students also involve different mood and emotional states, different skills, etc., which in combination with learning channels intervene in learning efficiency. We do not use only one learning channel; most people learn better by using more than one at once. If instructional design and content includes stimuli elements for the three learning channels, the efficiency will cover a broader audience.

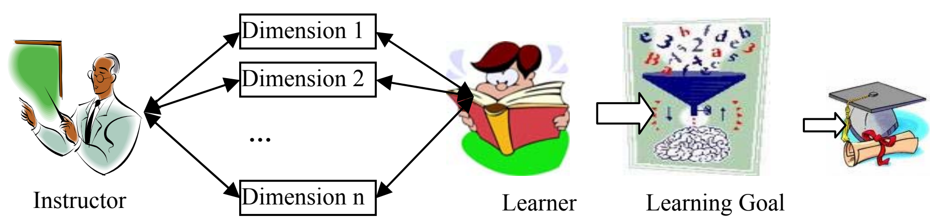

Fig. 1. Different dimension intervene in a knowledge transference task

Different other dimensions can be present in the learning process. The term *learning context*[1] (LC) might be used to group the different dimensions involved in any specific learning process. LC can include *personal learning contexts* (PLC) which are subsets of dimensions attached to specific persons either learners or instructors. We can

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[1] Here the term "context" is borrowed from NLP community where it is defined as a set of consistent statements describing a set of beliefs of a person. Thus unlike learning environment which includes external elements that influence a learning process [15], learning context pretends to be a personal internal view of an environment and so a more complete and precise view of the learning factors influencing such learning process.

identify *group learning contexts* (GLC), which can be restricted to the sum of PLC of learners and instructor involved in specific learning process.

Comprehensive approaches to learning are based on theories such as the integrative goals theory. Following these approaches, identifying, integrating and considering LC into the learning process would provide an efficient and more complete tool to reach a learning goal.

Traditional instruction methods can be considered incomplete in the sense that they do not involve different dimension present in the learning process. For instance, in some latin-american countries, there are educative institutions which rate the efficiency of instructors based on the percentage of failed or graduated students. This is a shortsighted point of view because it does not consider all the dimensions involved, learners might think that learning process is only responsibility of instructors. This stance seems to charge instructors with all the responsibility which is clearly an incomplete view for evaluating learning efficiency and even worst, it might convey a wrong message to some students and to some education authorities. Even the use of technology might provide incomplete methods. Distance learning can be an alternative for inaccessible education problems. However, if in a distance course the instructional content is just delivered to students altogether with guidelines to follow, and then learning evaluations are demanded, the student-instructor interaction can be reduced. It might be well suited for self learning oriented people but leaves out other kinds of learners.

On the other hand the ideal learning context might be almost impossible, unless instruction is personalized, in whose case might be less practical and surely expensive. We have to content ourselves with including the most dimensions as possible in a learning process, but perhaps more important is to be aware of the different dimensions intervening in specific learning processes.

2.2 Technology in learning processes

Technology has proved to be useful as a learning tool. Technology has contributed to reach learning goals by providing tools such as learning objects and learning objects repositories, learning management systems (LMS), content management systems (CMS), intelligent tutorial systems (ITS), and virtual reality for training, among others. Furthermore, there is a key point in using technology in the comprehensive approaches; it might allows us integration of different dimensions involved in the learning process, so it provides a tools to rise efficiency of learning processes. Among the successful technologies for training is Virtual Reality (VR).

3 Virtual Reality for training

Although Virtual Reality (VR) can be applied in different fields such as design, games, films, simulations, visualization, etc., it also allows integration and creation of different learning contexts which make it successful as a training tool.

Burdea and Coiffet [5] point out that training is one of the main application fields of VR. This technology provides benefits for training which are limited in traditional instruction. For instance, VR is ideal for dangerous training under no risk, allows visualization from different perspectives many of them inaccessible in real environments, allows virtual visualization of equipments, interactivity design allows active learning, provides learners the sense of control since they can repeat a lesson as many times as they need it and make progress at their own pace. We have also observed that interactive 3D animated environments are frequently more attractive than manual's photography to learners and this plays a positive role in learning.

Regarding companies which spend high amount of economical resources in training people, we have observed that VR systems for training tackle problems such as the high economical cost of training due to travel and stay expenses for people who have to move from job places to training centers. Besides this, it helps to increase the current limited number of trained personnel.

3.1 Virtual Reality

Before carry on, it is worth to say what VR is. The concept of VR has been approached from different perspectives and variety of terms starting with Jaron Lanier who coined the term *Virtual Reality* in 1989 as a 3D interactive environment generated by computer in which a person is immerse [3]. Other examples are *ciberespacio*, used by William Gibson [11] in his *Neuroromancer*. Here Gibson describes a virtual shared universe, operated within the sum of all computer networks in the world. *Virtual environments* consist of an interactive deployment of images enhanced by no visual deployment such as audio and tactile feedback in order to convince users of being immerse in a synthetic space [8]. We have attached ourselves to the following definition.

***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.* [12]

Unlike Lanier definition, we have seen that immersion is not mandatory to say that a system is based on virtual reality. In fact there is a wide variety of degrees of immersion whose extremes are non immersive virtual reality (Fig. 2) and immersive virtual reality (Fig. 3), in the former a user can interact with VR system by using only a mouse and a keyboard, in the latter a systems might need some variety of devices so that a user senses can be stimulated and user action can be monitored within the virtual environment. Between the two extremes we can find also the so called augmented reality (Fig. 4) which superposes virtual images to real ones so that a user is provided with a sort of "terminator's" vision.

Depending on the application field, sometimes immersion can be better than non immersive systems and vice versa. Without forgetting that a non immersive system is cheaper since it does not need VR peripheral devices for a user to be able to interact with the virtual environment.

Fig. 2. Non immersive VR

Fig. 3. Immersive VR

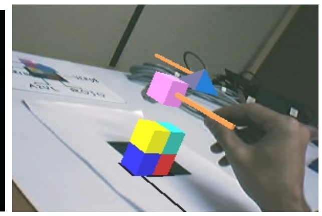

Fig. 4. Augmented reality

3.2. VR systems architecture for training

At IIE[2], different VR systems for free risk training have been developed for CFE[3], most of them are devoted to free risk training of highly dangerous maintenance procedures, involving medium and high tension live lines maintenance.

These systems operate in three modes namely, learning, practice and evaluation mode (Fig. 5). Before a user enters to any of these modes, the systems allows users to visualize and manipulate catalogs of 3D models of all the tools and equipment needed for maintenance work without being in a company's warehouse (Fig. 6).

The main feature in the learning mode is that the system has the control and indicates users step by step what has to be done to safely complete a maintenance procedure. Order must be cared since omission can be fatal. The practice mode allows users more freedom and user use this mode to go to specific steps and solve any doubt. In the practical evaluation mode a user must achieve a maintenance procedure with no help and errors will be recorded in a database for progress monitoring. The systems also include theoretical evaluations based on exams integrated by multiple choices questions whose outcomes are also recorded in a database.

The systems follow the same architecture (Fig. 7). They include the following modules: a) users' and courses management, b) maintenance procedures, c) licenses management and d) interface.

- *Maintenance procedures***:** This is the main module; it contains VR scenes and animations complemented with audio, information additional and text explanations (scripts). It includes the three modes namely learning, practice and evaluation modes.
- *Users and courses management module*: This module is used by the interface to determine if a user is entitled to use the system. Three different kinds of user can be registered in the system, namely administrators, instructors (facilitator), and students (participants).

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[2] IIE is the Spanish acronym for Electrical Research Institute, in Cuernavaca, México.

[3] CFE is the National Mexican electricity company

Fig. 5. Learning mode

Fig. 6. Tools catalog

- *Licenses management module*: This module is reserved only for system administrators. Granting a user's license, requires user's personal information as well as job adscription to make sure the license is requested by a company's employee.

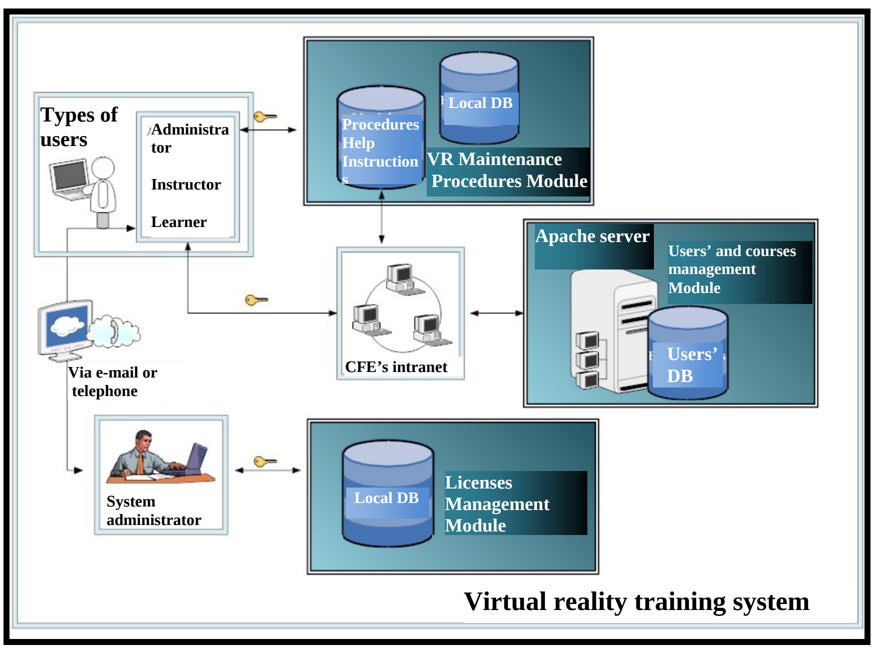

Fig. 7: Architecture of VR training systems

3.3 Development stages of a VRS

The development of a VRS follows the stages reported in the software engineering literature. Once we have a requirements specification and the design of the system (interface, since virtual environments design, might be guided by the real environment), these are the development stages we follow:

1. **Information gathering**: Depending on the application field, first we have to determine the number of objects and their complexity that will be part of the virtual environment. The information is video recorded so that images and physical dimensions of the objects are available to developers (Fig. 8). If technical specifications of equipment are available, objects measuring might not be needed.

Fig. 8: Equipment measuring

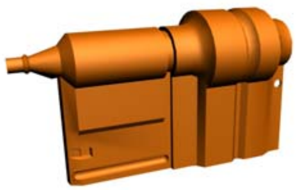

Fig. 9: 3D model

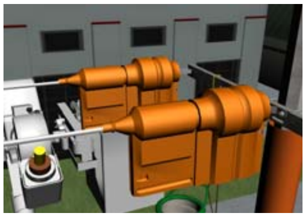

Fig. 10: Virtual scene

2. **3D modeling:** Here all 3D objects are made to scale (Fig. 9).
3. **Scene creation:** In this stage, all 3D models previously created are integrated so that a virtual scene or environment is created.
4. **Animation:** Here animation inherent to each 3D model is developed. For instance, the motion of a helicopter or fan blades or the movements of a crane, etc. (Fig. 4).
5. **Script elaboration:** It is similar to a film script; it contains explanations and instructions for user's interaction.
6. **Interaction and audio**: Sound is added to the scene according to the objects included. It is also implemented the interaction between user and system. Thus, according to users' actions, different behaviors of the scene are implemented, so users can perceive environment reactions to their interaction.
7. **Interface development:** The interface integrates a virtual scene, menus, explanations and instructions so that users' interaction is guided (Fig5. 5, 6).

These stages are also useful to gather information about the number and complexity of the objects to be modeled and animated. This in turn is useful to elaborate a cost-benefit analysis and therefore to determine whether or not the system is viable.

3.4 Preliminary study of VR efficiency

A preliminary study has been conducted to see how helpful these kinds of VR systems are in training. In this study two groups of 10 participants were randomly defined namely GrTrad and GrALen, the former was trained under traditional instruction and the later using a VR system. Both group had to learn one live line maintenance procedure. Then two evaluations were applied to all the participants a theoretical one consisting of a written exam and a practical one where couples of participants were asked to perform some key steps of the maintenance procedure. Finally exams were marked and compared (Figs. 11, 12); some are showed below (see [16] for detailed description of this study).

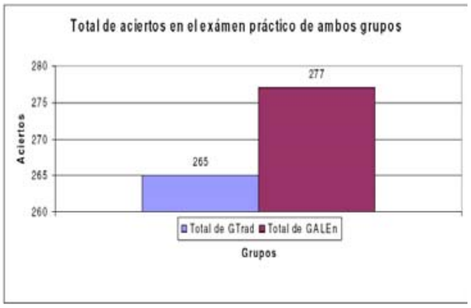

Fig. 11. Theoretical evaluation

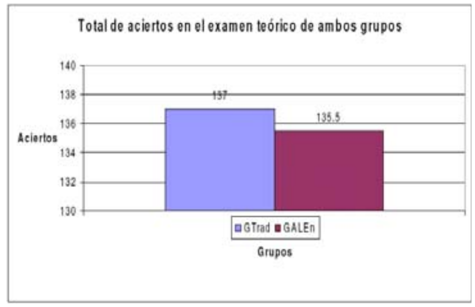

Fig. 12. Practical evaluation

These results are not still precise enough due to participants' background. The requisite to participate in the study was that they had no knowledge about live line maintenance. Nevertheless, during the study we realize that although the participants assigned for CFE were all beginners, they had already, notions in different levels, of live line maintenance and this might have affected the results.

3.5 VR training systems vs learning context

To start with, the three modes included in the architecture of the VR systems developed, provide students with a tool that reinforce the three stages of the learning process [13] namely: a) receiving information, b) processing so that information is retained in memory and c) using or applying the knowledge acquired.

In the learning mode student receive information provided by the system; the practicing mode helps students to review information and so to process it and therefore to retain it in memory. The practical evaluation might be considered only as a first approach to real live line maintenance (use of knowledge acquired) which can be observed in training sites.

- *Learner-instructor dimensions:* Although this dimension is quite subjective we observed that even in the validation stage when the system was yet incomplete, the content catched the attention not only of the target audience (maintenance workers), but also of different kinds of people including directives, female secretaries, children, etc. They all had short time informal access to the system (they just wanted to know what the system was about) but when they were asked about the content they all showed evidence of having learnt and retained something in memory. The systems are useful for instructors to teach and for students to learn even if they do not belong to the target audience.

- *Instructional domain dimension:* As mentioned above, the instructional domain of these systems is the free risk training of the highly dangerous maintenance work to medium and high tension lines. This domain involves both some theoretical knowledge including some electrical principles and mostly a sequence of dangerous physical activities.
- *Learning channels dimension:* A study mentioned in [14] shows that we have roughly the same preference for three learning channels:
  a) 37% of learning is *haptic or kinesthetic*, through moving, touching and doing.
  b) 29% of learning is *visual*, through pictures and images.
  c) 34% of learning is *auditory*, through sounds and words.

However, it is known that more than one sensory channel can be used at once while learning. Within study strategies literature, this is referred to as *multimodal study strategy* and according to Fleming [9], the majority as approximately 60% of any population fits that category. Each learning style uses different part of the brain, so the more channels are involved during learning, we remember more of what we learn [2].

Although there is a number of learning styles mentioned in learning literature [1;9] such as read/write, logical, verbal, etc., we focused on the three primary sensory learning channels [4] whose preference percentages were listed above; a VR system for training can be able to stimulate learning channels in some degree. Thus, whatever the channel is best for a student to learn, he/she still can benefit from a VR system as a learning tool. The system can include images, text and animations for those visual students. All the explanations provided in text are also reproduced in audio for those who prefer the aural learning style (although sound can be turned off under demand). Regarding the kinesthetic oriented students, thus far, they can interact with the system by using a keyboard and a mouse. An immersive system might provide more kinesthetic stimulus, but they are still expensive.

- *Instructional model dimension*

The practice mode, the interaction and repetition capability as well as the self learning facilities of the systems are helpful not only in constructing the users' knowledge within this instructional domain but to some extent, also they allow active learning and stimulates the kinesthetic learning channel of learners.

- *Company dimension*

The instructional domain is established by the company which also demands free risk training even though the real maintenance activities are highly dangerous. It also demands progress monitoring, controlled access to the systems and their instructional content, self learning capability, formal course training, among other factors. The architecture described covers all these demands.

4 Conclusions

The closest work that we have found related to VR systems for maintenance training within the electrical sector [17], describes an immersive prototype which includes only one procedure. Some differences are: being immersive the prototype involves an extra cost derived of peripherals use which in turn reduces availability; unlike this prototype, the systems we develop are used in real training and include at least 40 different procedures. The prototype was developed using WTK which is not available anymore and it does not keep records of learning progress. Regarding the use of virtual reality, it should have the advantages of this technology.

Experience in development of non immersive VR systems for training shows that VR is useful in integration of learning contexts; this makes it an efficient learning tool. We realize that 3D scenes and animations are appealing to people, no matter whether they are adults or children and no matter whether they are professional or not. Somehow the property of been able to create virtual contexts enables VR as a learning tool. It has been observed that introduction of VR in training, impacts not only training itself but also costs and modifies the way in which training is managed mainly in companies. For instance, one of the indicators used to measure training is the number of hours per person per year. When VR systems are available to potential learners, in some cases they spend many more hours than those defined by the company, mainly when they can install the system in a lap top that they can take home. These extra hours do not imply instructors' hours, which reduces costs. One last comments is that there might be instructional domains where learners can self learn using a system whose instructional content is comprehensive and really well done. In such cases presence of instructor might not be determinant for trainees. Nevertheless, for the systems mentioned here, this is not the case. Live line maintenance procedures involve a high risk, instructors agree that a first mistake can be the last one due that accidents are usually fatal and lives are lost. Live lines maintenance involves physical activity which is not provided by a non immersive VR training system, perhaps an immersive systems including peripheral devices such as pole, tools, cables, etc., might include it. The point here is that these systems are not entitled to emit a certificate to enable people to perform live line maintenance; this must be responsibility of a human instructor who will have to cover the physical and practical training.

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