THE UNAVOIDABILITY OF VIRTUAL REALITY IN TECHNOLOGICAL SOCIETIES' LEARNING ACTIVITIES

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Abstract. *Virtual Reality is becoming self imposed to the technological society, which may otherwise loose the ability to guarantee its future. The new generations are being grown in a world immersed in digital gadgets, in which physical reality hardly penetrates.*

Several technical tasks and learning activities are rejected by the youngsters because they are tedious. They are also frequently dangerous and expensive to perform and most certainly not appellative enough for youngsters. Considering that if you cannot beat them you must join them, one has to use the attraction exercised by the virtual world for training, teaching and learning. This way, technical skills can be effectively transmitted, minimizing, at the same time, the real risks when exposing the individuals to the actual situations.

In this paper we analyse several dangerous technological tasks in view of their implementation and support by means of virtual reality. The timing and methodology of how virtual reality tools can be used to perform technical apprenticing are analyzed, as well as the necessary steps to the development of low cost sensors, devices and equipments to facilitate its popularization. The advantages of three-dimensional modeling of the environment for learning the laws of mechanics and technology, and to trigger and sustain the interest over these subjects, are explored.

Keywords: *Virtual Reality; Teaching\learning; Risky professions, Mechanical Technology*

1. INTRODUCTION

The way of life of technological societies is supported by the availability of a large set of goods, either products or services. They are produced somewhere in the planet and made ready to the end users worldwide. International exchange is made increasingly easier because larger ships, trains, planes and trucks keep being built, and transportation paths are expanding more and more to reach distant places. Parte of the tasks to be carried out that are risky, tedious and/or difficult and a lot of skilled work must be done. Figure 1 shows two manufacturing situations where skilled professionals are needed, and risk is present.

Furthermore, the production of goods has become quite segmented, each phase of product life cycle having stratified activities and so requiring specific tasks

The continuous development towards and increasing better life quality tends to produce:

- Fast technological change;
- Longer periods of apprenticeship;
- Attraction for softer, unrisky, high profit professions;

Figure 1. Conventional manufacturing operations in a lathe (left) and a in a milling machine (right); Skilled professionals are needed to handle the machines, and risk is all time present.

To keep such way of life and avoid the execution of hard tasks is not possible however for everybody. Someone must be able to do particularly difficult jobs, either trough direct handling requiring physical strength, or maneuvering some sort of apparatus with mechanical help. Naturally this kind of jobs demand experience, and experience demands training.

Taking a look to any field of activity one easily identifies professions requiring manipulation skills that must be trained, because even small errors may result in severe damage either for the operator himself, for the equipment being manipulated or for a third part involved (either person or machinery). Yet somebody has to do the hard work that tends to be well paid since in professionals mastering the required skills are scarce.

In every job acquiring experience consumes time and materials and apprentices are exposed to the risks inherent to the task to be performed. As experienced generations get old, new generations need to be trained in order to get the skills needed to get the tasks done. An increasing percentage of the children and teenagers are kept out of the professional world not only because their work no longer is needed to help support their family, but also because longer learning periods are needed to achieve the level of knowledge required to integrate productive activities. During learning time most of them are attracted by white collar professions, and when finishing school they have no actual skills to join the available professions, often demanding physical competences they haven't acquired. Furthermore, there are also white collar professions often needing to qualify their professionals with new developed physical techniques (for example in surgery or in investigation activities – figure 2).

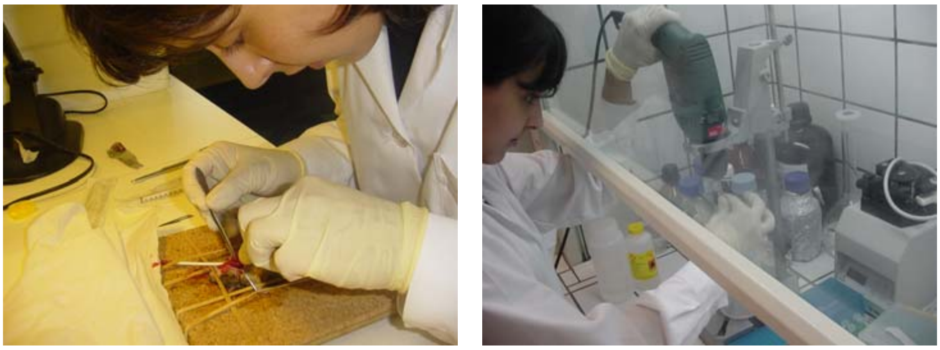

Figure 2. Sometimes white collar professions also need manipulation skills.

2. LEARNING ACTIVITIES: CHANGING THE PARADIGM

Young humans are used to play adult imitations in order to get prepared to perform the same activities later on. In old times the games that children used to play were part of the training needed in the later stages to carry on the adult jobs. Usually they consisted in imitations of adult activities: traditional games often had the role of preparing the future adult to develop the skills that would be needed later (hunting, fighting, using tools, rising kids). Nowadays, richer and more complex societies tend to maintain their youngsters much longer learning, but at the same time they avoid hard professions where personal risks are present, were difficulties are bigger, choosing less exigent and more agreeable ways of spending their lifetime. Frequently the danger associated with a profession makes the possibility of replication into conventional ludic activities almost impossible.

The use of the computer as a ludic tool (computer games) offers at the same time experiences that can be extremely useful in learning either soft or hard skills, taking advantage of the fact that children, teenagers or adults enjoy playing games. In effect, some of the best computer simulations have the game character, what increases its potential for pedagogic use [Roussou et al] [Standen et al]. The games allow a great variety of contexts and a flexible exploration of different situations by the player. Moreover because the answer is fast and individualized, youngsters (and even elders) normally develop fixation for computer games. Using computer support, nowadays a lot of ludic activities are offered in an environment that offers almost no physical harming possibilities, alternative worlds abiding more or less with physical reality, so constituting Virtual Reality Environments. Most computer games are not useful to prepare anyone to a particular activity, because the work there to be done is not yet replicated into an instructional game; yet useful gestures for accomplishing difficult tasks can be trained, at low cost, avoiding consumption of expensive scarce materials, avoiding actual health risks, and offering agreeable ways of learning and spending one's time.

Virtual Reality technologies in industrial applications can obtain excellent results [Ressler et al] [Kealy et al] [Grave 2001]. Expectations either in social terms (acceptance, comfort and motivation) either in industrial terms (shortened learning periods and cost reduction). An advantage is its feature of making possible to experiment endlessly the same sequence of operations or test alternatives; another is that Virtual Reality may increase the number of available and qualified professionals because the change in learning paradigm improves motivation.

Not only new goods are being made available and new technologies are being developed, but also increasingly some competences are becoming obsolete (people doing highly specialized tasks suddenly master a no longer needed technique). For example personal computers development provided the support for design enhancements such as accurate geometrical modeling. Increasing drafting capabilities of the CAD software available made the drafting profession obsolete. Some drafters changed into designers, upgrading their capabilities, some had to change to other professions because with computer help fewer professionals are needed to do the same amount of work. By the seventies of the 20th century *fac-simile* transfer (FAX) provided a revolution in communications because image transference was made easy, but soon the computer to computer file exchange universalization provided a faster and more reliable support for communications. As a consequence people working in conventional mail companies had to move to different jobs, the companies themselves changed operating focus and so on. Shortly: anyone joining a profession has no idea what skills may need in a few years and so learning became a long life requirement for professional success, even in the most basic jobs.

The new (emerging) activities have to be taught in a shorter period, at lower cost, otherwise risking to be put out of the game. Most tasks can be done by somebody else, but those who got better skills spend less time, waste less materials, etc. Due to the constant improvement in products and services, desirable skills change fast. There are not much alternatives: either one gets the new skills, or sooner or later will be replaced by someone else. The same occurs with companies. Neither worker unions are any longer able to warrant conservation of job specification for their associates, nor are companies able to keep their activity unchanged: continuous change by acquisition of new skills is the stronger alternative to obsolescence.

In the real world, training hard skills demands the consumption and consequent destruction of materials, often making training an expensive issue. Also if a work station is being used for training activities, it is not available for actual production. Most equipment is so expensive that its replication for learning activities is out of question. Equipment cost impeaches technological schools to keep their conventional hardware facilities up to date and there always were some equipment unavailable because of their cost or dimension.

Along the production chain of any product, there are tasks to be accomplished where some kind of skilled manipulation is needed. Some of the tasks to perform are commonly dangerous; need skillful trained operators or both. Both a computer and a car are assemblies of some dozens of components that undergo a lot of transformations from the raw material to the delivery to the end user. Taking a look over manufacture or maintenance, we conclude some essential activities arise that are not particularly attractive for youngsters as potential professions:

- Industrial base metal works - casting, welding, machining, wrought products, ironworks – needed to obtain the raw material of the component or the component itself (see figure 3);
- Assembling and finishing machines and equipment or spare parts, needed to produce the final shapes or to verify their accuracy;
- Manufacture and operation handling equipment for the items above;
- Assembling and mounting metallic structures: factories, containers, stores;
- Operating machines and equipment for generate and deliver the energy needed to their operation;
- Operating machines, equipments and material for their maintenance;
- Making tools and fixtures.

Besides investing in research and investigation of technological issues to keep up to date, companies must also invest in tools capable to improve and simplify training for their production processes so reducing the time and costs associated with personal skills adequation. Virtual reality appears as a promising bet for technological apprenticing.

Figure 3. Casting metals: a profession that is not particularly attractive for young people.

3. INTERACTING WITH THE ENVIRONMENT

Performing a task is interacting with the environment. First, one must acknowledge the current status (situation, dimensions, characteristics or possibilities), and do some sort of action over devices or tools in order to modify the status of the environment. People have few interfacing senses: sight, hearing, smell, taste and touch. When interfacing with the environment, different circumstances ask different level of use for each sense. For example one uses sight to acknowledge that a fish is hanging in a hook, but needs the hands to do the job of taking it off; with touch one feels the hardness and sharpness of the hook, and evaluates the complexity and potential danger of the operation. One also feels the softness and wetness of the fish that may affect the success of the releasing operation. The main senses involved are sight and touch, although of course smell is present; it helps to identify the presence of the fish, but it hardly will be helpful to take the fish out from the hook. Both hearing and taste are less or even not useful in the releasing operation

In industrial activities, most tasks, including the most dangerous or difficult ones, also demand mainly the use of both senses, sight and touch, often helped by hearing (sounds or noises that a trained ear identifies as meaning that the operation is running correctly or that something is wrong), or smell (identifying materials and their state conditions), but taste is usually unnecessary.

3.1. Virtual Reality Essential Sensations

From 1993, the definition of the Virtual Reality concept stopped restricting to the subject equipment, to include semantically to the imagination and the possibility of creating interaction with three-dimensional simulation environments. Burdea describes the virtual reality as an interface “high end” that involves the simulation in real time and interactions through multiple sensorial channels [Burdea and Coiffet, 2003]. Burdea defends although the Virtual Reality is a trio (I3) formed by immersion, interaction and imagination, the last being related with the capacity of noticing non existing things.

To built a realistic virtual environment were real tasks may be trained requires the definition of essential interface equipment. This equipment is the one needed to provide the adequate sensations regarding the senses that are used to perform the similar operation in the real environment. By sight and touch most information about size and shape of the world is acknowledged. People are kept safe by learning to avoid touching a flame, a sharp edge or stick, very cold or very hot metal and so on. It results that images have to be produced, and force, pressure, acceleration, coldness, heat and noise must be provided. Taste and smell are not so easily modeled but they are not mandatory also for the success of the virtual task training.

Nowadays touch, in particular, is under particular scientific attention. Researching around the sense of touch allowed the development of artificial members robotically operated in places and under environments where humans cannot work such as deep see or space or tiny spaces, places where there are dangerous conditions or materials, where a remotely controlled robot can be more useful than a person, operating under unbearable conditions for a human without special protective (expensive) equipment.

The way in which senses can be fulfilled in order the user acquires realistic perceptions are already available. Some consist in commodities of present daily life; some others are less frequently used:

- Sight can be fed by image delivering using wide screens and projection systems that are nowadays available, or specially built glasses or helmets (in close contact with the body provide complete immersion conditions); alternatives for vision possibilities range from complete immersion to mixed alternatives of projecting images on a screen or using specially developed helmets.
- Touch can be fulfilled by special instrumented gloves, but also by devices as levers, buttons, wheels or pedals, chosen in accord with the task to be simulated, and accordingly mounted and instrumented;
- Hearing is easily furnished by vulgar phones or earphones and the sounds or noises may even be caught in real situations and reproduced as needed;

- Smell, if really important, may be chemically produced, and released using adequate devices;
- Taste is normally not necessary to train most professional activities requiring human strength.

No actual previous knowledge of computer science is needed, since the interfaces with the system can be tailored to match the conventional actuators that the operator is expected to use when doing a real job. Anyway most of the industrial equipment is already equipped with computers that are accessed via some kind of user friendly interfaces (figure 4). Naturally these interfaces are also continuously being developed towards ergonomic features; then they can be found in a great variety of products and are easy to use even without any previous training.

Furthermore there is not much variety in industrial environment of human-machine interfaces: wheels, levers, buttons, keyboards and pedals; they may vary a little in shape or dimension, but are essentially actuated using the fingers, the hands or the feet, one at a time or two or even three at once.

Hardware cost for Virtual Reality systems begins already to be standard and easy, due to the increasing interest of game business, not only for children.

Figure 4. CNC Lathe: the man/machine interface includes user friendly elements such as a keyboard, a screen a wheel and some buttons.

3.2. Virtual Reality Equipment

An application for a Virtual Reality system must be conceived to provide the accomplishment of tasks similar to the real technological ones. Sometimes there are actual technological aspects preventing better results: discomfort might come from the use of helmets, gloves or other artifacts of Virtual Reality and the lack of touch sensation and force-feedback may allow incomplete immersion [Pierce1997] [Grave 2001].

The experience acquired by the users of virtual reality technologies as support to training constitutes an area to be explored by the industry, because it as very high potential to improve the production processes. In the area of teaching and training knowledge, different work can be done, namely in more specific areas as making and assembling products, ergonomics, and virtual prototyping.

Generally speaking the requirements of a successful Virtual Reality system must provide:

- Good level of realism of the scene depicted, in order to grant easy identification of the virtual surroundings (virtual equipment, objects or parts);
- Very good level of immersion for the user; it is not expected that virtual environment totally substitutes the reality but abstraction must reach a level that allow exclusive concentration in the exercises to be done;
- Absence of discomfort sensations like nauseas and disorientation, the virtual interaction devices of the system must be comfortable and easy to use;
- Provide tasks with increasing levels of difficulty; proficiency is achieved by passing successive levels, where the involvement degree results from the concern of users in the resolution of the realistic exercises under realistic conditions of manipulation.
- Eventual use of "avatars" to simulate actual personal presence of the trainee inside the scene.

It is expected that in the training sessions with a system of Virtual Reality each user needs a short period for initial adaptation to the devices of the system, followed of a longer period for mastering the virtual work station; the trainee will then be ready to execute a complete specific training lesson, broadly the same as when dealing with real machines.

Of course communication between programmers and the users of a system is expected to apport improvements to the application, either in the detection of underlying mistakes to the system, or in the correction of the functions/disposition of the objects in the system. To build a successful Virtual system expert technicians from the activity to be modeled are needed.

3.3. Limiting Factors in Virtual Reality

The main factors limiting the development of a Virtual Reality System are economical, technological and human. The cost of a Virtual Reality System must be kept within limits adequate to the problem that is intended to be solved; it must present a bearable cost and be scalable. Virtual Reality technology is undergoing a fast evolution; complete systems for teaching and training purposes using these technologies are still hard to find, due to their own limitations as well as for the high costs that they still implicate since they are designed based on specific scenarios. A third factor derives from the acceptance level by the potential final users, maybe the most important one, because the reaction of teachers and trainees to the solution found determines the success of the system. Without acceptance of the solution developed, and consequent acceptance of the technology adopted, it will be difficult to make additional improvements.

The central objective of a Virtual Reality System should be to train the students in doing the correct movements' sequence, the respective gestures and corporal movements, in the object recognition and manipulation (parts, interfaces, etc.) as well as in the adaptation to new situations. The usability is a priori the most difficult factor to control, once only by experience of actual trainees is possible to obtain answers and to conclude orientations. Some particular factors will influence the choice of the support for interaction in the Virtual Environment: for example helmets or plane projection on a great screen; specially instrumented gloves or a set of driving wheels, levers or buttons. This decision should take into account some considerations:

- Level of immersion that the trainee has to experience in the Virtual Environment to reach high concentration in the smallest period of time possible;
- The trainee should concentrate on the tasks to be carried out and not in the technology being used;
- The trainee should accomplish, in the Virtual Environment, the actions, gestures and corporal movements in a very similar way to those that will be produced in the Real Environment, and these gestures and movements are also integral part of the learning;
- The materials and equipments modeled in the Virtual Environment, shall be easy recognizable by the trainee, i.e., they shall generate similar senses as the real materials;

4. INDUSTRIAL SKILLS NEEDS

A study was recently carried out in Portugal to analyze the availability and quality of professional profiles of six reference industrial sectors [AIM]. It showed that the main lacks in appropriate professionals to fulfill industry needs occurs in specific technical positions of those sectors, mostly of technicians for undergraduate positions where manipulating skills are important.

From the information collected relative to professionals' availability the following conclusions resulted:

- Drafter, safety technician and driver, are positions that presented simultaneously enough quantity and adequacy to the profiles needed;
- Mechanical technician for product development positions were not enough, and the profiles of existent professionals in these areas where relatively inadequate.
- Maintenance and Computer Numerical Control machinery operator positions presented a deficit of personal, both in quantity and quality;
- A deficit also existed in the number of quality control professionals for technical positions, robots and numerical control programmers, since these are modern activities;
- Welders, and sheet metal technicians are growing occupations because the related sectors are expanding, and with the incorporation of new working methods and new materials being applied, a natural offer shortage is expected.

On the other hand, very few people respect eligibility criteria and complicated rules governing the quality certifications, safety and professional approval requirements of candidates' curricula, which turn the human resources scarce.

In the particular case of Portugal, it is well known that the professionals' formation for these sectors was not cared for many years. The uniformization of the national education system under the Ministry of Education led to the rarefaction of the public offer of technical teaching, but also to the depreciation of the status of technical professions.

To compensate the rarefaction or even lack of technicians with formal instruction for doing the necessary tasks industry used to hire people initiated in the profession as apprentices, most of the time in situations that configure nowadays illegal infantile work.

Simultaneously, the evolution of demand of the technical professions, the emergence of sophisticated equipments, the uprising of new variants of the professions and the exiguity of the offer of formal technical education drove in time, to the occurrence of the present shortage of professionals.

There are not enough Programmers/Operators of CNC Machines, Metalworkers, Turners, Welders, Mechanicals, Metrology and Quality Control Technicians, Product Development Technicians and other typical professions of this area for the market demand [CENFIM, 2007].

The modernization in course of the industry, the installation of new technically demanding industries, and the competition for skilled people in Europe demand that new professionals be prepared to fulfill the needs of the companies, and also the adaptation of the preparation of many of the existent professionals in these areas that nowadays present inadequate profiles is needed.

A primary Virtual Reality system is already deployed and integrated in most recent NC machines (figure 5). It simulates the real process, considering all ongoing variables of the machine but with the physical devices of the apparatus disabled. That enables the operator to check if everything will run as planned, without further consequences other than the virtual simulation of machining conditions. Nowadays, this support has been brought to our desktop computers, through the widespread CAM software.

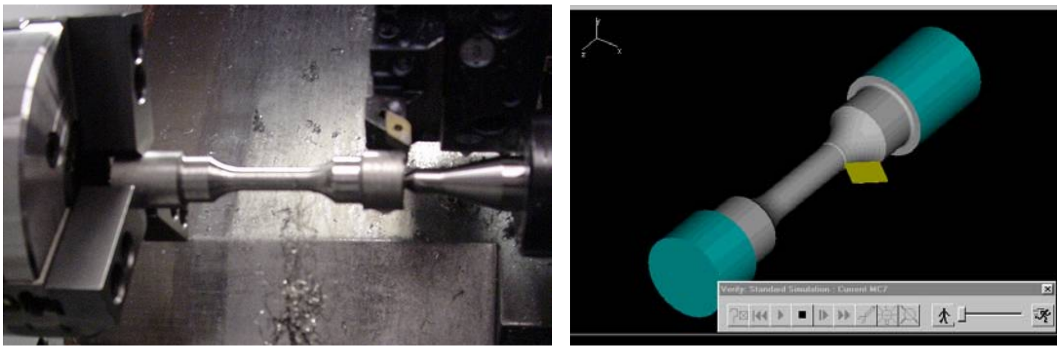

Figure 5. Manufacturing a tensile sample: the real sample (left) and virtual machining (right).

The present analysis points to the urgent necessity of development of solutions on technology teaching under Virtual Reality environment, to offer a solid technical teaching of trained professionals, to allow youths' integration in available work positions in present industrial companies. Also VR could guarantee the adequate updating of the professionals already working, offering the possibility for the acquisition of new skills so making it easier their reconversion and professional valorization.

Application examples of virtual environments include equipment operation training for medical, military or teaching situations. Also virtual prototypes can be produced to test and simulate assembly sequences or maintenance tasks.

4.1 Modeling Industrial Environments

In an industrial system, machines constitute the main production physical elements to be modeled. For a given plant one finds particular machines where particular objects, devices, tools and/or parts of particular shapes are to be mounted, fitting in particular places where they will interact. The result is generally a shape modification of a part which is then taken off. Besides these objects others exist near the machines like containers with raw parts to be worked and finished parts ready to delivery to the next workstation, or lockers for tools.

The virtual reproduction of the components of the environment must be made respecting their real dimensions, in order to replicate correctly working conditions. The parts, devices and tools must be modeled with detail to the real scale, since the requirement for virtual training includes correct identification of the workstation. Most of the objects present an irregular geometry that will be by large numbers of polygons. The usually large number of polygons generates a system potentially complex that influences the number of images generated per second and it demands larger use of resources on the part of the system.

Due to the constant alteration of the existent working conditions in a particular workstation to the introduction of new workstations lines in different plants the creation of a library capable to store the representations of the used objects must be considered. That turns into an advantage because it offers the possibility of reutilization of components when identical situations occur, so avoiding the effort of accomplishing a complete new series of geometric models. Avoiding this effort it is no longer necessary to hire specialized workers capable to model the objects and to integrate them in the application and to invest in specific software, resulting from that a cost reduction of maintenance of the application and of time spent.

5. FUTURE WORK

The first prototype of a virtual training environment is under development at our laboratories, involving experts from mechanical engineering, electronics and computer graphics (virtual reality, human computer interaction).

The first phase of the virtual training environment includes the development of an educational turning station to train skilled hand workers (that for years operated manual / traditional turning machines) for nowadays manufacturing industry, which requires computational skills, at least with basic keyboards and levers manipulation. The virtual machine to be modeled is based on a real one existent in the lab, to allow the execution of comparison tests of the effectiveness of the system. The system will be tested by the students in their practicing classes, and then made available to industry and technological schools. Most of the modeling effort of devices, machines tools and parts will also be done by students in the adequate disciplines. The reasons that motivated a study of effective training help are based in the following aspects:

- High number of skilled workers is needed every year that must undergo a training process and in industrial facilities;
- High cost of the acquisition and maintaining industrial equipment just for teaching tasks and training;
- The difficulties felt by the trainers in transmitting to the trainees the skills knowledge for the execution of the tasks they are supposed to do;
- The high risk level of the operation of this particular machine, due to inertia of rotating parts, to possible mishandling of devices and tools that may harm the operator, the machine or turn the part under manufacture useless;
- The existence of industries where an early passage from the theoretical formation to the shop floor forces the global work flow to be delayed for the new workers have to adapt themselves to the work station.

These critical factors point to the development of a Virtual Reality system that allow teaching and training off the production operation, leading consequently to a significant reduction of costs and a previous evaluation of the capacities of the futures operators. The possibility of using a virtual environment training off the shop floor to prepare certain critical production tasks, to check production times based in simulation of approximate estimations, to evaluate the feasibility of certain tasks, to help the engineering responsibles for the processes to plan out new production strategies are other advantages associated to Virtual Reality systems. Industrial partners are also getting involved in the ongoing phases, so an industrial scenario can validate the achieved results in the future.

6. CONCLUSIONS

To maintain the actual production capacities, at least a number of persons must be trained to replace the previous generations. Moreover, today shop floor workers face the fast changing technological challenges, where people are invited to acquire new skills and extend their curriculum during their lifetime.

Recent advances in computer technology made possible simulation speed, graphical accuracy visualization, and huge data storage capacities, which are allowing the generation of large-scale 3-D models and simulations of enormously complex phenomena. Entire Virtual Worlds may be built using computer modeling.

A Virtual Environment can be built where activities can be carried with almost no physical harming possibilities using computers. Yet useful gestures for accomplishing difficult tasks can be trained, at low cost, avoiding consumption of expensive scarce materials, avoiding actual health risks, and offering pleasant learning methods and agreeable ways of spending the time.

It is well known that experience improves performance. Although the amount of experience needed to achieve a certain level of performance varies with the individual and personal characteristics, some experience is always desirable, especially if risky tasks are to be performed. In this context, virtual reality appears as a possible solution to several training problems like: providing easiness in modeling new equipments parts or assemblies; or allowing the repeated training of an operation or a group of operations to improve performance; or even presenting no material waste.

This paper explains the motivation and the technical background in the origin of a Virtual Reality system that assists a basic learning test bed of a Manufacturing Laboratory. Its refinement and functional operative condition will enable replication in an industrial scenario, where Numerical Computer turning machine facilities require expensive inoperative lead times and costly learning skills. In this area, authors are convinced that Virtual Reality will play a major role in the forthcoming professional teaching and actual industrial expertise workforce reconversion.

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