VIRTUAL PANEL SYSTEM WITH TACTILE FEEDBACK

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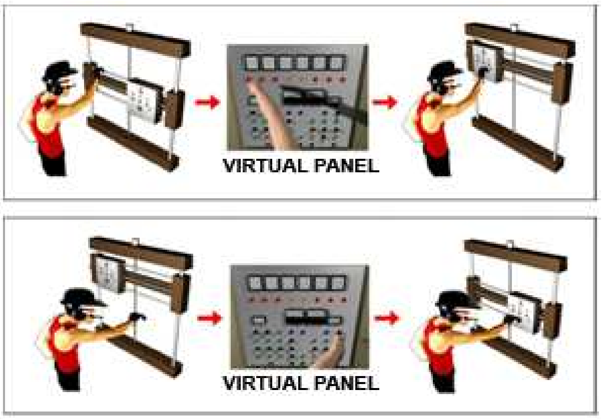
ABSTRACT:
This paper presents the work with the purpose of developing a search for creating a simulation and training system for the operation of control panels in various sectors of industrial sphere, having as main features the use of an immersive and interactive Virtual Reality system through the use of display equipment and a tactile feedback system composed of actual control devices.
The study also suggests the use of a numerical control system for controlling the movements of the tactile system in order to allow greater flexibility in the simulation, enabling the panels virtual training varied by modifying the system in accordance with the training needs.

Keywords: Virtual Reality, Tactile System, Augmented Reality, Simulation and Training.

1- INTRODUCTION:
Industrial activities, even the small-scale production, generally involve production processes with high costs and high operating precision levels, and very high risks of accidents. An example is the operating temperature control panels of industrial boilers, the auto industry panels, operations control panels in ports, hydroelectric plants panels, nuclear power plants, petrochemical plants, etc. Nevertheless many trainings are conducted in a theoretical way, a process which, although it represents gain, can be considered fragile and incomplete (Navarro, V et al 2009). These characteristics indicate the need for a well trained and skilled labor, creating the demand for training to provide a high quality learning.
Training is planned effort of an organization to facilitate the learning of behaviors required for the work (Lacerda and Abaad 2003), using training systems with a virtual simulation allows the learning of specific activities of operation and also has advantages such as do not interrupt the industrial activities and ensure safety to this learning, because it allows work on a fully controllable environment, and the flexibility to simulate different activities.
In many cases the virtual resources currently used in training are geared to experts and users - lay in many cases - expend a lot of time to learn the tools (Grave, L et al 2001). In this context the opportunity to create a realistic and interactive training environment, through visual immersion and even the tactile feel, is a more intuitive learning process where the user can absorb knowledge in an easily and directly way, looking at a very close activity with the real work situation. Furthermore, the use of a virtual simulation has the advantage of not interrupting the industrial activities and ensure safe training, because allows working in a fully controllable environment and flexibility to simulate different activities.
Advances in training systems, in addition to assist in the improvement of work processes and the current professionals, also allow the formation of new better skilled workers to enter the labor market.

2- THE PURPOSE:
Develop a simulation system able to provide a tactile response with low cost of implementation, using techniques of virtual reality and augmented reality combined with a positioning system controlled by computer(CNC) to simulate different industrial control panels with order to provide training and education to professionals of this field of activity. It is also proposed to present possible solutions and resources incorporated into the system to ensure greater immersion and better interaction, enabling the use of a virtual environment with a high level simulation of reality.

3- PROJECT CONCEPT:
The degree of a user's interaction within a virtual environment depends on the class of the virtual reality system used, as well as devices used (De Mello 2009). In this way the project was conceived in order to develop a simulation system that allows greater reality in control panels operation. For both defined, besides the use of a virtual environment, the use also of a low cost tactile response - which allows the operator the feeling of touching the panel, and also a computer-controlled drive system (CNC) - which allows the displacement of the tactile system as the simulation, enabling a wide variety of simulated panels, and also the use of an immersive display device (Picture 01). The methodological process of project design started from identification of project needs and research relating to its individual parts. The components of the proposed system were as follows:
. Interactive virtual environment;
. The tracking and interaction system;
. The tactile system;
. The CNC system;
. The immersion.



Picutre 01-The elements and the operation of the system

3.1- The virtual and interactive Environment:
The features indicated the need to use an interactive virtual environment that allows the tracking position, locating with some precision real and virtual objects, and the integration of some devices and features such as tactile CNC system, camera, viewing glasses and Augmented Reality resources. For the production of the virtual environment the following steps were followed: three-dimensional modeling and construction of the interactive environment.

3.1.1- The 3d modeling:
The construction of the virtual environment was initiated by the construction of a digital model that can simulate with good reality a comand panel of industrial activities. The model was based on a generic control panel with simple functions and controls, but the proposed system allows the flexibility to create simulations with different panels, that is, you can use 3d models in different ways by modifying system settings for different simulations.
To produce the digital model can be used any kind of CAD software that can generate a 3d mesh file having the ability to export the template for insertion in other applications to create an interactive virtual environment.

3.1.2- The Virtual Environment and the Augmented Reality:
Following the aim of developing a high-fidelity simulation project we were oriented interaction in first person. As an experiment in 1st person can consider situations where the user knows the virtual world through interacting directly with it, featuring a direct learning, subjective and often unconscious (Botega and Cruvinel 2009).
For this purpose at this step was necessary to use a software which, besides being able to produce an interactive scenario, could also incorporate augmented reality resources, and also could enable integration with other devices and software. In this way it was possible to generate an integrated simulation system where the devices and system interfaces communicate directly with the simulated environment. For this we used a software able to incorporate into your own environment other applications designed specifically for the job, as the system that transmits the user tracking data to the control system of the movement of the tactile system.
Application of Augmented Reality at work consisted not only in the use of its typical features for referencing the virtual images within the scene through the optical tracking camera and fiducial markers, but also in the use of these resources as tracking system of movement of the user and also as an important part of the motion system control of the touch system developed, so the augmented reality resources have been used as part of various system elements, being adapted to create a virtual reality system of simulation and training.
Therefore the interactive virtual environment production process was conducted in two stages: the import of 3D model and the introduction of other elements, such as fiducial tracking system and the external application developed to control the CNC system.

3.2- Tracking and interaction:
The function of tracking systems is to define the position and orientation of the virtual objects should be placed in relation to the actual scene. Therefore, it is necessary to relate the coordinates of virtual objects with the real scene (Silva 2006).
Motion tracking systems can be configured through several capture techniques, among them we can highlight the sitemas magnetic, optical, inertial, mechanical and acoustic (Ramon 2007).
For the study we used an optical system of low cost, designed from the use of Augmented Reality features built to work.It used a software which already has these features embedded in their work environment, which provided the direct use of a tracking system consists of the capture camera and the fiducial markers, without the need to use programming tools for the implementation of reference system between the real and the virtual scene.
The fiducial marker is a visual reference captured by the camera, through it the virtual 3D object is positioned relative to the scene, considering their perspective and creating a system that inserts the virtual model in the scene in real time.
This tracking system was used in this work for inserting the virtual panel, fixing its position relative to the user, and also for referencing the user interaction avatar. Furthermore, the markers were also used in adapted form to send commands to the CNC system, connecting the AR system with the tracking system of the user hand position.
The solution to the use of this system was the interpretation markers as tracking devices, taking his position captured in real time by camera and interpreted by the system. For that was set a marker in the user's hand with the dual function of positioning the avatar in the virtual environment and have captured, in real time, its position during the simulation, through the camera. This placement is transferred in real time to the CNC system for positioning the tactile system by using a

second marker attached to this system, that is the device mounted near real-time two marker coordinates, with the second marker always following the the user's hand.

3.3- The tactile System:

Virtual reality is, above all, an advanced user interface for accessing applications running on the computer, with the features to view and movement in three-dimensional environments in real time and interaction with elements of that environment, and may be characterized by stimulation of other senses such as touch and hearing (Tori, R et al 2006). So the use of a tactile system is intended to increase the sense of immersion and therefore the system simulation quality. Nevertheless systems that allow the tactile sensation are uncommon in simulations, in general this is due to the high market value they have. In the work the proposal was to use a real panel commands to create a tactile response with low cost of implementation, as actual buttons operation would be able to provide to the user the perfect sense of feel for the simulation. For this purpose would suffice combinations of these actual commands using a system that limits the visual perception of the virtual environment to the user.

The assembly of a panel with various buttons limit the system to certain types of control panels. From this problem occurred the need for greater flexibility to the system, enabling a greater variety of panel configurations, adapting its shape and size according to the needs of the simulation. The solution was to use a system that can move a group of real buttons (touch system) to track user's hand movement through a system of coordinates, the CNC system. The use of this technique permitted the flexibility of the system to adapt to a great variety of control panels, modifying the virtual environment according to the specific needs of each training.

3.4- The CNC System:

The technology CNC (Computer Numeric Control) started in the 50s, it was many years limited to large companies and became popular from the 90s (Fagali and Coelho 2003). Even today the most advanced features of this technology are used in greater quantities by large industries, however, with the spread of this system, you can find small machines being used widely in smaller items productions, and you can build them with low cost and simpler production processes.

Based on the research on CNC technology work was directed to the development of a small system. From the search and definition of the available resources has been developed a low-cost CNC machine prototype, adapted to the characteristics of this work. Taking advantage of some elements of a "traditional" setting for this type of machine, including the structure, mechanical and electronics system, the prototype was assembled. Moreover, it was dispensed using the third axis of motion, using only two axes of displacement. Thus the information found about the production of CNC systems have been adapted to the characteristics of the job. To this set was coupled the tactile system.

It is noteworthy that for the design of the prototype were analyzed the basic needs of the project and defined solutions with lower cost and ease of acquisition and implementation. This process involved from the determination of materials and processes used for the production of the structure, the setting of the mechanical system easier acquisition and the specification of the motors used. Defined solutions are not configured as definitive, being able to change them as needed, or you can create similar systems with higher capacities depending on the project needs.

Besides the construction of CNC set would require a solution to connect this system to trace, it was necessary that the tactile system accompany the user's hand movement and position itself as the virtual environment. To that end, it developed an application that works inside the software environment used to generate the virtual scenario. This was possible because the software used, as previously mentioned, has the capacity to extend its capabilities by incorporating external applications produced with a particular programming language. This feature allowed the creation of an extension application that interprets the coordinates of the markers and sends them to the CNC system to position the tactile system. So, the coordinates of the tracking system are utilized as reference for the positioning system, converting them into commands that are passed on to the electronic control of the CNC system, which orders the movements of the mechanical system. So you can position the tactile system as the user's hand moves during the interaction with the virtual environment.

3.4- The Immersion:

The purpose of providing to the user an immersive sensory experience in an artificial environment largely depends on the hardware used, it is through it that influences his senses (Cruz, M et al 2005). The need for complete visual immersion was the determining factor in defining the use of a display device as the Hmd type. Using this feature allows the users to a maximum level of immersion by limiting the visual field to the generated images from the virtual environment, allowing the experience to realize in real-time the environment which they interact from his own point of view and not an external point as in the case of using a common display screen. In the case of virtual panel system with tactile feedback, the user only sees the virtual representative panel of the panel to be simulated and your avatar, realizing the moves in a direct way through their own movement.

HMD used in the proposed system was adapted settling it a capture camera. It is through this camera that the virtual scene is positioned in relation to actual scene, locating the user and the tactile system CNC. The need of the camera is directly related to the use of AR resources and the tracking system employees and already mentioned.

3.5- The final configuration of the system:
The system was set with five basic elements:
. The interactive virtual environment where you can view the virtual panel and interacting with an avatar;
. The motion tracking system, which allows the user direct interaction creating a reference between the real and the virtual scene;
. The tactile system which consists of a panel with actual commands of an operation panel;
. The CNC system, using the user's hand tracking system information, positions the tactile system;
. The immersive system composed of the display device.

4- SYSTEM IMPLEMENTATION:

After all the system design were carried out the assembly of parts and testd to the implementation and validation, in which it was possible to observe the operation of the parties and the final integration of the full set.
The tests were as follows:
. Augmented Reality Test
. CNC system test
. AR and CNC integration tests
. Initial tests of interaction
. Final test

4.1- Augmented Reality Test:

The main objective of this test was to implement the features of Augmented Reality employees and analyze their behavior. In this initial test it was possible to realize the operation of the marker system and the characteristics of the software environment and AR tools.
The results showed a relative simplicity of operation of these features because the tools used allowed flexibility in the augmented reality implementation process, enabling the placement of 3D objects as the scene, including the two markers action, which would be indispensable for use that system for tracking the user's movements and positioning of the tactile system through numerical control (CNC).
The system responded as expected. Because the difficulties have not gone beyond the expected for this type of tool. The instability in the positioning of virtual objects, which sometimes lost the reference and out of the correct position was a difficulty found. The tests indicated that this problem is associated with the marker image occlusions, capture camera shake or by the possibility of confusion over the marker reference, that is the software sometimes confuses the position and direction of the captured image, reversing the position of the virtual object. All these options are considered characteristics common to the tracking system used. This type of problem can be reduced by using larger markers, increasing its area within the captured image.

4.2- CNC System Test:

The test consisted on an initial set of resources employed in order to control the mechanical assembly by the electronics assembly, performing the vertical and horizontal movements in the two axes by commands on a computer keyboard.
The first results demonstrated a lower speed than necessary for the training system, suggesting a review of the mechanical system, using techniques that ensure greater speed in the movements. Were also carried out modifications to the command code of the electronic control software CNC system, which contributed to a considerable improvement in system speed.
Despite the speed reached by the prototype was not ideal, but still the tests proved the feasibility of constructing this type of control system. Because research to the assembly of the prototype demonstrated the possibility of incorporating different improvements depending on the requirements of the job. In other words, you can build the system with different techniques and devices, including their transmission to the mechanical assembly, different specifications of stepper motors, and even different electronic settings via software. These modifications are capable of providing a higher speed to the system according to its specifications.

4.3- AR and CNC integration tests:

They were carried out in the three steps listed below:

4.3.1- Testing the extra application for CNC:

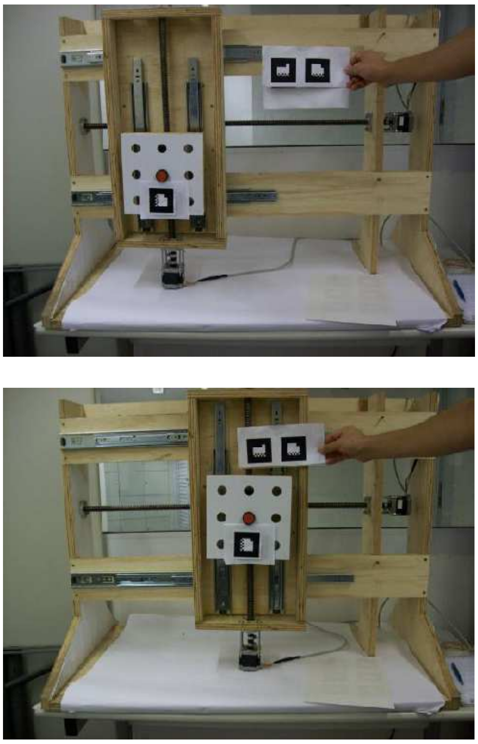
The incorporation of extra application developed for communication between CNC system and the interaction software development was tested. The purpose was to carry out an initial test using only keyboard commands. The work done was create commands within the interaction software development, through its specific programming language, to turn the keyboard commands on command interpreted by the electronic control software of CNC system. At this stage there was complete success, with complete control of movement through the use of the keyboard as the final result.

4.3.2- Testing the extra application by mouse:

In the next step, changing the code in the interaction software development, the keyboard movement controls were associated with the movement of the mouse, that is the mouse position coordinates were converted to commands sent through the serial communication the control board. Thus, it was carried out within the software development environment, programming with commands associating a limit of mouse performance space to a square visual reference, that is, within the area specified the movement of mouse was converted into command positioning system. This test step has been implemented with the purpose of preparation for next step and also showed a very good result, since the movements performed within the defined area were readily accompanied by the CNC tactile response panel.

4.3.2- Test with two markers:

In the last stage has been implemented using two markers, utilizing an initial marker, which provides the reference data, and a secondary one that tries to follow the first. That is, when the first marker is moved, the camera captures in real-time his position which is interpreted by the AR system, then the extra application incorporated in the system captures these coordinates and passes them to the CNC system that moves the second marker to the same position (Picture 02). The objective of this test was to evaluate the efficiency of this system to be implemented as tracking position, where the first marker would be set in the user's hand and the second set in the tactile system, which is associated with the CNC system drive.



Picture 02 - Tracking position

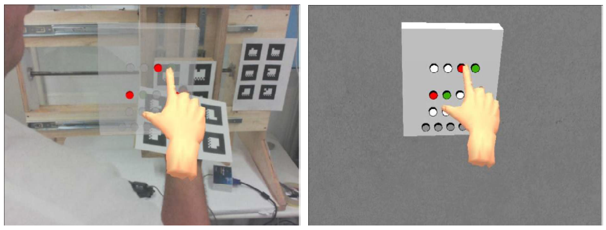
4.4- Inicial tests of interaction:

For the validation of the virtual panel system with tactile feedback was used an interaction system based on the use of an avatar that simulates the hand of the operator (Figure 03). That is, we used a digital model that represents the user's hand in the virtual environment. In this test the aim was to analyze the use of the marker system to position this avatar by checking the process of interaction with the real environment. For that was set a marker on the user's hand.

An important point to highlight regarding the use of fiducial markers is that in general there is a depth of reference problem as the virtual image is always inserted ahead of the actual image, that is real objects placed the lead appear behind the virtual image. In the case of this work this problem did not occur because there is no mix between real and virtual images, since the aim is that the user only sees the virtual scenario, utilizing an avatar to interact with it.

The results, as in previous tests also demonstrated the ease of implementation of marker system. The positioning of the avatar, as well as the connection to the user's movements, presented itself as a low-complexity task. This was due to the use of augmented reality tools for easy access and with the features to be made available ready for use.

The problems are also the same as the previous tests, low accuracy and occlusion problems, as mentioned, are common in the use of fiducial systems, and able to be amortized. As in the previous test is still possible to conclude that the system settings open possibilities for implementation of other types of devices for positioning the avatar depending on the required level simulation, but it is possible to conclude that for the work proposed devices used provided the enough to support the survey.



Picture 03 - The avatar and the Interactive and virtual environment

4.5- Final Test:

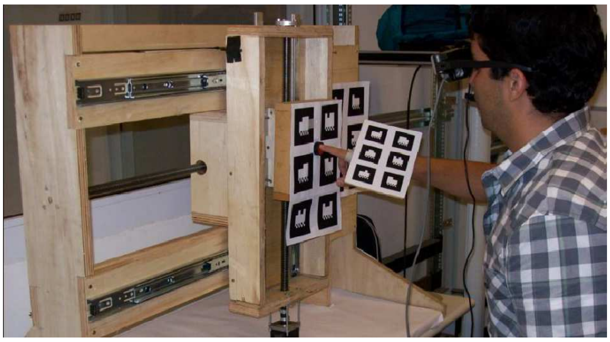
In the final test (Picture 04) the aim was to analyze the functioning of the complete set, integrating all elements of the system. They are: the virtual environment with AR devices implemented for tracking, tactile CNC system and the visual device, included in this final stage of testing.

For the visual device, as already mentioned, we used a Hmd equipment in order to provide greater immersion to the user, displaying only the images of the simulated environment for training. Coupled to the display system was used the capture camera, with which is performed the tracking of the markers. The use of this camera is also necessary to reference movements of the CNC system, and also to position the entire virtual environment, that is through the camera is still positioned the avatar and the virtual panel.

The results demonstrated as the greatest challenge positioning of the training objects, since the accuracy difficulties of using markers was multiplied when testing all elements simultaneously. Another factor that influenced the process was the establishment of capture camera on the user's head, for the camera steady movement hindered the setting position of the scene objects. Another difficulty was the small field of view of the camera used, because since it is a simulation where the object is very close to the user, it was difficult to frame in the picture the virtual objects and markers simultaneously.

Possible solutions to these problems are: the use of multiple reference markers for each object, the use of

more than one camera - a movable for positioning the fixed virtual objects and other static to track the user's hand - and the use of a camera model with wider field of view.
Despite the difficulties encountered the tests demonstrated the feasibility of implementing a low-cost training system, integrating the different features and techniques employed at work.



Picture 04 - The final test

5- CONCLUSIONS:
The entire work process involved knowledge from different fields associated with the common goal of this work. The tests demonstrated the feasibility of implementing the proposed system and also highlighted some points for improvement work.
Regarding the perceived qualities in the system can be highlighted:
. The easy implementation of the individual parts, especially the application of the Augmented Reality resources employed;
. The CNC system production process used different areas of expertise, from project of the structure, the mechanical system and assembly of electronics and programming. These features demanded a long process of research, but the results have demonstrated the feasibility of implementing this type of system. The construction of the mechanical system aiming at the use of more accessible resources for the production of a prototype validation lived up to expectations, as well as resources used for the control of this system;
. The resources used for the production of interactive virtual environment through AR tools have shown to be efficient, especially when considering the ease of work and the relative simplicity of implementation of this system with the employed tools;
. The integration of CNC system with interactive virtual environment also proved to be satisfactory and process control through this interface was also presented as a good deployment solution, since the resources used have not demanded large programming projects, enabling the integration of elements with the use of command lines low complexity.
Among the problems encountered during the work process can highlight mostly:
. Difficulties in the production of CNC prototype to achieve optimum speed of movement for the tactile simulation. The end results did not meet this requirement completely, but the experience of work proved the viability of the system, as research has shown the possibility of solutions that allow higher speed to the system, such as different techniques and devices for use in the assembly of mechanical system prototype for example;
. The challenges encountered in the use of fiducial markers affected the stability of the positioning of virtual objects. This difficulty is related to interference in the interpretation of the captured image (visual confusion between markers) and also the factor of occlusion of the markers in the scene (very common in optical systems in general). This was an effect already foreseen in the project, because it is a characteristic of fiducial systems.
Among the possible solutions we can consider using different types of markers for each specific function - reducing the risk of visual clutter - the use of larger markers or fixation with greater distances between the markers, increasing its area within the captured image.
. The same problems were perceived in the use of fiducial markers as user movement tracking system. However, besides the solutions already presented, it is still possible to incorporate the system several other forms of tracking, like other optical systems with infra-red reflective dots capture or as use of LEDs, or the use of inertial devices, etc.
. Especially in the assembly process of parts of the system other difficulties were encountered. Among them we can mention those found during the integrated use of the camera attached to the visual device, and tracking and positioning system.
One of the perceived effects has been occlusion of the markers occurred during the user's head movement, causing the loss of reference for the positioning of virtual objects and tracking movements. As a solution to these problems, we can mention the use of two capture cameras, one fixed on the user's head and the other used only for tracking the movements of his hands. We can also consider using a capture camera with a wider viewing angle, reducing the risk of occlusion during the simulation.
Another possibility of improvement that we can quote is the use of a more appropriate visual device for use Augmented Reality, wich already has an attached capture camera.

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