Control of a Remote Laboratory by Augmented Reality

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***Abstract*—A variety of advanced learning technologies has emerged to enhance learning, promote hands-on experiences, and increase interest in engineering and technical education. The possibility of access to a superior education is on hands of a great number of students while the resources which are available do not increase in the same way, limiting the quality of the teaching, so, it is necessary to look for alternatives that insure an access to the resources of a way regular, monitored an efficient. The remote laboratories avoid these gaps, however the development of these laboratories is of a great cost and their application is very specific. The fact of adding virtual information to the observed results by the students increases the quantity of information, provides us a great absorption of the contents and an expansion of the case studies. That is why it is possible to add the answer to questions like why this happens, or what would happen if the conditions of the experiment were different.The augmented reality provides an easy way to control a remote laboratory, creating a realist, simple and practical interface from any place in the world. To achieve the objectives mentioned above, this document shows how you can control a remote laboratory with augmented reality.**

***Index Terms*—artificial; augmented; and virtual realities; educational technologies; learning technologies; Engineering education; interactive environments; remote systems**

I. INTRODUCTION

Although, the initial concept of augmented reality (AR) goes back to the 1960s, a first formal AR system by Boeing Company has been developed only in early 1990s.

In the late 1990s, several conferences on AR began, including the International Workshop and Symposium on Augmented Reality, the International Symposium on Mixed Reality, and the Designing Augmented Reality Environments workshop [1].

The most popular definition for AR is from Milgram and Kishino [2]: "there is a continuum of real-to-virtual environment in which AR is a specific area within the generic area of MR" [3].

Another commonly accepted definitions was developed by Ronald Azuma [4], which explains the augmented reality as a technology that combines real and virtual worlds, real-time interactive and recorded in 3D, that is, augmented reality is a system of interaction that takes as input the information coming the real world and generate output information (such as objects, images, text, etc.) superimposed in real time on the perception that the user has the real world, thereby increasing the knowledge that the user has about the objects in their environment.

In augmented reality, digital objects are added to the real environment whereas augmented virtual, the real objects are added to virtual ones. In virtual environments (or virtual reality), the surrounding environment is completely digital [5], therefore, AR can supplement real-world perception and interaction, allowing users to view a real environment augmented with computer-generated 3D objects [6].

This technology in its simplest version uses the following components:

- *Webcam:* Device that takes real-world information and transmits it to augmented reality software;
- *Specific software:* A program takes data and transforms them into real augmented reality;
- *Mark or Tag:* The software performs a specific response for the detected mark, such as a 3D image display.

If we get a more powerful system, the use of proximity sensors, digital compass, accelerometer etc., augmented reality will reach another level, which will be able to detect the user's location, the surrounding environment, the climate, etc.

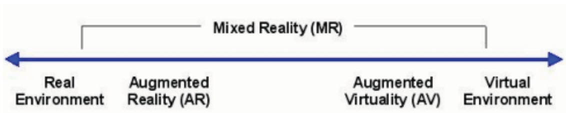


Figure 1. New technologies.

All of us have ever been attentive to the explanation of a teacher who urged us – with his best intentions – to "imagine that..." that phrase became a challenge for more than one of us. This technology can resolve that situation

It is in this way we can evolve, the additional information available, the three-dimensional virtual objects allows us to see and even interact with content that is beyond our imagination, such as the electrons of an atom or reconstruction of the Roman Coliseum, one of the most popular applications of augmented reality in education is the project of HIT group from New Zealand, called Magic Book [7].

At this point, we cannot refuse that it is necessary to pose new learning theories, in the future the roles of teacher and students will have to be redesigned [8], and the information will have to be adapted to the knowledge process through the disposable tools without forgetting that the role of teacher will change, but it will be always essential.

II. Context and Motivation: Educating with Reality

There are many new devices that appear continuously promising one way to make our lives easier, some of these devices or applications are accepted and other ones have been forgotten.

The potential for AR applications in education facilitates, the creation of learning scenarios, whereby a learner interacts with realistic objects with less risk than that associated with a real situation [9]. Also it is possible to indicate that "sense of presence" is a benefit of an AR environment compared with virtual or simulated environments that typically lack this sense of presence.

This interactive augmented reality made the students had more interest in learning, therefore, the proposed e-leaning system not only provides with audio-visual contents, but also improves the learning efficiency and concentration of students [10].

For that the augmented reality system allows achievement of the teaching and learning objectives should at least meet the following requirements [11]:

- Be a robust system;
- Provide, clear and concise learning;
- The educator must be able to introduce new information in a simple and effective way;
- It should facilitate easy interaction between teacher and student;
- The technological processes must be transparent to both the teacher and the student.

Fig. 2 depicts architecture of augmented instructions. Supposing flexibility of learning methods increases with factors of interaction and individuality, AR is considered to improve the both factors of printed learning materials by interactively presenting information at user's viewpoint [12].

The traditional approach to practical sessions in the real laboratories is changing dramatically with new available technologies and with remote laboratories spreading worldwide [13], [14].

It has been investigated and documented that remote laboratories provide similar learning outcomes, even better, to their class analogues [15].

The particular importance in the engineering educational context of the practical experience has shown that effective teaching requires an interdependent approach combining theoretical material supported by practical laboratory experiments [16].

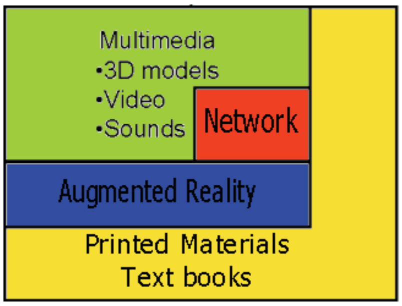


Figure 2. Architecture of augmented instructions. [12]

Andújar, Mejías and Márquez [17] have developed a augmented remote laboratory (ARL), which offers a training environment that is the same as those in a physical laboratory, proving the possibilities of AR technologies for practical online training in the scientific and engineering fields.

III. The Idea

The project arises from the idea of combining augmented reality and remote laboratories, to seek a practical learning where resources are limited in time and space. It is intended to provide students with a range of tools to operate remotely a computer. Some of these tools will be designed by themselves and they will be able to choose their own laboratory. The student will only print the laboratory developed controls.

The platform will enable control of any equipment in response to some pre-configured settings in a microcontroller. This microcontroller will transmit their orders to the hardware (this is the laboratory).

A. *Functional Diagram*

At this point, we discussed the operation scheme implemented in the application.

1) The user must have the marks that will identify each one of the laboratory controls;
2) The webcam captures marks. The augmented reality software will recognize the marks and superimpose the three-dimensional models on each one of them;
3) Processing software allows interacting with the controls. It will send commands by Internet towards software located in the laboratory;
4) The remote lab client receives and sends commands to the control hardware of the remote laboratory;
5) A microcontroller is responsible for collecting the orders sent and performes appropriate operations on the laboratory;

6) The user can observe the actions that have been carried out on the screen of his computer;

Fig. 3 shows the functional diagram of the developed application.

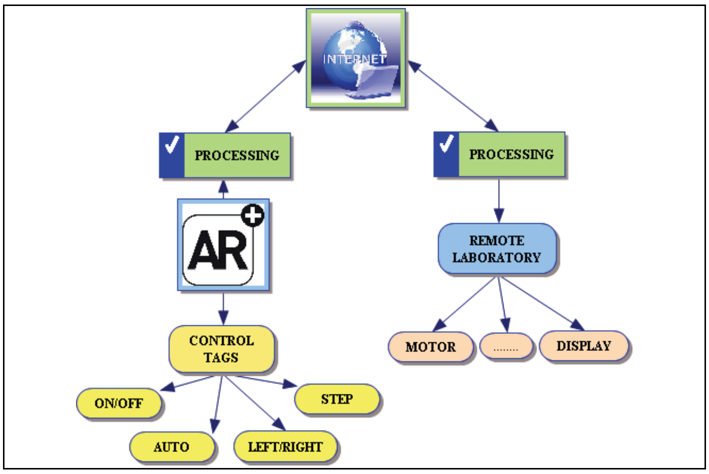


Figure 3. Functional diagram.

One of the advantages of using augmented reality with marks is that the software knows beforehand what must look for, due to it, pattern recognition becomes easier. This causes a decrease in image processing time, which increases the speed of the system as close as possible to a real-time system.

Most augmented reality systems based on marks detect a single tag and then they represent the 3D object on it. In our case the software is considerably more extensive because not only will be drawn a virtual object but 5, although the process is the same. In Fig. 4 an image of the marks can be seen before applying augmented reality and after running the AR software, each mark has been overlaid by a three dimensional object that represents the referenced control.

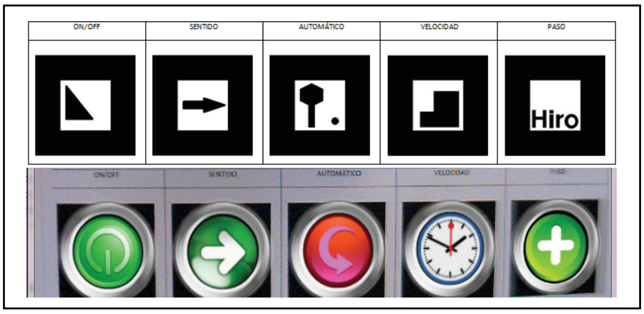


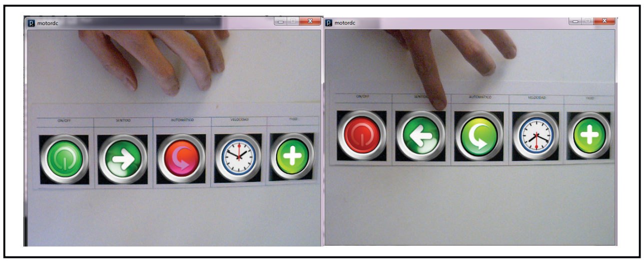
Figure 4. Marks without AR and marks with AR.

B. Interaction

To provide the system with interaction, we have emulated the click of a mouse by detecting or not of the pattern in a short period of time (250 milliseconds), so the user gets the interaction and feedback from the system due to the principle of action and reaction with the controls of the system.

If the mark is not detected for at least one second and then it is detected, the software will interpret it as a click on that button and the corresponding command will be sent to laboratory.

Fig. 5 shows how to interact with the mark, after clicking



on the control; it changes color or changes direction.

Figure 5. Example of interaction.

C. Sending Data

So far we have a system that represents 3D virtual objects on marks and simulates the click of a mouse to interact with the user. However, how do the commands are sent to the remote laboratory? To answer this question we have developed software that manages communication with the laboratory using the protocol TCP / IP and so, users can communicate with other equipment by Internet. Data are sent through TCP/IP and are caught by a microcontroller; this interprets the virtual commands and transforms them into real orders sent to the hardware that controls the laboratory.

In the Fig. 6, we introduce the electrical system in the hardware of the engine control.

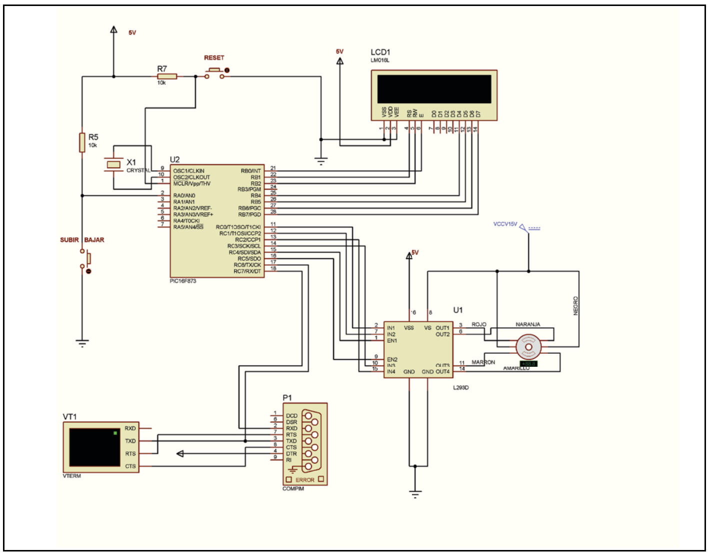


Figure 6. Electric schema.

IV. Results

To test the operation of the software and hardware, a small group of users has worked with it, in this case eight students in vocational training (Electronic Product Development Course).

The project was divided into two phases:

1) Test of augmented reality software by controlling a

step by step engine;

2) Assembly in PCB. Programming and control through augmented reality.

For each system was measured the impressions of participants using a questionnaire. Questions were answered on a scale from 5 to 1, ranging from “Strongly Agree” to “Strongly Disagree,” the questionnaire also includes open-ended comments from the participants on aspects of augmented reality immediately after they finished the trials. The items of the questionnaire are listed in Table I.

TABLE I. TABLE ITEMS OF QUESTIONNAIRE

1	The system presents the 3D model appropriately.
2	The system works stably.
3	The system response is enough to be fast.
4	You have to be accustomed to using the system.
5	User interaction with the system is simple.
6	The system is good at long-time use.
7	The system can be used together with printed materials.
8	You want to use the system in practice.

Fig. 7 shows the average results for each one of the items in the questionnaire. The students that have not previously worked with augmented reality technology think that the system is novelty, entertaining and fun. The use of this technology in the classroom was considered useful and practical to use it in distance education. These are some of the considerations made in the open-ended comments.

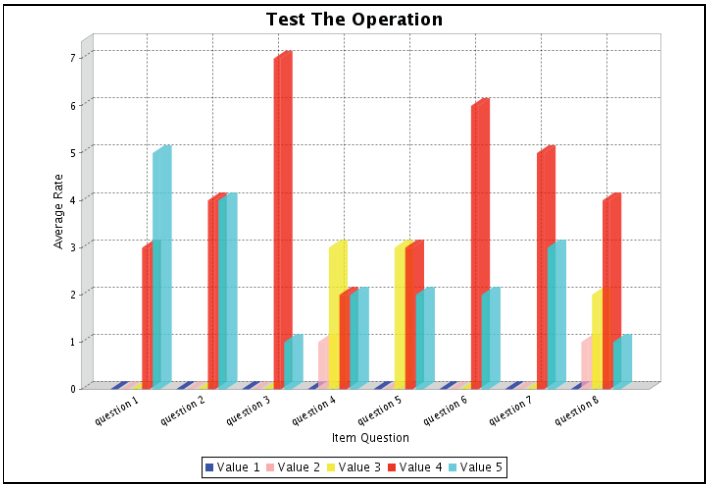


Figure 7. Results of questionnaire.

- 100% believe that the model is adequate and working properly.
- 12.5% believe that they must adapt to the system. This reply was given by those students who have had less contact with new technologies.
- 62.5% of students considered positive and very positive to use this system because:
  - The system is available 24 hours a day.
  - Its ease of use and entertainment.
  - The system avoids the fear of breaking the equipment of laboratory, providing security and additional information.

V. CONCLUSION AND FUTURE TRENDS

Augmented Reality allows to generate a natural experience, increase the effectiveness of teaching and attractiveness of learning for students, and improve attention and motivation of the students, however its potential in educational applications has recently begun to be known [18].

Augmented reality (AR) appears as a promising technology to improve students’ motivation and interest and support the learning and teaching process in educational contexts [19]. The use of augmented reality in mobile learning gives better experience to students’ visualization and manipulation of the circuit component [20], [21].

The use of the remote laboratories offer the possibility to access limited resources in both time and in the space in those specialties where the material results are expensive, dangerous or difficult to get. The augmented reality gives a value added to the remote laboratories. It offers additional information that increases the number of experiments with them, and these experiments are different of those that were designed in the first instance.

The join of both technologies forms synergy that eliminates a great part of the weak points of them to create a system able to generate a feedback in the skills of the students. We get interaction from the augmented reality to the laboratory and from the laboratory to the augmented reality.

On the one hand, the use of emergent technologies means an adaption of the teaching world. The new students have born with the technology, so if this technology is not present in the world that surrounds them, they lose interest, and they fall into the discouragement and they feel isolated.

On the other hand, the use of experimentation and technological involvement facilitates the absorption of knowledge, the motivation to learn and participate in an active and dynamic way. The technology must be employed as a tool to create, transmit and facilitate the knowledge in both the classroom teaching and in the distance teaching.

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