Design of an Augmented Reality System for Immersive Learning of Digital Electronic

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***Abstract*— This article describes the development of two mobile applications for learning Digital Electronics. The first application is an interactive app for iOS where you can study the different digital circuits, and which will serve as the basis for the second: a game of questions in augmented reality.**

***Keywords*— Digital Electronics, Augmented Reality, Mobile Application, Immersive Learning**

I. INTRODUCTION

Teaching and learning is a task with a high degree of difficulty. The use of new technologies [1] will allow the use of a teaching medium that facilitates the task of transmitting knowledge. On the other hand, there will be the advantage of using a medium that is very attractive to young students and will facilitate their learning motivation. In this way, tablets become an integration method and a great advance for the teaching-learning process.

This work focuses on the learning of Digital Electronics, its objective is to offer a tool that allows us to use such an attractive medium for today's students as it is mobile learning.

This article has two main objectives:

1. Description of a mobile application for iOS with digital electronics circuit simulators.
2. Description of an augmented reality mobile application for iOS based on pattern recognition that includes a game. In addition it integrates the Digital Electronics circuit simulators previously described.

This research aims to be useful for all those teachers and researchers interested in new ways of teaching technical subjects such as Digital Electronics.

The organization of this article is as follows: Chapter II gives a brief introduction to the use of mobile applications and specifically of augmented reality in education. Chapter III describes the mobile application for Digital Electronics developed by the authors. Chapter IV focuses on the other mobile application developed by the authors, in this case augmented reality. And finally the conclusions obtained in this work are provided in chapter V.

II. MOBILE AND AUGMENTED LEARNING

New technologies aim to greatly facilitate the daily tasks of each person, from being located anywhere and at any time to having information on any subject without having to have an Internet connection.

These mobile technologies are being used in all areas of society, of course also in education. Mobile learning can take place anywhere and at any time, in traditional classroom workshop environments, libraries, workplaces, at home or in the office. Also, having these devices and mobile connectivity allows the incorporation of other new technologies that will be seen later, such as augmented reality [2].

Authors like Lin [3] list some of the virtues that its use in education provides:

- Promotion of student participation in class. Even the most timid would have a chance to contribute.
- Maintain the level of attention of the student and his interest in following the contents, since they can be interactive, multimedia, etc.
- Encourage critical thinking and creativity, allowing the student to discover and participate in the construction of knowledge.
- Helps the teacher to find out the degree of understanding of the content in real time.

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- Flexibility and spontaneity in the presentation of content.

As for Augmented Reality (AR), it is a technology that had its beginnings in 1962. It began to stand out for the possibilities it offers in different areas, industry, marketing, commerce and education [4] [5] [6].

The most popular definition of RA is given by Milgram and Kishino [7] who indicate that: "*between a real environment and a pure virtual environment is the so-called mixed reality and this is subdivided into two, the augmented reality (closer to the reality) and augmented virtuality (closer to pure virtuality)*" [8] [9].

Another commonly accepted definition is the one provided by Ronald Azuma [10], which limits the RA to which it meets these three requirements:

- Combination of virtual and real elements.
- Interactivity in real time.
- Information stored in 3D.

III. Experience Description

The work is based on the design and development of two applications for the iOS operating system that facilitates the learning of Digital Electronics. Through the use of a Tablet, the student will have access to simple and intuitive menus that will allow them to quickly and effectively learn the necessary knowledge about Digital Electronics.

In both applications, the aim is to provide students with teaching materials on Digital Electronics that cover the following circuits:

- Logic gates:
  - NOT
  - AND
  - NAND
  - OR.
  - NOR
  - XOR
  - XNOR
- Combinational systems
  - Multiplexor
  - Demultiplexer
  - Encoder
  - Decoder
- Sequential systems:
  - Asynchronous high-level triggered R-S flip flop
  - Asynchronous low-level triggered R-S
  - Synchronous level triggered R-S
  - Synchronous level triggered D
  - Synchronous Master – Slave J-K
  - Synchronous level edge-triggered T

IV. IOS App with Components Information and Virtual Simulator

The first of these applications will be carried out under the support of Xcode and will consist of the completion of a Digital Electronics Course in which the following aspects will be covered: Logic gates, combinational systems and sequential systems.

In addition, all of them will have a simulator through which the operation of the real device can be simulated. Acting on the inputs, the outputs that would be obtained for each of the possible cases will be simulated.

The development of the contents within the application will be through the creation of information sheets for each of the circuits. These information sheets will contain the following data, as can be seen in Figures 1 and 2:

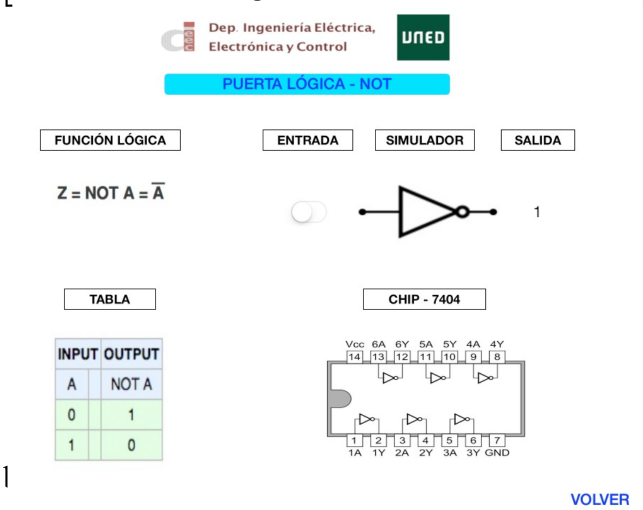

Fig. 1. Application screen developed with Xcode for NOT logical gate.

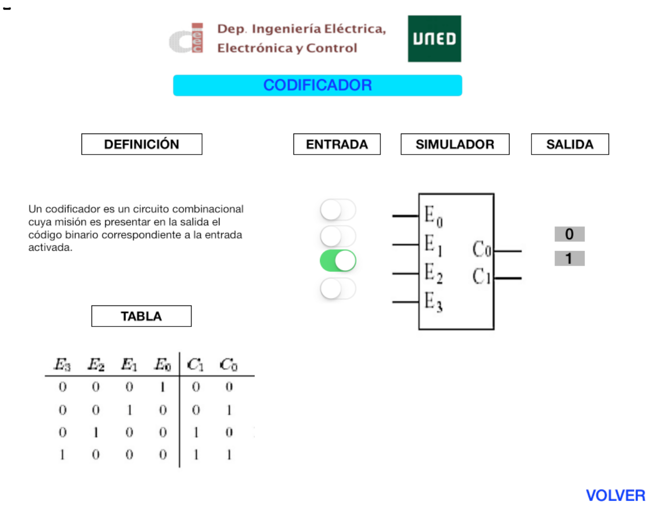

Fig. 2. Application screen developed with Xcode for combinational encoder circuit.

V. IOS Augmented Reality App

The second of the applications seeks to surprise students using a tool such as Vuforia, using the Unity development tool.

These are libraries that will allow us to use augmented reality. This technique consists of superimposing virtual images on real images captured by the camera in real time (Figure 3). It will be based on the same application made in Xcode but with the addition that Vuforia libraries offer us to develop augmented reality experiences.

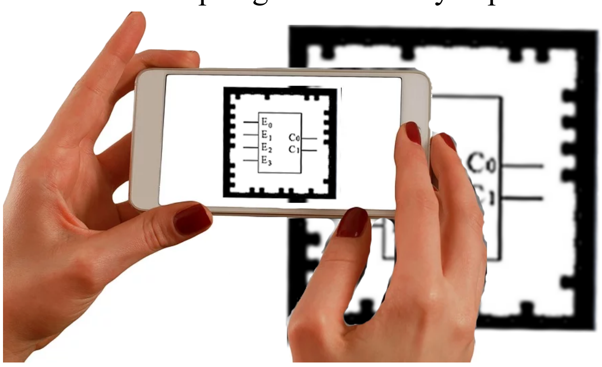

Fig 3. Combinational circuit pattern scanning with augmented reality application.

Starting from the aforementioned application, created in Xcode, it is intended to develop a Digital Electronics course that covers the same aspects but focusing on them in different ways. In the course of the course, the same types of circuits of the previous application will be shown, but in this case, the symbol corresponding to a circuit will be asked, which will be randomly selected for each question among all the types covered by the application. The student will answer the questions using the patterns. The camera of the device will show us if the answer is correct or wrong and will tell us both the successes and the errors.

A. Choice and use of patterns

Patterns or ImageTarget are images with the necessary complexity so that the Vuforia library can find enough references within it and thus be able to detect and treat them as patterns.

These images, once detected, as they contain multiple reference points, allow the library to continue detecting them even if they are only partially covered and focused by the camera.

An interesting feature is that you can use images selected by the programmer among the images you want to detect. To do this, an online tool is used, which can be found on the Vuforia (Target Management System) website.

The maximum number of images of this type that the library allows to detect simultaneously is five, although in the case we will only need to detect one simultaneously.

In the pattern selection process, it was determined that due to the simplicity of the symbols used in digital electronics, false detections or instability occurred when superimposing images on the patterns in the Unity environment. The solution found was the use of patterns that are prefixed with Vuforia attached to the symbols of the different circuits that we use. In this way the union of both images give us enough reference points for the detection of Vuforia to work accurately.

As an example, some of the patterns used are shown in Figure 4, such as the NOT gate, AND gate, encoder and RS flip-flop pattern.

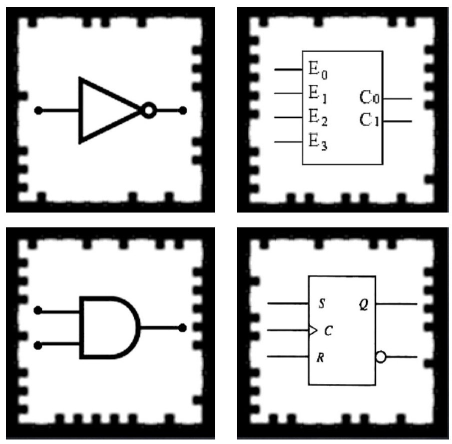

Fig. 4. Example Vuforia patterns used in the augmented reality application for Digital Electronics.

Once the master images have been designed, they must be uploaded to the Vuforia "Target Management System". This is the online tool provided by the Vuforia architecture for creating the recognition patterns used by the Vuforia SDK for the identification of objects and their subsequent treatment.

The “Target Management System” offers us a web-based tool for developers who use the Vuforia SDK to create these “DataSet” (Figure 5) from an image imported into the tool. The object you create will be stored on the Vuforia page and can be downloaded for use in our Unity application.

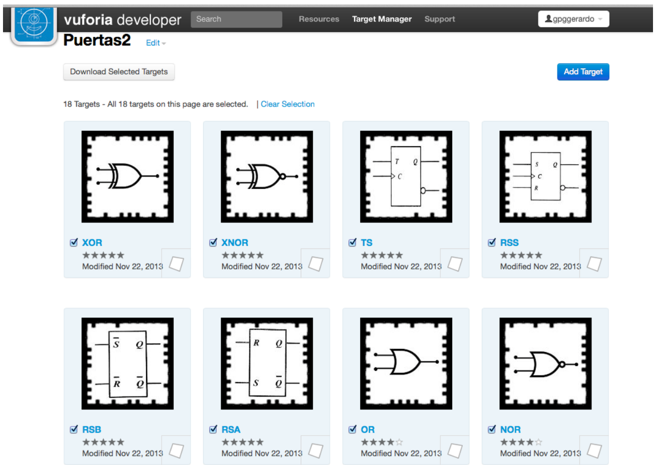

Fig. 5. Dataset with Digital Electronics patterns in the Vuforia TargetManager.

This application has been developed using 2 different development environments. On the one hand, Vuforia, which is in charge of capturing and recognizing the patterns corresponding to each circuit. On the other hand, Unity, which will allow us to create the application environment.

Once we have defined the Dataset with patterns, we can export it and integrate it into our Unity application, where we can develop our augmented reality application using them (Figure 6).

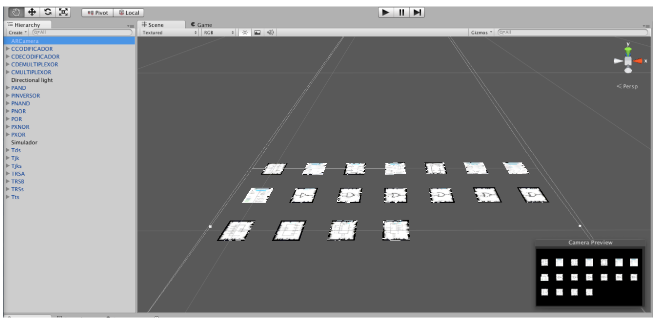

Fig. 6. Logic gate patterns in the augmented reality application developed in Unity.

B. *Operation of the app*

The application is divided into three sections that will develop the course from three very different aspects (Figure 7), although all of them based on the use of the device's camera on patterns designed for this purpose.

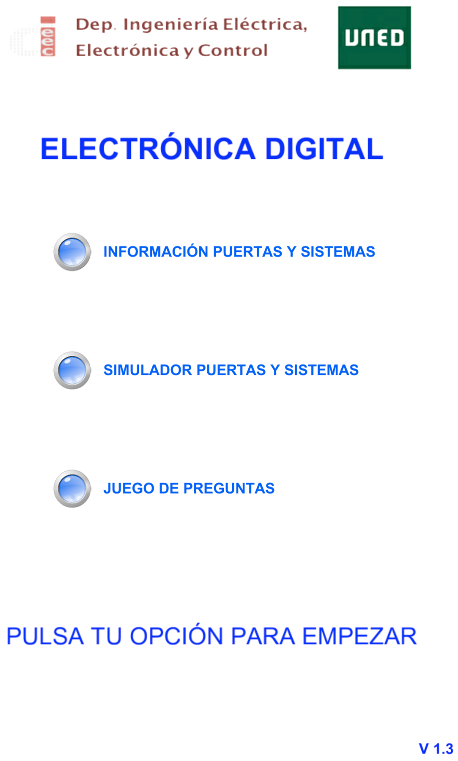

Fig. 7. Initial screen of the augmented reality application where the user is given the option to choose one of the 3 functionalities of the application.

These sections are:

1. **Information on gates and systems**. By focusing the pattern corresponding to each of the circuits, an image will be superimposed on the real image that will show us the information corresponding to the circuit that is assigned to the pattern focused with the device's camera. Figure 8 shows an example of what happens when the pattern for an AND gate is scanned with the mobile device. In this case, when the system detects it, it executes the associated action, which in this case is simply putting a previously designed image on top of the pattern.

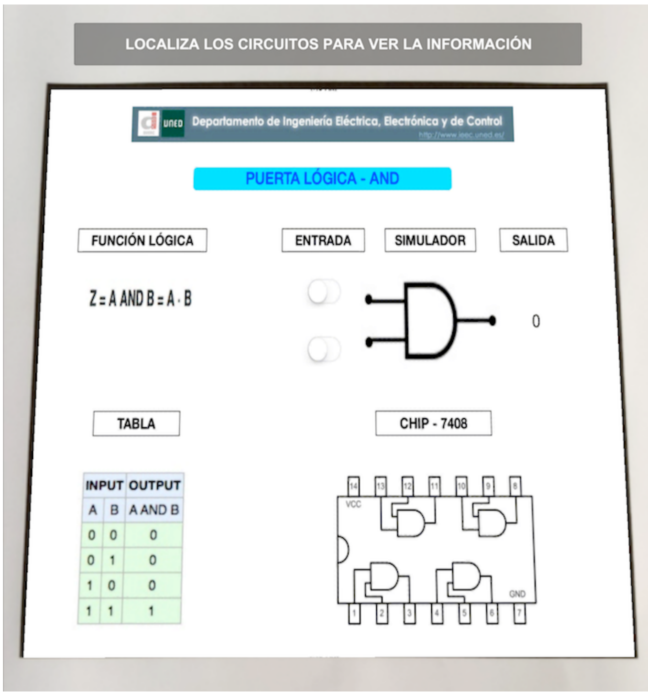

Fig. 8. Augmented reality application screen where you simply give information about the circuit by pointing to the corresponding pattern.

2. **Gates and systems simulator**. By pointing to the pattern corresponding to each of the circuits, an interactive virtual image with buttons for the inputs will be superimposed on the webcam image showing us the information corresponding to the circuit assigned to that pattern. (Fig. 9).

4.

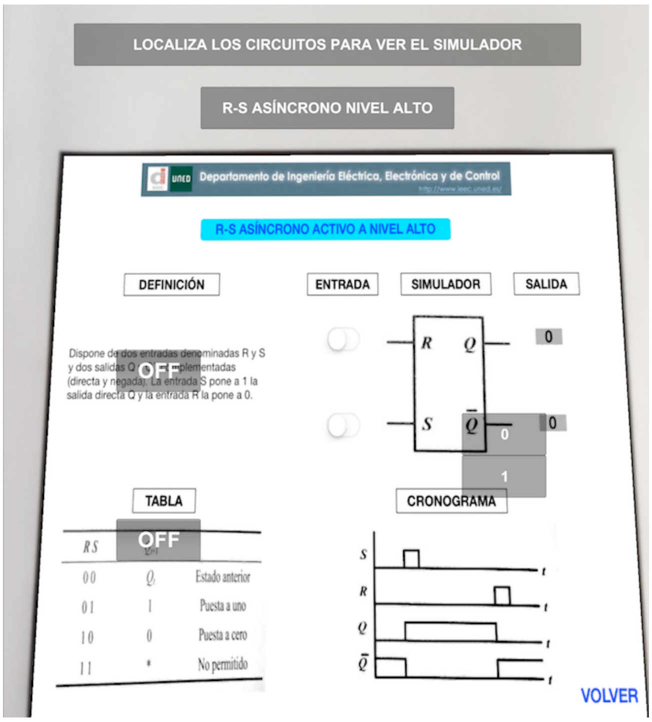

Fig. 9. Augmented reality application screen where, in addition to providing circuit information by pointing to the corresponding pattern, the user is allowed to interact with the inputs to see the results of the outputs.

In addition, a simulator of the corresponding circuit will be provided. It allows to interact with the inputs. The output will be simulated for each of the cases based on its truth table. This simulator consists of a script that, based on the value of the user-defined inputs, calculates and displays the result of the output. (Figure 9).

3. **Trivia game**. In this case, the symbol corresponding to a circuit will be asked, which will be randomly selected for each question among all the types covered by the application. It will be answered using the patterns and the device camera. The app will show us if the answer is correct or wrong (Figure 10).

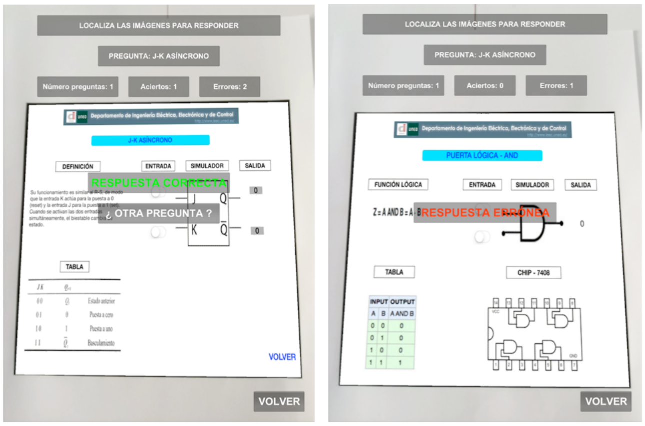

Fig 10. Scenes from the augmented reality game where the student is told if he has guessed correctly (left) or not (right).

Upon entering this section, the image captured by the iPad camera and the name of the circuit that indicates a question appears. Then the application will be ready to point to one of the patterns in the database to make the response. Once one of the patterns is focused, the application will recognize it and if it is at a enough distance it will indicate if the answer is correct or wrong. If it is correct, it will increase the number of correct answers and will give the option to ask another question. If it is wrong, it will add an error and will wait for a new answer with a different pattern.

VI. CONCLUSIONS

The use of mobile applications and augmented reality experiences in education has been widely covered in the literature. However, its use in technical education is still a minority. For this reason, the authors have developed these two applications as proof of concept that allow them to continue investigating the possible improvement of engineering student learning through these technologies.

The main drawback found in the development of these applications has been the speed with which the tools for the development of these experiences evolve, as well as the difficulty that these developments have for teachers without programming knowledge.

That is why, as future lines of work we mark the development of authoring environments of this type of educational applications that allow any teacher to develop them without having programming knowledge.

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