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DEVELOPING A MOBILE AUGMENTED REALITY APPLICATION USING UNITY

Thesis candidate for BSc Degree

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BUDAPEST, 2020

Contents

THESIS TASK DESCRIPTION

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Candidate for BSc Degree

Developing a Mobile Augmented Reality Application using Unity

Augmented and Virtual Reality systems have revolutionized various fields of man-machine interaction in the last decade and may fundamentally change the way humans consume content. These technologies are especially widespread in mobile devices where the built-in sensors and interactive technologies make such systems easier to implement. The widespread use of smartphone devices would make such systems easily accessible to most of the population.

The use of mobile mixed reality systems is especially valuable in education, where capturing the attention of students is of outmost importance. Despite this, most educational content is still offered in the traditional way: textbooks and other non-interactive methods. By combining the advanced content display methods of augmented reality, educational resources could be modernized, and more attuned to today's stimulus-hungry students.

The student's task for the thesis is to design and implement a mobile augmented reality application for adding and displaying digital content to traditional books, and to test and evaluate the created application's performance.

The student's tasks include the following:

- Explore the relevant literature. Present an overview of Augmented and Virtual reality solutions.
- Create a design for the application to summarize and detail its most important components and features.
- Implement the application and its features.
- Test the applications functionality and evaluate the accuracy of the method used.
- Evaluate the application's and its main components' computational efficiency.

Department Supervisor: Márton Szemenyei

Budapest, 25th, January, 2020

STUDENT DECLARATION

I, **Luis Sempere Sanchis**, the undersigned, hereby declare that the present BSc thesis work has been prepared by myself and without any unauthorized help or assistance. Only the specified sources (references, tools, etc.) were used. All parts taken from other sources word by word, or after rephrasing but with identical meaning, were unambiguously identified with explicit reference to the sources utilized.

I authorize the Faculty of Electrical Engineering and Informatics of the Budapest University of Technology and Economics to publish the principal data of the thesis work (author's name, title, abstracts in English and in a second language, year of preparation, supervisor's name, etc.) in a searchable, public, electronic and online database and to publish the full text of the thesis work on the internal network of the university (this may include access by authenticated outside users). I declare that the submitted hardcopy of the thesis work and its electronic version are identical.

Full text of thesis works classified upon the decision of the Dean will be published after a period of three years.

Budapest, 22 May 2020

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Luis Sempere Sanchis

Abstract

Nowadays, technologies play a vital role in our lives. These have evolved and provided new benefits to humans, which has allowed us to complete some jobs with less effort, being more precise or more optimally. Furthermore, it can be said that the new generations (born from 2010) have been growing at the same timeline as technological advances did.

My dissertation begins by emphasizing the possibilities that augmented reality presents today. The essential technologies capable of displaying AR on the appropriate devices are examined. Although technology has evolved for many years, in the last decade, the computing capacity of most devices has increased significantly. Knowing these advances allows me to examine the technological situation to work with the software and hardware that work best with AR.

The main objective of this thesis is to achieve an improvement in learning through the application of Augmented Reality technology. The app will be installed on the electronic devices that are provided in the educational field. The final result that is sought is that of an application that recognizes codes (QR and derivatives) and elements that will be tracked. Finally, an AR element will be played on the screen of the electronic device. The most outstanding points in the implementation of this application are:

- The scanning of areas in educational books to show elements in AR (they are and without AR code).
- Analysis and rendering evaluation of elements that will be shown on screen.
- A Cloud where the data can be stored.

The first chapter contains an analysis of the technological and educational contexts. In the second chapter, the theoretical background, the requirements, and the similar systems that have been studied appear. The third chapter shows the designs of the program operation, the technologies used, and the code recognition framework described in detail. Finally, the system is analyzed with tests, and the results are presented.

The application has been developed from Unity's real-time development platform and other tools, such as Vuforia Engine or Xampp for databases or Atom and Notebook ++ for programming.

Abstracto

Hoy en día, las tecnologías juegan un papel vital en nuestras vidas. Estos han evolucionado y han proporcionado nuevos beneficios a los humanos, lo que nos ha permitido completar algunos trabajos con menos esfuerzo, siendo más precisos u óptimos. Además, se puede decir que las nuevas generaciones (nacidas a partir de 2010) han estado creciendo al mismo tiempo que los avances tecnológicos.

Mi disertación comienza enfatizando las posibilidades que la realidad aumentada presenta hoy. Se examinan las tecnologías esenciales capaces de mostrar AR en los dispositivos apropiados. Aunque la tecnología ha evolucionado durante muchos años, en la última década, la capacidad informática de la mayoría de los dispositivos ha aumentado significativamente. Conocer estos avances me permite examinar la situación tecnológica para trabajar con el software y el hardware que funcionan mejor con AR.

El objetivo principal de esta tesis es lograr una mejora en el aprendizaje a través de la aplicación de la tecnología de Realidad Aumentada. La aplicación se instalará en los dispositivos electrónicos que se proporcionan en el campo educativo. El resultado final que se busca es el de una aplicación que reconoce códigos (QR y derivados) y elementos que serán rastreados. Finalmente, se reproducirá un elemento AR en la pantalla del dispositivo electrónico. Los puntos más destacados en la implementación de esta aplicación son:

- El escaneo de áreas en libros educativos para mostrar elementos en AR (son y sin código AR).

- Análisis y evaluación de la representación de los elementos que se mostrarán en la pantalla.

- Una nube de datos donde se pueden almacenar información.

El primer capítulo contiene un análisis de los contextos tecnológicos y educativos. En el segundo capítulo, aparecen los antecedentes teóricos, los requisitos y los sistemas similares que se han estudiado. El tercer capítulo muestra los diseños de la operación del programa, las tecnologías utilizadas y el marco de reconocimiento de código descrito en detalle. Finalmente, el sistema se analiza con pruebas y se presentan los resultados.

La aplicación se ha desarrollado a partir de la plataforma de desarrollo en tiempo real de Unity y otras herramientas, como Vuforia Engine o Xampp para bases de datos o Atom y Notebook ++ para programación.

1. Introduction

Over the years, technology has revolutionized the educational field, allowing both students and teachers to use more modern learning techniques. Today, a significant percentage of society is closely related to different types of technologies. Since a high percentage of the population has at least one electronic device at their disposal, it can be said that the benefits we have in our hands are increasing.

In the past decade, there have been significant advances in technologies. These changes have allowed many technologies to be introduced into people's homes, which was unthinkable in the past. Such examples are 3D printers, virtual assistants (Alexa, Siri, etc.) or augmented reality and virtual reality on mobile devices or glasses.

The close interaction between technology and society has allowed entities such as schools and universities to exploit new services that would be unfeasible without it. It is true that, at the beginning of the decade, many schools already introduced electronic devices in order to streamline the study method, in addition to reducing the cost of paper for books and lowering the cost of the school syllabus.

At first, this type of change presented some positive and other negative points, so the first years can be considered as an adaptation process in which technology entered schools and homes. It can be considered as a turning point for the youngest, since, at ages under 18, the use of electronic devices such as smartphones, tablets, or computers was used overwhelmingly for leisure. Once the use of technology is generalized in a more consistent way, a series of characteristics that add value to teaching are introduced. Among these, we find augmented reality.

Virtual reality and augmented reality provide people with new capabilities that always facilitate the interaction between machine and man. Along with technology updates, it is also easier to consume information in the present.

AR is an alternative that is very well adapted to the educational sector since it can be incorporated into tablets or documents reproduced on the screen, as well as books in education systems that still follow traditional guidelines. One way or another, introducing AR is a modernization of the system, facilitating the work of the teacher and stimulating the motivation of the students to study the topics on their initiative.

In this thesis, I show the process of creating an application that takes advantage of the opportunities that augmented reality provides us, either for use in digital media or traditional books. Despite the significant advances mentioned in the educational sector, this type of application is considered an added value to the way of teaching. It can provide good opportunities for students and teachers alike.

The main idea is that the application can reproduce text, landscape, mobile or textual elements, providing additional information that the student will investigate on their own. Therefore, the app allows the teacher to teach in a more generalized way. It means that teaching time in the classroom can be used more productively.

Among the tools used are the Unity development environment, applications to manage databases such as Vuforia Engine and Xampp, and other programming applications such as Atom or Notepad ++. These tools have been chosen for the practice observed in the university and the previous motivation that it entails.

In particular, the thesis begins with a simple schematic idea discussed with the supervisor, and then it is progressively developed in this dissertation. In the first half of the dissertation, I review the functioning of AR in the present, talking about the devices and applications that facilitate the use of augmented reality. The context surrounding the education and information technology sector is also detailed.

Then, some initial schemes are detailed, which are related to the components necessary for implementation. Finally, the final operating diagrams, implementation, algorithms, and hardware and software that have allowed this program to work are shown. Everything is recorded in the following sections.

Finally, the app is tested for frame recognition and storage, where functionality and performance are detailed. Two types of tests are carried out: one for precision and one for vulnerability. In the first test, it is observed how the operation of the camera is precise. Secondly, some points of the application are questioned. On the latter, future updates are explained in detail.

2. Literature review

This task tries to design and program an augmented reality application, and it must process graphic elements. Therefore, it is vitally essential to carry out a series of analyzes of the context that surrounds the same topic, AR, in the educational sector.

This chapter describes the theoretical background and existing development tools that will allow us to work on the subject of this thesis. Topics such as technology-related education are developed. There is also talk of IT related to augmented reality, processing and images, sensors, and their existing functions or limitations. Then, the available tools will be presented, analyzing their services, and specifying which of them are put into practice.

2.1 Technology and evolution in the educational field

It can be said that currently, the link between technology and education is entirely adapted. This is thanks to an evolution existing in the last decade.

Not only in the last ten years, but throughout the previous three decades, small changes can be observed in the structure of the teaching method related to the introduction of technological processes. In the graphic representation of Figure 1, the gradual evolution is exposed to educational technology for the past three decades. This refers to an investigation that can be extrapolated to the general society.
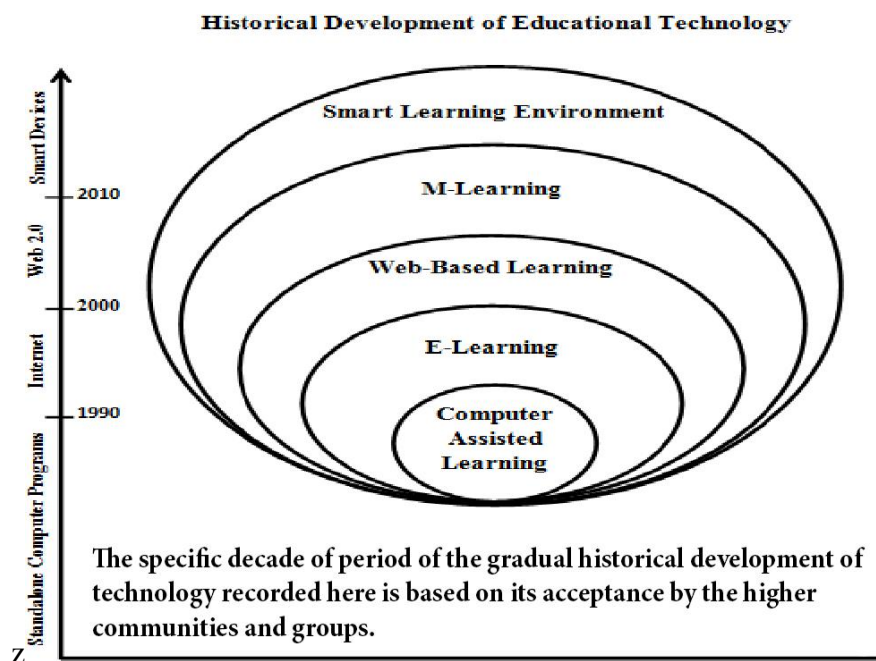

Figure 1 Historical Development of Educational Technology

This thesis focuses on the evolution existing in the last ten years, from M-Learning or E-Learning (The use of ICT resources to deliver digital content and instructions to act on or off campus) to Smart Learning Environment, where technological methods are already used to support education. [1]

With these advances, technology in education has served as a support in tutoring capable of generating an additional emphasis on teaching. That is why today, academic disciplines are broader and more moldable, providing a more significant framework of opportunities for the future. [2]

The topic "AR in education" has been chosen because it is an element of support that provides a benefit for both the student and the teacher. Since technology is a very active element in classrooms and deterministic results can be obtained, it is possible to classify education with technology as a more autonomous action that provides more critical thinking [3]. The school that is complemented by technology facilitates understanding and gives users more flexibility, among other characteristics. [4]

2.2 Technology with added graphical information

Today, people have access to technologies for personal use thanks to conventional devices such as smartphones, tablets, or computers, which we can easily find in all kinds of homes. The existence of these devices allows us easy access to information and content, which has become an experience in many cases. This is the result of the added graphic information technologies, among others.

With these, the real environment can be combined with real and virtual images created by computer or with totally recreated environments outside of reality. All of this refers to Augmented Reality and Virtual Reality.

Thanks to this type of technology, critical environments can be simulated, the tasks performed can be validated, or the information can be represented virtually [5]. This paragraph refers to fields such as medicine, aviation, or nuclear power plants. Sectors where the real practice is dangerous, and AR or VR help create a virtual environment as close as possible to reality.

Virtual Reality

Virtual reality (VR) is a computerized simulation of added spaces outside the real context. VR places the user in the experience and can interact with the 3D worlds. The limits to simulating reality with VR depend directly on computing power and content availability.

In more technical terms, what virtual reality refers to is described as "a three-dimensional, computer-generated environment with which a person can explore and interact" [6]. In this type of environment is where the person becomes part of this environment or interacts with it, being able to perform actions or manipulate objects.

This type of three-dimensional representation is introduced frequently in our current society. Besides, with technological advances and the greatest benefits that devices offer us, it evolves year after year [7]. Virtual reality can focus on leisure or sections of teaching. It is true that investments in sectors such as cinema or video games increasingly bet on immersing the user in the context of video games or films. Still, this work highlights more applications in science, sports, the arts, or entertainment.

Furthermore, this is an essential point of support for practices that are high cost or carry some risk. From airplane pilots to surgeons in their training, they can take their first steps more safely with sensations very close to reality.

Augmented Reality

Augmented reality, or AR, is a type of computer-generated content introduced in the real context [8]. Unlike virtual reality, this type of technology increases reality but does not replace it at any time. Given this information, it can be distinguished that the moment hardware combines digital content with the real world, it is referring to AR. [8]

This dissertation focuses on this type of technology that complements the real world with new elements, be they sound effects, graphics, or images, which always provide additional information to the user.

Thanks to the evolution of the last few years and, especially of the last decade, there are many sensors and hardware components that allow users to better interact with this type of technology. You can see the evolution of the hardware in general in Figure 2, which show how the CPU performance is progressing.

The acceleration in the CPUs when executing software is detailed. Although, after the year 2000, there is a slowdown in evolution, CPU performance continues to evolve with 21% per year. This is essential information because the execution limits will be lower, and the computing power will increase, which will facilitate work in different areas, such as augmented and virtual reality.
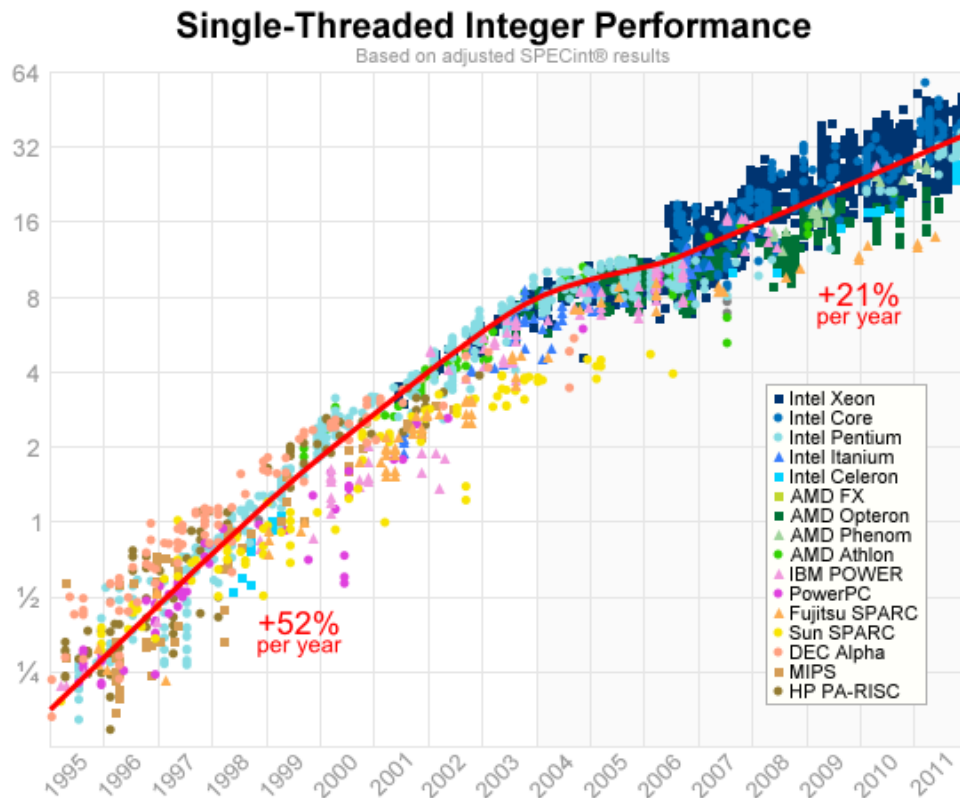

Figure 2. Logarithmic evolutionary scale: Single-Threaded Integer Perfomance in CPU's over the years (Source: https://preshing.com)

It can be seen how the performance of hardware technologies continues to evolve exponentially, reaching returns that are exceeded year after year. AR can be used in more and more areas, taking advantage of CPUs' technological evolution, as shown in the previous paragraph.

An excellent way to highlight these levels of progress is through the charts on Gartner.com where future technologies that could emerge and evolve in the coming years are studied and analyzed.

This part is highlighted in Figure 3. This graph corresponds to the analysis of 2019, where you can see technologies technologies are already gradually establishing themselves in our society, such as the appearance and use of 5G. [9]
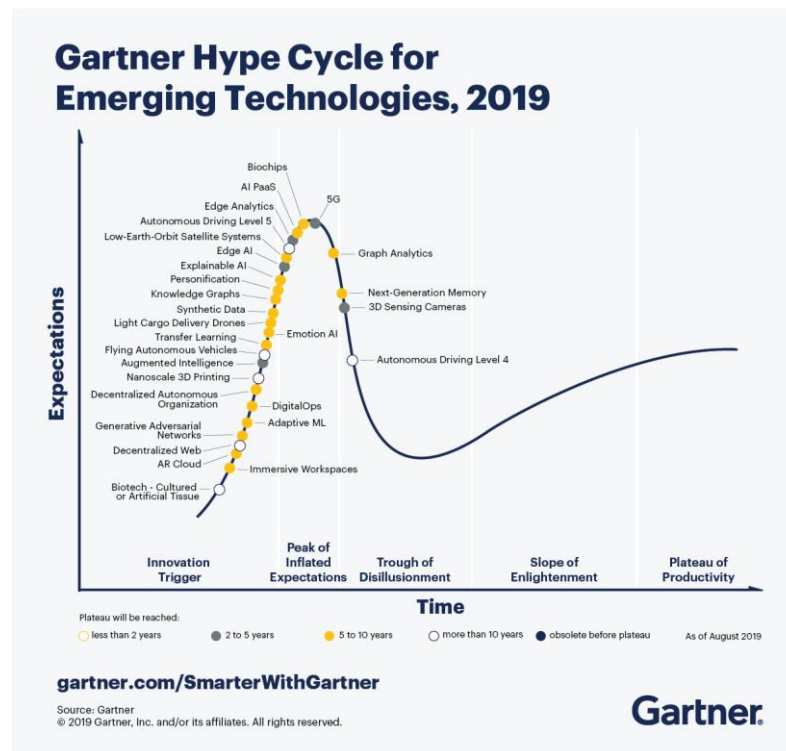
Figure 3.New emerging technologies that CIOs should experiment with in the coming year. (Source: www.gartner.com)

"The Hype 2019 cycle highlights emerging technologies with a significant impact on business, society, and people in the next five to 10 years," says analyst Brian Burke The situation during the first half of 2020 focuses entirely on the 5G peak. This condition can only favor AR.

Currently, there are many areas where AR has to work offline, which means that most processes are loaded internally. These situations cause limitations between connectivity and the implementation of this type of technology. With 5G, processes can be completed by accessing the network, and internal memory will be freed [9] [10].

As with VR, when augmented reality is referenced, it can be used in many contexts of everyday life. For example, AR may be present in purchasing apartments online, advertising, or video games, among many others.

Actually, a relatively prominent and recent case was that of the Pokemon GO video game, which used augmented reality and GPS technology to display its targets in exact positions for a specific time. [11]

Similarly, society increasingly relies on software with this type of technology. In the following paragraphs, two examples of current applications are explained. The first example is an application for everyday use, and the second is used in the entertainment section.

IKEA Place

An application that allows users to view catalog items using augmented reality. IKEA App allows the article that the individual wants to buy can be entered at home virtually through the screen. Users have a first look at the items in their homes without having to go to the store physically and without buying the product.

With this application and an electronic device, users can predict what the purchase of furniture or decorations will look like in their homes. (Figure 4.a). To sum up, the operation of this application can be adapted to any online store that has a catalog with items in stock.

Civilizations AR

In general, Civilizations AR is an application developed by the BBC linked to documentaries from the same station. The system use AR to show users different artifacts with explanations and things of interest. (Figure 4). This application is included in the field of entertainment and leisure. That is, this classification can be related to the app that is designed in the thesis.

Figure 4.a and 4.b. IKEA Place app and Civilizations AR App.

In addition to these highlights, there are thousands of applications (Instagram, Snapchat, Maps, etc.) that today use augmented reality because it is a tool that gives you additional functionality in most cases. [12]

Mostly the thesis focuses on this technology aimed at the educational field to create an application that complements the system that is used today in education.

The educational field is analyzed in this way because there are few alternatives for students and teachers to work in a more agile and independent way. Investigating a vital area such as education, in which I have been involved throughout my life, can be very useful for the analysis and improvement of some aspects.

2.2.1 Necessary elements in AR

Generally, for augmented reality to work correctly, some elements are necessary. Two aspects that are considered essential to interact with augmented reality are explained in detail below. The sections include an initial explanation and then detailed explanations of each of the elements.

First, the items to be tracked by the cameras, such as QR codes and other codes. Items viewed by the program without codes are also referenced. This tracking creates a link allowing the image or text acts in the same way as a QR code. Above all, the latter is beneficial for giving information before being seen with AR.

Secondly, reference is made to the necessary elements in the technological part. That is to say, in this second part of section 2.2.1, aspects such as cameras and their interpretations with AR will be discussed. Other available technological equipment or the interaction that a user must-have for the system to function appropriately will also be analyzed.

2.2.1.1 QR Codes and spatial mapping.

QR (Quick Response) codes are a type of barcode. These are capable of storing different kinds of information, such as a URL, text, image, etc. Thanks to the increased use of smartphones, QR codes are common. Figure 5 shows an example of scanning over a quick response code that offers a URL. [13]

In general, in all-new devices, the QR code reader is integrated, so in most cases, it is not necessary to install it. To make use of these, the user points the device's camera at the code and analyzes it. The software interprets the code, and the information is displayed on the screen. This can be a request to open a URL, a download, etc.
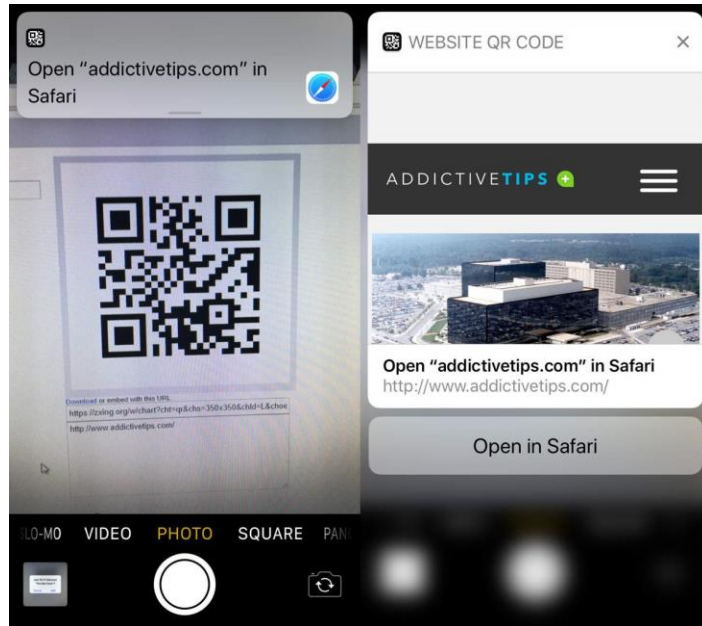
Figure 5. QR code scanning with iOs device camera. (Source: www.addictivetips.com)

Second, spatial mapping refers to the compression of computational geometry. You can refer to a simple mapping of a 2D object or refer to a 3D object. This type of technology distributes a mesh that extends to the environment.

Generally, this type of technology detects the depth of field, understanding the surface and the elements that compose it. In fact, for apps like Pokemon Go to work, mobile devices generate a more primitive mesh with the same functionality (Figure 6).
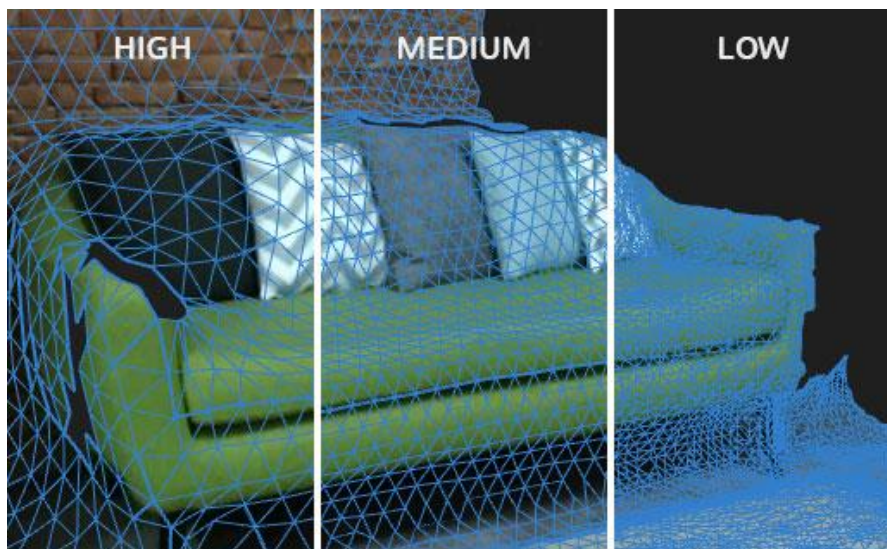
Figure 6. Virtual mesh representation depending on the electronic device.

Similarly, our application will detect the figures on a flat surface. Detection speed will largely depend on the hardware and software technology of the electronic device.

2.2.1.2 Other necessary technological elements

An ideal context for the programmer would be one in which the use of VR and AR applications would always be the same, but when it comes to reality, this is not the case. Technological evolution offers new opportunities, but many times with these advances, new complexities also appear. As a result, the programmer will have to foresee how the app will be used and, in the same way, the user who administers the application must use the software in the most efficient way possible.

Practically the technologies that surround us are adapted to allow users to work or program AR and VR applications. The developer will always seek to offer a form that is easy to use and does not consume many resources. Among the technologies available to be used by AR applications, the following stand out:

Projection by projector camera

This is the representation that best suits a large group of users. With this type of tool, we are creating a possibility in which different eyes can see augmented reality in the same way and simultaneously. For example, this situation can be experienced in classrooms or conferences, where the presenter user shows a result on the screen. As a result, all "listeners" observe the same item on the screen.

Something that negatively affects this method is the difficulty of preparing the team. Please note that the projector must be transported plus an external camera. If we compare this system with that of a mobile device or tablet, it increases the transport time and the cost of materials.

Handheld devices

This section includes electronic devices that people can easily carry. Here you can include smartphones, tablets, or laptops, among others. In short, these are electronic devices that contain an integrated camera, processor, sensors, and display.

A disadvantage that must be highlighted is that they are elements that must always be between the tracked area and the user's eye. In other words, the user is obliged to place the electronic device in front of their eyes. Despite this, they are the most common type of technology that works with AR.

Portable devices

Today several tools offer the experience of augmented reality.

Unlike handheld devices, within this section are helmets, goggles, belts, or other accessories that allow you to perceive AR. Unlike mobile devices, in this section, items don't have to have embedded processors, displays, or sensors. Many times it is necessary to combine them with a portable device, either for coverage or for pure functionality. Depending on the interface, the use of these elements will be through buttons, screens, or gestures, among others.

For example, Google Glass stands out in this section, although there are already several brands (Apple, Facebook) that are fully working with this type of idea [14]. either to create 3D maps or to replace portable devices such as smartphones.

Today, you can see a large number of vendors selling these types of items, especially aimed at leisure, entertainment (video games and movies), and for industrial use.

Other special equipment

Here, we discuss the projects that are currently being worked on and are expected to be launched on the market in the coming years. Not only are concepts like the new AR glasses from Microsoft Hololens or the Epson Moverio named, but there are also references to other high-ambition projects, such as Mojo Vision contact lenses (Figure 7.a and 7.b). These are contact lenses that allow you to show additional information in plain sight with virtually invisible technology [15] [16].

Figure 7.a and 7.b. Microsoft Holo Lens and Epson Moverio Glasses

AR control devices

Working with AR, it is necessary to know the different types of ways that exist to interact with this technology. A popular way is to use the touch utility through devices such as smartphones or graphics tablets, another way to intervene with this technology is through the use of gestures, where you can differentiate specific actions or gestures that give way to actions.

Today it is considered essential to be able to use technology with as few gestures as possible. In recent years, the use of technology has had an efficiency of close to 90% in many cases. Devices such as sensors and cameras, as well as a powerful CPU, are required to achieve significant profitability. [17]

2.3 Unity development environment

Unity is a video game and application development tool created by Unity Technologies. Today it is widely used software, whether for simple results or to create augmented or virtual reality experiences, including miniseries and interactive experiences.

Additionally, Unity is credited with the name of the world's most popular game engine, offering the developer a very extensive catalog of features, allowing them to work with the most complex ideas.

Similar to Unity, other tools allow applications to work with AR, such as Game Sparks or 3D Crafter. However, in this thesis, the Unity tool is chosen due to the following characteristics:

- Previous training at the university

- Free tool

- Wide catalog of computing resources

- Ability to work with AR and VR

2.3.1 Unity User Interface

Unity offers flexibility to configure the user interface. It can be customized to adapt to the user's tastes, in addition to adding, removing, or changing the size of the tools. Next, Figure 8 shows one of the designs that has been adapted when preparing this work.
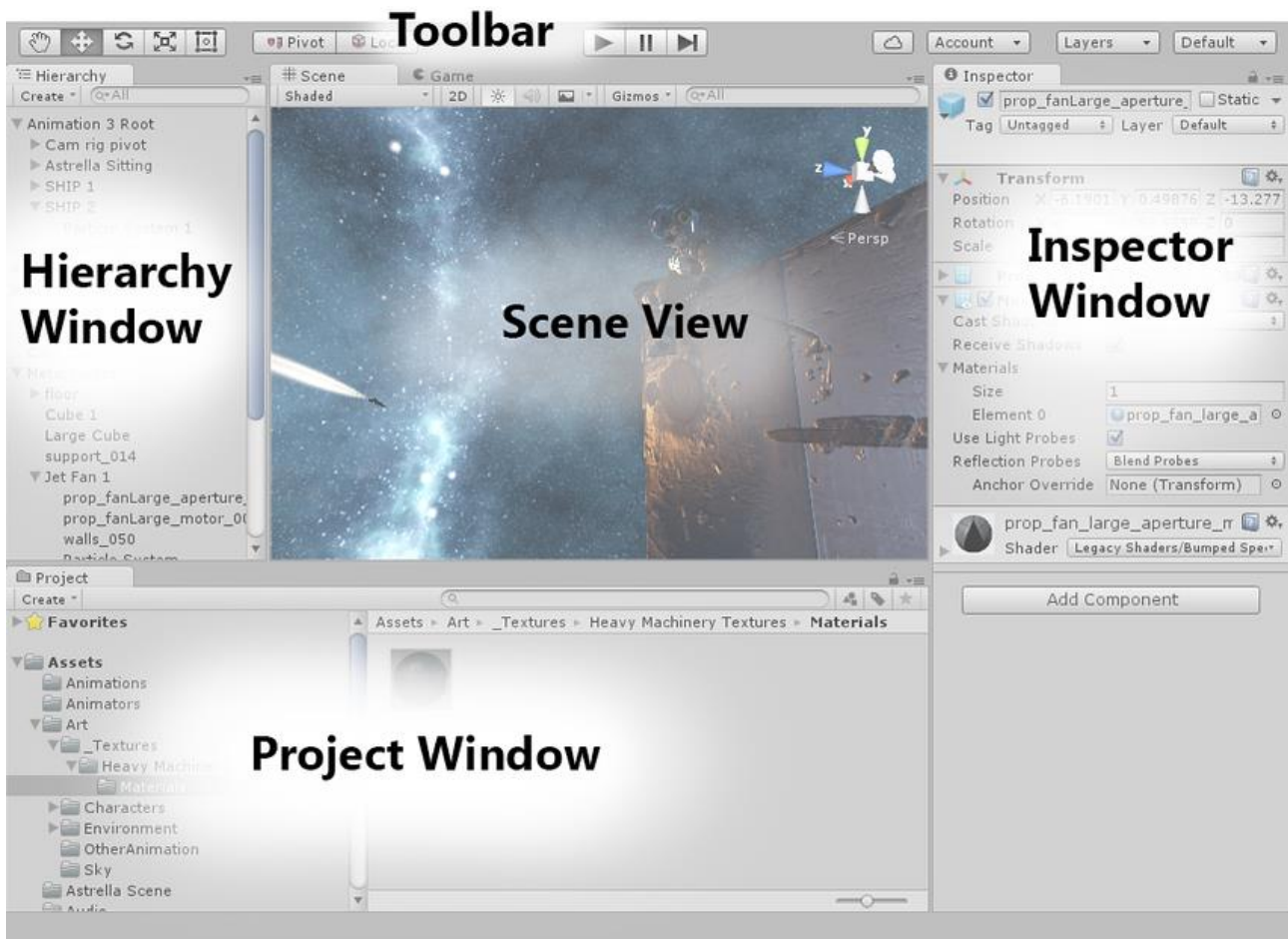
Figure 8. Unity User Interface (Source: docs.unity3d.com)

In the previous figure, the most critical parts in which this thesis has been developed appear. These are:

• Scene View

• Hierarchy View

• Inspector View

• Project View

First, Unity Scene View makes the image that will represents the scene being created available to the designer. Staging is referred to in general terms here, be it 2D, 3D VR, or AR video games. This part can be considered as the screen where everything happens. In the previous image, this part is located in the center-left area. [18]

In other words, most of the design focuses on this part. It is where the creator user introduces the elements and actions on the stage. It is possible to use the camera to observe the result that remains in the development environment [18]

Second, the Hierarchy View displays a list of all the objects that have been added to the main scene of the application. There are direct instances of elements (such as 3D models) or other custom instances where the user adapts them to their needs in the project. This thesis will focus on the first type of instances in Unity; that is to say, the instances will be permanent in most cases [18].

Last but not least, Scene Objects containing hyphens appear in the View part of the Inspector. Within this section, you can customize properties such as materials, directions, positions, or scale. It is one of the components that change throughout the progress. [18]

The Project View contains the resources associated with the application in the design phase. In this section, elements such as scenes, scripts, images, etc. are ordered. It is a place that must be taken into account at all times to advance in an orderly manner. This section appears at the bottom right of the previous image. [18]

2.3.2 Creating elements in Unity

Augmented and virtual reality has two ways to insert virtual elements. The objects that appear here are those that have markers. They could also be shapes that will be tracked to display a virtual item on the screen.

In general, elements with or without markers are those linked to a 3D or 2D shape. Thanks to Unity, combined with technologies such as ARKit and ARCore, it is possible to perform a shape recognition. First, a database is generated in Vuforia by assigning 2D names and images. This database is then loaded into the Unity program. As a result, virtual figures are seen at the top of the Vuforia database item.

Usually, the simplest shapes and combinations of these are used up to the most complex shape combinations (Figure 9). In this thesis, different visualization elements will be investigated. The items to be tested will be codes and images.

Figure 9. QR Codes and derivatives (Source: www.explainthatstuff.com)

Finally, there are objects without markers, this reference is made to objects with GPS mapping where the virtual object appears in a specific position thanks to the fact that one of the sensors that work with AR or VR, recognizes the exact location of the element.

Another option for markerless recognition is to assign an object or color to display the virtual item. This last option is great for the thesis.

2.3.3 Animating in Unity

Firstly, it is vital to create animations on the elements that need it most because they generate more confidence and are more adapted to entertainment contexts.

This thesis does not fully delve into the topic of entertainment, but it is necessary to generate a sense of learning on the part of the student, and that means reliability on the part of the object to the user who is consuming the content.

Actually, Unity presents a complete animation system that provides sophisticated and direct workflows, previews, and direct management of complex interactions between animations [17]. This feature can be incorporated into the elements present in the Scene View. This attribute generates a feeling of life on objects.

In other words, for both humanoid elements and different types of objects, Unity has large libraries with pre-created actions, which can be used in our environments. Another option is to customize the animations.

Adding animation to an object should be done by assigning actions to a GameObject, evaluating the previews, and modifying the necessary steps. All the states that make up the animation must be specified [17]. It is important to highlight in this part the importance of the animation controller, which allows organize and maintain a set of animations for a character or other animated object of the game or application.

To summarize, great importance is given to the animation controller because with it, you can organize and maintain a set of animations for a character or other animated object in the game or application. Figure 10 shows an animation controller that generates the "Execute" action. These types of operations can be assigned more visually, for example, as can be seen in the central diagram with directional lines. Another way to put animations is assigning codes to objects, using scripts. In this learning application of this thesis, only some items will contain animations such as 3D characters or 3D environments.
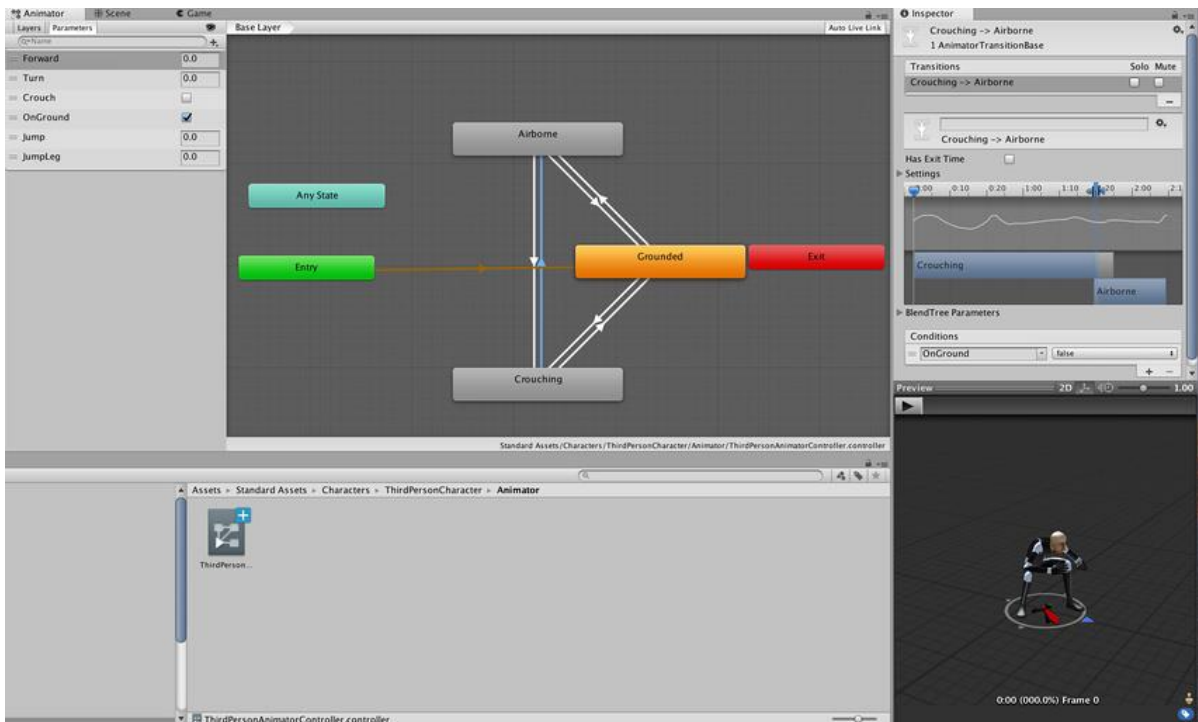
Figure 10. Animation System Overview (Source: docs.unity3d.com)

2.3.4 Vuforia Engine

Vuforia Engine is one the most current development tool to work with databases. It is a platform compatible with smartphones, tablets, or even glasses, where developers can add advanced vision functions that can be exported and played on Android, iOS, or Windows devices [18]. In other words, this is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications. It uses computer vision technology to recognize and track flat images and 3D objects in real-time [19]

This interface is easy to link with Unity by installing Vuforia as a package. Alternatively, you can enable Vuforia Augmented Reality Support through the XR Settings section of the Player Settings. The possibility of entering figures in a database is highlighted so that later, they can be recognized by the camera.

2.4 Development tools

This work has been developed based on some existing code libraries that have already been tested. These elements are incorporated into the thesis supposes added information that helps to progress more quickly. The following sections describe the tools used in this university works.

Unity User Manual

Starting a program in Unity means proposing a schematic structure that will be molded by the user through the interface. Since there are a lot of features and aspects of this development tool, users have to resort to APIs and libraries. The example of the library Unity3d is shown in Figure 11.

This is why Unity offers a very extensive manual. The Unity User Manual helps users to learn how to use Unity. This free library contains all the necessary aspects to use the Unity Editor. In addition, the documentation can be downloaded in PDF so that it can be viewed offline.
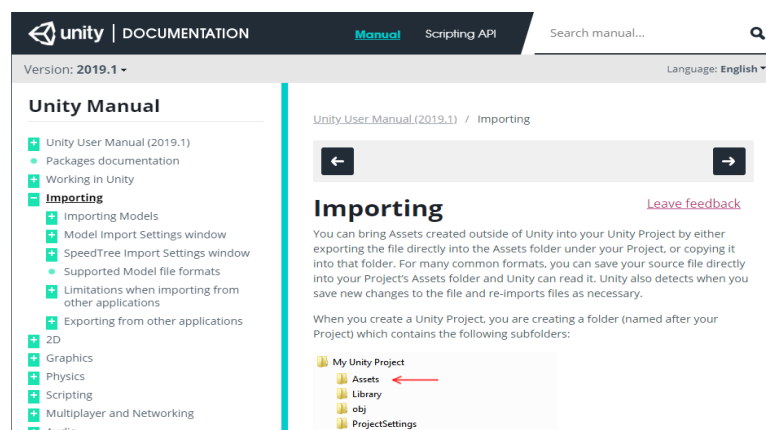
Figure 11. Unity Documentation Library (Own source)

Free3D and other 3D element libraries

First of all, in a scene of an application in Unity, it is essential to introduce elements that interact with the environment. These objects can be simple shapes like squares or circles, which can already be found in Unity. But they can also be more complex objects, for example, a human, a car, a house plan, etc.

In general, the user can create their two or three dimensional models using external programs like Blender3D. On the other hand, the user has the option of downloading elements from public libraries such as Free3D, which contains already created components. Above all, they are elements that integrate very well into Unity applications and games. Figure 12.

In conclusion, libraries such as Free3D are an alternative for the user who is inexperienced in 3D object design or who does not have a team dedicated to game design. For users starting in Unity, these public libraries allow the user to focus more on the operation and programming of the application.
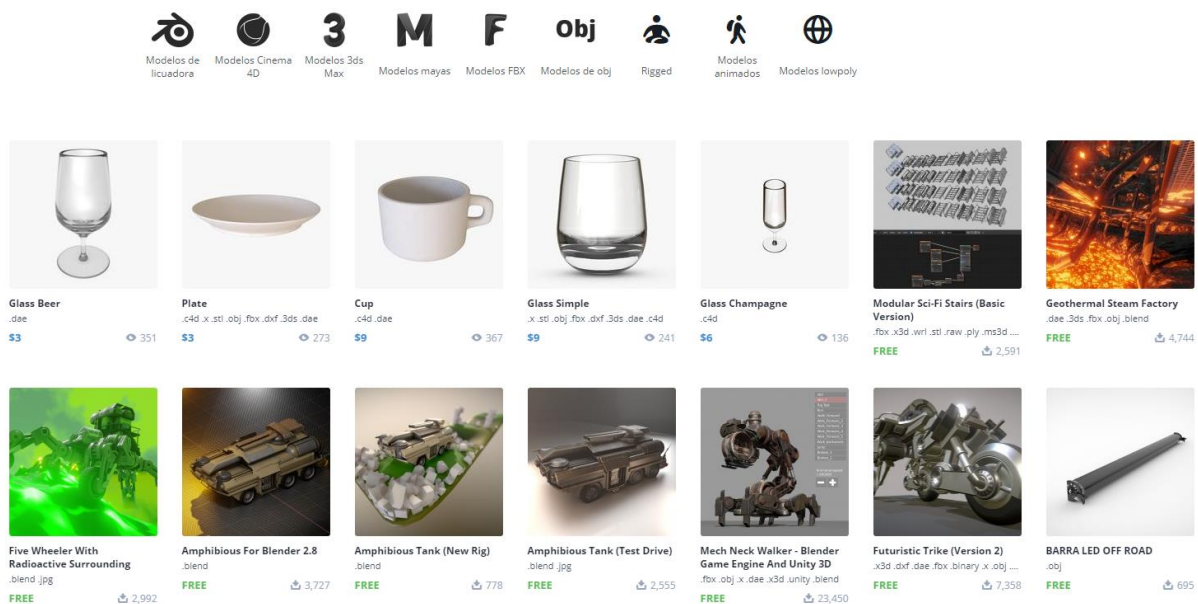
Figure 12. Objects in Free3D library (Source: www.free3d.com)

3. Task specification

3.1 Approaches

The application starts with a general idea whose main objective is to add value to teaching. The app will have functionality in handheld devices. From the first moment, it is specified that it is an application between user and machine, where in the same space and time, no more than one user with the same role will interact with it. The student role will have access to their camera and added content in the database, while the teacher role will have the same permissions as the student plus the writing in the database.

First sketch

First, a sketch of this program is shown, where you can see that a user with school documentation (physical or digital documentation), and at least a digital device with a camera and sensors is required. It can be a smart device, a laptop, or a tablet.

The application will be installed on the digital camera device. The teaching documentation (book, slide, or the like) will contain different QR codes and other items tracked in the parts where the program can offer additional information. The text paragraphs used in this thesis are "Lorem Ipsum" paragraphs, which will be used as placeholder text, since it is generally used for typographic proofs or design sketches. "Lorem Ipsum" is chosen to work in conjunction with this software because it represents a generic demonstration of all school subjects. The reality is that the application can reinforce books on all school subjects (architecture, science, humanities, etc.). See the design in Illustration 1.
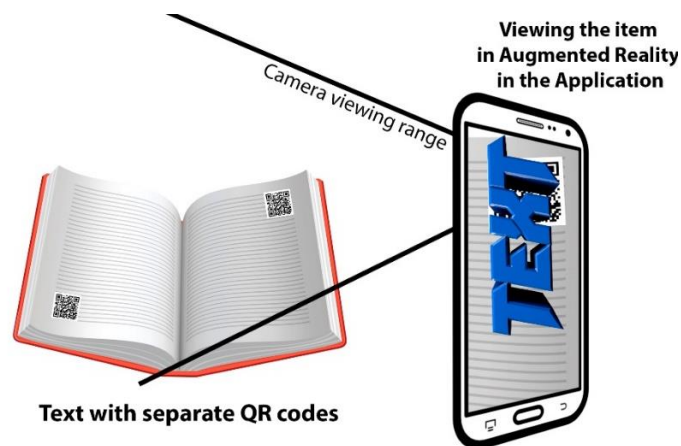
Illustration 1. Representation of the first sketch. (Source: Own representation)

The application starts when the user focuses the camera on the code, which will be located on some pages of the book, not all of them. Once focused, the application will display the item on the screen, and it can be a text, object, map, or character. Virtual items displayed on the screen may have animations. The loading of the elements, according to the QR code, is recognized from the cloud type database created by Vuforia. From this database, objects organized in Unity will be referenced according to the QR code.

Second sketch

Next, the design continues to work the same, except for the way to recognize codes. At this point, the idea of recreating virtual scenes is replaced so that QR codes become smaller codes located in the corners of the book in a more minimalist way. The purpose of the QR is left in the background, because it is considered this type of code can distort the text since it is a code that would be close to the central part of the document, thus breaking the structure of the written piece. The student needs additional motivation to want to see the virtual elements, so by placing the display elements (see Illustration 1) in the corners, the user will be able to see the written content at all times without the need for a specific space in the sheet.
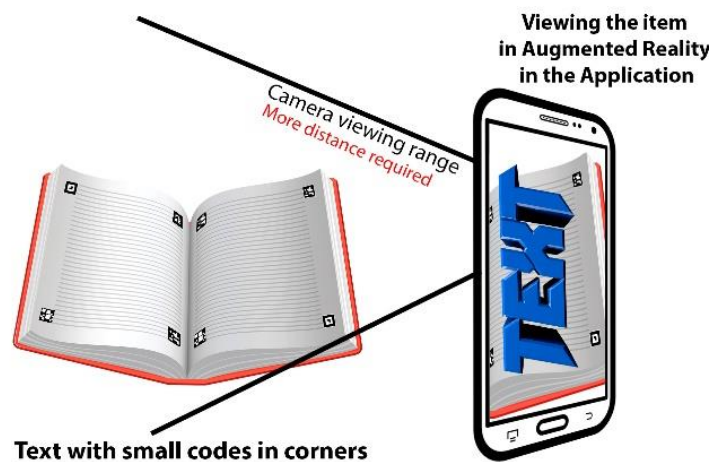
Illustration 2. Own representation of the second sketch

Updating the design of the second sketch

An in-depth analysis of the second scheme casts doubt on the design since, in this scheme, it is required to focus on the camera on the entire sheet (usually A4) to show the virtual element. However, completely replacing this approach is not considered the desired solution.

At this point, the decision is made to incorporate tracked elements with an added value (AR elements). At the time of reading the school document with this type of tracked images, the motivation of the student will increase in many cases. We show in Illustration 3 the methodology chosen at the final moment.

Third, it is essential to note the difference between the second sketch and its update. In the images that represent the diagrams explained, you can see how the visualization methods are combined. Now there will be times when the user will be able to interact with QR codes, corner codes, or tracked images. In this way, the monotony of documents will be broken, increasing curiosity and motivation.

There is also an opportunity to give the teacher the opportunity to create additional elements in the program. This type of information will be shown in another scene of the application, where the student will be able to see what the tutor adds in the database. This section requires a way to insert text notes into the program. These will be text fields that will provide more information to elements of augmented reality or textual parts of the school book. This field will be developed in the following points.
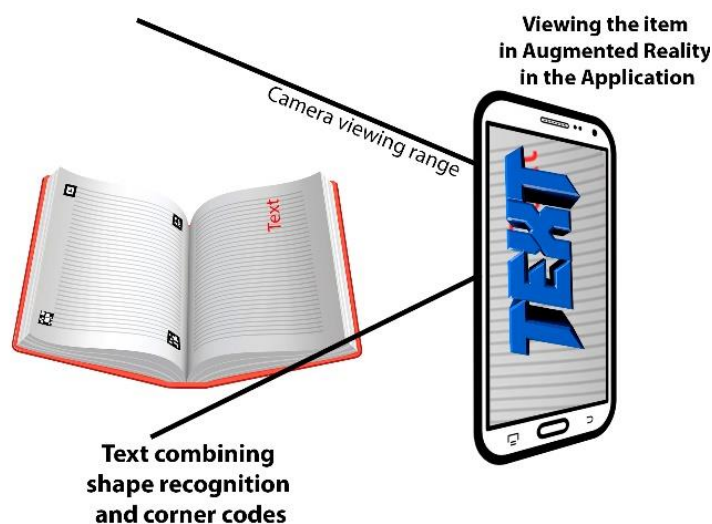
Illustration 3. Update of the second sketch

3.2 Necessary requirements

First, to program this learning app, some relevant requirements are necessary. In the first instance, electronic devices are essential for programming and testing the final results. Here we talk about a computer (laptop or desktop) and a mobile device with a camera (mobile, tablet, or computer). Importantly, devices must have non-obsolete processors and operating systems. This means being able to work with the latest versions of the installed software.

Then, the importance of the materials that will represent the school supplies. These will contain the QR codes and the tracked images. These can be books, PDF files, or anything else you can focus on clearly with a camera. It is recommended that they are used in bright light so that they do not distort the camera's vision.

Later, the importance is attributed to the software components of this project. 3D application development programs like Unity. Vuforia Engine or Xampp, dedicated to the database and, last but not least, to the programs in which it will be programmed, for example, Atom, Visual Studio or Notepad ++. The languages worked will be PHP and C#.

3.3 Limitations

This section discusses the limitations that have arisen from the project approach to its delivery. First, the small limitations were owning devices from different operating systems. In the case of this job, an iPhone was available to me while the job computer was running Windows. Mostly, iOS devices have many limitations when combining with other operating systems. This problem is solved using the laptop for both programming and the camera.

Secondly, the lack of knowledge in some concepts about 3D application programming caused difficulty. Firstly, I had to investigate the Unity 3D environment and its programming. The work begins with a codeless interface to which C # Scripts are progressively introduced. These scripts mainly refer to the connection to the database.

Eventually, social distancing during the Covid-19 crisis must also be highlighted. This problem eliminated the possibility of having in-person meetings with my supervisor at the university. Solutions to problems were resolved through the Internet by contacting the tutor from home university and the supervisor from the destination university. The intention was to test on different devices and achieve a final installation on Android or iOS. The result was finished developing on a computer.

4. Design and implementation

Once the literature surrounding the thesis topic has been reviewed, the following points show the design of the application and the progress in its implementation. The purpose of this part is to summarize the essential components that are necessary for the application to work with augmented reality.

Components that intervene in the process are presented in detail in this part of the work. Also, the algorithms that have been used during the development of the program are detailed. In the end, the correct functioning of the chosen framework is tested.

4.1 General system design

First, the application that constitutes the main basis for the operation of the camera scene focused on the object or the code is shown. The operation of this program appears in this thesis through a flow chart that represents the most important actions, processes, and decisions from the beginning to the end of its use.

In the first diagram that appears in Figure 13. Application User Flow Diagram. Scenes: Investigate (camera) and More Information (Own elaboration), the user starts the application with a simplified menu for the quickest possible use. When starting an app aimed at young and advanced students, it is essential to maintain a neutral and straightforward appearance. In this program, the main action is the use of the camera and sensors to reproduce elements in augmented reality. For this same reason, the person who is using the application will initially observe a simple menu that will allow him to open the camera or access fixed content (informative texts of the application, information on study methods and other elements value-added), to be nourished in the educational field.

Continuing with the flow lines after choosing to play the AR, by selecting this option, the application will turn on the device's camera and then proceed to recognize the item to play the virtual object. At this point, the user will be able to detect the code or not. If the application detects the QR codes or AR elements directly, it will load the items on the screen so that the user can see them. Otherwise, the flowchart will end.

If the user has the role of teacher, and he wants to add or manage the information in the "More Info" menu, he must first login correctly to proceed to administer. If they are not registered, they will access the part of the interface where they can register and later manage the site.
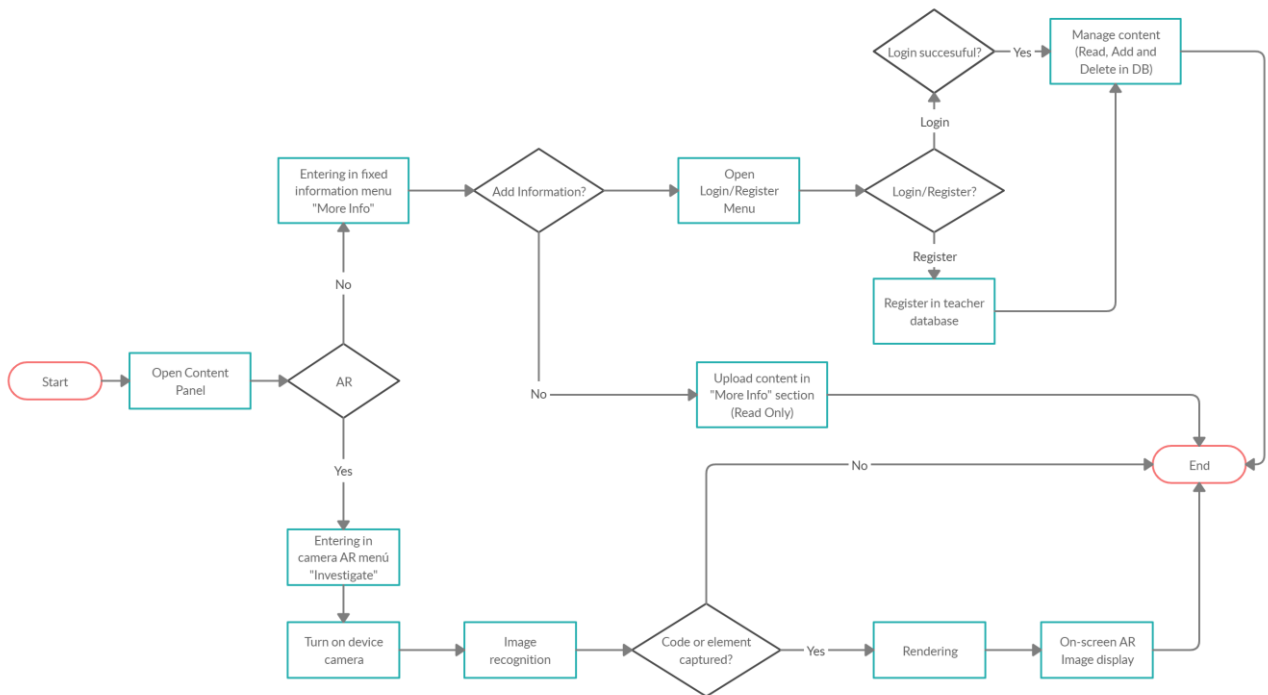
Figure 13. Application User Flow Diagram. Scenes: Investigate (camera) and More Information (Own elaboration)

In an augmented reality application for the education sector, it is essential to first think about what the system needs are, how the components will work together, how the different roles will intervene, and what requirements may arise when using this interface. The primary connections of the process that are annotated, where the system components appear are shown in Figure 14.

It is also especially important to talk about general user interaction, where we can refer to both students and teachers (they can add information about the database). Once the application is open and with the intention of testing augmented reality, the App calls the camera of the mobile device. In the diagram below, we will refer to the user as the set of these two roles. The roles will be differentiated in the following sections.

From the beginning of the sequence with the Augmented Reality scene, the Vuforia tool executes the mechanism. First, the camera calibration parameters configured for the mobile device are started. Once this is done, the database containing the images is loaded. Once the camera is turned on, it tracks markers or codes located in the real environment, through a user-centered approach. We highlight the option of adding objects such as texts or audios to virtual elements in points 5 and 6 of Figure 14. It is an option to facilitate the insertion of a personalized added value for teachers, in addition to augmented reality. In this way, the application will contain more personal style elements in addition to its static content. After showing the central diagram that reflects the general flow of the system, the main components and actions go on to be described:
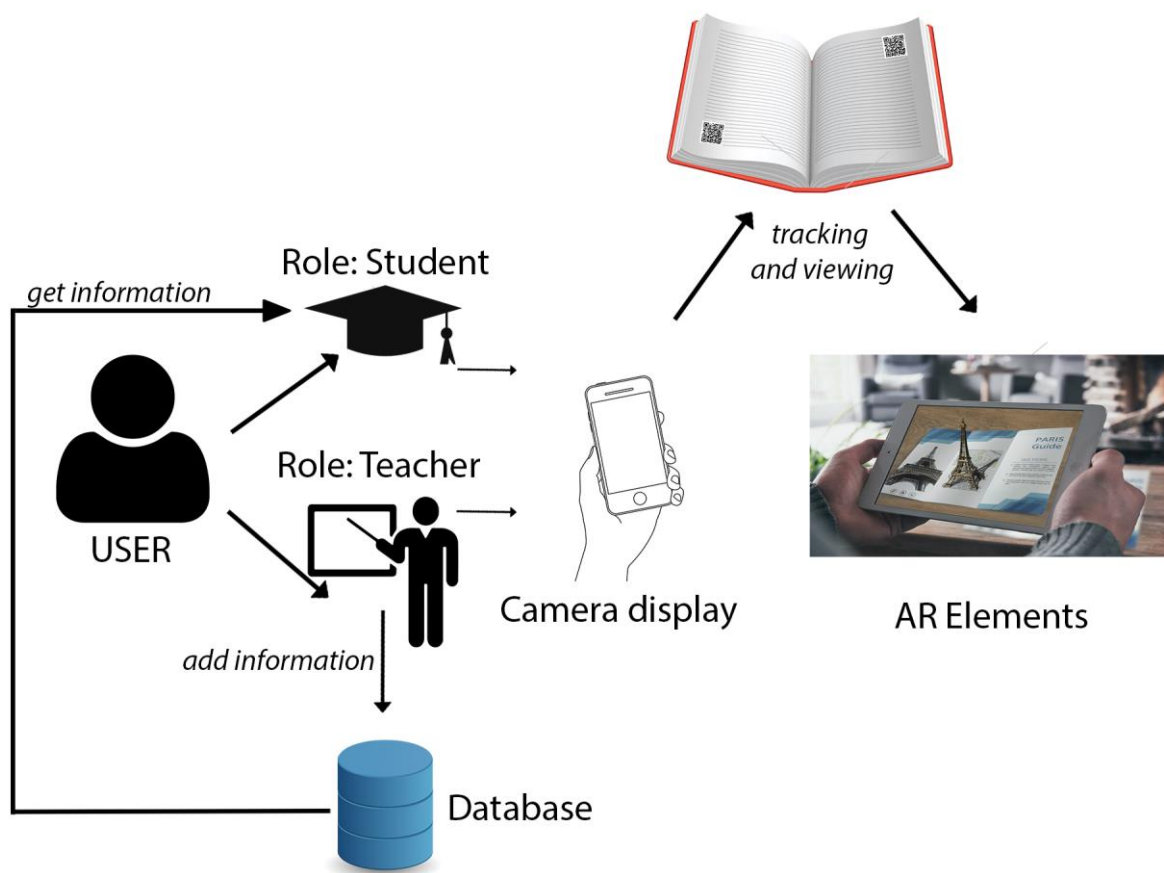
Figure 14. Interaction Flow Diagram. (Own elaboration)

Device camera

The use of the camera of an electronic device is an essential part of completing the tour of the vision of the general scheme. This part of the system will be able to interpret the environment with the selected element. From this process, the necessary information can be sent to the Unity application, and this will end up reproducing the AR elements.

The device camera will be directly linked to ARKit and ARCore software technology on Android devices. Thanks to this technology, the focused scene will be mapped, that is, the camera will have the possibility to map or scan the immediate environment, locating the device that performs it in that space, in real-time. [20]

2D recognition elements

In the system, it is necessary for the existence of elements that interpret codes or forms that will be tracked so that it ends up showing on the screen. In the context surrounding this thesis, these elements are imported from a database created by Vuforia Engine. These "Recognition Cards" indicates a type of qualification when we include them in Vuforia's primary database. The more stars it displays, the easier it will be for the camera to stream the rest (Figure 15). Actually, images and codes that have been used for this first sample of the application are dark due to the low level of focus of the camera of the device where the tests are carried out.

These elements are entered as images to be tracked on the Unity platform, in such a way that every time the application interface focuses on them with the camera, AR objects (3D elements, texts, etc.) are displayed on the screen. The parts that interact with this application are flat 2D images that will be placed in the student's book or slides. Items and custom codes and pictures have been tracked.

Figure 15: Tracking assessment in Vuforia Engine

AR Elements

The elements of augmented reality are those that are reproduced at the top of the images in the Vuforia Engine database. The nature of these objects in this application is primarily 3D, although video and other plain text content also appear. AR elements are the final part of the process that starts the camera. In other words, these elements are the added value that is sought to be generated in the teaching documentation.

These objects can be inserted directly into the Vuforia imaging lens or with additional elements, for example, on top of a textured plane. In this part of the practice, it is vital to consider the X, Y, and Z planes as it interacts with a three-dimensional plane. In general, there are two options for inserting content into an Image Target: First is to create it with Unity's assets. Unity provides several default assets that can be used from the get-go. The user can put into use materials, shapes, textures, etc.

The second option to insert content into Image Targets is to download the content or create it externally. It is mostly necessary to download a package containing the figures, materials, and textures, and animations, if applicable. A frequent option is to go to the Unity Asset Store since the packages can be downloaded and imported from the same application. The ones used in this practice are free packages.
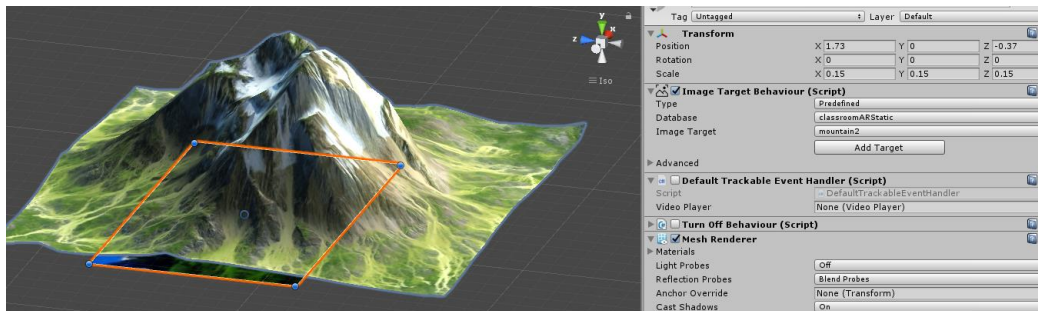

Figure 16: Insertion of AR element on x, y and z axes.

Databases

First, you can query the internal database in the application itself. This first one is a simple database that contains all the forms that the app will recognize. There are two options to establish this link: in the cloud or statically.

In this app, the library has been statically downloaded from Vuforia to work in Unity. This way of working was established from the first moment. A test was also done working with the cloud.

Second, the databases on the remote server are referenced. Remote databases allow teachers to enter, record, and store information for students. These database operations are managed using MySQL. For the operation of the application, three tables have been created within the database. One for teachers, one for added information, and one that connects them. Below is the graphic illustration that explains these relationships.
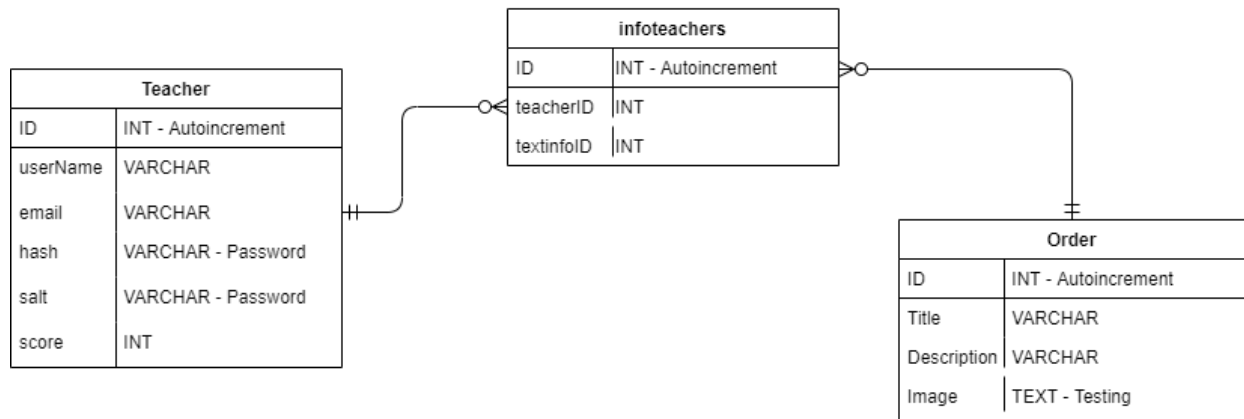

Illustration 4: List of teacher, infotext and infoprofessor tables. (Created in **https://app.diagrams.net/**)

In other words, at first, the work was done with Xampp applications, with which we activated MySQL and Apache to work on localhost, and with Atom, an app dedicated to PHP clients. With the evolution of practice, DDBB was imported to a remote server to which the latest updates were applied. Various tests have been carried out on this server, the test files of which are still avaliable in PHP or .cs in Unity.

Teaching documentation

In general, the documentation that the students will have will be physical or digital. This element is essential on our canvas since it will be where the 2D recognition elements will be: Images and QR codes.

In order to be able to test the application, a PDF document is added that simulates teaching documentation. This this file that will contain "Lorem Ipsum" texts, and there will be images that can be recognized by the camera.

Visualization

The final function of the application is to display the AR element that contains the image, the code or web information. This augmented reality will contain the real environment and the generated virtual environment. A virtual environment is made up of dimensional and three-dimensional objects.

To summamrize, I designed the overall system that shows the functions and the main elements that compose the application, so that the main types of operations that these application offers are recognized. Within the same app, there are several possibilities to read the cards, so the result displayed on the screen depends mostly on how the user uses it.

For example, the user can see 3D objects without movement, which would imply that necessary scripts are not activated. However, if the user focuses on a moving image or video, then, the user would enable some algorithms included in the program. It is also important to note that there is a big difference between the roles that complete this application.

The big difference is that a simple user can access the information published in the database and the scenario that allows him to scan items with the camera. On the other hand, the user with the primary role will be able to send information to the database. For this purpose, there is a registration and login screen.

4.2 Specialized system design

At this point, the main components and actions that make up the system have been discussed. This part describes all the operations and activities that can be developed through it. Depending on the student's curiosity and evolution, they will be able to obtain different types of information.

In the following paragraphs, the different actions that the user can experience with the application are detailed. Points from the camera scene and access to the database are discussed. The specific designs of each stage are also shown here in addition to the different scenes that can be seen. To start using the program, the user will install the application on the electronic device and click on the option that most interests them.

4.2.1 Operation of the application

Initially, when a user runs the application, they will access the main menu that shows two buttons with different options: "Explore" and "More information." If the user clicks on the "explore" option, they will access a stage where they can interact with the camera.

Figure 17: Main menu

The "Explore" scene has more than 20 linked ImageTargets containing 2D elements, such as plain text or videos, up to static and animated 3D features. By default, the camera scene has a method that continually searches for any objects entered from the Vuforia database. If nothing is found, the scene will only contain a view where the scene captured by the camera is seen, a capture button, and a Back button, with which they can go to the primary menu.

Also, the "Explore" scene has a built-in script that allows you to capture images and save them to the Android or iOS device. It is a sweep with two conditionals that detect what type of operating system works on the machine where the application was installed and allows saving the scene seen on the screen.

If the "Explore" scenario detects any of the ImageTargets that have been assigned to it, it will directly show the element at the top (3D or 2D virtual object). It is a Show method that will sometimes be accompanied by a Script. For example, when the camera captures the € 10 bill, a method that plays a video is activated. The implementation of video playback will be explained in the next section.

Second, by returning to the main menu and selecting the "More Info" button, the user will access a scene where three informative texts are displayed. To access this scene, it is not necessary to make any registration; that is, all users will have access to this textual content. That is, the 3 canvasses with text inside correspond to a selection from the database in which only the last 3 rows entered by the teachers will be selected. This selection includes a title and a description. The intention of showing this field is to give an added value in addition to the function of observing elements in AR.

Next, for adding information to the database, it is necessary to click on the "Add" button. The application will open a teacher login and registration menu where the teacher can choose the option he needs. The registration screen contains four fields for the username, email, and two for the confirmation of the password. The Login screen redirects the user to another screen where they can add the necessary information (this must contain a title and description). It should also be noted that all fields must contain eight or more characters to advance.
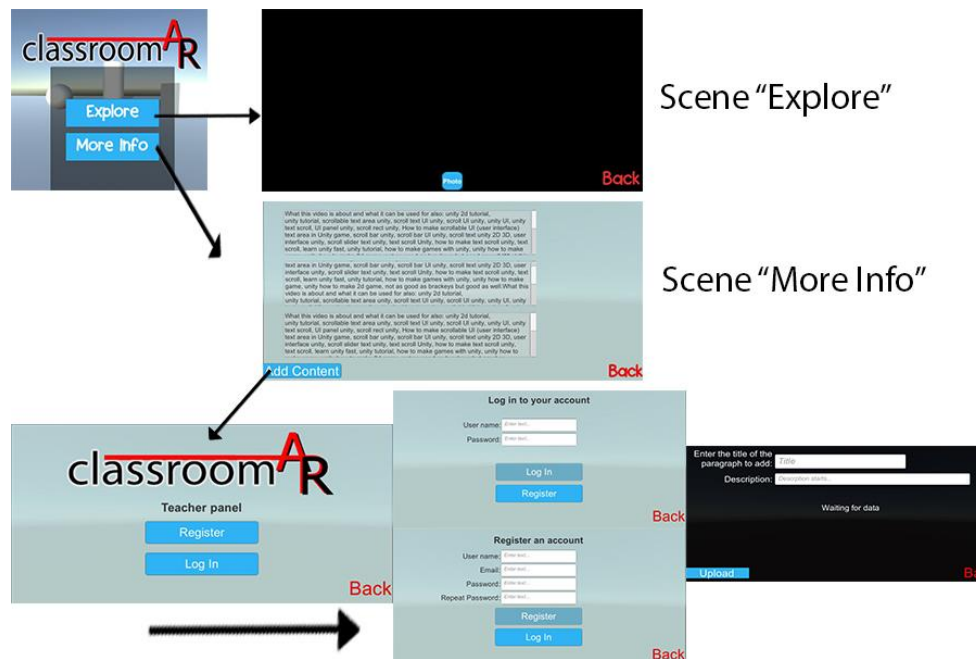
Illustration 5: Scene design and development (Own source)

4.2.2 General characteristics of Image Targets

As it is well known, ImageTarget is a component of the Vuforia Engine module. It allows you to capture an inserted element in the database to display an added virtual reality element that is combined with the real environment. First of all, it is essential to know that all these elements entered in the application belong to the ImageTargets attribute, but within them, they change according to the configuration. Each image features content ranging from plain text to a moving animal on a textured ground.

In other words, depending on the item focused on the camera, a different screen result may be obtained. There are several options to configure animations in Unity. One of them is to download the animations with the object of the Asset store or to program them from a new Script. The result in the element will be the same. Also highlighted is an ImageTarget that displays a video on top of the tracked item. In the next point, its functionality detailed.
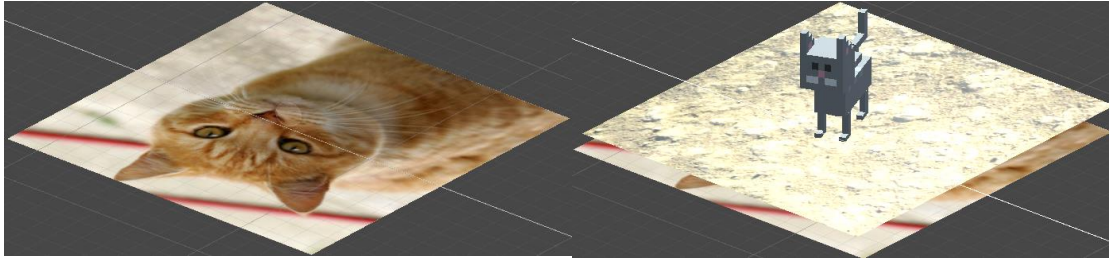
38

Figure 18: ImageTarget tracking of a cat image

4.2.3 Video recognition design

To begin, it is necessary to talk about the operation of the method that has been created. A Script is assigned in ImageTarget that contains the image in which the video will be played. This method is programmed in the Unity primary language, which is C #. The general operation is to search for the object as it does for images, but with the difference that Unity offers a framework to enter the video and then play it. The video only plays after the camera has tracked the 2D image (in this case, a € 10 bill). But the first method that was introduced didn't stop the video or the voice when it stopped focusing on it.

The script adds new lines of code that make the video stop entirely once it is no longer displayed on the screen. In this way, the user, whenever he points to the target, will see the video from the beginning. To achieve this type of interaction, a new variable called VideoPlayer is introduced. Then, in the method that contains the actions that are carried out once the image has been lost, we put a "stop" or a "pause".

```
protected virtual void OnTrackingLost(){
    if (mTrackableBehaviour)
    {
        videoPlayer.Stop();
        videoPlayer.Pause();
```

Figure 19: Function that freezes the video when the camera loses tracking

4.2.4 Roles and main function: User and teacher

Mainly the application has two types of users. Firstly, there is the role of the primary user who will only access the covers of "Explore" and "The main menu." This role presents some straightforward actions for the student to use it. Just by clicking on the app icon, they can interact with the real and virtual environment, or on the other hand, read the latest information published by their teachers.

Secondly, in the application, a user can operate under the role of "Teacher." This role differs from the student in that information can be entered that the student / general user will see shared in the app. This role works directly with a remote database.

Remote database for Teachers

First of all, the database was configured in MySQL to work locally. At first, we only start from a table in which we store teacher information. Then another table called "textinfo" was introduced in which the additional information loaded by the teachers is stored.

Second, when the database on localhost was already working correctly, the teacher can decide to migrate to a remote server. The main idea is to be able to test the application in a more realistic way. At first it was tried with cheap servers, but these ended up giving problems when working with MySQL or files. The final server was set up at "000webhost.com", a page that offers good features for what we were looking to test in this program.

Some of the features presented by this hosting were:

- 3000MB Monthly Bandwidth Quota

- 300MB Disk Space Quota

- 10000 Inode Usage Quota

In theory, ClassroomAR is designed for different users accessing the "Explore" part (which does not interfere or present concurrency problems), and the additional information part. All this will be done through the internet.

Finally, with those two tables in use, the decision was made to create a relationship table that relates the IDs of both tables to additional information. This last table is set with future software updates in mind. Looking ahead, new sections or components can be created that show which teacher each information belongs to, which department it belongs to, etc.
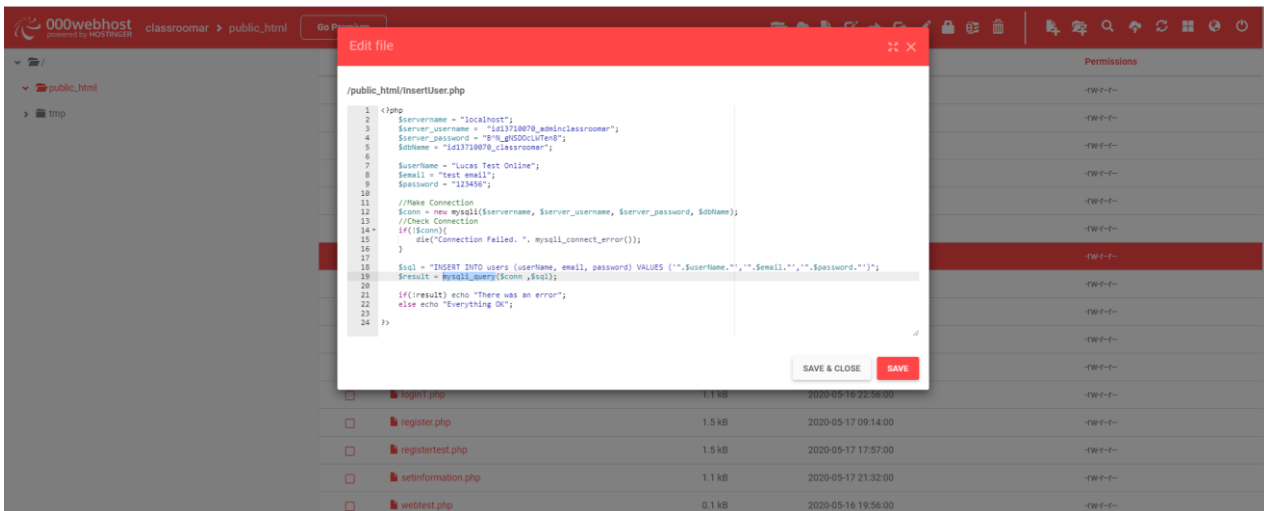
Figure 20: PHP client administration screen in 000webhost.com

Similar to how we initially worked with the database. MySQL is mainly managed from VirtualStudio. The PHP files are programmed with Atom and are subsequently uploaded to the server. During the evolution of programming, some files were reprogrammed on localhost before being tested on the remote server.

4.3 Hardware

For the programming and evaluation of this application, only one primary use of a device will be made: a laptop. Working with the Unity framework software, highly advanced features are not necessary. The recommended minimums are:

- OS: Windows 7 / 8 / 10.

- Computer processing unit: Core 2 Duo or superior.

- Memory: 1 GB RAM.

- Graphics: DirectX11 Compatible GPU with 512 MB Video RAM.

- Storage: 100 MB

- Sound card: DirectX compatible sound card
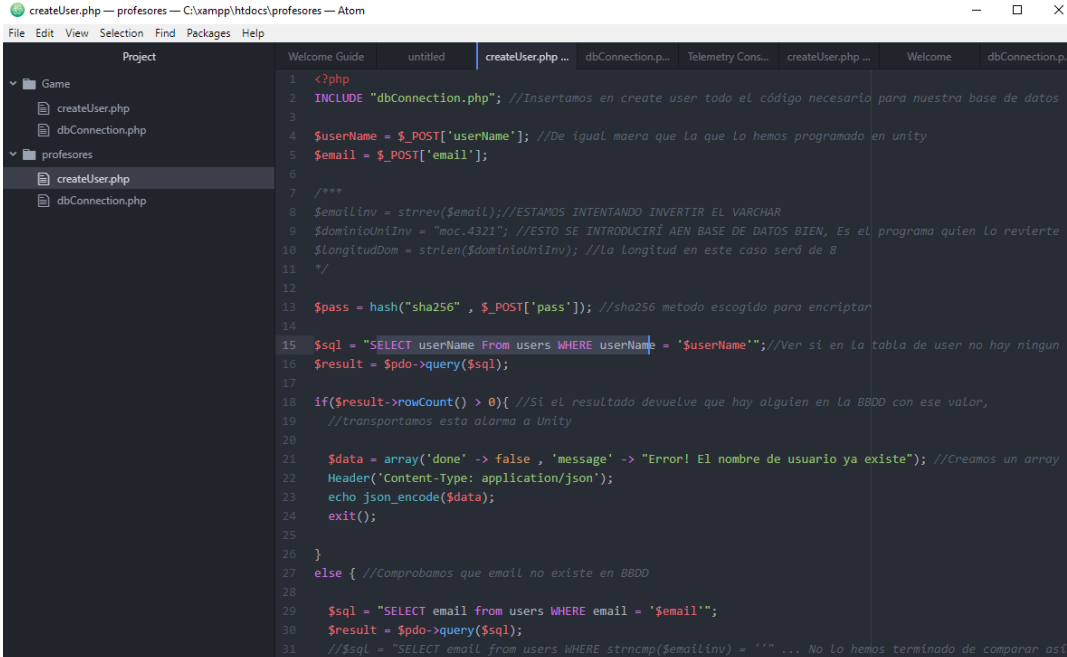
The hardware in this part is also used in the first instance to work as a localhost before exporting to the database, to a remote server that can be accessed from any other machine with the appropriate permissions. It should also be noted that at first tests were carried out with a smartphone but due to the little importance it attached to the implementation of this thesis, this type of device is not considered as the main hardware used. The smartphone operating system used was Android.

4.4 Software

For the most part, the Unity environment has been used for creating scenes, installing modules, and programming operation. The version of Unity that was used is 2018.4.17f. Unity currently has a newer version, which was released in early April 2020.

Second, the Microsoft Visual Studio 2019 tool for programming the scripts that determine how Unity scenes work. In addition to this tool, at certain times, some ".cs" files were opened in Notepad ++, a program that I have been more involved with in the past.

Then, for the administration of the database in MySQL, I used the Atom program. In this part of the thesis, I dedicated myself to the creation of client files programmed in the PHP language, which communicated with Unity obtaining and receiving the information from the tables. This is an open-source text editor that runs on all types of platforms, including Windows, the OS of the computer used in this work. Atom also supports implementation in conjunction with plugins written in Node.js. It also offers a tool that controls the built-in versions. This application is developed by GitHub [21]

Figure 21: Creation and selection of elements of a table in Atom.

4.5 Algorithms used

Various programming languages with different algorithms have been used in the ClassromAR application. For example, video playback and its completion when you are no longer focused on it. Other methods used are those that are entered directly from Unity Assets, creating animations on the characters. Establishing these types of algorithms was rather effortless.

```
    void ControllPlayer()
      {
            float moveHorizontal = Input.GetAxisRaw("Horizontal");
            float moveVertical = Input.GetAxisRaw("Vertical");

            Vector3 movement = new Vector3(moveHorizontal, 0.0f, moveVertical);

            if (movement != Vector3.zero)
            {
                    transform.rotation=Quaternion.Slerp(transform.rotation,
                    Quaternion.LookRotation(movement), 0.15f);
                    anim.SetInteger("Walk", 1);
            }
            else {
                    anim.SetInteger("Walk", 0);
            }

                    transform.Translate(movement  *  movementSpeed  *  Time.deltaTime,
                    Space.World);

            if (Input.GetButtonDown("Jump") && Time.time > canJump)
            {
                    rb.AddForce(0, jumpForce, 0);
                    canJump = Time.time + timeBeforeNextJump;
                    anim.SetTrigger("jump");
            }
      }
```

Figure 22: Example of animation script on object

In other words, animations are tested in the recording plane and, if its behavior is correct, it is assigned to the element to be animated. At this point, it is only necessary to adjust the action of the component with respect to the X, Y, and Z planes. Some other factors to consider are the recreation of gravity on the plane. After testing, a decision was made to eliminate this method that recreated a downward gravitational force. This was due to the fact that when testing with the laptop, the camera recorded tilted on the y-axis, unlike what a smartphone would do on the X-axis. The following is configured for the movement of some elements (animals 3D) in the virtual reality algorithm:

Second, another prominent type of algorithm that has been implemented is data-based selection. This type of algorithms worked together with PHP clients and Unity SC. The importance can be attributed to the way of inserting the information in the database.

First, to enter information into the database, the Unity fields are filled with information. From Unity, a URL is referenced where the PHP client is and performs its action returning a result for Unity. An example of data insertion is the part of the master record, where the user enters the information in the "name," "email" and "password" fields, and then, if the conditions are met, this user is inserted in the teacher's table.

4.6 Programming languages used

Mainly, two main programming languages have been used to create this application. One of them is PHP, which was used when working with clients that directly interacted with the MySQL database making selections, insertions, and connections on the tables.

Secondly, the C # language was used, which is the default for Unity and was used to establish a functioning in Unity. For the correct operation of the software created, the combination of these two languages is necessary.

The development environment where it has been programmed is in Atom and Notepad ++ for PHP clients and Virtual Studio 2019 for methods written in C #. In order for some simple settings to be made over the DDBB, it was also possible to work directly from its online interface, shown in Figure 20, on the "000webhost" website.

5. Last operations and checks

At the end of the application development, several tests were applied to the application. These assess the results obtained to create new future implementations. This section of the thesis will be divided into two crucial parts: precision and vulnerabilities. The "Classroom AR" application is presented in a reduced initial state, and it has been thanks to the progress on the app that I have noticed bugs that should be resolved. In the following paragraphs, I explain these observations about the software in more detail.
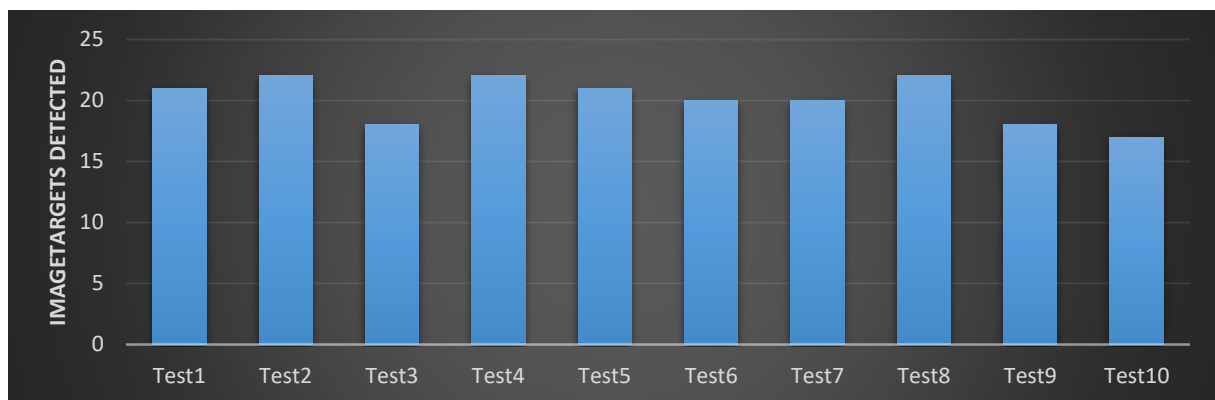
Illustration 6: Results obtained in the 10 tests observing the 22 ImageTargets

All the 3D elements were introduced with their corresponding animations and scripts, and I examined the precision with which my computer detected the ImageTargets and managed to reproduce them without any problem. In total, the application presents 22 different elements to show on the screen. The test was performed by passing the elements in a row without turning off the operation of the application or the camera. It was important to have the best lighting and to vary positions with all the elements. In other words, the item to be tracked was not static.
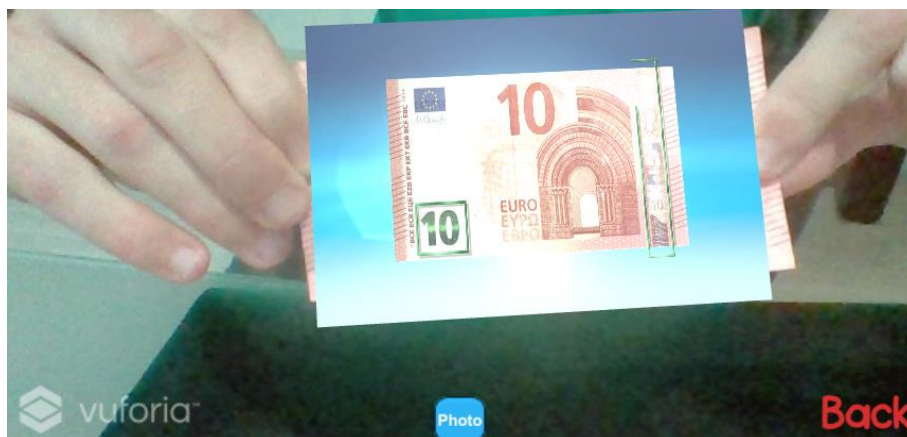

Figure 23: Image captured of the test stage.

In total, ten tests were carried out with elements where the application precision reached more than 80%. A vital notation is that with fewer components entered, such as ImageTargets, the application was more fluid. Despite this, the 22 images remain.

Observations on Vulnerability in the application

The ClassroomAR application is not designed on a theoretical framework of computer security, but as it is an application aimed at the educational field, it must be put in the context that surrounds education. In this section, I discuss application problems that involve vulnerabilities when operating with them.

First of all, the way to register as a teacher does not pass any filter. In other words, any user can register and proceed to add information. This problem would suppose that untrained users access the part where the insertion of new application content is administered.

Secondly, the encryption of the password is done manually with a $ hash and $salt, but today you can use new methods such as SHA or SHA1 in PHP. This is an option to consider in the face of future attacks by the application.

5.1 Future plans

Corrections

This software presents several points that can be improved in new updates. Mainly, all the vulnerability part should be taken into consideration when working safer and avoiding problems. It is vital that a barrier is created between the role of student and that of teacher, that a function of lower rank should not manage the upper parts. This could be achieved by inserting a new column called "University." Selecting this and also selecting the teacher's email domain, a first verification could be made as to how that email can be registered. In addition to this verification, a verification link should be sent to the email of the user who wishes to register. Once all these steps have been completed, the teacher is now able to administer the application.

New features

There are some considerations to keep in mind when implementing new updates. The first is the operation of the camera, along with the ability to take screenshots on all devices, not just the laptop or smartphones. Another related to this part is the introduction of an option that allows the user to save images in the gallery regardless of the device.

Second, a scene could be added for students to ask the teacher. In this way, not only would the teacher publish new content, but the student would also have an interaction with the tutors. This part would be similar to a chat or email.

Summary

In the first part of the dissertation, I describe the content surrounding augmented reality and the background that must be studied. I presented systems related to augmented virtual reality and reviewed the technologies available to work with these types of technologies.

The systems that facilitate the task of creating the application are then described. In addition, alternatives are studied and justifies the use of the tools that have been used during the implementation. At this point in the dissertation, I realized that augmented reality is a technology that is present in many contexts of society, for example, in education, but, at the same time, these technologies are not squeezed to the maximum.

In the second half of the dissertation, I describe the generalized system and the application-specific system. In this part, you can see the main elements involved in the development of the application process. The operation of the software is also detailed in a general way. The objective is to explain the operation of the application to a user interested in using this tool for school.

Then, some of the methods that have been implemented on both Unity and the MySQL database are exposed. These sections describe more technical aspects that deal in depth with the development and operation of the app.

To finish, I think that augmented reality has to open more space in education. Extends the framework of study for students, generating additional motivation when learning. Not only am I talking about an application with fundamental augmented reality, but they are used in more spaces such as chemistry, medicine, etc. Virtualizing elements in real contexts is an excellent way to practice actions that people couldn't do before.

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Table of figures