An Augmented Reality Application for Learning Anatomy

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Abstract. This work has been developed within the project of Applied Artificial Intelligence Group at UC3M, called "Augmented Science"[1], in order to disseminate and support education in science through Augmented Reality (AR) tools. The project is part of new developments provided with AR systems on mobile devices and their application in promoting science teaching. Generically, we understand that technology Augmented Reality as supplementing the perception and interaction with the real world and allows the user to be in a real environment augmented with additional information generated from a computerized device. In education the AR is an especially effective technology platform in everything related to how students perceive physical reality, since it allows break it down into its various dimensions, to facilitate the uptake of its various peculiarities, sometimes imperceptible to the senses. So with the AR is feasible to generate multidimensional models that simplify the complexity of the world, which, from the perspective of popularizing science, brings wholeness to any learning experience. In this context, we explore the suitability of the use of Artificial Intelligence techniques for the development of AR applications. As a use case, the development of an application for Android devices, which, through techniques of AR overlays a bony hand model is described. The application allows user interaction in order to discover the name of the bones of the hand. The article conducts an assessment of the application to analyze their educational impact.

1 Introduction

The term Augmented Reality (AR) has been given different meanings in specialized literature. We will focus on AR as a concept, whose definition can be more durable and useful tan defining AR as a technology. AR can be, therefore, defined from diverse perspectives,[1] Azuma defines AR "as a system that fulfills three basic features: a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects". [2] Klopfer and Squire

[1] http://cienciaaumentada.uc3m.es

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give a wider definition: "A situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information". AR is, in short, a "situation or technology that blends real and virtual information in a meaningful way".[3]

AR is an excellent tool to improve the educational process, allowing interaction in both the real and virtual world. AR is based on a set of techniques and tools that allow user interaction between these two worlds. Artificial Intelligence techniques found in the AR one of their challenges:

1. First, it is necessary to contextualize and recognize the real world on which the virtual information is projected. Thus, different pattern recognition techniques are used, which, from the available sensors recognize the real world.
2. Once recognized the real world, rendering techniques that improve the overlay the virtual to the real world are needed. Usually, these will be 3D models, but also can be any multimedia information.
3. Finally, it is intended that the user interaction involves a rich experience. In this case, it would be of interest to research in intelligent behaviors of virtual objects created and overlaid on the real world.

The possible applications of Artificial Intelligence techniques to AR are broad. In this work we will conduct a proof of concept of the implications of AI in AR. Above all we will see how recognition techniques are applied using Vuforia SDK [4] as well as the use of 3D models for representation using Unity3D [5]. All with the aim of developing a mobile application for learning the bones of the hand using AR techniques.

2 Related Work

2-D media in education, such as paper and blackboards, is "very convenient, familiar, flexible, portable and inexpensive"[6], and is the most used option in educational institutions worldwide. Nevertheless, those classical teaching methods don't allow dynamic content, and, mainly, don't give students the opportunity to be immersed and interact with real world situations. Although Virtual Reality can solve this problem, it can make students "become divorced from the real environment"[6]. AR, however, gives students the opportunity to be immersed into virtualised real world situations which are mixed with their real context. For instance, AR could be used to teach open heart surgery to medicine students, who could try to conduct the surgical procedure by themselves. This hypothetical AR application is just one example, but it illustrate the real potential of AR in education, which is giving students the opportunity to visualize and interact with real life situations which aren't usually accessible or feasible to interact with.

Iulian Radu made an extensive analysis on Augmented Reality in education in his paper *"Augmented reality in education: a meta-review and cross-media analysis"* [7]. He analyzed 26 publications that compared learning in AR versus non-AR applications. By doing so, he identified "benefits and negative impacts of AR experience learning and highlight factors that are potentially underlying these effects”. We will now offer a brief summary of his research.

Iulian Radu’s research found that ”A large propotion of the surveyed papers indicate that for certain topics, AR is more effective at teaching students than compared to other media such as books, videos, or PC desktop experiences”.[7]

AR can be, if used properly, beneficial in many ways within the educational experience. It can increase long-term memory, group collaboration, motivation and content understanding. However,it should not be used as a substitute of conventional education, but rather as a complement to it.

We’ve already stated that AR can be beneficial for teaching and learning. Nevertheless, there are many ways to utilize this technology, both in hardware and software aspects. Hardware-wise, there are three popular options: Head-Mounted Displays, Spatial Augmented Reality and Handheld Devices. Handheld devices, such as smart-phones and tablets, are, for many reasons, the best option for modest AR experiences that have the purpose of enhancing the educational experience. They are inexpensive, and they use a great amount of sensors, which are critical for a useful AR system. Those sensors, like GPS, accelerometers, gyroscopes, digital compasses and, last but not least, cameras, can be used to correctly identify what and where the user is doing at any given time. They also count with the ability to connect fluently with the internet, and have enough computing power. However, the main advantage that smart-phones and tablets have is their penetration in the market. [8] For instance, in Spain, the smart-phone penetration in the market, as of 2013, was about 80% population-wide, number that grows to 91% for people younger than 25. It is clear that a platform like smart-phones is much more powerful for this purpose than the others we mentioned.

Many attempts have been made in the mentioned platform,and thus there are many AR projects that focus on teaching and learning. For instance, Google created Sky Map, an AR application for both iOS and Android handheld devices; that uses GPS location, real time sky tracking, and user’s device’s sensors like the gyroscope and digital compasses to show in the device’s display a real-time projection of the night sky. This is just an example of astronomy teaching using AR. This technology is also used to teach and learn architecture, history, art, space exploration, chemistry, physics or even maths.

However, many of this, on the other hand, valuable applications, lack a real user-machine interaction, with which the student can feel immersed into the augmented world that is being projected. Artificial Intelligence (AI) developments can be used to correct these deficiencies. Techniques such as computer vision and real-time pattern recognition are helpful for enhancing the AR experiences, and advances have been made on the area. [9]

After an analysis of what is being done and what could be done, we discovered a lack of use of computer vision techniques on AR software made for educational purposes, and that this software (specially software for handheld devices) don’t offer the user a real immersion and the opportunity to interact more strongly with the augmented world. Our proposal, which we will deeply explain now, combines computer vision, 3-D CGIs, and real time user-machine interaction to give students a new opportunity in anatomy learning. We will propose a general scheme and infrastructure for AR applications for handheld devices, which uses AI techniques, and give an example of how this scheme can be used.

3 A Proposed Architecture for AR Applications in Education

Given the undoubted growth of mobile devices, along with the increasing availability of wireless internet connection, our work will be based on mobile devices (Smart-phone or Tablet). Theses devices support a large number of sensors, of whom the most important are accelerometers, GPS, camera and compass, that enable the device to recognize its surroundings. Our proposed architecture is divided into three principal layers. First, the Situation Assessment module, whose function is contextualizing and recognizing the real world. In this layer, the device must be able to recognize its surrounding environment. The second layer is intended to complement real-world objects through content generated by a computer, which is the "Augmented layer". Finally, the Interaction layer, which is responsible of keeping track of stimuli received from the user, and modifying the behavior of the augmented layer.

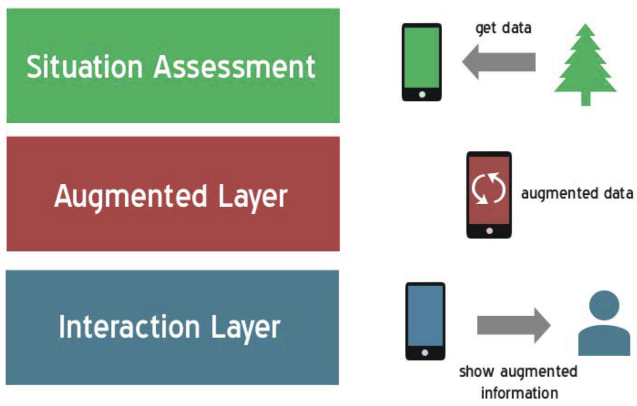

Fig. 1. Our architecture is divided in three principals layers

Situation Assessment. There are different ways to recognize where we are. In this case, we are interested in the use of the camera device, because our goal is to get an "imaged resource". A useful tool to do this work is OpenCV [10], a open source resource focused on real-time applications. Based on BSD license, it allows to use it with academic and commercial purpose. However, there is a problem with its efficiency, as it is not able to process a high mount of images in a powerless device like a mobile phone. Seeking efficiency, for our proposal we selected Vuforia SDK [4] as a system of recognition and object tracking for mobile devices.

Vuforia is a SDK developed by Qualcomm, whose focus is Augmented Reality technology for Android, iOS and Windows. This technology is able to recognize planar images and simple 3D objects, like cylinders and boxes, and use them as a "target", to get a point of reference. This point of reference allows the program to locate and know where it is. Vuforia tracks the target perspective, and takes it as the perspective of all the figures that the program will generate later, so if the user moves around the target, and takes another perspective, the application will show another view of the figures, like if there was an object over the target.

Vuforia offers some extra features, like an online target recognition, which allows to recognize any target in Vuforia's database, so the program is able to detect different targets and do something in function of the target that it has recognized. Figure 2 shows the possibility of representing different objects depending of the target. If the number of targets is small, their respective planar images could be stored in the device's local data store. Another useful feature are virtual buttons, which allow the program to detect if any part of the target has been covered, and to behave as in these parts there were a button. In the Figure 3 we can appreciate how an user can place his finger over the specified part, being detected by the program. This is used, for example, if it is needed a special animation when the user has to interact with the virtual object, or simply when you want to change the object. This can be specially useful when a real-time interaction with the user is needed.

Fig. 2. Possibility to track two different target by the same program

An advantage of using Vuforia is that you don't need to use a traditional marker, like a QR code. Vuforia allows to use any type of image, because it uses sophisticated algorithms to track the image and recognize it as a defined target. Vuforia has its own images rating, to evaluate how well a image could be tracked. It is recommended that a image has the best rating that it's possible, because

Fig. 3. Effect of pushing a virtual button

it will allow the device to detect the image easier, offering more efficiency and better user experience. Contrast is the other variable that we need to keep in mind. A high contrast image will have more features than a less contrast one. This also proves that a higher resolution image will be better, because the density of pixels indicates the precision of the image details. The features distribution influence too the target quality. A image whose features are only located in a small area of the image will have a bad rating. Accordingly, the features must be uniformly distributed around the image.

When the device has tracked the image, it has to render and transform the real world coordinates, to other coordinates that can be understood by the device using the equation $y = Tx$, where X are the coordinates of the real world, T are the algorithms needed to transform the real coordinates X, to a projection of them (Y)[2]. First of all, in order to test the target quality, Vuforia transforms the image to its gray scale representation. The image will get a bad rating if it doesn't have sufficient contrast and its histogram is narrow and spiky.

We know that in order to work with Vuforia it is necessary to have a target that is as well rated as possible, so the target needs a no repetitive pattern with high definition. Although this is not enough to have a real-time interaction with the user, there is where we need something to identify the user's hand, but the problem is that Vuforia technology is not able to detect complex objects like a hand. Here is where we could use virtual buttons, arranging the buttons like a hand shape, and when a user put his hand over the button's target, we are able to detect that this is the user's hand, and dispose the specified function. In this case, we want to show the hand's skeleton to the user. We will add instead constraints to detect if the object is a hand.

With this idea, the user only has to track the target, and put his hand over the target, "pushing" on all the virtual buttons. In this moment, the device will display the hand skeleton, with clickeable bones, that will let the user interact with the application and its augmented information of the hand skeleton.

Augmented Layer. When the device has recognized the hand, and has a reference point, our program has to transform this data to another which the device is able to use. First of all, the system needs to be secure that the object that is on the target is a hand. For solving that, we have created a series of constraints that lets the device to identify a hand form. Besides, we have to take care of the hand's size, because this program can be used by children and teachers, and thus we have established functions that are able to detect the user's hand size. The other data the device has got is the tracker, which informs us where the user's hand is in the space, allowing the device to know where exactly the skeleton hand will be represented. Besides, we have to take care to the user's movements, because we can't keep a static image in the same place if the user moves his hand. The program has to manage all of this constraints, transforming all of the data the device has tracked, on information that will be displayed to the user in the Interaction Layer.

In order to display the bones and the camera view concurrently, the device would need a high optimization of the functions that it use. This is the reason we preferred to use an automated optimization system to do this, Unity3D [5].

Unity is a game engine developed by Unity Technology focused in the design of video games for a lot of platforms. This environment is able to optimize the render of both constraints, allowing the application to show the hand bones properly to the user without lag. This platform allows programming with both Javascript and C#, and is totally compatible with android mobile devices.

Interaction Layer. A User Interface must be enjoyable and easy to use by the user, especially when our target market are children. This is the reason we have used colors to identify the different types of bones (red to distal phalanges, blue to intermediate phalanges, green to proximal phalanges, yellow to metacarpals and purple carpals). This allows the student to recognize and memorize easily the hand's bonds. If the user has any doubt, the application has a simple tutorial that appears at the beginning of the app, which can be skipped if the user is not interested in it. The interface has a interactive functionality that allows the user to click on each bone to get more information about them that the application shows by default. This functionality will let us to add an "game-mode" with the objective of memorizing the bones.

4 Evaluation

In order to assess whether this implementation is a useful tool to learn anatomy, we had to conduct a quantitative research. Based on the topic's literature, we based our test on Radu's work [7], and Di Serio's paper "Impact of an augmented reality system on students' motivation for a visual art course" [11]. They both propose some questions that can be useful to determine how successful an AR application for education has been. We will now list the questions we made, and detail afterwards the results our app had.

Q1 Have you had any previous contact with an augmented reality application? If so, please rate your experience from 1 to 5.

Q2 Have you had prior contact with an educational application? If so, please rate your experience from 1 to 5.

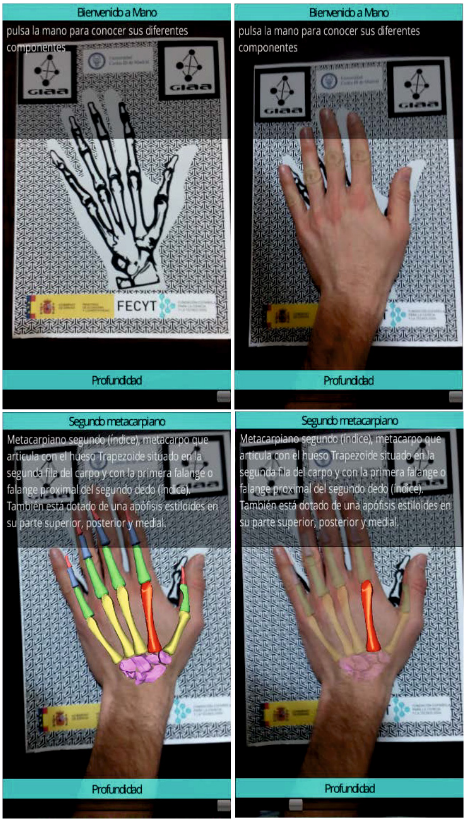

Fig. 4. Some screenshots of the application usage

Q3 Please rate the level of interaction with the user of the application "Hand's anatomy".
Q4 Please rate the difficulty level of use of the application "Hand's anatomy".
Q5 In general, are you satisfied with the application "Hand's anatomy"?
Q6 Do you think that "Hand's anatomy" is capable of doing learning anatomy easier?
Q7 Do you think that "Hand's anatomy" draws attention to the fundamentals of learning anatomy?
Q8 Please show your level of agreement / disagreement with the following statement: ""Hand's anatomy" allows the user to feel immersed in learning anatomy"
Q9 Please show your level of agreement / disagreement with the following statement: ""Hand's anatomy" allows the user to interact with spatially complex problems"

We gave smart-phones running the application to volunteers. They used it and interacted with the application for a few minutes, and then they answered the 9 questions we indicated before, and personal questions such as genre and age.

In this study, thirty-seven people aged 14-61 from different backgrounds were surveyed. They took the test just after testing the app, and answered the questions directly to the interviewer, who took note of their answers using Google Forms, which is a web-based application that allows conducting surveys. 17 out of 37 were males, 20 were females, and the average age was 24.

In Table 1, we sum up the results the survey showed, which we will comment later.

Table 1. The study results

Question	*Average*	*Standard deviation*
Q1	3.054	1.268
Q2	3.378	1.163
Q3	3.864	0.696
Q4	4.486	0.692
Q5	3.837	0.833
Q6	4.135	0.855
Q7	3.594	0.864
Q8	3.837	0.799
Q9	2.622	1.001

The table shows that the previous contact the respondents had with both AR and educational applications gave average results, with a lot of variability. However, when they were asked about our application, the results were much better, and with less deviation. Furthermore, the respondents agreed that our app is really easy to use and interaction was also well rated. In the educational aspect, respondents agreed that our implementation is useful for learning anatomy, and it makes the user feel immersed in the educational experience. Finally, our implementation was not as good as in the other areas in the "spacial complexity" area, probably due to the fact that this application doesn't focus on areas that can be spatially complex, such as geometry teaching.

5 Conclusions and Future Work

In this paper, we have demonstrated the ability of Augmented Reality techniques for use in learning. Moreover, we have seen the need to research on techniques and tools of Artificial Intelligence in order to improve the user experience in AR applications. The possibilities of AR, regarding the development of training materials and learning activities are multiple and heterogeneous in virtually all university disciplines primarily on scientific and technological disciplines.

Soaring performance of Smartphone and Tablet have turned these devices into useful tools for using AR technology. Through its new capabilities and its increasingly sensitive cameras, faster processors and complex functionalities allow to handle 3D graphics and incorporating sensors (accelerometers, compasses, gyroscopes, GPS, etc.) undoubtedly facilitate their adaptability to the requirements of AR systems. In the future will be required Artificial Intelligence techniques that use this set of sensors in order to improve the recognition of the environment of a user, and therefore create applications that enhance user experience. Society is changing, people are demanding more interaction, innovation and participation with content. And the AR in mobile environments meets all these requirements.

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