

Augmented Reality in Medical Education, an Empirical Study

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Abstract. Even though we live in a high tech world some of the learning techniques used in medical schools are outdated or are not taking advantage of the latest technologies available. This is partially due to the cost associated with adopting new and ever-changing technologies in emerging economies and lacking awareness of their existence. We created an application that has the potential to help students train themselves better by using Augmented Reality and gamification techniques. It detects the student's face through the laptop or phone camera and maps realistic skin conditions on the detected face, prompting the student to recognize them. With the overwhelmingly positive response from the surveys, the application should deepen student knowledge of pathologies.

Keywords: Augmented Reality · Medical · Education · Face detection · Gamification

1 Introduction

Medical education has been the subject of much research ever since its inception. Different technologies and techniques, for example simulation have appeared throughout the years. [5] Classical, physical simulation while becoming more sophisticated with advances in engineering and new materials, had an offshoot in the form of digital simulation. Virtual Reality and Augmented Reality becoming more sophisticated as 3D technology matured. On the teaching side technology takes an ever increasing role, for example in ontologies based eLearning [7]. In the last decade a new approach to education, namely gamification, has been gaining ground. The goal of gamification is to engage and motivate students to learn by using video game design elements in their learning environments [27].

Nowadays, both preclinical and clinical training have to grow well beyond the traditional approaches, with new ways of learning, new techniques and with the introduction of the media into the academic curriculum [18]. One of the new interactive ways to enhance normal environments or situations is Augmented Reality. Augmented Reality (AR) refers to a series of technologies that overlay CGI (Computer Generated Images), text and video on the real world. Ronald Azuma [1], defined the implementation of AR by three characteristics [33]:

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1. the combination of the real world and virtual elements
2. which are interactive in real time
3. which are registered in 3D

Augmented Reality (AR) is closer to the real world than its counterpart virtual reality, where both the generated objects as well as the world are computer generated. Even so Augmented Reality is still closely tied to Virtual Reality (VR) since the core concept of AR evolved as an extension or variation of VR. According to [33] AR represents the cutting edge of modern society's technological development. The information presented to the user in Augmented Reality is seamlessly added to their surroundings. The simulation can be either constructive (i.e. will build on the surrounding environment), or destructive (i.e. will mask the surrounding environment).

Since the price of most AR devices can be prohibitive for most medicine students, we were interested to know weather we can enhance their study with smartphones/laptops which they are likely to posses. Section 3 details how we merged AR with Gamification to enhance the study experience for medical students. The approach overlays the likeness of various pathologies (more in Sect. 3.2) on the face of anybody it is pointed towards (more in Sect. 3.1). The student then has various choices to identify the condition. In turn, they get to gain points and compete for high scores with their peers (Sect. 3.3). Not only do the students get more varied exposure to pathologies but it also incentivizes repetition through game mechanics. We conducted a small scale study with third-year medical students on a working prototype with positive results (Sect. 4). We conclude in Sect. 5 our hope that this new approach will promote self-learning and be more advantageous for both the students and the faculty, increasing the desire to learn.

2 Related Works

Virtual reality as a precursor to Augmented Reality has been and continues to be the subject of research in medical education [14]. Applications using VR have managed to increase learning outcomes for various medical specialties in different training procedures [3,24,25,29]. While the case for VR has been made an equal if not greater case for AR can also be made. AR's strength is combining a physical simulation in the form of mannequins or laparoscopy equipment for example, with virtual overlays to give better feedback and make the learning experience more immersive [2].

Literature reviews agree that a well-designed AR system has the potential for improving healthcare education [2,13,17,34]. The authors from [2] claim that there are relatively few AR apps in medicine, it is worth mentioning that ProMIS [4] seems over-represented in the literature. [34] found that 2/3 of papers focused on surgery, primarily laparoscopic surgery. Other uses include a navigation tool during surgery [6] or as a therapeutic tool for the patients [15].

Gamification is most commonly defined as the "use of game design elements in non-game contexts" [9]. Shorter attention spans among students, and ever

more potent distractions has prompted research into the gamification of learning, in an attempt to capture their engagement, and to inspire learning [[35]]. The concept is relatively recent and it has already been used to enhance graduate medical education. Kaizen-IM software developed by [20] have used daily questions and leaderboards to facilitate acquisition of new knowledge and engaged a large number of residents. In [19] authors used "Top Gun" and "Jeopardy" style contests to motivate thoracic surgery students to study more, which they did. There are a lot of interesting experiments with gamification in the literature, applied to many fields. For example [[36]] found 19 reports of gamified systems pertaining to health and well-being, with 59% positive and 41% mixed results. Physical health related behaviors were positive, while the cognitive behaviors were mixed.

On the intersection of AR and gamification [21] argues strongly for the potential use. [11] sees a huge possibility for AR and gamification, though clarifies that more study is warranted on gamification's side. In studies not related to learning, [26] proposes a AR and Gamification solutions to alleviate boredom for adolescent drivers. [12] and [26] mention gamification as applied in their AR game systems.

3 AR for Medical Education

3.1 Face Detection

The Human face is a very difficult object to detect since it comes in many forms and colors, is highly dynamic and a lot of times the features are not regular. In order for our idea to be practical we had to opt for a marker-less AR in the classical sense, and use the human face itself as a marker. Although a lot of algorithms exist in order to detect faces, a lot of them are too computationally expensive to work in real time [32]. The core of our application is the Open Computer Vision Library (OpenCV) together with the Unity3D cross-platform game engine[1]. We chose unity to be able to run it on both PC and Android so it can reach a wider audience. The classification algorithm used in this project for object and face detection is AdaBoost, with a machine learning approach proposed by Paul Viola and Michael Jones, based on Haar Feature cascade classifiers [30].

OpenCV is an open-source library computer vision, image processing, video processing, and object detection[2]. In order to use it inside Unity3D, we needed a third party plugin that lets you use OpenCV inside Unity3D by translating OpenCV into C# provided by Enox Software[3]. The AdaBoost Classifier cascades, are based on Haar-like features and not on pixels. A Haar-like feature is a weak classifier and will be used for face recognition [8]. The Viola-Jones face detection also uses an important concept of a rejection cascade. This allows the algorithm to be fast and to discard photos were no face is recognized with little

[1] https://unity.com/.
[2] https://opencv.org/.
[3] https://enoxsoftware.com/.

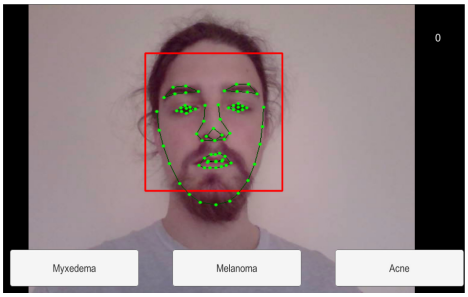

Fig. 1. Face tracking visualization

computational cost. It works by having layers of classifiers. The first test with a classifier in the cascade is designed to discard as many negative windows as possible, and if one of the features does not appear in the windows the whole process is stopped. Then a new window is tested and the process is repeated. After checking the last window, the scale of the window is increased and the detection process begins again. In the end, every face detected in the different windows, are merged and are considered as one at the closure of the process. Therefore, using weak classifiers we are capable to detect faces fast and with reasonable accuracy. An example of the real-time highlighted face features can bee seen in Fig. 1.

3.2 Considered Skin Diseases

For the study, we have chosen 3 types of diseases and skin conditions that have really specific characteristics: xanthelasma, herpes, malignant melanoma.

The xanthelasma is typically present in middle-aged and senior adults, most often around the eyelids. Xanthelasma is composed of xanthoma cells, which are foamy, lipid-laden histiocytes [23]. They are characterized by a macroscopic yellow hue. We chose this condition because it is usually found around the eyes and its yellowish color, which makes it instantly recognisable to medical students.

Malignant melanoma is a malignant tumor of melanocytes, which are the cells that make the pigment melanin and are derived from the neural crest. It mostly appears on the skin, but also rarely on mucosal surfaces. Melanoma represents a fraction (5%) of skin cancers but results in the highest mortality rate [16]. Some signs of melanoma are a darker or variable discoloration, itching, increase in size or development of satellites and later even ulceration or bleeding. It's easily identifiable by its color and can be found everywhere on the skin of a person, including the face. It also is the most dangerous type of skin cancer [28], therefore is extremely important to be recognised, so medical students should pay close attention to it. To mimic reality, pictures from various melanomas were used, two can be seen in Fig. 2.

Herpes simplex virus 1 is a member of the Herpesviridae family. It is known from ancient times and it frequently infects human beings [31]. Many of those

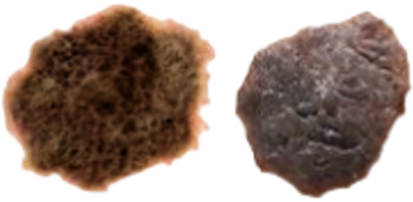

Fig. 2. Melanoma examples, used in the application.

infected do not have any visible signs or symptoms of the virus, but for some, the infection can even be life-threatening. Some of the symptoms of herpes include, but not limited to, itching, burning sensation, pain around the infected area, cold sores, blisters and redness in close proximity of the lesion point. Around 67% of the world population under 50 years old is infected with Herpes (HSV-1) [22]. In depicting the disease we focused on oral herpes, represented with redness, blisters, and cold sores. Being that common, a lot of people have seen herpes in real life, so it is easily discernible.

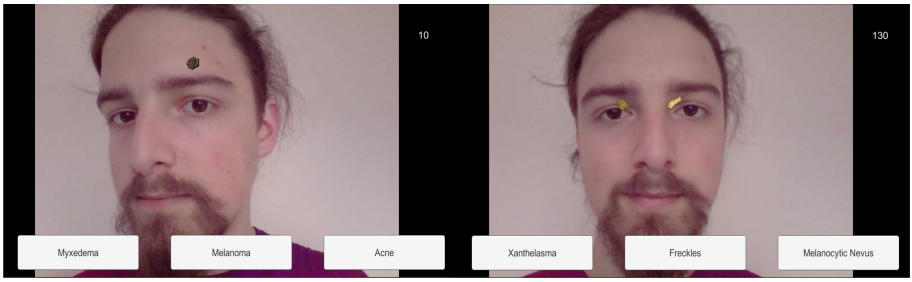

Fig. 3. Rendered Melanoma(left), and Xanthelasma(right)

Photos of the mentioned maladies as they appear in the application can be seen in Fig. 3. The original background was set to transparent in order to eliminate the clutter of the picture and to be accurate for any skin color of the subject. After every picture was cropped and adapted according to our needs, a normal map and a specular map of them was created, using ShaderMap4[4]. The normal map is a way to imitate the texture of an object (i.e. the indentation, coarseness, smoothness, the way it reflects light) by using shading. The specular map uses white and black values to create zones that have different reflectivity percentages. Meaning that some surfaces will appear shinier than the others. We can also increase the contrast of the surface to make it more recognisable in relation to its neighbours.

[4] https://shadermap.com/home/.

The 3D models of the diseases were made using the Unity in-game editor. We created a plane object and a material from an image of the skin condition. The material is a Specular Bump Transparent material. Transparent material implies that the transparent parts of the image will not show, leaving only the excrescence. The bump or normal material allows us to create variations in the way light bounces off the surface of the picture. It creates the illusion of 3d and improves low-polygon models making them appear more detailed.

3.3 Gamification Elements

The number of game design elements in gamification can be vast. For example [20] a number of elements: points, badges, levels, leaderboards and instant feedback. These in turn can be used to motivate participants towards desired outcomes. The aforementioned study reported that leaderboards were the most important motivator of participation amongst the residents.

When we designed our system we opted for an instant feedback approach for a positive feedback loop together with auditory feedback. Buttons were added to the bottom of the screen such that the player can choose what disease they believe is showing on the subject's face. If the player guesses correctly 10 points are added to his overall score. If he chose wrong 5 points will be subtracted from the final score. This together with a leaderboard is meant to foster competition amongst the students. Leaderboards serve as a social comparison tool.

As the primary gameplay loop a disease is mapped on the subject once the algorithm detects a face in the live video stream. The first disease is chosen randomly and stays until the user makes its choice. The diseases are randomised each round. The position of the melanoma and herpes changes so that the users can be better trained since in real life both afflictions could be found in various locations on human faces. For a stronger competition the leaderboard would need to be shared amongst the participants together with a timer. As well as some kind of progression mechanic, possibly in the form of leveling.

4 Discussion of Results

A study was conducted on third-year Medical Students with ages between 21–23. The sample size is low, only 9 participants. When our application is further developed the study should be redone on a larger sample, the overwhelmingly positive results are a strong indicator of the approach. The study consisted of explaining to the students the concept of the application and letting them use it for 5–10 min. While this was taking place we left the room. At the end of their trial usage, they were asked to complete a survey. All of them correctly recognised the diseases, validating that the diseases resemble their real-life counterpart/medical book description. Third-year medical students in Romania already had to study Semiology/Symptomatology, Anatomical Pathology and Physiology, all of which helped them with the identification task. It must be mentioned again that the

Table 1. Likert scale survey results

Concept of interest	Very negative	Negative	Neutral	Positive	Very positive
Visual accuracy compared to medical textbook	0%	0%	0%	66.67%	33.33%
Visual accurate compared to real life	0%	0%	0%	0%	100%
Perceived usefulness	0%	0%	0%	33.33%	66.67%
Willingness to compete with peers?	0%	0%	0%	66.67%	33.33%
Likeliness to recommend	0%	0%	0%	0%	100%

diseases were specifically chosen to be easily identifiable by people with medical training (Table 1).

Subsequently, some of them were interested if we could add more gamified elements to the application, like the concept of "combo", winning streaks or timers. The fact that our application is not static and you can examine the diseases from different angles made them curious because until then they were only exposed to pictures/descriptions of some of the pathologies, never seeing them in real life. This feature allowed the students to get a new point of view for the diseases.

Since all responses were purely positive, the demonstration of statistical significance is not warranted. The discrepancy between the first 2 questions, although the sample size is small, revealed that the medical textbook description and representation of disease differ with real-life diseases. Further studies are needed to verify the accuracy with medical professionals.

5 Conclusion and Further Work

The goal of this study was to review the usefulness of an application that combines Augmented Reality with gamification, in the context of a medical university. Even with the small sample size, the responses suggest potential in our approach. Students are willing and excited about using new technologies and they are ready to accept new learning methodologies like gamification in their day-to-day lives. Most of the students agreed that an application like this would be useful with their studies and that it presents an interesting complement to textbooks.

The study also shows that the models were realistic enough and that the students could quickly identify the signs of the disease and make an assumption based on their previous knowledge. Further work is needed to refine the techniques of simulation and broaden the symptoms. As stated in [10], gamification in education is an emerging trend. Even though early adopters of gamification

are Computer Science professors, we think that it is well designed and used correctly, it has the potential to improve the learning conditions of the students in the medical field.

The application can be further enhanced by moving away from multiple choice questions towards personalized testing and suggestion along the lines of Developing Ontology-Grounded Methodology and Applications [7]. The gamification aspect of the application could also be improved and tested with game mechanics other than points, progress bar, and leaderboard. Some students could benefit from specific or immediate goals, visible progression systems, and digital badges. This could be a follow-up study with significantly increased sample size, and a control group. On a technical level, detecting other parts of the body and to have more skin conditions and diseases added in would be important.

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