

An Augmented Reality Application for Computer Engineering Curriculum

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Abstract- Today, smart phones and tablet PCs have a huge application area due to their capabilities and ease of use. One of these application areas is education. Especially, supportive technologies have brought big innovations on teaching abstract concepts to the students. One of these technologies is Augmented Reality (AR) which moves graphic&animation usage one step towards. In this study, we shared our experiments on the usage of AR in computer engineering curriculum and presented the application that developed with using AR for supporting the abstract concepts of Discrete Mathematical Structures course.

Keywords- Augmented reality, e-learning, mobile applications

1. INTRODUCTION

AR is defined as enhancing Real World with artificial objects. For this purpose, AR uses some computer vision techniques such as image matching and image tracking. Simply, with using a camera, when an AR application faces with a “learned” image named as “target”, it overlaps an artificial object on the image. This seemingly simple job opens the way for the realization of many things. One of these things is the changing humans’ habit of interacting with objects in their environment. For example, you can listen to it beyond the reading a book or watch videos about visuals in the book. Or, you can virtually see the product information or user comments on the product’s packet in a supermarket. The usage of AR in education is an emerging area in The World. Here, we will mention about some essential studies on AR and Education, then present the works on supporting the abstract concepts of Discrete Mathematical Structures course with AR.

The remainder of the paper is organized as follows: In Section 2, the relevant studies are presented. Department of Computer Engineering curricula and AR suitability is argued in Section 3. Section 4 gives material and methods. Various important points to be considered are discussed in Section 5. Lastly, section 6 summarizes the paper.

2. RELATED STUDIES

Zagorasnki and Divjak have developed a tool that can be used as a virtual laboratory. [1]. Its results have shown that virtual tools could be useful in the lack of real

experimental equipment. Liarokapis et. al, have developed an application which provides interaction capability to users with 3D Web content using virtual and augmented reality [2]. In the study, real engine components are augmented with virtual 3D components. Freitas and Campos have developed an AR system called as SMART (System of augmented reality for teaching). They used 2D and 3D model of animals, automobiles and transportation to improve childrens’ motivations on the curriculum [3]. Yang Li has suggested a shared AR medium for distance learning [4]. This system overlaps the content that created by a computer on the related video and delivers the augmented video to all clients. Chen et. al. have developed a system that aims to improve students’ spatial awareness and learning motivations on engineering graphics [5]. Bazzaza et. al. have developed a magic book and an AR application [6]. The application aims to recognizing an image with using a mobile phone; searching the image on a remote database and bringing related content into the phone. Hence, it is possible that including desired contents at anytime. İbili and Şahin have developed AR software that enriches geometry chapter of 6. class mathematics book with 3D shapes [7]. For more information about AR usage in education, the studies [8-11] can be examined.

The main motivation of this study is to overcome the difficulties on teaching abstract concepts of Discrete Mathematics Course and overcome the difficulties on the understanding by students. Especially, teaching a dynamic concept with using static printed materials has some difficulties. Supporting the learning process with smart phones and a small application will increase students’ motivations as well as make easy to understanding.

3. CURRICULA OF DEPARTMENTS OF COMPUTER ENGINEERING

Although there are some differences between curricula of departments of computer engineering, compulsory courses are almost the same. These courses or course categories can be listed as follows: Discrete Mathematics, Algorithms, Programming Languages, Data Structures, Object Oriented Design, Web technologies, Digital Electronics, Computer Organization, Operating Systems, Computer Organization and Architecture, Database Systems, Software Engineering and so on. All of these courses contain abstract concepts. Also, some of these courses have laboratory practices. From this point of view we can say that AR applications can be used to enrich the contents of the courses listed above. Certainly, the evaluation of applicability of AR to each courses' topics can be considered as another study. In this study we concentrated on Discrete Mathematics, one of the basic courses on computer engineering. Discrete Mathematics covers the following topics: logic and proof, sets, functions, sequences, sums, matrices, algorithms, number theory, counting, relations, probability, graphs, trees, Boolean algebra. Discrete mathematics can be used in computer engineering on following topics [12]: algorithms, data structure, programming languages, compilers and interpreters, computer networks, operating systems, computer architecture, database systems, cryptography, graphics and animation, artificial intelligence. The above list covers almost all of the areas in computer science. Based on this information, it would not be wrong to say that the most important basic course for computer science is Discrete Mathematics. In this study, we concentrated on a subset of these topics which includes sets, functions, sequences, matrices, graphs and trees.

4. MATERIAL AND METHOD

The study is divided into 2 stages. The first stage consists of deciding the course materials which will be enhanced with using 3D models and modeling of these materials. The second stage consists of development of the application with using 3D materials and an AR Software Development Kit (SDK). Firstly, we selected examples from Discrete Mathematics and its Applications book [12]. We paid special attention on selecting examples. The selected examples are more abstract and harder to understand. We make the decisions based on the results of the exams in previous years. We detected the success rates of students by subject and we gave priority to the issues that students are less successful. Some of the selected examples are shown in Fig. 1. After that, we took the photos of the selected examples from the book with using a standard smartphone camera in a classroom for different light levels. A problem that may be encountered in this phase is that, how appropriate a photo to be a target? To find out an answer for this question, we should know that which features make an image a good target. These

features are sharp edges and corners. So, we should to calculate the numbers of sharp edges and corners on an image. This process requires a little bit image processing knowledge. Sharp edges and corners can be easily detected with using an image feature (keypoint) detector like ORB (Oriented FAST and Rotated BRIEF). For this purpose, we developed a test script with using Opencv Open Computer Vision Library and Python. The obtained 486 keypoints from Fig. 1b are shown in Fig. 1c. According to our experience we can say that a photo that has more than 300 keypoints can be a good target. The results of the experiment for different photos with different keypoint number are given in Table 1. 5 photos with 100-200 keypoints, 5 photos with 250-350 keypoints and 5 photos with 400-500 keypoints have been used for experiments.

Table 1. Image Recognition Experiments

	100-200 Keypoints	250-350 Keypoints	400-500 Keypoints
Recognition Rate (%)	68	92	100

```
import numpy as np
import cv2
import matplotlib.pyplot as plt
img1 = cv2.imread('mdg.jpg',0)
orb = cv2.ORB_create()
kp1,d1=orb.detectAndCompute(img1,None)
print "Number of Keypoints: ",len(kp1)
img2= cv2.drawKeypoints(img1,kp1,None)
plt.imshow(img2),plt.show()
```

The recognition rates are given in Table 1 for different conditions (in class, outdoor and different light levels). We can say that more keypoint provides a higher recognition rate. Additionally, the usage of images which contain very large number of keypoints may not be correct. In this case, the recognition time will be adversely affected and the performance of the application will be decreased.

Note that, the number of keypoints can vary from a feature detector algorithm to another one, from a photo to another. Another way to identify that how good is a photo can be target is (with a more strenuous approach) to do trial and error. After that, we animated the examples. For this purpose, we used Blender 3D modeling tool to animate the materials [13]. This tool is easy to use and can be used free of charge.

In the second phase, we used Unity game engine [14] and Qualcomm Vuforia AR SDK to develop the application. Unity is preferred because of ease of use and multiplatform support (IOS, Android, Windows Mobile etc.). There are more than 40 AR SDK in the market.

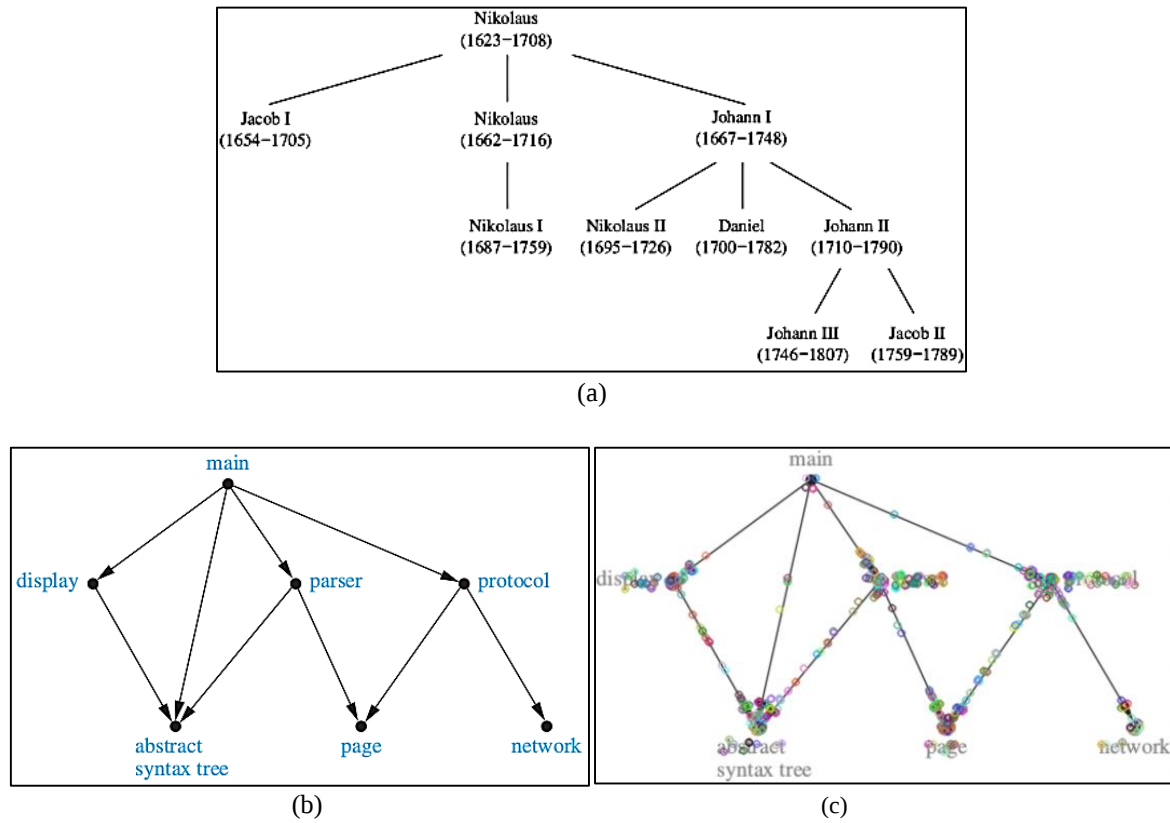


Figure 1. Examples: (a) Bernoulli family tree (b) Module dependency graph [12]

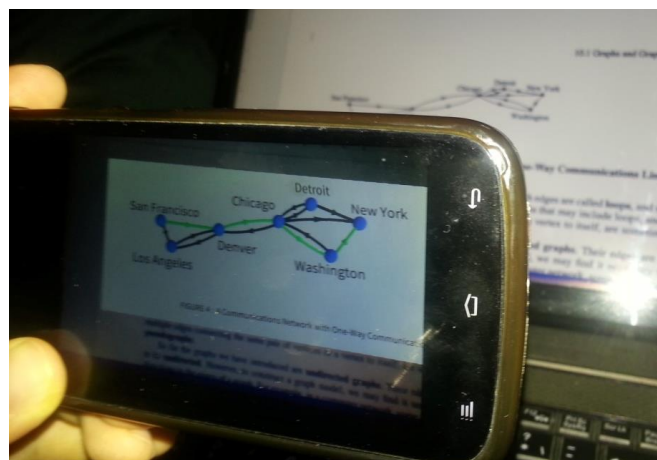
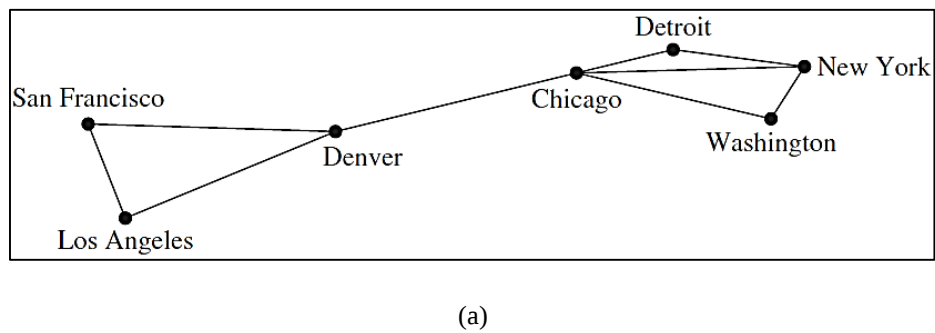


Figure 2. Application: (a) Communication network graph [12] (b) Developed application

Although, there are advantages and disadvantages of each SDKs, we preferred to use Vuforia SDK by considering technical support, reliability and compatibility with wearable devices. In addition, it is possible to develop AR applications with using Unity and Vuforia by writing very little code. The explanation of the usage of Unity and Vuforia SDK is beyond the scope of this study.

A communication graph and its animation are shown In Fig. 2.

5. DISCUSSION

There are some important technical issues in an AR application. These are response time of the application, scalability, cost, applicability and compatibility with wearable devices.

5.1. Response time of the application

The response time of the developed application (time duration between recognition of the image and displaying animation on the screen) is about 80ms. We measured this time with using a timer that is placed at the beginning of recognition codes and at the end of displaying codes. At this point we should say that this time may vary from one application to another. In this study we used a small amount of images as targets which two of them are shown in Fig. 1 and Fig 2. (exactly 17 images). Other applications may require a higher number of image targets. Hence, the time that searching for correct image may increase. On the other hand, some other applications may require huge number of image targets. In this situation, it will be more useful to store image targets on a remote server. In this case the communication delay is added too. As a result, the recognition delay will increase further. Although there is no specification on delay of image recognition in AR applications, we know that acceptable delay is less than 150 ms in real-time applications such as Voice over IP (VoIP) [16]. So, we assume that this value is the upper limit of human perception of delay.

5.2. Scalability and Cost

The size of the developed application is around 100 MB. Each course has its own characteristics, but the size of an application that will be developed to cover all the topics and examples in a textbook can easily reach to a few GBs. If we develop an application for all courses in a department, the application size will reach to enormous levels. Such an application would not be practical for students' usage on their phones. Additionally, maintenance and updating will be a great problem. In large scale implementations, storing course contents on a server and reaching these contents on demand is a better approach than adding all content into one application. This approach has some drawbacks too. One of them is the mobile phone must have an internet connection. Beside, AR SDK producers apply different licensing

policy. For standalone application development it is enough to pay licensing fee one time. However, for cloud approach, the developer has to store the targets and the content on the producer's servers and has to pay per image recognition. It means, we have to pay license fee over the lifetime of the software. So, the development cost reaches to huge prices for a large scale application.

5.3. Applicability

It is a bit hard to support some topics with 3D models. For example, 4 and more dimensional matrices cannot be modeled. To enrich these types of topics, other types of materials should be used instead of 3D illustrations.

5.4. Compatibility with wearable devices.

Smart glasses have popularized in the last few years. It is possible to find smart glasses at reasonable prices in the market. Especially in applications that require the use of hands such as laboratory applications in education, the usage of smart glasses is unavoidable. Therefore, the compatibility of the developed AR applications with smart glasses is a major issue. Although, today the majority of smart glasses are powered by Android operating system, each smart glass has its own characteristics. Therefore, compatibility of the developed applications for smart phones with smart glasses should be considered. For this purpose, it should be avoided the usage of unnecessary features of devices. We tested the developed application on Epson Moverio BT-200 smart glass and the results show that it is fully compatible.

6. CONCLUSION

Considering smart phone usage rate among the young people, it will be useful to support their learning activities. In this study, we only concentrated on technical issues of AR applications in education. Another phase of the study must be the measurement of the application's benefits on educational processes. In this context, the experimental and control groups of students should be determined; survey and exam questions should be prepared and the application should be tested during one semester.

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