Architectural Model For An Augmented Reality Based Mobile Learning Application

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Abstract— The work developed an augmented reality (AR) based mobile learning application for students. It implemented, tested and evaluated the developed AR based mobile learning application. This is with the view to providing an improved and enhanced learning experience for students.

The augmented reality system uses the marker-based technique for the registration of virtual contents. The image tracking is based on scanning by the inbuilt camera of the mobile device; while the corresponding virtual augmented information is displayed on its screen. The recognition of scanned images was based on the Vuforia Cloud Target Recognition System (VCTRS). The developed mobile application was modeled using the Object Oriented modeling techniques. The developed model was implemented using java programming language on an android platform.

The results of the evaluation showed that; on a scale of 1 – 10, the system has a mean score of 6.2500 for its ease of use. It learnability was scored at a mean value of 7.0000 and it effectiveness scored at a mean value of 5.7500.

The work concluded that augmented reality based method provides an effective and enhanced learning experience for students.

Keywords—*augmented reality; mobile learning; android; mobile applications*

I. INTRODUCTION

The new generations of students are technology savvy with high knowledge of and interest in social media, mobile technologies, and strategy games [1]. Among several classes of digital technology, Pan et al. discussed that using Virtual Reality (VR) learning applications may result in an efficient and effective learning [2]. More recently, a growing number of schools and educational institutions have shown interest in adopting such technologies in order to create a productive educational environment [3].

This paper presents an architectural model and test implementation of a mobile application that uses augmented reality technology to create a more effective learning method using an android device to enhance learning experience of students. This work developed a system that uses Augmented Reality technology to create a more effective learning method that enhances the learning experience among students. It presents a model to utilize an Android based smart phone camera to scan 2D templates and overlay the information in real time. The model was implemented and its performance evaluated with respect to its ease of use, learnability and effectiveness.

II. LITERATURE REVIEW

Augmented reality, commonly referred to as AR has garnered significant attention in recent years. This terminology has been used to describe the technology behind the expansion or intensification of the real world. To "augment reality" is to "intensify" or "expand" reality itself [4]. Specifically, AR is the ability to superimpose digital media on the real world through the screen of a device such as a personal computer or a smart phone, to create and show users a world full of information which has not been possible to conceptualize until now [5].

In addition, Milgram and Kishino [6] defined Milgram's Reality-Virtuality Continuum as shown in Fig 1. They describe a continuum that spans from the real environment to a pure virtual environment and in-between there are Augmented Reality (closer to the real environment) and Augmented Virtuality (is closer to the virtual environment).
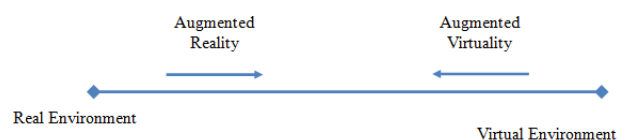

Fig. 1. Reality-Virtuality Continuum [2]

Table 1 is a short chronology of Augmented Reality, from 1962 when a cinematographer called Morton L. Heilig designed a Sensorama, to 1968 when Sutherland [7] developed an AR system called "The Sword of Damocles" that used optical see-through head-mounted display that is tracked by one of two different 6 Degrees of Freedom (DOF) trackers. Further development took place in 1980, when Steve Mann came up with more ideas about wearable devices by putting a camera in front of his eye to capture real time image and overlay it with virtual ones, also known as EyeTap. In 1990, Tom Caudell [8], a Boeing researcher coined the term Augmented Reality to refer to overlaying computer-presented material on top of the real world, Möhring et al demonstrated for the first time that AR can be supported on mobile devices. The work used 3-dimensional markers to track real world objects with simple computer vision methods [9].

Augmented Reality technology involves a combination of hardware and algorithm components. AR includes a display component for sending real-time feedback to the user, a tracking system for registering and monitoring the position of real world objects in the system. It also optionally involves an input system for interactivity and computational algorithms to process the registered objects and determine their relative position to the user [10].

TABLE I. A SHORT AUGMENTED REALITY CHRONOLOGY

Year (Range)	Comments
1962	Heilig designed a Sensorama
1968	Ivan Sutherland developed The Sword of Damocles [7]
1980	Steve Mann creates the first wearable computer EyeTap
1990	Tom Caudell coined the term Augmented Reality [8]
2004	Möhring *et al.*first present AR on Mobile Devices [9]

III. RELATED WORKS

Multimedia Augmented Reality Interface for E-learning (MARIE). MARIE is a user-friendly interface to experimentally explore the potential of augmented reality by superimposing Virtual Multimedia Content (VMC) information in an Augmented Reality (AR) tabletop environment, such as a student desk workspace. In MARIE, the user can interact with the VMC, which is composed of three-dimensional objects, images, animations, text (ASCII or three-dimensional) and sound. It uses 2-D markers that have been created by the teachers and this approach was employed in this work [11].

Imaginality is designed to enhance students' understanding of spatial, temporal and contextual information in an intuitive and engaging way that is both fun and easy to use. It supports prescriptive, self-paced learning for visual, audible and kinesthetic learners. It also offers unique forms of interaction with virtual objects that are not possible in any other style of learning. It uses 2D markers called paddles that are created by the teachers using an interface.

It is necessary to note that, this represents one of the most advanced use of Augmented Reality technology in Learning in literature, hence, can be described as state-of-the-art. The only drawback to Imaginality is that it requires a PC and webcam, it does not make use of mobile devices. Head Mounted Display (HMD) are expensive and might not be afforded by the average student and at the time of doing this work the amount of computing power was limited hence, there was a limit to the type of information that could be overlay to the student.

IV. DESIGN ARCHITECTURE

The system uses the client-server architecture, where the mobile application communicates with the Vuforia Cloud Target Recognition System (VCTRS). Scanned AR Markers are sent to the VCTRS as requests and the corresponding metadata is returned as response. Fig. 2 shows the relationship between all the system modules.

The mobile application was implemented as an Android application using Java as the primary programming language. This component is responsible for controlling the viewfinder of the camera for scanning Quick Response (QR) codes and Augmented Reality (AR) Markers, recognition of QR codes, giving the appropriate interpretation, sending requests based on the scanned AR markers, sending those requests to the VCTRS for recognition to obtain metadata and displaying the interpreted information from the metadata as augmented information on the phone's display. The Vuforia Cloud Target Recognition System (VCTRS) is an enterprise class image recognition solution that enables developers to host and manage image targets online. It acts as a recognition system that compares requests from the mobile application with the targets saved in the cloud database to find a match, once a match is found, the appropriate metadata bound to the target is returned as response to the client.
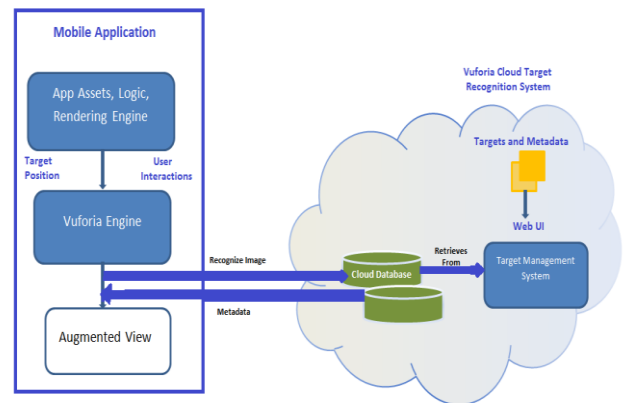

Fig. 2. System Architecture

Targets are uploaded to the cloud database using the target management system provided by the Vuforia at https://developer.vuforia.com/targetmanager.

V. MODEL DESIGN

The design of this system was done using object-oriented modeling. The guidelines that were used for the development of the system are discussed in the following sub-sections:

A. Use Case Diagram

The use-case diagram in Fig. 3 showed the various user activities that can be performed in the system. These use cases are described as follows:

1) Scan QR Code: This is the first interaction of the user on the system. This user case is called when the user wants to scan the QR code on the front of the AR popup book.
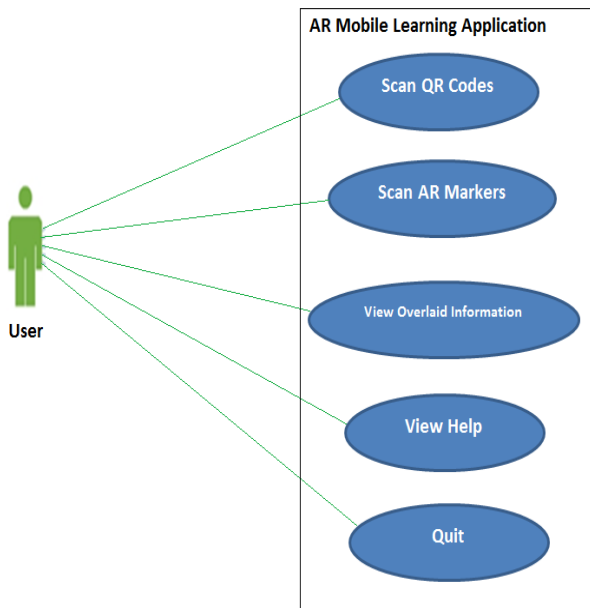
Fig. 3. Use Case Diagram

2) Scan AR Markers: This interaction is called when the users wants to scan the various AR markers in the AR popup book after successfully scanning the QR code of the AR popup book.

3) View Overlaid Information: This interaction is called when the user wants to view information overlaid after successfully scanning the AR markers.

4) View Help: This interaction is called when the user wants to view help information. It is a simple call that terminates after the information is displayed.

5) Quit: This interaction is the link to the application endpoint. All calls to this use case represent a request to terminate the application.

B. Sequence Diagram

Fig. 4 showed a high-level sequence diagram showing the messaging between different components of the system. The components of this system are the AR MobileApp, QR Code Scanner, AR Controller, the Android Camera and the Vuforia Target Recognition Service (VTRS). Scanning QR codes and AR Markers requires the QR Code Scanner and AR Controller respectively to get the camera image from the camera of the Android device. The AR MobileApp gets the information to overlay in real time via the AR Controller from the VTRS.

C. Activity Diagram

Fig. 5 described the flow of activities that a user can accomplish when using the system. The user first scans the QR code for the AR pop-up book, and on success of this operation, he then scans the various AR markers inside the pages of the AR pop-up book.

On scanning AR markers, the mobile application connects to the VCTRS to obtain metadata that is interpreted and overlaid on the screen to the user.
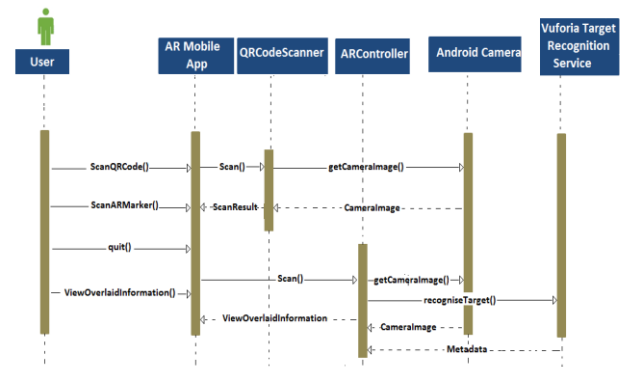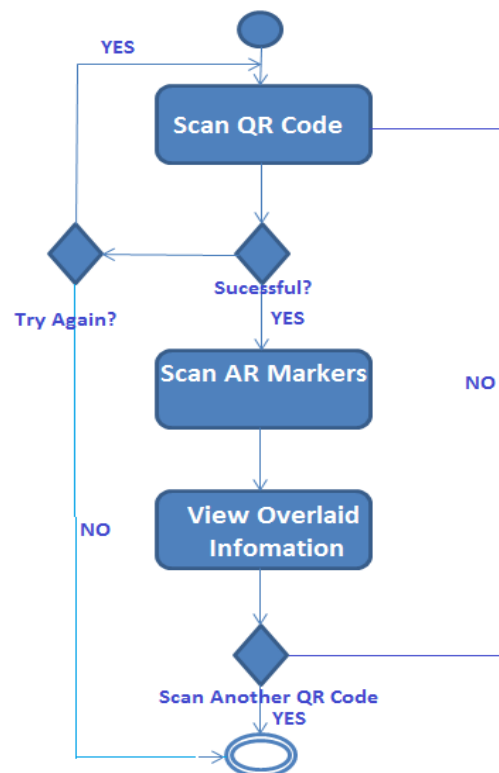

Fig. 4. Sequence Diagram

Fig. 5. Activity Diagram

VI. IMPLEMENTATION AND RESULTS

The augmented reality mobile learning application comprises of five components that are integrated to achieve its aim. They are AR pop-up book, Quick Response (QR) code scanning module, Augmented Reality (AR) marker scanning module, cloud target recognition service and information overlay module.

1) AR Popup Book: For the application to be used, an AR pop-up book is required to be scanned, the AR Pop-up books created for the purpose of this work were created using Microsoft Word 2013, the QR codes on the first page of the books were created using the website at http://www.qrstuff.com/ and the information encoded in the QR codes are JavaScript Object Notation (JSON) objects. An example of the JSON object encoded is shown below, and the corresponding QR code is shown in Fig. 6. Fig. 7 shows the first page of a printed AR pop-up book.

```
{
"n" : "Computer Programming (CSC201)",
"k" : "1223c43223aae43431201201",
"s" : "1289121ad31212f121212c122",
"y" : 2015,
"a" : "Adegoke Obasa"
}
```
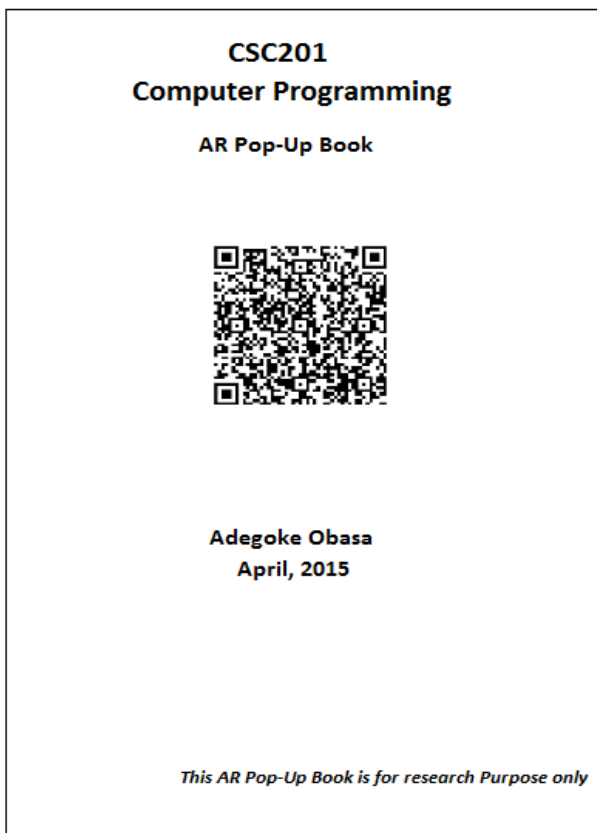

Fig. 6. A Sample QR code

Fig. 7. First page of AR pop-up book

Subsequent pages contain AR markers on them, this serve as image targets that can be scanned and used to overlay the corresponding digital information.

2) QR Code Scanning Module: The QR code scanning module is that part of the application that scans and interprets QR codes. Scanning of the QR code via the camera of the mobile device as well as interpretation of the QR code was implemented using the ZXScan QR code scanner library. The QR code scanning takes place in real-time and does not require the user to take a snapshot of the QR code, once the QR code scanning is successful, the interpreted data is returned and this could be used for further processing. This module requires the camera permission to be able to access the device camera; hence it was added to the AndroidManifest.xml file. The code snippet is shown below.
<uses-permission android:name="android.permission.CAMERA" />.
In addition to the camera permission, since the application does not require all camera features (auto-focus and flash), the android.hardware.camera features were declared in the AndroidManifest.xml file. This was done because applications that requests the camera permission but does not declare any camera features with the <uses-feature> element will be assumed to use all camera features. Thus, the application will not be compatible with devices that do not support all camera features.
This module is implemented in the MainFragment.java file and the method to start the scanner view is the startEmbeddedScanner method, while the method to stop the scanner view is the stopEmbeddedScanner.

3) AR Marker Scanning Module: The AR marker scanning module is the part of the application that uses the camera of the mobile device to capture images in real time and pass the images as input into the cloud target recognition service. It was implemented using the Vuforia AR library. Scanning is done in real-time and as the camera scans, images are sent to the cloud recognition service. Fig. 8 shows a screenshot of the application during the AR marker scanning process. This module requires the camera permission to be able to access the device camera, but this had already been added while implementing the QR code scanning module.
The module was implemented in the method enterScanningMode in the BookActivity class, it also starts the cloud recognition service so that AR markers can be recognized in real-time.

```
private void enterScanningMode()
  {
    // Hides the 2D Overlay
            hide2DOverlay();

  // Enables Cloud Recognition Scanning Mode
            TrackerManager trackerManager =
TrackerManager.getInstance();
            ObjectTracker objectTracker =
(ObjectTracker) trackerManager

.getTracker(ObjectTracker.getClassType());
```

```
        TargetFinder targetFinder =
objectTracker.getTargetFinder();

    // Start Cloud Recognition

    targetFinder.startRecognition();
    // Clear all trackables created previously:

    targetFinder.clearTrackables();

    mRenderer.setScanningMode(true);
        // Updates state variables

mRenderer.showAnimation3Dto2D(false);

mRenderer.isShowing2DOverlay(false);

mRenderer.setRenderState(BooksRenderer.RS_SCA
NNING);
 }
```
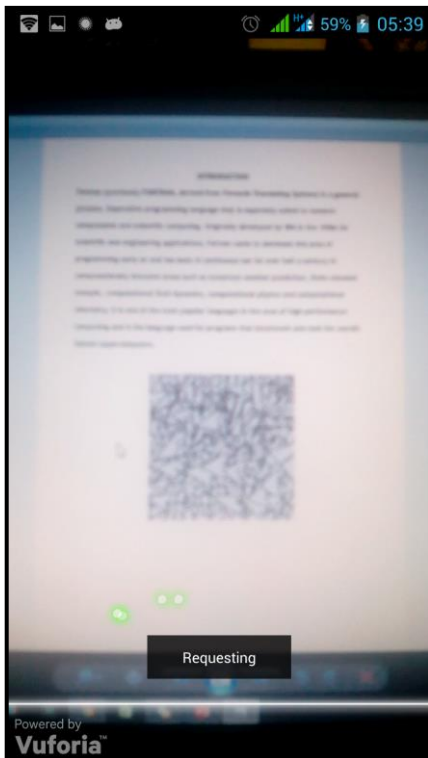

Fig. 8.   AR marker scanning

4) Cloud Target Recognition Service: The cloud target recognition service was used to map real world objects; that is AR markers to digital objects metadata by sending scanned AR markers in real-time to the Vuforia Cloud Target Recognition System (VCTRS) over the Hypertext Transfer Protocol (HTTP) connection. The VCTRS immediately compares the images sent with the image targets already existing in the cloud database, if there is a match, the VCTRS responds with the corresponding metadata of the matched target, if there is no match an appropriate error message is sent as response.

The cloud target recognition service requires an active internet connection to work; hence it's necessary to check the network state of the mobile phone before attempting to send requests to the VCTRS, to be able to check the network state the ACCESS_NETWORK_STATE permission was added to the AndroidManifest.xml file. The code snippet is shown below.

```
<uses-permission
android:name="android.permission.ACCESS_NETW
ORK_STATE" />
```

After the network state must have been checked and it is ascertained that there is an active internet connection, for the service to open network sockets either via mobile data or Wi-Fi, it's necessary that the internet permission is set. The code snippet shown below was added to the AndroidManifest.xml file to give the application the internet permission.

```
<uses-permission
android:name="android.permission.INTERNET" />
```

5) Information Overlay: The metadata returned by the VTRS is encoded in JavaScript Object Notation (JSON). A sample of the JSON object received is shown below.

```
{
"name": "Official Python Website",
"link": "https://www.python.org",
"description": "Click to learn more about Python",
"image":
"https://krishnannakul.files.wordpress.com/2011/07
/screenshot1.png"
}
```

The JSON object has four attributes; name, link (a Uniform Resource Locator (URL)), description and image (a Uniform Resource Locator that points to an image).

In order to interpret the response metadata, it was parsed from a JSON object into a Java object (instance of class Page). The method fromJson in the Page class is used to parse the metadata string into a Java object.

The information was retrieved from the object using the getter methods getName, getLink, getDescription and getImageLink, and finally a 3D texture overlay was created on top of the marker and made visible to the user using the method createPageTexture in the Book Activity class. The 3D texture overlay is able to scale as the user moves closer and farther from the AR markers. Fig. 9 shows a screenshot of the application with overlaid information after a successful scan of an AR marker.

6) Results: The evaluation of the system was done by installing the Augmented Reality Mobile Learning Application (ARML App) on a Tecno A+ mobile device and the device was given to four different students from each of the concerned disciplines within the scope of this work; that is Science, Technology, Engineering and Mathematics for them to evaluate the application.

They were allowed to use the ARML App after which they were interviewed and asked to evaluate

the system usability based on the following criteria: Ease of Use; This refers to how easy it is to use the application, Learnability; This refers to how fast it was for the user to adapt to the application., Effectiveness; This refers to the level to which the application enhanced the learning experience of the user. Table 2 shows the results of the evaluation done by students of Science, Technology, Engineering and Mathematics; all metrics are on a scale of 1 - 10. The science student gave the application a 5 on ease of use, a 7 on learnability and 5 on effectiveness; the Technology student scored the application a 6 on ease of use, 9 on learnability and 7 on effectiveness; the Engineering student scored the application 7 on ease of use, 6 on learnability and 7 on effectiveness; the Mathematics student scored the application 7 on ease of use, 6 on learnability and 4 on effectiveness.

TABLE II.   EVALUATION RESULTS FROM STUDENTS

Category	Ease of use	Learnability	Effectiveness
Science	5	7	5
Technology	6	9	7
Engineering	7	6	7
Mathematics	7	6	4
	6.25	7.00	5.75

The mean scores were computed for each criteria and the results show that the mean scores for ease of use, learnability and effectiveness are all above average (6.25, 7.00, and 5.75 respectively), this implies that the application has been able to enhance the learning experience of students.

CONCLUSION

The paper presented an Augmented Reality (AR) based mobile learning application. The augmented reality technology employed uses the marker-based technique and the Vuforia Cloud Target Recognition System (VCTRS). The application employed the use of the object oriented modeling techniques.

The result of the application performance evaluation showed that augmented reality based method enhances the effectiveness of learning in education. Further work intends to implement an offline target recognition sub-system for the recognition of scanned images.

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