

Design and Development of Augmented Reality Applications in Computer Network Topology Animation

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Abstract— Technology can be applied in developing teaching materials so that students can explore material outside the classroom. One relevant technology is Augmented Reality (AR), which allows the appearance of three-dimensional objects in the real world. The implementation can be applied to important subjects in the field of information and communication technology, namely computer network. However, this course faces several obstacles in implementing the teaching and learning process, including expensive equipment costs and expensive maintenance requirements. Apart from that, the teaching methods currently used still tend to be monotonous. Considering these factors, the aim of this research is to incorporate Augmented Reality technology into the teaching of a computer networking course. An Augmented Reality application has been developed and tested using the black box method. This approach has the advantage of assessing software quality, ensuring that the software meets the desired expectations. Test results on two mobile devices show that the Augmented Reality application runs well on operating systems above Android 5.0. When tested with a marker distance of between 10 cm to 100 cm with angles of 45°, 90°, and 180°, the results obtained were that 3D animation objects could be displayed well at a distance of 20 cm to 100 cm. Black box testing also concluded that all menus and features function properly. The aim of developing this application is to produce interactive learning media so that users can interact with virtual objects to gain direct experience of how the topology and function of computer network devices work. Apart from that, this application aims to stimulate interest in learning, especially for users with special needs, by adding text and audio features to each learning material. Further research was carried out by applying similar augmented reality through a marker less-based approach so that the use of the application becomes more flexible because it does not require markers.

Keywords— *Application, Augmented reality, Black box, Computer network, Marker based.*

I. INTRODUCTION

The Computer Networks course is an important skill for students to master in engineering disciplines such as informatics, computer science, and electrical engineering. Some of the material presented in computer networking courses includes information about network equipment and its functionality. A literature study [1] highlights challenges faced in computer networking courses, such as minimal facilities for practicing computer networking, particularly due to high procurement costs and maintenance expenses for network equipment. Additionally, the learning methods applied are often monotonous, failing to motivate students effectively. Therefore, there is a pressing need for innovation in computer network learning, allowing students to better comprehend computer network subjects, especially concerning the introduction of network equipment and its operations.

According to [2], advancements in the field of ICT have permeated various levels of society. Augmented Reality (AR) stands out as an innovation garnering significant attention. This technology seamlessly integrates physical and virtual elements into the real world, enabling real-time interaction and the

amalgamation of three-dimensional (3D) objects by embedding virtual elements into physical reality [3]. As elucidated by [4] the primary function of Augmented Reality technology is to bridge the gap between the physical world and the virtual reality constructed through computers. Over time, the development of AR has progressed rapidly, leading to its application across various sectors, including education and entertainment [5]. The implementation of Augmented Reality technology in educational settings aims to provide users with the ability to perceive objects directly in their real environment, fostering interaction between users and these objects. In practice, Augmented Reality (AR) technology is implemented through two approaches: marker-based and markerless. The marker-based approach utilizes special marks with specific patterns recognized by camera devices to display three-dimensional objects. Conversely, markerless methods do not rely on special markings but utilize the surface of the surrounding environment as a reference for displaying objects. In research [6], the marker-based approach was chosen for Augmented Reality visualization of wood materials due to its

compatibility with Android devices that do not necessitate high specifications and performance.

In research [7], Augmented Reality technology was implemented as an endeavor to develop learning materials in the field of computer networks. The application utilized AR technology employing a marker-based method, wherein 3D network components are displayed by scanning markers on the image. This study employed the Research and Development (R&D) method to validate the application with input from experts. This differs from the approach taken in research [8], which applied Augmented Reality technology to facilitate learning about network connections through IP addresses. Testing was conducted using the same marker-based method, involving three network topologies: bus, ring, and star. The testing scheme assessed the success of connections based on IP address classification; connections between PCs were considered successful if the IP addresses belonged to the same class, while connections failed if the IP addresses were not in the same class.

Based on the outlined problems and background, this research focuses on implementing marker-based Augmented Reality to develop computer network learning. It presents animated network topology objects accompanied by CPMK features, text, audio, and practice questions. The primary aim of developing this application is to create interactive learning media, enabling users to interact with virtual objects and gain direct experience of how computer network devices' topology and functions operate. Furthermore, the application seeks to enhance learning interest, particularly for users with special needs, by incorporating text and audio features into each learning material. This application can enhance the efficiency and effectiveness of computer network learning as materials can be accessed anytime and anywhere. Moreover, this research contributes to enhancing training and education by offering interactive simulations and improved visualization, thereby facilitating better understanding of complex concepts.

II. METHOD

This activity is conducted by applying the waterfall method, which progresses through stages until the final stage. This method is commonly utilized in software development but can also be adapted for hardware development [9]. Employing this method enables research to proceed in a clear and detailed sequence, ensuring each stage is completed thoroughly and minimizing the risk of errors. As a result, researchers can identify the primary requirements in the application creation process to ensure the application is suitable for use as a learning tool. The flow or steps of the research carried out using the waterfall method are illustrated in Fig. 1.

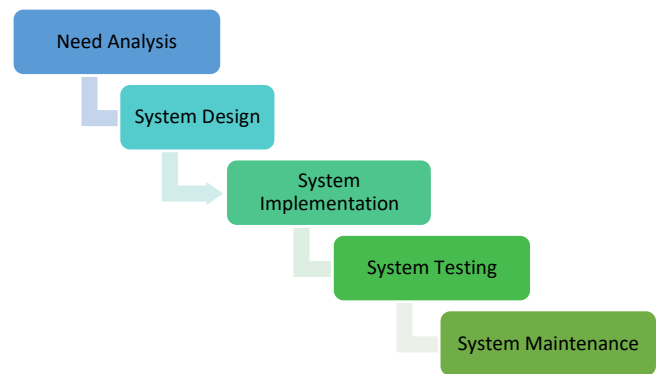


Figure 1. Waterfall Method

A. Need Analysis

This stage involves analyzing needs based on existing problems. The needs can be identified through observation and literature study searches. This step is crucial in determining the scope of application development by considering user requirements. The requirements encompass both software and research supporting data. For development, Unity 2021.1.20 and Vuforia SDK are utilized. These software tools enable the creation of augmented reality applications by incorporating visual effects and 3D objects, rendering the application interactive. Vuforia offers support for multiple platforms, including iOS, Android, and Unity 3D, facilitating native application deployment on mobile devices such as smartphones and tablets. Additionally, 3DS Max 2021 software is employed for crafting three-dimensional (3D) animated objects. Furthermore, this stage involves analyzing hardware requirements to support the application and compiling information to be used as content for the AR application.

B. Writing Format

The next stage involves system design aimed at creating a system that functions optimally and facilitates students' understanding of the material. During this stage, flowchart designs and application interface designs are developed. The system design is interactive, meaning it can respond to user actions, and it can visualize three-dimensional (3D) animated objects as realistically and comprehensively as possible. The application system flowchart is depicted in Fig. 2.

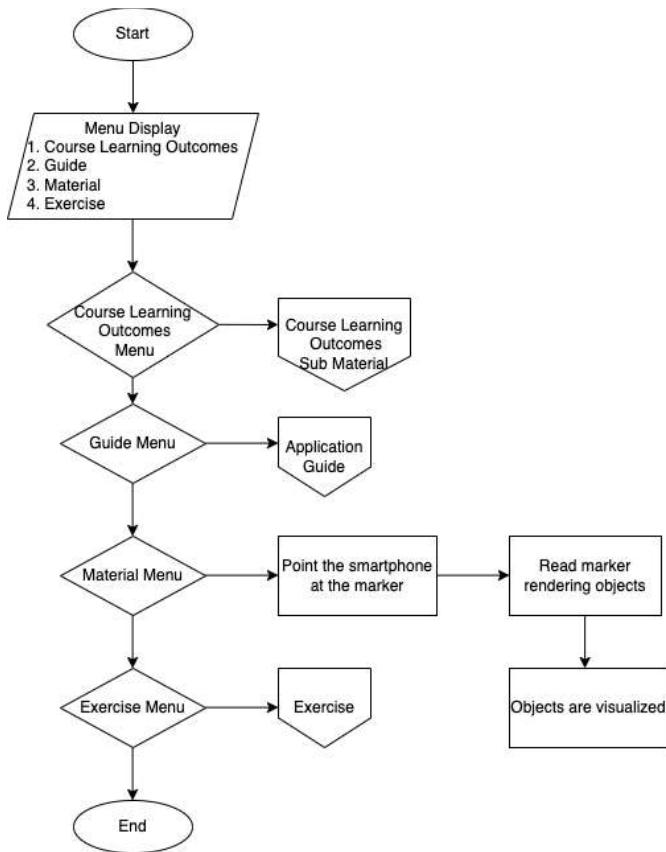


Figure 2. System Flowchart

After designing the flowchart, the next step is designing the application interface. The design was carried out taking into account the needs of computer networking courses.

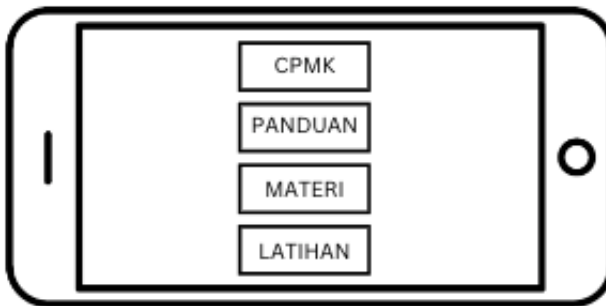


Figure 3. Main Page Storyboard

In Fig. 3, there is a storyboard for the main page. This describes the initial or front display which consists of 4 menus, namely CPMK, guide, materials and practice questions. The CPMK menu contains text from one of the Sub CPMK Computer Networks, while the guide menu contains text that guides application use.

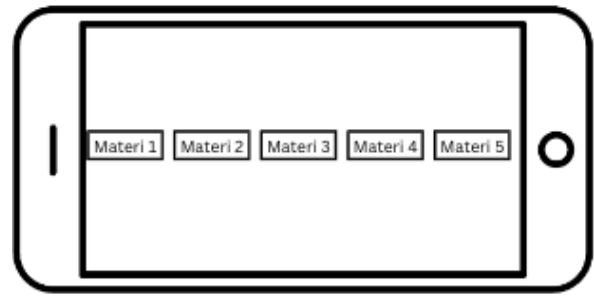


Figure 4. Material Selection Page Storyboard

Meanwhile, on the material page as shown in Fig. 4, there are 5 materials that discuss how computer network components work with visualization of network topologies, including data transmission in a star topology with a hub component, data transmission in a star topology with a switch component, data transmission with a cable. coaxial in bus topology, data transmission in wireless mesh topology, data transmission in two networks.

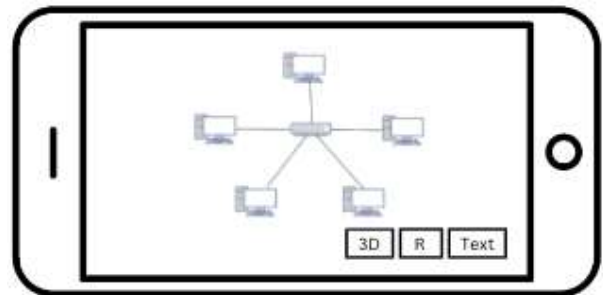


Figure 5. Material Page Storyboard

Each material displays a 3D animated object that can be rotated 360o, displays text and produces an audio explanation of each material.



Figure 6. Storyboard of the Quiz Home Page

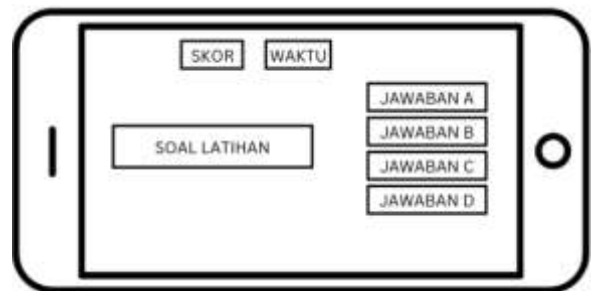


Figure 7. Quiz Page Storyboard

The last menu provided is a practice quiz. After the user selects the "Exercise Menu" button on the main page, the user will be directed to the exercise home page. Here, users can choose to start a quiz. On the quiz page, a series of questions will be displayed, each accompanied by four answer options. Users can also see the scores they have obtained and observe the running time.

C. System Implementation

This stage involves the process of implementing the system design that has been created. All 3D animation object resources that have been created are integrated through a series of programming commands on the computer and configured for testing on Android mobile devices.

D. System Testing

The next step is system testing. Applications that have been built in the apk extension are then installed on mobile devices. The method used is black box. Testing with this method focuses on software quality. This stage tests all parts of the application such as menus and content to determine system performance so that there are no problems (errors). Testing is carried out using a black box approach to check whether the features in the application operate adequately [10].

E. System Maintenance

The applications that have been developed are then utilized by users. If any problems (errors) arise, the application will be repaired.

III. RESULT

A. Implementation of Interface Design

The following is the result of designing the main page interface. On this page there are four menus in the form of Course Learning Outcomes, Guide, Material and Practice Questions.



Figure 8. Main Page

The functions of the 4 menus on the main page are:

1. Course Learning Outcomes: To present Course Learning Achievements in the Computer Networks sub-material.
2. Guide: To present information on using the Augmented Reality application.
3. Material: To present five materials on how computer network components work.

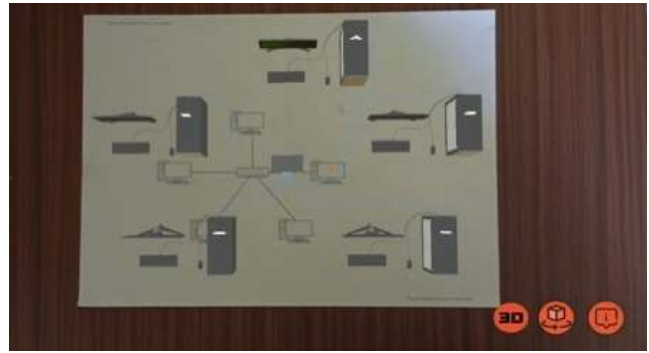


Figure 9. Material Page

On the material page, Fig. 9, presents three-dimensional (3D) animated objects using a marker based approach. The first step is to point the camera at the marker until the 3D animated object appears. Apart from that, there are 3 menus that support animated objects, namely the object removal menu, object rotation, text and audio. Users can zoom in, zoom out and rotate 3D objects by moving the device screen.

4. Practice: To present practice questions after studying the material.



Figure 10. Quiz Page

In the quiz page design, there are 10 questions, where each question has one question and four answer options. There is also a timer and score feature to display the number of correct answers.

In developing interface designs, researchers face challenges, namely slow performance in applications. However, researchers improved performance and responsiveness by optimizing application code and assets, including utilizing efficient rendering techniques and ensuring optimal memory management. This development produces an application that provides a more immersive and interactive user experience in studying computer networks.

B. Testing on Mobile Devices

Research [11] designed an Augmented Reality application to introduce regional culture. This application has been tested on several Android mobile devices with various specifications. The results show that testing can be carried out well, with a minimum operating system requirement of Android 5.0. So in this research, testing was carried out on two Android mobile devices with operating systems 8.1 and 11. The AR application was installed on the devices to find out whether the objects and interface design could be displayed properly.

TABLE I
TEST RESULTS ON MOBILE DEVICES

Devices	Specification	Information	Distance (cm)	Angle	Result
REALME C1 2019	OS: Android 8.1 (Oreo)	Applications can be installed properly, interface designs and objects can be displayed well	30	180	√
	RAM: 2 GB			45	√
	Main Camera: 13 MP			90	√
	CPU: Octa-core 1.8			180	√
INFINIX NOTE 12 2023	OS: Android 11	Applications can be installed properly, interface designs and objects can be displayed well	40	45	√
	Cortex-A76 & 6x2.0 GHz			90	√
	RAM: 8 GB			180	√
	Cortex-A55			45	√
	CPU: Octa core 2x2.05 Gh			90	√
	Main Camera: 50 MP			180	√
				60	√
				90	√
				180	√
				45	√
				70	√
				90	√
				180	√
				45	√
				80	√
				90	√
180	√				
				45	√
				90	√
				180	√

The results of testing on two mobile devices as in Table I show that the AR application can be installed well and 3D animated objects can run well. This is in line with previous research that the application will be able to run well on the minimum Android 5.0 operating system.

C. Marker Testing

Research [12] developed an Augmented Reality application to present house catalog objects. This research used a marker based method which was tested using an Android device. Object testing scheme at a distance of 5-30 cm, angle of 30°-90° and light intensity indoors (200-1000 lux) and outdoors (40-200 lux). The results of this test show that distance and angle influence the appearance of objects. Based on this research, marker testing is intended to test the maximum distance when using a marker. The maximum distance specified is 100 cm at an angle of 45°, 90°, and 180°. The mobile device used is the Infinix Note 12 2023 with 8GB RAM specifications, 1080x2400 screen and 50 MP rear camera. Marker test results are shown in Table II.

TABLE II
MARKER TEST RESULTS

Distance (cm)	Angle	Result
10	45	x
	90	x
	180	x
20	45	√
	90	√

The results of marker testing at three angles 45°, 90°, and 180° with distances ranging from 10 cm to a maximum distance of 100 cm showed that for a distance of 10 cm with angles 45°, 90°, and 180° it was stated that the object did not appear. This is because the marker looks large so the corners of the marker image are not clearly visible. So it can be concluded that for other distances, the results obtained show that 3D animated objects can be displayed well.

F. Black Box Testing

Black box testing is a form of application testing that involves testing without requiring an understanding of the

internal details of the code or program being tested. In this approach, testing is carried out by understanding the expected function of the program, but without the need to know in depth how its internal processes take place. Research [13] developed an Augmented Reality application to display 3D objects of traditional tools. In this research, the black box testing method was used to look for errors. This test is intended to find out whether there are problems with the system and also to carry out an evaluation to check whether the system can operate properly when the application is run. The main focus is on the output that the software produces to achieve that result. The test results are as shown in Table III.

TABLE III
BLACK BOX TEST RESULTS

Testing	Action	Desired Result	Test Result
Main Page Display	Touch	Main Page Scene Appears	Accordance
CPMK Menu Button	Touch	Display CPMK Text	Accordance
Guide Menu Button	Touch	Display Guide Text	Accordance
Download Marker Button	Touch	Display Downloaded Files	Accordance
Material Menu Button	Touch	Display 5 material buttons	Accordance
Material Button 1	Touch	Directs to the scan marker page	Accordance
Material Button 2	Touch	Directs to the scan marker page	Accordance
Material Button 3	Touch	Directs to the scan marker page	Accordance
Material Button 4	Touch	Directs to the scan marker page	Accordance
Material Button 5	Touch	Directs to the scan marker page	Accordance
Displaying 3D Object	Point the Camera at the Marker	Directs to the scan marker page	Accordance
3D Button	Touch	Show/remove 3d objects	Accordance

Testing	Action	Desired Result	Test Result
Rotate Button	Touch	Rotate 3D objects 360°	Accordance
Text Audio Button	Touch	Display text and audio narration	Accordance
Back Button	Touch	Returns to the main page	Accordance
Exercise Menu Button	Touch	Redirects to the start exercise page	Accordance
Exercise Page Close Button	Touch	Closes the practice page	Accordance
Start Training Button	Touch	Directs to the Practice questions page	Accordance
Select Answer Button	Touch	Choose the answer to the question	Accordance
Quiz Score	Display Quiz Score	Displays training results	Accordance
Time	Display Quiz Time	Display quiz time	Accordance

Table 3 shows that all menu options and features available in the application are in accordance with the initial plan. This shows that the application that has been developed has an adequate level of quality for use.

IV. CONCLUSION

This research has succeeded in creating a marker-based Augmented Reality application with three-dimensional (3D) network topology animation objects. Test results on two mobile devices show that the Augmented Reality application runs well on Android operating system above 5.0. When tested with a marker distance of between 10cm to 100 cm with angles of 45°, 90°, and 180°, the results showed that 3D animated objects could be displayed well at a distance of 20 cm to 100 cm. Black box testing also concluded that all menus and features function properly. Further research was carried out by applying similar augmented reality through a markless based approach so that application use becomes more flexible because it does not require markers.

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