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Learning Media Application for Basic Digital Courses Using Augmented Reality with the Marker Based Tracking (MBT) Method

Syamsul Buchori Pane
Informatics Engineering
Malikussaleh University
Lhokseumawe, Indonesia
syamsul.210170186@mhs.unimal.ac.id

Eva Darnila
Informatics Engineering
Malikussaleh University
Lhokseumawe, Indonesia
eva.darnila@unimal.ac.id

Fajriana
Informatics Engineering
Malikussaleh University
Lhokseumawe, Indonesia
fajriana@unimal.ac.id

Abstract— The rapid development of digital technology presents new opportunities to enhance the effectiveness of learning media, particularly through the use of Augmented Reality (AR). This study develops an AR-based learning media application for basic digital courses using the Marker-Based Tracking (MBT) method as a novel approach to delivering abstract digital concepts. The presented materials include number systems, logic gates, Boolean algebra, Karnaugh maps, and flip-flops. The development process follows the waterfall model, including literature study, needs analysis, system design, implementation, and testing. The resulting application is capable of displaying interactive 3D objects in real-time through features such as rotation, zoom, and audio. User testing showed that 84% of students found the application improved their conceptual understanding, while 76% reported increased interest in learning. The implementation of MBT in AR-based digital learning proves to be an innovative and effective medium for enhancing comprehension of abstract content.

Keywords— Augmented Reality, Marker-Based Tracking, Digital Learning, Number Systems, Logic Gates.

I. Introduction

Learning media in the current era has experienced very rapid progress along with the development of digital technology. One of the innovations in the field of technology that has the potential to be developed is the use of media based on augmented reality (AR) [1]. Augmented reality is a technology that combines two-dimensional and three-dimensional objects and then projects these virtual objects into real time and a real environment [2].

In the context of education, AR has shown potential to bridge gaps in subjects where traditional teaching tools fall short, particularly in digital basic courses. These courses are fundamental to informatics engineering programs, covering topics such as number systems, logic gates [3], Boolean algebra, Karnaugh maps [4], and flip-flops. However, students often struggle to grasp these abstract and symbolic concepts using static or text-based instructional methods.

There are several software used in making augmented reality applications including unity, vuforia software development kit and blender. Unity software as a game engine which is software used in developing two-dimensional or three-dimensional games, unity can be used to create other interactive games such as architectural visuals and real-time three-dimensional animations [5]. Meanwhile, the Vuforia software development kit is often used as a plugin and database to create augmented reality [6]. And Blender as software for creating three-dimensional images or animations, by combining these three software, an augmented reality technology innovation can be created [7].

The method used in the development of augmented reality (AR) technology in this study is marker-based tracking (MBT). To address this challenge, this study proposes the development of an interactive learning media application that leverages AR technology with the Marker-Based Tracking (MBT) method [8]. MBT enables real-time recognition and rendering of 3D objects through the use of specific visual markers, allowing learners to interact directly with virtual representations of digital components. This method is particularly suitable for controlled classroom environments where marker reliability and stability are essential.

One of the main concepts in this course is the number system. Number systems play an important role in representing data and performing logical operations on digital systems. The four types of number systems commonly used in the digital realm are binary, octal, decimal, and hexadecimal [9]. Logic gates consist of several main types, including or, and, nand, and not gates, each of which has its own logical function in forming a digital circuit. Then boolean algebra is used to analyze and simplify digital circuits or logic gates.

The proposed application aims to make abstract digital concepts more tangible and intuitive by visualizing them in 3D, complemented by interactive features such as object rotation, zoom, and audio narration. The system was developed using Unity, Vuforia SDK, and Blender, following a waterfall development model that includes literature review, requirements analysis, system design, implementation, and testing.

In research that has been conducted by [10], This research contains about the application of digitalization of car marketing using augmented reality. This research has quite significant differences, namely in the application system that will be created in the form of a learning media application for basic digital courses using augmented reality with the marker-based tracking method. In addition, the system that will be created by researchers is a solution for most students who have difficulty understanding and mastering abstract theoretical concepts [11].

Unlike previous AR implementations that primarily focus on general education or commercial applications, this study introduces a novel use of MBT specifically tailored for foundational digital logic education. The application serves as a learning aid to improve student engagement, comprehension, and retention by transforming abstract theories into interactive experiences [12].

By integrating AR with targeted pedagogical design, this research offers a promising solution to longstanding difficulties in digital basic learning. The study not only contributes to AR-based educational media development but also demonstrates the potential for scalable application across other STEM disciplines that involve abstract or symbolic content.

Augmented reality (AR) technology is designed to be used as an interactive learning medium in digital basic courses. This technology allows students to interact directly with three-dimensional objects such as number systems, logic gates, boolean algebra, karnaugh maps and flip-flops so that they become more concrete and intuitive. The latest developments in augmented reality can be a fundamental part of modern interactive systems to achieve user engagement and a sweetened experience during teaching and learning [13].

With the problems that exist in the teaching and learning process in digital basic courses, it is necessary to apply learning media for digital basic courses using augmented reality with the marker-based tracking method. Through the application of an interactive, innovative and fun learning approach, it is hoped that students can learn digital basic courses in a more interesting, relevant and easy-to-understand way.

II. RELATED WORKS

A. Augmented Reality

Augmented Reality (AR) is a technology that combines two-dimensional (2D) and three-dimensional (3D) objects into a real environment in real-time, so that users can interact directly with virtual objects displayed in a real-world context [14]. This technology provides a more engaging, interactive, and informative visual experience, especially in the field of digital technology-based education and training. In its implementation, AR allows integration between digital and physical elements that can improve visual understanding of concepts. The combination of real and virtual objects must be supported by an effective tracking system in order to produce an appropriate display, and support optimal interactivity and integration [15]. The effectiveness of tracking depends heavily on the method used, such as marker-based tracking or markerless tracking.

B. Marker-Based Tracking

Marker based tracking is a tracking method in Augmented Reality (AR) technology that requires the presence of certain markers or visual markers to be recognized by the device's camera [16]. This technique uses a special marker, namely a square-shaped image dominated by black and white [17]. When the camera detects the marker, the system will process the image and display the virtual object in real-time at the appropriate position in the real environment. The use of the marker-based tracking method is considered more stable in good lighting conditions and controlled environments.

C. Use Case Diagram

A use case diagram is a diagram that is used to explain the relationship between actors and the system being designed [18]. This diagram shows how actors, both humans and external systems, perform a series of actions or processes with the system to achieve a specific goal. Here is the use case diagram for augmented reality that will be created:

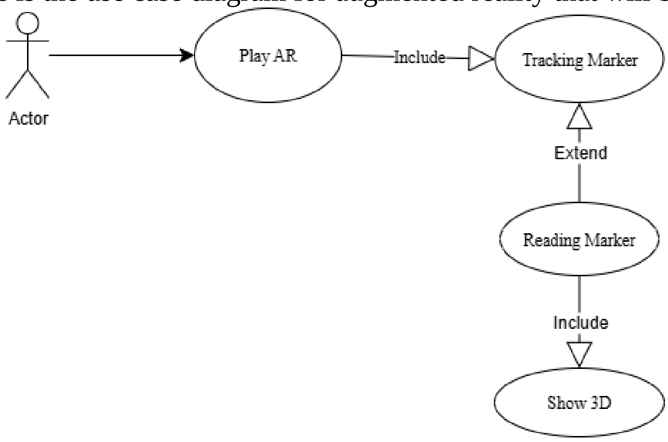

Figure 1. Use Case Diagram

D. Number System

Number system is a set of symbols and rules used to represent a value or quantity. It provides a structured way to express numerical information using digits, where each digit has a positional value based on the system's base, also known as the radix. Essentially, a number system allows humans and computers to understand and manipulate numerical data consistently and logically.

There are several types of number systems commonly used in digital systems. These systems include the decimal system (base 10) [19] , which is used in everyday arithmetic; the binary system (base 2), which is fundamental to computer architecture and logic design; the octal system (base 8); and the hexadecimal system (base 16), which is often used as a more compact representation of binary values.

E. Logic Gates

Logic gates are the fundamental building blocks of digital systems, responsible for processing input signals and producing outputs based on specific logical relationships. These inputs are typically represented as high (1) and low (0) voltage levels, directly corresponding to binary numbers. Each gate performs a predefined logical operation—such as AND, OR, NOT, NAND, NOR, XOR, or XNOR that manipulates binary inputs to generate a binary output. [20].

F. Boolean Algebra

Boolean algebra is a that deals with binary logic values, namely true (1) and false (0) [21]. It serves as a fundamental tool in digital electronics, where binary values are used to represent the two possible states of a digital signal. Boolean algebra is primarily used to analyze, design, and simplify digital circuits and logic gates.

G. Karnaugh Map

Karnaugh map is a visual used to simplify algebraic expressions in Boolean algebra functions without having to use complex theories or equation manipulation [22]. A Karnaugh map is created by inputting the output data from a truth table into a Karnaugh map table. By combining the truth table data into a two-dimensional grid, a Karnaugh map allows designers to visually detect redundancy and eliminate unnecessary logic operations. This simplification process results in more efficient digital circuit designs with fewer logic gates, which contributes to reduced cost, power consumption, and implementation complexity.

H. Flip-Flop

Flip-flop is a fundamental element in a sequential logic system that plays an important role as the main component in various digital circuits. This component has two stable conditions that can be set alternately through input signals, and is generally represented in the form of binary logic "0" and "1" [23].

III. METHOD

This research was conducted through a series of methodological stages that include literature study, needs analysis, data collection, system design, system implementation, system testing, and system evaluation. All stages will influence and become the basis for sustainability with the waterfall model approach [24]. Here is an illustration of a waterfall:

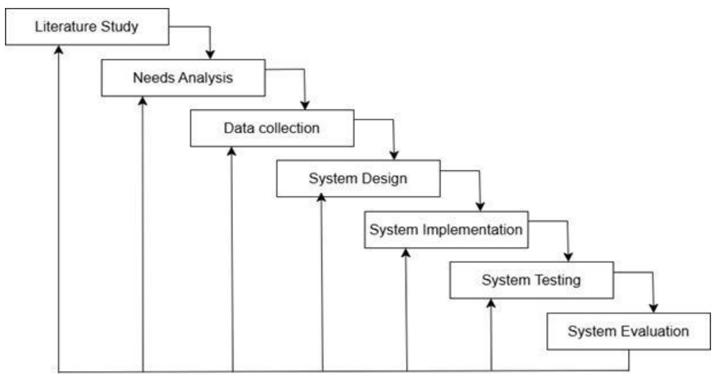

Figure 2. Research Flow

A. Scheme System

The system schema is part of the implementation stage that describes the overall application workflow. In this system, there are several stages of the process that are run, starting from the appearance of the main menu in the application, menu selection by the user, activation of the camera display, inputting markers, to the appearance of three-dimensional objects. Furthermore, the system displays a selection of available learning materials, and after the user makes a selection, the system will present learning materials according to the selection. A complete illustration of this system schema is presented in Figure 2.

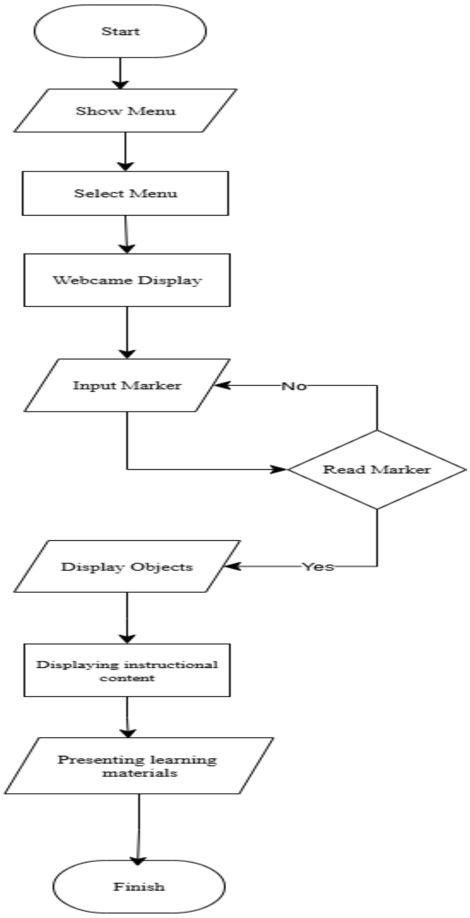

Figure 3. Scheme System

B. Technical Implementation

The technical implementation of the AR-based learning media involved the integration of Unity as the main development platform, Vuforia SDK for marker-based object recognition, and Blender for designing 3D models. Markers were designed in a high-contrast black-and-white format to ensure accurate recognition under controlled lighting conditions. The application includes interactive features such as zoom, rotation, and audio support, allowing users to manipulate and explore virtual learning objects in real-time.

To evaluate the effectiveness of the system, A usability test was conducted involving 1 class consisting of 40 undergraduate students enrolled in a basic digital course. The evaluation measured aspects such as ease of use, user engagement, and conceptual understanding.

IV. RESULT AND DISCUSSION

A. Implementation Augmented Reality System

Based on the research results that have been analyzed and tested, the digital basic course learning media application system using augmented reality with the marker based tracking method can provide a new, interactive and innovative experience in teaching and learning in the classroom, so that it can increase students' interest in learning.

1. Application Splash View, This display will show the initial part of the application when it is first opened or the initial part before entering the home screen.

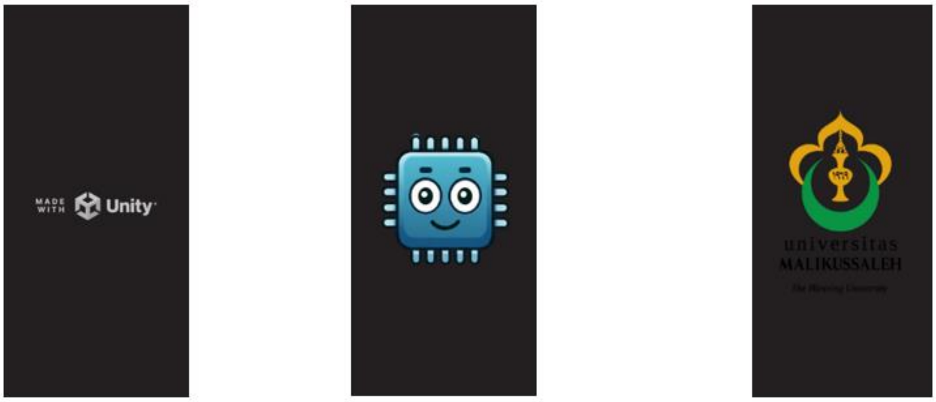

Figure 4. Splash

In figure 4 is part of the application splash image, starting from the first image is an image of the Unity logo where the logo will appear in the splash when it is first opened, then there is the application logo and the last is the logo of Malikussaleh University and as the last splash before going to the main page.

2. Home Page View, This section shows the main part of the application or the homescreen of the application.

Figure 5. Home Page View

The image above is part of the main page of the application which consists of 3 types of options, namely play to start augmented reality, about contains information about the application developer and exit to exit the application.

3. Play view, this section is the play section before starting to detect markers.

Figure 6. Play View

Figure 6 shows the display before carrying out marker detection. This display serves as an initial stage before the Augmented Reality (AR) system begins the process of identifying the specified marker. At this stage, the camera will be activated and the system is ready to receive input in the form of a marker to be scanned. The presence of this initial display is very important in the application workflow, because it is a bridge between the user and the system in the process of tracking virtual objects. With this display, the user can adjust the position of the marker so that it is optimally detected by the system.

4. AR marker display on the app

Figure 7. Marker AR

Figure 7 shows the result of the AR marker number system in the application. There are several buttons displayed when the marker is detected, including the number system button which is a button to see what materials will be studied in the number system, then there is a rotation button, this rotation button functions to rotate three-dimensional objects, then there is a zoom in button functions to zoom in on three-dimensional objects, the zoom out button functions to zoom out on three-dimensional objects and the voice button to on-off the sound that can be heard when the marker is detected.

5. Number system page view

Figure 8. Number system page view

Figure 8 shows the number system page display in an Augmented Reality-based application designed for learning basic digital materials. In this display, four types of number systems commonly used in the computer world are presented, namely Decimal, Binary, Octal, and Hexadecimal. Each number system is accompanied by information about the digits used and its base.

6. Zoom in Object View

Figure 9. Zoom in Object View

Figure 9 shows the virtual object display of the marker scan result that is undergoing the zoom in process in the Augmented Reality application. This display shows that the number object “01” is visualized in three dimensions that can be enlarged according to user needs. The zoom in feature functions to clarify the details of the displayed object, so that users can see the components or visual representations in more depth.

7. Zoom Out Object View

Figure 10. Zoom Out Object View

Figure 10 shows the results of the virtual object visualization in zoom out conditions on the Augmented Reality-based learning application. The number object "01" is visualized on a smaller scale compared to the previous display (zoom in), allowing users to see the entire shape of the object more completely in one field of view. This zoom out feature provides flexibility for users in adjusting the scale of the object, especially when they want to get a complete picture or spatial context of the object displayed.

8. Rotation Object View

Figure 11. Rotation Object View

Figure 11 shows the visualization results of objects in rotation mode in the Augmented Reality (AR) application based on learning the number system. The number object “10” is displayed in three dimensions that can be rotated or repositioned interactively by the user through the Rotate feature. This feature allows users to change the viewing angle of the object, so they can observe the visual display from various directions.

9. About Page View

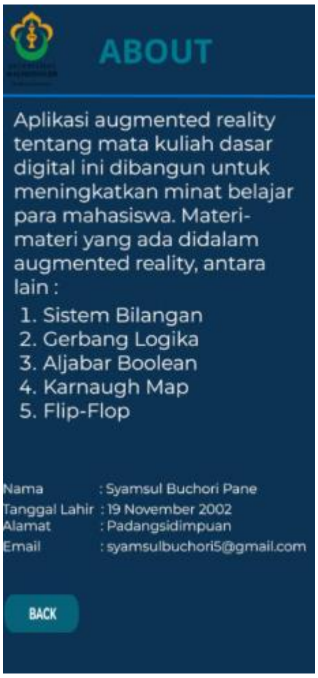

Figure 12. About Page View

Figure 11 shows the About page in the Augmented Reality application developed as an interactive learning media for the Digital Basics course. This page presents information about the purpose of creating the application, which is to increase students' interest in learning through the delivery of more interesting and technology-based materials. And personal information by the application creator.

B. Feedback on AR-Based Learning Application

The results of user testing involving 40 undergraduate students indicated that the AR-based application significantly enhanced the learning experience. Quantitatively, 84% of participants stated that the application was helpful in visualizing abstract and complex concepts such as logic gates and number systems. Furthermore, 76% of them reported increased motivation and interest in learning digital basic materials after using the application. The following bar chart illustrates these feedback results.

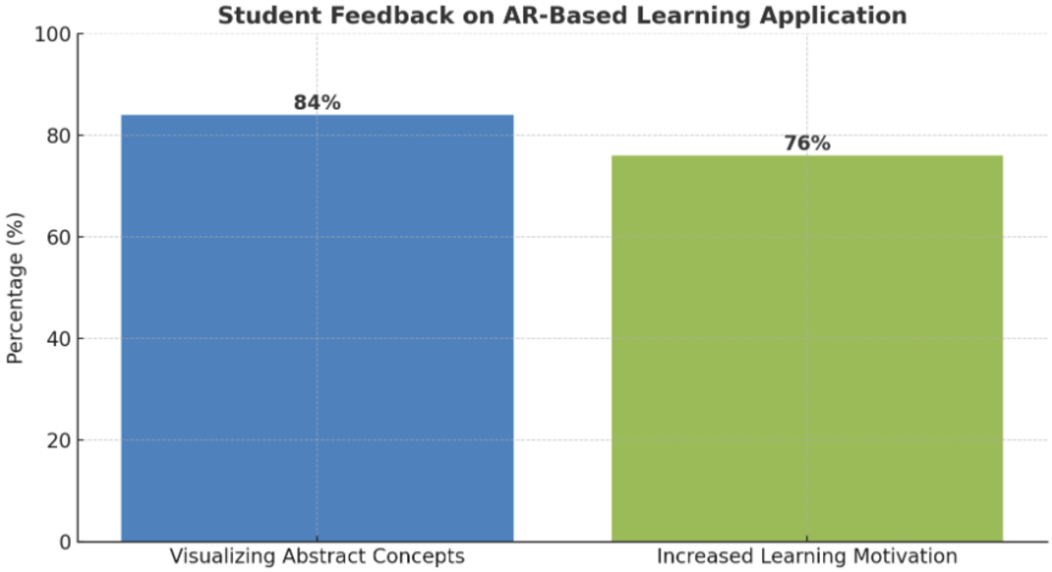

Figure 13. Feedback on AR-Based Learning Application

Qualitative feedback also supported these findings, with several students highlighting that the interactive features—particularly the zoom and rotation functions—enabled them to better understand the spatial relationships and structures of the learning materials. Users appreciated the ability to manipulate 3D objects in real-time, which made the learning process more engaging and intuitive.

V. CONCLUSION

The development of an Augmented Reality (AR)-based learning media application using the Marker-Based Tracking (MBT) method for basic digital courses has been successfully completed and tested. The application offers an innovative, interactive learning experience through the real-time visualization of 3D objects, which helps students better understand abstract concepts such as number systems, logic gates, Boolean algebra, Karnaugh maps, and flip-flops.User testing results demonstrated increased engagement and comprehension, with 84% of students finding the application effective in improving conceptual understanding, and 76% reporting higher motivation to study digital basic topics. The integration of MBT provides a stable and reliable AR experience, making it highly suitable for classroom use.

For future work, the application can be expanded by including additional course materials and conducting broader trials involving different institutions and student demographics. This research highlights the potential of AR technology not only in digital basic education but also as a scalable solution for other STEM-related subjects that involve abstract and visual-spatial learning. The success of this system suggests a promising path forward for the integration of immersive technology into modern education.

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