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DEVELOPMENT OF MARKERLESS BASED AUGMENTED REALITY INTERACTIVE LEARNING MEDIA OF 3D GEOMETRY SHAPES

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Abstract
Education is one sector that continues to experience significant development, especially in terms of the use of information and communication technology (ICT) in the learning process. This research is intended as a development in terms of creating an Augmented Reality 3D geometry shapes interactive learning based on the previous researches featuring a Markerless Based, that is expected to be more effective to use. The conclusion of this research is that Markerless Based Augmented Reality Interactive Learning media of 3D Geometry Shapes has been be developed succesfully. The application development stage was successfully carried out by applying the waterfall model and obtained successful results in the testing plan on the Black Box Testing of application prototypes on mobile android devices, indicates that the developed application has fulfilled all the functional requirements.
Keywords: 3D Geometry Shapes, Augmented Reality, Interactive Learning Media, Markerless Based Augmented Reality.

1. Introduction

The education sector is rapidly evolving, particularly with the integration of information and communication technology (ICT) in learning. Technological advancements offer new ways to enhance student comprehension, especially in complex subjects like three-dimensional geometry. Traditional learning tools such as textbooks and physical models often fail to engage students or convey these concepts effectively [1]. In contrast, Augmented Reality (AR) provides an innovative solution by creating interactive, engaging, and easily understandable learning experiences [2]. AR allows students to visualize and interact with three-dimensional shapes within real-world contexts, making abstract concepts more concrete and comprehensible. This approach is particularly beneficial for younger students who need more tangible visualizations to aid their understanding. Research on Augmented Reality (AR) for elementary school students has shown promising results in enhancing learning and engagement [3]. An AR-based application was developed for third-grade science education, which improved material delivery through marker detection patterns, indicating potential for wider educational use. Another AR-based learning application was created using Marker Based tracking methods [4]. However, research found that Markerless Based tracking is more accurate and effective than Marker Based tracking at 150 cm, achieving a 93% accuracy rate compared to 83.3% [5]. Building on these findings, the current research aims to develop a more effective AR application for teaching three-dimensional geometry using Markerless Based tracking. This approach is expected to significantly improve the quality of education and better prepare students for future technological and scientific demands.

2. Theorical Basis

3D Geometry Shapes

A geometric shape is a three-dimensional spatial structure with boundaries in the form of flat planes and/or curved planes [6]. Spatial shapes have certain properties, namely they have sides, edges and corner points [7]. The following are 3D geometry that will be included in research :

1) Cube
   A cube is a three-dimensional geometric shape consisting of six rectangular areas. A cube is a geometric shape bounded by 6 congruent square sides. The cubic shape has certain properties, namely that there are 6 sides in the form of a square that have the same area, there are 12 edges of the same length, there are 8 corner points, each of which is 90° or right-angled, consisting of 12 field diagonals and 4 space diagonals [8].

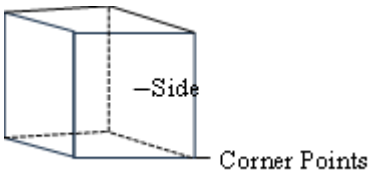

Figure 1. Cube

2) Triangular Prism
A triangular prism is a type of prism that has a triangular base and/or cover, and a rectangular cover. A triangular prism has several properties, namely that it has 5 sides, 3 of the sides are rectangular and 2 of the base and top are triangular, has 6 vertices, and has 9 edges, 3 of which are vertical edges [9].

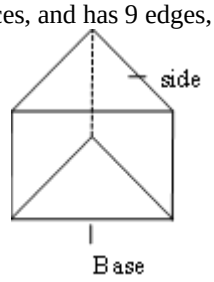

Figure 2. Triangular Prism

3) Cylinder
A cylinder or cylinder is a three-dimensional shape formed by two parallel circles of equal size and a rectangle surrounding the two circles. The cylinder has 3 sides and 2 ribs. The two circles are called the base and lid of the cylinder, and the rectangle that surrounds it is called the cylinder's envelope [9].

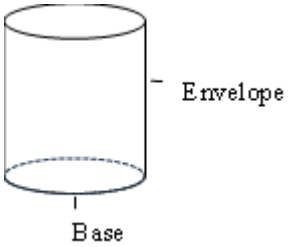

Figure 3. Cylinder

4) Sphere
A sphere is a geometric shape that only consists of one curved side. This means the sphere has no edges or corners. The elements of a sphere are the center point, radius, diameter, volume and surface area [9].

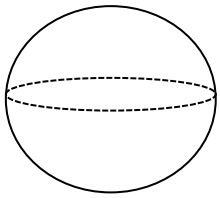

Figure 4. Sphere

Learning Media

Learning media are tools, methods and techniques used to make communication and interaction between teachers and students more effective in the education and teaching process at school [10]. Learning media is anything that can convey or channel messages from a learning source in a planned manner, resulting in a supportive learning environment where the recipient can carry out the learning process efficiently and effectively [11].

Application

Application is the implementation of a system design to process data that uses the rules or provisions of a particular programming language [12]. Applications allow users to carry out various activities through the devices they use, such as data processing, entertainment, learning, and so on.

Augmented Reality

Augmented reality is a combination of real and virtual objects in a real environment, can run interactively in real time, and there is integration between objects in three dimensions, namely virtual objects are integrated in the real world. Combining real and virtual objects is possible with appropriate display technology, interactivity is possible through certain input devices, and good integration requires effective tracking [13]. Augmented Reality (AR) tracking is of two types: Marker Based and Markerless Based. Marker Based AR uses specific markers like images or QR codes to trigger digital content on a device. Markerless Based AR uses real-world objects or natural features for tracking, allowing for more flexible and natural interactions.

3. Research Methodology

This research uses Waterfall Model as development method and Black Box method for testing.

Waterfall Model

Waterfall Model is a sequential development model. The Waterfall model is systematic and sequential in. building software [14]. The stages of the Waterfall Model consist of communication, planning, modeling, and construction. The following are stages of Waterfall Model :

1) Communication
   At this stage what will be done is the identification of requirements that consists of functional requirements and non-functional requirements..
2) Planning
   Tasks that will be done in this stage, namely preparing a tasks schedule, planning what designs will be carried out, planning what functions and features will be created, planning for the testing plan using Black Box method.
3) Modeling
   Design will be carried out on the user interface using Figma, 3D models and animations of the 3D geomety shapes using Blender 3D, the architecture and the flow of application system using UML.
4) Construction
   The construction will be in the form of implementing the user interface, the 3D models and animations, and the features of the application by using Unity, as well as the prototype finishing

Black Box Testing

After the stages of the application development phases are complete, the application will be tested using the Black Box Testing method. Testing will be carried out on the successful implementation of the user interface, the 3D models and animations, also the functions and features based on the requirements identification that has been carried out. Application testing using the Black Box method aims to find out whether the results is appropriate and good.

4. Research Results

Communication

In this stage, identification of requirements is carried out which includes functional and non-functional requirements as a basis for carrying out the following stages. The following are the results of identifying the requirements for the Markerless Based Augmented Reality Interactive Learning Media of 3D Geometry shapes application.

a) Functional Requirements
   1) Augmented Reality can be tracking using Markerless Based method into surfaces using mobile phone camera in Android OS.
   2) Display 3D Geometry Shapes, namely Cube, Triangular Prism, Cylinder, and Sphere in AR.
   3) Feature to able choose any available 3D Geometry Shapes to display in AR.
   4) Display sides, corner points, nets, edges, surface area formula, volume formula, and object examples in 3D animations through Augmented Reality of each 3D Geometry Shapes.
   5) Feature to able choose any available 3D animations to display in AR.
   6) Feature to adjust scale and rotation of 3D Geometry Shapes in Augmented Reality.
   7) Feature to explain about the learning materials of each 3D Geometry Shapes through voice.
   8) Display guide about the function of every button in the app.

b) Non- Functional Requirements
   1) Ensure smooth performance and responsiveness of the app on various mobile devices.
   2) Using Bahasa Indonesia that is easy to understand.
   3) Incorporate engaging visuals and animations to enhance user experience.
   4) Using background music and sound effects to enhance user experience.

Planning

The planning stage consists of a designs plan, and testing plan that contains the necessary planning. After that, an estimate of the time for each planned tasks are made, then organized into a tasks schedule. The following is a description of the planning stage :

a) Designs Plan
   1) User Interface
      This designs plan consists of designing display elements in the app, such as scenes, buttons, icons, and sliders.
   2) 3D Models & Animations
      This designs plan consists of creating and animating the 3D objects through Blender.
   3) Features
      This designs plan consists of designing the flow of the app functions by using UML diagram, such as use case diagram.

b) Testing Plan
   Testing plan is planning for test the application prototype in this case using the Black Box method.

Modeling

a) User Interface Design

Figure 5. App Opening Page UI Design

Figure 6. App Starting Page UI Design

Figure 7. Main Menu Page UI Design

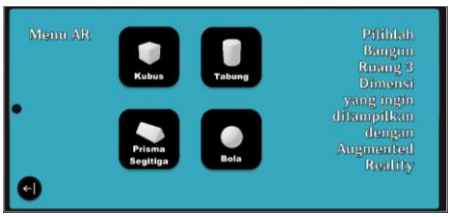

Figure 8. Choose 3D Geometry Page UI Design

Figure 9. AR Displayer UI Design

b) 3D Models & Animations Design

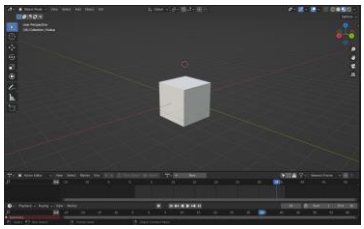

Figure 10. Cube's 3D Shape Design

Figure 13. Sphere's Shape Design

c) Features Design

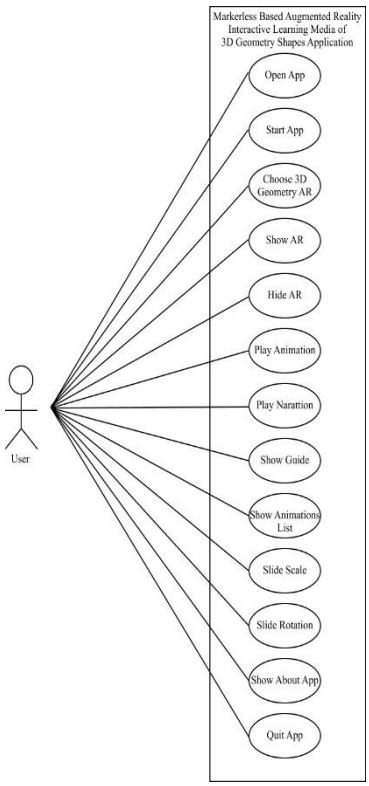

Figure 14. Use Case Diagram

Construction

a) User Interface Implemetation
UI implementation is done in Unity based on the UI design that has been made before in Figma. Each UI element is created into a different Scene in Unity. The assets such as buttons, icons, and sliders are imported from Figma to be used in Unity. Each elements need to be arranged by using the fit anchor preset in order to make the UI can be adaptive to different devices with various screen ratio. Unity provides the simulator for various devices to preview the UI in different screen ratio.

b) 3D Models & Animations Implementation

Implementation of 3D models and animations are being done by importing Blender project files as assets in Unity, in this way the 3D models and animations still can be edited, then automatically will be changed immediately in Unity. The 3D models need to be placed in an area that marked as surface target provide by EasyAR Sense's package for Markerless Based AR.

c) Features Implementation

To Implement the features through Unity, it will need to create C# scripts and Unity gameObject according to each feature's needs. Markerless Based AR can be applied by using EasyAR Sense's package which can be downloaded from their website. It requires Sense License Key to be able to use the AR session in Unity.

Figure 15. Markerless AR Using Surface Tracking Result

Figure 16. Installed App in Android Device

Black Box Testing

Table 1. Black Box Testing Results

No	Test Scenario	Test Case	Expected Result	Testing Result
1	Open App	Opening App.	The app can be launched succesfully without error.	Success
2	Starting App Page	Starting page.	After the opening scene, the Starting page is displayed succesfully.	Success
3	Starting App Page	Starting App button.	The button works, and it directs to the Main Menu Page succesfully.	Success
4	Main Menu Page	Main Menu page.	The Main Menu page is displayed succesfully, with the buttons included.	Success
5	Main Menu Page	Start AR button.	The button works, and it directs to the Choose 3D Geometry AR Page succesfully.	Success
6	Main Menu Page	About App button.	The button works, and it directs to the About App Page succesfully.	Success
7	Main Menu Page	Quit App button.	The button works, and it displays the reconfirm panel window, and the app can be closed succesfully.	Success
8	Choose 3D Geometry AR Page	Choose 3D Geometry AR page.	The Choose 3D Geometry AR page is displayed successfully, with the buttons included.	Success
9	Choose 3D Geometry AR Page	Four option buttons to choose any available 3D geometry.	Every button works, and it directs to the AR Displayer according to the choosen 3D geometry option succesfully.	Success
10	AR Displayer	AR displayer camera.	The camera is able to be launched on the screen succesfully.	Success
11	AR Displayer	Show AR button.	The button works, it displays the 3D object succesfully. Then, the button is replaced by Hide AR Button.	Success

12	AR Displayer	Hide AR button.	The button works, it hides the 3D object from the screen succesfully. Then, the button is replaced by Show AR Button.	Success
13	AR Displayer	Play Animation button.	The button works, and the animation of the 3D object is playing succesfully. When, it's clicked again the animation can be replayed.	Success
14	AR Displayer	Play Narration button.	The button works, the narration is playing succesfully. When, it's clicked again the narration can be replayed.	Success
15	AR Displayer	Show Guide Window Panel.	The button works, it displays the Guide window panel overlapping the AR Displayer succesfully.	Success
16	AR Displayer	Show Animations List Window Panel.	The button works, and it displays the Animations List window panel, including the buttons to display eight different animations of each 3D geometry object.	Success
17	AR Displayer	Eight Animations Option Buttons to choose any available animations.	Every button works, and it displays other 3D object with animation according to the choosen option succesfully.	Success
18	AR Displayer	Scale Slider.	The slider works, it's able to adjust the scale of the 3D object that is currently displayed	Success
19	AR Displayer	Rotation Slider.	The slider works, it's able to adjust the rotation of the 3D object that is currently displayed.	Success

Based on the result testing of the application prototype using 2 different devices, the developed application has fulfilled all the necessary functional requirements. The application successfully able to be installed and launched on device without any error. Every feature that developed is success fullfilling the expected results in testing results. All pages of the application are worked, which can be changed and displayed on devices without any problem. Every button works, and it directs to the AR Displayer according to the choosen 3D geometry option succesfully. The AR Displayer is able to launch the camera and start to tracking Markerless AR for each 3D models and animation as it should be. The application performance shows an efficient and fast response time in displaying AR objects, as well as maintaining the consistency of tracking performance on the surface using the camera. The scale slider and rotation slider are works and able adjust the scale and rotation of every 3D models. Guide and Animations List window panel are able to be displayed when its button is clicked. Lastly, the app is able to be shutted down when the Quit button is clicked.

5. Conclusion

The conclusion of this research is that Markerless Based Augmented Reality Interactive Learning media of 3D Geometry Shapes has been be developed successfully. The application development stage was successfully carried out by applying the waterfall model and obtained successful results in the testing plan on the Black Box Testing of application prototypes on mobile android device, indicates that the developed application has fulfilled all the functional requirements.

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