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The Implementation of Augmented Reality in Geometry for Primary School Students

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HIGHLIGHTS

- Augmented Reality technology can be used as an alternative media for the learning process.
- The Linear Congruential Generator method and the Fuzzy Tsukamoto method can be implemented in the Augmented Reality Geometry application.
- Augmented Reality Geometry can attract students' interest in studying geometry.

ABSTRACT

Mathematics is a subject studied from elementary education up to the university level. In general, learning mathematics uses a conventional approach using a whiteboard. This method has shortcomings in the process of visualization and simulation, especially in the material of geometry. This research develops a learning application by utilizing Augmented Reality technology with the content of geometry for sixth-grade primary school students. Augmented Reality can visualize and simulate geometry for students with an interaction model. Linear Congruential Generator (LCG) and Fuzzy Tsukamoto methods are used in this application as a randomization method and score determination method. The results obtained from the testing process show that the LCG and fuzzy Tsukamoto methods can run according to the design. In user testing using a questionnaire, the results obtained 4.6 of scale 5.0 indicating that respondents provided good responses for the Augmented Reality Geometry application.

Keywords: *Augmented Reality, Linear Congruential Generator, Fuzzy Tsukamoto, Geometry*

INTRODUCTION

Mathematics is one of the exact sciences that is taught starting in early childhood education (Baroody et al., 2019), (Björklund et al., 2020). Learning mathematics requires a good understanding and persistence in the learning process. Mathematics has a variety of topics, one of which is the discussion of geometry. Geometry are three-dimensional shapes that have area and volume formula (Kurbonov & Istamova, 2021). The learning process in the classroom about geometry is generally done in a conventional way. Learning is done by explaining on the whiteboard, so there are limitations in its delivery. The limitation of conventional learning is in the process of visualizing and simulating the geometry material. Students tend to have difficulty learning and understanding geometry. This is due to students' inability to visualize and simulate the shape of each type of geometry shape.

The evolution of technology has influenced how people learn. The use of technology in the learning process has been found to have a positive impact (Chen et al., 2017) ,(Pradibta, 2018), (Ewais et al., 2019). One of

the technologies that is widely used in the learning process is Augmented Reality (AR) technology. AR is a technology that combines two-dimensional (2D) or three-dimensional (3D) virtual objects with the real world and then projects them in real time (İbili et al., 2020)

This research will create an AR-based learning media that takes the theme of geometry as its content. In the learning process, it is enhanced with quiz feature. The LCG (Linear Congruential Generator) and Fuzzy Tsukamoto algorithm is used as an algorithm for scanning questions and determining scores. By implementing AR technology in the learning process, it is expected to make it easier for students to learn by visualizing object models of the concepts learned.

LITERATURE REVIEW

Overview

The application that will be made is an augmented reality application for learning geometry. The application will display three-dimensional geometric objects and be accompanied by brief materials. Three-dimensional objects and materials that appear are adjusted to the marker used. In addition, in this application, there is a quiz with a two-dimensional scene and a menu choice of the type of geometry. The questions displayed on the quiz are calculated according to the selected quiz menu. The Linear Congruential Generator method is used to randomly select the questions that will be shown so that when playing, users do not get the same sequence of questions. Then the Fuzzy Tsukamoto method is used to determine the score from the calculation of points earned and the time to answer the question. Application users are intended for sixth-grade primary school students.

Augmented Reality

Augmented reality is a technology that combines virtual objects and the real environment (Pradibta & Nurhasan, 2021), (Pradibta et al., 2021). Augmented reality does not change reality completely but only adds virtual objects to the real environment so that users can interact directly with virtual objects in the real environment. The use of augmented reality technology in the learning process is an attempt to connect developing technology to the learning process. In the learning process of geometry described in this study, a marker is needed. A marker is an image with a special pattern; where the marker can be read or recognized by the camera, it is matched with the database, from which the camera then renders a three-dimensional object on the marker (Pradibta & Nurhasan, 2021).

Linear Congruential Generator (LCG)

Linear Congruential Generator (LCG) is one of the oldest and most popular types of algorithms for generating random numbers. LCG is used as an algorithm for randomly selecting questions in the quiz feature. The generated random numbers are in positions 1 to n, as determined by using the LCG formula to generate the n value, then sorting the numbers from smallest to largest. The sequence is the generated random number. The LCG method formula is (Sesari et al., 2019):

$$Xn = (a * Xn - 1 + b) mod\ m \quad (1)$$

Description:
a = multiplying factor
b = increment
m = modulus
Xn = the n^{th} random number of the sequence
Xn-1 = previous random number

Fuzzy Tsukamoto

In this research, the Tsukamoto fuzzy method is used as an algorithm for score calculation. In the Tsukamoto fuzzy method, each consequent in the If-Then rule must be represented by a fuzzy set with a monotonous membership function. As a result, the output of the inference results of each rule is given strictly (crips) based on the predicate (fire strength) The final result is obtained using a weighted average(Nugraha et al., 2019).

Quiz Game

Games are one of the recreational activities that aim to find pleasure, utilize leisure time, or do light exercise, which is usually done individually or in groups. While the quiz game is a type of game that displays questions that players (individuals or teams) try to answer correctly, the questions displayed can be in the form of text, images, or sounds. This game is designed to assess and measure ability or knowledge in a short period of time. A quiz is a type of game where the player must answer the given questions correctly in order to achieve a learning goal. In addition to adding interest, quizzes can also train students to think quickly and develop their self-confidence.

METHODOLOGY

The methodology used in this research is the Multimedia Development Life Cycle (MDLC) method, with six stages (Ahmad et al., 2021) shown in Figure 1.

Figure 1. Multimedia Development Life Cycle

Here are the six phases in the MDLC method, namely:

1. Concept
   The first step in designing this Augmented Reality Build Space application is to create an application concept, determine the target user of the application, determine the type of application, and determine the purpose of the application.
2. Design
   The design stage is the stage of making detailed specifications of the program architecture, display style, and material requirements for the program.
3. Material Collecting
   The next stage is the collection of materials needed by the application.
4. Assembly
   The assembly stage is where the materials that have been collected are put together in accordance with the design and concept stages that have been completed.
5. Testing
   The testing stage is carried out when the assembly stage is complete by running the application and correcting any errors that appear.
6. Distribution
   The distribution stage can be carried out after the designed application is declared complete and feasible to use. The application is downloaded in .apk format and installed on an Android smartphone.

Testing Method

Testing was carried out in several stages. The initial stage of the testing process was carried out using a functional test approach. The functional test process includes testing the methods and algorithms used. The next stage is the user testing process. The testing process was conducted at primary school (SDN Pungging, Kecamatan Tutur, and Kabupaten Pasuruan, East java Province, Indonesia). Ten sixth-grade students and five teachers were tested.

Design Gameplay

The gameplay design of this application is that the player sees the material with AR then takes a quiz with a specified time and if the player answers correctly then the player will get points. The gameplay design created is as follows:

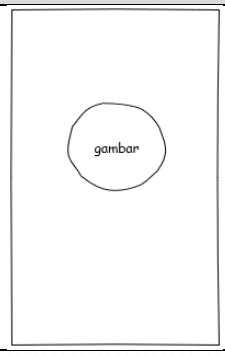
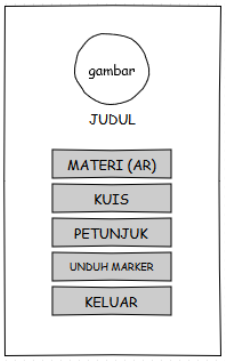
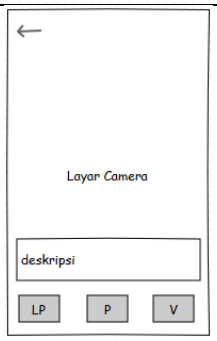
1. When the app is first opened, it will display a splash screen.
2. It will then display the main menu, namely Material, Quiz, Instructions, Download Marker, and Exit.
3. How to view the material is by selecting the material menu, then pointing the camera at the downloaded marker.
4. Then the way to play the quiz is to choose one of the answers. The quiz time limit is 300 seconds, with a total of 5 questions that must be answered. Each question has 20 points, so your total will increase by 20 each time you answer the question correctly.

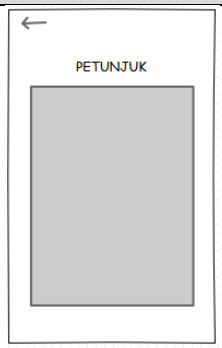
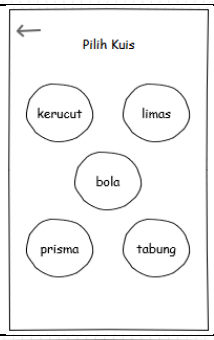
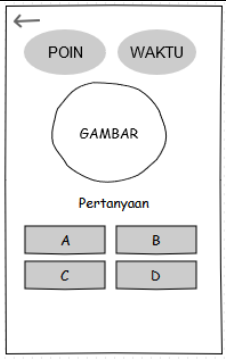
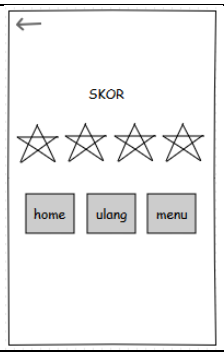
5. There are two categories of questions that will be issued: volumetric questions and surface area questions. The questions issued are randomized using the Linear Congruential Generator method.
6. The time and points earned will be processed using the Fuzzy Tsukamoto method. And then display the star score.

Storyboard

A storyboard is used to describe the description of each scene contained in the application. The following is a storyboard explaining the design that will be displayed in Table 1.

Tabel 1. Story Board

View	Description
	**Splash Screen** On the Splash Screen Page there is an Application Logo and Title
	**Menu Display** In the menu view there are 5 menus, namely : 1. Material: displaying an AR camera 2. Quiz: displays quiz options. 3. Instructions: displays instructions for using the application. 4. Download the marker: to download the marker 5. Exit: to exit the application
	**Material Display** On the material display, it will display an AR camera and 3 buttons, namely : 1. Explanation: Explanation about building space 2. LP: Explanation of Surface Area 3. V : Explanation of the Volume of Buildings

View	Description
	**Instruction Display** On the instructions page, it describes how to use the application.
	Quiz Menu Display In the quiz menu display, there are five buttons to display questions according to the type of building space.
	**Quiz View** • There is a countdown timer and points earned, and there are pictures of questions and questions. Then there are several answer choices. • The problem that will be displayed is a story problem. • The story problem lies in "understanding the problem," namely the ability to know what is known from the problem, what is asked in the problem, what information is needed, and how to solve the problem.
	**Score Display** On the score display, there are stars earned by players along with three *buttons*, namely: 1. Menu: To return to the quiz menu 2. Retake: to repeat the quiz 3. Home: to return to the main menu

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IMPLEMENTATION

Asset Creation

The initial process is the creation of assets in accordance with the storyboard that has been made. Asset creation uses Adobe Illustrator CC 2014 software, and three-dimensional object creation uses Blender software. Blender supports all three-dimensional workflows such as modelling, rigging, animation, simulation, rendering, compositing, and motion tracking.

Figure 2. UI Design

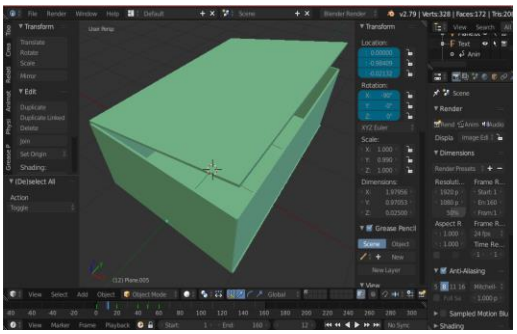
Figure 3. Three Dimension Object

The next step was the creation of the marker using Adobe Illustrator 2014 CC shown in Figure 4. The materials that have been collected are then assembled using Unity 5.5.1 and the C# programming language. Unity is a platform-based game engine (Figure 5).

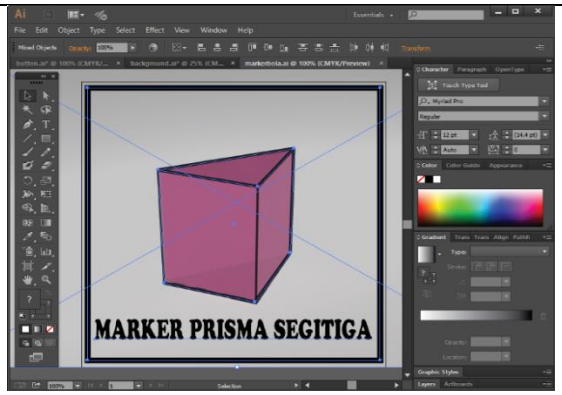

Figure 4. Marker


Figure 5. Game Development in Unity

Fuzzy Tsukamoto Implementation

In determining the score using the Tsukamoto fuzzy method, there are several stages, specifically determining the fuzzy set, determining the membership function, and determining the rule. Then, in the score calculation process, the value of time and points will be calculated according to the membership function that has been made, and defuzzification will be calculated by the centralized average method.

Table 2. Fuzzy

Variable	Fuzzy Input Set	Range
Time	Slow	225 – 300 seconds
	Medium	150 – 300 seconds
	Fast	75 – 225 seconds
	Very Fast	75 – 150 seconds
Poin	Low	25 – 50
	Medium	25 – 75
	Many	50 – 100
	High	75 – 100
Variable	**Fuzzy output set**	**Range**
Skor	Less	0 – 25
	Simply	25 – 50
	Good	50 – 75
	Very good	76 – 100

Figure 6, 7 and 8 show the membership function of each variable:

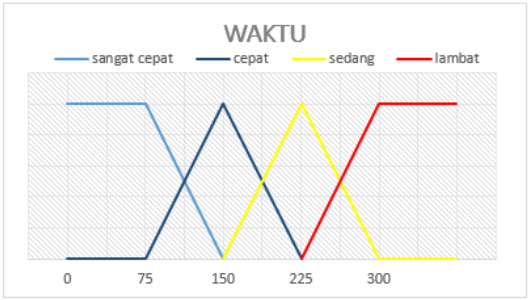

Figure 6. Time Membership Function

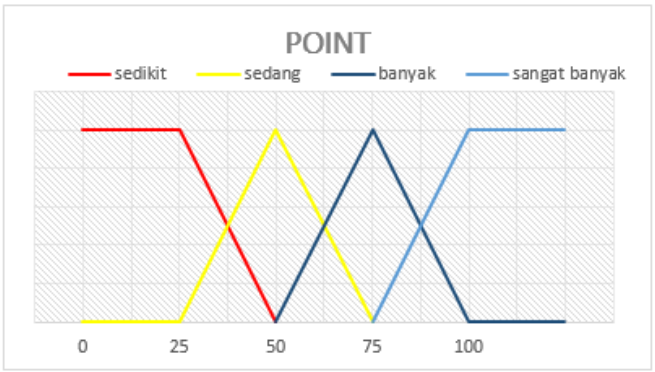

Figure 7. Point Membership Function

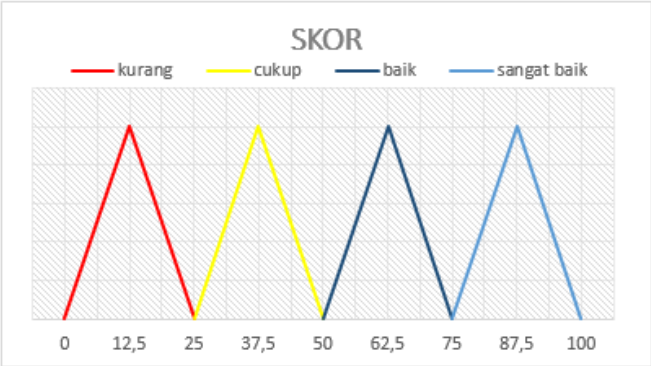

Figure 8. Score Membership Function

Next in table 3, shows the composition of the Fuzzy Tsukamoto rules used in the Augmented Reality Geometry application.

Table 3. Rule Composition

IF	Time	Point	Score
R1	Very Fast	A little	Low
R2	Very Fast	Medium	Good
R3	Very Fast	Many	Good
R4	Very Fast	High	Very good
R5	Fast	A little	Low
R6	Fast	Medium	Low
R7	Fast	Many	Good
R8	Fast	High	Good
R9	Medium	A little	Less
R10	Medium	Medium	Low
R11	Medium	Many	Low
R12	Medium	High	Good
R13	Slow	A little	Less
R14	Slow	Medium	Less
R15	Slow	Many	Low
R16	Slow	High	Low

RESULTS AND DISCUSSION

The following is the result of the application that has been installed on the android smartphone device shown in Figure 9.

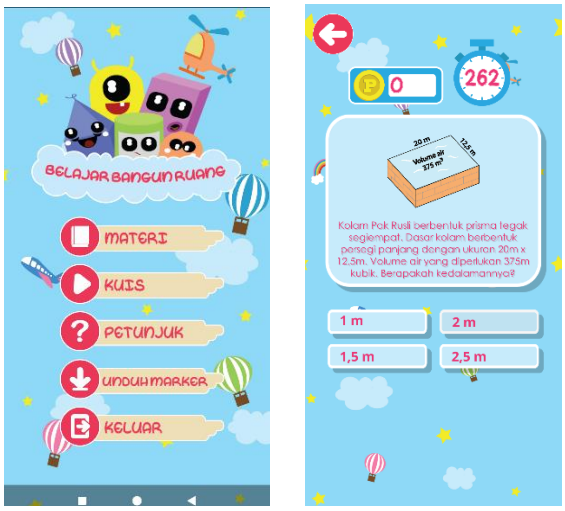

Figure 9. Smartphone Display

Here are the test results of the Linear Congruential Generator method for randomizing questions and the Fuzzy Tsukamoto method for score calculations that have been carried out, and it can be seen that the LCG and Fuzzy Tsukamoto methods are successfully applied to the Augmented Reality Geometry application.

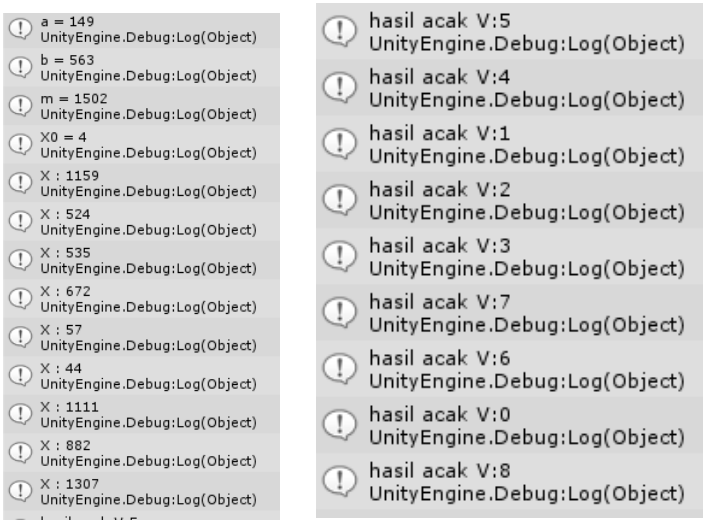

Figure 10. LCG Randomisation Result

Testing the LCG method is seen from the console unity which shows that it can generate random numbers.

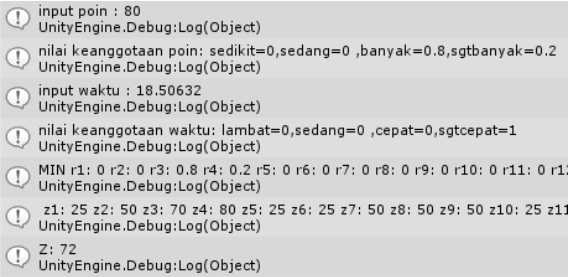

Figure 11. Fuzzy Tsukamoto Calculation Results

The test above shows that the Fuzzy Tsukamoto method can generate scores based on point and time inputs. Additionally, the results of the questionnaire that has been filled out by respondents are shown in Figure 12 below.

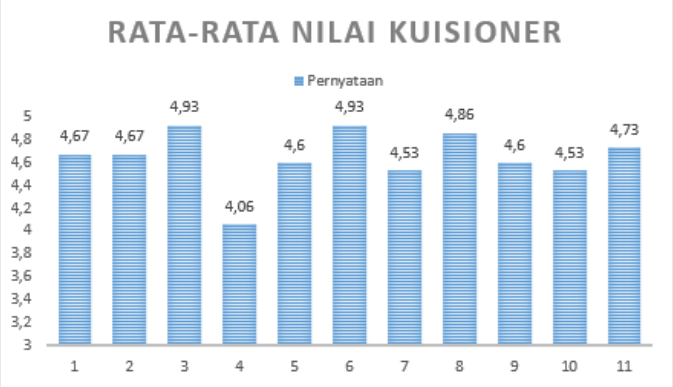

Figure 12. Average Questionnaire Results

From the results of questionnaires obtained from 15 respondents, consisting of 5 teacher respondents and 10 student respondents who have tried the Augmented Reality Geometry application, the statements "Applications can train and arouse students' interest in learning geometry" and "provide information that is easy to understand" obtained the highest scores.Additionally, the average score for all assertions on a scale of 5.0 is 4.64, indicating that respondents provided accurate responses for the Augmented Reality Geometry application.

CONCLUSIONS

Based on the research that has been done, it can be concluded that AR application an work well following the concepts and designs that have been made

1. The Linear Congruential Generator (LCG) method is successfully applied in the Augmented Reality Geometry application as a question randomizer on the quiz.

2. The Fuzzy Tsukamoto method is successfully applied in the Augmented Reality Geometry application as a determinant of the score obtained by the player and displays stars.
3. From the results of the questionnaire, respondents answered well, with a score of 4.64 on a scale of 5, or 92.8%, for the Augmented Reality Geometry application.

CONFLICT OF INTEREST DISCLOSURE

The authors have disclosed that they have no potential conflicts of interest.

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