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Implementation of multimarker augmented reality on solar system simulations

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Abstract: The solar system is one of the natural phenomena taught at school. However, delivering the material is still text-based. One of the current technology-based learning uses technology Augmented Reality as a support for learning aid. Augmented Reality is an integrated two worlds, the real and the virtual. Augmented Reality for the solar system learning application was developed by applying the concept of the Rule-Based System algorithm as a simple artificial intelligence that aims to help augmented reality systems in simulating knowledge and experience from humans with several rules prepared. The existence of Augmented Reality facilitates the process of learning on specific topics such as the solar system more attractive and interactive, with aims to inspire students to learn the solar system. Based on the testing results at SDN Purwantoro 2 Malang, Indonesia 95% of respondents are interested and captivated by learning media applications using Augmented Reality technology.

Keywords: augmented reality, solar system, learning aid

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Introduction

The solar system is one of the subjects taken from natural science lessons taught at school. Most of the studies are still in a conventional method, textbooks-centered, and lack teaching aids. Students must memorize and imagine, without barely knowing the planets, the solar system, solar eclipse, etc. One of the lessons that have adopted current technology is learning media through AR (Augmented Reality) technology [1].

In recent years, AR (Augmented Reality) technology has grown rapidly and applied in various fields. Augmented Reality is an integrated world between the real and the virtual. Combining these things is expected to help clarify the information provided to make it more exciting and feasible. Augmented Reality development aims to make clear and neat for the present situation of the users, wherein Augmented Reality systems apply media in the real world as markers to create 2D or 3D objects [2]–[4].

By using the concept of the Rule-based method as an Artificial Intelligence that helps Augmented Reality systems run knowledge and experience from humans by following several rules. Simply put, the Rule-Based System method is designed to solve a complex problem using if-else rules. The definition of a Rule-based Expert System is defined in reference [5]: "An Expert System can be defined as a collection of programs that use the human experience as knowledge, that knowledge is stored in a coded form and can solve a problem." The combining concepts of Augmented Reality and Rule-Based systems believes that by combining information that the Rule-Based system has processed, the effectiveness of Augmented Reality increases significantly and makes it easier to perform.

This research will create an Augmented Reality-based application to simulate the Solar System. The purpose of the study is to help elementary students learn the basics of the Solar System; the target of this application is elementary students studying the Solar System by applying Augmented Reality (AR) to make learning activities more fun and interesting through the display of the 3D object.

Methodology

The work structure that will be applied to this system uses concepts and flows taken from the Multimedia Development Life Cycle. The method has 6 (six) stages: concept, design, collecting, assembly, testing, and distribution, as disclosed in reference [6], [7].

Concept

The concept is the initial stage in the MDLC cycle. The concept stage began with determining the purpose of making the application and the user of the application. The purpose of the study is to help elementary students in learning the basics of the Solar System; the target of this application is elementary students who are studying the Solar System by applying Augmented Reality to make learning more fun and engaging through the display of the 3D object.

Design

A mature concept makes it easy to describe what should be done. The design is focused on the process of creating the specifications in detail about the project architecture, the appearance, and the needs of project material and style. In the design stage, several flowcharts describe the flow of the application so that the final results are by the concept stage, namely; Use case diagrams and Flowchart diagrams.

Material Collecting

Collecting material is the stage for collecting materials that are suitable for the student's needs. These materials include 3D objects, markers, animation, video, audio, and text that has been made or that still need to be modified according to existing needs. The author designed 3D objects by utilizing references from books about the solar system in elementary schools, designing as closely as possible according to references.

Assembly

Assembly Stage is the stage of making all multimedia materials. The application to be created is based on the design stage, and according to the design of the Flow Chart. Some applications used in this stage are Unity, Vuforia Database, 3Ds Max, and Corel Draw X7.

Testing

Testing is done to ensure that the results of making multimedia applications are following the plan. Stages of the black box testing carry out the tests by the application maker. Then they will be given to be tested by the end-user.

Distribution

This stage is the last step in the development cycle of this method. Distribution can be done after the application is declared feasible to use. The application will be stored on a storage device such as a CD or mobile device at this stage. The cube markers can be stored in the form that has been made or still in the raw form that still needs to be printed.

Use Case Diagram

Use Case diagram describes the relationships that occur between actors with activities that occur in a system. Actors in the system are users, while the system is an augmented reality application. The design of the use case diagram is shown in Figure 1. Use Case Diagram.

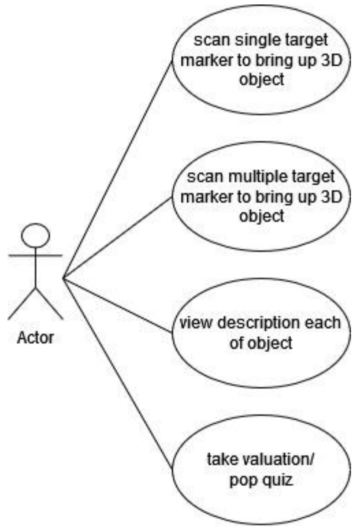

Figure 1. Use case diagram

From the use-case diagram, we can find out the definition of system functional and operational requirements. The definition of each use case is:

a. Scan Object marker to bring up the 3D object
   The system detects a marker, and if the marker is suitable it will issue objects in the form of 3 dimensions.
b. Scan 2 Object (Combine Object)
   The system detects 2 or more markers, and if the marker matches the rule-based method applied, a new object will appear.
c. View Description of each object
   The system will display a description of an object that has been scanned marker. The description can be a brief explanation of a planet.
d. Take Evaluation / Pop Quiz
   The system will display the quiz feature, where the user is required to answer a short question that is randomized to the order so that one user with another user will get a different question.

Flow Chart

The overall system flow for the Solar System Learning Media in the form of flowcharts is as to Figure 2 Flow Chart.

a. Learn Menu
   If the user selects the Learn menu, the application will direct the user to a camera display interface, where the user can scan the marker prepared. If the marker scanned is only 1 piece, the system will check whether the object is in accordance with the database. Otherwise, the system will not respond until the object is the same as the database.
b. Quiz Menu
   After the user plays and learns in the learn menu, the user will be directed to a test Evaluating the understanding of the Solar System that has been explained in the Scan Menu. The system will scramble the questions that have been provided by the author using the Linear Congruential Generator method, then it will be displayed to the user.
c. Menu Description
   In the description menu, the system will display a popup description of the selected planet, in that popup, there is an explanation of the planet.
d. Exit Menu
   The exit button is used to end the application.

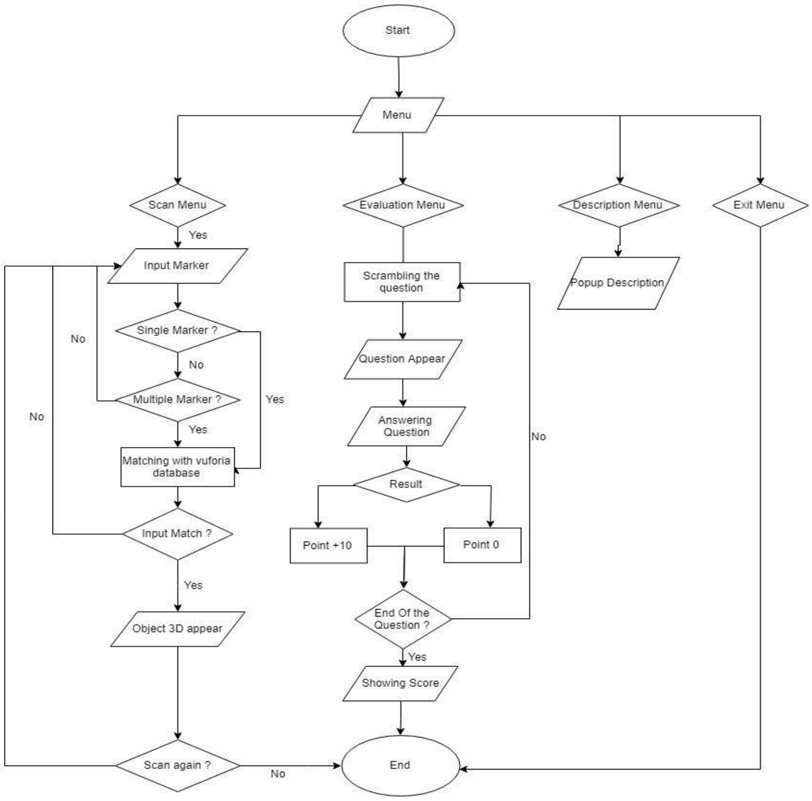

Figure 2. Flow chart

Marker Design

The function of the marker is to bring up a three-dimensional object if the marker is scanned by the camera. Markers are made in Corel draw X4. Figure 3 shows the marker design that has been made. The design marker shows a picture and the name of the planet (Nama Planet in Bahasa Indonesia).

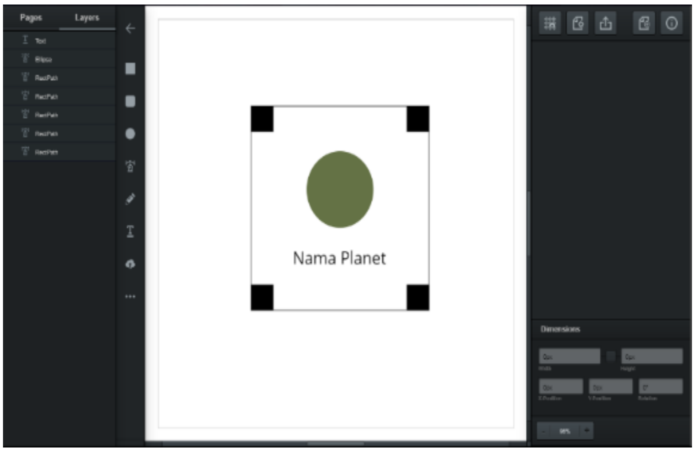

Figure 3. Design marker

Designing Interface

Designing User-Interface will be built using unity, and will also be a compiler so that project unity can be run in android in the form of an extension (.apk). The programming language used is C Sharp (C #). In the design, there are several User Interface pages, Figure 4 shows the main menu design, Figure 5 shows the AR design, Figure 6 shows the description of the planet, and Figure 7 shows the quiz page.

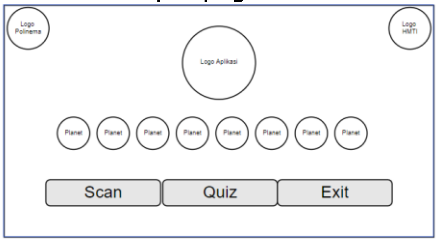

Figure 4. Main menu design

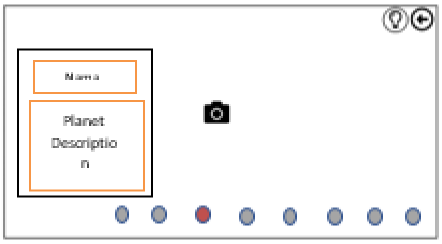

Figure 5. Augmented reality design

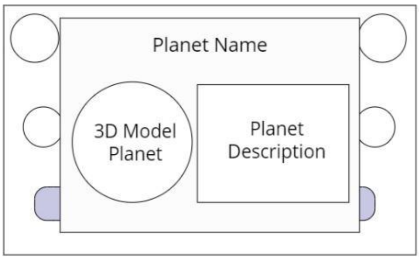

Figure 6. Design description of the planet

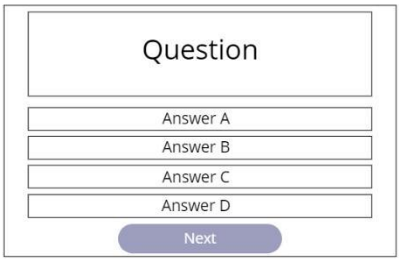

Figure 7. Quiz page

3D Planet Model Design

The process of making three-dimensional models of this application uses the Autodesk 3Ds Max version 2015. Figure 8 shows the process of developing the three-dimensional planet models.

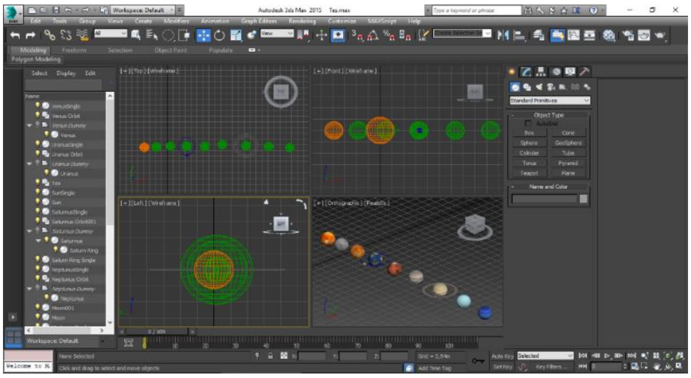

Figure 8. 3D planet models

Designing a Rule-Based System

The rule "if" translated literally has rules. Around us, there are so many rules that exist. The function of these rules is to limit what is done. Examples of rules that exist in life are laws, traffic rules, and rules for using objects. In IT terms, Rule-Based Systems will provide a tool that is useful in the development of specific applications. According to a reference to a book[8], the basic form of a rule-based system is as follows.

rule: (preconditions) -> (conclusions) (1)

Where conditions (preconditions) are a formula that defines when the rule or rule is applied, and the results (conclusions) are the effects of the application of the rule or rule [9]. Table 1 describes the rules in the solar system application.

Table 1. Rules in rule-based systems

Information	Condition (Rule)	Results (Conclusions)
Solar markers	Detected by camera	Display descriptions of the moon in the form of text & audio, and the position of the sun.
Moon Marker	Detected by camera	Displays a description of the moon in the form of text & audio, and the position of the moon.
Mercury Marker	Detected camera	Display descriptions of planets in the form of text & audio, and Mercury's position in the solar system.
Venus Marker	Detected by camera	Displays a description of the planet in the form of text & audio, and the position of Venus in the solar system.
Earth Markers	Detected by camera	Display descriptions of planets in the form of text & audio, and the position of the earth in the solar system.
Mars Markers	Detected camera	Display descriptions of planets in the form of text & audio, and the position of Mars in the solar system.
Jupiter Marker	Detected by camera	Displays descriptions of planets in the form of text & audio, and Jupiter positions in the solar system.
Saturn Markers	Detected by camera	Display descriptions of planets in the form of text & audio, and Saturn's position in the solar system.
Uranus Markers	Detected by camera	Display descriptions of planets in the form of text & audio, and Saturn's position in the solar system.
Neptune marker	Detected by camera	Displays descriptions of planets in the form of text & audio, and the position of Neptune in the solar system.
Earth & Moon Markers	Detected by camera	The condition if the marker of earth and moon caught by the camera device is to eliminate the 3-dimensional model of the two markers, then the new 3-dimensional model will emerge along with the available animations.

Results and Discussions

Marker Implementation

The application used the markers of planets in the solar system. Markers are created using Corel draw X4 software with an extension file.jpg. Markers that have been created will be entered into the Vuforia database. Figure 9 shows the sun, earth, and moon markers.

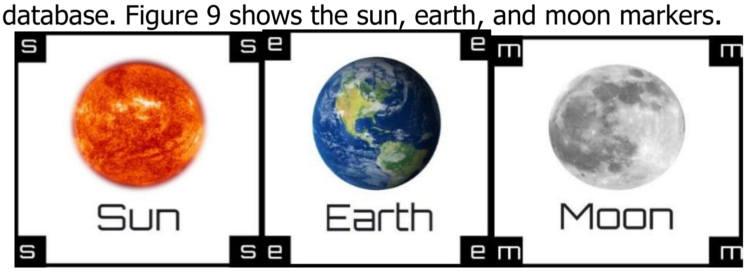

Figure 9. Marker

Interface Implementation

The interface implementation appears on the application. The following are the interfaces contained in the application according to the design that was built in the previous chapter. Figure 10 shows the home menu interface of the application. Figure 11 shows the scan marker window. Figure 12 shows the scene description Interface, the description of the planet written in Bahasa Indonesia. Figure 13 shows the quiz page. Each question is written in Bahasa Indonesia.

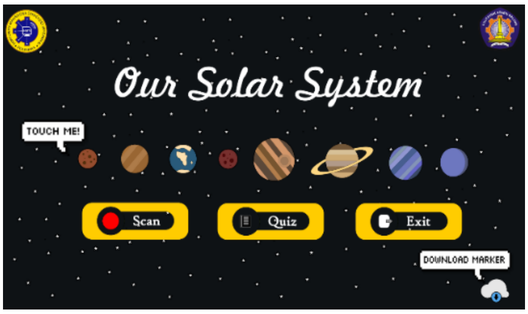

Figure 10. Scene menu interface

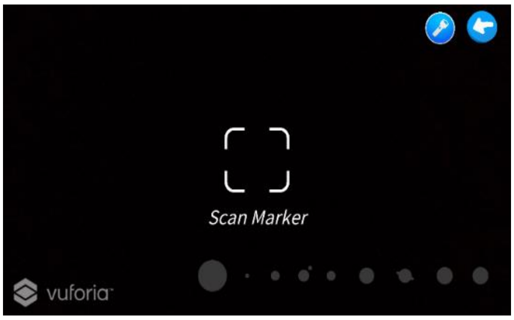

Figure 11. Scene scan marker

Figure 12. Scene description interface

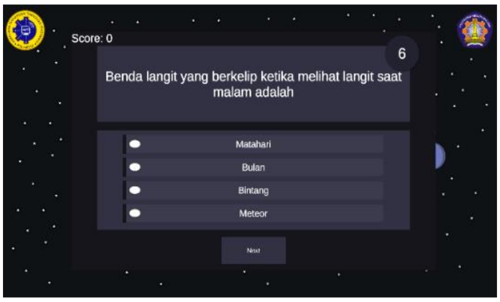

Figure 13. Quiz page

Augmented Reality Testing

Augmented RealityTesting is testing a system to test all the components that have already been designed and implemented into the system. The purpose of this test is to test whether markers that have been entered into the Vuforia database are running and can display object 3 in the application. Figure 14 shows the augmented reality content of the marker.

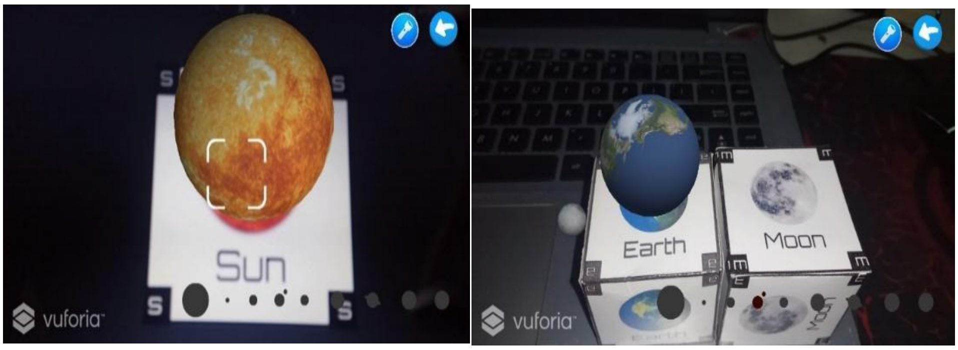

Figure 14. Augmented reality result

Marker Efficiency Testing

The process of identifying markers was carried out to determine the marker pattern by searching for the marker pattern captured by the camera recorded by reference comparison on the stored marker pattern file and integrated into the program [10]. Table 2 describes the results of the test markers. The distance column shows the distance between the camera and the target marker. The degree of angle column shows the camera angle with the target marker. The lightning column describes the conditions of the environment used at the time of testing. For example, dark light indicates the condition of a dark room. The results column shows the testing process results, whether the content can appear properly or not.

Table 2. Test markers

Distance	Degree of angle	Lighting	Results
5 cm	0	Dark light assisted flashlight	• The tracking process does not find a target
5 cm	15	Dark light	• The tracking process does not find the target
5 cm	25	Dark light, assisted by flash-light	• Tracking does not find the target
10 cm	0	Dark light	• The tracking process does not find the target
10 cm	0	light is dark, assisted by flashlight	• The tracking process is easy to find the tar-get
			• 3D objects are only partially visible Anima-tion runs
10 cm	0	Light is sufficient	• The tracking process is easy to find the tar-get
			• 3D objects only appear partially Animation runs
15 cm	0	Dark light	• The tracking process does not find the target
15 cm	0	Dark light, assisted by flash-light	• The tracking process is easy to find the tar-get
			• 3D objects are only partially visible Anima-tion runs
15 cm	0	Light is sufficient	• The tracking process is easy to find targets
			• 3D objects only partially visible Animation runs
20 cm	0	Dark light	• The tracking process does not find a target of
20 cm	0	Dark light, assisted by flash-light	• The tracking process is easy to find the tar-get
			• 3D objects only appear partially Animation runs
20 cm	0	Enough light	• The tracking process is easy to find the tar-get
			• 3D objects only appear partially Running ani-mations

The test results in Table 2 show that the test results indicate the conditions under which the solar system application can run well. The ideal conditions for solar system applications are between 10-20 cm with sufficient lighting conditions.

Testing

Applications trial to users taken place at SD Purwantoro, Kelurahan Purwantoro, Blimbing, Malang, East Java. The author conducted a user acceptance test, "Solar System Learning Media Based on Augmented Reality Using Cube Object Marker" to grade 6 students, with total respondents of 18 students. The test activities are shown in Figure 15.

Figure 15. User acceptance test

The author distributes questionnaires to students to assess applications of Solar System Simulation. There are 7 questions developed in the questionnaire. The first question is regarding the ease of use of the application. The second question is about content design. The third question is regarding the clarity of the appearance of 3D objects. The fourth question is regarding the clarity of content description. The fifth question is regarding content animation. The sixth question is regarding the interest in AR in general. The seventh question regarding the intention to use the AR solar system application. The results obtained from the testing process of 18 respondents shown in table 3 are as follows, one respondent answered that the solar system simulation application was not attractive, two respondents stated that the 3D objects made were unclear and unattractive. Three respondents had difficulty understanding the description of the solar system simulation. The results of the questionnaire that have been distributed to students are shown in Table 3.

Table 3. Student questionnaire result

Question Number (Q)	Result (%)	
	Yes	No.
Q1	100%	0%
Q2	100%	0%
Q3	100%	0%
Q4	94%	6%
Q5	88%	12%
Q6	83%	17%
Q7	100%	0%

The percentage of results obtained from student questionnaires is calculated by summing all the percentage results obtained in each question category.

$$total\ percentage = \frac{Q1\%+Q2\%+Q3\%+Q4\%+Q5\%+Q6\%+Q7\%}{Total\ number\ of\ Question} \tag{2}$$

The total results obtained are ± 95% so it can be stated that this application is helpful to elementary students in 6th grade in learning the Solar System.

Conclusion

Augmented Reality Solar System applications have been successfully applied to the education sector by bringing up 3D objects and descriptions in the solar system. From the test on the subject of the use of AR for solar system simulations, the result shows that 95% of respondents gave a positive response. Augmented Reality technology makes it easier to simulate the planets in the solar system more realistically and interactively to arouse students' enthusiasm to learn about the solar system. The rule-based method used in this application can run well and according to system requirements. The application can detect both one marker and multiple markers.

Acknowledgments

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