Learning Media Development for Basic Arithmetic Concept with Interactive Augmented Reality

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ABSTRACT
Demands and needs for learning media are now increasingly complex. These demands become a challenge to build an interactive instruction system that is designed and implemented as a basic arithmetic learning media prototype in Mathematics. Every student's learning interest in Mathematics, especially basic concept of Arithmetic, might be increased by stimulating the visual senses with an Augmented Reality technology. It allows students to interact with the learning media as a visual object that is incorporated into the real world through video display. The prototype that has been developed in this research used Augmented Reality Technology that is integrated with the basic concept of arithmetic involving its operands and operators as physical marker and visual objects that appear on the Smartphone screen with a real-world background captured by the camera. This application was developed by applying Linked List Concept to store a temporary sequence of markers that are successfully read by the device then processed in sequences as simple arithmetic operations. The results of the implementation testing show a low risk of complexity and meet all the designed functions. Then the application is ready to be tested for usability as a learning media.

CCS Concepts
• Software and its engineering → Software prototyping

Keywords
Interactive Augmented Reality; Learning Media; Linked List; Software development; Waterfall Method.

1. INTRODUCTION
The activity of studying mathematics in elementary school requires an improvisation to increase the student's learning interest. Some research had proved that learning mathematics through media, such as computer software, increased student's interest and had made a positive result on their learning process [1]. Also, it's discovered that computer's software could gain student's ability of problem-solving significantly. The research was based on testing computer-assisted video-based with structured instruction [2] and also exploratory problem-solving software [3]. Some research also showed higher ratings of students' presence when they were learning with visual display like a Head Mounted Displays (HMDs) [4].

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One of the basic techniques of teaching is to stimulate the visual senses with a technology that allows students to interact with the learning media, such as via Augmented Reality Technology. Augmented Reality technology has long been developed as a method to incorporate a visual object into the real world through video display [5].

The prototype that has been developed in this research is an implementation of Augmented Reality (AR) Model. It integrated the basic concept of arithmetic involving it's operands and operators as visual objects that appear on the Smartphone screen with a real-world background captured by the camera. Students are directed to interact with the application by directing operand and operator markers to be read by the camera. The app then displays 3D object corresponding to the marker, sorts the values and then calculates the result of operation by the order of marker's input based on the basic rules of arithmetic [6].

AR itself is a variation of the Virtual Environment (VE) or commonly referred to Virtual Reality (VR). This VR technology creates a simulation where the users feel as if they are inside an artificial environment and cannot see the real world around them. Then AR is a model that allows users to view the real world with additional virtual objects that are combined with the surrounding environment captured by camera [7]. AR can be interpreted as the midline between the Virtual Environment (fully synthetic) and tele-presence (fully real) [8]. Milgram and Kishino (1994) defined the combination between Virtual and Real environment that is viewed as lying at opposite ends of a Reality-Virtuality (RV) continuum. This concept is illustrated in Figure 1.

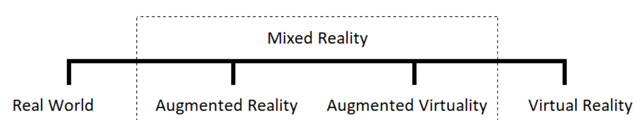


Figure 1. Reality-Virtuality Continuum by Milgram and Kishino

Since it was first researched, Augmented Reality (AR) technology has experienced steady progress as a method to smoothly combine the real and virtual world. The basics in the study of Augmented Reality are the concepts of tracking, display and input devices [9]. Learning media needs are increasingly complex and pose challenges to building interactive instruction systems. The interactive instruction model is built using the basic principles of

AR that are able to recognize input in the form of physical objects that are read as input to display visual objects [10]. In other studies, AR technology has been proven to help students observe a natural phenomenon by using AR markers to manipulate various virtual objects and observe changes that occur [11].

Simple arithmetic operations consist of addition, subtraction, multiplication and division. This operation is then further developed as the basis of operand manipulation such as percentage, root, rank, and logarithmic functions. Arithmetic is calculated in the order of its operation [12]. In basic arithmetic operators, the first priority of operations is multiplication and division, the second priority is the addition and subtraction operations. This system's need is to receive data input in the form of infix notation which will be converted into postfix notation to be operated. This postfix notation is used to check the priority of operations. It can be automated and process a more complex operation than using infix notation. The operands and operators that are used in the operation are collected into the data sets inside the algorithm.

The Linked List has a similarity to the array as both are used to store the data sets [13]. Unlike the array that allocates memory for all its elements into a single block of memory, the Linked List allocates space for each element separately in its own block called "Linked List Element" or "Node". The list gets its whole structure by using a pointer that connects all the nodes as a chain. Each node has two fields; the data field and next field. The data field is used to store any type of element stored in the list, while the next field is used as a pointer to connect a node to the next node [14]. This Linked List will then be used in this research to arrange the order structure of the readings of Augmented Reality marker on simple arithmetic operation application developed.

Generally, application requirements can be defined in full, explicit, and correct at the beginning of the project. Thus an application development method is needed that can answer the problem in sequence by defining in detail the application requirements into a design. After the draft is prepared carefully, the application can be implemented and then unit testing is done before it can be released. Waterfall model is described as an example of a flawed, non-working model. The actual process may vary depends on a prototype, it is not always in a strict top-down model [15]. The original waterfall model followed in order by System and software requirements, Analysis, Design, Coding, Testing and Operations [16]. This model is illustrated in Figure 2.

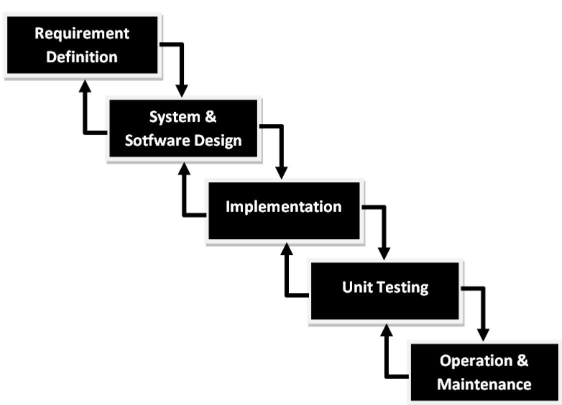


Figure 2. Waterfall Software Process Model

2. REQUIREMENTS

Software is purposed of reading the order of the marker and registering the sequence on the Linked List for reprocessing. The application works by pointing the camera towards the marker one by one. Users will get information displayed on the screen of the device, including 3D models displayed when markers are detected, what marker text is currently detected, current Linked List content, notifications for errors or calculations, number of currently detected objects, and conversion results from infix notation to postfix. The developed applications require as follows:

1. The system can access the camera of the device used.
2. System can detect marker and display model according to marker.
3. The system can enter the value of the operand marker and operator into the Linked List.
4. The system can display notifications when marker equals are read, which contains a blank list notification, failed operation, or the result of an arithmetic calculation.
5. The system can calculate from the input in the form of Linked List with infix notation content.
6. The system can perform arithmetic calculations by converting infix notation to postfix notation.
7. System can eliminate 3D model if marker not detected by camera.
8. The system is able to reset the content of the Linked List and the variables used when the missing marker is of type equals.

3. DESIGN

At the start of the application, the camera of the mobile device will be activated to read the marker. When the marker is detected, the system will display the 3D Model based on the marker listed in the database and then distinguish whether the detected object is classified as an operand, operator, or equals. When an object is detected as an operand or operator, the system will enter the value of the detected object into the Linked List. If the system detects an object of type equals, then the system will distinguish whether the Linked List is filled or not. If the Linked List is not loaded, the system will display a notification showing that the list is empty and does not perform the operation. If the Linked List is filled, the system will check for arithmetic operation requirements. If there is an error in the content in the Linked List, the system will display a notification that the operation failed. In addition the system will perform calculations and display the results of arithmetic operations. When the "equals" marker is kept away from the camera, the system will perform a reset function. This function resets the variables and the Linked List used during the application running to its original state. The system will also remove the 3D model from the user's device display when any type marker disappears from the camera view of the device.

There are two types of assets used in this research; the first is 2D physical Marker with 24-bit color depth level stored to jpeg format, second is 3D visual model. Each asset consists of ten operand assets, comprising the numbers 0 to 9. The operator assets, consisting of sums (+), subtract (-), multiplication (*), division (/), Exponent (^), opening and closing parenthesis, and also special assets of type equals (=). List of asset requirements in the application is shown in Table 1.

Table 1. List of asset requirements

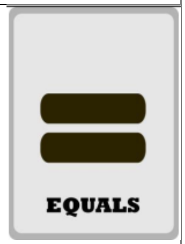
Type	Function	Work Principle	Example asset
2D Assets	Printed as physical markers	Read by camera to marked area that will be placed by 3D virtual object in monitor display. • Number marker; used as operands • Arithmetical symbols; used as operator between two or more operands • Equals marker; as executor of all arithmetical marker's queue	 EQUALS
3D Assets	Virtual Objects	Placed by system above the physical markers	

Figure 3 shows a sequential diagram that summarizes the design of interactions between objects and classes involved in application scenarios to carry out functions of Interactive AR. First of all, the Camera scans the environment in front of it to find a frame as 2D markers. Then the camera will track the image pattern inside the marker frame and match it to the list of images stored in the system database. If there is a match, the system will access 3D object assets and it's value, then add the value to the list. Finally, the system will augment the asset above the 2D marker image and combine it into the camera's capture of real environment.

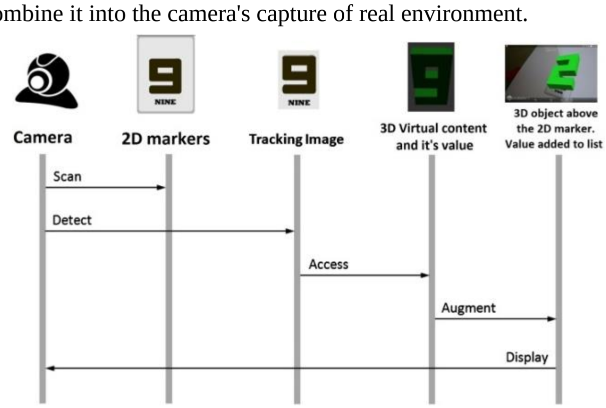


Figure 3. Sequence Diagram of the Interactive AR designed

4. IMPLEMENTATION

The printed physical markers are first stored in the "Vuforia" database server library and imported into the "Unity 3D" engine. Furthermore the database has been filled in all marker files imported engine. Figure 4 shows the order of implemented system. Operand marker detected by camera and displays the 3D model visualization. Marker is read sequentially from operand 2, multiplication operator, open bracket operator, operand 8, reduction operator, closing bracket operator, power operator and operand 3. The calculation will be performed when the device camera captures the marker "equals". Operation count 2 * (8-5) ^ 3 yields the value 54 derived from postfix operation 285-3 ^ *.

Figure 4. The Order of System's Scenario

5. TESTING AND ANALYSYS

This test is performed to determine the value of Cyclomatic Complexity of the method used as the basis of the process of reading and marker processing. Figure 5 is the Flow Graph of the method. In the Flow Graph there are nine independent channels:

1. Line 1: 1-2-3-4-5-6-7-8-19-28
2. Line 2: 1-2-3-4-5-6-9-10-11-19-28
3. Line 3: 1-2-3-4-5-6-9-12-13-14-15-19-28
4. Line 4: 1-2-3-4-5-6-9-12-13-14-16-17-19-28
5. Line 5: 1-2-3-4-5-6-9-12-13-18-19-2853
6. Line 6: 1-2-3-4-5-6-9-12-19-28
7. Line 7: 1-2-20-21-22-23-24-25-26-27-28
8. Line 8: 1-2-20-21-22-25-26-27-28
9. Line 9: 1-2-20-27-28

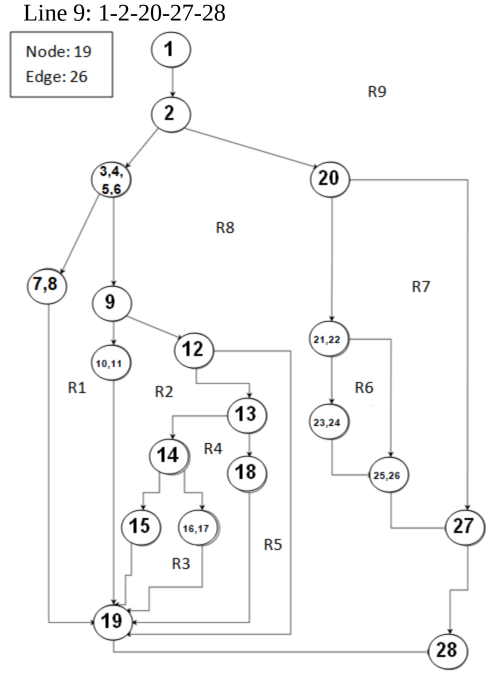


Figure 5. Flow Graph of the method

Mathematical calculations of Cyclomatic Complexity – V(G), as follows [17]:

$$V(G) = E - N + 2 \quad (1)$$

Then

$$V(G) = P + 1 \quad (2)$$

Which *V(G)* means total region, *E* for Total of edges, N for Total of nodes and *P* for Predicate nodes. The Cyclomatic Complexity based on (1), (2) and Flow Graph at Figure 5 are:

1. V(G) = 9, since there are 9 regions (R1 to R9).
2. V(G) = 26 - 19 + 2 = 9; as there are 26 edges and 19 nodes.
3. V(G) = 8 + 1 = 9, because there are 8 predicate nodes.

Thus, it can be concluded that the value of V(G) in the above Flow Graph is 9, which means the risk of complexity is low. Low risk complexity of this development has an impact on the low effort required in carrying out maintenance [18].

After testing of each independent path, then the functional testing results of the application shown in Table 2. There are nine units tested. From the table below it concludes that all of the functions designed are working properly to meet the requirements and the application is operable.

Table 2. Functional testing results of the application

No.	Function	Validity
1	3D models with markers of operand type successfully displayed and inserted into the linked list	Valid
2	3D models with operator type markers are successfully displayed and inserted into the linked list	Valid
3	3D models with markers of type equals successfully displayed, the notification appears to fail to perform the operation because the value of the isError method is true	Valid
4	3D models with markers of type equals successfully displayed, a notification appears in the form of calculations.	Valid
5	3D models with markers of type equals successfully displayed, a notification appears that the list is empty	Valid
6	3D model whose unknown marker type is displayed on the screen	Valid
7	3D models with markers of the equals type stop showing, the system resets the value of the variable and the contents of the linked list	Valid
8	3D models with markers other than equals stop appearing	Valid
9	The system eliminates 3D models when there is no transfer state	Valid

6. CONCLUSION

Based on the results of application development in this research can be concluded that the system has met the needs in accordance with the design with a low level of complexity so that it needs low effort in carrying out maintenance. All functions have been designed to work properly in order to meet the requirements and the application is operable. In the next stage the application can be tested its usability based on learning media test rules.

7. REFERENCES

[1] Mushi, S. 2000. *Use of interactive video technology to teach middle school mathematics*. Chicago: Northeastern Illinois University.

[2] Shyu, H. Y. 1999. Effects of media attributes in anchored instruction. *Journal of Educational Computing Research*, 21(2), 119-139.

[3] Funkhouser, C. 1993. The influence of problem-solving software on student attitudes about mathematics. *Journal of Research on Computing in Education*, 25(3), 339-346.

[4] Moreno, R., & Mayer, R. E. .2002. Learning science in virtual reality multimedia environments: *Role of methods and media. Journal of educational psychology*, 94(3), 598.

[5] Milgram, P., & Kishino, F. 1994. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77(12), 1321-1329.

[6] Wijaya, H., Wardhono, W., & Arwani, I. 2018. Implementasi Linked List pada Interaksi Antar Marker Augmented Reality untuk Operand dan Operator Aritmetika. *Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer, 2*(9), 3328-3332.

[7] Azuma, R. T. 1997. A survey of augmented reality. *Presence: Teleoperators & Virtual Environments*, 6(4), 355-385.

[8] Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. 1995. Augmented reality: A class of displays on the reality-virtuality continuum. *Telemanipulator and telepresence technologies* (Vol. 2351, pp. 282-293). International Society for Optics and Photonics.

[9] Billinghurst, M., Clark, A., & Lee, G. 2015. A survey of augmented reality. *Foundations and Trends® in Human-Computer Interaction*, 8 (2-3), 73-272.

[10] Funk, M., Kosch, T., Greenwald, S. W., & Schmidt, A. (2015, November). A benchmark for interactive augmented reality instructions for assembly tasks. *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia* (pp. 253-257). ACM.

[11] Chang, R. C., Chung, L. Y., & Huang, Y. M. 2016. Developing an interactive augmented reality system as a complement to plant education and comparing its effectiveness with video learning. *Interactive Learning Environments*, 24 (6), 1245-1264.

[12] Tapson, F., 2006. *The Oxford mathematics study dictionary*. Oxford University Press

[13] Parlante, N., 2001. *Linked list basics*. Stanford CS Education Library, 1, p.25.

[14] Csegeek, 2013. *Types of Linked List* [online] <http://www.csegeek.com/csegeek/view/tutorials/algorithms/linked_list/list_intro.php> (Accessed: October 8, 2017)

[15] Benington, H. D. 1983. Production of large computer programs. *Annals of the History of Computing*, 5(4), 350-361.

[16] Royce, W. W. 1987. Managing the development of large software systems: concepts and techniques. *Proceedings of the 9th international conference on Software Engineering* (pp. 328-338). IEEE Computer Society Press.

[17] Pressman, R. S. 2005. *Software engineering: a practitioner's approach*. Palgrave Macmillan.

[18] Heitlager, I., Kuipers, T., & Visser, J. 2007. A Practical Model for Measuring Maintainability. In *Proceedings of the 6th International Conference on Quality of Information and Communications Technology* (pp. 30-39). IEEE Computer Society.