Original Research Article

Analyzing the Distance and Intensity of Light in Learning Augmented Reality Marker Based Tracking Application

ABSTRACT

Aims: This study aims to analyze the distance and intensity of light that is effective in displaying 3-dimensional virtual object images from applications using 3 different types of smartphone device models, and also to evaluate the level of user satisfaction using the USE Questionnaire and Likert scale in programming algorithm learning applications with augmented reality.
Study design: An application was made to help to program learning through physical media by using augmented reality. In testing the system with the black-box testing method, were get a successful answer for each scenario in the application test.
Place and Duration of Study: Department of Informatics, Universitas Multimedia Nusantara, between January 2022 and July 2022.
Methodology: The initial step in this research is a literature study to gather information about the theory of the research, and for the next step is design and analysis is carried out based on the literature study carried out, then application is made and then continued to testing and comparison, and for final step is evaluation and documentation, to make conclusion of this research.
Results: The results showed that the analysis of the marker-based tracking method was tested with variable indicators to prove the application succeeded in bringing up 3-dimensional objects at a minimum distance of 10 cm and for the maximum distance obtained was 163 cm, at the lowest intensity condition, namely 192 lux and the highest light intensity with 1620 lux, as well as camera specifications smartphone also affect the detection marker. Based on the questionnaires that have been distributed from 36 respondents, users get a percentage above 80% on each developed question which states the application is very effective.
Conclusion: The marker-based tracking method in the application has been successfully tested by testing the application using a marker on study cards. The lower the light intensity, the lower the camera specification smartphone, and the farther the detection distance of smartphone will affect the minimum and maximum distance in detecting markers to bring up 3-dimensional objects in the application.

Keywords: Augmented Reality; Distance and Intensity of Light; Learning Applications; Marker Based Tracking

1. INTRODUCTION

In this research, the implementation of augmented reality with the marker-based tracking method is used in learning programming algorithms through applications that are intended for students who want to learn about programming algorithms in a practical and easy way to learn [1],[2]. Augmented reality is a relatively new technology and is still being developed until now. The concept is to combine real-world dimensions with digital objects from the virtual world to create the impression of real-world dimensions enriched with three-dimensional visual objects [3]. The purpose of Augmented Reality is to help human performance in the virtual world, so that the surrounding environment can be visualized in the form of digital data [4],[5]. The use of augmented reality can assist individuals in seeing the results of the implementation or process of the program algorithm learning materials carried out [6],[7]. By utilizing the marker-based tracking method, which will read a marker pattern printed on physical media by a smartphone camera directed to the marker pattern section, the display on the smartphone will show the results of the implementation or process of the programming algorithm in the 3D visual form [8],[9]. In the marker-based tracking method, the program will still be able to recognize the marker pattern even though its position changes according to the camera device smartphone as long as the marker pattern still enters the camera's point of view [10]. The displayed 3-dimensional visual object will still stick to the marker pattern and each marker pattern will show a different 3-dimensional visual object [11].

Augmented reality based on the tracking method or tracking on the marker is influenced by the distance indicator and the amount of light intensity [12]. Currently, the marker-based tracking method is not yet known about the distance and effective light intensity based on the type of smartphone used [13]. Therefore, in this study, an analysis will be carried out on the effect of distance and light intensity on the success of bringing up virtual objects that will be tested using several types of smartphones. In this application, in this research will apply sorting algorithm learning materials because the sorting algorithm is a sorting algorithm that sorts a collection of data elements into a specific order based on the value of each element [14], [15]. This makes the sorting algorithm easier to apply in the form of a 3-dimensional visual model because it only requires elements that have random values which will then be animated from these random elements into the actual order of the values of each element based on a predetermined way from different types of sorting algorithms [16].

AR technology is growing rapidly because it provides a new experience in delivering information [17]. Through the development of increasingly sophisticated technology among children as well as among the productive age, providing education is getting easier, wrong the other is through Augmented Reality (AR) technology [18],[19]. Augmented reality based on the tracking method or tracking on marker is influenced by distance indicators and the amount of light intensity. Currently, the marker-based tracking method is not yet known about the distance and effective light intensity based on the type of smartphone device used [20]. Therefore, in this study, an analysis will be carried out on the effect of distance and light intensity on the success of bringing up virtual objects which will be tested using several types of smartphones.

2. METHODOLOGY

One method that can be applied to augmented reality is the marker-based tracking method by utilizing a marker which is a black and white square illustration with a thick black border and white background. Marker-based tracking is a augmented reality method that uses marker or a two-dimensional object marker that has a certain pattern which will then be read by the computer via webcam media or a camera connected to a computer. The computer will recognize the orientation position of the marker and create a 3-dimensional shape with the X, Y, and Z axes. The marker-based tracking method has long been developed for use as a method in augmented reality. In displaying 3-dimensional visual objects using the marker-based tracking method through the smartphone camera, the application will recognize the registered marker to display 3-dimensional visual objects on the smartphone camera. A visual description of the marker-based tracking method can be seen in Figure 1.

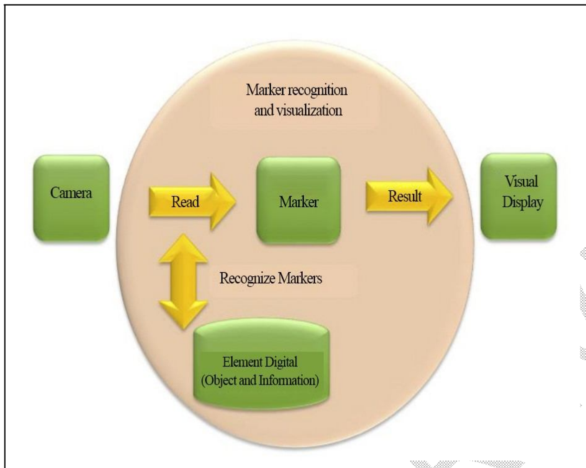


Fig. 1. Stages in the Marker-Based Tracking Method

Luminous intensity is a basic physical quantity to measure the power emitted by a light source in the direction of a certain unit angle [21]. In a study conducted by Kumar regarding the effect of the characteristics of lighting on tracking an object in a closed space in the application of mobile augmented reality light produced by several different colors of lamps with the same power turns out to produce different light intensities. The smaller the value of the light intensity received means the light emitted by the lamp is getting dimmer [22].

The application starts displaying a start page containing a menu list of applications consisting of each algorithm, namely the bubble sort algorithm, selection sort algorithm, and the insertion sort algorithm. When one of the menu lists is selected, the application will access the camera smartphone if the marker of one of the selected algorithms is visible on the camera, the smartphone screen will display a 3-dimensional object based on the shape of the marker and the previously selected menu option. When accessing the smartphone camera there is a back button to return the screen display to the home page where there are several choices of the sort algorithm. Flowchart in Figure 3 is a flowchart of the entire programming algorithm learning application using augmented reality with the marker-based tracking method.

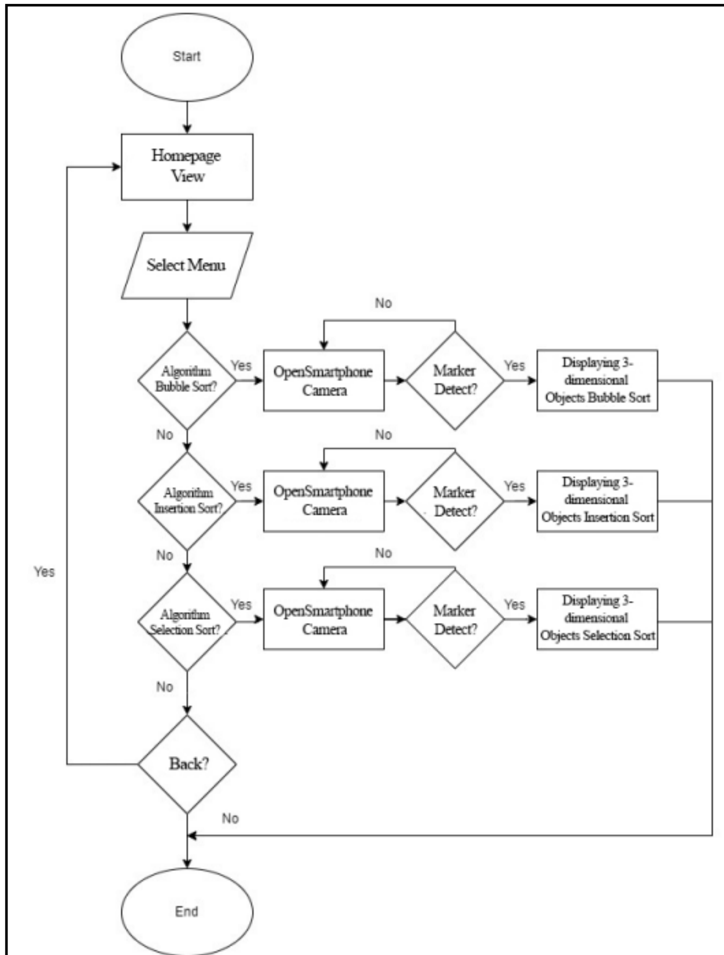


Fig. 2. Application Flowchart

The flowchart has also presented how the marker-based tracking method works, namely by accessing the smartphone camera and if the marker from the selected algorithm learning card is detected by the camera, the screen smartphone will display a 3-dimensional object based on where the marker is located. In developing a programming algorithm learning application using augmented reality with the marker-based tracking method using Unity with the Vuforia engine the development requires license manager as a condition to use the Vuforia engine to create augmented reality applications on Unity.

In this study, the learning card media will be used as a medium that provides information about the sorting algorithm, which consists of the bubble sort, selection sort, and insertion sort algorithms, along with different markers on each algorithm used for detection to display augmented reality from the smartphone camera. Using the learning card media in this study will make it easier for researchers to evaluate programming algorithm learning applications using augmented reality with the marker-based tracking method on physical media because each learning card image represents an algorithm that has an explanation along with marker respectively. Study cards were made using Adobe Photoshop with a sci-fi themed design related to technology according to the content of the learning card, namely explanations and markers of programming algorithms. The following is an illustration of the design of the study card that has been designed, which can be seen in Figure 3.

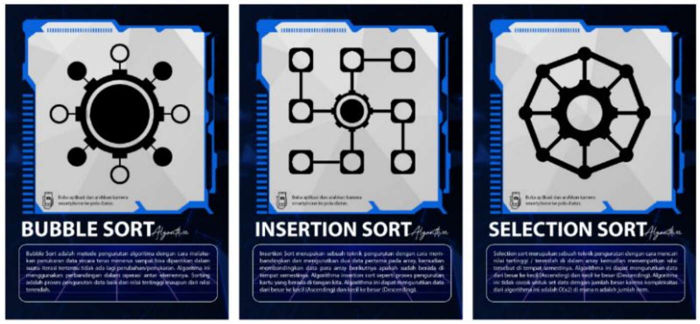


Fig. 3: Study Card Design

Each algorithm that shown in Figure 3, has its own 3-dimensional object arrangement along with different animations, where each card will present the sorting algorithm such as bubble sort, selection sort, and insertion sort algorithms. In the process of making 3-dimensional objects using software Blender along with animations which will later be export into Unity and used as 3-dimensional objects that will appear in augmented reality. Each algorithm has a different animation in Blender the animation is determined based on keyframe where each object movement will be recorded based on a certain time.

The shape of the 3-dimensional model is made in the form of a cube with numbers on each side so that when displayed in the 3-dimensional form in augmented reality, users can see the numbers on the cube from all sides of the camera angle smartphone and on the animated 3-dimensional cube object that If it is moved it will turn yellow so that the user can pay more attention to every movement animation.

Thorough testing will be carried out after the manufacture and implementation of the application has been completed. Tests will be carried out to prove the answers to the problems written in this study. Problems related to the creation and user experience of programming algorithm learning applications using augmented reality using the marker based tracking method, and testing the method based on distance and light intensity. The smartphone device, variable indicator, sub-variable, and measurement scale used can be seen in Table 1.

Table 1. Variable Indicator For Measurement Scale

Device smartphone	**Indicator Variable**	**Sub Indicator Variable**	**Measurement Scale**
Brand Type & specification camera smartphone	Distance Detection	1. Detection on 2cm distance	cm
		2. Detection on 5cm distance	
		3. Detection on 10cm distance	
		4. Detection on 30cm distance	
		5. Detection on 50cm distance	
		6. Detection on 100cm distance	
		7. Detection on 300cm distance	
	Intensity Light	1. Source of sunlight	Illumination Intensity (lux)
		2. The light source is based on color of the lamp, namely yellow, red, blue and bright white	

The test is carried out using a marker found on the study card with a different pattern image on each algorithm for the marker-based tracking method by testing on different devices, distances and light intensity according to the variable indicators then the application will A trial was conducted on several users to assess the level of satisfaction when learning programming algorithms using augmented reality in the application and the rating will be measured based on the USE questionnaire and a Likert scale. System testing is also carried out using the black-box testing method to test the applications that have been designed and built which will then be carried out using the black-box testing method to test the requirements specification of the system which includes testing of functionality and suitability of the flow of the application. The minimum number of questionnaire respondents required in testing the level of user satisfaction is conducted not only on the population but also on respondents outside the research target and only 30 respondents are sufficient.

After the process of testing and comparison has been completed, the data from the test results will be concluded to formulate the results research conclusions. With the results of these conclusions, an evaluation of the research results can be carried out. After the conclusion and evaluation process has been completed, the next process will do documentation step, where all forms of work will be documented in a manner appropriate to the relevant stages. All forms of documentation can be in the form of research photos, screenshots from smartphone, and results from research evaluations.

3. IMPLEMENTATION

The application of augmented reality for programming algorithm learning applications using the marker-based tracking method will be implemented using Unity with the Vuforia engine. Previously, at the design stage, the license was created as a condition for using the Vuforia engine on Unity and database which contained the image target marker from each sort algorithm consisting of the algorithm. Bubble sort, selection sort, and insertion sort.

In each scene file that implements the augmented reality sort algorithm in the hierarchy section, a file from the Vuforia engine will be created, namely the ARCamera file which functions to access the camera from deviceor smartphone which will be used and the ImageTarget file which is used to implement the marker image from the database. In the ImageTarget file in the hierarchy section of the three scene files each sort algorithm has a different marker image according to the sort algorithm that will be implemented in the file the scene. Figure 4 shows the implementation of the marker image from the ARTest database in the scene sort algorithm.

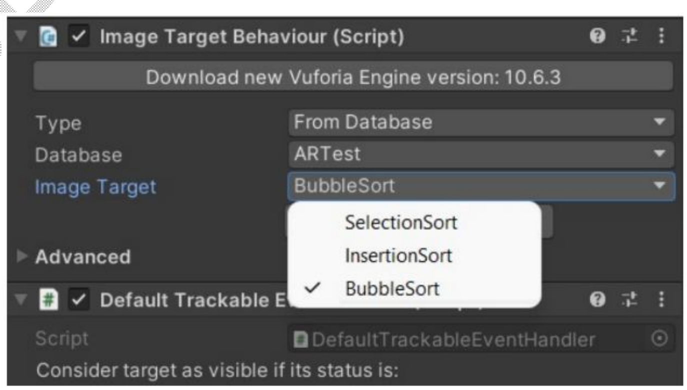


Fig. 4: Implementation of marker images from database in Unity

After finishing applying the license and database on Unity and implementing marker images from the database on each file scene of the sort algorithm. The next process is to implement the created 3-dimensional object for each file scene sort by importing the created 3-dimensional file in FBX format into Unity and then placing it in the hierarchy section of the file ImageTarget. After all the implementation and implementation processes are complete, the next step will be to run the program file that will use the camera on the laptop and the study card which will be displayed on the smartphone screen for a while before entering the testing phase of the augmented reality of each algorithm on marker on the study card. The implementation of augmented reality has been successfully carried out, it can be seen in Figure 5

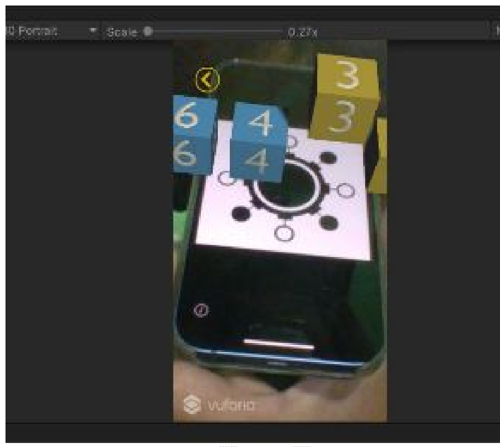


Fig. 5: Augmented Reality implementation result

After all the implementation and implementation processes are complete, the next step will be to run the program file that will use the camera on the laptop and the study card which will be displayed on the smartphone screen for a while before entering the testing phase of the augmented reality of each

4. RESULT

In the system testing process with black-box testing, it is carried out after the inter-face design and augmented reality implementation process is complete, which means that after the application has been built, the system is tested using the black-box method to ensure the specifications of the system are met, and the function flow of the application is appropriate with the initial plan. System testing is carried out by the examiner and is divided into three parts, namely testing when detecting markers and displaying animated 3-dimensional visual objects on the bubble sort, selection sort, and insertion sort algorithms. The following test results using black-box testing can be seen in Table 2. Testing the Marker-Based Tracking Method.

TABLE 2
APPLICATION TESTING RESULT WITH BLACK-BOX TESTING

Description	Input	Expected Output	Result
The application can open the smartphone camera when one of the sorting algorithm menus is selected	Pressing the bubble sort button on the menu on the app start page	Accessing and opening the camera on a smartphone	Success

	Pressing the selection sort button on the menu on the page start of application.	Access and open the camera on the smartphone.	Success
	Pressing the insertion sort button on the menu on the page application start.	Access and open the camera on the smartphone.	Success
Applications can perform augmented reality functions with detects markers and generates 3-dimensional animated objects based on the selected sorting algorithm menu.	The camera detects a marker that has been programmed according to the pattern imagemarker of algorithm bubble sort.	Applications can display 3-dimensional animated objects from bubble sort attached to marker images on learning cards according to the algorithm the bubble sort.	Success
	The camera detects a marker that has been programmed according to the pattern imagemarker of algorithm selection sort.	The application can display 3-dimensional animation objects from selection sort attached to the marker image on the study card that matches the selection sort algorithm.	Success
	The camera detects markers that have been programmed accordingly with a marker pattern image from the insertion sort algorithm.	Applications can display 3-dimensional animation objects from insertion sort that are attached to the marker image on the study card that matches the insertion sort algorithm.	Success

In testing the marker-based tracking method of programming algorithm learning applications using augmented reality, which has been designed and built, it will be carried out using learning cards that have been designed with marker images and an explanation of each algorithm. The textit sort consists of three study cards: bubble sort, selection sort, and insertion sort. The test will be carried out by running the application on the smartphone Vivo v15 by selecting each menu option on the home page to test the marker on each algorithm by accessing the camera and directing the smartphone toward the marker, then generating a 3-dimensional object on the marker according to each algorithm. The marker-based tracking method experimental results can be seen in Figure 6.

Fig. 6: Marker Based Tracking on Bubble Sort, Selection Sort and Insertion Sort Algorithm

The results of the marker-based tracking method have been successfully carried out; this can be seen in Figures 7, where the 3-dimensional animations on each algorithm sort in place of the marker position can be animated on the study card.

The distance and intensity of light when detecting marker to bring up 3-dimensional objects will be tested. The test was carried out using three different smartphone devices: iPhone 13, Vivo V15, and Samsung galaxy J5. The reason why using three different types of smartphone devices is that each smartphone of the iPhone 13, Vivo V15, and Samsung Galaxy J5 have different camera specifications when shooting video. The specifications of the three types of smartphone devices on the iPhone 13, Vivo V15, and Samsung Galaxy J5 can be seen in Figure 7.

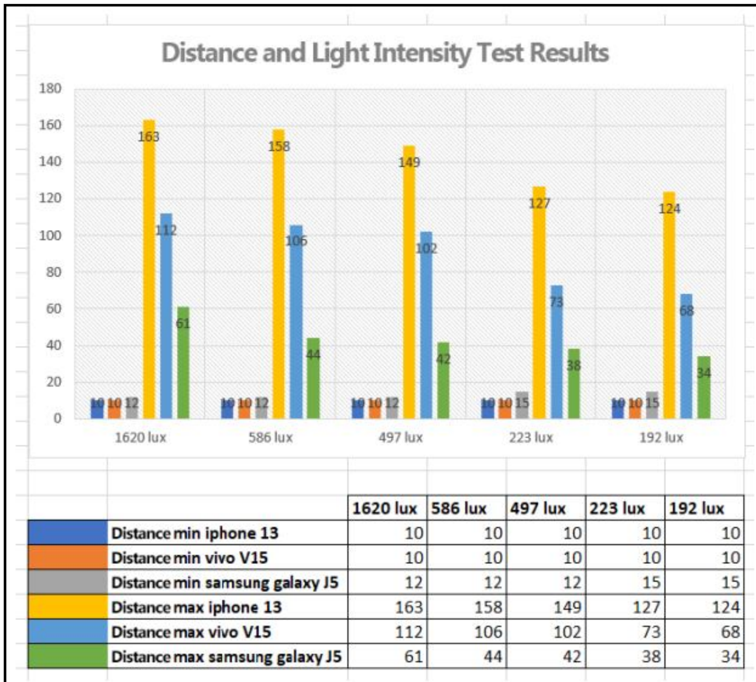
Apple iPhone 13		
MAIN CAMERA	Dual	12 MP, f/1.6, 26mm (wide), 1.7µm, dual pixel PDAF, sensor-shift OIS
		12 MP, f/2.4, 120˚, 13mm (ultrawide)
	Features	Dual-LED dual-tone flash, HDR (photo/panorama)
	Video	4K@24/30/60fps, 1080p@30/60/120/240fps, HDR, Dolby Vision HDR (up to 60fps), stereo sound rec.
vivo V15		
MAIN CAMERA	Triple	24 MP, f/1.8, 1/2.8", 1.12µm, Dual Pixel PDAF
		8 MP, f/2.2, 13mm (ultrawide), 1/4.0", 1.12µm
		5 MP, f/2.4, (depth)
	Features	LED flash, HDR, panorama
	Video	1080p@30fps
Samsung Galaxy J5		
MAIN CAMERA	Single	13 MP, f/1.9, 28mm (wide), AF
	Features	LED flash
	Video	1080p@30fps

Fig. 7: Smartphone Specification as Test Tool

Figure 8 shows the specifications of the smartphone; from figure 8, it can be concluded that the smartphone iPhone is in the first place, the Vivo v15 is in second place, and the Samsung Galaxy J5 is in third place based on the quality of the camera when taking pictures and videos and features available on a smartphone camera. Testing the distance and light intensity in the application uses three types of smartphones which will be tested whether different smartphone camera specifications will affect the detection of augmented reality against a marker on the distance and light intensity scale certain. The tools used to measure the distance and light intensity in the application are the lux meter which is a tool to measure the light intensity and the meter that will be used to measure the distance between the learning cards containing marker and smartphone on when running the application when it detects marker to bring up a 3-dimensional object on the marker. The description of the tools used in testing the distance and light intensity can be seen in Figure 8.

Fig. 8: Instruments for Measuring Distance and Light Intensity

In the next stage, a test will be carried out using a variable indicator for the measurement scale, namely the distance to the intensity of light consisting of a source of sunlight, yellow light, red light, blue light, and white light. Each different color in the light will affect the amount of light intensity which will later be measured using a lux meter, and the distance between the learning card and the smartphone using a meter. In the end, it will be concluded from the test results of each smartphone device on all indicators of the measurement scale variable, namely distance and light intensity in graphic form, and an explanation of the results of the conclusion from the results of the distance and light intensity test will be given in the application. In the tests that have been carried out regarding the distance and light intensity trials on three smartphones with variable distance and light intensity indicators to determine the effect of detection distance and light intensity on the success of the marker-based tracking method in bringing up 3-dimensional objects, it can be seen in Figure 9.



	1620 lux	586 lux	497 lux	223 lux	192 lux
Distance min iphone 13	10	10	10	10	10
Distance min vivo V15	10	10	10	10	10
Distance min samsung galaxy J5	12	12	12	15	15
Distance max iphone 13	163	158	149	127	124
Distance max vivo V15	112	106	102	73	68
Distance max samsung galaxy J5	61	44	42	38	34

Fig. 9: Distance and Light Intensity Test Result

From the graph of the test results in Figure 9 the data results that can be translated into several important points related to the results of testing the effect of distance and light intensity on the marker based tracking method in programming learning applications using augmented reality are as follows:

1. In the application's success in generating 3-dimensional objects, there is an ideal distance for the three smartphones categorized as a minimum distance and a maximum distance. Distance influences the success of the system in generating 3-dimensional objects. The results for the minimum and maximum distances in the marker-based tracking method with the lowest minimum distance is 10 cm and the highest maximum distance obtained is 163 cm.
2. In the lowest light intensity condition, namely 192 lux in blue light, and the highest light intensity with 1620 lux in sunlight, the marker-based tracking method can work well despite the addition of the minimum distance and reduction of maximum distance when the amount of light intensity decreases.
3. The third smartphone has a different detection distance depending on the specifications of the camera you have and the amount of light intensity.

In testing the user satisfaction level of the programming algorithm learning application using augmented reality with the marker-based tracking method. Testing the level of user satisfaction will use Google form media and users can use the application by downloading it via the Google drive link provided in the Google drive description. Inside the Google drive link there are two folders containing applications for android and iOS in each folder. The questions given were 27 questions. The questions in the questionnaire refer to the use questionnaire package. The purpose of filling out the questionnaire is to find out about user satisfaction with the application of learning programming algorithms using augmented reality with the marker-based tracking method that has been used.

This application has been tested on users, and 36 respondents have filled out the questionnaire. In calculating the percentage will be calculated using a Likert scale with each answer to the question; the average percentage value of the answers will be calculated using the Likert scale formula then from the final measurement result the formula will be measured based on the interpretation criteria of the score on the Likert scale to assess the level of satisfaction user.

Application trials are carried out by users where the application is downloaded via the Google Drive link provided in the questionnaire description. Questionnaires were distributed through social media such as Instagram, Facebook, Line, and Whatsapp, as well as direct testing of the application and filling out the questionnaire by approaching the closest person to the researcher. From the results of filling out the questionnaire, most of those who filled out were 86.1% students, 8.3% workers, and 5.6% school students. Below is the process of calculating the score for each point on the application usability aspect (usefulness), user satisfaction aspect (satisfaction), and ease of use aspect (ease of learning). Based on questionnaires distributed from 36 user respondents, the percentage above 80% on each question asked, which states the application is very effective from the overall usability aspect of the application, the satisfaction aspect users, and aspects of user convenience.

5. CONCLUSION

Based on the research that has been done, it can be concluded that the programming algorithm learning application using augmented reality with the marker-based tracking method has been designed and built. The implementation carried out in the development of the application is the implementation of the application interface design and the implementation of augmented reality using Unity with the Vuforia engine as well as 3D animation objects created using software Blender and study cards designed using Adobe Photoshop as assets used in the implementation of programming algorithm learning applications using augmented reality. The system testing results with the black-box testing method gave satisfactory results with the suitability of the success category output for each scenario in the application test.

The marker-based tracking method in the application has been successfully tested by testing the application using a marker on study cards and has succeeded in dis-playing different 3-dimensional visual objects based on each sorting algorithm, namely the sorting algorithm; bubble sort, selection sort, and insertion sort. Testing was also carried out on the marker-based tracking method using the distance and intensity of light when displaying 3-dimensional objects with variable indicators that have been designed and carried out using three smartphones with different specifications. The lowest light intensity is 192 lux, and the highest light intensity is 1620 lux as for the results at the minimum and maximum distance when displaying 3-dimensional objects using the marker-based tracking method with the lowest mini-mum distance is 10 cm and for the highest maximum distance obtained is 163 cm. The lower the light intensity, the lower the camera specification smartphone, and the farther the detection distance of smartphone will affect the minimum and maximum distance in detecting markers to bring up 3-dimensional objects in the application.

To complete the research, the marker-based tracking method used in the application of learning programming algorithms using augmented reality is also tested for user satisfaction levels. The metrics are measured using the USE Questionnaire with 3 factors in measuring usability according to ISO, namely efficiency, effectiveness, and satisfaction, and using the Likert scale as the measurement scale of the questionnaire results. Based on the questionnaires distributed from 36 respondents, users get percentage results above 80% on each question asked, which states the application is very effective in all aspects of application usability, user satisfaction, and user convenience aspects

REFERENCES

[1]. M. Jumarlis and M. Mirfan, “Implementation of Markerless Augmented Reality Technology Based on Android to Introduction Lontara in Marine Society,” IOP Conference Series: Earth and Environmental Science, vol. 156, no. 1, pp. 1–7, 2018, doi: 10.1088/1755-1315/156/1/012017.doi:10.1088/1755-1315/156/1/012017

[2]. G. Liestøl, “Situated Simulations: A Prototyped Augmented Reality Genre for Learning on the iPhone,” International Journal of Interactive Mobile Technologies (iJIM), vol. 3, no. April, p. 24, 2009, doi: 10.3991/ijim.v3s1.963.doi:10.3991/ijim.v3s1.963

[3]. J. Bacca, S. Baldiris, R. Fabregat, S. Graf, and Kinshuk, “Augmented reality trends in education: A systematic review of research and applications,” Educational Technology and Society, vol. 17, no. 4, pp. 133–149, 2014.

[4]. A. Suryanto, D. A. Kusumawati, and I. M. H. Sanhoury, “Development of Augmented Reality Technology Based Learning Media of Lathe Machines,” Jurnal Pendidikan Teknologi dan Kejuruan, vol. 24, no. 1, pp. 32–38, 2018, doi: 10.21831/jptk.v24i1.18245.doi:10.21831/jptk.v24i1.18245

[5]. Y. Chen, Q. Wang, H. Chen, X. Song, H. Tang, and M. Tian, “An overview of augmented reality technology,” Journal of Physics: Conference Series, vol. 1237, no. 2, 2019, doi: 10.1088/1742-6596/1237/2/022082.doi:10.1088/1742-6596/1237/2/022082

[6]. J. Carlina, “3D Visualization For Augmented Reality In ‘Jajanan Pasar’ Puzzles,” ULTIMART Jurnal Komunikasi Visual, vol. 11, no. 2, 2019, doi: 10.31937/ultimart.v11i2.1021.doi:10.31937/ultimart.v11i2.1021

[7]. W. Istiono, “Bilingual Color Learning Application as Alternative Color Learning for Preschool Student,” International Journal of Interactive Mobile Technologies, vol. 16, no. 5, pp. 224–233, 2022, doi: 10.3991/ijim.v16i05.28319.doi:10.3991/ijim.v16i05.28319

[8]. Z. H. Majeed and H. A. Ali, “A review of augmented reality in educational applications,” International Journal of Advanced Technology and Engineering Exploration, vol. 7, no. 62, pp. 20–27, 2020, doi: 10.19101/IJATEE.2019.650068.doi:10.19101/IJATEE.2019.650068

[9]. A. Kusumaningrum, A. Ayuningtyas, and J. B. Lopes, “Utilization of Augmented Reality Technology in 3D Visualization of High School of Adisutjipto Technology Based on Android,” International Journal of Engineering Technology and Natural Sciences, vol. 1, no. 2, pp. 40–44, 2019, doi: 10.46923/ijets.v1i2.49.doi:10.46923/ijets.v1i2.49

[10]. N. Nursamsu, A. S. Bania, and T. M. Sarjani, “Development of Augmented Reality Technology Applications Gadget Based,” BIRCI-Journal, vol. 24, no. 1, pp. 32–38, 2018.

[11]. M. Kristian, I. Fitri, and A. Gunaryati, “Implementation of Augmented Reality for Introduction To Android Based Mammalian Animals Using The Marker Based Tracking Method,” Jurnal Informatika dan Sains, vol. 3, no. 1, pp. 1–6, 2020, doi: 10.31326/jisa.v3i1.623.doi:10.31326/jisa.v3i1.623

[12]. E. Budiman, M. B. Firdaus, and U. Hairah, “Augmented Reality Peripheral Performance: Light Intensity, Distance, Occlusion and Marker Testing,” Journal of Physics: Conference Series, vol. 1898, no. 1, 2021, doi: 10.1088/1742-6596/1898/1/012013.doi:10.1088/1742-6596/1898/1/012013

[13]. J. C. P. Cheng, K. Chen, and W. Chen, “Comparison of Marker-Based and Markerless AR: A Case Study of An Indoor Decoration System,” Proc. Lean & Computing in Construction Congress, vol. 2, no. July, pp. 483–490, 2017, doi: 10.24928/jc3-2017/0231.doi:10.24928/jc3-2017/0231

[14]. N. Elmqaddem, “Augmented Reality and Virtual Reality in education. Myth or reality?,” International Journal of Emerging Technologies in Learning, vol. 14, no. 3, pp. 234–242, 2019, doi: 10.3991/ijet.v14i03.9289.doi:10.3991/ijet.v14i03.9289
[15]. M. L. Hamzah, Ambiyar, F. Rizal, W. Simatupang, D. Irfan, and Refdinal, “Development of Augmented Reality Application for Learning Computer Network Device,” International Journal of Interactive Mobile Technologies, vol. 15, no. 12, pp. 47–64, 2021, doi: 10.3991/ijim.v15i12.21993.doi:10.3991/ijim.v15i12.21993
[16]. M. F. Stallmann, “Algorithm Animation with Galant,” IEEE Computer Graphics and Applications, vol. 37, no. 1, pp. 8–14, 2017, doi: 10.1109/MCG.2017.2.doi:10.1109/MCG.2017.2
[17]. R. N. Fauziah and S. Dwi, “The Development of Applications using Augmented Reality Technology as the Teaching Media of Special Mirror Lights,” Journal Pendidikan Fisika, vol. 9, no. 2, pp. 117–124, 2021, doi: 10.26618/jpf.v9i2.4899.doi:10.26618/jpf.v9i2.4899
[18]. A. Fakhrudin, “The Implementation of Augmented Reality Technology in Teaching Natural Sciences to Improve Elementary Students’ Learning Achievement,” Al-Ta lim Journal, vol. 25, no. 1, pp. 13–21, 2018, doi: 10.15548/jt.v25i1.374.doi:10.15548/jt.v25i1.374
[19]. M. Cabanillas-Carbonell, P. Cusi-Ruiz, D. Prudencio-Galvez, and J. L. Herrera Salazar, “Mobile Application with Augmented Reality to Improve the Process of Learning Sign Language,” International Journal of Interactive Mobile Technologies (iJIM), vol. 16, no. 11, pp. 51–64, 2022, doi: 10.3991/ijim.v16i11.29717.doi:10.3991/ijim.v16i11.29717
[20]. M. Ivanova and G. Ivanov, “Enhancement of Learning and Teaching in Computer Graphics Through Marker Augmented Reality Technology,” International Journal of New Computer Architectures and their Applications, vol. 1, no. 1, pp. 176–184, 2011, [Online]. Available: http://tesla-project.eu/
[21]. T. Bergen, “A practical method of comparing luminous intensity distributions,” Light and Engineering, vol. 20, no. 2, pp. 78–84, 2012, doi: 10.1177/1477153511435769.doi:10.1177/1477153511435769
[22]. P. Kumar et al., “Modeling the luminous intensity of Beijing, China using DMSP-OLS night-time lights series data for estimating population density,” Physics and Chemistry of the Earth, vol. 109, pp. 31–39, 2019, doi: 10.1016/j.pce.2018.06.002.doi:10.1016/j.pce.2018.06.002