AUGMENTED REALITY – BASED SHOOTING SIMULATOR SYSTEM TO ANALYSIS OF VIRTUAL DISTANCE TO REAL DISTANCE USING UNITY 3D

[1]KURNIAWAN TEGUH MARTONO, [2]OKY DWI NURHAYATI, [3]CAHYANI GALUHPUTRI WULWIDA

[1,2,3]Diponegoro University, Department of Computer Engineering, Faculty of Engineering, Diponegoro

University, Semarang, Indonesia

E-mail: [1]k.teguh.m@live.undip.ac.id , [2]okydwin@gmail.com, [3]mulwinda@gmail.com

ABSTRACT

The development of computer technology particularly in computer graphics has provided simplicity in doing engineering in any fields. One of the engineerings done is by building a simulation system. Simulation is one of the accurate solutions in learning a very complex problem or in doing an efficiency process towards the cost spent if using a real system. Shooting is one of physical activities involving the brain ability and response of other parts of body. This activity requires a skillful ability in terms of accuracy and acceleration. Shooting is mostly done by army or the community of wild hunters. In the activities of shooting practice, it needs high cost in its implementation in addition to a quite secured location.

Augmented Reality (AR) is one of technologies that can be used in the development of shooting simulator system. The built system is by changing the shooting target in the form of virtual object. Thus, this activity can be done in a room without any needs to add the security system. This Augmented Reality Shooting Simulator application is built using the extreme programming method, which consists of Planning, Designing, Coding and Testing steps. The research aims were produced shooting simulator system to measure virtual distance estimation to the real distance.

In this research, shooting simulation was created using Augmented Reality. They uses three distinct black and white square markers measuring 20cm x 20cm which will be captured by camera and display in three dimensions virtual object. The research results concluded that light intensity and markers angle affect the virtual distance accuracy. Augmented Reality Shooting Simulator distance estimation gave best results in light intensity range of 10 lux – 30 lux and 0° angle. The other results were estimated virtual range of rifle with target and the number of shots that hit it.

Keywords: *Simulator, Shooting, Augmented Relity, Extreme Programming, Distance, Computer Graphic*

1. INTRODUCTION

The development of computer technology particularly in computer graphics has simplified the activities of engineering in any fields. One of the engineerings done is by building a simulation system. Simulation is one of appropriate solutions in learning a very complex problem or in doing a process of cost efficiency if done using a real system. One of the examples of simulation system that can be implemented using the technology of computer graphics is the shooting practice system. With this system, it is expected that the high cost can be minimized.

Shooting is one of physical activities that involve a brain ability and response of other parts of body. This activity requires a skillful ability in terms of accuracy and acceleration. Shooting is mostly done by the army force or the community of wild hunters. To have a good shooting abilty, it needs a practice that is done continually. For the real practice or activities of shooting, there are some factors that can cause this activity unable to be done flexibly including:

1) The weather condition that always changes and hard to be predicted from the good weather to the rainy or storm. Hence, it can make the implementation in field difficult.

2) Location or shooting range available for the shooting is quite far; therefore it takes high cost.

3) It requires more ammos or bullets to be used for the shooting; thus, it needs a high cost.

Augmented reality (AR) is a part of the development of graphic computer technology. It is a technology combining the real world to the 3D-virtual object built by computer that can be accessed in realtime [1]. AR Technology broadly is divided into several fields including technology of tracking, interaction and appearance[2]. AR technology can be used in any fields such as education, health, military or art. Figure 1 shows the general description of AR technology.
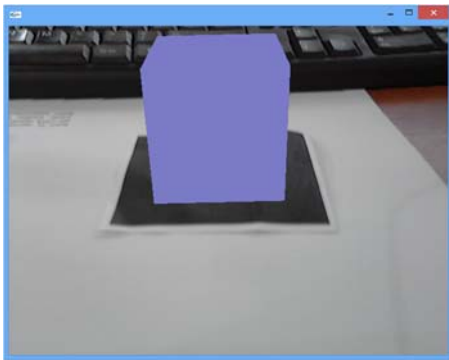

Figure 1: Augmented Reality System

As described in Figure 1, a virtual object in the form of cube is displayed exactly above a real object in the form of paper in real-time. The real object used in AR technology is known as marker, an object used for the identification process for the system to enable the virtual object to be displayed. The process of detection and identification is conducted using a camera [3]. The marker mostly used in the development of AR technology is by using the two dimension image. The color pattern used in making marker is by using two colors: white and black. The use of these colors aims to prevent the process of color identification [4]. Figure 2 shows the types of two dimensional marker frequently used in the development of AR technology.
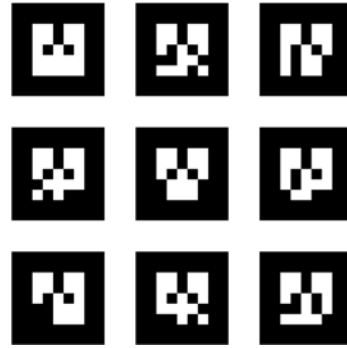

Figure 2: Two-Dimension Marker

To display the image of virtual object in AR technology is divided into 2 models: using Video See Through and Optical See Through. The process of Video See Through is a process to display a virtual object through a monitor. To see the surrounding environment, the user of application uses a camera that has been set up in the system. The object that has been captured by the camera would be combined with the image that has been made on the scene generator computer. This process would result in a virtual object displayed on the monitor. Figure 3 depicts a scheme of Video See Through.
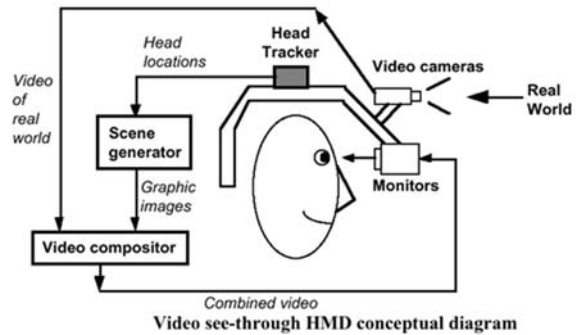

Figure 3: Video See Through[5]

Other model used in displaying an object is by using Optical See Through. In this model, the user of applicaton can directly see the outside environment using the eyes. To see the virtual object in this system, a mirror is used in which it will reflect a virtual object from the monitor. Figure 4 illustrates the scheme of optical see through.
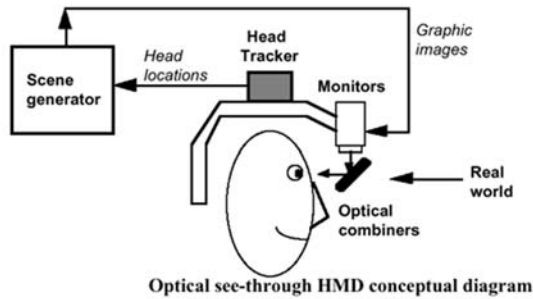
Figure 4: Optical See Through[5]

In general, AR technology requires a component in the form of tracking module used to measure the relative positon of camera to the real-world. This model is also used to add the virtual object displayed in the application. Figure 5 presents the scheme of flow chart of AR.
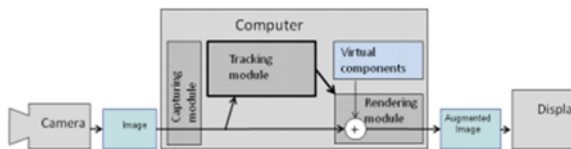

Figure 5: Flow Chart Of AR [6]

This paper discusses about how to build the shooting simulator system using AR technology. The concept of the shooting simulator system is by using a virtual object as the target of shooting. The firearm system used was by using the replica of firearm that has been modified to be able to interact with the AR system. To display the virtual object, it needed a marker based system. The shooting simulation using the AR technology is expected to be one solution in improving the shooting ability for those needing. In addition, it could minimize the cost spent for the practice activity.

The research aims were produced shooting simulator system to measure virtual distance estimation to the real distance. The scope of this research are included designing a shooting simulation system with unity 3D and ARToolkit programs. It's made using three markers with each of the targeted shoot virtual models. The focus of this research was to analyze the distance with a virtual camera shotgun to the target shot. The results displayed only the virtual distance, and the number shotting on the target. The accuracy of shots and shots was ignored in the results and not be displayed. Based on the background, the exact research question is how to measure the virtual distance to the real distance based on Augmented Reality shooting simulator system?

2. RELATED WORK

Many researches have been conducted in AR technology either from its tracking or from its interaction. This technology can be a solution in coping with the existing issues. For example, in health sector, there has been a research on the use of AR technology to assist the neurosurgery process. Neurosurgey has experienced the technology revolution during the last decades started from trigsination to the navigation of picture manual. The advance in virtual reality (VR) and AR represents a number of the latest modalities integrated into the neurosurgical practice[7]. This research aims to assist a doctor in learning the theory of neurosurgery. The use of technology of visualization by combining the virtual object and the real environment enables to give a doctor a new experience in learning the neurosurgery. The method with AR technology can be used to ascertain that the operation process safe as the anatomic structure would be visualized. Hence, a doctor can figure out the positions of the structure to conduct an operation[8]. Figure 6 shows one of the results of the use of AR technology in health sector for the operation process.
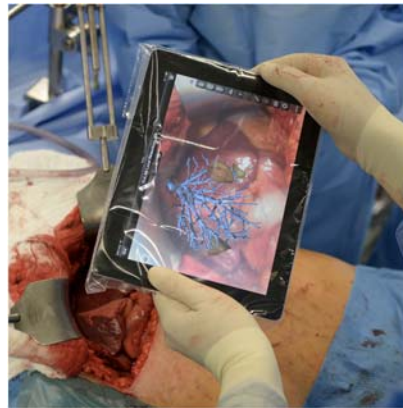

Figure 6: Augmented Reality Ipad App Guides Surgeons During Tumor Removal[9].

Figure 6 describes the research result conducted by Fraunhofer Institute for Medical Image Computing MEVIS using Ipad to assist the surgeon to remove the   liver tumour without damaging the important vessels in the organ by using the AR technology. A CT scan was performed before the surgery and the imaged vessels were identified within software, all of which were then transferred to the iPad. During the procedure the surgeon could navigate the imaged liver to see where the vessels were, and if the camera was turned on and pointed at the exposed liver the app automatically superimposes

the vessel structure of the organ onto the live picture[9].

Other researches in the use of AR technology are in the education in which AR technology has been used to complete the learning materials from the pre-school, grade school, to high school. This technology has enabled the students to have a new experience in terms of learning as the interface used was different. Figure 7 presents the results of the research by means of AR technology in education field.
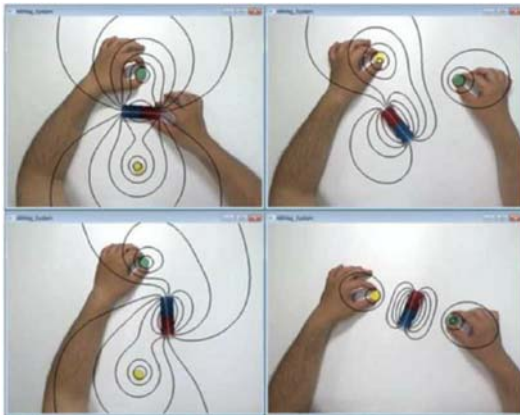

Figure 7: AR-Based Education Media To Show The Line Of Magnetic Field [10].

Based upon the research above, a student is able to figure out the descripton of the line of the magnetic field when the magnetic poles are close to each other or when there is a barrier [11].

3.   RESEARCH METHODOLOGY

The research method conducted is presented as follows:

1.   Study literature

Study literature is an initial part in the research activities. Literature used was by searching a number of previous researches on the AR technology through Xplore Digital Library, sciencedirect or other journals. The aim of the activity of literature study was to find the variables to be studied, differentiate the things that have been done, determine several things needed to be done, do syntheses and obtain a new perspective and determine the meaning and relation among variables.

2. System Design

System design in the activities of this research was divided into two groups: software design system and hardware system design. What was needed in the software system design was how to make the system with the soft computation process to make the application able to run in realtime. The

software used in the activities of this reseach was by using ArToolkit, Unity3D, and Blender. ARToolkit is a library used to build the AR application. This library functioned to measure the position of camera and to make the pattern orientation of the marker in realtime. In addition it was used for the video tracking. The way of working of ARToolKit is shown in Figure 3.1.
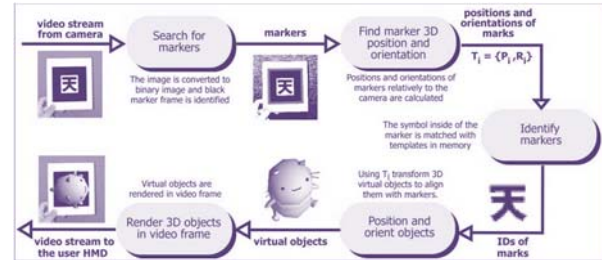

Figure 8: The Workings of ARToolKit[12]

The steps of detecting this marker were as follows:

1.   Camera would take the video in the real world onto computer.
2.   The software application on the computer would search each frame of video detected in the marker.
3.   If the marker was found or detected, then the software application would measure the position of the camera to the marker.
4.   When the position of the camera has identified the marker, then the computer would describe the model that has previously been made.
5.   The model that has been made would be displayed on the detected marker[12].

Three dimensions (3D) Unity is the software application used to develop any types of graphic computer-based application. We used Unity because it is easy to use and implement. In this research, the use of this software application was to build the environment of the shooting simulator system. To make the 3D virtual object, this research used the Blender software. Meanwhile, the hardware used in this research was in the form of replica of firearm, camera, Oculus rift 2 and switch. Here, the camera used was webcam camera that was used to identify the environment of the real environment and to detect the position of the marker. The display of the video used the oculus rift 2 in which it was expected that the user could feel the real condition when using the application. The flow chart of the process of identification and detection

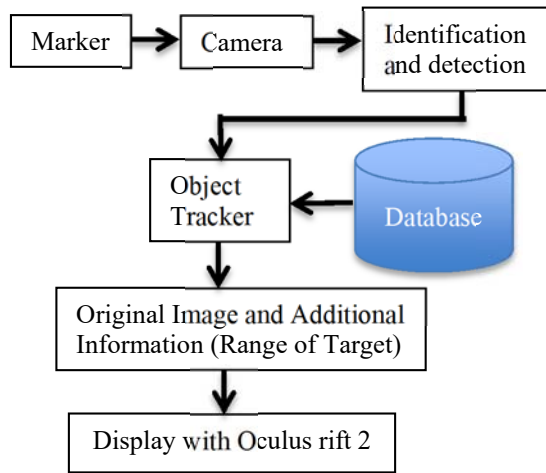of marker in the shooting simulation system are shown in Figure 9.

Figure 9: Flow Chart of Shooting Simulation System

The work of the system included: the marker image was captured by the webcam camera installed in the system. Marker image that has been captured would be identified and detected based upon the pattern. Later, it would be sent and later would be sent into the tracker object from the software. The tracker object would be connected to the databse for the identification of the marker to be able to display the suitable image and information. The result that would be displayed was in the form of the image of shooting target and the distance between the tip of the firearm and the shooting target in the virtual form.

3. Implementation

The implementation process refers to the way of translating the result of the system design into the real form. This process includes the creations of the marker, interface and the application of shooting simulation. Figure 10 displays the types of the marker and the content used in the shooting simulaton system.
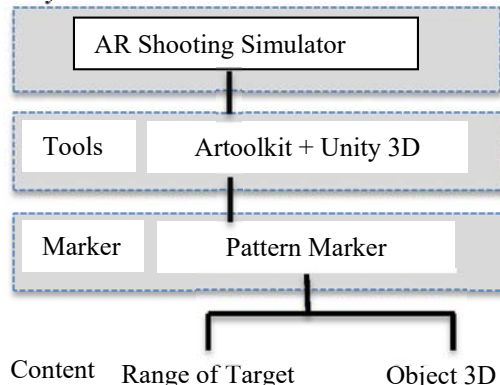

Figure 10: Types of Marker and Content

4. Testing

The testing was conducted to observe the result of the implementation process whether it has been suitable. It was done by testing the measurement between the virtual distance and the real distance, the function of interface position and the distance of the marker to the camera. The implementation of the test was conducted in the room with the standardized lighting.

4. IMPLEMENTATION AND RESULT

The implementation of the shooting simulation system on the computer with specification is shown in Table 1.

Table 1: Computer Hardware Specification

Component	Description
Procesor	I5-4460 processor (3.2 ghz, 6m cache)
Memori	4gb ddr3
Vga	Amd radeon r5 330 2gb
Camera	Logitech hd webcam c310

The interface built from the shooting simulator system included the splash screen, menu, info and main interface in the application. The page of *Splash Screen* shown in Figure 11 was the page firstly appeared when the application was opened. This page contained the title in the application logo. The title of this application was *Shooting Simulator* – a game of shooting simulation. This title was given animation and the simple sound effect. Once the animation was over, there would be the text of *Shoot to Start* instructing the users to click the left button of the mouse to start the game.

Figure 11: The Page of Splash Screen application

From the *Splash Screen*, there would be the ndow of the camera equipment setting appeared if there was a camera detected. From the setting, it then

continued tto the menu page with the background of camera capture.

If there was no any camera detected, then the window of *error* would come out. Figure 12 shows the message of error if there is no camera detected.

Figure 12: The window of error if the camera is not detected

The main interface of the shooting simulation system is depic in Figure 13.

Figure 13: Page of Application Menu

This page consisted of several simulation components including the column of distance estimation, number of shoots hitting the target, pointer of shooting and the button of out. If the camera was on and the marker has been read, then in this page there would be the 3D virtual model of shooting target. The number of shoots hitting the target would be added if the users click the left button of mouse when the pointer was in the area of target shoot that is the blue area. Figure 14 depicts the testing of shooting simulator system.

Figure 14: Testing Process

The measurement of virtual distance was conduted in SDK Unity 3D. In the environment of Unity 3D the function of Vector3 as the representation of 3D vector in the unity environment is available. Vector3 was used to deliver the variable of position and direction in the environment of 3D. To measure the distance in this application, the parameter of Vector3.Distance in Vector3 has been used. It functioned to determne the score of the distance between the object *a* and *b* in which *a* referred to the marker and *b* referred to the position of the camera, the score of this distance presented the Unity in the form of Unity Units.

In the manual of Unity it is not explained specifically about the level of the score of Unity Units in SI (International Unit) as principally the unit of the Unity follows how the programmer initiates and uses it. Therefore, to make the unit of Unity Units to be the unit that is easily measured and understood, and then it is necessary to do the conversion from the Unity Units to centimeter (cm).

The sample of the real distance of camera and marker and the virtual distance obtained from the function of Vector3 is shown in Table 1.

Table1. The sample of the real distance wiith the virtual distance

No.	Centimeter (cm)	Unity Units
1.	40	0,3119
2.	45	0,3547
3.	50	0,3951
4.	55	0,4358
5.	60	0,4768
6.	65	0,5158

7.	70	0,5554
8.	75	0,5969
9.	80	0,6364
10.	85	0,6767
11.	90	0,7169
12.	95	0,7547
13.	100	0,7963
14.	105	0,8347
15.	110	0,8775
16.	115	0,9211

The the difference of the distance obtained in Table 1 was then measured in each 5cm of the change of the distance in Unity Units. The difference measurement displays in Table 2.

Table 2 Sample of real distance with the virtual

No.	Centimeter (cm)	Unity Units
1.	5	0,0376
2.	5	0,0404
3.	5	0,0407
4.	5	0,041
5.	5	0,039
6.	5	0,0396
7.	5	0,0415
8.	5	0,0395
9.	5	0,0403
10.	5	0,0402
11.	5	0,0378
12.	5	0,0416
13.	5	0,0384
14.	5	0,0403
15.	5	0,0381
Total of the difference of virtual distance =		0,5960

Having found the difference, 15 samples taken in each 5cm were then totalized and its mean score was sought using the Mean formula as given below.

$$\text{Mean} = \frac{x_1 + x_2 + x_3 + \cdots + x_n}{n}$$

$$= \frac{0,5960}{15}$$

$$= 0,03973 \text{ Unity Units}$$

Remark

$x_{1+\ldots n} = $ Number of differences of the virtual distance to sample n

n   =   Number of samples

From the measurement above on average 5 cm of the real distance of the camera with the marker was 0.03973 of the firearm distance and the target in the Unity Units. To convert the Unity Units into the unit of centimeter it needed to initially figure out how long one Unity Units if measured in the unit of centimeter in the following measurement.

0,03973 Unity Units =   5 cm

1 Unity Units $= \dfrac{5}{0,03973}$ cm

1 Unity Units $=$ 125,8495 cm

Having found that 1 Unity Units was 125,8495 cm, the score obtained was then used in the function of Vector3.distance in the program code in Unity to provide the output of the estaimation of the virtual distance in the unit of centimeter. The codes of the program and its explaination are given below.

```
private double konversi = 125.8495;

    double distance1 = uni_dist1 * konversi;
    double distance2 = uni_dist2 * konversi;
    double distance3 = uni_dist3 * konversi;
```

The program code private double konversi = 125.8495; was used to call the conversion score obtained from equation 2. Variable distance1 with the type of *double* data was the virtual distance of firearm with the virtual target 1 in centimeter that later would be displayed in the program interface. Uni_dist1 referred to the virtual distance of firearm and the virtual target 1 in the Unity Units obtained from the function of Vector3.distance from Unity. Uni_dist1 was multiplied with the score of konversi to make the unit of Unity Units to be centimeter later displayed in the program interface. Variable distance2 with the type of the *double* data referred to the virtual distance of firearm with the virtual target 2 in centimeter that subsequently was displayed in the program interface. Uni_dist2 meanwhile referred to the virtual distance to the virtual Target 2 in the Unity Units that were obtained from the function of Vector3.distance from Unity. Uni_dist2 was multiplied with the score of konversi; thus, the unit of Unity Units became centimeter to later be displayed in the program interface. The variable distance3 with the type of the *double* data referred to the virtual distance of firearm

with the virtual Target 3 in centimeter that was furthermore displayed in the program interface. Uni_dist3 referred to the virtual distance of the firearm to the virtual Target 3 in the Unity Units obtained from the function of Vector3.distance from Unity. Uni_dist3 was multiplied with the score of konversi so that the unit of the Unity Units became centimeter subsequently displayed in the program interface.

A. Testing and Analysis

The testing was conducted by taking 10 samples using the wooden rail with the measuring apparatus with the unit of centimeter and arch in the rool with the light intensity measured by means of the Lux Meter. This testing measured the consistency of the real distance and the virtual distance towards the parameter of light intensity and the marker angle.

The test was conducted in the light intensity at the minimum of 10 lux and maximum of 30 lux. This test was conducted using one *marker* in the room with the normal lighting. If the light intensity was reduced by less than 10 lux, the *marker* could not be detected as the light was inadequate and this has made the white part in the marker could not be read and became close to black or grey. The result of this test is shown in the graphic in Figure 15.
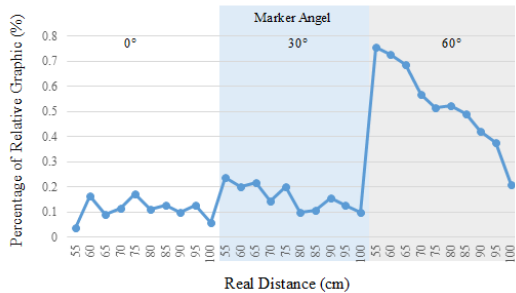

Figure 15: Graphics of First Testing Error

When the marker angle to the camera was at 0°, the error of measurement was in the range of 0,02 cm to 0,13 cm with the largest error percentage of 0,173%. On the other hand, when the marker angle to the camera was at 30°, the error of measurement was in the range of 0,08 cm to 0,15 cm with the largest percentage of error at 0,2%. Subsequently, for the marker angle to the camera at 60°, the error of the measurement was in the range of 0,21 cm to 0,45 cm with the largest percentage of error at 0,758%.

The test was conducted in the light intensity with the minimum of 90 lux and maximum of 160 lux. This test was conducted using one marker in the room with the quite lighting. In this testing, the 3D model was more stable and clearer as the marker could be clearly read by the system. The result of this testing is shown in the graphic in Figure 16.
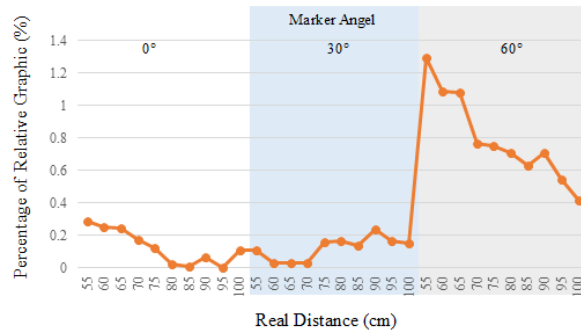

Figure 16: Graphic of second testing error

When the marker angle to the camera was at 0°, the error of the measurement was in the range of 0 cm to 0,16 cm with the largest percentage of error at 0,29%. On the other hand, when the marker angle to the camera was at 30°, the error of the measurement was in the range of 0,02 cm to 0,21 cm with the largest percentage of error at 0,234%. Then, for the marker angle to the camera at 60°, the error of the measurement was in the range of 0,42 cm to 0,72 cm with the largest percentage of error at 1,292%.

The test was conducted in the light intensity at the minimum of 1000 lux and in the maximum of 15000 lux. This testing was conducted using one marker outside the room but not under the direct sunlight. In this testing, the 3D model of target was more stable and clearer as the marker could be read by the system but the error of the measurement in fact was higher compared to two previouus tests. The result of this test showed the graphic as in Figure 17.
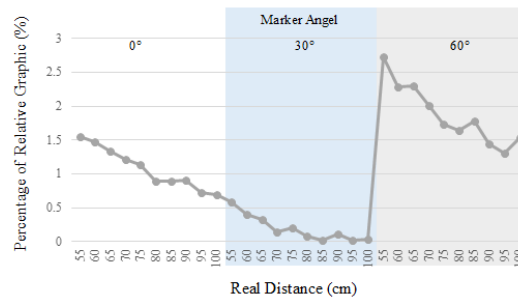

Figure 17: Graphic of third testing error

When the marker angle to the camera was at 0°, the error of the measurement was in the range of 0,69 cm to 0,9cm with the largest percentage of error at 1,557%. Whilst, when the marker angle to the camera was at 30°, the error of the measurement was in the range of 0,02 cm to 0,32 cm with the largest percentage of error at 0,578%. Then, for the marker angle to the camera at 60°, the error of the measurement was in the range of

1,26 cm to 1,56 cm with the largest percentage of error at 2,724%.

From the testing 1 to testing 3, the result of the lowest level of error was in testing 1 with the light intensity at the minimum of 10lux and in the maximum of 30 lux and with the marker angle at 0°. This was because when taking the sample of the virtual distance in the Unity Units, the sampling was conducted in a room with the light intensity of the minimum of 10lux and maximum of 30lux with the decivity of the marker angle of 0°; thus, the application functioned maximally when being in the condition of the equal light intensity. In addition, when the marker angle was at 30°, the virtual distance tended to be shorter compared to when it was at 0°. When the marker angle was at 60°, the virtual distance tended to be longer compared to when it was at 0°.

Some limitations of our work after results analysis are this research should be done in a room with normal lighting range 10 lux to 30 lux. If the light intensity decreases from 10 lux, marker not detected. Measurement errors can be caused by measure errors and inaccuracy application or leak of shooting simulator system. Strengths of our work after results analysis is our shooting simulator system give an error rate of 0,173%.

5. CONCLUSION

A. Conclusion

Based upon the research that has been conducted, a number of conclusions can be drawn as follows:

1. The research conducted has obtained and analyzed the score of the real distance of the camera to the marker with the virtual distance of firearm to towards the target.
2. The research successfully has resulted in the applicaton of the Augmented Reality based shooting simulator system with the estimation of the virtual distance of firearm with the target.
3. This research used the function of vector3 providing the Unity and presented the virtual distance in the unit of Unity Units. From the sample taken, it has been found that one Unity Units was equal to 128,185 cm.
4. From the research, it can be seen that the light intensity has an influence to the level of the virtual distance. It was because the sampling to determine the conversion of virtual distance has been conducted in the room with the light intensity at the minimum of 10 lux and at the maximum of 30 lux.In such condition, the system could work optimally with the accuracy of 99,9%. If the light intensity was less than 10 lux, the *marker* could not be detected by the system and therefore, the model of 3D target could not appear. When the light intensity was at the minimum of 30 lux to maximum 15000 lux, the percentage of the error increased and then the accuracy only reached 98,67%.
5. The decivity angle of marker also has an effect on the result of the measurement. The difference in the accuracy when the decivity angle was at 60° only reached 98,67% with the difference almost 3cm from the real distance. Meanwhile, for the angle of 0° and 30° the minimum level of the accuracy reached 99% with the highest difference of the real distance reaching 1,5cm.

B. Recommendation

Based upon the conclusions of the research that have been explained, the recommendations that can be given for the following reseasrches are presented as follows:

1. The next researchers can add the function showing the accuracy of the shooting to the target and the trace of the shooting to which point the target shot.
2. The next researchers could add the *multi marker tracking* to make the object of the target able to be seen from any sides.

REFERENCES

[1] S. Andrew , J. Julie A, The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, Second Edition, © Taylor & Francis, 2007.

[2] Feng. Zhou, Henry. Been-Lirn Duh, Mark. Billinghurst. 2008. Trends In Augmented Reality Tracking, Interaction And Display: A Review Of Ten Years Of ISMAR. Singapore: Nanyang Technology University.

[3] J. Köhler, A. Pagani , D. Stricker. 2010. Detection and Identification Techniques for Markers Used in Computer Vision. from : http://drops.dagstuhl.de/opus/volltexte/2011/3095/pdf/6.pdf

[4] M. Hirzer. 2008. Marker Detection for Augmented Reality Application. from: http://studierstube.icg.tu-graz.ac.at/thesis/marker_detection.pdf

[5] http://csis.pace.edu/~marchese/DPS/Lect3/dpsl3.html. Accessed in 8.00 pm, 1July 2017

[6] http://www.vtt.fi/inf/pdf/science/2012/S3.pdf accessed in Accessed in 6.15 pm 1July 2017

[7]   Panayiotis E. Pelargos, Daniel T. Nagasawa, Carlito Lagman, Stephen Tenn, Joanna V. Demos, Seung J. Lee, Timothy T. Bui, Natalie E. Barnette, Nikhilesh S. Bhatt, Nolan Ung, Ausaf Bari, Neil A. Martin, Isaac Yang, Utilizing virtual and augmented reality for educational and clinical enhancements in neurosurgery, Journal of Clinical Neuroscience, Volume 35, January 2017, Pages 1-4, ISSN 0967-5868, https://doi.org/10.1016/j.jocn.2016.09.002.

[8]   H. Iseki, Y. Muragaki, K. Naemura, M. Hayashi, T. Hori and K. Takakura, "Clinical application of augmented reality in neurosurgical field," *Proceedings Computer Graphics International 2003*, 2003, pp. 44-49. doi: 10.1109/CGI.2003.1214446

[9]   https://www.medgadget.com/2013/08/ augmented-reality-ipad-app-guides- surgeons-during-tumor-removal.html. Accessed in 1July 2017

[10]   S. Matsutomo, T. Miyauchi, S. Noguchi, and H. Yamashita, "Real-Time Visualization System of Magnetic Field Utilizing Augmented Reality Technology for Education," IEEE Trans. Magnetics, vol. 48, no. 2, pp. 531-534, Feb. 2012

[11]   M. E. C. Santos, A. Chen, T. Taketomi, G. Yamamoto, J. Miyazaki and H. Kato, "Augmented Reality Learning Experiences: Survey of Prototype Design and Evaluation," in IEEE Transactions on Learning Technologies, vol. 7, no. 1, pp. 38-56, Jan.-March 2014. doi: 10.1109/TLT.2013.37

[12]   https://archive.artoolkit.org/documentation /doku.php?id=3_Marker_Training:marker _about accessed in 9.25 pm 4 July 2017