

## Development of Augmented Reality (AR) Based Gamelan Simulation with Leap Motion Control

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**Abstract**—One of the traditional musical instrument from Indonesia is *gamelan*, that is now less desirable because people nowadays prefer to play modern musical instruments, or because of its expensive price. This study combines the modern technology of AR and Leap Motion and also utilizes the sophisticated smartphone to develop a *gamelan* simulation that is presentable to the user. There are two kinds of an experiment performed in this research. The first is Augmented Reality (AR) experiment which authenticates that the distance and the height parameters are the keys to get a 100% success in running the *gamelan* simulation. The distance is ranged from 45 cm to 65 cm and the height is ranged from 25 cm to 30 cm. And the second one is the usability evaluation to five users, who resolves the completion task very well, acquires the result of 86.48%.

**Keywords**—Virtual instrument, hand gesture, traditional music, head mounted display (HMD)

### 1 Introduction

In 2018, the number of smartphone users today based on the survey has reached 2.53 billion [1]. The development of smartphone technology is now equipped with various sensors that allow it combined with other tools, such as Head Mounted Display (HMD) and Leap Motion. HMD is a computer display device or monitor, usually used to support the Augmented Reality (AR) and Virtual Reality (VR) technology. Some studies have conducted the implementation of HMD on a certain area, for instance, the HMD is used in the Android Application Controller using Internal Gyroscope Sensor [2] and also the HMD for activity recognition [3]. Augmented Reality (AR) is a system that is built by combining reality and virtual world. Leap Motion Controller is a small USB-based device that allows the user to control or play the computer by using motion [4], [5].

Gamelan is a traditional musical instrument from Indonesia. The term Gamelan consists of word “gamel” which means to heat or to beat, and word “an” which makes it a noun [6]. So that the term Gamelan has a meaning as a unity of musical instruments played together. It consists of a set of instruments which have their own utilities but complement each other, which are Gong, Demung, Barung, Peking, and Slen-

them [7]. Fig. 1 shows the picture of Gong and Fig .2 shows the picture of Demung. But nowadays, there are not many people understand about gamelan. The difficulty of getting gamelan musical instruments is because of the aspect of its scarcity and also because of it's highed-price.



**Fig. 1.** Gong



**Fig. 2.** Demung

Gamelan notes consist of the numbers that represent the note. Similar to general musical notes which also use numbers as representations of the names of the notes used, Table 1 describes the general musical notes and Table 2 shows the gamelan notes.

**Table 1.** General Musical Notes

Notes	Name
1	Do
2	Re
3	Mi
4	Fa
5	So
6	La
7	Ti

Source: [6] (2003)

**Table 2.** Gamelan Musical Notes

Notes	Short Name	Long Name
1	Ji	Siji
2	Ro	Loro
3	Lu	Telu
4	Pat	Papat
5	Mo	Limo
6	Nem	Enem
7	Pi	Pitu

Although there were some studies that already discuss the gamelan simulation using AR technology, there is a big difference in the way of playing the simulation to the real one [8]. Based on the previously described background, this study is expected to introduce gamelan and how to play it similar to the real gamelan by utilizing AR and Leap Motion technology to smartphone users. This research has a purpose to develop the AR-based gamelan simulation with Leap Motion control, which is expected to have a decent accuracy and performance. This gamelan simulation application is not only giving the Gamelan library of sounds an a visual impression of the instruments, but it is also presenting the proper technique of playing gamelan through the simulation and also how to play the simulation that similar to how to play the real gamelan music instrument. So we can conclude that if we compare this gamelan simulation application to the application in the market that only provides the sounds library, this simulation is much better.

## 2 Related Work

Smartphone has already been used as musical instruments in some studies [9], [10]. In 2013, a study related to gamelan and Augmented Reality was conducted by [8]. The study evaluated the application to play gamelan musical instruments by using the marker as the virtual button. When the marker was covered, it meant that a note of the gamelan was played. but the app is not played similarly to the original gamelan. There was also a research into the use of Leap Motion for controlling traditional musical instruments. The Leap Motion detected the hand gestures above it and send the data to

the computer as the signature for playing the musical instrument in the computer, but the shortcoming of this research is that it is desktop-based application [11]. In 2017, [12] conducted a study that uses Leap Motion as the Arabic sign language translator. The method used was Naïve Bayesian algorithms to classify 26 alphabets in sign language.

The research that evaluated the AR application with Leap Motion was also done by [4], [5], but they used the SDK alpha from the Leap Motion Corp. that the access cannot be downloaded and used by the developers anymore.

### **3 Proposed Method**

#### **3.1 Storyboard**

In this research, the storyboard is meant for describing the flow of the gamelan simulation. The storyboard may show the whole idea of the system in a simple way [13]. The storyboard is in the form of images sequences that illustrates the relationship between the actions or inputs of the user and also the outputs of the system [14].

Fig. 3 describes the storyboard of the gamelan simulation system. The first step is connecting the Leap Motion to the computer as the server:

- a) The Leap motion sends the data to the server
- b) The server processes the data from the Leap Motion and sends it to the smartphone via the Wifi network
- c) The user puts on the HMD with the Leap Motion and the smartphone are attached
- d) The user sits in front of the marker, prepares to run the gamelan simulation
- e) The image of the storyboard shows the user's after completing the previous stage
- f) The image shows the perspective of the user when the gamelan simulation application detects the marker and it displays the 3D gamelan object
- g) The image describes the user's perspective that is ready to play the gamelan simulation

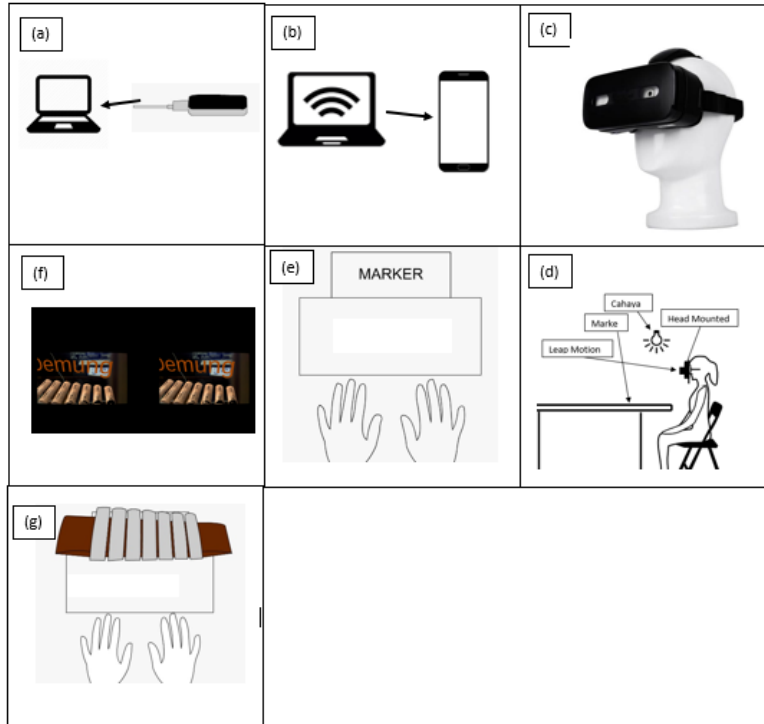


Fig. 3. Storyboard

### 3.2 System architecture

The system architecture in this study is shown in Fig. 4. The Leap Motion sends data to the server, then the server processes the data to be sent to the smartphone through the Wifi connection. The smartphone is attached to the Head-Mounted Display (HMD).

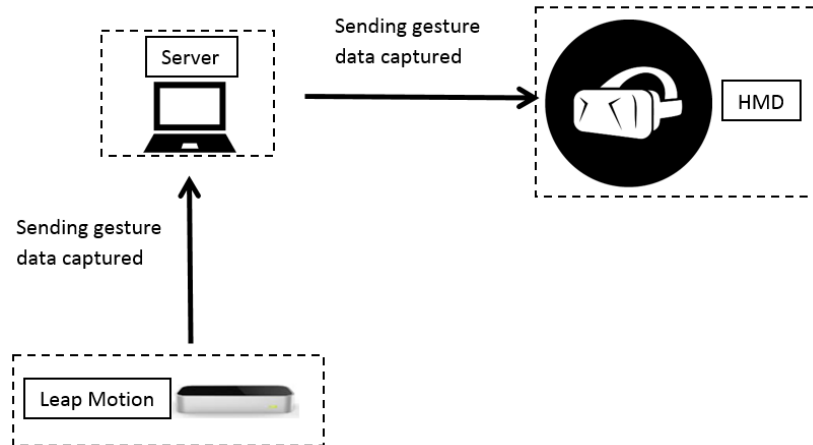


Fig. 4. System Architecture

### 3.3 Server

The server is used for receiving and processing the gesture data sent by Leap Motion. It also resends that data to the smartphone afterward. The server controls the 3D hammer that is used for striking the gamelan. The server application has some features, which are: screen and buttons. The server application preview is shown in Fig. 5.



Fig. 5. The Server Preview

The screen is for displaying the hand gesture captured by the Leap Motion. The buttons are used to adjust the hammer position in AR gamelan simulation (x, y, z positions). The buttons are divided into two groups; the buttons for arranging the left-hand position and for the right hand.

The use of this server application is to synchronize the network used by both devices which are the computer as the server and the smartphone that runs gamelan simulation.

### 3.4 Implementation

The AR-based gamelan simulation with Leap Motion control has some buttons for the user options in the Main Menu, those are Play, Library, Developer, Help, and Exit. The display of the main menu is shown in the following Fig. 6.

When the user picks the Play button, the application will go to the Play menu page with three buttons (a)

Saron button, Demung button, Back button.

Saron button and Demung button is the options for the user to play the AR gamelan simulation with Leap Motion controller.

The Library button carries the user to the Libray Menu which contains a brief description of the gamelan (b)

If the user wants to know the information about the gamelan simulation developer, they can choose the Developer button (c)

The Help button can be tapped if the user needs to figure out the description of how-to in the gamelan simulation application (d)

Fig. 7 shows the pages for the buttons in the main menu.

The recording process is done to record each tone from the musical instrument gamelan which will be used as a sample musical instrument that will be applied in the application of Augmented Reality-based gamelan simulation with Leap Motion control. This process is also making the results of the recording as an asset for the application of Augmented Reality-based gamelan controls with Leap Motion controller.

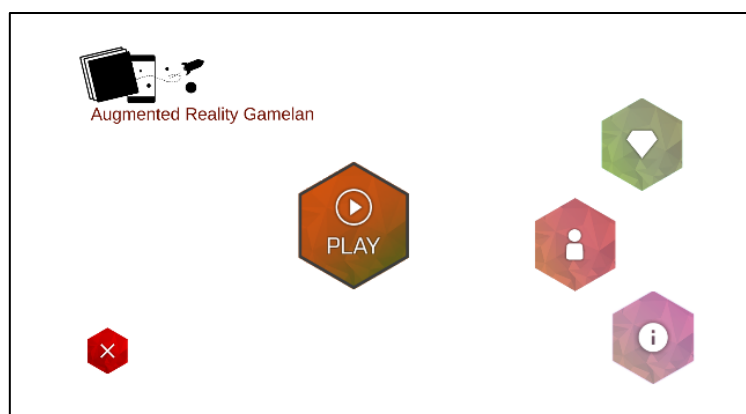


Fig. 6. The Display of Main Menu

On the implementation process of gamelan simulation, Leap Motion connects to the server and captures the user's hand gesture data. The server receives that data from the Leap Motion and resends it to the smartphone through the wifi network. When the application scans the marker, it will render the 3D object of gamelan musical instrument. Fig. 8 is the user's perspective after the marker is detected. Fig. 9 shows the implementation of the gamelan simulation being played by a user.

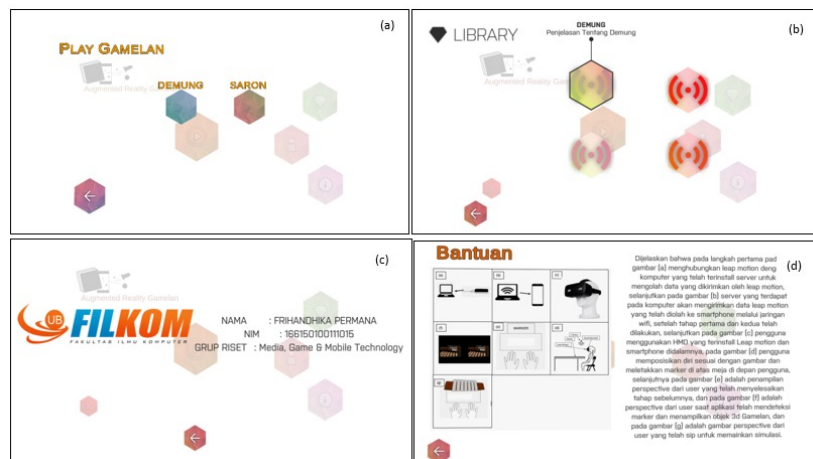


Fig. 7. The Display of the Menus in the Application

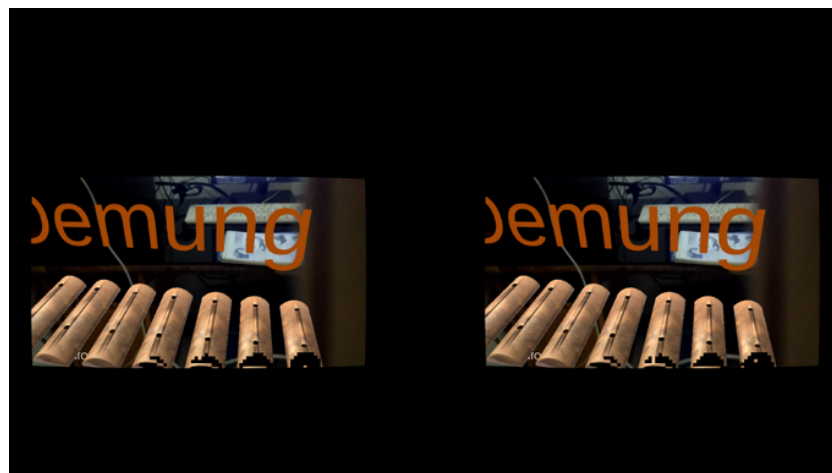


Fig. 8. The User's Perspective after Marker is Detected



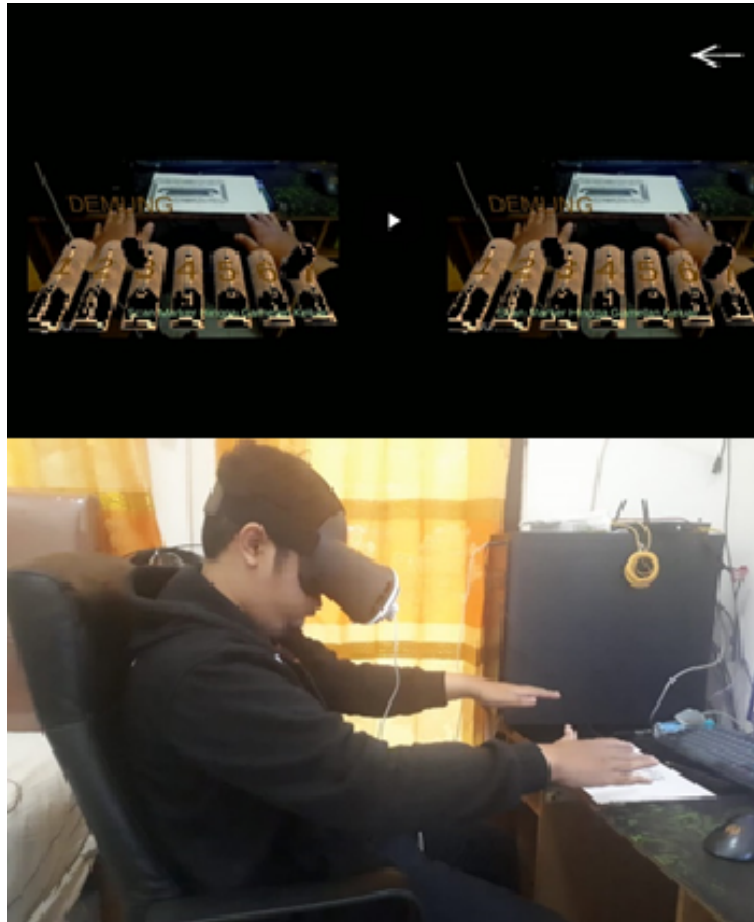


Fig. 9. The Implementation of the Gamelan Simulation

## 4 Experimental and Analysis

### 4.1 Augmented Reality

In this study, we have the Augmented Reality experiment which aims to measure and discover the essential parameters in this gamelan simulation. The experiments are held for some factors that are: the light, the distance, and the angle.

**The Light Parameter:** The light parameter experiment is meant to assure the light effect to the success of the application. By giving some different kind of light intensity, this experiment makes sure that different light condition will cause a certain result.

The user's perspective that seen in HMD is not affected by the light itself, because when the light intensity drops or gets lower, the preview on the smartphone display is adjusted to the proper light intensity to the user's vision.

This experiment shows that the light intensity influences the process of the marker scanning. Even though there is low light intensity, but if the smartphone camera still can capture the marker, then the 3D gamelan object will still be able to be rendered in the simulation. Table 3 is the experiment result for the light parameter.

**Table 3.** The Light Parameter Experimental Result

Light Intensity (lux)	Visible Marker	Rendered <i>Gamelan</i>	Status
50 - 56	✓	✓	Success
11 - 12	✓	✓	Success
9	✓	✓	Success

**The Distance and Angle Parameter:** The distance and angle parameters are the factors that relate to each other because the angle is obtained from the angle that forms from the distance and the height of the HMD to the marker. Fig. 10 shows the position of the angle  $\phi$ , the distance and the height of to HMD in the experiment.

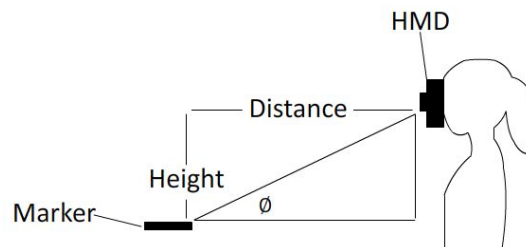
The calculation of is obtained by using the trigonometric formula shown in the following equation:

$$\tan \phi = \frac{\text{Height}}{\text{Distance}} \tag{1}$$

$$\phi = \tan^{-1} \left( \frac{\text{Height}}{\text{Distance}} \right) \tag{2}$$

This experiment is held for five users [15], they have to run the gamelan simulation at some determined distances and heights. In each trial, the results are noted and combined to calculate and acquire the users' success average in playing the simulation. The calculation of the success average obtained from the experiment is shown in following Table 4 and the graphics are shown in Fig. 11.

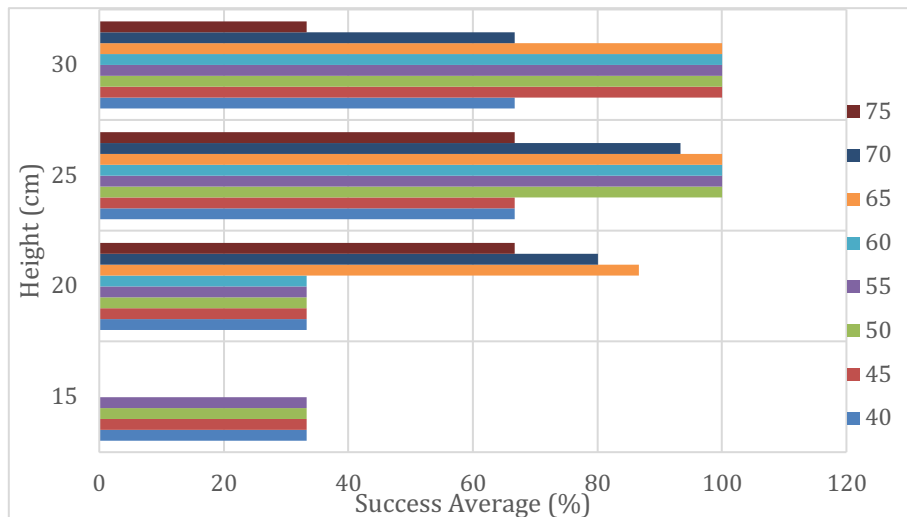
The highest (100%) success average of is obtained in the experiment of distance 45 cm and height 30 cm, the distance 50 cm, 55 cm, 60 cm, 65 cm and height 25cm and 30 cm. The calculation of the angle was achieved from the ration of the height and the distance of the HMD worn by the users. The experiment shows that the angle parameter is not the most significant influencing factor in the process of playing gamelan simulation. The range of the angle that allows users to play the simulation with 100% success average is between 21,097 o to 33,690 o.



**Fig. 10.** The Position of the Angle  $\phi$ , the Distance and the Height of the HMD in the Experiment

**Table 4.** The Success Average Result from the Experiment

Distance (cm)	Height (cm)							
	15		20		25		30	
	Angle $\phi$ (°)	Success Average (%)	Angle $\phi$ (°)	Success Average (%)	Angle $\phi$ (°)	Success Average (%)	Angle $\phi$ (°)	Success Average (%)
40	20,556	33,33	26,565	33,33	32,005	66,67	36,869	66,67
45	18,435	33,33	23,963	33,33	29,055	66,67	33,690	100
50	16,699	33,33	21,801	33,33	26,565	100	30,964	100
55	15,255	33,33	19,983	33,33	24,444	100	28,611	100
60	14,036	0	18,435	33,33	22,619	100	26,565	100
65	12,995	0	17,103	86,66	21,098	100	24,775	100
70	12,098	0	15,945	79,99	19,654	93,33	23,199	66,67
75	11,309	0	14,931	66,67	18,435	66,67	21,801	33,33



**Fig. 11.** The Graphic of Success Average Result from the Experiment

## 4.2 Usability

The usability evaluation for the AR-based gamelan simulation with Leap Motion control has five categories: Learnability, Memorability, Efficiency, Satisfaction, and Errors [16][17]. Some tasks are given to five users as they try to perform the gamelan simulation, as described in Table 5.

The user is given the questionnaire for each category, with a Likert scale for obtaining the result of the evaluation from 1 to 5. The score for the answer is described in Table 6. Except for the Error category, that is by scoring the result of the task with maximum 100 points. The result of the questionnaire is presented in Table 7.

**Table 5.** The list of the Task for the Users

No.	Tasks
1.	Open the application and pick the <i>Demung</i> Library page.
2.	Open the application and enter the Developer page.
3.	Open the application and play the <i>Saron</i> simulation.
4.	Strike the note 1 – 7 with the left hand
5.	Strike the note 1 – 7 with the right hand
6.	Open the application and play the <i>Demung</i> simulation
7.	Strike the note 1 – 7 with the left hand
8.	Strike the note 1 – 7 with the right hand
9.	Close the application by tapping the Exit button.

**Table 6.** The Score of the Answers

Score	Description
5	Strongly Agree
4	Agree
3	Neutral
2	Disagree
1	Strongly Disagree

**Table 7.** The result of the Questionnaire

No.	Statement	Score					Total Score
		1	2	3	4	5	
<b>Learnability</b>							
1.	I think the AR-based <i>gamelan</i> simulation with Leap Motion control is easy to play	0	2	2	1	0	14
2.	I think the interface of the AR-based <i>gamelan</i> simulation with Leap Motion control is easy to be recognized	0	0	2	2	1	19
3.	I think the page of the AR-based <i>gamelan</i> simulation with Leap Motion control is easy to find	0	0	0	2	3	23
4.	I think the text of the AR-based <i>gamelan</i> simulation with Leap Motion control is easy to read	0	0	0	1	4	24
5.	I think the icon of the AR-based <i>gamelan</i> simulation with Leap Motion control is easy to understand	0	0	3	2	0	17
<b>Memorability</b>							
1.	I think I can recall the number of the notes of <i>Demung</i>	0	0	0	2	3	23
2.	I think I can recall the number of the notes of <i>Saron</i>	0	0	0	2	3	23
3.	I think I can recall the way to access the <i>gamelan</i> simulation	0	0	1	2	2	21
<b>Efficiency</b>							
1	I think the <i>gamelan</i> simulation can respond my hand gesture very well	0	0	1	2	2	21
2	I think the <i>gamelan</i> simulation is not lagging	2	1	2	0	0	10
3	I think the text appears in the <i>gamelan</i> simulation provides enough information	0	1	3	1	0	15
4	I think the <i>gamelan</i> simulation helps me to get to know <i>gamelan</i>	0	0	0	2	3	23

5	I think the <i>gamelan</i> simulation is reliable to help me understand the way to play gamelan	0	0	1	3	1	20
<b>Satisfaction</b>							
1.	I feel comfortable to play the AR-based <i>gamelan</i> simulation with Leap Motion control	0	1	3	1	0	15
2.	I think the UI of the AR-based <i>gamelan</i> simulation with Leap Motion control is interesting	0	0	0	2	3	23
3.	I think the sound of the notes of the AR-based <i>gamelan</i> simulation with Leap Motion control is sounded clearly	0	0	0	1	4	24
4.	I think the AR-based <i>gamelan</i> simulation with Leap Motion control is interesting and attractive	0	0	0	0	5	25
5.	I think this <i>gamelan</i> simulation overall is satisfying	0	0	2	2	1	19

The result of the questionnaire is then calculated to get the criteria for each aspect of the usability as shown in Table 8. After that, the result is processed to get the usability score, as seen in Table 9 [18].

The evaluation for the error aspect is obtained from the users' task completion. The maximum score is 100. For the task number 1, 2, 3, 6, and 9 the score is either 0 or 100 (success = 100, unsuccessful = 0). Hence for the task number 4, 5, 7, and 8, the scores are obtained from the number of successes divided by 7 and multiplied by 100. The result of the calculation is described in Table 10.

**Table 8.** The Calculation Each Aspect of Usability

No	Usability Aspect	1	2	3	4	5	Total
1.	<i>Learnability</i>	0 × 1	2 × 2	7 × 3	8 × 4	8 × 5	97
2.	<i>Efficiency</i>	2 × 1	2 × 2	7 × 3	8 × 4	6 × 5	89
3.	<i>Memorability</i>	0 × 1	0 × 2	1 × 3	6 × 4	8 × 5	67
4.	<i>Satisfaction</i>	0 × 1	1 × 2	5 × 3	6 × 4	13 × 5	106
TOTAL		2 × 1	5 × 2	20 × 3	28 × 4	35 × 5	359

After all the aspects are calculated, the usability average of the AR-based gamelan simulation with Leap Motion control can be enumerated, as seen in Table 11.

Learnability aspect obtains 77.6%, efficiency aspect obtains 89%, memorability aspect obtains 89.3%, satisfaction aspect obtains 84.8% and error aspect obtain 91.7%. The usability average of the AR-based gamelan simulation with Leap Motion control is 86.48%. The graphic of the usability evaluation of the AR-based Gamelan Simulation with Leap Motion Control is described in Fig. 12.

**Table 9.** The Usability Score Result in Each Category

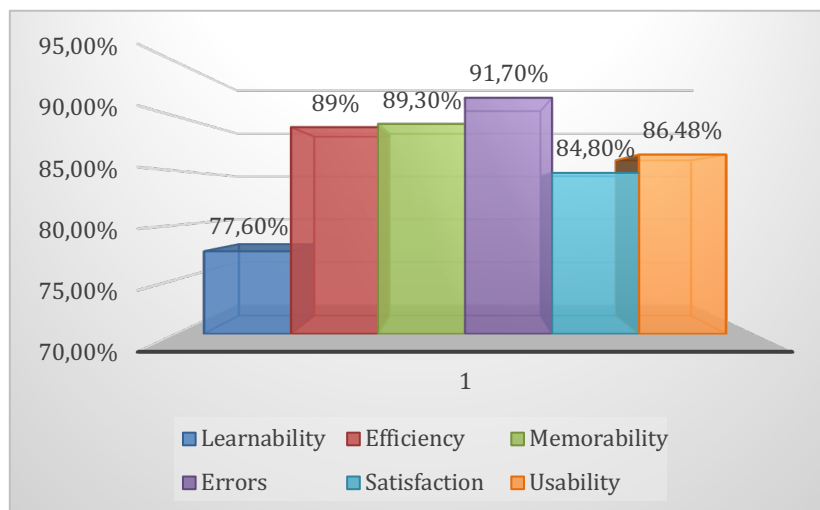
No	Usability Category	Total Score × Likert Score	Highest Score	Result
1.	<i>Learnability</i>	93	125	$(93/125) \times 100\% = 77,6\%$
2.	<i>Efficiency</i>	89	100	$(89/100) \times 100\% = 89\%$
3.	<i>Memorability</i>	67	75	$(67/75) \times 100\% = 89,3\%$
4.	<i>Satisfaction</i>	106	125	$(106/125) \times 100\% = 84,8\%$

**Table 10.** The Error Aspect Usability Evaluation

No.	Task	User					Score (%)
		1	2	3	4	5	
1	Open the application and pick the Demung Library page.	100	100	100	100	100	100
2	Open the application and enter the Developer page.	100	100	100	100	100	100
3	Open the application and play the Saron simulation.	100	100	100	100	100	100
4	Strike the note 1 – 7 with left hand	100	85,714	57,143	100	71,429	83
5	Strike the note 1 – 7 with right hand	100	71,429	42,857	85,714	71,429	74
6	Open the application and play the ation	100	100	100	100	100	100
7	Strike the note 1 – 7 with left hand	100	85,714	71,429	100	85,714	89
8	Strike the note 1 – 7 with right hand	100	71,429	57,143	100	71,429	80
9	Close the application by tapping the Exit button.	100	100	100	100	100	100
Average							91,7

**Table 11.** Usability of the AR-based Gamelan Simulation with Leap Motion Control

No.	Usability Aspect	The result (%)
1.	Learnability	77,6
2.	Efficiency	89
3.	Memorability	89,3
4.	Satisfaction	84,8
5.	Error	91,7
Usability Average		86,48



**Fig. 12.**Graphic of the Usability Evaluation of AR-based Gamelan Simulation with Leap Motion Control

## 5 Conclusion

This research is about the AR-based gamelan simulation with Leap Motion control. For a 100% success in playing the gamelan simulation, the parameter of distance and height of the smartphone camera in the HMD to the marker is very important. The experiment verifies that the appropriate distance is from 45 cm to 65 cm, and the height is from 25 cm to 30 cm. From the experiment conducted, the lamp light does not affect the performance of the application if the lamp has a brightness from 9 to 56 lux.

The usability evaluation that applied to five users establishes that the highest aspect is 91.7% in error aspect. It shows that the users are able to carry out the completion task very well without making any significant mistakes. And the lowest score is 77.6% in learnability aspect. It is because the questionnaire was given to the users who are not familiar with the gamelan simulation. The average of the usability is 86.48% that is pretty much satisfying. The learnability improvement can be increase if the user was given the tutorial how to play the simulation before the user plays the gamelan simulation.

The traditional musical instrument gamelan can be introduced to the user to make it more familiar for them. The technology of AR and Leap Motion involved can be an allurements for the user that never try or know gamelan before.

The use of Augmented Reality can be increased by using the markerless. The next research Can use the official version of Leap Motion (if it has been released) to make the application more flexible and easy to use. The use of higher hardware smartphone specifications will make the application run more smoothly.

In the future, this study may emphasize improving the gamelan simulation into a better application. Whether the improvement of the response speed, the application's ergonomics, and the usability.

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