The Development of A Cross-Platform Multi-Player Virtual Application of Kolintang Musical Instruments Using Various Controllers

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***Abstract*— Kolintang (Indonesian's xylophones) is popular nationwide as the traditional music instruments from Minahasa, a regency in North Sulawesi. It is usually played in ancestor worshipping rituals as it was believed that Kolintang had a close relationship with the traditional belief of North Sulawesi's natives and as their culture. Currently, there are several Kolintang applications developed that run either on Windows and Android and use different types of controllers like a web camera, touch screen, and keyboard. Despite their differences, these applications are played offline by a single player only without using an Internet connection. In addition, there is no depth discussion on how the performance of these applications was tested. Thus, this research will develop a more advance Kolintang application that can be played by multiple players simultaneously on multiple platforms, Android and Windows Based, using various controllers such as webcam, keyboard, mouse, or touch screen. The findings revealed that the interaction is best visualized within the range of two to three meters long. The sounding range of this application is safe for human hearing. The Root mean square error (RMSE) and Mean Absolute Error (MAE) tests can only be done to measure the real time auditory feedback from the application since there is no avail ideal data model for sounding range and application load time. The loading time for this application is faster than any Kolintang applications that have been previously developed. This application needs further improvements on the real time auditory feedbacks by diagnosing the variation in the errors in a set of forecasts.**

Keywords— Kolintang, Multiplayers, Cross-Platforms, Virtual, Performance Control.

I. INTRODUCTION

Kolintang (Indonesian xylophones) is popular nationwide as the traditional music instruments from Minahasa, a regency in North Sulawesi. It also belongs to the pitched percussion category. As an idiophonic instrument, the source of Kolintang's source is from its bars that vibrate when being hit. According to Kaseke, the name of Kolintang came from the sound: TING (high pitch note) and TANG (moderate pitch note), TONG (low pitch note). In the local language, the invitation "Let us do some TING TANG TONG" is: "mangemo kumolintang" [10]. Hence, the name of the instrument is called Kolintang. Kolintang consists of five different instruments, namely bass, cello, tenor, alto, and melodi. It is usually played in ancestor worshipping rituals as it was believed that Kolintang had a close relationship with the traditional belief of North Sulawesi's natives and as their culture.

As the technology is growing at a rapid pace, Kolintang instruments no longer interest the young generation due to various reasons. Firstly, Kolintang is not commonly sold at music stores because they mostly sell modern musical instruments like drums, keyboards, guitars, and others. Therefore, Kolintang must be specifically ordered to the Minahasa's craftsmen. Secondly, its price is considered expensive that are not affordable by many people. Thirdly, the original Kolintang is not portable to be moved around. Moreover, it requires a big dried storage to keep it. Fourthly, Kolintang has several instruments that are played differently, like the number of sticks used, type of sticks, the number of simultaneously hitting notes, and many more.

There are several Kolintang applications developed with limited features included such as Kolintang instrument selections, player and instrument interactions, and pertinent information about Kolintang. The applications are Aplikasi Alat Musik Tradisional Kolintang Dengan Menggunakan Webcam Sebagai Sensor Deteksi Gerakan [1] dan Aplikasi Alat Musik Kolintang Berbasis Android [6], Aplikasi Kolintang Virtual Berbasis Android [2], Virtual Kolintang by Elago Tech, and others.

These applications were developed using Action Scripts or Java programming languages. The controllers used in the applications are such as a web camera, touch screen, and keyboard. Furthermore, Windows and Android operating systems were utilized to develop and run the applications. Despite the differences mentioned above, these applications have similarities that these applications can be played offline by a single player only without using an Internet connection. Also, there is no depth discussion on how the performance of these applications was conducted.

This new developed application will measure its visual interaction, real time auditory feedback, sounding range, and application load time using RMSE and MAE to ensure its quality and reliability. The results of these tests will reveal the difference between values predicted by a model and the values actually observed [4].

Based on the shortcomings of these applications, there is an opportunity to develop a more advance application that can be played by multiple players (maximal 4 players) simultaneously on Android or Windows platforms. This new application provides options for players to use a

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webcam as motion detection sensor to play the Bass Kolintang. The player can also use keyboard or mouse to play Kolintang simultaneously with other players through the Internet. The instrumental sounds played by those players can be heard on the computers of each player. Features added to this application include history of Kolintang, types of Kolintang instruments, orchestra videos, 3D videos of Kolintang, and many more. These features are to lure the attraction and interest of players to play Kolintang instruments.

II. Research Question and Objectives

The formulated research question is "how to develop a cross-platform multi-player virtual application of Kolintang musical instrument using various controllers that can preserve the Minahasa's culture using various controllers?". In this regard, the research objectives are as follows:

1. To introduce and preserve musical instrument Kolintang originated from Minahasa, North Sulawesi – Indonesia by luring interest and attention from the young generation.
2. To develop a virtual application of musical instrument Kolintang played by multiple players on multiple platforms using various controllers such as webcam, keyboard, mouse, and touch screen.

III. Literature Review

A. Kolintang

According to Kaseke, the standard of Kolintang orchestra is seven players, with instrument compositions of two (2) melody Kolintang, 2 alto Kolintang, 1 tenor Kolintang, 1 cello Kolintang, and 1 bass Kolintang [8][10][11].

Figure 1. Kolintang's Bars [10]

Each Kolintang has its own instrumental name as shown in the following table:

Table 1. The Kolintang Instruments in Minahasa's Language [10]

No.	Kolintang Instruments	Minahasa's Language
1	Melody	Ina
	a. Melody I	Ina esa
	b. Melody II	Ina rua
	c. Melody III	Ina taweng
2	Cello	Cella
3	Tenor	Karua
	a. Tenor I	Karua
	b. Tenor II	Karua rua
4	Alto	Uner
	a. Alto I	Uner
	b. Alto II	Uner rua
	c. Alto III	Katelu
5	Bass	Loway

Tools used to hit the Kolintang bars are called stick that must suit the instruments played. For high pitch instruments, we must use a stick that has a hard surface, for example melody Kolintang does not use a rubber cover on its head. The lower the bar notes to hit, it required soft sticks with tick rubber covers on their heads. The thickest rubber cover is used for the bass Kolintang stick. For one instrument, the player can use sticks that have different thickness.

Figure 2. Kolintang Sticks [10]

B. Multimedia-Based Kolintang Applications

There are several Kolintang applications developed in the last three years. In 2013, Angdresey created Aplikasi Alat Musik Tradisional Kolintang Dengan Menggunakan Webcam Sebagai Sensor Deteksi Gerakan that runs on Android [1]. This application provides five instruments Kolintang where the player can only play one instrument on Android at a time. It has history of Kolintang, lyrics and sound settings.

In 2014, there were four unpublished thesis about the developments of Kolintang applications that all run on Android. Firstly, Aplikasi Kolintang Virtual Berbasis Android using Java and XML done by Sukma [2]. Secondly, Multimedia Interaktif Alat Musik Tradisional Kolintang using Adobe Flash and Cockos Reaper for sound samples was developed by Norman [13]. It has the history of Kolintang using animation, visualization of Kolintang and its sticks using 3D that can be viewed 360^0, tutorial on how to play Kolintang by providing a sampled song. Thirdly, Wijaksana developed Aplikasi Android Virtual Instrumen Kolintang Minahasa that has animated Kolintang bars when got hit [3]. Lastly, Rewur did his thesis on the development of Aplikasi Alat Musik Kolintang Berbasis Android that also provides five Kolintang instruments along with the history of Kolintang, type of Kolintang instruments, and video of Kolintang orchestra.

Elago Tech has just published a Virtual Kolintang with a multi touch ability this year. The sounds were sampled from real kolintang instruments. It can record and playback on virtual kolintang. It also provides history of Kolintang and basic tutorial how to play kolintang.

C. User Interaction and Virtual Musical Instruments

A system can be classified as an instrument when there is "a feedback between the output of the virtual device and the user in real time" [9]. Stofringsdal points out that instrument input is the excitation process that includes the parameter controller and interface [4]. On the other hand, instrument output is the sound radiation characteristics. The following figure will show a general system of a performer actuating over a virtual musical instrument.

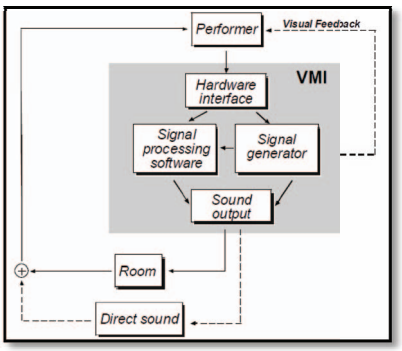


Figure 3. User Interaction and Virtual Musical Instrument [9]

As seen in the figure above, it is noticeable that physical and visual interactions play important role to provide feedback system between the player and the instrument. Digital media developments have abilities to possibly control every parameter that modifies sound with ease and efficiency.

D. Evaluation Models

It is important to perform a series of test to identify and measure the accuracy for continuous variables used in the application. In this research, RMSE and MAE were particularly selected as evaluation models to diagnose the variation in the errors in a set of forecasts.

The **RMSE** is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs,i} - X_{mo\,del,i})^2}{n}}$$

X_{obs} is observed values and X_{model} is modeled values at time/place *i*. In other words, RMSE is "a quadratic scoring rule which measures the average magnitude of the error, giving a relatively high weight to large errors. This means the RMSE is most useful when large errors are particularly undesirable" [7].

Meanwhile, MAE measures the average magnitude of the errors in a set of forecasts without considering their direction. It measures accuracy for continuous variables. The formulae of MAE can be seen as follows:

$$MAE = \frac{\sum_{i=1}^{n} | X_{obs,i} - \hat{X}_{\mathrm{mod}el,i} |}{n}$$

The MAE and the RMSE can be used together to identify the variation in the errors in a set of forecasts. The RMSE will always be larger or equal to the MAE; the greater difference between them, the greater the variance in the individual errors in the sample. If the RMSE is equal to MAE, then all the errors are of the same magnitude. Both the MAE and RMSE can range from 0 to ∞ [7]. They are negatively-oriented scores: Lower values are better. According to Chai and Daxler, the values of RMSE based on the convention are as shown in the table below [12].

Table 2. Value of RMSE

Compatibility of a Model	Value of RMSEA
Good	<= 0,05
Excellent	<=0,06
Adequate	<=0,08

Sound Power and Pressure

Basically, decibel is used as a logarithmic unit used to describe a ratio where it describes very big ratios in power with numbers of modest size. Atassi points out that "for sound intensity, the reference level (for air) is usually chosen as 20 micropascals, or 0.02 mPa. (This is very low: it is 2 ten billionths of an atmosphere. Nevertheless, this is about the limit of sensitivity of the human ear, in its most sensitive range of frequency. Usually this sensitivity is only found in rather young people or in people who have not been exposed to loud music or other loud noises." [5]

IV. Design and Implementation

As a traditional musical instrument from Minahasa, Kolintang should be preserved but it is unfortunate that the young generation nowadays has no interest in playing these instruments. Hence, there is an opportunity to develop a more sophisticated application for Kolintang musical instruments that can be run cross-platforms by multiple players simultaneously using various controllers.

A. Analysis of Recent Developments of Kolintang Applications

As mentioned before, the development of Kolintang instrument applications have been done over the years by several people like Angdresey and Rewur. The following table will only show the comparison between these two applications.

Table 3. The Comparison of Angdresey and Rewur's Kolintang Applications [1] [6]

	Angdresey	Rewur
I. Programming Language	Action Script 2	Java
II. Operating System	Windows	Android
III. Controller	Webcam and keyboard	Touch screen
IV. Number of Players	- Single player for using a webcam - Multiple players when using keyboard	Single players
V. Features		
a. Instrument Selection	√	√
b. History of Kolintang	√	√
c. Introduction of Kolintang Instruments	√	
d. Lyrics	√	√
e. Video Demo	√	-
f. Sound Settings	√	√
VI. Key Performance Indicator		
a. Visual Interaction	Ideal distance between a webcam and the player is 2-3 meters	-
b. Application Load Time	1 minute	30 seconds
c. Delay	8 seconds	10 seconds

B. Requirement Specifications

List of requirement specifications for developing the cross-platform multi-player virtual application of Kolintang musical instruments using various controllers is as follows:

1. To provide several options for controllers used in the application, namely webcam, touch screen, keyboard, and mouse, by which each controller will function differently and be used in either Windows or Android operating system.
2. The webcam controller can only be used to play the Bass Kolintang due to the number of bars, limited screen display, distance, and light sensitivity.
3. The touch screen controller is used to playing the Kolintang instruments in Android.
4. Players can play together simultaneously online where they are also able to see and hear the plays of others online.
5. To provide features like the history of Kolintang, type of Kolintang instruments, lyrics, video demo of playing Kolintang instruments, chatting, and setting.
6. To perform numerous testing on the application by measuring its performance, including visual interaction, real time auditory feedback, sound performance, and application load time.

C. Technology For The Application Development

Supporting software for this application are as follows.

Table 4. Software Required For Application Development

Programming	Adobe Flash Professional CS6, Java Eclipse, Android SDK, ADT-21.1.0
Image Editing	Adobe Photoshop Profesional CS3
Animation	Adobe Flash Profesional CS
Modelling	Microsoft Office Visio 2007

D. Implementation of Application

The following will depict the application interfaces.

Figure 4. Main Menu

Figure 5. Main Menu

Figure 6. Instrument Selections

Figure 7. Bass Kolintang Played Using Keyboard

After loading the application, the player needs to do the following:

1. Select the controller to use such as a web camera, touch screen, and keyboard.
2. The web camera is used to playing the Bass Kolintang only. The touch screen is for playing the Kolintang instruments on Android. The keyboard is used to playing the instruments by multiple players simultaneously online.
3. Select one of the Kolintang instrument to play. This application provides five different instruments to select from that are melody, bass, alto, tenor, and cello.
4. The ideal distance between the player and the web camera when playing the Bass Kolintang is 3 meters in order to have a better light sensitivity.
5. This application allows the player to play with others online by selecting the desired instrument. This player can also view the plays of others and hear the sounds produced by others from his/her computer.
6. There are several features included in this application such as record and play, chatting, video demo, lyrics, introduction to Kolintang, and more.

V. APPLICATION TESTING ON EVALUATION MODELS

Testing was performed on this application in order to measure RMSE and MAE using the following computer specifications.

Table 5. Computer Specifications For Testing

Processor	Core i3 2.27 Ghz
RAM	2 GB
Operating System	Windows 7 32-bits
	Android 4.0
Web camera	VGA web camera (1.3 mega pixels)

After performing a series of testing, the results are as follows:

1. Visual Interaction

Using a VGA web camera, the ideal distance for the player to play the Bass Kolintang is about 3 meters. The motion detection sensor of this application works well with a higher resolution web camera due to the light sensitivity. Also, it is highly recommended that the background from which the player stands when running this mode consists of one color only, especially light colors like white, light blue, light yellow, and others.

2. Sounding Range

The following table will show the sounding range gathered from the test results on the application based on different types of Kolintang instruments.

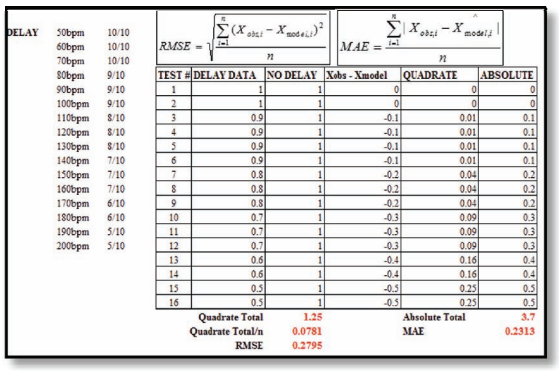
Table 6. Sounding Range

Kolintang Instruments	Sound Intensity Level (dB)
Cello	20
Alto	41
Bass	14
Melody	18
Tenor	16

This application measures the decibel to give the sound level for a single sound rather than a ratio by which a reference level is then chosen. The findings reveal that the sound pressure in this application is acceptable for human ears.

3. Real Time Auditory Feedback

This application was also tested for its real time feedback using Metronome and the results were measured using the RMSE and MAE as shown in the following figure.



$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \qquad MAE = \frac{\sum_{i=1}^{n}|X_{obs,i} - X_{model,i}|}{n}$$

DELAY		
	50bpm	10/10
	60bpm	10/10
	70bpm	10/10
	80bpm	9/10
	90bpm	9/10
	100bpm	9/10
	110bpm	8/10
	120bpm	8/10
	130bpm	8/10
	140bpm	7/10
	150bpm	7/10
	160bpm	7/10
	170bpm	6/10
	180bpm	6/10
	190bpm	5/10
	200bpm	5/10

TEST #	DELAY DATA	NO DELAY	Xobs - Xmodel	QUADRATE	ABSOLUTE
1	1	1	0	0	0
2	1	1	0	0	0
3	0.9	1	-0.1	0.01	0.1
4	0.9	1	-0.1	0.01	0.1
5	0.9	1	-0.1	0.01	0.1
6	0.9	1	-0.1	0.01	0.1
7	0.8	1	-0.2	0.04	0.2
8	0.8	1	-0.2	0.04	0.2
9	0.8	1	-0.2	0.04	0.2
10	0.7	1	-0.3	0.09	0.3
11	0.7	1	-0.3	0.09	0.3
12	0.7	1	-0.3	0.09	0.3
13	0.6	1	-0.4	0.16	0.4
14	0.6	1	-0.4	0.16	0.4
15	0.5	1	-0.5	0.25	0.5
16	0.5	1	-0.5	0.25	0.5
	Quadrate Total	1.25		Absolute Total	3.7
	Quadrate Total/n	0.0781		MAE	0.2313
	RMSE	0.2795			

Figure 8. RMSE and MAE Results

Based on the real time auditory feedback performed, the findings revealed:

1. The faster the player presses the note, the longer delay occurred. The optimal performance can be obtained when playing songs that have sound speed ranging from 50-130 bpm.
2. The RMSE is 0.2795 and MAE is 0,2313 which show the difference between the forecast and corresponding observed values. As Cort and Kenji pointed out that when the RMSE is larger or equal to the MAE, the variance in the individual errors in the sample is quite significant [7]. Hence, there is an urgent need to improve the accuracy of continuous variables used in this application.
3. The variation in the errors in a set of forecasts requires further improvement on the application to reduce its delay to <=0.06 for best performance of the model. The lower the values of RMSE and MAE the better real time auditory feedback provided by this application.

4. Application Load Time

The loading time for this application is 10 seconds that is faster compared to other developed Kolintang applications explained before.

VI. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The following conclusions were presented with reference to the research questions:

1. The new developed Kolintang application can help preserve the Kolintang by virtualizing the way it is played.
2. The application has provided varying options for players to play the Kolintang instruments, including type of operating systems and controllers.
3. The players can choose what operating system the application to run from as it will determine which controllers are to use. In this regard, should the player choose run the application on Windows, he/she can do a

live musical performance with the other players by selecting what instrument to play with. Furthermore, this player can view the plays and hear the sounds produced by each player from his/her own computer. Should the player decide to play on Android, he/she can only select and play one Kolintang instrument at a time using the touch screen controller. It cannot be played by multiple players simultaneously like on Windows.

4. The player can experience the use of web camera as the motion detection sensor when playing the Bass Kolintang. The ideal distance between the player and the web camera is 2-3 meters due to the light sensitivity. Unfortunately, it only provides a one-octave Bass Kolintang instrument because of the limited screen display.
5. Functionalities provided in this application include pre-recorded sound experience, chatting, demo video, and others.
6. The sounding range is within the acceptable range and safe for human ears. The situation is also applied to the application load time which runs as fast as expected.
7. The RMSE and MAE tests can only be done to measure the real time auditory feedback from the application since there is no avail ideal data model for sounding range and application load time.
8. The RMSE and MAE results also showed that there was a difference in the forecast and corresponding observed values which requires further investigation on how to improve the accuracy of continuous variables used in this application. It needs to reduce the real time auditory feedback to <=0,6 for better performance.

B. *Recommendations*

The recommendations for further research are:

1. For the Android version, it is highly recommended that the application can be played by multiple players simultaneously so that it can show a live Kolintang musical performance to a wider range of audience.
2. There is a need to add more octaves to the Bass Kolintang for the web camera. It is strongly urged that all the Kolintang instruments can be played using web cameras as well.
3. It is suggested to include options to choose type of Kolintang woods for each instrument due to the differences in timbre that can enrich the sound experience.
4. To create a computer-based model of analysis and simulation on different timbres produced by each Kolintang instrument.
5. To create an application that can automatically translate notes into respective sounds based on the selected instruments.
6. It is better to include the rhythmic movements and moveable rhythms that cover gestural aspects of performed rhythm which are required for live performances.
7. The real time auditory feedbacks need further improvement by diagnosing the variation in the errors in a set of forecasts.

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