ENHANCING EXPRESSIVE NATURAL PLAYING EXPERIENCE FOR VIRTUAL KOMPANG USING TRI-AXIAL ACCELEROMETER AND GYROSCOPE

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ENHANCING EXPRESSIVE NATURAL PLAYING EXPERIENCE FOR VIRTUAL *KOMPANG* USING TRI-AXIAL ACCELEROMETER AND GYROSCOPE

By

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April 2019

Chair : Noris Binti Mohd. Norowi, PhD
Faculty : Computer Science and Information Technology

This thesis seeks to enhance expressive natural playing experience by design a virtual percussion instrument for *Kompang* which closely imitate the acoustic one. The thesis implemented orientation determination and expressive sound manipulation features to closely mimic the similar playing style on acoustic *Kompang* to provide an expressive natural playing experience to the user. A series of studies were conducted to evaluate musicians' experience on the developed prototype. A set of initial design criteria which guided development of the prototype were then identified. An external approach was made by inviting expert musicians to use the virtual instrument, discussed their experiences and refined the criteria. A usability study was then conducted to evaluate whether the virtual instrument did enhance musicians' playing experience in terms of expressivity and naturality. Data analysis of these studies were made via several source of data such as video recordings, log files, questionnaires. The results of the studies identified that adding orientation determination and expressive sound manipulation features can significantly improve the user experience on the virtual instrument. The orientation determination feature reminded the similar hand posture used for playing the acoustic *Kompang* whereas the expressive sound manipulation feature allowed musicians to dynamically manipulate the sound output based on the strength of their hand movement. Questionnaire findings indicated these features further increases simplicity, enjoyment, reality, and some other metrics, when compare to the condition in which both features were not implemented.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia, sebagai memenuhi keperluan untuk ijazah Master Sains

MENAMBAHBAIKKAN PENGALAMAN EKSPRESIF UNTUK KOMPANG MAYA DENGAN PENGGUNAAN PECUTAN TIGA-PAKSI DAN GIROSKOP

Oleh

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Pengerusi : Noris Binti Mohd. Norowi, PhD
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Tesis ini bertujuan untuk menambahbaikkan pengalaman untuk *Kompang* maya secara ekspresif dan semulajadi. Tesis ini mengimplementasikan ciri-ciri ekspresif dan semulajadi seperti penentuan orientasi dan manipulasi bunyi yang ekspresif untuk meniru gaya bermain *Kompang* akustik. Kajian-kajian telah dijalankan untuk menilai pengalaman pemain mengenai prototaip yang dibangunkan. Satu set kriteria reka bentuk awal yang membimbing pembangunan prototaip telah dikenalpasti. Kajian bersama pakar muzik turut dijalankan untuk membincangkan pengalaman mereka semasa bermain instrumen maya *Kompang* dan seterusnya menapis kriteria awal itu. Kajian pengguna kemudiannya dijalankan untuk menilai sama ada instrumen maya *Kompang* dapat menambahbaikkan pengalaman pemain *Kompang* dari segi ekspresi dan semulajadi. Analisis data dijalankan melalui beberapa sumber data seperti rakaman video, fail log, soal selidik. Hasil kajian menunjukkan bahawa ciri-ciri ekspresif dan semulajadi itu dapat menambahbaikan pengalaman pengguna secara signifikan terhadap instrumen maya. Ciri penentuan orientasi mengingatkan postur tangan yang digunakan untuk memainkan *Kompang* akustik manakala ciri manipulasi bunyi ekspresif membolehkan pemuzik untuk memanipulasi output bunyi secara dinamik berdasarkan kekuatan pergerakan tangan mereka. Penemuan soal selidik menunjukkan ciri-ciri ini mampu menambahbaikan pengalaman dari aspek kesederhanaan, kesenangan, realiti, dan beberapa metrik lain, berbanding dengan keadaan di mana kedua-dua ciri tidak dilaksanakan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research conducted, and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
DMI	Digital Musical Instrument
HCI	Human-Computer Interaction
MIDI	Musical Instrument Digital Interface
MEMS	Micro-ElectroMechanical System
NIME	New Interfaces for Musical Expression
QUIS	Question for User Interface Satisfaction
SUS	System Usability Scale
UX	User Experience
VR	Virtual Reality
VRMI	Virtual Reality Musical Instrument

CHAPTER 1

INTRODUCTION

1.1 Overview

Virtual musical instrument (VMI) or virtual instrument is used to describe software simulations, extensions of existing musical instruments, and ways to control them with new interfaces for musical expression (Johnston, et al., 2008). At the earlier years of the progression of the computer music, musicians attempted to simulate traditional musical instruments such as guitar, piano, and drums to enable users to perform music with a computer system. Until today, research on VMI continues to grow in development of novel musical interface design. Following the rapid pace of technological advancement, a growing list of devices are built with the natural user interface has opened a wide range of possibilities in the creation of VMI in making the human-computer interaction to be much more natural and intuitive.

This thesis is concerned with the design and implementation of natural interaction method on a virtual musical instrument which offers user an expressive natural playing experience. By creating such a playing experience, people can enjoy using the virtual musical instrument without having to obtain a real musical instrument. In order to grant expressive natural playing experience to the user, the thesis suggests that mimic similar playing style on the acoustic instrument can improve the music playing experiences significantly.

The musical instrument that was developed in this thesis is a virtual percussion instrument for *Kompang*, namely Virtual *Kompang*. *Kompang* is a single-headed frame drum made with goat or cow skin, nailed to a round wooden frame by metal nails. An image of a *Kompang* is shown in Figure 1.1. To play a *Kompang*, a player holds the instrument upright with one hand, while hitting the membrane skin with the other bare hand (see Figure 1.2).

Figure 1.1: A *Kompang*

Figure 1.2: Hand Posture to Play a *Kompang*

The *Kompang* is selected as the target musical instrument for several reasons. Firstly, *Kompang* can be easily modelled as Natural User Interface (NUI) because it is naturally played by being strike with bare hands. With the available input technologies which offers natural playing experience on musical instrument, it is possible to preserve the natural interaction of using hand to play an acoustic *Kompang*. Users do not need to remember complicated output sound with wider pitch range as it generally produced two timbre sounds which are “Puk” and “Bum”. Additionally, the thesis also intends to transform this traditional instrument into the virtual form by embracing suitable digital technology. People can enjoy playing the *Kompang* without having to obtain the acoustic one.

Despite the vast amount of existing music applications, two main issues were not concerned by the developer during the development of new musical instrument. Firstly, the developers did not concern on maintaining the natural playing style of the real instrument as they were more emphasized on creating new way of interaction on the virtual instrument. The users had to adapt themselves with the new interaction method if they wanted to play it. This does not benefit users, specifically the musicians by improve their playing skills on the real instrument after practising the virtual instrument. Secondly, the degree of expressivity granted to common drum applications are limited to simple trigger-type input method. This means that the sound is triggered when users touched or clicked on the screen surface of the virtual musical instrument. Additionally, the sound samples to play in these applications are static, suggesting that users are not able to modify the qualitative aspects of a hit such as striking force and hand movement in terms of acceleration on the virtual instrument. Thus, the thesis intends to offer user an expressive natural playing experience by implementing an orientation determination and expressive sound manipulation features. The thesis believes that by adding these features can improve expressive natural playing experience of user when they are playing the Virtual *Kompang*. To achieve this aim, the thesis implemented user-centered design (UCD) techniques to develop the Virtual *Kompang*. This means that prototypes were developed iteratively and then evaluated repeatedly to examine closely the experiences of musicians who used it. The contribution from this thesis are:

1. The development of a virtual percussion instrument which uses hand input as the unique interaction paradigm;
2. The implementation of tri-axial accelerometer to extract expressive feature of the virtual percussion instrument.
3. The implementation of tri-axial gyroscope and accelerometer to estimate orientation angle of the input device.
4. A set of design criteria informed by practice and user studies.
5. Adoption of HCI evaluation to the developed musical instrument that can improve expressive natural playing experience.

1.2 Problem Statement

Music interaction (referring to “Music and Human-Compute Interaction”) can be viewed as a sub-discipline of Human-Computer Interaction (HCI) as it shares similar elements from HCI to evaluate the overall user experience when playing with the music interface. There are some research works relating to music interaction and music making technology. For example, the Reactable, a tabletop music instrument with tangible user interface. (Jordà, Kaltenbrunner, Geiger, & Alonso, 2006). It allows user to control the sound through direct manipulation of the musical objects they designed. Another popular musical instrument created for research work was the Song Walker Harmony Space (Holland, et al., 2011). It allowed users to use asymmetrical collaborative of whole-body interaction to control tonal harmony.

While music interaction has great commonality in designing new musical interface, very few research works were focused on the impact of different input methods (e.g. touch input and gestural input) from various input devices on music interaction, specifically on a percussion instrument. Despite the growing number of musical percussion applications via various platforms, such as desktop, mobile device, and tabletop, it is not clear how are these input methods affected the way people interact with the virtual percussion instrument. Thus, one of the problems highlighted in this thesis is to identify which existing input method can provide natural playing experience using bare hand to play the virtual instrument.

Secondly, the handheld percussion instrument such as *Kompang* are less popular comparing to other modern percussion instrument such as the drum kit (Collicutt, et al., 2009; Dolhansky, et al., 2011). However, it is a valid universal problem in music playing, as the current virtual instruments are developed without concerning the consistency and naturalness of the playing style of the acoustic instrument. The naturalness of the playing style is including the hand posture to hold instrument and the interaction method used to produce sound. Additionally, it was previously observed that some virtual percussion instruments seem to be lacking expressivity when played. What expressivity meant is being able to transmit manipulate the sound expressively as desired by the users. By providing solutions for the naturalness and expressive issues, music playing experience can be improved significantly. With the availability of embedded sensor technology, it becomes possible to create a musical application that able to extract expressive qualities of each drum hit. Thus, another research question highlighted in this thesis is how the existing sensor technology should be implemented to the designed virtual instrument for expressive natural playing experience.

One of the key components to define the success of a musical instrument is by incorporating the design criteria to the system. However, the discussion of design criteria for all musical instrument is still unsolved. This is because many VMIs are created for a niche group of musicians who are already familiar with the physical instruments. Whereas, in HCI perspective, the VMI must be designed to be used by all potential users including experts and beginners. Each of the new musical interfaces has their unique characteristic which could form a set of design criteria that guided the development of the interfaces. The thesis intends to identify what are the design criteria which guide the development of the Virtual *Kompang*.

Lastly, evaluation of music interaction is a key component in determining whether the designed musical system is a successful one. To identify whether the designed virtual instrument did improve expressive natural playing experience, the virtual instrument can be evaluated using metrics in the field of HCI, such as performance speed, number of errors, and time on tasks. In general, there are still plenty of opportunities to evaluate a new musical interface from HCI perspective. This is because, many existing musical interfaces were developed without having an explicit link to HCI research, and without a proper systematic evaluation (Stowell & McLean, 2013). Therefore, the thesis is hoping by embracing HCI elements for systematic and qualitative evaluation on the developed virtual instrument.

1.3 Aim of the Thesis

The thesis aims to address the following overarching research question: "*What are the challenges and opportunities provided by expressive handheld percussion instrument that offers natural playing experience using hand as input among the beginners and experts?*"

The question is motivated by the literature reviews, that the modern computer technologies can potentially provide an expressive natural experience of playing music instrument with computing devices. However, it is still unclear how these technologies should be used to offer expressive natural playing experience for percussion instrument with heterogeneous group of users, including the beginner and expert musicians. The approach implemented in this thesis is to investigate how the beginners and experts use the proposed application for music playing, in order to have better understanding of the current issues and to identify the potential of the application. The thesis focuses on various gaps found in the literature:

1. Exploration of which existing input devices are suitable for natural music performance, especially for the hand percussion instrument.
2. Exploration of new approaches to improve expressive natural playing experience on hand percussion instrument with the existing sensor technologies.
3. Exploration of suitable methods to evaluate the developed virtual instrument from HCI perspective.

1.4 Research Questions

The above observations are then led to the following subsidiary research questions:

1. What are the existing technologies that were used for designing an expressive and natural musical interface?
2. How should the developed application be designed based on the existing sensor technologies to offer expressive natural playing experience?
3. What are the design criteria that can be used to measure the design process of the developed application?
4. How to evaluate the developed application by borrowing elements from HCI study?

The discoveries can be helpful to understand the music interaction on percussion instrument with the computerized device and can be the basis to establish guidelines for designing percussion applications which also used natural hands for music performance purpose.

1.5 Research Objectives

The main objectives of the thesis are as follows:

1. To identify and introduce the input technology that offers the most natural playing experience for music performance using hand motion as input.
2. To identify and design mapping strategies to percussive gesture using sensors for expressive natural playing experience.
3. To devise a set of design criteria for virtual hand percussion instruments
4. To evaluate the efficiency of the designed virtual instruments and user experiences.

1.6 Significance of the Research

The rapid growth in new interface technologies opens a wide range of possibilities in the creation of Digital Musical Instruments (DMI) or New Interfaces for Musical Expression (NIME). This, coupled with the enhancement in computer power, has made the development of advanced audio-visual music applications possible even on low-cost hardware. As the evidence of the level of interest in this field, a large number of interactive music applications are being developed for various research purposes.

As computing devices have become faster and smaller in size, the interaction between human and an application or a machine is no longer limited to pointing and keyboard devices. Nowadays, user can now interact with computing devices in a various type of new and intuitive interaction methods, which uses human innate features, such as touch, speech, and gestures, which is more natural for users. Therefore, this thesis presents a study to identify which input method is preferred by users for natural hand interaction on a percussion instrument.

Given there were broad range of approaches used for designing virtual instrument with musical expression. In this thesis, the concept that a virtual instrument is expressive when users are able to manipulate the sound dynamically based on their input actions. One of the key issues for designing the expressive musical instruments has been the mapping issue between user gestures to the output sound. When users simply swing their hand, just like the way they play on real percussion instrument, the output sound should exactly same as user expects it. The orientation determination of the device is also important to relate and imitate the playing style of the acoustic instrument. It allows user to spend less time on re-learning the proper style of playing when users are playing the acoustic instrument. Therefore, the thesis also presents orientation determination method to estimate the angle of the device and sound mapping method for detecting drum hit and producing output sound, through the implementation of various sensor technologies, such as accelerometer, gyroscope and many others. The findings could come useful for researchers who are interested to investigate on designing expressive natural musical interface using a different combination of sensors.

The developed virtual instrument for this thesis is focused on the *Kompang*. Very few efforts can be seen in the research field to promote and raise awareness of traditional musical instrument like *Kompang*. Thus, the finding of this thesis brings significant benefit by reproducing *Kompang* as a musical application. The intention is to adapt *Kompang* to the digital area in forms that new generations are interested. Instead of purchasing a physical instrument, people can try out and develop better understanding of a *Kompang* with the developed virtual instrument. With the introduction of the Virtual *Kompang*, more people will have the opportunity to play the *Kompang*, which helps to preserve its among younger generation.

1.7 Research Scope

In general, every virtual musical instrument has its unique way to make musical sounds. For example, string instruments produce sound from vibrating strings; the brass instrument through the air vibration in the tubular resonator, or percussion instrument, by being hit on the surface of the instrument. One of the interesting scopes set for the thesis is on the selection of input device as bases of interaction for musical activities. To imitate similar playing experience of a *Kompang*, the selected input device for this thesis should allow user to use direct hand interaction to play the virtual instrument. The thesis is also wanting to ensure that the upfront costs of purchasing and weighted computer hardware are not a barrier for user to try out the virtual instrument. Hence, the selected input device must be portable, easily accessible and affordable by the user so that user can easily get it with the price they could pay for it.

Furthermore, the thesis is focused on using sensors technology to create a musical interface for expressive musical activities. The sensors are also essential to infer the hand postures that are similar as holding the real musical instrument by sensing thee device rotation. The thesis is seeking for suitable devices which need not to install external hardware to enjoy the virtual instrument. Thus, the selected input devices should have embedded sensors to help extract percussive gesture features performed by the user.

The thesis targets a heterogeneous group of *Kompang* musicians which covers the experts and beginners as the users. Feedback from both groups are needed as they perceived differently according to their knowledge of understanding on *Kompang*. Four applications were created in total, two of them for the preliminary study. Iterative prototypes were developed based on feedback during user studies. In general, these prototypes provide expressive natural control to play the instrument interestingly.

1.8 Structure of the Thesis

The rest of the thesis organizes as follows:

Chapter 2 discusses a review of the past research works in related studies. The review topics covered the background of *Kompang*, the controllers or the input devices for designing virtual musical instrument, sensor technologies for musical expression, and summarizes and compares the existing virtual musical instrument in research field.

Chapter 3 describes the research methodological design to explain how research was carried out. The methodological design is including description of research approach, research methodological framework, general details of each study, including tasks, participants, materials, procedure, data collection and analysis methods.

Chapter 4 presents the findings of the preliminary study with *Kompang* expertise using the developed prototypes on the gestural-based and touch-based interface.

Chapter 5 discusses the results of the orientation determination study to evaluate user experience when using the developed Virtual *Kompang* with orientation estimation dynamic sound manipulation features.

Chapter 6 presents the results of the user evaluation study to evaluate user experience of the Virtual *Kompang* based on music expertise's perceptions. Findings obtained through interview sessions with the expertise are reviewed.

Chapter 7 presents the outcome of the usability study for evaluation by comparing user playing experience at normal condition and expressive-enabled condition.

Chapter 8 summarized the findings from the user studies. The implications of the findings and the development of the revised design criteria are also discussed in this chapter.

1.9 Summary

This chapter explicitly describes an overview of the important structure of the thesis. The current issues regarding the virtual instrument and input devices are explained in general in this chapter. The chapter then explicitly detailed the problem statement and the objectives formed based on the research questions discovered throughout the research journey. Significance studies, and scope and limitation are also mentioned. A short explanation of the conducted studies is also explained based on the stated research objectives. A long-detailed review of past research works will be presented in the next chapter, such as the background of *Kompang*, existing input device for music interaction, and comparison on existing virtual music instrument.

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