
UNIVERSITI PUTRA MALAYSIA

# CONTINUOUS LINE BEZEL CORRECTION WITH ROTATABLE ORIENTATION SCREEN IN IMPROVING COLLABORATIVE DRAWING ON THE MULTI-MOBILE SYSTEM

ONG BENG LIANG

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By

ONG BENG LIANG

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of in Master of Science

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**April 2018**

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As a more robust alternative to tabletop system, the multi-mobile system is also benefiting humans' interaction by combining multiple mobile devices to become shared and larger touch surface display. Although it functions similarly to a tabletop system, several issues arise from the interaction and collaboration of mobile devices' users in a multi-mobile system which were not found in the interactive tabletop technology:(i) gaps between the screens and bezels issues and (ii) the inverted users' views caused by the user interface .This research investigates the effects of bezels and screen orientation on a larger shared screen display, and further proposes and implements the solution which is the "Continuous Line Bezel Correction with Rotatable Screen Orientation" that supports on the interaction challenges, particularly in collaborative drawing activities. The user-centered design approach was adopted throughout the research which was based on three key characteristics; including the early focus on users and tasks, empirical measurement and iterative design. Three main studies were carried out with the prototypes by using quantitative and qualitative approaches to understand the underlying issues. Firstly, the preliminary study investigated the impact of bezels and screen orientation on a multi-mobile system in a drawing application such as upside-down orientation, participants' working position, and disjointed drawing outcomes. The second and third studies measured the performance of the "Continuous Line Bezel Correction with Rotatable Screen Orientation" in solving the bezel and screen orientation issues via the user-based usability tests final two different versions of prototypes. After analyzing the collected data, positive increment on the proposed solutions was found. With the implementation of the continuous spatial configuration, the average time taken for participants to complete the task was improved by 9% and the gaps and disjointed object had improved visually. Moreover, with the implementation of rotational function, the average time taken for participants to complete the task had been shortened by 7.6% and with no inverted object drawn. As a result, the outcomes revealed that the gaps and spaces between mobile screens were found to have been reduced by 94.8%, where the participants remained in a static yet productive position. Hence, these findings

implied that the proposed solutions can enrich the users' experience on the system. In conclusion, the findings of this research contributes to the growing body of research on multi-platform or multi-device system by implementing the proposed solution to further address similar issues in their research works.

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

**GARISAN BERTERUSAN PEMBETULAN BEZEL DAN ORIENTASI SKRIN BOLEH-PUTAR DALAM PENAMBAHBAIKKAN AKTIVITI LUKIS KOLABORATIF PADA SISTEM MULTI-MUDAH ALIH**

Oleh

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**April 2018**

**Pengerusi: Noris Mohd Norowi, PhD**
**Fakulti: Sains Komputer dan Teknologi Maklumat**

Sebagai alternatif yang lebih teguh untuk sistem *tabletop*, sistem multi-mudah alih juga memberi manfaat kepada interaksi manusia dengan menggabungkan pelbagai peranti mudah alih untuk menjadi paparan permukaan sentuhan yang lebih besar. Walaupun ia berfungsi sama seperti sistem *tabletop*, namun beberapa isu timbul daripada interaksi dan kerjasama antara pengguna peranti mudah alih dalam sistem multi-mudah alih yang tidak terdapat dalam teknologi *tabletop* interaktif: (i) ruang antara skrin dan isu-isu bezel dan (ii) keterbalikan paparan pengguna disebabkan oleh antara muka pengguna. Kajian ini menyiasat kesan bezel dan orientasi skrin pada paparan skrin yang lebih besar, dan seterusnya mencadangkan dan melaksanakan penyelesaian iaitu "Garisan Berterusan Pembetulan Bezel dan Orientasi Skrin Boleh-Putar" yang menyokong cabaran interaksi, terutamanya dalam aktiviti melukis secara kolaboratif. Pendekatan reka bentuk yang berpusatkan pengguna telah digunakan sepanjang penyelidikan yang berdasarkan tiga ciri utama; termasuk fokus awal pengguna dan tugas, pengukuran empirikal dan reka bentuk berulang. Tiga kajian utama dijalankan dengan prototaip dengan menggunakan pendekatan kuantitatif dan kualitatif untuk memahami isu-isu asas. Pertama, kajian awal menyiasat kesan bezel dan orientasi skrin pada sistem multi-mudah alih dalam aplikasi lukisan seperti orientasi songsang, kedudukan kerja peserta, dan hasil lukisan yang terputus. Kajian kedua dan ketiga mengukur prestasi "Garisan Berterusan Pembetulan Bezel dan Orientasi Skrin Boleh-Putar" dalam menyelesaikan isu orientasi bezel dan skrin melalui ujian kebolehgunaan berdasarkan pengguna dua versi prototaip berbeza. Setelah menganalisis data yang dikumpul, peningkatan positif terhadap penyelesaian yang dicadangkan telah ditemui. Dengan pelaksanaan konfigurasi spasial berterusan, purata masa yang diambil untuk peserta menyelesaikan tugas itu ditingkatkan sebanyak 9% dan ruang serta objek terputus-putus telah bertambah baik secara visual. Selain itu, dengan pelaksanaan fungsi skrin boleh-putar, purata masa yang diambil untuk peserta menyelesaikan tugas itu telah dipendekkan sebanyak 7.6% dan tiada objek songsang yang dihasilkan. Seterusnya, hasil menunjukkan bahawa jurang dan ruang di antara skrin mudah alih

dapat dikurangkan sebanyak 94.8%, yang mana para peserta tetap berada dalam posisi statik namun produktif. Oleh itu, penemuan ini menunjukkan bahawa penyelesaian yang dicadangkan dapat memperkayakan pengalaman pengguna terhadap sistem. Kesimpulannya, penemuan penyelidikan ini menyumbang kepada cabang penyelidikan yang semakin bertambah dalam sistem kepelbagaian platform atau multi-peranti dengan melaksanakan penyelesaian yang dicadangkan untuk menangani isu-isu serupa dalam kerja-kerja penyelidikan mereka.

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

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Date:

**Declaration by Graduate Student**

I hereby confirm that:

- this thesis is my original work;
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Name and Matric No.: Ong Beng Liang (GS41202)

**Declaration by Members of Supervisory Committee**

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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| | |
|---|---|
| HCI | Human Computer Interaction |
| FCSIT | Faculty of Computer Science and Information Technology |
| UPM | Universiti Putra Malaysia |
| UCD | User-centered design |
| UEV | Usability evaluation |
| PDA | Personal digital assistant |
| LCD | Liquid crystal display |
| PC | Personal computer |
| RNT | Rotate 'N Translate |
| SDG | Shared Display Groupware |
| GUI | Graphical user interface |
| IDA | Interactive Drawing Application |
| PSSUQ | Post-study system usability questionnaire |
| IBM | International Business Machines Corporation |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research background

With the fast moving of transformation in this edge of innovation, digital technology becomes a vital necessity to accommodate people's daily lives. With the rapid rising of generation in multi-platform media, the available technology has presents numerous types of smart gadgets and tablets such as smartphones, computers, tabletop system which are currently experiencing popularity attentions and also exploiting mobile world to accommodate the user's needs for their daily activities (Westlund & Färdigh, 2015). With these emerging digital tools, human activity has become more vibrant which contemplates a new context for human communication (Crook, 2012). The vibrant use of digital technology aids in searching and unlocking enormous of information collection and communication data that will positively impact on individual, organizations and business management.

Human communication is at ease of reaching out each other through the access of smart gadgets. Hence, the importance of human interpersonal communication cannot be neglected. Along with the integration of technology and human communication, mobile gadgets has brought collaborative work to next level (Ertmer, 2005). The rapid adoption of collocative technology such as tabletop systems and multi-mobile system has raised expectations about accessibility and user experience in the working space (Lischke, 2013). People usually uses mobile technology for collaborative works, such as video discussing and conferencing, completing a group task, and etc. In addition, this innovation has impacts on the work collaboration which needed excellence interaction and communication whereby a team of workforce shares a common goal by sharing ideas, information, and work. Hence, it promotes frequent active interaction and communication when the users are working together. Furthermore, it closes the gap between humans through communication and discussion (Damian & Zowghi, 2003).

Human-Computer Interaction (HCI) is the study of the way in which computer technology influences human work and activities (Dix, 2009). Nowadays, the term "computer technology" often relates to the use of multiples technologies application, from computer desktop with screens and keyboards to telecommunication gadgets of mobile phones and tablets, home and personal appliances, vehicles built-in navigation systems and even embedded sensors and servomechanism such as automatic lighting (Xu *et al.*, 2014). This study of human computer interaction is on how the co-existence of abundance mobile devices and tablets gadgets in the market which can be utilized on impromptu work collaboration.

Moreover, mobile devices are currently experiencing a high popularity among the community with a large availability number of mobile devices in the market (Kaplan &

Haenlein, 2010). These tools can aid user in their daily activities such as outgoing and receiving incoming call, sending mail, messaging and so on (Dragunov *et al.*, 2005). Mobile devices are also referred to a handheld, handheld device or handheld computer. Mobile device is also referring to a pint-sized computing device (Lu *et al.*, 2005). Mobile devices usually come with a touch or non-touch display screen. Some devices are equipped with mini keyboard. There are various types of mobile devices available in the market which includes mobile phones, smartphones, tablets, personal digital assistants (PDAs) and etc (Figure 1.1).

**Figure 1.1: Types of Mobile Devices**[1]

Mobile gadgets have a great impact and influencing power towards the contemporary society. Moreover, they are abundantly found in the expanse of ground for knowledge acquirement purpose, entertainment, education, medical, communication provider, and military operations and so on. Users can use mobile devices to do online shopping, watch video, chatting and etc. However, only limited user interaction can be performed by mobile devices with their restricted screen size (Malik *et al.*, 2016). For instance, although possible, it is difficult to do a group discussion on the small screen.

**However,** there is an increase in the number of human computer interaction systems is employing interactive table surfaces (Šekoranja *et al.*, 2015). Tabletop system is a collaborative work space providing large touch screen which is capable of multi-touch interface (Wigdor *et al.*, 2007). The typical tabletop system is comprised of a touch-enabled display and a computer embedded on the table. It is also refers to the interactive display surfaces that allow users to interact with the digital contents on the table display and allow multiple-users interaction (Higgins *et al.*, 2011). Tabletop system offers collaboration activities to users when performing specific tasks such as discussion, gaming and sharing. Tabletop displays support a particular kind of actions which are usually used in collaborative work spaces such as bodily configuration,

[1] Why mobile devices are a huge security threat [Online image]. (2013). Retrieved October 18, 2017 from **http://www.btechonline.com/2013/11/18/why-mobile-devices-are-a-huge-security-threat/**

standing and sitting (Rogers, 2011). In a study by Buisine *et al.*, they found that the digital tabletop did not influence on the creative performance, but it did improve collaboration where the participants had more equitable contributions compared to the control flip chart condition (Buisine *et al.*, 2012). Figure 1.2 displays the example of tabletop system.

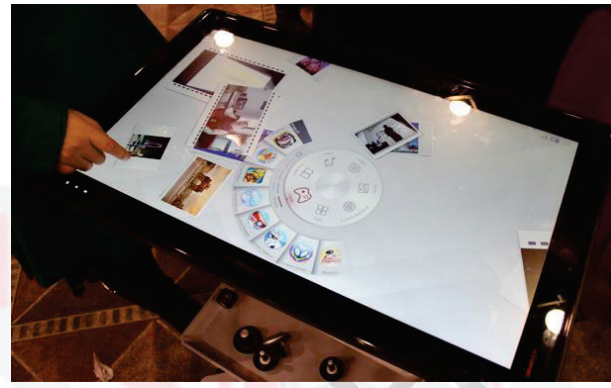

**Figure 1.2: Tabletop System**[3]

There are few products available in the market that is using tabletop technology such as Microsoft PixelSense and Lenovo Horizon 27. Multi-touch tabletop has been used as an education tool in European countries to improve learning process. The first tabletop classroom, SynergyNet (AlAgha *et al.*, 2010), was an interactive studio with five tabletops users consisting of four student tabletops and one with controls for the teacher. Through a series of studies, researchers analysed how elementary school students collaborated at the tabletops and how a teacher adapted their pedagogical strategies (Higgins *et al.*, 2011). Following this, TinkerLamps has been used as a the tangible device for the second study in which attempted the design of orchestration tools, assisting teachers to manage the flow of class activities for an education program (Do-Lenh *et al.*, 2012). Meanwhile, the first multi-tabletop technologies used in the classroom as part of actual authentic curricular activities and also explored the impact of providing the university teacher with real time visualisations to support awareness of student work and progress was called MTClassroom (Martinez-Maldonado *et al.*, 2013). More recently, the authentic sessions for elementary school students, using MTClassroom to empirically discover the type of functionalities that are preferred in their tabletop classroom deployments (Vasiliou *et al.*, 2015). Previous studies showed that the tabletop system help improve collaboration in the sense that participants had more same amount of contributions to complete a collaborative task (Buisine *et al.*, 2012). However, the adaptation rate of this technology has been slow by schools as the cost to own a tabletop is way too expensive (Lien *et al.*). Additionally, it has poor portability due to its physical size and heavy weight. Therefore, researchers

[3] Kowaliski C., (2013). Lenovo all-in-one doubles as tabletop PC [Online image]. Retrieved October 18, 2017 from http://techreport.com/news/24167/lenovo-all-in-one-doubles-as-tabletop-pc

have begun to develop multi-mobile system by stacking mobiles phone together in order to provide similar co-located collaborative benefits as tabletop system (K. P. Hinckley, 2009).

Multi-mobile system is a system that uses multiple mobile devices that to be connected together as a groupware environment to create one large display (Chen *et al.*, 2004). The extended surface allows multiple users to interact and work, similar to the tabletop system. In comparison, the mobile devices were lower in cost and portable as compared to the tabletop system. Furthermore, it has been used in multiple different areas, especially for collaboration purposes, for instance, slide presentation, general discussion and also entertainment. The display will be useful where a group of people come together to share or present information in a visual and interactive manner (Lucero *et al.*, 2011). However, there are still abounding issues related to the current design of collaborative multi-mobile system and applications, such as the inclusiveness of the gaps and spaces between the mobile devices, and also the orientation and enforcement of the ownership of content of the system (McKnight, 2012). Hence, these interactive issues have affected the user experience and interaction (Hassenzahl & Tractinsky, 2006). Figure 1.3 shows the example of a multi-mobile system.

**Figure 1.3 Multi-Mobile System**[4]

This research studies on the relationship of human's factors with the abundance of mobile devices and tablets available in the market for maximal utilization on interaction and collaboration purposes. This research also aims to study the interactive issues which involve bezels and screen orientation of multi-mobile display and hence design a solution to address these challenges. A multi-mobile system which has the capabilities of an interactive tabletop technology has been introduced in this research to adhere the existing problem whereby the interaction and collaboration among mobile

[4] Image from Lyons, K., Pering, T., Rosario, B., Sud, S., & Want, R. (2009). Multi-display composition: Supporting display sharing for collocated mobile devices. In IFIP Conference on Human-Computer Interaction (pp. 758-771). Springer, Berlin, Heidelberg.

devices' users are restricted due to (i) gaps between the screens and bezels issues as compared to the interactive tabletop technology, (ii) inverted users' views caused by user interface problems. When a group of people working collaboratively, especially group drawing on the multi-mobile system (the mobile phones are arranged in 2 x 2 grid patterns), an opposed being used in the multiple display screen has only single orientation. Therefore, the view of the opposed users in the multiple display screens are inverted.

Hence, the multi-mobile system which is an application that combines multiple mobile devices to become a shared and larger touch surface display has been introduced. The multi-mobile device system allows users to perform multi-user interaction, object manipulation during collaboration purposes that has the similar experience as tabletop system. Nevertheless, the multi-mobile system which comprises the features of mobile devices and tabletop technology helps smoothening project discussions, multiple tasks distribution, and enhancing collaborative work.

## 1.2 Research problems

Due to today's borderless environment, a broad range of tools that enable groups of people working together to carry out or complete a task towards specific shared goals has been invented. Tabletop systems have been introduced using multi-user horizontal interfaces for interactive shared displays which indeed benefit in the collaboration context. Large displays are very useful when multiple people are joined together to work and accomplish a single target for information visualization (Bravo *et al.*, 2006). Touch screen technology has been widely and successfully implemented in public information kiosks, ticketing machines, bank teller machines and so on (Cockburn *et al.*, 2012). However, tabletop systems are exquisitely expensive and cumbersome to be carried around due to its extreme size (Li & Kobbelt, 2012). Hence, researchers started to develop multi-mobile system by stacking mobiles phone together in order to provide similar collaborative benefits as tabletop system. Unfortunately, when people conduct group drawing in a collaborative environment that involve multiple devices, two of the major interactive issues have been observed.

1. Firstly, when conducting a collaborative group drawing, users can become distracted about the existence of the space and gaps between the mobile screens due to the physical design of mobile devices. Gaps and bezels between the mobile display causes inherent design problems to the multi-display structure and users are always confused with the spaces between devices whether the spaces are included (Rashid, 2012). The space between the mobile screens could be minimized if and only if the spaces are eliminated. Furthermore, the physical design of the digital mobiles cannot be altered and modify easily, for instance, the new Samsung S7 Edge provides borderless experience but not all devices are bezel-less, and those which are, are expensive.

2. Secondly, the users can become confused about their actual working position when they perform collaborate tasks on multi-mobile surface. Inverted users' views on the ongoing collaborative drawing activities on a multi-mobile system. Users are always confused with their working position when performing collaborative work in a multi-mobile system (Miao, 2010). The main goal of an user interface is to allow the end user undergoes an effective operation and control on the machine, at the same time allowing the machine to provide feedback to aid on the decision making process of the operators. There can be many orientations when users' working positions are different during an ongoing collaborative work. Hence, information cannot be reached precisely to all users because of different working position and screen orientation. With the aid of user interface and interactive function such as screen orientation and appropriate user's position, it can minimize the problem of inherent design.

Therefore, this study will focus on designing a multi-mobile system with an interactive drawing application by using the existence of touch screen technology of mobile devices which are easily accessible today to solve the interactive issues that caused by the bezels and screen orientation.

## 1.3 Research objectives

Three main research objectives for this research have been identified:

i. To identify and solve the effects of bezels and screen orientation on the interaction of users on a multi-mobile system.
ii. To design and introduce the "Continuous Line Bezel Correction" as a solution to solve the bezels issue.
iii. To design and introduce the "Rotatable Orientation Screen" as a solution to solve the screen orientation issue.

## 1.4 Significance of the study

With the transformation in the field of multi-mobile system, there are several amount of study focused on screen orientation and bezels challenges. The foundation of this research is to provide an effective and efficient solution to address bezels and screen orientation issues in a multi-mobile system.

The study is significant because it fills the gaps reviewed in the current literature with regards to the interactive challenges of bezels and screen orientation in a multi-mobile system. This study presents the effects of bezels and screen orientation by employing user-based usability test. Furthermore, this study has coped with the difficulty when users were performing a drawing using a multi-mobile system. This knowledge comes

in useful to either professionals like researchers, mobile and application developers as well as educators or interested individuals for developing useful, effective and efficient multi-mobile system that encourages collaboration and interaction activities.

The findings of this study are significant because they may contribute to the growing body of research on multi-platform or multi-device system by implementing the proposed solution to address similar issues in their research works. These findings imply that the proposed solution can improve the user experience and usability of the system.

Additionally, this research hopes to bring more attention to the influence of multi-mobile industry because the current literature is facing some limitations and lacking of similar kind of research work. It is hoped that the findings of this study can be a source of reference that provides guiding principles in designing a multi-mobile system. Furthermore, it is also hoped that this study helps to makes a contribution to the design and development of a better multi-mobile platform, especially in the context of Malaysia.

## 1.5 Scope of the study

The research work presented in this study was conducted in three stages which are discussed in Chapter 3. User-centered design approach was employed as the main approach for this research work to ensure that a software system is designed with levels of usability. In order to conduct this research smoothly and effectively in the process of data collection through employing prototypes design, undergraduates in the Faculty of Computer Science and Information Technology (FCSIT) at Universiti Putra Malaysia (UPM) was the population of interest as this group of people has more knowledge on mobile technology in order to ease the research work can be conducted smoothly. Additionally, the developed drawing application is installed into four tablets to form 2 x 2 grid pattern with Android operating system. Although there can be many combinations of layouts, this study only involves four tablets which are arranged in a 2 x 2 grid pattern throughout experiments because of this grid pattern can form a perfect rectangular shape in order to ease the drawing application for better visual results (Figure 1.4). Figure 1.5 shows the main scope of this research study.

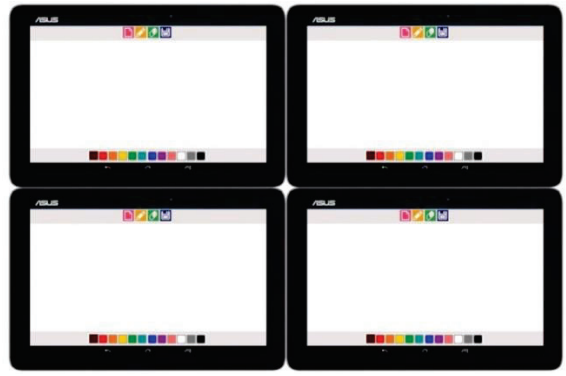

**Figure 1.4: 2 x 2 Grid Layout**

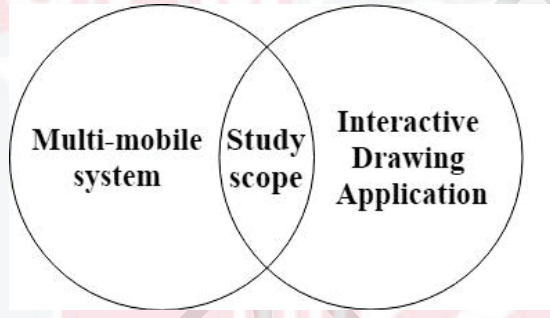


**Figure 1.5: Scope of the Study**

The main scope of this study is focusing on designing a multi-mobile system and an interactive drawing application. An interactive drawing application on multi-mobile system is designed and developed in this study to study the research objectives. Drawing activity has been selected in this study because it is easier for conducting collaborative works and it is fun and interesting (Schwamborn *et al.*, 2010).

## 1.6 Thesis organization

This section provided a brief summary of the thesis organization. A total of five chapters were included in this research.

**Chapter one** presents general introduction to the research work and provides with the research objectives, statements and scope of study.

**Chapter two** reviews the related literatures and discusses in some specific areas associated with the research field in previous researches and also describes the user-centered design approach as the main research framework.

**Chapter three** describes the details of three studies that conducted with process of prototypes development, data analysis methods and procedure, the design of the usability test, and the planning and conducting of the user studies.

**Chapter four** presents the preliminary study and the findings of the study. A discussion of the findings is provided following after the outcomes of the research work were analyzed.

**Chapter five** presents the bezel issues study and the results and findings of the research. A discussion of the findings is provided following after the outcomes of the research work were analyzed. A comparison between two sets of data is carried out between the high-fidelity prototype and iterative prototype with solutions design for the purpose of improving the overall usability of the system.

**Chapter six** presents the screen orientation issues study and the results and findings of the research. A discussion of the findings is provided following after the outcomes of the research work were analyzed. A comparison between two sets of data is carried out between the high-fidelity prototype and iterative prototype with solutions design for the purpose of improving the overall usability of the system.

**Chapter seven** concludes the thesis based on the information presented from Chapter one to Chapter six. This chapter also provides the recommendation for future study to provide a possible improvement to the current research findings.

## 1.7 Chapter summary

This chapter presents and explains the motivation behind the research study work. The background of the research is described briefly and discussed. The objectives and significance of the study are presented. Finally, the thesis organization and a brief description of it are provided.

The following chapter is concerned with providing a detailed background and relevant sources for the research. This will provide a rich backdrop to the aims and objectives of conducting the research.

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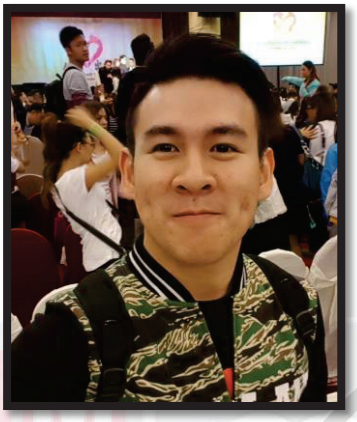
**BIODATA OF STUDENT**



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## LIST OF PUBLICATIONS

### Proceedings

Liang, O. B., Ming, T. R., Norowi, N. M., Mansor, E. I., Dey, P., & Jamil, I. (2016, April). Mobitop: Interactivity Issues In A Multi-Mobile System. In Proceedings of the 2th International Conference in HCI and UX on Indonesia 2016 (Pp. 54-61). ACM.

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### Journal

Liang, O. B., Ming, T. R., Norowi, N. M., Mansor, E. I., Dey, P., & Jamil, I. (2016). Mobitop: Interactions Employed By Users When Using a Collocated Ad-Hoc Collaboration Application, 17580-17587.

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