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USABILITY EVALUATION FRAMEWORK FOR MOBILE APPS

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USABILITY EVALUATION FRAMEWORK FOR MOBILE APPS

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

July 2020

DEDICATION

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

I dedicate this thesis to…

my beloved late husband, Maswira bin Haji Sukiman,
for his continuous moral support, patience, understanding, undivided love and tolerance…

my lovely son, Muhammad Hafizhiy bin Maswira,
who spent his childhood years, bearing hours of lab time, 24-7 with me,

my ginger tabby cat, Robbin,
who bravely face his hear, travelling with me back and forth from Batu Pahat to Serdang for hours, and staying alone indoor at home, waiting me to finish my lab works every day,

without whom, none of this would have happened.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

USABILITY EVALUATION FRAMEWORK FOR MOBILE APPS

By

HAZWANI BINTI RAHMAT

July 2020

Chairman : Associate Professor Hazura binti Zulzalil, PhD
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Mobile phones have evolved from cell phone to smartphone through various and integrated technology. This technological advancement has transformed mobile apps user interface into a complex interface features. However, the importance of usability in mobile apps has been commonly neglected during the mobile apps' development life cycle due to the perception of cost and skills required for conducting the usability evaluation. As a result, mobile apps in the marketplace suffers low user retention, which is indicated by the high rate of mobile apps uninstallations after minimal usage. Consequently, extensive frameworks have contributed to addressing usability for mobile phones in various aspects. However, the frameworks are only pertinent mostly in terms of ergonomics, physical user interface, and mobility aspects in using mobile apps. In addition, much of the previous framework conceptualisation was built on desktop computing measurements such as desktop and web applications checklist or scarcely addressed mobile apps user interface. The frameworks focus mainly on the interface features for desktop applications. Therefore, the measurement in the frameworks did not reflect a comprehensive mobile apps interface features such as the navigation drawer and spinner. However, mobile apps are built on different interface features and operating mechanism. Thus, conducting usability evaluation for mobile apps using previous usability evaluation frameworks would result in irrelevant results. Moreover, in real practice, usability evaluation is performed by the non-usability specialist. Lack of usability experience could risk misinterpretation of usability measurement, thus leads to unreliable usability evaluation. Therefore, this study aims to develop a usability evaluation framework for mobile apps that addresses these issues. Initially, a set of usability criteria and interface features are developed to characterise the usability dimension for mobile apps. The usability criteria and interface features are constructed based on content analysis of relevant literature concerning mobile usability measurement, particularly checklist and heuristics. Subsequently, the resulting interface features are enhanced to comply with a user interface in mobile apps of Google Inc. android developer guide. Next, a set of design patterns were conceptualised from the usability criteria to form usability features. The usability features, usability criteria, and interface features are incorporated from the viewpoint of different skills of evaluators.

A survey was then administered to assess the comprehensiveness of the usability features and usability criteria in characterising usability dimensions for mobile apps. The usability features and usability criteria are then refined based on the survey responses. Consecutively, a feasibility survey was conducted among industrial software engineering practitioners in Malaysia to evaluate the feasibility of implementing the usability features and usability criteria for usability evaluation of mobile apps in real practice. Finally, the usefulness of the framework measurement for evaluating the usability of mobile apps in view of the non-usability specialist is empirically assessed through an expert review. The experiment is replicated in comparison with a framework from another study. The findings showed that the formulated framework significantly outperformed the framework from another study. Altogether, the two surveys and expert review suggested that the formulated framework is comprehensive, widely acceptable, and more useful compared to another framework. However, the framework focuses on mobile apps for the smartphone. Therefore, these results are not applied to other mobile devices such as feature phones, handhelds, and tablets.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KERANGKA KERJA PENILAIAN KEBOLEHGUNAAN BAGI APLIKASI MUDAH ALIH

Oleh

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Telefon mudah alih telah berkembang dari telefon sel ke telefon pintar melalui teknologi yg pelbagai dan bersepadu. Kemajuan teknologi telah mengubah antara muka pengguna aplikasi mudah alih kepada ciri antara muka yang kompleks. Namun, kepentingan kebolehgunaan bagi aplikasi mudah alih kebiasaannya diabaikan sewaktu kitar hayat pembangunan aplikasi mudah alih kerana kos dan kepakaran yang diperlukan untuk melaksanakan penilaian kebolehgunaan. Akibatnya, aplikasi mudah alih di kedai aplikasi mengalami pengekalan pengguna yang rendah, ditunjukkan oleh penyahpasangan aplikasi yang tinggi setelah digunakan hanya seketika. Kesannya, kerangka kerja yang meluas telah disumbangkan bagi menangani kebolehgunaan telefon mudah alih dari pelbagai aspek. Walaubagaimanapun, kerangka kerja tersebut hanya sesuai dari aspek seperti ergonomik, antara muka pengguna fizikal dan mobiliti di dalam menggunakan aplikasi mudah alih. Tambahan pula, kebanyakan pengkonsepsualan kerangka kerja sebelum ini terbina dari pengukuran perkomputeran komputer meja seperti senarai semak komputer meja dan aplikasi sesawang atau kurang menekankan antara muka pengguna mudah alih. Kerangka kerja tersebut menekankan terutamanya ciri antara muka bagi aplikasi komputer meja. Maka pengukuran di dalam kerangka kerja tersebut tidak menggambarkan ciri antara muka aplikasi mudah alih yang menyeluruh seperti laci pelayaran dan pemusing. Maka, perlaksanaan penilaian kebolehgunaan aplikasi mudah alih menggunakan kerangka kerja kebolehgunaan sebelum ini akan menghasilkan keputusan yang tidak relevan. Tambahan, di dalam pengamalan sebenar, penilaian kebolehgunaan dilaksanakan oleh ahli yang kurang pakar. Kekurangan kepakaran akan membawa kepada penyalahtafsiran pengukuran pengguna, justeru mengakibatkan penilaian kebolehgunaan yang kurang tepat. Maka, kajian ini bertujuan bagi membangunkan kerangka kerja kebolehgunaan bagi aplikasi mudah alih dalam menangani isu-isu ini. Di awalnya, sekumpulan kriteria kebolehgunaan dan ciri antara muka dibangunkan bagi menggambarkan dimensi kebolehgunaan bagi aplikasi mudah alih. Kriteria kebolehgunaan dan ciri antara muka berkenaan dibangunkan berdasarkan analisa isi kandungan kajian literatur berkenaan tentang pengukuran kebolehgunaan, terutamanya senarai semak dan heuristik. Seterusnya, ciri antara muka yang terhasil

ditambahbaik agar selari dengan antara muka pengguna di dalam aplikasi mudah alih pembangunan android oleh Google Inc. Kemudian, satu set corak rekaan dikonsepsualkan melalui kriteria kebolehgunaan bagi membentuk ciri kebolehgunaan. Ciri kebolehhgunaan, kriteria kebolehgunaan, dan ciri antara muka tersebut digabungkan melalui pandangan penilai yang berlainan kepakaran. Tinjauan kemudian dilakukan bagi menilai kemenyuluruhan ciri kebolehgunaan dan kriteria kebolehgunaan berkenaan dalam menggambarkan dimensi kebolehgunaan aplikasi mudah alih. Ciri kebolehgunaan dan kriteria kebolehgunaan berkenaan kemudian ditambahbaik berdasarkan maklumbalas tinjauan tersebut. Seterusnya, tinjauan kesesuaian dijalankan dikalangan pengamal kejuruteraan perisian di industri bagi menilai keseuaian mengamalkan ciri kebolehgunaan dan kriteria kebolehgunaan berkenaan di dalam amalan sebenar. Akhirnya, kebergunaan pengukuran kerangka kerja ini dalam menilai kebolehgunaan aplikasi mudah alih dari pandangan ahli yang bukan pakar dinilai melalui kajian pakar. Eksperimen ini diulang dalam perbandingan dengan kerangka kerja dari kajian lain. Hasil kajian menunjukkan bahawa kerangka kerja yang dibangunkan mengatasi rangka kerja kajian lain. Secara keseluruhan, kedua-dua tinjauan dan kajian pakar menyimpulkan bahawa kerangka kerja kajian ini adalah menyeluruh, diterima secara meluas, dan lebih berguna daripada kerangka kerja yang lain. Namun, kerangka kerja ini tertumpu kepada aplikasi mudah alih bagi telefon pintar. Maka, hasil dapatan ini tidak terpakai untuk aplikasi mudah alih di telefon mudah alih lain seperti telefon ciri, telefon bimbit, dan tablet.

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

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TABLE OF CONTENTS

		Page
ABSTRACT		i
ABSTRAK		iii
ACKNOWLEDGEMENTS		v
APPROVAL		vi
DECLARATION		viii
LIST OF TABLES		xiii
LIST OF FIGURES		xvi
LIST OF APPENDICES		xvii
LIST OF ABBREVIATIONS		xviii
CHAPTER		
1	**INTRODUCTION**	1
	1.1 Research Background	1
	1.2 Problem Statement	3
	1.3 Research Objectives	5
	1.4 Research Scope	5
	1.5 Thesis Organization	6
2	**LITERATURE REVIEW**	7
	2.1 Introduction	7
	2.2 History of Usability and User Interface	7
	2.2.1 Command Line Interface (CLI)	8
	2.2.2 Graphical User Interface (GUI)	8
	2.2.3 Web User Interface	9
	2.2.4 Mobile User Interface	10
	2.3 Mobile Usability Studies	10
	2.4 Mobile Apps Checklist-based Usability Frameworks	12
	2.4.1 Attribute-based Framework	12
	2.4.2 Integrated-based Framework	13
	2.4.3 Theoretical-based Framework	14
	2.4.4 Decision-based Framework	15
	2.5 Comparison of Framework Development Approaches	15
	2.5.1 Framework Structural Base	15
	2.5.2 Evaluator Viewpoint	16
	2.5.3 Intended Platform	16
	2.5.4 Scope of Evaluation Items	16
	2.6 Discussion of Literature	17
	2.6.1 Context of Use of the Approaches	17
	2.6.2 Benefits and Drawback of Approaches	17
	2.7 Selection of Framework's Checklist	20
	2.7.1 Adopted Frameworks for the Development	20
	2.7.2 Compared Framework for the Experiment	29
	2.8 Summary	30

3	**RESEARCH METHODOLOGY**		31
	3.1	Introduction	31
	3.2	Conceptualising Usability Dimension	32
		3.2.1 Establishing Mobile Apps Conception	33
		3.2.2 Developing Framework Structure	35
	3.3	Validating Framework Measurement	35
		3.3.1 Developing Survey Instrument	36
		3.3.2 Validating Measurement Properties	37
	3.4	Evaluating Framework Usefulness	43
		3.4.1 Selection of Comparative Checklist	43
		3.4.2 Preparation of Evaluation Plan	44
		3.4.3 Conducting Expert Review	44
	3.5	Summary	47
4	**CONCEPTUALISATION OF MOBILE APPS USABILITY**		48
	4.1	Introduction	48
	4.2	Establishing Mobile Apps Usability Conception	48
		4.2.1 Elicitation of Usability Criteria	49
		4.2.2 Elicitation of Interface Features	50
		4.2.3 Redundancy Analysis	52
	4.3	Developing Framework Structure	56
		4.3.1 Determination of Framework Rationale	56
		4.3.2 Determination of Framework Component	56
	4.4	The Formulated Mobile Apps Usability Evaluation Framework	59
	4.5	Summary	62
5	**VALIDATION OF FRAMEWORK MEASUREMENT**		63
	5.1	Introduction	63
	5.2	Analysis and Discussion of Results	63
		5.2.1 Findings and Results of Content Validity Test	64
		5.2.2 Findings and Results of Comprehensiveness Survey	69
		5.2.3 Refinement of Framework Measurement	73
		5.2.4 Findings and Results of Feasibility Survey	75
		5.2.5 Discussion of Findings	79
	5.3	Summary	83
6	**EVALUATION OF FRAMEWORK USEFULNESS**		84
	6.1	Introduction	84
	6.2	Expert Review Conduction	84
		6.2.1 Research Hypothesis	84
		6.2.2 Design of Experiment	85
		6.2.3 Experimental Procedure	86
	6.3	Findings and Result of the Expert Review	87
		6.3.1 Demographic of Participant	87
		6.3.2 Fulfilment of the Statistical Requirement	88
		6.3.3 Framework Usefulness	89
	6.4	Discussion of Findings	91
		6.4.1 Discussion on Demographic of Participant	91

6.4.2 Discussion on Framework Usefulness 91
6.5 Threats to Validity 92
6.6 Summary 93

7 CONCLUSION AND FUTURE WORKS 94
7.1 Research Conclusion 94
7.2 Contributions of the Study 95
7.3 Implications of the Study 96
7.4 Limitations of the Study 96
7.5 Future Works 97

REFERENCES 98
APPENDICES 104
BIODATA OF STUDENT 158
LIST OF PUBLICATIONS 159

LIST OF TABLES

Table		Page
2.1	Work of Hussain and Kutar (2009) and Saleh et al., (2017)	13
2.2	Work of Xu and Jonsson (2012) and Ji et al. (2006)	13
2.3	Studies for Theoretical-based Framework	15
2.4	Comparison of GQM, AHP and Pairwise-Comparison Approach	18
2.5	Comparison of Framework Developed using Content Analysis Approach	19
2.6	Usability Principles by Their Cluster	20
2.7	UI components by Their Categories	21
2.8	Usability Dimension for Mobile Games	21
2.9	UI aspects and Usability Requirement Checklist	22
2.10	Usability Criteria and Guidelines	23
2.11	Usability Heuristics for Touchscreen-based Mobile Devices	24
2.12	Usability Criteria, Sub Criteria and Questions	25
2.13	Usability Criteria, Sub Criteria and Assessment Items	26
2.14	Usability Criteria for Visually Challenged People	27
2.15	Usability Design Aspect and Description	27
2.16	Usability Heuristics and Sub heuristics	28
2.17	Usability Criteria, Design Features, and UI elements	28
2.18	Comparison of Matching Frameworks	29
3.1	Distribution of Redacted Checklist	34
3.2	Expertise of the Content Evaluation Panel	36
3.3	Quality Attributes Covered by Usefulness Questionnaires	46
4.1	Reviewed Bibliographic Source	49

4.2	Usability Criteria for Mobile Apps	49
4.3	Revised Usability Criteria in Source04	50
4.4	UI Elements Identified in Items from Google Inc	51
4.5	UI Elements Identified in Items from Academic Literature	51
4.6	Excerpt of the Paired Usability Checklist	52
4.7	Conceptually Similar, Repeated, and Conflicting Items	53
4.8	Handling of Conflicting Items	53
4.9	Splitting Multidimensional Item	54
4.10	Changes in Number of Checklist for the Redundancy Analysis	54
4.11	Example of Item Rephrase	55
4.12	Framework Measurement Organisation and Conceptual Definition	57
4.13	Decomposition of Framework Measurement	61
5.1	Demographic of the SMEs	64
5.2	I-CVI for Usability Features Before and After Revision	66
5.3	I-CVI for Usability Criteria Before and After Revision	67
5.4	S-CVI, S-CVI/UA, and S-CVI/Ave Before Revision	68
5.5	S-CVI, S-CVI/UA, and S-CVI/Ave After Revision	68
5.6	Cronbach Alpha for Comprehensiveness Survey	69
5.7	Composite Reliability for Usability Features	70
5.8	Respondent Background in Comprehensiveness Survey	71
5.9	Distribution of Agreement on the Usability Criteria	72
5.10	Distribution of Agreement on the Usability Features	73
5.11	Composite Reliability for the Framework Measurement	75
5.12	Respondent Background in Feasibility Survey	76
5.13	Distribution of Rating Score for Usability Features	77

5.14	Distribution of Rating Score for Usability Criteria	78
6.1	Usability Criteria from ISO/IEC 25010 Product Quality Model and Usability Criteria from This Study	87
6.2	Demographics of the Experts	88
6.3	USE Scores for Both Frameworks	89
6.4	USE Score Normality Result	89
6.5	Paired Samples Statistics	90
6.6	Paired Samples Test	90

LIST OF FIGURES

Figure		Page
1.1	Generation of Mobile Phones	1
2.1	Usability Discipline and User Interface Evolution	7
2.2	Scope of Mobile Usability Studies	11
3.1	Research Methodology	32
3.2	Pfleeger and Kitchenham (2001) Survey Process	37
3.3	Calculated Sample Size by Raosoft	41
4.1	Activity flow in Formulating the Framework	48
4.2	Redundancy Analysis Process	55
4.3	The Framework Abstraction Levels	60
4.4	Decomposition of Interaction Usability Features	61
5.1	Amended Framework Measurement	74
5.2	Level of agreement for Usability Features during Content Validation, Comprehensiveness Survey and Feasibility Survey	81
5.3	Level of Agreement for Usability Criteria in Content Validation, Comprehensiveness Survey and Feasibility Survey	82
6.1	Design of Experiment	85
6.2	Position of Calculated t Statistics	91

LIST OF APPENDICES

Appendix		Page
A	Language Validation Form For Both Questionnaire	104
B	Ammended Questionnaire For Comprehensiveness Survey	106
C	Content Validation Form For Questionnaire	121
D	Open-Ended Response For Comprehensiveness Survey	126
E	Questionnaire For Feasibility Survey	131
F	Open-Ended Response For Feasibility Survey	138
G	Checklist From This Study	140
H	Reviewer Biography Form	154
I	Usefulness, Ease Of Use, And Satisfaction Questionnaire	156

LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
CLI	Command Line Interface
CSUQ	Computer System Usability Questionnaire
GQM	Goal Question Metric
GUI	Graphical User Interface
HCI	Human Computer Interaction
HE	Heuristic Evaluation
IBM	International Business Machine
I-CVI	Item-Level Content Validity Index
LUI	Logical User Interface
MMS	Multimedia Messaging Service
PACMAD	People at the Centre of Mobile Application Development
PDA	Personal Digital Assistant
PUI	Physical User Interface
PSSUQ	Post Study System Usability Questionnaire
SMEs	Subject Matter Experts
SMS	Short Messaging Service
SUS	System Usability Scale
SVI-UA	Scale-Level Validity Index Universal Agreement
SVI-Ave	Scale-Level Validity Index Average
UEM	Usability Evaluation Method
T-CSUQ	Turkish Computer System Usability Questionnaire
TAM	Technology Acceptance Model

UI	User interface
UMUX-Lite	Usability Metric for User Experience
UPM	Universiti Putra Malaysia
USE	Usefulness, Satisfaction, Ease of Use
UTHM	Universiti Tun Hussein Onn Malaysia
UX	User experience
WIMP	Windows, Icons, Menu and Pointers

CHAPTER 1

INTRODUCTION

1.1 Research Background

Mobile apps have transformed mobile phones from a single-purpose communication device into an indispensable tool that supports a broad range of tasks (e.g., streaming online movies, browsing information, and performing online transactions) without the need for a computer.

Back in the year 1990, the introduced mobile phone; cell phone (also known as the brick phone, resembling a brick rock) supports only 1G, the first generation of analogue wireless technology. Phone using this technology was limited to voice calls with poor quality and prone to dropped calls. It has a physical key to dial a phone number, which is displayed on a tiny screen.

Later, around the year 1995, 2G digital technology was introduced in the candy bar phone. It is rectangular in shape, resembling a candy bar with a relatively small screen. However, besides phone calls, it supports polyphonic audio, Short Messaging Service (SMS) and picture message; Multimedia Messaging Service (MMS). The screen size is about a quarter of the phone length, and soft keys are used to operate the interface features such as monochrome icons, links, and menu options in performing actions.

Finally, the arrival of 3G technology is supported in the feature phone and handheld. The phone supports mp3 audio, has a wider screen with the size about half of the phone length, equipped with a camera, and sometimes a touch screen. Video call and mobile internet access were possible, however with slow connection compared to nowadays. Interface features such as colour and animated icons were introduced in the User Interface (UI). Figure 1.1 exhibits the generation of a mobile phone.

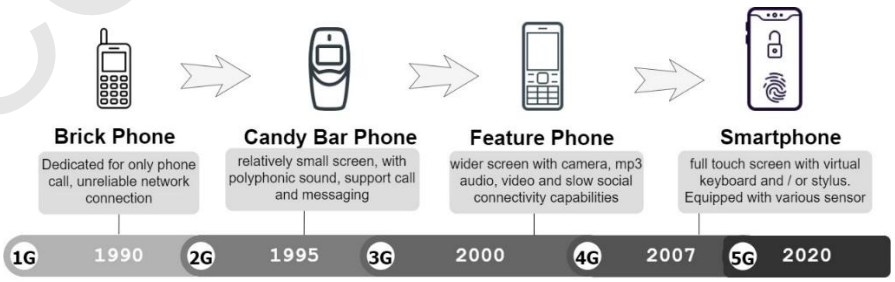

Figure 1.1 : Generation of Mobile Phones

Unlike its predecessor (e.g., cellular phone, feature phone and handhelds), key characteristics that differentiate smartphone from its predecessor is, it's specialised operating system (e.g., Android, iOS, windows, and blackberry) with the capability of installing third-party applications (mobile apps) from marketplaces such as Apple's App Store and Google's Android Market. Mobile apps are used on-the-go for activities such as navigating direction and communicating, thus open up to divided attention while used in different mobility conditions (e.g., sitting, walking, and driving). New features and functionalities are introduced to date to enhance the mobile user interface upon constant version updates. Unique interface features of complex interaction mechanisms such as gestures, motion, and speech recognition are introduced to enhance existing interface features such as a virtual keyboard that replaces the physical key in a feature phone, and a full touch screen that replaces the non-touchscreen.

The whole phone surface is a touch screen of around 5-inch size. It is still considered small in screen size, with limited battery life and memory capacity than desktop. Smartphone runs 4G technology and is equipped with augmented sensors for tactile, motion, and proximity. Although the Physical User Interface (PUI) of the smartphone remains in the form of full screen touch phone until date, technological advancement has improved smartphone qualities such as the screen dimension, physical weight, and processing power.

The evolution of the mobile phone has shaped the trend of usability studies. Early mobile usability studies concern the effectiveness of traditional Usability Evaluation Methods (UEM) for evaluating mobile apps. Thus, various techniques and methods have been proposed, such as by (Kjeldskov and Stage, 2004) and (Dongsong Zhang and Boonlit, 2005), which later progressed and mainly referred to in mobile usability studies. Feature phone and handheld have been the base platform for early mobile usability studies that pave the evolution of mobile user interface from static monochrome to dynamic use of interface features. However, the emergence of the smartphone made a great impact on the mobile user interface, introducing interface features such as navigation drawer and toast which are not present in the introductory of desktop and web application, nor earlier mobile apps. The advancement of mobile user interface leads to the second issue in hand; effectiveness of current usability measurement for evaluating mobile apps, which remains as a focus in current studies. This issue is addressed in studies (Dunn et al., 2013; Hoehle et al., 2016; Malatini and Bogliolo, 2015) which highlight the importance of conceptualising mobile apps usability dimension by its interface features.

Although a large number of studies have contributed to emphasising the mobile user interface, two issues have been identified. Mainly, the interface features are desktop computing user UI elements. Secondly, there are inconsistencies of mobile interface features between the industry and academia. These two issues are further discussed in the next section.

1.2 Problem Statement

Extensive frameworks have contributed to characterising mobile apps usability dimension. Earlier frameworks (Harrison et al., 2013; Hussain and Kutar, 2009; Zhang et al., 2010) focus on the PUI and functionalities which consequently characterise mobile apps usability dimension in terms of usability attributes. However, as mobile technology improved with various sensors and introduces specific mobile interface features, recent frameworks (Hoehle et al., 2016; Malatini and Bogliolo, 2015) attempt to characterise the usability dimension in view of interface features. Nevertheless, despite these efforts in characterising usability for mobile apps, four issues are noticed in the existing usability frameworks.

Firstly, the mobile user interface is hardly acknowledged in the framework measurement. Usability factor is commonly conceptualised by quality attributes, heuristics or principles. However, as mobile technology progresses, the mobile user interface is continually improved to enhance the existing interface features. Consequently, scholars (Coursaris and Kim, 2011; Heo et al., 2009; Zamfiroiu, 2014) acknowledged that the interface features of a mobile user interface is an emergent property that affects usability. Mobile device characteristics are thoroughly deliberated in previous frameworks. Unfortunately, the framework measurements are tailored for feature phones and handhelds. Thus, they may not hold unique characteristics of a smartphone into account, particularly the interface features. In other areas of usability studies such as desktop and web usability, the platform emergent properties have been acknowledged as part of features affecting the usability. This is demonstrated in previous frameworks (Hasan et al., 2013; Junior et al., 2012). For example, in desktop computing, Windows, Icons, Menus, and Pointers (WIMP) is the primary evaluation basis of usability. As for web usability, cross-platform, links, and navigation are the primary concern in usability evaluation. This implies that mobile apps usability deserves to be characterised according to mobile interface features.

Secondly, usability is not comprehensively addressed in the existing frameworks. Previous frameworks have characterised usability in view of mobile device concerns (Gómez et al., 2014), usability principles (Fatih Nayebi, 2015; Hoehle et al., 2016), usability criteria (Saleh et al., 2017) and interface features (Dunn et al., 2013; Malatini and Bogliolo, 2015). Nevertheless, characterising usability solely on usability principles or usability attributes suffers the lack of reflects on interface features in details such as notification and interaction method, which is another aspect influencing mobile apps usability. However, on the other hand, depending on solely the UI component for the evaluation would be inappropriate for measuring usability factor.

Thirdly, recent usability frameworks managed to focus on mobile apps. Nevertheless, they focus on a performance-based measure such as accuracy. Hence, the resulting works are tailored for usability testing, which requires highly skilled evaluators; usability specialist (e.g., usability tester and user experience designer) who are rarely included into a development team. Several previous frameworks (Fatih Nayebi, 2015; Hoehle et al., 2016; Saleh et al., 2017) are dedicated to a single evaluator viewpoint; (e.g.,

developer, usability specialist, and novice evaluator). In practice, the role of evaluating mobile apps is mostly performed by a non-usability specialist. However, conducting usability evaluation by an inexperienced evaluator (e.g., software engineer and designer) will risk the miss of mobile-specific usability problems, thus concluding to irrelevant results. This result in a degradation of validity on the evaluation result (Heo et al., 2009; Ji et al., 2006). Inexperience evaluator perceives usability in view of their subject matter (Ferré et al., 2001). Considering mobile apps short time-to-market where usability specialists are rarely involved during the usability evaluation, there is a need to support particularly non-usability specialists in conducting reliable usability evaluation from their point of view. These suggest for mobile apps usability framework, which incorporates multiple evaluator viewpoint. However, this would result in different evaluation basis such as interface features and usability features, in contrast to usability specialists and developers who mostly view usability in terms of usability heuristics and quality criteria.

Fourthly, previous frameworks scarcely evaluate the usefulness of their proposed work (Ji et al., 2006; Saleh et al., 2017; Xu and Jonsson, 2012). Although usefulness is evaluated in previous frameworks (Gómez et al., 2014; Heo et al., 2009), they solely measuring the effectiveness of their frameworks instead. Whereas, usefulness is characterised in most usability studies (Grudin, 1992; MacDonald and Atwood, 2014) and available usefulness questionnaires (e.g., Usefulness, Satisfaction, Ease of Use (USE) and Technology Acceptance Model (TAM)) as a composition of usability and as is utility. This includes a composition of several usability criteria such as ease of use, learnability, and satisfaction, in addition to as is utility.

Filling these voids is the primary motivation of this study. This could be achieved by capturing the interface features and usability features that would address multiple evaluator viewpoints in a framework, thus addressing the shortcomings in previous frameworks. This is possible by comprehensively bridging the semantic gap between different abstraction levels of usability constructs; interface features, usability features, and usability criteria into one comprehensive framework for evaluating the usability of a mobile apps.

1.3 Research Objectives

Issues in usability measurement for mobile apps have led this study to an attempt of improving usability conception for mobile apps. Therefore, this study aims to develop a framework for usability evaluation of mobile apps. Specific objectives of this study include:

1) To propose the usability criteria and interface features for mobile apps.

2) To incorporate the usability criteria and interface features in conjunction with different evaluator viewpoints into a framework abstraction levels.

3) To validates the comprehensiveness and feasibility of the framework measurement.

4) To evaluate the usefulness of the framework in comparison with the previous study.

1.4 Research Scope

Usability studies on the earlier generations of mobile phone concern on the effectiveness of traditional UEM. However, upon smartphone emergence, usability issue on a mobile phone has shifted to the effectiveness of mobile apps usability measurement. This study focuses on the latter issue by formulating a usability evaluation framework, which is conceptualised in view of a mobile user interface. The measurement which built the framework is tested for its comprehensiveness and acceptability by Subject Matter Experts (SMEs) and software engineering practitioners in Malaysia context for the purpose of data collection and its validation. Although the frameworks are developed from mobile studies, mobile technology is evolving at a fast rate. Thus, the framework measurement in this study is bounded by the mobile user interface available at the point of elicitation of the interface features. In addition, most of the previous studies evaluate their work in terms of satisfaction. This study conducts an expert review which compares the formulated framework with an existing framework to investigate the usefulness of the formulated framework.

1.5 Thesis Organization

This thesis is organised into seven chapters. This chapter gives an overview of the research area, pinpoint the problem statement, research objective, research scope, and describes the contents of the upcoming chapters. The remainder of the chapters is organised as follows.

Chapter 2 provides insight into the evolution of user interface and the changes it brings in conceptualising the usability dimension of different computing domain which are the desktop and mobile computing. Later, this chapter reviews the existing mobile apps usability framework. The rationale, features, components, as well as limitations of existing mobile apps usability framework, are discussed and pinpointed. The reviewed literature provides a base for the framework formulated in this study.

Chapter 3 outlines three main steps in achieving the objectives of this study. The process of identifying mobile apps usability criteria, establishing a usability evaluation framework for mobile apps, and designing an experiment in assessing the framework are described in this chapter.

Chapter 4 describes the process of conceptualising the mobile apps usability dimension through content analysis. The identified usability criteria and interface features are abstracted into usability features to formulate a comprehensive framework and validated in Chapter 5 to support the framework.

Chapter 5 presents the result and findings from the surveys conducted to validate the framework comprehensiveness and feasibility. The outcome of a hypothesis testing conducted to measure the significance of the framework measurement is presented.

Chapter 6 describes the expert review, which determines the usefulness of the framework in comparison to an existing framework from the previous study. The hypothesis testing, significant difference and effect size of the result from the expert review are presented.

Finally, the last chapter concludes this study, highlights the research contribution, implication, and limitations of this study. The potential direction of the research is recommended by pointing out further work.

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