Investigation into Usability Attributes for Embedded Systems Testing

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***Abstract*— Usability in embedded systems is an important factor in determining the quality of a whole system. Embedded systems are proliferating in vast application areas of life with ever increasing multifarious functionalities. As a result, these possess more challenges in its design for interactive usage, performance and acceptance. Therefore, the need to have product with ease of use is imperative. In this paper we discuss usability testing attributes for embedded systems. Usability testing attributes are considered to be an integral part of any successful usability testing exercise. Consequently, we propose a set of usability testing attributes based on the ISO 9126 quality model through a review of current trend and practices. These set of attributes were carefully mapped to the characteristics of embedded systems to facilitate easy evaluation for testers and system designers.**

Keywords — Usability testing, embedded systems, usability attributes, usability models.

I. INTRODUCTION

The increasing growth of complex computing devices has witnessed a major shift in the development, design and deployment of software applications. As a result of this development, companies are seeing the benefits of designing and developing their products with user–oriented methods instead of technology oriented methods, and are endeavoring to understand both users and products, by investigating the interactions between them [1]. Software usability has become a major and basic determinant of productivity and of the acceptance of software applications. Hence, it is considered to be one of the most important quality factors in the development of an interactive software application [2].

An embedded system is a system designed to perform a specific tasks [3]. With the rapid development of embedded technology, embedded systems have been widely infiltrated into science, engineering, military technology and other areas of daily life, no matter what field of embedded systems is the usability is essential, which affects product performance, and acceptance.

Embedded systems have peculiar characteristics, which makes them different from computer-based product like software and websites. In addition to their software, embedded system products also have hardware-oriented features such as menus, and have more dimensions that need to be considered with regard to usability [4]. Therefore, the need to design usable and interactive product has been the interest of usability experts and software designers as well. However, this depends on the robustness of the usability model (attribute).

A number of definitions of usability concept were proposed by researchers, standard organizations and authors in the field of Human–Computer Interaction (HCI) and Software Engineering (SE). However, in this paper the definition proposed by ISO 9126 [5], which is from the SE perspective is considered: ‘‘the capability of the software product to be understood, learned, operated, attractive to the user, and compliant to standards/guidelines, when used under specific conditions’’. In this view, usability is seen to be as one specific characteristic that affects the quality of a software product.

Developing a highly usable interactive system can be considered as a complex task. There are several methodologies for Software development teams to adopt from the area of Usability Engineering [6].

Usability is complementary with the functionality of the systems and helps in its evaluation. Absence of usability causes failure of the software system that will eventually lead to a substantial financial loss, user dissatisfaction, staff unproductivity and time wastage. Therefore, usability testing is very essential for the process of designing usable software system. But still there is no generic model for usability evaluation because of its fuzzy characteristics [7]. Methods to evaluate the usability of various software packages have been of passionate interest to HCI researchers and practitioners alike as compared to SE.

Usability evaluation has been established as an indispensable part of interactive systems development [8] that helps to determine whether interactive systems support users in their works [9]. A variety of analytic and empirical evaluation methods can be used to access and evaluate usability of interactive computer application.

However, computer professionals and HCI experts need robust, easy-to-use usability evaluation methods to help them improve systematically the usability of computer artifacts [10].

In this paper, we proposed a list of attributes for usability testing of embedded system. The usability testing attributes

defined by the ISO 9126 model will be used in addition to other attributes defined by others standard and models.

II. BACKGROUND

A. Embedded System and Usability Evaluation

Despite the increasing number of usability professional, there is a growing concern that achieving usability in some domains is an overwhelming challenge [11]. Usability evaluation has been carried out on a number of systems belonging to different computing domain, to mention but a few: e-commerce domain [12, 13], pervasive computing [14, 15] and a number of devices such as mobile phone [1, 16] medical applications or devices and related issues [17, 18], consumer electronic products [19, 20, 21], where most of these devices constitute embedded system.

Methods for usability evaluation are being used across ever growing spread of domain that is type of contexts in which interactive systems are to be implemented [8]. Similarly, the usability of an interactive system depends on the context of the system [22].

Usability Evaluation Methods are used to evaluate the interaction of the human with the computer for the purpose of identifying aspects of this interaction that can be improved to increase usability. They typically come into play some time after needs assessment and before beta testing [23]. Irrespective of the method employed, usability evaluations need to be conducted in consideration with the context [24]. Therefore, the domain of interest in this paper is embedded systems.

B. Usability testing attributes

Usability testing attributes are essential in carrying out any usability studies or evaluations as they constitute the overall usability outcome of both in definition and in practice. Various studies reveal the importance and the use of different usability testing attribute to determine the overall interactiveness of software application. Some of which are reported in this study. Table 1 shows studies related to different usability attributes.

Usability in embedded system has become a major issue in their design because of the growing complication, multi-functionality and intelligent therein [19]. According to [21], the integration of IT into embedded system products has led to miniaturization and increasing to be accessed through ever smaller user interfaces. This and some other characteristics have challenged usability experts, practitioners and software testers to identify more aspects of usability for these types of systems that need to be evaluated. Table 2 presents studies related to usability testing on embedded system applications.

From Table 2, it shows that most of the usability testing attributes often evaluated emanates from the existing famous model such as Shackel, Nielson and so on as reported in Table 1. However, these models are general and not domain specific, yet some of the attributes are used to evaluate system across different computing domains. Therefore, of all the attributes used by these studies none of them uses all the attributes defined by ISO 9126 despite its relevance as an important quality model. Learnability is the only attribute used by almost all these studies repeatedly. Thus, the absence of these attributes is considered as a missing property and need to be addressed. This is the motivating factor that prompted the proposed set of usability testing attributes for embedded systems based on ISO 9126 model.

Table 1 Usability testing attributes from various standards and models

Usability Attributes	Shackel (1991)	Dix et al. (1993)	Nielsen (1993)	ISO 9241 (1998)	ISO 9126 (2001)	Abran et al. (2003)
Effectiveness	+	+		+		+
Learnability	+	+	+		+	+
Flexibility	+					
Attitude	+					
Memorability			+			
Efficiency		+	+	+		+
Satisfaction		+	+	+		+
Errors			+			
Understandability					+	
Operability					+	
Attractiveness					+	
Security						+

Table 2 Studies related to usability attributes of embedded system

Author/Reference	**Aspect of usability (attribute)**	**Device/System**
Alsheri and Freeman [25]	Learnability, efficiency, memorability, flexibility, safety	Mobile
Guo et al. [4]	Efficiency, Effectiveness, satisfaction	Consumer electronic (phone and GPS)
Muzaffar et al. [14]	Satisfaction, learnability, effeteness, efficiency, memorability, correctness, simplicity, intuitive, usefulness, security	Pervasive/mobile
Han et al. [26]	Image impression, performance	Consumer electronic
Harvey et al. [27]	Safety, adaptability, learnability, effectiveness, efficiency, satisfaction	In-Vehicle Information System
Zhang and Adipat [16]	Satisfaction, effectiveness, efficiency, performance, error, simplicity, comprehensibility, memorability, learnability	Mobile
Kim and Han [19]	Simplicity, consistency, efficiency, learnability, error, accessibility	Consumer electronic

C. Usability in ISO 9126 standard

The ISO 9126 model is a quality developed by ISO/ICE 2001. The model is considered to be the more comprehensive among all the quality models develop to date [13]. This international standard model divides software quality into six general categories of characteristics: Functionalities, Reliability, Usability, Efficiency, Maintainability and Portability, which is widely use among the software testers.

The characteristics defined are applicable to every kind of software, including computer programs and data contained in firmware and provide consistent terminology for software product quality. Therefore, this study discusses usability as defined by this model. This quality factor consists of five sub-characteristics [5]:

i. Understandability describes the users' effort for recognizing the logical concept of an application and the applicability of that logical concept.
ii. Learnability is the users' effort for learning the application as for example, operation control, input and output. A Learnability measure should be able to assess the time and effort required by user to learn how to use particular functions such as interfaces and operations.
iii. Operability is the capability of the software to enable the user to operate and control it. An Operability measures should be able to assess whether system user can easily operate and control the system.
iv. Attractiveness is the capability of the software component to be attractive to the user.
v. Usability compliance, which is the capability of the software component to adhere to standards, conventions, style guides or regulations relating to Usability.

Apparently, to practically evaluate usability it must be looked at from a wider perspective to include usability evaluation in HCI. Especially in some domains that are complex.

III. USABILITY TESTING ATTRIBUTES FOR EMBEDDED SYSTEMS

Considering the peculiar characteristics of embedded system, it is important to note that it will require a number of attributes to be able to effectively evaluate their usability. Figure 1 shows the process that lead to generation of this set of attributes.

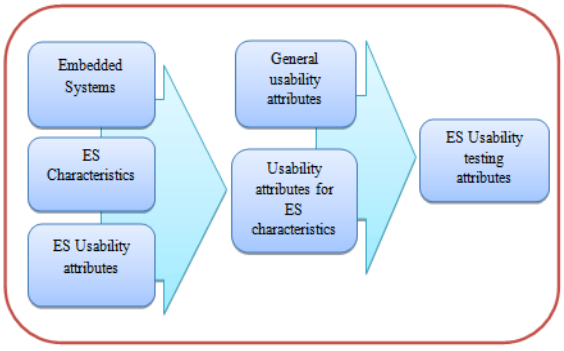

Fig. 1 Process adopted to generate usability attributes

The process is similar to the one used by [28] in designing usability evaluation framework for ubiquitous computing devices. Therefore, the following process lead to the derivation of the proposed set of attributes.

i. Understanding embedded systems both in concept and operation.
ii. Identify the characteristics of embedded systems
iii. Identify the general usability testing attributes and usability testing attributes for embedded systems from existing models and literatures respectively.
iv. From the combination of general usability testing attributes and the testing attributes for embedded system leads to generating a comprehensive usability testing attributes for embedded system.

Meanwhile, the attributes defined by the ISO 9126 were chosen because of its wider acceptance among software engineering experts and its comprehensiveness in terms of software quality metrics.

Therefore, in addition to the usability testing attributes defined by the ISO 9126 model, the following set of attributes are defined and proposed for Embedded System (see Table 3):

Table 3 Embedded System Usability Testing Attributes

Usability Attributes	Description
Understandability	Describes the users' effort for recognizing the logical concept of an application and the applicability of that logical concept.
Learnability	The users' effort for learning the application as for example, operation control, input and output.
Operability	The capability of the software to enable the user to operate and control it.
Attractiveness	Capability of the software component to be attractive to the user.
Effectiveness	Accuracy and completeness with which users achieve goals.
Efficiency	Resources expended in relation to the accuracy and completeness.
Satisfaction	The comfort and acceptability of use.
Safety	Describes the extent to which system is harm free

The additional attributes were chosen because they are considered most important to the concept of usability (Table 1 attests to this fact). In essence, the general usability attributes are chosen as usability attributes of embedded systems because of the fact that usability attributes constitute definition of usability as a concept.

IV. ANALYSIS OF THE PROPOSED SET OF ATTRIBUTES

The goal of the analysis is to ascertain to what extent the proposed set of attributes can be useful to evaluate:

i. usability during the design and development of software before it deployment.
ii. usability as a quality in use characteristic during operation and maintenance of software after it has been deployed.

This would be achieved by carefully mapping the characteristics of embedded system to an attribute or set of attributes. Table 4 shows the characteristics of embedded system and the usability testing attributes that can be used to evaluate it. The mapping was achieved by clearly understanding the conceptual meaning of this set of attributes and as well the characteristics of embedded system.

Table 4 Embedded System characteristics and Usability testing attributes

Codes	Characteristics	Attributes							
		Understandability	Learnability	Operability	Attractiveness	Efficiency	Satisfaction	Effectiveness	Safety
C1	Specific task oriented (dedicated toward certain application)			√		√		√	
C2	Reactive and Real time	√		√		√			
C3	Complex algorithms for complex operation			√					
C4	Dedicated User interface	√	√		√		√		
C5	Concurrency (Multi rate): ES need to control and drive certain operations at one rate and certain other operations at different rate.	√		√			√		
C6	Time and resource constraint	√		√				√	
C7	Connected to physical environment through sensors and actuators			√					
C8	Must be efficient: C8.1 Energy efficient					√			
	C8.3 Run-time efficient					√			
	C8.2 Code-size efficient (especially for systems on a chip)					√			
C9	Must be dependable: C9.1 Reliability			√		√			
	C9.2 Security: confidential and authentic communication						√	√	
	C9.3 Stability					√		√	
C10	Exception handling/ Usually runs forever (no reboot)			√				√	
C11	Safety critical (must function correctly)	√	√	√		√			√
C12	Flexibility in operation		√	√			√		
C13	Image/impression (aesthetic integrity)				√		√		

The overall essence of usability testing attributes is to help in evaluating usability of a component or system in order to help improving its design, development and usage. Which in turn positively affect the users' experience. In order to achieve these, the usability experts need well-defined usability attributes that are selected by taking into consideration system peculiar characteristics. From the background study, the proposed sets of attributes were analyzed as follows taking into consideration their relationship with embedded systems.

i. understanding the conceptual meaning of the selected attributes. In order to effectively put an attribute to use, it's meaning most to be clearly understood.
ii. understand the context of use and the application. This has to do with understanding of how application work and its objectives. To adequately evaluate the usability, operation principles of system need to be clearly studied and comprehended.
iii. identify system characteristics which attributes can be used to evaluate.

Once the aforementioned are achieved, then mapping of usability attributes and characteristics to be evaluated of such system can be carried out. Measures for usability attributes defined by the ISO 9126 have two types of methods of application, namely: user test and test of the product in use [29]. Therefore, any of these methods can be employ to achieve usability.

V. Conclusion

The objective of this paper is to propose a set of usability testing attributes for embedded systems based on its peculiar characteristics. Various usability models were studied in order to facilitate the generation of the attributes. The proposed set of attributes was carefully mapped to the characteristics to help both system designers and testers in terms of their choice of attributes to evaluate a given characteristics.

On the future direction of this, we intend to validate and evaluate the applicability of the attributes using a rubric to determine its application and impact.

Acknowledgment

This publication is funded by Research University Grant (RUGS) Q.J130000.2628.08J20 and supported by Universiti Teknologi Malaysia.

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