An Integrated Measurement Model for Evaluating Usability Attributes

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ABSTRACT

In order to develop an easy to use, effective and efficient software system that satisfies the stakeholder needs, usability attributes should be addressed and measured appropriately during all development stages. However, measuring usability is widely recognized as the most challenging task for the system development team. Such a challenge can be attributed to the absence of an existing comprehensive usability model that covers all the fuzzy usability attributes. This paper aims to elicit and analyze usability attributes from previously existing usability models for developing an integrated usability model from different practitioners' and researchers' views. The main contribution of this model is constituted in the attempt of gathering and modeling several fuzzy usability attributes in a homogeneous manner, and providing different measures for these attributes, in order to facilitate measuring them during every stage of software development. Hence, this will assist in detecting and tracing usability problems in each stage, handling them with less time, efforts, resources, and in evaluating the usability of the implemented system as well.

Categories and Subject Descriptors

Knowledge Engineering, Information and Communication for developing

General Terms

Evaluation, Measurement, Usability

Keywords

Usability, Evaluating Usability, Measuring Usability

1. INTRODUCTION

A development teams' main goal is to develop a suitable software system that satisfies their stakeholder's needs. Usability has long been recognized as a quality requirement, which significantly affects the productivity of the implemented software system [1]. Recently, many definitions have been introduced for defining the concept of usability, the most referenced one was introduced by the ISO 9241-11 standard, it defined such a concept as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [2].

One of the most critical responsibilities facing a development team is applying the usability measurement process appropriately. However, we believe taking such a process into account at very early development stages from different stakeholder views (i.e. developers, managers and end users) has many benefits in-return. One of these benefits is getting continuous feedback along the system development process to ensure achieving the required usability objectives [3]. Another benefit is manifested by detecting the potential usability risks and handling them at an early stage, thereby reducing consumption time, efforts, and resources.

To facilitate such a responsibility, a wide range of usability models was proposed by both the industrial and academic fields. These proposed models were aimed to simplify the abstractness of usability by dividing it into different sets of attributes. According to Bevan *et al.* [3], the ideal way for measuring usability is constituted in specifying these attributes and measuring if they are presented in the developed system. In spite of the introduced efforts, measuring usability is still considered as a tough and complicated task. One of the reasons for this is the absence of existing a comprehensive model which covers all the ambiguous usability attributes, in addition to the absence of providing clear steps for measuring these attributes during the development stages.

Consequently, this paper intends to introduce an integrated usability measurement model based on previous existing models, where we aim to discuss and analyze usability attributes suggested by different practitioners and researchers as a participation for gathering several fuzzy usability attributes and provide different measures for measuring each one of which. The proposed model can be used during every stage of system development to ensure the system reaches the required level of usability. Furthermore, the Soft-goal Interdependence Graph was used to model our proposed model.

2. USABILITY ATTRIBUTES THROUGH ACADEMIC VIEWS

Over the past three decades, a variety of usability models have been introduced as a contribution to develop usable and suitable software systems. For example, Shackel has emphasized by his proposed framework [4] that the usable system must be accomplished with four attributes: effectiveness in terms of the performance of human use (such as error and time), learnability by providing manual and training that will assist end users master dealing with system functionalities within specified time, flexibility to provide the capability to expand or change existing functionalities in a suitable and convenient way, and attitude in which studying the users'

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attitude toward system behavior and determining their acceptance level of such system.

Furthermore, Nielsen [5] noticed usability should be taken into account in all system aspects where human interaction was possible. Nielsen referred, by his proposed model [5], that the usable system should be: efficient to use to increase its productivity, satisfying and pleasing to the users during or after its use, has few and non-catastrophic errors, in addition to providing the ability to overcome these errors, easy to learn and easy to remember while their users don't need to learn the system from scratch every time it's used, they just need to easily remember the steps of how to use the system.

Another effort has proposed by Abran *et al.* [6], where they discussed the concept of usability in terms of the ISO 9241-11 and ISO 9126 standards, they also discussed the limitation of these ISO standards in order to propose an enhanced model aimed at improving the evaluation process of software usability. Similar to the division of Shackel [4] and Nielsen [5] models, the proposed enhanced model decomposed usability into effectiveness, efficiency, satisfaction, and learnability attributes. The authors believed that the security should be considered along with the four attributes listed above. Where the system should prevent any unauthorized access to the systems or users data.

Moreover, Seffah *et al.* [7] developed a consolidated model, called Quality in Use Integrated Measurement (QUIM). Their proposed model relies on previously existing models. QUIM decomposed usability into ten attributes, the first four attributes are constituted in efficiency, effectiveness, learnability and satisfaction, they are similar to those proposed by Shackel [4], Nielsen [5] and Abran *et al.* [6] models. The rest of the six attributes are:

1. Productivity: reflects the achieved effectiveness level with regards to the consumed system resources, by users and the system (e.g. financial costs of usage and time to complete tasks), for completing specific user tasks.
2. Safety: implies the ability of the software product to limit the risks that may harm users or resources (e.g. hardware).
3. Trustfulness: reflects the faithfulness level which is offered by a software product to its users.
4. Accessibility: is concerned with whether a software product can be used by different people, including those people who have a type of disability.
5. Universality: reflects the system's ability to accommodate a variety of users who have different cultural backgrounds
6. Usefulness: reflects the system's ability to allow their users to solve and handle real problems in an acceptable manner.

All the previously discussed models have suggested different measures for measuring their proposed usability attributes. We will review the measures that can be used for measuring our proposed usability model attributes in Section 4.

It is worth to mention that almost all the other proposed usability models (see, for example, [8]) divided usability into the same attributes that were covered by the previously discussed models.

3. USABILITY ATTRIBUTES THROUGH ISO STANDARDS

The International Organization for Standardization (ISO) has shown an obvious attention through its standards toward assisting the development team in developing high quality software systems. Usability was categorized, by ISO standards, as a quality characteristic that contribute in implementing such software systems. This section aims to discuss the usability characteristic through these standards.

The ISO/IEC 25010 [9] standard was released in 2011 as a revision of the ISO 1926 standard, under the title "Systems and software Quality Requirements and Evaluation (SQuaRE)". According to ISO/IEC 25010 standard, software product quality life cycle passes through three main phases (see Figure 1). In the first phase, the internal quality requirement should be specified using internal quality measures for evaluating and verifying product internal quality (for example, verifying the quality of the software product source code and documentation). The next phase includes specifying the external quality requirements using external quality measures, evaluating these requirements is necessary for validating and verifying the product's technical aspects. In the last phase, the quality requirements, which are derived from the end users' needs, should be specified by specific quality-in-use measures. These requirements should be evaluated for the validation of the software product quality by its end users.

The first phase should be applied during the product development stage, the second phase during the product testing stage, while the last phase is applied through using the system in a realistic context. Moreover, noticing from Figure 1, the product's internal quality can be considered as an indicator for the product's external quality, which in turn can be considered as an indicator for the product's quality-in-use.

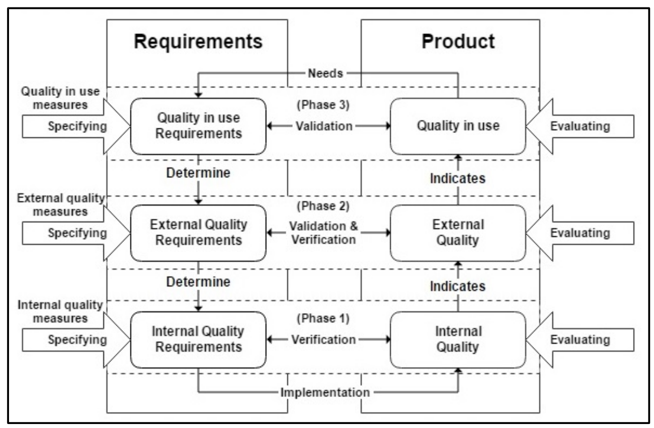

Figure 1. Software product quality life cycle [9]

In order to apply this life cycle, ISO/IEC 25010 standard defines two quality models, the first one is the software product quality model, and it could be applied to both the system computer and software products. This model consists of eight characteristics, each one of them is divided into several internal/external sub-characteristics which should be measured using internal/external measures to quantitatively evaluate the software quality. Usability was classified as one of the eight quality characteristics and it is defined as "the degree to which the software product can be understood, learned, used and most attractive to the user, when used under specified conditions". The internal and external properties of the usability characteristics are modeled with the same following six sub-characteristics:

1. Appropriateness recognizability: reflects the users' ability to correctly choose the system or product which provides the appropriate functionalities for their intended objectives.
2. Learnability: evaluates the degree to which specific users are easily able to learn the system and use it within minimum time.

3. Operability: evaluates to which extent the users are capable of easily operating and controlling system attributes.
4. User error protection: reflects the system's ability to protect its users from making errors.
5. User interface aesthetics: assesses the users' satisfaction and pleasure with regard to system user interfaces aesthetics.
6. Accessibility: evaluates to which extent the system can be accessed by different users (includes disabled users) with a wide range of capabilities and characteristics.

The second quality model introduced by the ISO/IEC 25010 standard is quality-in-use model, it composes of five main characteristics: effectiveness, efficiency, satisfaction, freedom from risk and context coverage. Some of them are decomposed into further sub characteristics, each of which can be measured when using the system in a realistic context. Usability is constituted as a subset of this model, it is represented by the following three characteristics:

1. Effectiveness: Reflects the capability of specified users to use system in a particular context and achieve their goals in a complete and accurate manner.
2. Efficiency: Evaluates to which extent a specific user consumes resources in order to achieve their goals effectively.
3. Satisfaction: Reflects the users' satisfaction level to use system in a particular context. Furthermore, this sub characteristic is further divided into four attributes:
   - A. Usefulness (cognitive satisfaction): reflects to which extent users are satisfied in achieving their pragmatic goals.
   - B. Trust: assesses to which extent the users have confidence that the behavior of the system will be as intended.
   - C. Pleasure (emotional satisfaction): evaluates the degree to which users get pleasure from achieving their personal needs.
   - D. Comfort (physical satisfaction): reflects the degree to which users are physically comfortable when using the system.

The measurement methods of all software product quality model characteristics are provided by ISO/IEC 25023 standard [10]. This standard clarifies that all of these characteristics can be measured internally or externally by different methods for different purposes. The usability attributes can be measured internally and externally with the same introduced measures. Whereas the characteristics of quality-in-use model are measured by the ISO 25022 standard [11]. We will discuss the measures which will be included in our proposed model in the next section.

4. THE PROPOSED USABILITY MODEL

This section presents our proposed usability model, it is divided into three subsections: The first subsection discusses the main attributes that will be included in the proposed model. The second subsection discusses the measures that will be used for measuring the included attributes. Finally, the last subsection, models the proposed model using Soft-goal Interdependence Graph.

4.1 The Usability Attributes of the Proposed Model

According to the discussion in Section 2 and 3, it can be noticed that the previously proposed usability models breakdown the concept of usability into different attributes in a heterogeneous manner. Hence, leading to increase the difficulties of their use during the system developing stages. Our proposed model aims to model these attributes in a coordinated and coherent manner.

The proposed model in this paper divides usability into 12 main attributes: effectiveness[A], efficiency[B], satisfaction[C], productivity[D], universality[E], learnability[F], appropriateness recognizability[G], accessibility[H], operability[I], user interface aesthetics[J], and user error protection[K]. Table 1 shows the appearance of these attributes ([A-I]) in previous proposed usability models.

Table 1. The appearance of the selected usability attributes in previous proposed usability models

Usability Models	Usability attributes										
	A	B	C	D	E	F	G	H	I	J	K
Shackel [4]	√		√			√					
Nielsen [5]		√	√			√					√
Abran [6]	√	√	√			√					
Seffah [7]	√	√	√	√	√	√		√			√
Dubey [8]	√	√	√			√					
Schneider man [12]	√	√	√			√					
Preece [13]		√	√			√					
Gupta [14]	√	√	√	√	√						
ISO 25010 models [9]	√	√	√			√	√	√	√	√	√

4.2 Measuring the Proposed Usability Attributes

This section presents the measures that are included in the proposed model for measuring and evaluating the selected usability attributes (see Table 2).

Table 2: Usability attributes measures

Usability attributes	Measures	Description
Effectiveness	Task completion	Measures the ratio of tasks executed and completed correctly [11].
	Task effectiveness	Measures the ratio of tasks' goals that are achieved correctly [11].
	Error frequency	Measures the frequency of errors that result from users, and compared it with the target value [11].
Efficiency	Time efficiency	Measures the time required to complete a task compared with the actual time [11].
	Relative task time	Measures the time users take to complete a specific task and comparing this time with the time it takes an expert to complete the same task [11].
	Task efficiency	Measures the ratio of the goals which are achieved by users per unit of time [11].

Satisfaction	Usefulness	Satisfaction scale	Measures the user satisfaction level of the system in general [11].
		Satisfaction questionnaire	Measures the user satisfaction level of certain features in the system [11]
		Discretionary utilization of functions	Measures the average utilization of system functionalities [11].
		Proportion of customer complaints	Measures the ratio of system customers who filed complaints [11].
	Trust	Trust scale	Conducts a questionnaire to determine to which extent the users trust the system [11].
		Error tolerance	Measures to which extent the system can withstand with error occurring in the system environment [14].
	Pleasure	Pleasure scale	Conducts a questionnaire to determine to which extent the users obtain pleasure from using the system [11].
	Comfort	Comfort scales	Conducts a questionnaire to determine to which extent the users are comfortable using the system[11].
Productivity	Economic productivity		Measures the cost-effective for performing a task by the user [11].
	Productive proportion		Measures the ratio of time it takes users in order to perform productive actions [11].
	Relative number of user actions		Measures to ensure whether the user performs the minimum number of actions needed [11].
Universality	Standards compliance		Measures to which extent the system is in compliance with the international standards, regarding usability.
	Cultural universality		Measures the ability in using the system by those people who have different culture background [14].
Learnability	Memorability	Memorability of system's functionalities	Measures the average time the users spend to remember over time the steps of using specific functions without the need to re-learn them from scratch [4].
	Completeness of user documentation		Measures to make sure that all systems functionalities or any help facilities are complete and correctly described [10].

	Ease of help access	Completeness of user documentation and /or help facility
	Understandable error messages	Measures to make sure any error message clarifies the cause of the error occurrence and the ways to resolve it [10].
	Time to learn	Measures the average time the users spend to learn specific functions in the system [5, 7].
Appropriateness recognizability	Description completeness	Measures to ensure the system functions are described in an understandable manner [10].
	Demonstration capability	Measured to ensure that all system functions which require demonstration have been implemented as required [10].
	Understandable I/O	Measured to ensure that users are able to understand all data input and output items of the system easily [10].
Accessibility	Accessibility for physical disability	Measures the functions proportion that can be accessed by users who have physical handicaps [10].
Operability	Operational consistency	Measured to ensure all the similar system tasks are working in a consistent way [10].
	Message clarity	Measures the number of system messages that are clearly described and can be easily understood by users [10].
User interface aesthetics	The appearance customizability of user interface	Measures the ratio of interface items that can be customized in appearance by users to be convenient for them [10].
	Attractiveness	Conducts a questionnaire to determine to which extent the system attractive for its users (e.g. through the interface color) [7].
User error protection	Avoidance of incorrect operation	Measures the number of functions that are able to avoid the occurrence of incorrect operations which produce serious defects [10].
	Input validity checking	Measures the rate of input items which conduct regular check-ups in order to validate data [10].
	User error recoverability	Measures the number of errors the system can recover or repair [10].

4.3 Modeling the Proposed Usability Model

This subsection presents the proposed usability model. It's modeled using Soft-goal Interdependency Graph (SIG) [15]. SIG is introduced by Chung in 1999, while it's considered a useful tool for modeling and describing the Non-Functional Requirements (NFRs) and the relation between them [16]. The SIG approach is based on decomposing the NFRs to more specific soft-goals and operationalizing soft-goals until one or more solution which satisfies the NFRs is reached.

As shown in Figure 2 and 3, the proposed model divided usability into two main parts: usability during the system development and usability while using the system (i.e. usability-in-use).

The first part consists of seven attributes, each of which is decomposed into sets of measures. The first part could be used for evaluating usability during the system development and testing phases (see Figure 2). Whereas the second part could be used for evaluating usability while using the system in a realistic context. Figure 3 clarifies that this part consists of four main attributes, each of which is decomposed into sets of measure.

5. CONCLUSION

Over the last years, a variety of usability models were proposed in order to facilitate applying the usability measurement and evaluation process at early development stages. Despite the proposed efforts, such process is still considered as the hardest challenge that faces the development team, due to the absence of existing comprehensive model that covers all the fuzzy usability attributes. The aim of this work is to study and analyze the usability attributes from previous existing usability models in order to introduce an integrated usability measurement model. The main contribution of this model is constituted in covering several fuzzy usability attributes, modeling them in a homogeneous manner, and providing different measures for measuring and evaluating these attributes during every stage of the system development. Finally, our future work includes proving the efficiency of our proposed model by introducing a real case study

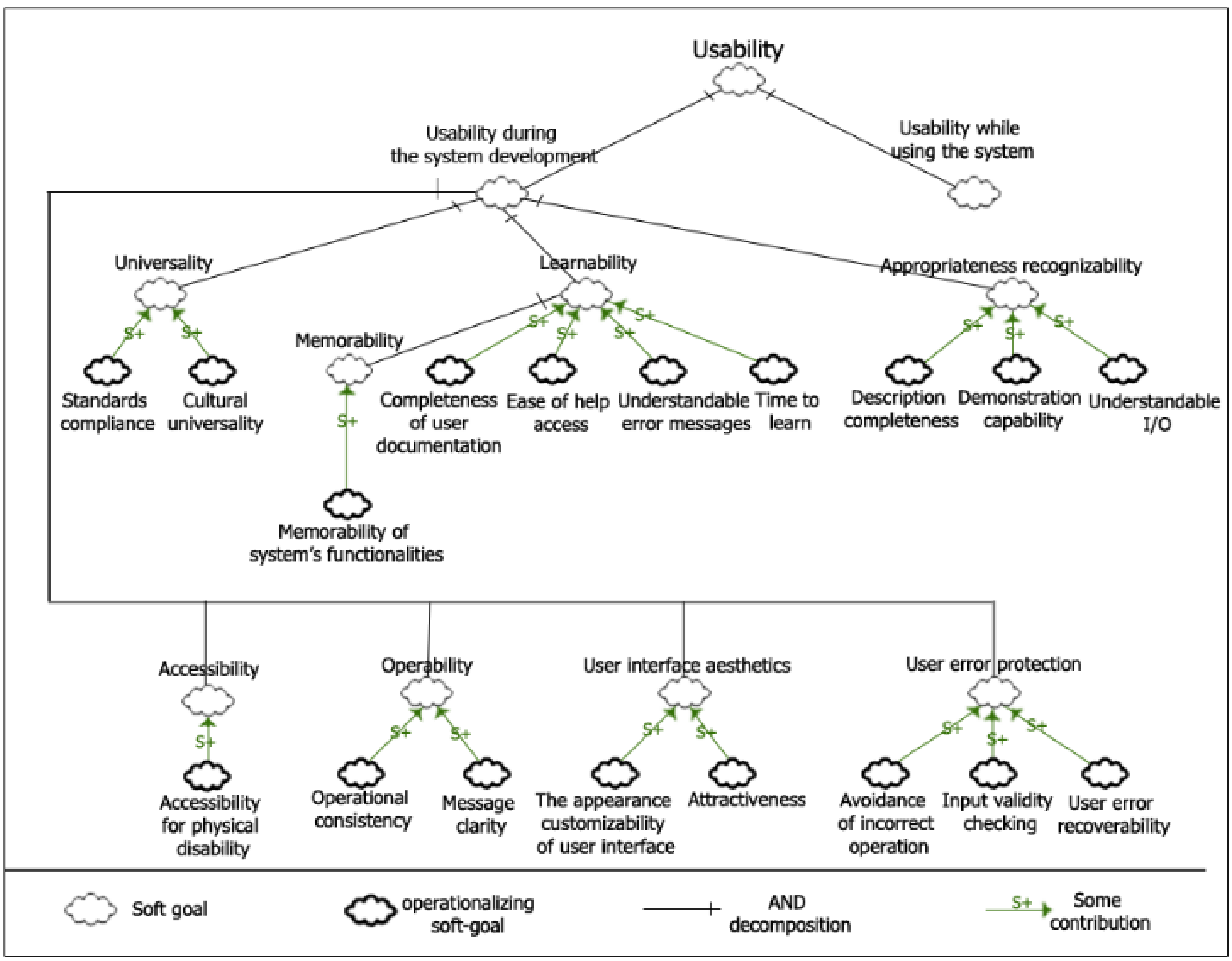

Figure 2. The first part of the proposed usability model

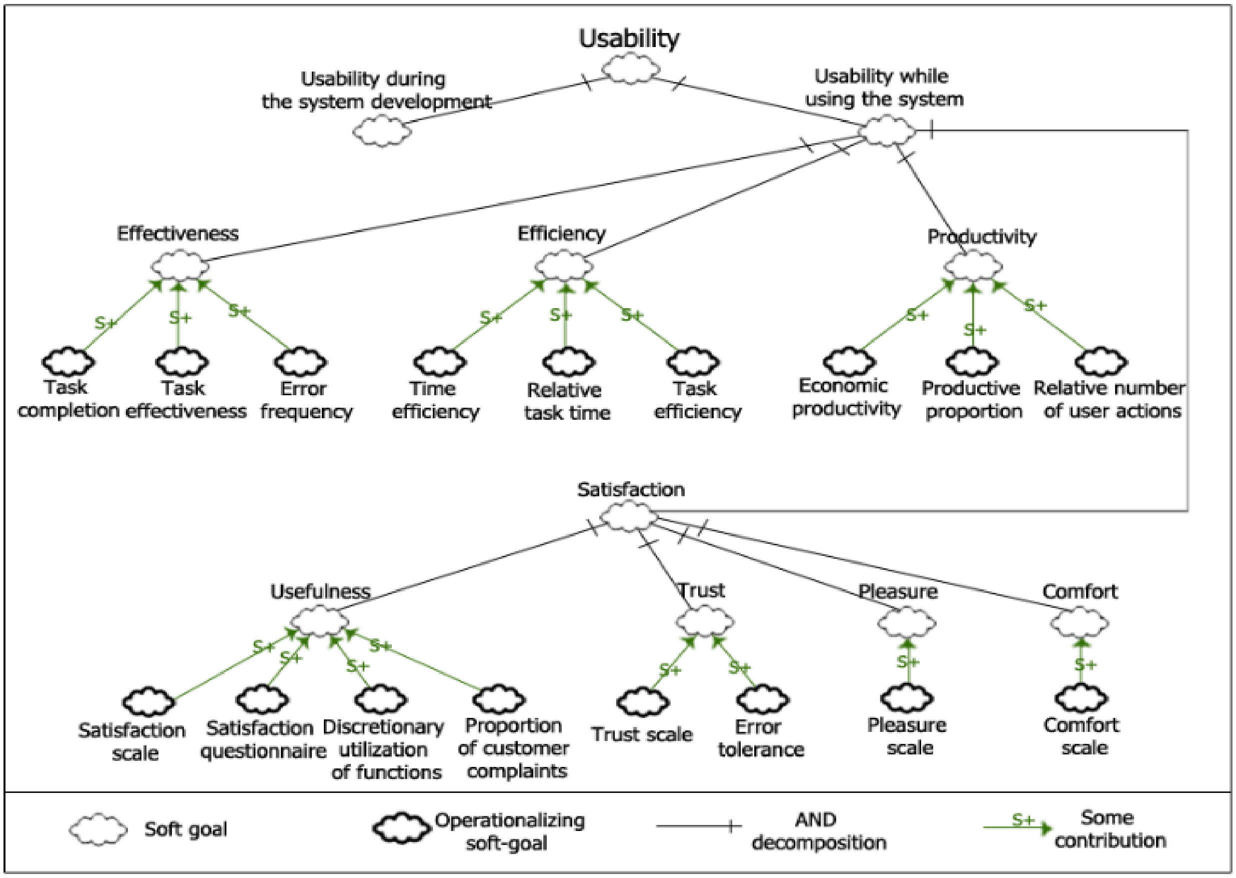

Figure 3. The second part of the proposed usability model

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