Analytical Comparison of Usability Measurement Methods

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ABSTRACT
Usability plays very important role in fulfilling the quality requirements of a software system as it expresses the relationship between the software and its application domain. If the software system is usable then it is more productive, useful and thus it satisfies user's expectations. Inspite of such importance of usability there are no explicit criteria to measure it because usability can be measured with the help of usability experts, industry experts, research scholars and end users. This paper provides analytical view about various usability evaluation methodologies with their comprehensive structure.

General Terms
Software Engineering

Keywords
Quality, Usability, Model, Measurement, Software system

1. INTRODUCTION
Usability is the important factor in measure of quality of a software system. It not only saves money but fulfils user expectations as well. There are many benefits of usability from user's point of view as they satisfy with the product quality, its efficiency and performance. This way they will also develop confidence and trust in the product. From providers point of view also there are benefits of usability such as reduced training time and costs, reduced errors, reduced support costs, reduced development time and costs.
The Institute of Electrical and Electronics Engineers [20], proposes as a definition for usability as "the ease with which a user can learn to operate, prepare inputs for and interpret outputs of a system or a component". Shackel [42] defined usability as "the artifact's capability, in human functional terms, to be used easily, effectively and satisfactorily by specific users, performing specific tasks, in specific environments". Nielsen [33] defines usability as "the measure of quality of experience of user while using the product". Usability is defined in ISO 9241-11 [22] as the "the extent to which a product can be used by specified users to achieve specified context of use". Subsequently, ISO/IEC 9126-1 [23] classified usability as one of the components representing internal and external software quality, defining it as " the capability of the software product to be understood, learned, used and attractive to the user, when used under specified conditions".
Usability fulfils the user expectations by stating how satisfactory users can make use of the functionality of the system. The fulfillment of this expectation is very much related with usability measurement. Usability measurement is the evaluation of usability which is important in order to measure the quality of the software system.

Usability measurement is the measure of quality of the software product which is very important from user's point of view as it gives reliability and assurance that the product is of a standard or good quality. Usability can be measured at any point of the development using usability experts, industry experts, research scholar and end users. Usability is rarely measured as it costs four times as much as it would have in conducting qualitative studies. Usability measurement is done relatively to the user's performance based on given set of test tasks. The main aim of usability measurement is to check that the product that is being distributed reaches the minimum level of usability that is required. It also provide feedback in order to check whether objectives are met or not and identify errors in the product. According to Bevan [5] benefits of usability measurements are:

i. predict, ensure and improve product quality
ii. control and improve the production processes
iii. decide on the acceptance of a software product
iv. select a product from alternative products

This paper analytically describes various usability measurement methods and provides comprehensive views on such methods.

2. USABILITY IN QUALITY MODELS
Usability is recognized as the most important aspect of software quality. A very important tool for quality and usability engineering as well as for early evaluation is a quality model. Software quality is defined as "conformance to requirements." There are various Quality models such as McCall *et al.* [30], Boehm [8], ISO 9126 [21], FURPS [10, 11], QUIM model 40] etc.

2.1 McCall's Quality Model
Jim McCall *et al*. [30] take both users and developers views for software quality factors. It consists of three major perspectives. These are revision (ability of product to undergo changes), product operation (ability of the product to operate) and product transition (describes how adaptive the product is to the new environment). These perspectives are sub categorized. Product revision is categorized as maintainability, testability and flexibility. Product operation is categorized as correctness, reliability, efficiency, integrity and usability. Product transition is categorized as portability, interoperability and reusability. Usability is further categorized as operability, training and communicativeness.

2.2 Boehm's Quality Model
Boehm [8] describes software quality with a set of attributes, metrics and criteria. According to him characteristics that help in evaluation of quality of a software can be high level or intermediate level or low level. High level characteristics

define the high level requirements of actual use of the software quality evaluation. Intermediate level characteristics represents quality into seven characteristics i.e. portability, reliability, efficiency, flexibility, testing ability, usability and understandability. The lowest level or primitive characteristics provide foundation for defining quality metrics. Here usability is further categorized into reliability, efficiency and human-engineering.

2.3 ISO 9126 Quality Model

ISO 9126 [21] introduced a standard known as software product evaluation-quality characteristics and guidelines for their use. There are many versions of ISO 9126 models that were extended year by year. ISO 9126 [23] contains two parts quality model i.e. internal or external quality model and quality in use model. These were subcategorized later on. The internal or external quality model can be subcategorized into functionality, reliability, usability, maintainability, portability and efficiency whereas quality in use is subcategorized into safety, productivity, efficiency and satisfaction. In this model usability is further categorized into understandability, learnability, operability, attractiveness and usability compliance.

2.4 FURPS Quality Model

It was originally proposed by Robert Grady [16] but was further extended by IBM Rational into FURPS+. This '+' denotes the added features such as design constraints, implementation requirements, interface requirements and physical requirements. FURPS contain various characteristics such as functionality, reliability, supportability, usability and performance. In this quality model usability includes consistent user-interface, context help, training and documentation.

2.5 Dromey's Quality Model

Dromey [11] proposed a quality model which is a product based model. Product based means that evaluation of quality is different for each product. According to this model, the quality of the software component is evaluated by measuring its quality properties. Component can be anything depending on type of model like functions and variables are components of an implementation type of model.

2.6 QUIM Quality Model

QUIM (Quality in Use Integrated Measurement) is proposed by A. Seffah [40]. It is a combined model for measurement of usability. It uses a hierarchical approach i.e. it first divides the usability into various factors, further into criteria and then finally into metrics. In this model usability is categorized into 10 factors. These are productivity, efficiency, effectiveness, safety, learnability, accessibility, satisfaction, trustfulness, universality and usefulness.

3. LITERATURE SURVEY

Following subsections provide literature survey on usability and usability measurement is mentioned in detail.

3.1 Usability

Users always prefer usable systems. Shackel [41] stated that a system is usable to an extent that it is effective, learnable, flexible and subjectively pleasing. Lowgren [28] mentioned that usability is the outcome of relevance, efficiency, learnability and attitude. Hix and Hartson [18] considered that usability is related to the interface efficiency and also of user reaction to the interface. They classify usability into initial performance, long term performance, learnability, advanced feature usage and long term user satisfaction. Dumas and Redish [13] believes usability means that "people who use the product can produce them so quickly and easily in order to accomplish their own tasks". Dumas & Redish [12] stated that usability is a characteristic of the product and not of the user, although usability may vary depending on the user's prior experience with similar products. Lamb [26] claims usability issues should be extended beyond interface usability, to include content usability, organizational usability and inter-organizational usability. Usability can be specified and tested by means of a set of the operational dimensions. Usability dimensions include:

i) ease of learning [27]
ii) performance effectiveness [27]
iii) flexibility [17, 27]
iv) ease of use [17]
v) few errors and system integrity [17]

Guillemette [17] refers usability as "the degree to which an information system can be effectively used by target users in the performance of tasks". Initially the term usability was derivative of the term "user friendly". Afterwards it was replaced by "quality in use" [4]. Usability can also be related to usefulness and usableness. Gluck [50] made this assessment and states that usability refers to functions such as "Can I invoke this function?" or "Did it really help me" or "Was it worth it"? In terms of usability framework, Thomas [45] categories usability attributes into three categories: outcome (includes effectiveness, efficiency and satisfaction), process (includes ease of use, interface, learnability, memorability, and error recovery) and task (includes functionality and compatability). Clairmont *et al.* [9] also stated, "Usability is the degree to which a user can successfully learn and use a product to achieve a goal." Usability can also be examined from the perspectives of graphic design, navigation, and content [44]. Kengeri *et al.* [24] categorized usability using four attributes namely effectiveness, likeability, learnability and usefulness. Arms [3] once claimed that usability comprises of various aspects including interface design, functional design, data and metadata, and the computer systems and networking. Practitioner Quesenbery [35, 36, 37] states that the 5 Es of usability provide more tough definition. These 5 Es include effectiveness, efficiency, engagement, error forbearance, and ease of learning. Turner [46] proposes a checklist to evaluate usability. The categories include usability into navigation, page design, content, accessibility, media use, interactivity and consistency. Blandford and Buchanan [7] suggest that usability is technical, cognitive, social and design oriented and it is important to bring these different perspectives together, to share views, experiences and insights. Kim [25] finds that "the difference between interface effectiveness and usability is not clear". Interface effectiveness is one of the most important aspects of usability as it is the medium through which users communicate and interact with the system. Oulanov and Pajarillo [33] state that usability tool entails the following eight criteria: Affect, Adaptability, Control, Helpfulness, Efficiency, User Effort, Measures of Effectiveness, and Retrieval Features. Furtado *et al.* [14] also consider usability from ease of use point of view and add that usability should also include ease of learning. From the view of Abran *et al.* [1] usability refers to a set of multiple concepts, such as execution time, performance, user satisfaction and ease of learning. Also, usability has some

categories such as product effectiveness which includes output and satisfaction at the time of use of the product, product attributes such as interfaces, capability of the organization and process used to develop the product [1].

3.2 Literature Survey on Usability Evaluation

The techniques involved to evaluate usability includes formal usability, testing, usability inspection, card sort, focus groups, questionnaires, think aloud, analysis of site usage logs cognitive walkthrough, heuristic evaluation, Software Usability Measurement Inventory, Metrics for Usability Standards in Computing, etc. Table 1 gives comparative summary about various usability measurement methods. Following sub-sections describe usability evaluation methods in brief:

3.2.1 Usability Testing

This approach requires experts to work on distinctive tasks using the system or prototyping models. Prototyping models finalize the products and tests the elements of the final product. If the final product is not ready then simply the model is tested. Testing helps the evaluators to check how user interface helps users in their tasks. Testing methods include the following:

3.2.1.1 Coaching Method [31]

This technique can be used for usability test, in which the members ask any system-related questions to an expert who will gives answers to the questions with his best potential. The main goal of this method is to collect information about the needs of user in order to improve the documentation.

3.2.1.2 Performance Measurement [31, 43]

It is classical method of software evaluation that provides quantitative performance measurements. Mostly while the test is going on, there is no communication between the user and the tester.

3.2.1.3 Question – asking Protocol [13]

In this protocol you prompt users by asking direct questions about the product. Their ability to answer your questions can help you see what parts of the product interface were obvious, and which were not.

3.2.1.4 Retrospective Testing [31]

The operator gives a "walk through" of the performance previously recorded on the video which means it is a follow up to any other videotaped testing session where tester and participant review the tape together.

3.2.1.5 Thinking Aloud Protocol [31]

For this protocol there are experts who capture a video tape on certain subjects and perform complete protocol examination. This method is effectively used by research scientists in order to find user interfaces with minimum training.

3.2.1.6 Co-discovery Learning [31, 13, 39]

Co-discovery learning involves observation of two users working on the same task with the system prototype. Users are asked to work mutually and express all their thoughts.

3.2.1.7 Teaching Method [47]

A teaching method is used as an alternative to the concurrent think-aloud method for usability testing. Many usability testing methods require recording of actions a user may make while exercising an interface.

3.2.1.8 Remote Testing [19]

The tester can view the user's interaction in real time on the user's own computer and communicate with the user during testing or the tester can have user data collected automatically by the software installed on the user's computer.

3.2.2 Usability Inspection

The Usability Inspection approach requires usability specialists or software developers, users and other professionals to examine and judge whether each element of a user interface or prototype follows established usability principles. Commonly used inspection methods are:-

3.2.2.1 Cognitive Walkthrough [38, 49]

In this a group of software engineers examine the code in a certain pattern to search problems. During the walkthrough of a task, the evaluator attempts to suggest a user's problem solving process while examining each action.

3.2.2.2 Heuristic Evaluation [32]

Heuristic evaluation is usability engineering method for finding the usability problems with the help of experts in a user interface design. Experts evaluate usability individually and note their observations for usability measurement on the basis of which they provide the ranking.

3.2.2.3 Feature Inspection [32]

Feature inspection lists sequence of features used to accomplish typical tasks, checks for long sequences. It also analyzes the availability, understandability, and other functionality aspects for each feature.

3.2.2.4 Pluralistic Walkthrough [6]

It is a usability inspection method used to identify usability issues in a piece of software or website in an effort to create a maximally usable human-computer interface.

3.2.2.5 Standards inspection/guideline checklists [48]

Standards Inspection ensures compliance with industry standards. This method is to ensure a product's market conformance.

3.2.2.6 Perspective- based Inspection [50, 51]

Prescriptive guidelines are given for each perspective on what to check and how to perform the required checks.

3.2.2.7 Card Sorting

This method is to explore how people combine the items so that users are able to find items easily. It is cheap and easy technique and is mainly used for defining website arrangement.

3.2.2.8 *Tree Testing*

Tree testing is basically reverse of card sorting. This method allows us to test navigation and findability visually. Hence this technique is more reliable

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3.2.3 Usability Inquiry

Usability inquiry involves experts to get information about the user requirement for the system by communicating with them or observing them while users are operating the system. Inquiry methods include:

3.2.3.1 Field Observation [31]

These are used to collect detailed information about how people work, the context in which the work takes place, which tools are more important and less important and which design changes to existing tools would help make their work easier.

3.2.3.2 Interviews/ Focus groups [31]

A focus group is an informal assembly of users whose opinions on a selected topic are requested. The main aim of this method is to find the user's understanding and perception about a selected topic.

3.2.3.3 Proactive Field Study [31]

This technique is to be used during the requirement or early design stage of software development. This should be the first step of usability work for a project.

3.2.3.4 Logging Actual Use [31]

Logging involves having the computer automatically collect statistics about the detailed use of the system. It is useful because it shows how users perform their actual work.

3.2.3.5 Surveys [2]

This method is basically used to get information concentrated on the conclusion and problems faced when the system is used.

3.2.4 Software Usability Measurement Inventory (SUMI)

It is designed by Porteous *et al*. [34] to gather information about what users think about the quality of the software system by giving users a psychometric questionnaire. Answers to these questionnaires are analyzed with the help of SUMISCO (computer program).

3.2.5 Metrics for Usability Standards In Computing (MUSiC)

This method is designed by Macleod *et al.* [29] and it is based on Usability Context Analysis. This means it collects information about the users by their experience and tasks and also keeping in mind the constraints (technical or environmental).

3.2.6 Diagnostic Recorder for Usability Management (DRUM)

It is also designed by Macleod *et al.* [29] and it directly supports MUSiC and assists in many different aspects of analyst's work like managing data, video analysis etc. It speeds up the analysis and it helps the analyst to build up a time log of each evaluation session and calculates performance measures.

4. CONCLUSION

Usability is an important quality attribute for efficient software system. This paper reviewed several significant usability measurement methods. Different methods and some commercial tools for usability measurement are also discussed in this paper. The analytical view presented in this paper will be beneficial for both the researchers and practitioners in the context of usability measurement information.

Table 1. Comparison of usability measurement methods

Evaluation Method Type	Evaluation Method	Applicable Stages	Description	Pros	Cons
Testing	Coaching method	Design, code, test and deployment	Collects information about the needs of the user	Coach is easy to find users usage problems on the spot	Overall interaction between coach and users is not so good and they find less usability problems
	Performance Measurement	Design, code, test and deployment	Collects information about performance of an organization or an individual	Compares different interfaces and checks if aim of the user has been met or not	It gives emphasis to first time usage and covers only a limited number of interface features
	Question Asking Protocol	Design, code, test and deployment	Users ability to answer questions is checked	It is simple and through this protocol we know what parts of interface were obvious and what were not	Interpretation for this can be wrong
	Retrospective	Design, code, test	It gives a	Used for participants	It is time

	Testing	and deployment	walkthrough of the performance recorded previously on video.	for whom talking or writing and working may be difficult	consuming
Testing	Thinking aloud protocol	Design, code, test and deployment	It is conducted with experimenters who videotape the subjects and perform detailed protocol analysis.	It is not so expensive and the results are close to the observations made by users	It is not user friendly protocol
	Co-Discovery Learning	Design, code, test and deployment	It involves observation of two users working on same task.	Users feel free to discuss with each other	Difference in learning and culture style may affect the feedback
	Teaching Method	Design, code, test and deployment	Used as an alternative to think aloud method	Number of verbalizations are more hence the participant interactive behavior provides the participants' though process and search strategy	It is time consuming since briefing the participants is necessary
	Remote Testing	Design, code, test and deployment	Testers can view user's interaction in real time	Three major issues (effectiveness, efficiency and satisfaction) of usability are covered	An additional software is also required to observe users from distance
Inspection	Cognitive walkthrough	Design, code, test and deployment	A group of experts examine the code in a certain pattern to search problems	It does not require a fully functional prototype	It does not address user satisfaction as well as efficiency
	Heuristic Evaluation	Design, code, test and deployment	Finds usability problems in user interface	No need of formal training required for evaluators	Biased by preconceptions of evaluators
	Feature Inspection	Code, test and deployment	It lists features used to accomplish tasks.	It does not require large number of evaluators.	Takes a long time if applied for all features of the system
	Pluralistic Walkthrough	Design	Identifies usability issues in a piece of software	more number of usability can be found at a time	The most important issue of usability i.e. efficiency is not addressed
	Card Sorting	User requirements and early design	Technique that involves users to group information for a web site.	It is simple, organized, cheap and fast to execute	Results of card sorting may vary
Inspection	Tree Testing	user requirements and design	Reverse of card sorting	Allows to test navigation visually thus it ensures reliability	It is not moderated thus researchers cannot see users or participants
	Field	Test and	Collects detailed	It is highly reliable	Some task may not

	observation	deployment	information about how people work and the context in which works takes place.	and less expensive	be in the manner they are observed
	Interviews/Focus groups	Context and user requirements and testing	Takes out views and understandings of the users about a selected topic	Useful ideas are produced which also results in healthy customer relations	Data collected has low validity
Inquiry	Proactive Field study	Requirement and design	It is used in early design stage to understand the needs of the users	Individual users characteristics, task analysis and functional analysis is found	It cannot be conducted remotely and collected data is not quantitative
	Logging Actual use	Test and deployment	Automatically collect statistics about the detailed use of the system	It can show the statistics of each action	It shows what users did and not why they did it
	Surveys	Test and deployment	Acquire information focused directly on problems and conclusions.	It is comparatively faster in determining preference of large user groups	It does not capture details and may not even permit the follow-up
SUMI	Questionnaire	User requirements and testing	It is a method of measuring quality from user's point of view	Provides objective way of assessing users satisfaction	Results produced by SUMI are only valid if questionnaire has been administered in same way to all users and if results are interpreted properly and carefully.
MUSiC	Context Analysis		It aims on achieving qualitative and quantitative data to support the systems	It is used to find performance metrics of the user	It fails to capture an accurate and reviewable record
DRUM	Video Recording		It finds diagnostic information from an analysis of videotape	It helps analyst to create a time log of the user actions	it needs to be licensed to organizations because of the risks involved.

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