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USABILITY: KEY CHARACTERISTIC OF SOFTWARE QUALITY

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Summary:

The paper emphasizes the importance of software usability as a key quality characteristic of software during its use. At the beginning of the paper, a retrospective of formal definitions of usability is given in order to show the evolution of views on usability for more than three decades. To ensure the required quality in use, it is necessary to measure and evaluate many characteristics that affect the usability of software. The paper gives a brief chronology of attempts to identify different dimensions of usability based on its definitions. Since it is not easy to determine the characteristics that contribute most to the quality in use, two methods are applied in identifying the key attributes that affect usability, and they are to be given special consideration when building a model of usability.

Key words: ISO*, quality standard, software quality.*

Introduction

Usability is a qualitative feature of software during its use which allows the user to perform desired tasks easily, effectively and comfortably. Usability has a multi-dimensional character and cannot be viewed only from one point of view because it is influenced by various factors. In the literature, the term usability is widely used and means different things to different people. Usability is a key element in defining the overall quality of a software system and is commonly recognized as a quality factor in the technical aspect. This is a field of interaction of people and computers (HCI), which provides the theoretical background and suggests techniques for producing quality user interfaces. Usability can be seen as the usefulness and ease of use of the system. Usability also has several other aspects, including interface design, design functionality, data and metada-

ta and computer systems and networks (Arms, 2000). All these different aspects of usability are of interest to software designers, developers and users in order to get a usable system. Usability is often used in a different context where a precise meaning can be lost. Because of many aspects of usability, it is necessary to consider various definitions of usability and to analyze a comprehensive set of attributes that constitute usability in order to obtain a clear idea of usability.

Usability is a term that means "easy to use" in situations when a person interacts with the interface of the system and its functions; it plays an important role in the software development process. Usability is a measure of the usefulness of the proposed solutions, or the answer to the question of how easily and how effectively users can complete the desired task. Usability is primarily related to the quality of design applications and includes user interface design, method development, testing and commissioning.

Definitions of usability

Although the concept of usability plays an important role in the interaction between people and computers, there is still no universally accepted definition of usability. As a quality characteristics, usability is defined by different researchers and several ISO standards. A retrospective of formal definitions will be given further on in order to demonstrate how researchers' views on usability have changed over more than four decades.

As described earlier, based on the definitions of usability in the HCI field, researchers have identified various dimensions of usability. An appropriate definition of usability can act as a guideline for the development of an efficient software system, but there is still no definition consistently accepted by developers. Although several definitions of usability and its attributes have been proposed in the previous literature, an agreement on the concept of usability has not been reached yet between researchers and standardization bodies (Abran et al, 2003). Different views on the attributes of usability and the lack of authentic definitions of usability are the main reasons for poor usability of software systems. An analysis of different definitions of usability from different studies can help developers of software systems to develop an efficient and usable software system. The aim of this work is to see how the characteristics and their attributes are defined in previous studies.

In the study of Dubey et al. (Dubey et al, 2010, pp.4723-4729) 37 formal definitions are examined, and a total of 152 attributes are allocated and grouped into 22 categories. They found that, in the above definitions,

the most often used usability attributes are: learnability, satisfaction, flexibility, efficiency, effectiveness and ease of memorization. However, the drawback of this study is the fact that it considers only the publications with the definitions of usability from a single source (citation database Scopus index) published before 2010.

Below is a chronological summary of the examined attributes of usability in different models, definitions and standards, from 1977 to 2012.

The first and most widely used software quality model was proposed by McCall (1977) who describes usability as operability, training and communicativeness. Eason (1984) characterizes usability in three independent parts (the characteristics of the task, the user and the system) on the platform on which the task is performed and with the users' reaction, which is a variable. Makoid (1985) proposes that different definitions of usability may include various parameters (customer satisfaction, error type). Butler (1985) suggests that the system is considered usable if users can complete a specific task within a predetermined period of time. Reed (1986) defines usability as ease with which the system can be learnt and used. In the same year, Shack introduced an operational definition of usability that allows to evaluate the system during the development life cycle. He presented one of the most commonly used definitions of usability indicating that the system is useful to the extent to which it is effective, easy to learn, flexible and subjectively friendly. Gould (1988) classifies the usability with regard to the system performance, system functions and user interface (Dubey et al, 2010, pp.4723-4729).

Booth (Booth, 1989) finds it difficult to identify and measure the flexibility of the system and believes that usefulness should be the basis for usability. He modifies Shackel's criteria and states that usability has four factors: usefulness, efficiency, ease of learning (or ease of use) and attitude (or appeal).

Later, Shackel and Richardson (1991) recognized the importance of usability engineering and suggested four important characteristics of usability called learnability, efficiency, flexibility and attitude?. Efficiency refers to the impact of the implementation of tasks, learnability implies a degree of learning to achieve tasks, the flexibility is the ability to adapt to task changes and attitude relates to customers' satisfaction in the work with the system.

Bevan et al. (1991) argue that usability is based on the product, the user, ease of use and acceptability of the product for a specific class of users to perform specific tasks in a specific environment. In the quality model proposed in 1992 by Grady called FURPS (Functionality, Usability, Reliability, Performance, and Supportability), usability includes human fac-

tors, aesthetics, consistency in the user interface, online and context sensitive help, wizards and agents, user documentation and training materials (Dubey et al, 2010, pp.4723-4729).

The ISO 9126 (ISO/IEC 9126, 1991) definition contains 21 attributes arranged in six areas: functionality, reliability, usability, efficiency, maintainability and portability, out of which usability attracted the attention of most researchers.

In 1992, the Institute of Electrical and Electronics Engineers (IEEE Std 1061) defined usability as: the ease with which users can learn to operate, prepare input and interpret the results of a system or a component and proposed a model that usability depends on the following factors: user-friendliness, ease of learning and communicativeness. Hix and Hartson (1993) define usability via performance, ease of learning, knowledge retention over time, advanced functions of use, the first impression and long-term user satisfaction. Löwgren (1993) stated that usability is the result of relevance, efficiency, ease of learning and attitude (Dubey et al, 2010, pp.4723-4729).

Nielsen (Nielsen, 1993) recognizes usability as an important attribute that affects the acceptance of the product. Usability and complaisance can help product utility that enhances the users' ability to perform their tasks. He divides acceptability to practical and social acceptability and identifies five important attributes associated with usability, which are: learnability, efficiency, memorability, errors and satisfaction. Social acceptability indicates whether the system is designed for ethical purposes. Practical acceptability is a generalization about the acceptance of system costs, compatibility with existing systems, reliability, availability, usefulness and other such considerations. Usefulness refers to the question whether the system can be used to achieve a desired goal. Usefulness can be further divided into usability and utility. Utility is related to forecasting functionality of the system to do what is necessary. Usability is a question of how well users can use this functionality. So, all these elements of the system of acceptability are very important for a general attitude. Usability is only one of many, but still needs to be one of the criteria for evaluating software or services.

The SUMI method of measurement (Software Usability Measurement Inventory) also describes usability by its attributes: efficiency, effectiveness, helpfulness, control and ease of learning (1993). Dumas and Redish (1993) suggest that usability means that people who use the product can quickly and easily accomplish their tasks and it focuses on four main points: users, productivity, tasks, and ease of use (Dubey et al, 2010, pp.4723-4729).

Rubin (Rubin, 1994) said that likeability is also an important usability attribute that represents the user's perception, feelings and opinions about the product.

Luis (1995) introduced a questionnaire PSSUQ (Post Study System Usability Questionnaire) which identifies usability attributes grouped into three factors, ie. usefulness of the system, the quality of information and the quality of the interface. Thomas (1998) categorizes the attributes into the result, the process and the task. In their model, Dix et al. (1998) represent system usability in three categories: ease of learning, flexibility and robustness (Dubey et al, 2010, pp.4723-4729).

After that, the International Organization for Standardization (ISO) published usability standards from two different points of view on usability, i.e. ease of use (ISO 9241-11, 1998) and quality in use (ISO/IEC 9126-1, 2001). ISO 9241-11 establishes the effectiveness, efficiency and satisfaction as the basic dimensions and defines usability as an 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 (ISO 9214-11, 1998).

Lecerof et al. (1998) provide a definition of usability, addressing the importance of user needs, efficiency, subjective feelings of users, ease of learning and system security function, such as giving users the rights to nullify actions that can lead to errors. Clairmont et al. (1999) suggest that usability is a degree to which the user can successfully learn and use the product to achieve the goal. Arms (2000) states that usability has several aspects, including interface design, functional design, data and metadata of computer systems and networks alike. Frojkaer et al. (2000) argue that the components of effectiveness, efficiency and satisfaction should be considered as separate and independent aspects of usability. Doniaee et al. (2001) developed an integrated model of measuring quality in use (QUIM). The attributes included in QUIM are: effectiveness, efficiency, satisfaction, productivity, safety, accessibility and internationalization. Battleson et al. (2001) proposed to improve the interface usability so that it can be easy to learn, remember and use, with few mistakes for target users and designed to support specific tasks (Dubey et al, 2010, pp.4723-4729).

A little later, ISO 9126, 2001, established the following usability subatributes called: user-friendliness, ease of learning, functionality, attractiveness and usability compliance. An Oulan and Pajarillo's study, called CUNY + (2002), primarily used a questionnaire as a method of evaluating usability. The authors conducted a study in two stages to compare the usability of text-based and Web-based CUNY Web sites. The criteria applied were impact, efficiency, control, attentiveness and adaptability

(Dubey et al, 2010, pp.4723-4729). Blandford et al. (2002) indicate that usability is technically, cognitively, socially and design-oriented and that it is important to gather these different perspectives together. Brinck et al. (2002) suggested that usability be: functional correctness, efficiency of use, ease of learning, ease of remembering, error tolerance and a subjective feeling of comfort. Abran et al. (2003) combine the attributes of ISO 9126 and ISO 9241 and develop a new model with the attributes: efficiency, satisfaction, ease of learning and safety. To describe the usable software systems, Bas et al. (2003) have qualities such as interchangeability, flexibility, re-use, performance, security, etc. Campbell et al. (2003) explicitly state that usability refers to the relationship between tools and their users. Shneiderman et al. (2005) identified five measures of usability, namely: learning time, speed, error rate profile, retention of knowledge over time and subjective satisfaction. Jeng (2005) also used efficiency, satisfaction and ease of learning as the attributes of usability for digital libraries. It identifies inherent and obvious usability. Inherent usability is inseparable and makes the product easy to understand, easy to learn, efficient to use, comfortable to use and with fewer errors while obvious usability is related to a visual impression of the interface. Krug (2006) looked at usability from a user's perspective with the need for an intuitive experience.

In 2006, Seffah et al. developed a consolidated model for measuring usability and metrics, called QUIM (Quality and Use Integrated Measurement). They combined different standards and models, such as ISO 9241 and ISO 9126, in one single consolidated, hierarchical model. They give the methods for determining the quality requirements as well as the identification, implementation, analysis and evaluation of the process and product quality metrics. This initial model is suitable for users who have little knowledge of usability and can be applied by both usability experts and not experts. The QUIM model consists of 10 factors (efficiency, effectiveness, satisfaction, ease of learning, productivity, security, trust, accessibility, usability and universality), divided into 26 measurable criteria that include 127 specific metrics. The model is used to measure the actual use of the software in operation and to identify problems. The QUIM model connects the factors with the criteria and metrics in a clear and consistent manner. It can be used in a general form or it can be adapted to a specific context (Dubey et al, 2010, pp.4723-4729).

Juristo et al. (2007) presented certain characteristics of usability, getting inspiration from a number of real applications. Seffah (2008) argues that there is a need to develop new environment for usability testing and methodology, since technical environment is developing and the current

laboratories are limited. Sauro et al. (2009) calculated the correlation of usability attributes from 90 different studies such as time on task, degree of completed tasks, errors, satisfaction upon task completion and satisfaction after testing. The results of this research have helped to clarify the attributes that have contributed to the connection of the structure of usability studies. Bevan (2009) argues that, despite the authoritarian nature of international standards for usability, many of them are not widely used (Dubey et al, 2010).

The Website Evaluation Framework (WEF) model consists of five quality characteristics (Zhou, 2009): aesthetics, ease of use, multimedia, rich content, and reputation. Oztekin proposes the UWIS methodology that integrates established dimensions of the quality of web services (reliability, integration of communications, navigation, control, security, accountability and quality of information) and usability of information systems (efficiency, effectiveness and satisfaction) (Oztekin et al, 2009, pp.2038-2050). Gardner-Bonneau (2010) discusses how much human factors and usability of the system will be effective when there are more and more changes in the technological environment (Dubey et al, 2010). According to Rhodes (Rhodes, 2010), usability is further subdivided into five important factors or attributes of the user interface as follows: efficiency, ease of learning, memorability, error rate and satisfaction. According to a survey (Karahoca et al, 2010, pp.5813-5819), the elements of usability are ease of learning and efficiency, aesthetics and navigation, content and functionality, accuracy and consistency, technical adequacy, help and documentation and debugging.

From 2011 until today, the current standard in the field of software quality has been ISO 25010, which represents the second generation of standards for software quality, and was issued with the intent to define the reference models and the quality of the evaluation process which will replace the ISO/IEC 9126 and ISO/IEC 14598 series. At present, the current series of international standards (SQuaRE) includes two models of quality: quality model in use and the quality of the product model (ISO/IEC 25010). However, ISO 25010 does not include the quality of information because ISO 25012 is intended for this purpose. This standard is a general model for data quality and is intended to be used together with ISO 25010. It aims to establish standards in data quality as well as in planning and performing data quality assessment.

Figure 1 is a graph showing a model of quality in ISO/IEC 25010 (SQuaRE).

These definitions of usability are usually used to identify usability problems of traditional graphic user interfaces. However, the emergence of

the Internet as a basic working and development environment with its specific properties contributes to the speedy development and massive use of Web-based applications that are a rather specific software product. Although some of these definitions of usability can be equally successfully applied to a variety of web applications, the need for a positive user experience in interacting with the application is further emphasized in the web environment.

Some researchers in the field of quality of web applications (Bublione, 2002), (Becker and Olsina, 2010), (Olsina and Molina, 2008, pp.385-420), (Lew and Olsina, 2011, pp.214-229) indicate that the characteristics of software quality given in the ISO/IEC standard quality models (ISO 25010) are not sufficient to describe the quality of specific software products such as Web applications.

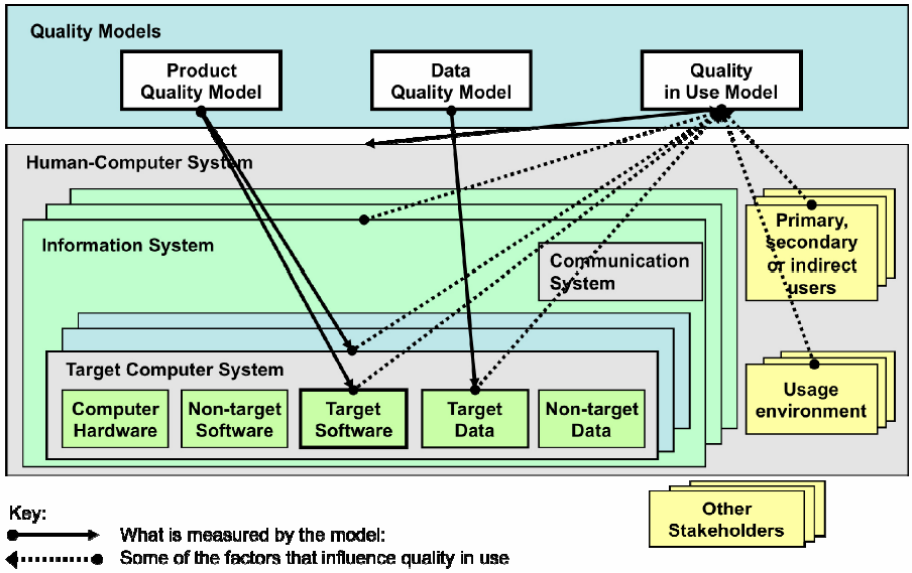

Figure 1 – Models of quality in SQuaRE
Рис. 1 – Модели качества в системе SQuaRE
Слика 1 – Модели квалитета у SQuaRE

Research efforts over the past decade have given a number of models of software quality of Web applications oriented to a specific domain. Thus we have the quality designs for specific domains such as e-Learning (Chua and Dyson, 2004, pp.184-190), (Bhuasiri et al, 2011, pp.843-855), (Kasse and Balunywa, 2013), e-commerce (Loiacono et al, 2002), (Barnes and Vidgen, 2002, pp.114-127), (Lee and Kozar, 2006, pp.1383-1401), (Lazić, 2010), hospitality (Spremić et al., 2008, pp.229-238), e-banking

(Moraga et al, 2008, pp.113-129), academic sites (Olsina et al ., 2001), public administration (Quirchmayr et al, 2007) and so on. In addition, there are a lot of general quality models tailored specifically for Web applications, such as (Olsina and Rossi, 2002, pp.20-29), (Li and Suomi, 2009), (Montero et al, 2008, pp.220-233), (Bjarnik, 2001), (Offut, 2003) and (Bublione, 2002).

Decomposition of usability

To ensure the required quality in use, it is necessary to measure and evaluate many characteristics that allow us to determine the usability of software, where metrics play an important role. The main problem with the definition of the product is that it is very difficult to determine its characteristics and their attributes that need special consideration. Only a few models of software quality solve the aspect of usability in a detailed and structured way (Abran et al, 2003, pp.325-338).

The previous section provides a broader and chronological set of different standards and studies with formal definitions of usability and quality models which are the basis for further work. In order to isolate those attributes that influence usability the most, two approaches were used: the first one analyzes the attributes of usability in various formal definitions of usability, and the other one analyzes the attributes in the key usability models.

The first approach involves analyzing the contents of all formal definitions given in the reviewed publications and extracting the key attributes of usability. The selected attributes are analyzed, followed by the identification of their characteristics, based on which they are grouped into certain categories of usability attributes. However, it has been noted that the proposed definitions are informal, too short and ambiguous.

In the formal definitions presented in the previous chapter, the author has identified 186 different attributes which are grouped under 22 different categories. Out of all attributes, 21 appear 2 or more times (total 154 frequencies) and they are grouped in a separate category, while 32 attributes appear only once and they are grouped under the name "others".

The usability attributes and their frequency of occurrence in the reviewed standards and studies are shown in Table 1. They are arranged in the descending order, from the attributes with the highest frequency in the top of the table to the last attribute with the smallest number of occurrences.

For the ease of analysis, the frequency of usability attributes in the reviewed studies and standards is shown graphically in Figure 2. Based on the overall frequency of attributes in all included definitions, it can be concluded that the attributes: ease of learning, satisfaction, flexibility,

efficiency, effectiveness and ease of memory have the highest impact on the usability of software systems.

Another approach examines the key attributes of usability in usability models proposed by researchers and international standard organizations (Eason, 1984), (Shackel, 1991), (Nielsen, 1993), (ISO 9241-11, 1998), (ISO 9126, 2001), QUIM model (Seffah et al, 2006), (ISO 25010, 2010), etc.

Although all models have many different attributes, the analysis of their common characteristics has pointed to their similarities. Based on the studies on the similarities between usability models and the frequency of attribute occurrence in all discussed usability models, it can be concluded that 5 attributes (effectiveness, efficiency, satisfaction, ease of learning and accessibility), have the biggest impact on software usability. Table 2 shows the usability attributes in the discussed usability models and their frequency of occurrence.

Table 1 – Reviewed usability attributes and their frequency
Таблица 1 – Обзорные атрибуты применяемости и их частотность
Табела 1 – Прегледани атрибути употребљивости и њихова учесталост

Attributes	Frequency	Percent
The ease of learning	23	12.4%
Satisfaction	18	9.7%
Flexibility	16	8.6%
Efficiency	18	9.7%
Effectiveness	12	6.5%
The ease of memory	8	4.3%
Interface Design	7	3.8%
The ease of use	6	3.2%
Errors	5	2.7%
Safety	5	2.7%
Help	5	2.7%
Functionality	4	2.2%
Communications	4	2.2%
Task	4	2.2%
User	4	2.2%
Productivity	3	1.6%
The first impression	3	1.6%
Tolerance to errors	3	1.6%
Advanced Features	2	1.1%
Operability	2	1.1%
Training	2	1.1%
Other	32	17.2%
Total	186	100.0%

The comparative analysis of the results of the two approaches can result in a conclusion that the characteristics: effectiveness, efficiency, satisfaction, ease of learning and flexibility have the highest impact on the usability of software.

Effectiveness is a measure of the system performance to successfully complete a specific task or goal in time.

Efficiency refers to the accuracy and completeness of a certain objective and represents the successful completion of the task using the system.

Satisfaction is a pleasant feeling that a user gets during or after the use of the system. It can be seen as appeal or acceptability of the system by the user, in this context of use.

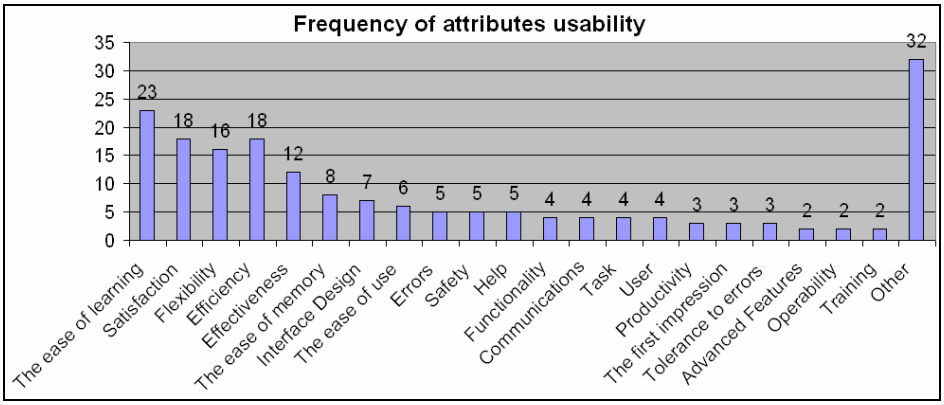

Figure 2 – Frequency of the usability attributes in the reviewed standards and studies
Рис. 2 – Частотность атрибутов применяемости по стандартам и исследованиям
Слика 2 – Фреквенција атрибута употребљивости у прегледаним стандардима и студијама

Table 2 – Comparison of the usability models
Таблица 2 – Сравнение моделей применяемости
Табела 2 – Поређење модела употребљивости

Attributes of usability	Eason (1984)	Shackel (1991)	Nielsen (1993)	ISO 9241-11 (1998)	ISO 9126 (2001)	QUIM (2006)	ISO 25010 (2011)
Efficiency		√		√		√	√
Effectiveness	√		√	√		√	√
Satisfaction			√	√		√	√
The ease of learning	√	√	√		√	√	√
Accessibility						√	√

The ease of learning is the ability of the software product to enable the user to learn its application. The system should be easy to learn and understand. It should be easy for the user to carry out a task using the software system. It also includes the effort needed to understand and work with an unfamiliar system, the user's additional time for learning as well as user's training after certain time from the time of installation of the system.

Flexibility represents the variations in the system work relating to an existing one, such as flexibility to the context in use, accessibility in use or expandability to the context in use.

Conclusion

The characteristics of today's business world (global networking - Internet, software dependence, Web applications, etc.) emphasize the need for predictive usability of software in an easy and user-friendly way. Today, there are numerous methods for assessing usability. As a result, there is the question of choice of the most appropriate method for assessing the usability of a particular software product. The choice of an adequate method can significantly improve the efficiency of the evaluation process and usability of the software product. Choosing the right method is not an easy task, since it depends not only on the type of the software product, but also on the development of the objectives of the project and the context of use; therefore, it would be necessary to have an effective formal mechanism for assessing the usability of a product to be supplied. In fact, the choice of method is conditioned by various criteria, some of the most important being the resources required to perform the method (time, money, the number of evaluators and their expertise, the number of users for testing, place and test equipment), the required level of objectivity and the possibility of applying the method in different application development stages.

The quality models defined by the current ISO standards are too general to cover all application domains, and most practitioners only use them as a guide or a starting point for quality modeling and measurement. Of course, it is not possible to measure all the internal and external characteristics, or to measure quality in use in all possible cases. Together, quality models serve as a framework that ensures taking into account all the quality characteristics.

Although we intuitively know what usability is, it is not easy to formalize a set of characteristics that contribute to good usability. In addition, we often turn to those attributes that are useful and easy to measure rather than to those that are really necessary.

In order to understand and measure usability, it is necessary to build a model of usability first. One of the most important areas of usability research focuses on usability attributes, principles and characteristics. To define a usability model for a particular domain of software use means to face the question, "Which quality characteristics are to be included in the model and what are the relations between them?".

Usability models are conceptual views which determine key areas to demonstrate the usability of existing software. The analysis of different usability models proposed by researchers and international organizations for standards can help in identifying the key attributes that affect the usability of a software system and in developing efficient and usable software systems.

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ПРИМЕНЯЕМОСТЬ: КЛЮЧЕВАЯ ХАРАКТЕРИСТИКА КАЧЕСТВА ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ

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Резюме:

В данной статье подчеркнуто значение применяемости программного обеспечения, как ключевой характеристики качества программного обеспечения в процессе его использования. В вводной части статьи представлено обозрение определений применяемости, в котором прослежена эволюция взглядов исследователей в отношении применяемости за последние тридцать лет.

Для обеспечения соответствующего качества в использовании, необходимо измерять и оценивать различные

характеристики, влияющие на применяемость программного обеспечения. В работе приведен хронологический обзор попыток идентификации различной частотности применяемости, предпринятых разными исследователями на основании определений применяемости.

Учитывая, что не всегда легко удается определить какие именно характеристики способствуют качественному использованию, автор статьи применил два метода идентификации ключевых атрибутов, влияющих на применяемость, которые необходимо иметь в виду при разработке модели применяемости.

Ключевые слова: характеристики качества, качество программного обеспечения, применяемость программного обеспечения.

УПОТРЕБЉИВОСТ КАО КЉУЧНА КАРАКТЕРИСТИКА КВАЛИТЕТА СОФТВЕРА

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ВРСТА ЧЛАНКА: стручни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду је наглашен значај употребљивости софтвера као кључне карактеристике квалитета софтвера приликом његове употребе. Представљена је и ретроспектива формалних дефиниција употребљивости, са намером да се покаже еволуција погледа истраживача на употребљивост током више од три деценије. Да би се обезбедио захтевани квалитет при употреби потребно је мерити и вредновати многе карактеристике које утичу на употребљивост софтвера. Такође, хронолошки су приказани покушаји истраживача да на основу дефиниција употребљивости идентификују њене различите димензије. Имајући у виду да није лако одредити карактеристике које највише доприносе квалитету при употреби, у раду су примењене две методе за идентификовање кључних атрибута који утичу на употребљивост, а које треба посебно размотрити приликом изградње њеног модела.

Кључне речи: карактеристике квалитета, квалитет софтвера, употребљивост софтвера.

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