Usability Aspects in Pervasive Computing: Needs and Challenges

Abdul Wahab Muzaffar
National University of Science and Technologies, NUST Islamabad, Pakistan

Farooque Azam
National University of Science and Technologies, NUST Islamabad, Pakistan

Hina Anwar
National University of Science and Technologies, NUST Islamabad, Pakistan

Ali Saeed Khan
National University of Science and Technologies, NUST Islamabad, Pakistan

ABSTRACT

Computing is generally a combination of tools and technologies, which we may broadly refer to as software, hardware, connectivity, protocols and standards. In the recent years, mobile industry has experienced a phenomenal growth in mobile computing also known as pervasive computing. The field of pervasive computing is painting the picture of future as this is the most needed and sought after technology of tomorrow. The high demand for mobility and ubiquity has set a stage for the wide spread use of pervasive computing. In the past few decades the focus of the technology has shifted from technology perspective to utility and usability perspective and one may safely deduce that technology is more social and people oriented. Usability is a general concern that is more related to how humans efficiently and effectively utilize the solutions and applications offered on top of computing platforms. Usability concern becomes more critical when one comes to the world of pervasive computing. The aim of this paper is to review and analyze the existing literature in usability of in different applications from two aspects, i.e. needs and challenges. Furthermore critical success factors and concepts associate with the above mentioned metrics are identified and categorized under different views. A model is proposed to categorize usability characteristics.

Keywords: HCI, SDLC, Pervasive Computing, Ubiquitous Computing, PC, Needs, Challenges.

1. INTRODUCTION

Pervasive computing applications making ubiquitous information access to anyone, anywhere, and at any time [1]. One can check account balance, deposit bills, and chat using these applications. Pervasive computing means that smart and agile computing devices, though invisible, are embedded everywhere in the environment. The beauty about pervasive computing is that it is integrated in to the users' environment in a way that it is visible and invisible, global and local, personal and social all at the same time. Components of the pervasive computing are: pervasive devices, pervasive applications, pervasive networking and pervasive middleware [2]. Pervasive computing is growing rapidly and no doubt it will be the future of the current transition, though it is also used in today's fast paced lifestyle. This smooth transition was in parallel with the medium of communications i.e. one-to-one, one-to-many and many-to-many. As the medium of communications has changed, so are the devices and the applications are growing.

In modern times, the usage of smart phones and its applications are growing tremendously as very diverse range of applications are being offered for smart phones. Along with the hardware; the software applications for these devices also gained a lot of popularity and companies linked with this business are earning revenue in trillions of dollars. The end users have an option to choose the one or the other application with more functionality and usability. This research in hand is done with an intention to focus the needs, challenges of usability in above mentioned area. In usability the more focus is on a single question: whether the product is usable [3]? The answer of this question is mostly expressed in terms of user task performance and subjective response to the product.

Usability is one of the most important characteristics to achieve the quality of the systems. Guidelines are there to measure the usability of the desktop applications but these guidelines, used for traditional Human-computer interaction (HCI), are not always applicable to the usability of pervasive computing as it contains a lot of distinct features [1]. Ron Patton in [4] says "Usability is how appropriate, Functional and effective the HCI is". Usability must be considered from the day first through all the phases of software and hardware development [5].

High demand and fast growth of pervasive computing applications attract the researchers and practitioners [1]. A study of mobile device in the United Kingdom shows that 1 in 7 cell phones are returned within the first year of purchase as faulty. Of these returns, about 63% has no hardware or software fault but the reported problems relate to usability problems, mismatch with user's expectations or issues relating to the configuration of the handset [6].

Usability is the critical Success factor for these applications and this is the hottest research topic in the pervasive computing. The easy-to-use and intuitive interface is the demand of the future [1]. A lot of research has been done to point out the attributes/needs/characteristics and challenges of usability for different areas of applications e.g. desktop applications, pervasive computing applications, web-based applications. Usability is the quality of the systems and is subjective, so it's always hard to quantify and measure. Ease of use will have different levels for different end users; most of the usability concepts are subjective and confusing. The usability aspects in pervasive computing applications are very important and need a bit more attention than all the other areas i.e. desktop applications and web-based applications.

Work has been done to measure the usability attributes but there are limited number of usability needs/attributes and associated challenges related pervasive application have been identified. These usability aspects will provide basis for defining the

metrics against each need/ attribute and will overcome the challenges this domain is facing.

The rest of the paper is organized in following sections: section 2 describes the Literature Review which analyses and summarizes the published knowledge, section 3 Empirical analysis, section 4 Benchmarks identified from literature section 5 is Proposed usability model and Section 6 conclude with Conclusion and Future Work.

2. LITERATURE REVIEW

The aspect of usability that is referred here as needs of usability is written in literature as attributes/ characteristics of the usability [1, 2, 3, 5, 8, 9].The smart phone applications are somewhat different from conventional PC applications so these applications obviously need separate stream of usability measures. The intention of the author in this paper is to find out the needs, challenges related to usability aspects of the smart phone applications.

The evaluation of usability for mobile application in development process is done by usability testing as a common tool [7]. The pervasive nature of mobile computing environments is facing with some distinctive challenges in application development, quality assurance, and deployment, requiring unique testing strategies [8].

The author in paper [9] mainly discussed that some aspects or concepts usability of mobile computing which affects the quality of user interface. These concepts are: characteristics/ needs, problems and recommendations. This paper provides baseline for the usability aspects but no technique, model or guideline to improve the usability.

Sang-hwan Kim et al, in research article [10], has analyzed that Mobile phone industry in past some years has grown exponentially and the use of hand held devices touched its maximum. Mobility and portability is one of the noteworthy characteristics of mobile devices, usability testing of this domain is facing many challenges. Also describes some techniques of usability testing as: Environment mounted, Device mounted, Subject mounted. The characteristics and limitations of each technique are also pointed and at the end recommends that subject mounted equipment is more advantageous than the other two techniques.

The article [3], mainly focus on usability testing and other aspects of usability i.e. needs/ characteristics. Specific to mobile and hand held device's usability, problems and recommendations, to adopt the usability techniques for improving the user interface of the system, are also part of paper. Author describes that usability should be focused throughout the software development lifecycle.

In the research report [11], two case studies have been discussed and the research is done by BugHuntress QA labs, a leading organization working on testing of mobile applications, web2.0 application and all new technologies. In one case study the test engineer was facing problems of Lack of requirement analysis, Lack of business analysis, Lack of user interface design and in second one the excess of these factors. In both the case studies the challenges was faced so author recommends that there should be a balance of these factors for successful usability. Author recommends that usability should be from requirement analysis to design and even till deployment. Other things to be done are techniques for data gathering, environment used for usability testing should be satisfactory.

Dongsong Zhang [1] focused on the usability challenges, methodologies, and issues and proposed a generic framework for usability. The same author discusses the usability challenges of the mobile applications/ pervasive computing applications but the author just focus on the hardware related limitations or challenges and ignores the usability challenges related to the software or applications.

Rod Patton writes in his book [4] basically focused on all the aspects of testing and also usability testing for all types of applications. Also author focused more on seven important traits of usability are identified. These traits are applicable to all the user interfaces for any type of applications. Testing techniques for usability are also discussed in detail in this book.

Jeroen Keijzers et.al, in research paper [6], precisely identified needs and challenges of usability in smart phone domain. In the recent year the problems faced by the smart phone industry is the discussion through out the paper. The implementation problems in mobile phone are very common.

This article [12] is primarily focused on the usability challenges of mobile phones/ pervasive computing. Authors have categorized the usability challenges into technical challenges, environmental challenges, and social challenges primarily and then subcategorized them.

In this paper [13] author focused all the aspects of usability, which are necessary to improve the usability, i.e. usability patterns for software architecture, important needs of usability, properties and challenges.. Also emphasizes on the use of usability pattern in the software architecture to improve the usability of the software product. Author suggested that most of the usability patterns are architecture sensitive so its leads to higher cost implementing usability pattern after software implementation. Usability patterns have an impact on the software architecture as the usability pattern component directly communicates with the other software components so it's inflexible to change software components after implementation. Author suggests that usability needs and pattern have to identify earlier in the system design to implement the system effectively and efficiently. However the usability needs level of properties and pattern depend upon the application and requirement. Measuring the usability needs or attributes through observation, interviewing the end users of the system using usability engineering techniques.

In this paper [14] authors have mentioned the different aspects of usability as: attributes, goals, and definitions of the usability. These aspects must be implemented in user-centric design. Also authors mention the challenges for identifying the key attributes of the system. Other issues related to the usability whether it's global usability or local usability.

This paper [15] discusses different usability models by ISO and specifies that these models do not cover all aspects of usability so cannot integrate into software engineering also these models do not have tool support. Authors propose a new model by addressing some of the limitations in ISO models. Authors also states that the attributes or needs of usability that must be in a product depend on the nature of user, tasks and environment

where it will be used. This is a comprehensive paper on different models of usability some of them are: ISO 9126, ISO 9241, and Nielsen model of usability. The paper highlights main attributes or needs of usability and models of usability.

M. Xenos [16], focused on the usability perspective in different software quality models, namely FCM, CSQ and ISO 9126 also in ISO 9001 quality assurance international standard, Malcolm Baldrige National Quality Awards and in Capability Maturity Model. Author also describes five views of software quality as: 1) Transcendental view 2) User view 3) Manufacturing view 4) Product view and 5) Value-based view. Every software quality model describes the quality as a collection of attributes and usability is one of them; usability itself is not a concrete term but it is an abstract one and need different attributes to define it.

FCM divides quality into 11 factors, usability is one of them. Each of the factors is associated with a set of criterion and each criterion is associated with one or more metrics. CSQ model focuses on software quality from developer perspective and divides quality into seven factors. Usability is not discussed as a prime factor in this model. ISO 9126 devise the quality of the software into six basic independent characteristics and usability is one of the basic characteristic. Neilson mention the five major attributes of the usability as learnability, efficiency, error rate, satisfaction, and user retention over time. ISO 9001 is a generic model which describes the over quality system in an organization; usability perspective is not explicitly discussed in this model. Malcolm Bardrige National Quality Awards are USA based and measure the overall quality of processes in organizations. The Award is divided into 7 major categories, each category has number of criteria, and usability is in 7th category. Capability maturity model (CMM) is divided into 5 maturity levels and each level is divided into process Areas each process area is described by key practices. Process categories are management, organizational and engineering and usability is related to engineering key process areas. Usability is an important trait to achieve quality. Some of the models do not focus more on usability e.g. ISO 9001 and CMM, but most of them focus on it heavily. This is a comprehensive paper which describes the usability in software quality but it does not describe any challenges of usability [16].

Nigel Bevan [17] describes the quality framework ISO/IEC 9126 and usability in terms of quality, basic needs/ attributes of usability the usability and its perspectives and characteristics. Three perspectives of quality in this framework are: 1) Internal quality 2) External quality 3) Quality in use. Quality in use can be viewed broadly as usability. This paper also describes some of the metrics and the relation of usability with other quality factors.

Anjoo Navalkar [18] mentioned usability engineering and the need of usability in the current market, saying that user reviews usability as one of the parameter while choosing any device or software. According to author usability is defined in the ISO 9241 part II: a standard giving comprehensive guideline on usability. This paper also describes a model of usability, defined in the ISO 13407, having five stages. The Schaffer Method is discussed by the author that provides the foundation of efforts to institutionalize usability assurance.

3. EMPIRICAL ANALYSIS

Given below is the tabular description of the reviewed literature showing areas of considerations i.e. Needs, Challenges of usability for pervasive computing or mobile computing. Furthermore strengths and weakness of the reviewed paper against the benchmarks are the parts of the table.

Table 1: Usability Aspects

Authors	Aspects of Usability Discussed		Strengths	Weakness
Reference	Needs of Usability	Challenges of Usability		
[1]. Dongsong et al. , 2005	User satisfaction, Effectiveness, Efficiency, Performance, Correct, Simplicity, Comprehensive, Memorability, Learnability.	Limited bandwidth, Unreliable networks, Complexity, mobile context, connectivity, small screens, Resolution, limited processing capability.	Paper focuses on the challenges, issues, and methodologies and also proposed a framework for usability	Ignores the software challenges of usability
[3] Anna M. Wichansky, 2000	User satisfaction, Effectiveness, Efficiency, Performance, Intuitive, Simplicity.	Lack of RE, Lack of design, Short time to market, Portability, Lack of planning, Lack of usability culture, multitasking. Unreliable networks, small screens, limited processing capability.	Need and challenges discussed and also provide guideline for usability.	No techniques or model for usability is discussed or proposed
[4]. Ron Patton, 2nd edition	Useful, Intuitive, Correct, Simplicity, Consistent, Flexible, Standardized.	No challenge discussed	It covers all the aspects of testing and also usability testing for all types of applications needs	It ignores challenges and techniques of usability also models are not covered

Authors	Aspects of Usability Discussed		Strengths	Weakness
Reference	**Needs of Usability**	**Challenges of Usability**		
[6]. Jeroen Keijzer et al. , 2008	User satisfaction, Effectiveness, Efficiency.	Budget, Short time to market, Lack of planning. Complexity, mobile context, connectivity, small screens, Resolution, limited data entry.	It is mainly on smart phone domain, aspects of usability covered precisely.	It ignores the techniques to implement usability, recommendations and guidelines
[9]. Bug Huntress QA lab, 2007	User satisfaction, Effectiveness, Efficiency, Useful, Less time consuming, Performance, Intuitive, Correct, Simplicity, Comprehensive, Memo-ability, Learn-ability.	Short time to market, Portability, Lack of usability culture, Lack of specialty, privacy/ security.	Needs and Challenges of usability have been identified, which provide baseline for the improvement of usability process	No techniques or model for usability is discussed or proposed
[10]. Sang-hwan Kim et al.	No need discussed	Lack of design, portability, mobility, privacy/ security.	Focuses on challenges, techniques and recommendations for usability testing of mobile phones domain	Author did not validate why to use a discussed technique.
[11]. Kenny Bellew et al. , 2007	Efficiency, Useful, Performance.	Lack of RE, Lack of design, Budget, Portability, Lack of planning, Lack of usability culture, Lack of specialty.	Focus on the usability from requirement engineering, design, implementation and testing throughout the SDLC	No techniques or model for usability is discussed or proposed
[12]. L. Gorlenko et al. , 2003	No need discussed	Budget, Lack of planning, Mobility, Multitasking, Privacy/ security. Limited bandwidth, Unreliable networks, Complexity, limited processing capability, large infrastructure, weather conditions.	It covers challenges of usability in pervasive computing domain and categorized these challenges.	It ignores other aspects of usability and also author does not device any technique or model of usability
[13]. Elke Folmer et al. , 2003	User satisfaction, Efficiency, Correct, Learnability, Consistent, Flexible.	Unreliable networks, limited processing capability.	Author focus on usability patterns for software architecture, important needs of usability, properties and challenges	It misses the techniques or model to be used for usability
[14]. Vince Bruno et al	User satisfaction, Effectiveness, Efficiency, Useful, Performance, Correct, Simplicity, Comprehensive, Memorability, Learnability.	Budget, Short time to market, Lack of usability culture.	It describes usability and its aspects in detail.	It ignores the techniques and models of usability
[15]. Alain Abran et al	Understandability, operability, attractiveness, compliance, security, effectiveness, efficiency, satisfaction, learnability, tolerance for errors, and memorization.	Does not discuss any challenge of usability	It has reviewed the models of usability with respect to usability attributes and also discussed the needs in detail	It does not identify challenges of usability.

Authors	Aspects of Usability Discussed		Strengths	Weakness
Reference	Needs of Usability	Challenges of Usability		
[16]. M. Xenos, 2001	Understandability, operability, attractiveness, security, effectiveness, efficiency, satisfaction, learnability, and memorization.	Does not discuss any challenge of usability	It specifies the Usability attributes/ needs from each of the quality models	It ignores the challenges faced by usability implementation
[17]. Nigel Bevan, 1997	Understandability, Learnability, and Operability	Does not discuss any challenge of usability	It explains a quality framework (ISO/IEC 9126) and characteristics of usability in terms of quality.	Ignores the challenges of usability
[18]. Anjoo Navalkar	Effectiveness, Efficiency and User satisfaction	Does not discuss any challenge of usability	It describes usability standards and techniques and basic attributes of usability in ISO 9241, ISO 13407 and Schaffer Methods	It ignores the challenges faced by usability implementation

4. BENCHMARKS

Based on the literature reviewed Author identified some of the benchmarks. Following are those attributes of usability that are decided as benchmarks:

1. **User Satisfaction:** The satisfaction of user can be determined by the flexibility of user interface and opinion of user after using the system. It can also be observed by the working hours a user uses a system.

2. **Learnability:** Easy and quick beginning of task performs by user with new system and how easily remembers to operate the system.

3. **Effectiveness:** Capable of producing intended results.

4. **Efficiency:** Number of tasks performed by user in unit time or speed of performance

5. **Memorability:** Retention over time

6. **Correct:** Low error rate

7. **Standardization:** Following Guidelines heuristic with consistency and comprehensiveness.

8. **Simplicity:** Must be in accordance with the natural tasks like use of icons, menus, dialog boxes etc.

9. **Intuitive:** Naturally understanding the tasks rather than reasoning or observation.

10. **Usefulness:** Strictly follow the requirements by users, perform the desired tasks.

11. **Security:** Defensive against failures, prevention from unauthorized access.

5. PROPOSED MODEL OF USABILITY

Usability has been taken into account from previous several decades and different researchers have tried to propose some models. Nielsen proposed a model of usability that contains concise characteristics of usability [15]. In this paper modified those characteristics and a new model of usability is proposed. Figure 1 below describes the Nielsen's model of usability.

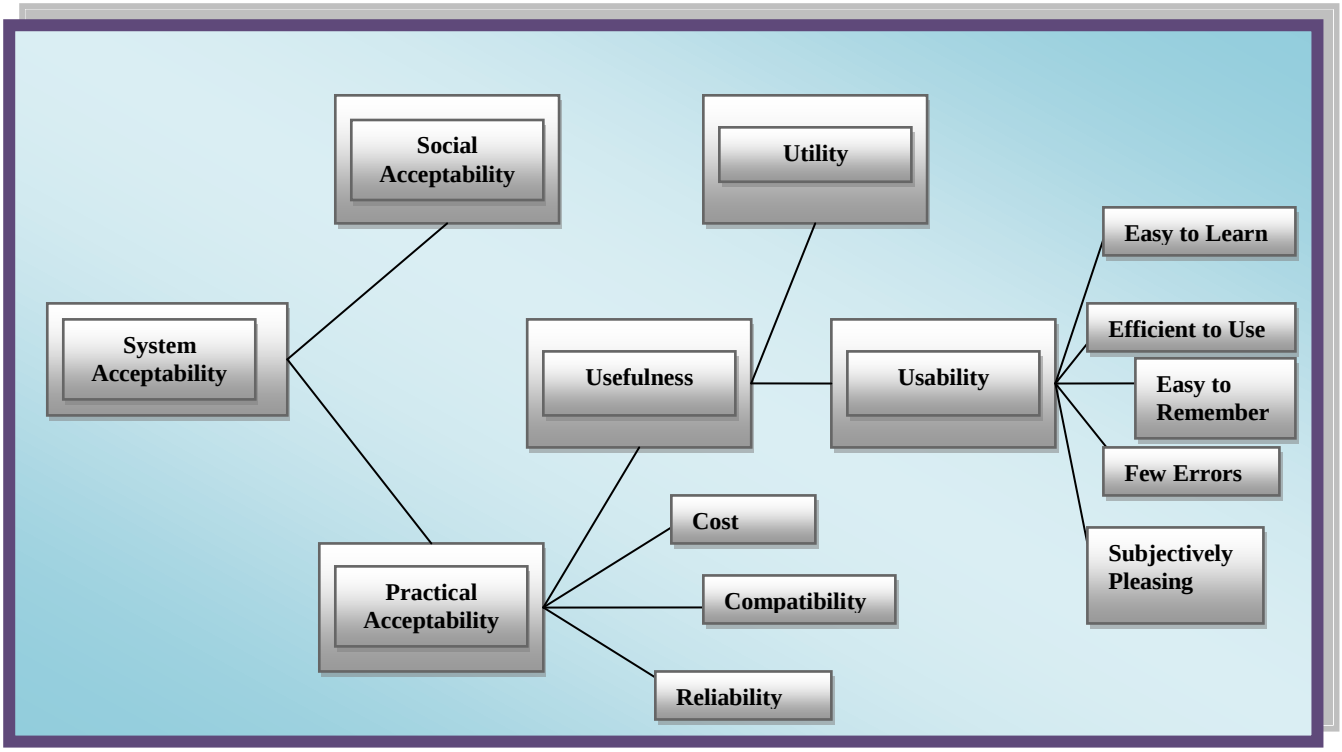

Figure 1. Nielsen's Usability Model

As Nielsen's model of usability based on the categorization of different usability attributes and some other detail too. In current paper, authors have tried to propose a model that will consider the usability and other proposed characteristics in pervasive computing. An attempt is made to present a comprehensive model, which focuses on the practically accepted characteristics of usability. Figure 2 below shows the overall view of the proposed usability model. These characteristics are explained in the previous section.

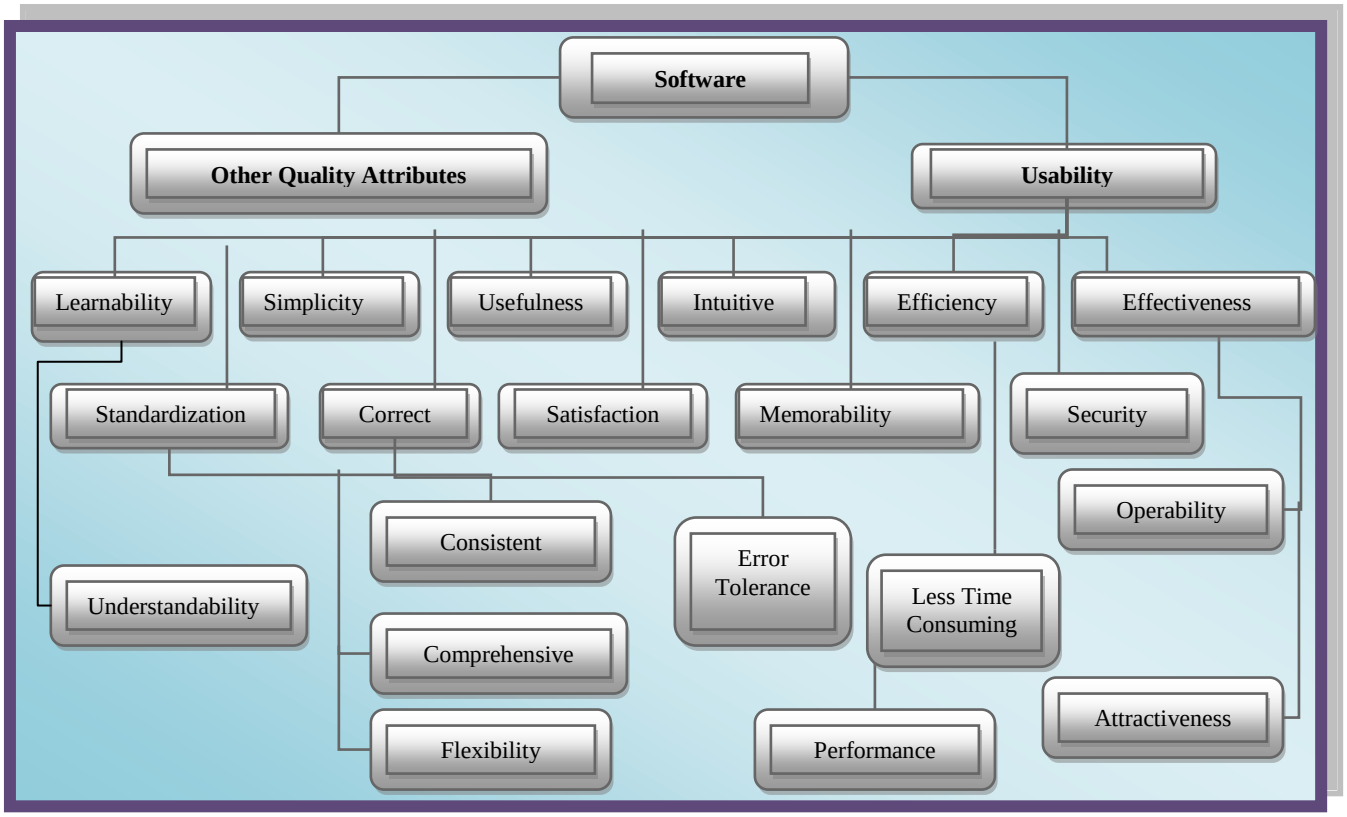

Figure 2. Proposed Usability Model

6.CONCLUSION AND FUTURE WORK

Pervasive computing is generally referred to as the use of computing through smart devices. Usability for smart devices is always very important as these devices are small and tiny so users normally have more difficulty to use them as compared to other devices. In this paper needs and challenges of usability in pervasive computing are studied and analyzed and summarized into tabular forms for clarity and understanding. Author has focused on the needs of usability in general and usability of pervasive computing/ mobile phones applications in particular. The other factors identified are the software and hardware problems and issues referred to as hardware and software challenges that directly or indirectly impact the usability.

A model is proposed to identify the usability attributes/ characteristics used in previous work. Usability characteristics (referred as usability need in this paper) and associated model i.e. Nielsen, is used as a basis for the proposed model. Different characteristics are categorized as multiple views. In short, the identified needs of usability help a lot to go in further details to explore advance concepts of usability, which is more qualitative and subjective than quantitative and measurable. In future work an attempt will be made to enhance the proposed model. Also author will try to validate the proposed model by making comparison with existing usability models and surveying.

7. REFERENCES

[1] Dongsong Zhang, Boonlit Adipat, July 2005, "Challenges, Methodologies, and Issues in the Usability Testing of Mobile Applications ", International Journal of Human-Computer Interaction, Volume 18, Issue 3, pages 293 – 308.

[2] Ramesh Singh, Preeti Bhargava, Samta Kain, , April 2008, "Smart Phones: A Tutorial", ACM Ubiquity, Volume 9, Issue 14

[3] ANNA M. WICHANSKY, 2000, "Usability testing in 2000 and beyond", Oracle Corporation, [On-line]. Vol. 43 [2000], Available: ht tp://www.tandf.co.uk/journals.

[4] "Software Testing" Ron Patton, 2nd edition, pp. 169-178.

[5] Jim Miller, November 2006, "Usability Testing A journey, Not a Destination", IEEE Computer Society,.

[6] Jeroen Keijzers, Elke den Ouden and Yuan Lu, September 2008, "Usability Benchmark Study of Commercially Available Smart Phones: Cell Phone Type Platform, PDA Type Platform and PC Type Platform", ACM, MobileHCI 2008, Amsterdam, the Netherlands.

[7] Anne Kaikkonen, Aki Kekäläinen, Mihael Cankar, Titti Kallio, and Anu Kankainen, November 2005, "Usability Testing of Mobile Applications: A Comparison between Laboratory and Field Testing", journal of usability studies, Vol. 1, Issue 1, , pp. 4-16,.

[8] "Testing Mobile Business Applications", Sun Microsystems.

[9] BugHuntress QA Lab, 2007, "Mobile usability testing Problems and solutions", Research Report, at conference QAMT Ukraine, November 1-2,.

[10] Sang-hwan Kim , Mijeong Kim, Sung Woo Kim and Hyun-joo Kang, "Usability Test Equipment for Mobile Devices", Whitepaper, Samsung Electronics Co, Ltd.

[11] Kenny Bellew, Tori Sadler, 2007, "Mobile usability testing Problems and solutions", Research Report, at conference QAMT Ukraine, BugHuntress QA Lab, November 1-2,.

[12] L. Gorlenko, R. Merrick, 2003, "No wires attached: Usability challenges in the connected mobile world", IBM SYSTEMS JOURNAL, Vol. 42, No 4, pp. 639-651,.

[13] Elke Folmer and Jan Bosch 2003,"Usability Patterns in Software Architecture" , Available: http://www.eelke.com/files/pubs/2003_HCII_patternsinSA.pdf

[14] Vince Bruno and Ghassan Al-Qaimari ,"Usability Attributes: An initial step toward Effective User-Centred Development",Available:http://www.brunoplace.com/~vince/Data/OZCHIUsabilityAttributesV12.pdf

[15] Alain Abran et al, "Consolidating the ISO Usability Models".

[16] M. Xenos, 2001 "Usability Perspective in Software Quality", Usability Engineering Workshop, Proceedings of the 8th Panhellenic Conference on Informatics with international participation, Vol. 2, pp. 523-529, Cyprus,.

[17] Nigel Bevan, 1997 "Quality and usability: A new framework", J (eds) Achieving software product quality, Tutein Nolthenius, Netherlands,.

[18] Anjoo Navalkar, "Usability Engineering – Quality Approach (ISO 13407)", by ISO Process consultants.

[19] Malykhina, E.. 2006, Smartphone buyer's guide. InformationWeek,http://www.informationweek.com/story/showArticle.jhtml?articleID=193402812 (Accessed June 08,2009)

[20] Elena T. Beck et.al., "Experimental Evaluation of Techniques for Usability Testing of Mobile Systems in a Laboratory Setting", [Available]: http://www.cs.aau.dk/~jesper/papers/OzCHI03-final.pdf .