User and Usability Modeling for HCI/HMI: A Research Design

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***Abstract*—A key reason for the presence of poor usability in products is the insufficient specification of usability perspectives effectively in product requirements specifications. The explicit expression of usability perspective in product requirements specifications is quite important in providing a clear visibility of usability aspects for both product developers and testers. Such specifications incorporating usability of human-interactive systems can be built for optimal usability and also evaluated effectively to uncover usability related issues. In this paper, we present a design science-oriented research design to test the proposition that incorporating user modeling and usability modeling in product requirements specifications improves design. We expect our proposal and the research design will make a contribution to knowledge by theory testing and to practice with effective techniques to specify usable human-interactive systems.**

***Keywords*—User modeling, usability modeling, Human-Computer Interaction (HCI), Human-Machine Interaction (HMI)**

I. INTRODUCTION

The science of the design or creating the artificial is known as design science [1] and it is described as an inventive or creative problem solving activity [2]. The primary focus of design science is on how to develop and produce artifacts and artificial systems having desired properties [3]. Simon has seen natural science as the knowledge about natural objects and phenomena and design science as knowledge of artificial objects and phenomena [4]. According to Simon, the distinction between natural science and design science or the science of the artificial is that the former is concerned with how things are and the latter is concerned with how things ought to be to attain goals [5]. Design science has been emerging since the mid-70s and now become a research method in many disciplines. In a much cited paper relating to information technology discipline, March and Smith [6] describe 'build' and 'evaluate' as two fundamental design science processes and four types of products in design science namely, constructs, models, methods, and instantiations. According to their definitions, constructs or concepts form the vocabulary of a domain, a model is a set of propositions or statements expressing relationships among constructs, a method is a set of steps used to perform a task, and an instantiation is the realization of an artifact in its environment. Design science concepts reported by March and Smith were further developed by a number of authors recently [7]-[8].

In a recent publication, Peffers et al. [9] reported a design science research process for information systems research consisting of six process elements: problem identification and motivation, objectives of a solution, design and development, demonstration, evaluation, and communication. Hevner, March, Park, and Ram [10] claim that design activities are central to the information systems (IS) discipline and present a conceptual framework for understanding, executing, and evaluating IS research combining behavioral science and design science paradigms. Figure 1 shows research as addressing both the rigor required of research and the practical environment of use.

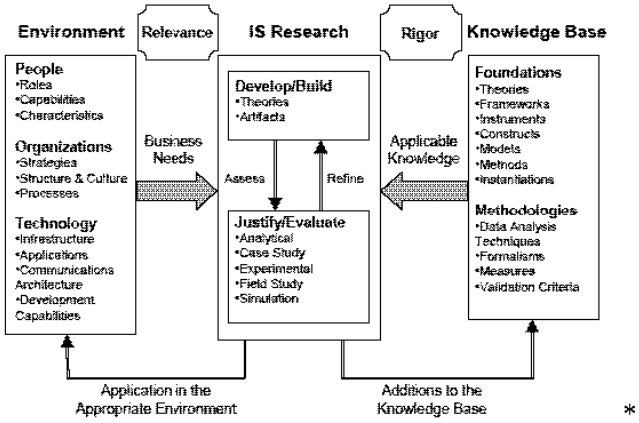


Figure 1. Information Systems Research Framework proposed by Hevner, March, Park, and Ram [10 page 80]

Human-Computer Interaction (HCI) and Human-Machine Interaction (HMI) are disciplines primarily focusing on design, evaluation, and implementation of interactive systems; hence design science research is appropriate for IS as well as for HCI/HMI.

This paper presents a design science-oriented research design in HCI/HMI to test the impact of user modeling and usability modeling on requirements specifications. The development of conceptual user model, conceptual usability

attribute model and the relevance of design science for HCI/HMI also will be explained.

The overall aim of this research study is to address towards an effective solution for usability related issues arising late in the software/product development process during testing and deployment [11] due to deficiencies in current requirements engineering practice. We propose user modeling and usability modeling as two key components of usability to be integrated into product requirements specifications.

II. USER AND USABILITY MODELING

A key objective of HCI/HMI is to gain a detailed understanding of cognitive, perceptual, and motor components of user interactions with human interactive systems [12]. We look into the usability from two perspectives namely User Modeling and Usability Modeling. These two models are used to develop a detailed understanding and to elaborate the functional specifications of interactive systems and these will be formally designed as specifications.

A. *Conceptual User Model*

The design of user interface is based on user models and descriptions derived from studies of able-bodied users [13]. A user model is a representation of information and assumptions about users [14] and can be viewed from three perspectives: modeling user knowledge, modeling user plans, and modeling user preferences [15]. Modeling user knowledge involves the accurate estimation of users' background knowledge, skills, and experience. Modeling user plans aims to investigate the sequence of user tasks required to achieve user goals. Modeling user preferences primarily focuses on users' information needs and preferences.

According to our observations, the attributes of a user model are context dependent and vary across the application domains, but certain user attributes can be considered as quite important in relation to a user model. Figure 2 illustrates our proposed user model consisting eight user attributes.

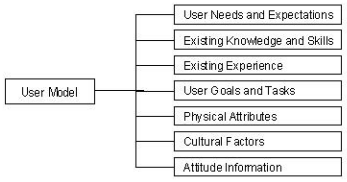


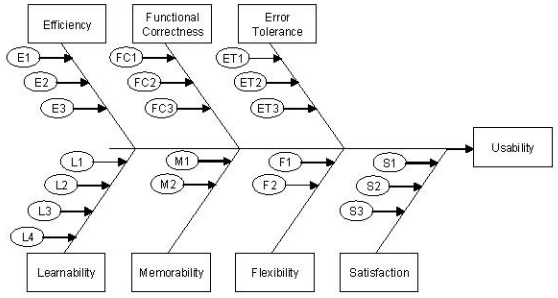
Figure 2. Conceptual user model consisting user attributes

The design model is the conceptualization that the designer has in mind and Norman argues that a user model can be used to improve the usability of computer interfaces and ideally the user model needs to match the design model [16]. This is a part of the proposition to be tested.

For this research a user model of the existing system is created through a contextual enquiry process consisting user interviews, observations and persona development. The outcome is a specification of the model for use in this specific research, but it also follows a more general pattern for the specification of user models.

B. *Conceptual Usability Attribute Model*

Usability has been defined by the international standards organization 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 [17]. There are many definitions of usability and its attributes published in the literature, and some of the important usability attributes are: learnability [18], memorability [19], functional correctness [20], efficiency [21], error tolerance [22], flexibility [23], and satisfaction [24]-[25].



Efficiency	Functional Correctness	Error Tolerance
E1 – Task completion in minimum time	FC1 – Task completion in minimum time	ET1 – Appropriate error messaging for invalid conditions
E2 – User tasks are not misleading	FC2 – User tasks are appropriate, effective and match the user needs	ET2 – Ability to exit error conditions or unwanted states
E3 – No workarounds are needed	FC3 – User spends minimal time on "Help"	ET3 – No workarounds are needed
	Satisfaction	
	S1 – User desirability of the system and user tasks	
	S2 – User opinion about user experience	
	S3 – User opinion about frustration or confusion	
	Learnability	
	L1 – Clear visibility of current system status and a feel about what to do next	
Memorability	L2 – User tasks are not misleading	**Flexibility**
M1 – No memory recall to carry out tasks	L3 – Task completion in minimum time	F1 – Multiplicity of ways to carry out user tasks
M2 – User spends minimal time on "Help"	L4 – User spends minimal time on "Help"	F2 – User control of task performance

Figure 3. Conceptual usability attributes model and measurable criteria

Figure 3 shown above uses an Ishikawa diagram to illustrate the conceptual usability attribute model and its measurable criteria. It shows that usability is a combination of seven usability attributes: efficiency, functional correctness, error tolerance, learnability, memorability, flexibility, and satisfaction, and each usability attribute is governed by several usability related measurable aspects of the system. For example, the usability attribute "Efficiency" can be measured, based on the evaluation of three components: E1- Task completion in a minimum time, E2- User tasks are not misleading, and E3- No workarounds are needed.

Same as for the user model, the usability model will be created by analyzing the existing system in *situ*. The measures of the usability attributes will be established. The result will be a specification of the usability model for use in this specific research, but also a more general pattern for the specification of usability for product developers and testers.

III. RELEVANCE OF DESIGN SCIENCE FOR HCI/HMI OF USE

With reference to information systems research framework (see Figure 1), the investigation into the context of use of the existing system is primarily to analyze the environment to identify the problem and to establish objectives of a solution or the need. In other words, it is the relevance of the need of the

environment to the body of the research. This need is fulfilled by user modeling, usability modeling, and design and development of artifacts in the form of constructs, models, methods, or instantiations. Artifacts will be used in simulations and experimentations to demonstrate the capability of artifacts to provide solutions to the problem or the need. Evaluation is the comparison of the objectives of a solution to actual observed results from use of the artifacts in the demonstration. Communication is the research findings to inform the problem, the artifacts, its utility, the rigor of its design and its effectiveness.

IV. RESEARCH DESIGN AND RESEARCH PROCESS

First, functional specification for an existing human-interactive system is presented to a product designer who produces a user interface design. We then provide the product designer with user and usability specifications to refine the design on the basis of the added information. The two designs are evaluated against the usability criteria and compared to detect the differences. This process is repeated with a number of product designers. Results are aggregated to see where, and in what ways, the product designers' work differed and how the differences might have impacted on the quality of their design. A number of designers (at least 6 designers) will participate in the research. Our proposed research design is illustrated in Figure 4.

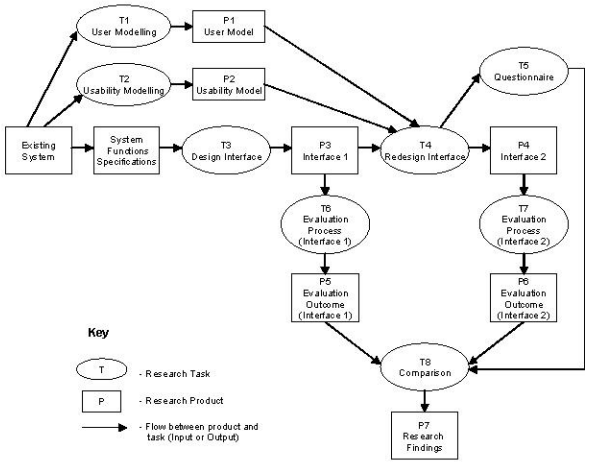


Figure 4. Proposed research design

The research design aims to test whether systems design quality is improved when product functional specifications are explicitly enhanced with user modeling and usability modeling.

Summary of activities in the research design are:

- T1 & T2 • User-centred designers carry out user modeling and usability modeling producing two artefacts: user model and usability model. (See Figure 2 and 3).
- T3 • Systems/product designers design and produce Interface 1 based on system functional specification only.
- T4 • Systems/product designers redesign the interface and produce Interface 2 using Interface 1 and the user model and usability model.
- T5 • Systems/product designers fill out a questionnaire expressing their views, design experience and opinions on redesigning the interface.
- T6 & T7 • Interface testers carry out an evaluation process against user requirements and usability requirements on both interfaces involving end users.
- T8 • Outcome of the evaluations are compared to come up with research findings.

V. ISSUES WITH THE PROPOSED RESEARCH DESIGN

Following issues are to be addressed to ensure research steps are reasonably rigorous as per Hevner's information systems research framework (see Figure 1).

A. Information relating to user and context of use needs to be removed from the functional specification

Aim of this separation is to ensure that designer doesn't have relevant information about user and context of use in the functional specification and, this separation of information goes some distance towards isolating the sources of design decisions.

B. Designers' tacit user and usability models that are expressed in their first interface design

Whether these mental models are similar across designers or not becomes less of an issue if the user and usability information is presented independently of the functional specification. It is the difference between the two designs that is important, not the quality of the designs per *se*.

C. Number of participants in the design exercise

The strength of the results will be limited by the low number of participants. This will be problematic if the results are mixed, but less so if they show a strong trend.

D. User interface tester bias

Tester bias is an issue that is addressed by the formality of the usability model. This model is the usability test protocol and is being designed to be prescriptive. There is a world of contextual judgment about usability and testers will no doubt make comments outside the formal test instrument. These comments will be used to inform the results, but not strictly as part of the comparison of interfaces.

VI. ENHANCED REQUIREMENTS SPECIFICATION

In this paper, we propose that user interactions with a system in a design need to be represented based on a conceptual user model and a conceptual usability model similar to Figure 3 and Figure 4 to ensure optimal usability and positive user experience in end products. User modeling will ensure that user interactions match user needs and expectations, users' existing knowledge and experience, user goals and tasks,

users' physical attributes, cultural factors, and users' attitudes to the system. Usability modeling will ensure that user interactions are efficient, functionally correct, error tolerant, learnable, memorable, flexible, and satisfying.

The addition of user model and usability model to the functional specification produces an enhanced requirements specification. The research described will compare the designs resulting from the enhanced requirements specification with those produced from using only the functional specification to test the proposition that enhanced requirements specifications produces more usable and testable designs that are better suited to their environment.

VII. CONCLUSION

This paper outlines a research design to integrate user-centred design approaches into interface development through enhanced requirements specifications.

It is hoped that this research will lead to make three kinds of contributions: first, evidence as to the impact of user and usability specification on design; second, techniques for the practical specification of these specifications; third, a reflection on the 'design science' research approach. It is also expected that the proposed research design would prove interesting enough to be reused and refined in other interface research settings.

If the outcome of the research found to be making no difference to design quality, then it casts doubt on the common wisdom that user and usability modeling help in the design process. On the other hand, if the research shows that enhanced requirements specifications make a distinct improvement in design quality, the implications for practice may be considerable. Our proposed conceptual user model and conceptual usability attribute model can be used as the basis to produce enhanced requirements specifications. As our proposed enhanced requirements specifications are of user-centred nature, such specifications will be a value-added aid to the build phase of a product development process. Product developers will be able to incorporate usability aspects effectively into systems for optimal usability and product testers will be able to test systems efficiently to uncover usability related issues and functional issues. Accordingly, such approaches using enhanced requirements specifications will ensure that systems that go live will be with minimal or no usability errors hence minimizing the usability issues in end products and enhancing the positive user experience.

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