Formal Specification of Usability Measures in Model-driven Development of Context-sensitive User Interfaces

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ABSTRACT
Developing usability studies to evaluate user interfaces (UIs) is a task requiring a wide variety of skills. In this paper we propose conceptual architecture for design and integration of usability tests in model-driven development of context-sensitive user interfaces. Upon the extended model for development of context-sensitive user interfaces, we introduce a generic framework that developers can use to design usability tests. This is enabled by using common vocabulary for description of usability test models and human models. Basic principles of the proposed approach are given in brief. As an example, we give formal model of human working memory that can be used in design of various cognitive load metrics.

Categories and Subject Descriptors
H.5 [Information Interfaces and Presentation]: User Interfaces; H.5.2 [Information Interfaces and Presentation]: User Interfaces-ergonomics, evaluation/methodology, user-centered design; H.1.2 [User/Machine Systems]: Human factors

General terms
Human Factors, Design, Languages.

Keywords
Human-centered design, model-driven development, usability measures, context-sensitive user interface, multimodal interaction.

1. INTRODUCTION
Running usability studies to evaluate the usability and suitability of software for its intended users is an important activity. For many software developers, however, it is perceived as a complex task that requires expertise from different fields. Automatic generation of user interfaces from formal specifications has made some progress, but it still faces many challenges, especially concerned with integration of usability concerns during development. Since the automatic generation does not guarantee feasible user interfaces, i.e. acceptable from a usability point of view, a combination of automatism and human designer assisted transformations is required.

In this paper we describe an early research into the use of formal models of usability measures as the basis for design of user interface evaluation studies. The first and the most important step is the definition of a common language for formal description of models in different domains. Here we rely on existing vocabulary for description of human factors [1]. From there we derive conceptual architecture for model-driven development and usability testing of context-sensitive user interfaces. Dedicated part of the system is responsible for user interface personalization. During communication with the end user this system will iteratively customize user interface until it reaches satisfactory level of usability from the perspective of concrete user.

2. PROPOSED ARCHITECTURE
The proposed architecture is sketched in Figure 1 in terms of its major components and their relations. The basic idea of the architecture is that developers define interaction context by providing descriptions of end user, device, environment and interaction models in terms of existing vocabularies. For example, International Classification of Functioning, Disability and Health (ICF) defined by the World Health Organization provides a comprehensive overview of many important functions of humans. The ICF is a good candidate for describing human aspects relevant for interaction, as it provides a detailed description of human functions. In addition, the classification allows specification of impairment level for each function.

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Figure 1. Conceptual architecture for formal specification and application of usability tests.
Human models are described in terms of ICF concepts. Together with device, environment and interactions models they provide interaction context for user interface design.

A general consensus in model-driven user interface design exists to distinguish several levels of abstraction [2]. Task model is provided for the end user’s tasks. Abstract User Interface model describes Uls independently of any interaction modality and implementation. Concrete User Interface model describes a potential UI after a particular interaction modality has been selected (e.g., graphical, vocal, multimodal). Final User Interface is reached when the UI code is produced from the previous levels. Connections between models from different abstraction levels are established through a sequence of transformations. At the moment, these transformations cannot be performed in a fully automated way, but should be executed by humans using interactive tools.

On the other hand, the ICF ontology is used to design ergonomic tests for measuring human interaction capacities and performances. In test design we borrowed the ergonomic parameters primarily from interaction technique survey provided in [0]. These ergonomic measures refer to basic psychological processes that are necessary for any interaction technique (i.e. cognitive load, perceptual load, motor load). The explanation of remaining measures can be found elsewhere [0]. User interface models provide testing context, while, in turn, test results are used in design of user models. What enables this is using the same terms for high-level descriptions of both the tests and the humans. Systems that generate user interfaces can use this information to select appropriate modalities, or change them in real-time. If original interface is not appropriate for the user or situation, we can redesign it into a new form, changing inappropriate modalities, while maintaining the usability level of user interface.

All models are expressed as instances of corresponding meta-models. In our opinion software developers and user interface designers have to base their work on common, wide-accepted and standardized notation for expressing models. That is why we rely on UML language and standards. Meta-models are realized in form of UML profiles. In our implementation we make use of the Eclipse Modeling Project (EMP) [4]. An important feature of EMP is a mechanism for import of various formats into UML models. This is very important since we customize existing vocabularies (i.e. ICF) in order to tailor them for use in software development. An important aspect is the choice of technology for model transformations. Taking into account wide user community, mature tool support and rich knowledge base, we have opted for Atlas Transformation Language (ATL) [5] for design of transformations.

Figure 2. describes relations between user interface models’ elements and context models’ elements. Here we reuse previous research on modeling multimodal interaction [6]. User interface element uses specific interaction modalities that engage human capabilities and produce effects on users. On the other side, human, environment and device entities specify contextual factors which affect produced effects.

Figure 3. gives UML stereotypes for modeling contextual factors. Proposed classification builds on existing approach to modeling of accessibility issues [7]. Contextual factors are associated with a set of effects which they affect. This relation describes the level in which some effects are available for a given contextual factor in terms of associated rating scale. We introduced the additional concept of a rating scale in order to allow different resolutions of scoring. Contextual factors are classified as simple and complex. We identified two types of simple factors: internal and external. Internal contextual factors are associated with human characteristics which are classified into human entities and human features. Human entities describe the ability of humans to exploit some of the effects from the perspective of human functions. Human features model end user’s subjective characteristics (such as abilities and preferences) or knowledge and interests related to specific domain. In both cases, it is a human subjective mark of the effects. External contextual factors model the influence of the interaction environment (environment entity) and computing platform (device entity). The resulting contextual factor in a particular situation will be a combination of user's characteristics, as well as various environmental and device factors relevant to that situation.

Figure 3. Contextual factors classification.
3. WORKING MEMORY EXAMPLE
Cognitive load is a global term and refers to mental resources a person has available for solving problems or completing tasks at a given time [9]. In this section we give formal description of working memory model [8] which is one of the main theoretical foundations of cognitive load theory in human-centered design [9]. According to this model (Figure 4a) visuospatial sketchpad maintains visual materials such as pictures and diagrams in one area of working memory, while a separate phonological loop stores auditory-verbal information. These two components are coordinated by a central executive. On the other hand, in terms of lower-level modality processing they are viewed as functioning largely independently. This is what enables the effective size of working memory to expand when people use multiple modalities during tasks. The central executive performs higher-level cognitive functions such as planning future actions, initiating retrieval of long-term memories, modality integration and others.

Figure 4b gives UML model of human working memory described in terms of ICF human memory functions (modeled as UML stereotypes). Proposed model can serve as a basis for design of various cognitive load metrics [10]. In our previous research in design of educational games we introduced user modeling technique based on intelligence type [11]. We intend to extend this research with proposed approach in order to show its feasibility.

Figure 4. (a) Working memory theory (taken from [8]); (b) UML class diagram – working memory components (left side) are modeled as stereotypes of human memory functions from ICF classification, together with memory transfer entities (central part) and long term memory concepts (right side).
4. CONCLUSION

The integration of usability evaluation methods into model-driven development process has several advantages. High-level specifications of usability issues could serve as a common ground for investigating both design and implementation concerns by UI developers from different disciplines. Having these in mind, there are several advantages to having a common vocabulary for description of both human models and ergonomic tests. For example, the ability to compare usability studies of the same user interface by team members from different fields (as all studies which follow the ‘skeleton’ will have a common structure). Different evaluation techniques can be applied iteratively until the concerned models reach the required level of usability. Using meta-studies we can perceive important relations and differences in early phases of development. This leads to more general approach where we might be able to produce generic templates for usability studies based on formal models. In this way we could provide integrated support for UI development on tool level. Our current work is concerned with aforementioned issues.

5. REFERENCES

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