Flexible Tool Support for Collaborative Design of Interactive Human-Machine Systems

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ABSTRACT
The Usability Engineering Repository (UsER) and its mobile frontend MUsER compose a flexible, web-based platform to support collaboration in User-Centered System Design. Modules for different stages of cognitive and usability engineering are provided and can be applied as needed. Analysis and design entities can be linked through hypermedia relationships. In this manner, a semantic network emerges from analyzing the context of use through design up to the summative evaluation of the product. Results can be presented in a document with a linear structure and is suitable for purposes like formal project deliverables or contracts. Heterogeneous and distributed design teams can benefit from immediate data exchange, better awareness of co-workers' activities and appropriate visualizations for different organizational roles and expertise. Images of cognitive artifacts and other findings from user research and field studies in mobile contexts can be documented and shared among project members.

Author Keywords
Usability Engineering; Human-Machine Systems; Cognitive Systems Engineering; Mobile Computing

ACM Classification Keywords
H.1.2 User/Machine Systems; H.5.2 User Interfaces; D.2.2 Design Tools and Techniques;

INTRODUCTION
Principles for user-centered system design and cognitive systems engineering are well-known for at least 30 years. They are regarded as being necessary in order to develop usable interactive systems [3,6,8]. However, usability is still a major challenge in projects or a neglected factor [4].

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Insufficient tool support for collaborative user-centered development in heterogeneous or distributed teams is one of the main reasons for this circumstance [1]. While there are several tools for specific software engineering aspects (e.g. version control systems, continuous integration environments, bug trackers, code analytics), usability engineering is still performed with general-purpose applications like spreadsheets or word processors in many cases. This needs to be changed in order to emphasize the engineering perspective of usable interactive systems.

The Usability Engineering Repository (UsER) and the Mobile Usability Engineering Repository (MUsER) are able to fill this gap. These applications have been under development in collaboration with industrial partners for now more than four years and follow the general principles of user-centered development according to ISO 9241-210 [2]. The phases of the development process are supported by different modules of UsER and MUsER (see Figure 1). They will be described in the following sections.

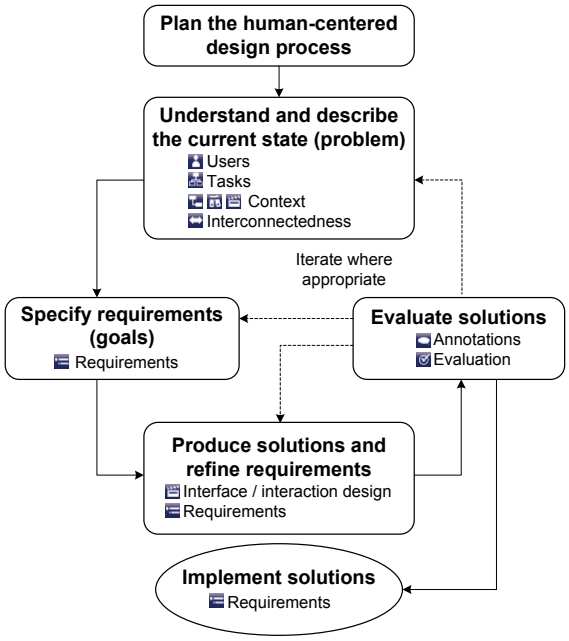

Figure 1: The Basic Process Model for UsER [1]

SYSTEM COMPONENTS AND ARCHITECTURE

In the following sections, the Usability Engineering Repository (UsER) designed for desktop computers and the Mobile Usability Engineering Repository (MUsER) designed for tablet PCs are described. Technical aspects will only be outlined.

The Usability Engineering Repository (UsER)

Based on Java, Google Web Toolkit (GWT), Hibernate and MySQL, UsER has been developed as a Rich Internet Application (RIA). Currently, it is an advanced prototype which has already been applied within the development of business and safety-critical applications.

UsER offers several modules (see Table 1) which can be applied to a specific project. Entities like scenarios, personas or work objects can be interlinked and annotated in order to contextualize these artifacts within the development process. Further modules can be easily been integrated due to the modular software architecture.

Name and Icon	Description
User Analysis	Different methods for representing users (user classes, personas, user goals).
Task Analysis	Tasks can be structured in hierarchical task trees (HTAs).
Organizational Analysis	Structures and functions for organization charts with different organizational units.
Artifacts	Work items of any kind can be described with attributes and values.
Requirements	All requirements accumulated over the development process can be managed, including detailed description, refinement, and links to other elements.
Scenarios	Verbal descriptions of tasks or contexts, enhanced with pictures, ease the communication between the involved parties, as they do not require any additional formal or syntactical knowledge. Scenarios can be specified with different properties like pre- or post-conditions.
Process Modeling	Representation of tasks and processes in the form of workflow diagrams according to a subset of the Business Process Model and Notation (BPNM) 2.0 standard.
Evaluation	Managing questionnaires, distributing them to test persons for evaluations and visualizing results for interpretation.
Rich Text	Text passages can be written for any case without requiring any specific attributes or structure.
Styleguide	Information according to color schemes, layout or design of interaction elements can be represented.

Table 1: UsER modules [9]

Using the example of task analysis with the means of a hierarchical graph, the overall layout and approach of UsER can be explained (see Figure 2).

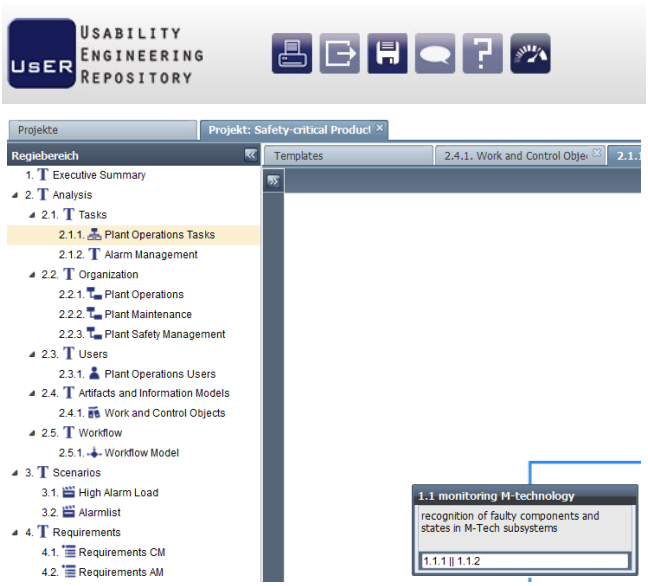

Figure 2: Navigation area and part of HTA module of UsER

On the left side of the UsER screen, the navigation area provides access to all modules currently in use for a project. The entries can be understood as “chapters” and may be rearranged any time. This linear structure provides the basis for classical project documents. If a user accesses one module, it will be placed in a tab and its content, e.g. a hierarchical task tree, will be displayed on the right side of the user interface. Details according to a specific entity can be displayed in a dialogue overlapping the content area on demand (not shown in Figure 2). The tabular interface eases switching between frequently needed modules. Basic functionality (e.g. login/logout, saving, printing or settings) has been placed in the header area of the screen.

Mobile Usability Engineering Repository (MUsER)

The mobile frontend of UsER has been developed within a scenario-based design process [10]. About 10 usability and software engineering experts participated in semi-structured interviews. Topics of the conversations ranged from job history to currently used tools and aids. Based on the results of this measure and literature review, problem-, activity-, information- and interaction-scenarios were derived. They address three basic use cases:

- preparing workshops and meetings with current project information while traveling;
- making use of multimedia functionalities of mobile devices during a meeting (e.g. taking pictures and videos, recording interviews);
- documenting impressions and insights immediately during and after user research and field studies in mobile contexts.

Tablet PCs, if needed with an additional keyboard dock, are a suitable hardware solution to these uses cases and a good compromise between screen size, mobility and input modalities. Therefore, MUsER has been developed as an application for the mobile operating system Android and designed for display sizes of 10 inches and more. Following the common design patterns for Android applications, MUsER has a modular structure which can be extended without affecting existing parts to a high degree. The support of other operation systems will follow.

With respect to the UsER modules mentioned before (see Table 1), the experts interviewed mentioned the following features as being mandatory for MUsER:

- describing and recording cognitive artifacts and other entities of the working environment (Artifacts Module);
- performing evaluations with users following test runs in the field (Evaluation Module);
- taking different kinds of notes (Rich Text Module);
- managing requirements (Requirements Module);
- representing workflows and processes graphically (Process Modeling Module);

The prototype currently includes the Artifacts and the Rich Text Module. Requirement lists can be accessed in a read-only mode. The others are considered for development.

Support for rough drafts in MUsER and more detailed versions in UsER have been requested by some participants. Project members at the user's workplace could draw a sketch of a workflow and refine it later. This would enable project members to recognize details rather than recall them from notes. The latter might even be hard to read by the author, let alone others, some days later.

Figure 3: Team member taking a picture of a cognitive artifact

Therefore, further details about a cognitive artifact like shown in Figure 3 – a tag for registering patients used by Emergency Medical Services in extraordinary missions with many casualties [5] – could be recorded and annotated immediately after taking the photograph.

MUsER has been evaluated with 14 participants. Half of them had previous experience with UsER. Both groups had to solve tasks related to the scenarios mentioned before. Feedback from users during the usage of the prototype was recorded by an observer. Following this, users were asked to complete the questionnaire ISONORM 9241/110-S [7]. It consists of 21 items and has been accepted as a valid measure for usability.

While the think-aloud protocols revealed some minor design flaws (e.g. confusing icons for accessing an item or related sub-items), all participants felt comfortable using the tablet PC – a Google Nexus 10 in this case.

Results of ISONORM 9241/110-S evaluations can range from 21 to 147 points. MUsER received an average score of 105.8 (group with UsER experience: 112.1; group without UsER experience: 99.4). These are promising results for the usability of MUsER.

Data Storage and Data Transfer

UsER has been implemented following the principles of conceptual layers (e.g. persistence, service, business logic, presentation) and multi-tier architectures. By means of object-relation mapping data is stored on a database server. MUsER makes uses of the data model and the four backend-related layers of UsER in order to ensure consistency and maintainability as development progresses. Requests and responses between MUsER-Client and UsER-Server are handled with the hypertext transfer protocol (HTTP). Java objects are serialized by the server and transferred to MUsER-clients as XML-files. After deserialization, data can be displayed or applied.

COLLABORATION WITHIN THE USER ENVIRONMENT

In the next sections, use cases for collaboration in design teams with the aid of UsER and MUsER are described.

Distributed Design Teams

If team members are working at different locations, they not only have to exchange information related to the design process (e.g. personas, scenarios, mock-ups) but as well about their personal work structure (e.g. name and location of files). This can lead to inefficient workflows or even the loss of work results. In any case, team members need to deal with artifacts related both to context and development process.

With the aid of UsER and MUsER, team members can share project-specific information, search for datasets and leave comments on co-workers' contributions. They make use of a single database and avoid working on different versions of a specific artifact or creating it repeatedly. MUsER enables team members to work outside their offices, e.g. while traveling to customers or being in the application field.

Heterogeneous Design Teams

If teams consist of experts from different domains, collaboration may be complicated because different skills and preferences cannot be met with tools representing one specific perspective. Two examples:

1. While usability experts might be interested in details of formative or summative evaluations, project managers might prefer an executive summary and explanation of the results.
2. While graphic designers might want to deal with color schemes and design concepts, software developers might want to use style sheet languages or source code templates.

With the aid of UsER and MUsER, team members could be enabled to create and interlink different representations of certain artifacts or take other perspectives on them. Automatic translations are conceivable, e.g. colors picked by a designer from a tool with a graphical user interface could be stored as a stylesheet file available to developers.

User Research and Field Studies in Mobile Contexts

Today, many applications, even safety-critical ones, are used in mobile contexts. Therefore, development (e.g. analyzing the context of use) has to be performed partially outside of labs or meeting rooms. Currently, team members involved in such actions use laptops, sheets of paper and recording equipment in order to save and share their findings with colleagues and customers. Possibly, details need to be remembered several days later back at the office.

With the aid of UsER and MUsER, team members can take a picture of a cognitive artifact, add notes and share them with developers whenever and wherever needed. Evaluations can be performed right within the application context, compiled and distributed automatically.

CONCLUSION

UsER and MUsER compose a flexible platform for collaboration of distributed or heterogeneous design teams for interactive human-machine systems. While there are fully-fledged software engineering environments, cognitive and usability engineering still lack sufficient tool support. Usable solutions need to integrate methods and tools from different disciplines (e.g. human factors, design, programming) and allow for usage in offices as well as in mobile contexts.

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