Designing for Usability : A Case Study

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ABSTRACT This paper is concerned with an investigation into a structured, user-centered design methodology using a case study approach. The case study selected was a new genealogical information system (GIS), to replace the University of Port Elizabeth's genealogical information system (UPEGIS), which exhibited a number of usability problems. The methodology selected was the Method for Usability Engineering (MUSE). This paper will show that the use of a user-centered design approach, coupled with a structured methodology, resulted in a useable design. Several limitations were, however, discovered in the use of the MUSE methodology. Specifically, MUSE was found to need extensions in the areas of object modelling and detailed user interface design.

KEYWORDS Design methodology, MUSE, object modelling, usability, user interface design.

1. INTRODUCTION

The current trend towards highly interactive systems has resulted in a shift in design emphasis from functionality to usability. Traditionally, the user interface (UI) design was left until relatively late in the system development lifecycle. With the advent of user-centered design, the focus has changed to addressing human factors issues much earlier in the design. Under design methods, two different approaches have evolved: *rapid prototyping* and structured analysis and design methods. Rapid prototyping is based on the premise that the design process will consist of an iterative process of prototype construction and testing. This activity normally involves little design analysis and specification and may result in numerous iterations. In addition, the resultant design may suffer from inherent design defects and a lack of adequate design documentation (Walsh, 1989), (Newman, 1995),

(Redmond-Pyle, 1995). Prototyping is considered, nevertheless, by some to be essential for producing good UI design. Our hypothesis is that structured methods, possibly incorporating iterative design, can also achieve a good UI design, without incurring the disadvantages of pure prototyping.

Structured analysis and design methods, on the other hand, are characterized by a stage-wise approach and have a definite set of deliverable design products for each stage. Specifically, design analysis is completed before design specification and implementation, although an iterative process may also be used. These methods have been developed in two main areas: Software Engineering (SE), and Human-Computer Interaction (HCI). SE methods have traditionally adopted a data or process-oriented approach to systems development, whereas HCI methods focus on user-centered design. The two main techniques proposed in SE were Structured Systems Analysis and Design

(SSADM) (DeMarco, 1978), which concentrates on functional analysis, and Semantic Data Modelling (SDM) (Hull, 1987), which focuses on data analysis. These two different approaches were later combined and replaced with Object-Oriented Analysis and Design (OOAD), which encapsulates data and processes into objects. During the past few years, several structured HCI design methodologies have emerged. These include the Method for Usability Engineering or MUSE (Lim, 1994), the TRIDENT methodology (Bodart, 1995), and the Graphical User Interface and Design or GUIDE method (Redmond-Pyle, 1995). These methods are all based on task analysis but vary considerably in stages covered, notation used, and degree of formality.

The use of a case study to evaluate a structured method is motivated for several reasons. Few case studies have been published reporting on the use of structured methods and more empirical evidence is needed to fully evaluate these methods. The case study will be used to apply all the stages of the structured method, and an evaluation made at several stages, in order to evaluate not only the method, but also the final product. This approach has also been used by other authors to evaluate new design methods (Sullivan, 1996). The choice of the case study is important: the nature of the case study should be highly interactive if usability is to be seen as a critical factor. The case study selected was a new genealogical information system (GIS), to replace the University of Port Elizabeth's Genealogical Information System (UPEGIS). This system consists of a database of some 300 000 persons, representing the results of extensive genealogical research relating to a period of some 350 years of South African history. The system is highly interactive in nature, and exhibited many obvious usability problems, particularly in the area of UI design and task support.

2. COMPARISON OF STRUCTURED DESIGN METHODOLOGIES

Several different design methodologies, including both Software Engineering (SE), and Human-Computer Interaction (HCI) methods were compared and evaluated using a set of evaluation criteria. The purpose of this evaluation was to select the most suitable method for the analysis and design of the case study. The methodologies evaluated were Structured Systems Analysis and Design (SSADM), Semantic Data Modelling (SDM), the Object Modelling Technique (OMT) (Rumbaugh, 1991), the Methodology for Usability Engineering (MUSE) (Lim, 1994), the TRIDENT methodology (Bodart, 1995), and the GUIDE methodology (Redmond-Pyle, 1995). The criteria selected were the following: support for the entire software development lifecycle (SDLC), support for extant systems analysis, task analysis, data (or object) analysis, functional analysis, top-level UI design, detailed UI design, data (or object) design, functional design, and prototyping the UI design. The results of this evaluation are contained in Table 1 below.

The MUSE methodology was selected as the most suitable method, since it effectively covers the entire lifecycle from task analysis to implementation, and involves a detailed usability study of existing systems. A number of limitations were however noted. The conceptual model in MUSE is represented using a *semantic net*, which is inadequate for the detailed design of the database. No specific guidelines are given in MUSE as to the selection and placement of interaction objects on the screen. We suggest, however, that these limitations can be overcome by extending the data model to produce an *object model*, using techniques from OMT, and by including detailed UI guidelines from the TRIDENT methodology.

The next section will briefly review the MUSE methodology, before going on to illustrate how this method was used in the design and implementation of the new GIS.

Criteria	SSADM	SDM	OMT	MUSE	TRIDENT	GUIDE
1. Entire SDLC	√	×	√	√	×	×
2. Extant systems analysis	×	×	×	√	×	×
3. Task analysis	×	×	×	√	×	√
4. Data (object) analysis	×	√	√	√	√	√
5. Functional analysis	√	×	√	√	√	√
6. Top-level UI design	×	×	×	√	√	√
7. Detailed UI design	×	×	×	√	√	×
8. Data (object) design	×	√	√	×	×	×
9. Functional design	√	×	√	×	×	×
10. Prototyping UI design	×	×	×	√	√	√
TOTAL	3	2	5	8	5	5

Table 1 Evaluation of Structured Design Methodologies

3. METHOD FOR USABILITY ENGINEERING (MUSE)

The MUSE method defines the UI design process by specifying the design products to be generated and the procedures to be followed at each stage (Lim, 1994). The MUSE method is structured into three phases, each of which is divided into several distinct stages:

- 1) The Information Elicitation and Analysis Phase is concerned with capturing user requirements using techniques such as task analysis. Existing and related systems are analyzed to derive a high-level, device-independent task model. The stages included here are Extant Systems Analysis and the Generalized Task Model Stage.
- 2) The Design Synthesis Phase is concerned with deriving a conceptual design for the target system, based on the task models produced earlier. The stages involved here consist of the Statement of User Needs, the Composite Task Model and the System and User Task Model Stages.
- 3) The Design Specification Phase produces a device-dependent specification of the UI design, including descriptions of the screens, interaction objects and dialogue design. Its stages comprise the Interaction Task Model, Interface Model and Display Design Stages.

Each stage of the method is characterized by a set of design products, each with an associated set of procedures and documentation or notation. Part of the notation used has been adapted from existing SE methods, such as the Jackson structured diagram (JSD)

notation (Jackson, 1983), and semantic nets. Integration with existing SE methods is supported through the existence of several *handshake* points, such as the Functions List produced during the Design Synthesis Phase. The basic focus of the method should be seen as *user-task oriented*, implying that a user model may be constructed or *synthesized* from the task model. The focus of the method remains, however, on the UI design, no explicit integration with a SE method is proposed.

4. CASE STUDY: A GENEALOGICAL INFORMATION SYSTEM

The MUSE method was used to analyze the detailed requirements for a new genealogical information system (GIS), to replace the University of Port Elizabeth's Genealogical Information System (UPEGIS). This method was supplemented in the Design Synthesis Phase with object modelling techniques from OMT (Rumbaugh, 1991). The object model derived using this process was then used, together with design guidelines from the TRIDENT methodology (Bodart, 1995), in the Design Specification Phase to produce the user interface (UI) specification. This process will be discussed briefly in the sections that follow.

4.1 Information and Elicitation Phase

Two extant systems: UPEGIS, and a related system, Brother's Keeper for Windows (BKWIN), were analyzed to characterize the user needs and problems.

The products produced during this phase were those prescribed by the MUSE method. In particular, the Task Descriptions (TDs(ext)), and the summary of user problems and needs (SUN(ext)), served to identify the problems with both UPEGIS and BKWIN. The major problems identified were the following:

- The crucial task of locating a person in the GIS was not well supported. The search for a person was based only on name or Id number, and did not include any date or place information.
- The user view was limited to only two generations: the current person, the spouse and the parents.
- In the case of UPEGIS, entering a person required entering the Id numbers of both parents.
- In the case of UPEGIS, entering a marriage required re-entering the Id numbers of both spouses.
- UPEGIS only provided support for first-order events: namely birth, baptism and death dates only. Second-order events had to be encoded using special *field markers* in the Information field.
- References and images could not be linked to individual events as well as to persons.

The above problems are illustrated in the UPEGIS screen contained in Figure 1 below. The names of the father and mother are not displayed, only the Id numbers. Note also the use of the field markers (*, =, #, &, >), in the information field to denote birth, baptism, burial, other, and source information respectively.

Figure 1 Browse Screen in UPEGIS

The Generalized Task Model (GTM(y)), developed during this phase provided a device-independent model

of the tasks in the target system. This model was used to ultimately design the menu structure in the Design Specification Phase (see section 4.3).

4.2 Design Synthesis Phase

During this phase, the results of the extant systems analysis were summarized and extended to produce several products. The MUSE method does not, however, address the issue of a conceptual data model, other than from the perspective of the Domain of Design Discourse (DoDD(y)). The DoDD(y) summarizes the semantics of the target system by identifying explicit relationships among the various domain entities and is represented using a semantic net of nodes and relations. The DoDD(y) and the Actions/Objects List were thus extended to produce an *object model* using the Object Modelling Technique (OMT), as initially proposed by Rumbaugh (Rumbaugh, 1991) (see Figure 4).

The production of the object model was seen as essential, not only for the design of the database for the new GIS, but also for the detailed design of the user interface. We consider that the objects in the user interface (*user view*), should be based on the objects in the conceptual data model. This approach to object-oriented user interface (OOUI) design is supported by several other authors (Collins, 1995), (Redmond-Pyle, 1995), but is significantly missing from the MUSE methodology. The object model depicted in Figure 4 was used to decide both on the *presentation units* (PUs), and the selection and placement of the *abstract interaction objects* (AIOs). The actual method used to derive these was based on the TRIDENT methodology, and is discussed briefly in the next section.

4.3 Design Specification Phase

During this phase, the conceptual design was refined and decomposed to produce the UI specification. In addition to the products prescribed in the MUSE method, it was found necessary to draw an *UI Class Table* for the target system. The purpose of this table is to describe each of the screens in the System Task Model (STM(y)), in terms of the user view, the domain objects, and the user actions (tasks) supported in each view. This concept of views of user objects is similar to

that used in the GUIDE methodology (Redmond-Pyle, 1995), and may be compared to the concept of presentation units (PUs), in the TRIDENT methodology (Bodart, 1995). Separate screens were not designed for each task: screens were designed for each visible UI class. The selection of the UI classes were based both on the task model, and the object model. This object-oriented approach resulted in significantly less screens than would have been produced by either the MUSE methodology, or TRIDENT.

The MUSE method does not give detailed guidelines as to the design and layout of the different screens. This may be considered as one of the major shortcomings of the MUSE method. Guidelines from the TRIDENT methodology were therefore used to derive the layout of these. These guidelines are the subject of several papers (Bodart, 1993), (Bodart, 1994a), (Bodart, 1994b) and (Bodart, 1995), and are summarized here as follows:

- The selection of a suitable interaction style or UI environment (UIE). In the case of the new GIS, MS-Windows was selected as the target UIE.
- The definition of screens (PUs), based on both the task and the object model.
- The selection of applicable abstract interaction objects (AIOs), independent of the chosen UIE.
- The translation of AIOs into suitable *concrete interaction objects* (CIOs), based on both the UIE selected, and the object and user model.
- The placement of the CIOs on the screen, using a Right/Bottom strategy.

Examples of the screens produced for the new GIS are contained in Figures 2 and 3 below. The Browse screen depicted in Figure 2 displays information for three generations on one screen. The layout of this screen was based both on the task model, and the object model. Information for the current person, spouse, father, mother or child is edited using the Edit screen in Figure 3. The Edit screen is also used for searching for a person, the search process being based on *all* data entered. The design of this screen thus encapsulates the Person object, together with all the available operations on this object, and is therefore seen to be object-oriented. The use of object modelling as a basis for the UI design is supported by several authors (Collins, 1995), (Redmond-Pyle, 1995). Object-oriented UIs are seen as providing *isomorphism* between the conceptual model and the UI design. The main benefits of this are in the area of learnability, where the simplicity and consistency of the UI design can have significant usability advantages (see section 6).

Figure 2 Browse Screen in the New Genealogical System

Figure 3 Edit Screen in the New Genealogical System

5. OBSERVATIONS

The use of the MUSE method to design the new GIS resulted in several observations. The major advantages of using the method are seen to be the following:

- The MUSE method is based on task analysis and adopts a user-centered approach. This was found to be particularly important when designing a highly interactive system, like a GIS.
- A single notation is used throughout the method, namely that of the structured diagram.
- MUSE is one of the few methodologies which prescribes an in-depth study of the usability of extant and partially related systems. This enabled us to identify the usability problems of both UPEGIS and BKWIN.

The above must, however, be seen in the light of several disadvantages which were encountered in the use of the method:

- The use of the structured diagram is inappropriate for describing device-level interaction in a Windows-based interface. As a result of this, difficulties were experienced in modelling the dialogue in both BKWIN and the new GIS.
- The method produces a large number of intermediate design products and is very time-consuming.

- The method does not currently have any computer-aided support tools. The structured diagrams and supporting tables had to be drawn with a word processor, and the screens were created using Visual Basic.
- The method needs to be explicitly integrated with an object-oriented analysis and design method (Booch, 1994), (Rumbaugh, 1991), (Yourdon, 1994). The object model for the new GIS was essential both for the presentation design, and for the database design.
- The presentation design stage does not provide any explicit human factors guidelines and fails to take into account the data model of the target system. This stage had to be supplemented with guidelines from the TRIDENT methodology.

6. DESIGN EVALUATION

A detailed usability analysis of the design of the new GIS, BAOBAB, was performed by conducting an analytical evaluation (Newman, 1995). This comprised a heuristic evaluation of the UI design, a comparative keystroke-level analysis of two critical tasks, and a cognitive walkthrough of the same two tasks. The heuristic evaluation revealed that the overall system usability was good. Minor design problems were identified in the areas of learnability and flexibility, but

the area of robustness was found to be particularly strong (Dix, 1993), (Nielsen, 1993). The observability and recoverability of the systems were found to be good, and a high degree of task conformance was evident.

Keystroke-level analysis was used to compare the methods used in UPEGIS, BKWIN and the new GIS (BAOBAB), to perform the critical tasks of inserting and updating person information. BAOBAB was found to exhibit the lowest interaction time for the two tasks. This we attribute both to the object-oriented design of the UI, and the user-centered design approach of the MUSE methodology.

Cognitive Walkthroughs were used to assess the degree of user support provided in the UI design. The results obtained here corresponded closely with the heuristic evaluation: no user problems were encountered in the performance of either the two critical tasks.

7. CONCLUSIONS

Although the subject of this paper has discussed the design of only a single case study, yet several conclusions can be made. Firstly, since significant gains in usability have been achieved in the design of the new GIS, the use of structured methods to produce useable systems is supported. These gains are attributed to the broad lifecycle support provided by the MUSE methodology, and in particular, the study of extant systems. The problem had to be approached, however, from two sides: UI design and object modelling. More work is needed, therefore, to develop an integrated, user-centered design methodology which will seamlessly integrate UI design with an object-oriented design approach.

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Figure 4 OMT Model for the Target Genealogical System