Human-centred Development of Interactive Systems: Improving Usability in Early Lifecycle Stages

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Abstract

In this paper we discuss the importance of using a human-centred iterative lifecycle in order to develop cost effective, highly usable systems. We propose a new approach that takes into account the fundamental concepts involved in usability and discuss the results obtained from applying it to the development of a ubiquitous multimodal dialogue system for the elderly people assistance.

1. Introduction

Usability is a key aspect in system quality evaluation. It deals with how hard it is for the users to interact with the systems to achieve their goals in a particular context. Human-centred development processes help us to get this information in early stages of the system lifecycle so that the resulting product can adapt perfectly and constantly to the users expectations and needs.

The paper is structured as follows. In section 2 we discuss the concepts of usability and human-centred system development. Section 3 describes a novel approach on how to merge both concepts in order to produce highly usable and cost effective interactive systems. Section 4 presents a case of study, applying partially the approach to design a new multimodal dialogue system to assist elderly people in their daily home activities. Section 5 presents the results derived from the study. Finally, the paper presents the conclusions and points out some future work guidelines.

2. Human-centred development to foster system usability

2.1. Definition of 'usability'

Several international standards have been made available to define what 'usability' is and provide guidelines for achieving and evaluating it in interactive systems. For example, [1] presents a detailed list of international standards for Human-Computer Interaction (HCI) and usability. Among all the available standards, we highlight the ISO 9241-11 which provides the most widely accepted definition of usability: *"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"*. We can distinguish four key tasks involved in this definition:

1. Identify the target users of the system.
2. Find out what are the objectives of the users when they use the system, which can differ from those envisioned by the analysts. This difference is essential to study the actual user needs and incorporate them into the system development process.
3. Delimitate the system context of use, which can be achieved by ethnography studies.
4. Evaluate usability in terms of effectiveness, efficiency and satisfaction, which represent subjective measures which values for a specific system may vary among users.

Thus, usability clearly differs from other system quality measures such as maintainability, reliability or portability in that the user point of view plays a determinant role in it. As a result, the objective of the interactive development cycle must not be only to obtain fully functional systems, but must also be concerned with the development of systems which adapt to the user needs, expectations and goals. It is impossible to ignore that systems are intimately linked with how users perceive them [2], and this link is included in the definition of usability given by the ISO/IEC 9126 standard: *"the capability of the software product to be understood, learned, used and attractive to the user"*.

The previously commented usability characteristics make it essential to take the user opinion and objectives into account throughout the whole software life cycle. The classic machine-centred approach, in which the system design and implementation are carried out following the technological aspects and functional user requirements, is no longer suitable. Therefore, it becomes necessary to incorporate issues concerned with user capabilities, capacities, context and preferences which constitute the basis of human-centred design.

2.2. Definition of human-centred system development

Human-centred system development is a multidisciplinary activity, which incorporates human factors and ergonomics knowledge into the classical software engineering tasks. There is no consensus about which aspects define human-centred system development. In [3] Hoffman et al. present it as a triplet user-machine-context to analyze capabilities, capacities and objectives of people in the context of their social environment; i.e. hierarchies, roles, social rules and restrictions which permit the system to adapt itself dynamically to different situations. In [4], Vouros and Partsakoulakis present an approach based on "social agents" for carrying out the same task. In the NASA approach the authors propose their own triplet [5]: Human-

System Modelling, Multimodal Interfaces and Decision Systems. As can be observed, all these different notions involve studying users (task 1 in section 2.1) and the way they interact with the system (tasks 2 and 3 in section 2.1). In section 3 we describe our own tuple.

2.3. Promoting usability throughout the human-centred system development cycle

Several studies (e.g. [5]) show that the life-cycle cost of complex systems is affected in approximately 70% by the decisions made in the early design stages. Thus, to mitigate life-cycle costs and risks it is very important to create user performance models that let the system designers quantify the real operation scenarios at the early design stages.

In [1] the authors distinguish four key aspects related to usability to be ensured during the development cycle: i) organizational capability, usability capability within the life cycle processes employed; ii) process quality, user centred development process; iii) product quality, good interface and interaction; iv) quality in use, user satisfaction with the system usage in context.

There are some standards that have to do with the fulfilment of these four objectives. For example, the ISO 13407 describes human-centred design processes for interactive systems. It has been compared in literature (e.g. [6]) with the standard definition of usability from the ISO 9241-11 commented in section 2.1. Although it provides guidance for including usability in the development process, it has been shown that it is only partial and some of the most important tasks (e.g. describing user goals) are not very well limited and are left to the authors' criteria. This fact has provoked the apparition of several approaches to the development process.

In [7] it is proved through experimental results that the classic cascade system development process used by some authors is not suitable for the needs of human-centred design. Thus, the authors propose the usage of an evolutionary model that permits the early involvement of human factors and ethnography experts. However, this approach seems to be incomplete without the direct involvement of the users along with the experts. Some other approaches have overcome this problem taking the user opinion into account from the early stages of system development. One of the most important ones is presented in the TRUMP project [8], involving three main stages: i) arrangement of a meeting with the main stakeholders to develop a shared vision of the system, specially about the usability goals; ii) evaluation of early designs from the user perspective before a detailed design or coding; and iii) test of the prototypes along with a usability pattern.

3. The proposed approach

Our proposal merges some ideas from the approaches commented in the section 2.2 considering three key features of a system: interaction management, user modelling and multimodal interface. We assume that the interactive system has a multimodal interface because it is the most complex case (less restricted interface) and can be correctly particularized to all subtypes of interactive systems, as for example traditional web based systems (keyboard and mouse input, visual output) or oral response systems (oral input and output).

These three features take into account relations between the triplet: user, system and context. On the one hand, the interaction management establishes a relationship between the system and the context. Thus, for example to interpret a user gesture the system must have information about the dialogue and the social and situational contexts. On the other hand, the user models establish a relationship between users and their context. Thus, if the user is an elderly person, it is important to know e.g. whether s/he leaves alone and his/her disabilities. Finally, the multimodal interface provides a way for the system-user communication.

Besides, the three main features are highly related with each other. The interaction management is related to the user models as the former needs information about the user context to disambiguate the user inputs, choose which output modality to use and make decisions. The multimodal input/output is related to the interaction management because the latter decides the modalities to use for the input/output, considering environmental conditions and user preferences. Finally, the user models are related to the multimodal input/output as long as they contain information expressing preferences about the multimodal interface.

As commented before, the user modelling relates user to context. Thus, establishing this relation is the first stage towards the creation of user models that consider the users' social, physical and psychological context. Also, this process requires to take into account the way the user employs the system to register his/her preferences, misunderstandings and difficulties.

In order to do so, we propose to carry out five tasks. In the first one, the system designers arrange a preliminary set of requirements based on their expertise specifying necessary and desirable functionalities and properties for the system. The second task is to refine these requirements taking into account the final users' points of view about the proposed functionality and characteristics, including also their new ideas and suggestions. The refined set of requirements allows in a third task the creation of a good system specification. The fourth task is the construction of a preliminary system design that complies with the specification. Finally, the fifth task finds the usage context of the preliminary design, which is incorporated into posterior designs in an iterative way (evolutionary model).

4. A case of study: elderly assistance multimodal dialogue system

4.1. Particularization of the proposed approach for multimodal dialogue systems development

In this section we discuss the application of the approach discussed in the previous section to design multimodal dialogue systems. As these are a subtype of interactive systems [9], all the tasks are applicable and can be particularized as follows:

- Setting a preliminary set of requirements based on the designers' expertise on multimodal dialogue systems.
- Refinement of the requirements collecting user opinions and needs by means of a survey.
- Defining a preliminary design that complies with the specification.

- Definition of the usage context, which can be achieved in two steps. Firstly, the context of the multimodal dialogue is gathered using the so-called Wizard of Oz (WOZ) technique [10]. Secondly, the usage context of the whole system is registered by means of role playing and drama, which are the more intuitive way of representing the usage of new and unfamiliar systems, and one of the best ways of promoting the involvement of users and experts (as stated in [11]).

4.2. Definition of the case of study

To prove the advantages of the proposed approach we applied it to the design of a multimodal dialogue system to assist the elderly people in their daily activities at home. We focus on the work done at the moment, which includes the setting-up of a preliminary set of requirements and the accomplishment of a survey considering potential users.

4.2.1. Preliminary set of requirements

The purpose of the requirement analysis is to define properties and restrictions that the system must satisfy. The properties or objectives (functional requirements) restrict the problem domain and express the essence of the system. The restrictions (non functional requirements) limit the set of possible solutions to those that fit some characteristics.

In the requirement analysis of our system we established the functional requirements to include the multimodal control of home appliances such as lamps, ovens, windows and heating. We also considered that the system should include some entertainment functionality, such as music and TV remote control and programming. We also found interesting that our multimodal system included a directory for helping the elderly users to make telephone calls. This way they could utter the name of the person they wish to call without remembering his/her telephone number.

When we had restricted the problem, we reduced the possible solutions by establishing a set of non-functional requirements. Therefore, a suitable system that accomplished all the functional restrictions should also have the following characteristics: *non intrusive* (it would not interrupt users in their activities unless it is necessary), *proactive* (it would decide when to help users autonomously considering the environment's current status) and *adaptive* (it would take into account the environment conditions in terms of noise and lighting to decide the most reliable interaction modalities). The system would also allow external communication, e.g., it could make emergency phone calls, and would accept incoming user calls to operate several devices (e.g. switching the heating on before the user arrives home). Finally, to enhance the user experience, it should be *customizable, friendly* and *easy to use*.

4.2.2. Users survey

The survey was created following several style rules. The first was the usage of an easy language so that the questions it contained could be perfectly understood by every polled, potential user. Thus, we avoided foreign or very specialized words. As the survey was directed to elderly, we avoided asking about something that had been explained long ago, and employed very concise questions. Besides, questions were ordered from general to specific, clearly divided in different thematic areas. Due to the difficulty for the elderly to understand concepts related to new technologies, we explained every idea and illustrated it with a drawing representing a person interacting with the system. We carried out the survey in two ways: one was by giving a printed copy of the survey to the polled, while the other was interviewing them orally. For the former we used large fonts for the text so that it was easy to read for them. For the latter, an interviewer read the form and took notes of the polled answers and opinions.

The survey was divided into four main parts. Firstly, a section introduced the system we are planning to develop and explained why the user collaboration was very important for the design. Secondly, there was a section with questions related to personal details (age, gender, residence place, studies and labour situation). A third section listed all the system functionality (functional requirements) discussed in the previous section. A final section included questions about the system properties (non functional requirements).

The survey was answered by 200 men and women with ages ranging 50-80 who lived either in towns of different sizes. Most interviewed were aged 60-70, 58% out of them were women due to the grater longevity of this gender, which makes the proportion of women greater than for men for the older than 60 sector. Some people older than 80 did not understand or answer the questions properly due to different communication disabilities.

5. Survey results

Figure 1 sets out the survey results (in percentages) concerned with the different system functionalities (functional requirements).

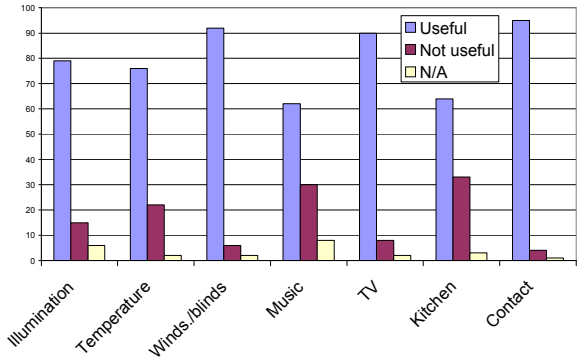

Figure 1: *Usefulness of system functionalities.*

It shows the results are very encouraging, as in all the cases the polled people found the functionalities useful, although their usage varies (e.g. music control was found useful but it would not be used very frequently), as shown in Figure 2.

We also confirmed the importance of making a human-centred design in that the findings about user preferences and opinions where in some cases very different to those expected by the expert designers. For example, when the potential users were asked what they would do if the system misunderstands them, surprisingly most said they would repeat the same thing until it finally understands. The top second answer was to shut

the system down. This fact clearly shows the difficulties in developing a multimodal dialogue system for the elderly, as they would not trust the system if it fails. In fact, 5% of the interviewed would never use the system again in case of error.

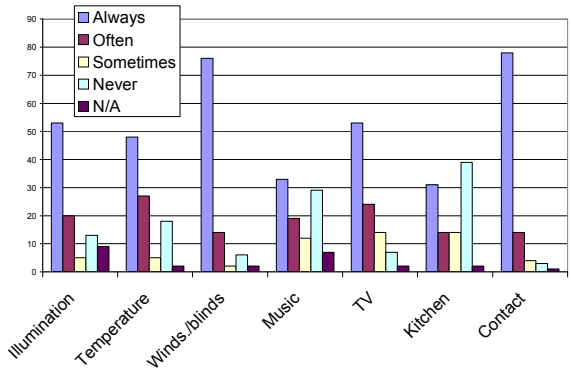

Figure 2: *Intended frequency of use of system functionalities.*

In addition, we verified the significance of making a good delimitation of the target users (as commented in section 2.1) as we obtained that the acceptance of the system functionality and properties highly depend on the specific user profile. For example, the ability of the system to control kitchen appliances (e.g. ovens) was not very well accepted as most people answered they would never use this function. We think the reason is that most of the polled elderly do not make the home duties alone (as they indicated in the first part of the survey), either because they share them with other family members, or because somebody does that work for them. We found that 50% of people who make all duties (usually women) considered this function really useful, while 69.4% of the polled who do not do the home duties said they did not find it useful and would never use the system for those tasks.

6. Conclusions and future work

This paper has presented the importance of using a well defined human-centred development cycle for interactive systems to reach high quotes of usability. We have introduced a new proposal to system design based on three main features: interaction management, user modelling and multimodal interface. This proposal is the result of merging previous strategies towards evolutionary system development with the guidelines proposed in several international standards about usability. A very important factor of the new approach is that it takes the final users' needs and preferences into account right from the initial design states.

As a case of study, the approach has been partially applied to the design of a new multimodal dialogue system to assist elderly people in some of their daily home activities. The user survey has shown that the functionalities and characteristics which a priori seemed to be useful in the expert designer's point of view, were not considered as such by the potential users and vice versa.

We also checked the importance of making a detailed study of the target users to achieve better quotes of usability described in terms of the system capability to be easily learned, understood and used by the users.

Future work includes carrying out the three remaining tasks of the proposed approach which have not been addressed in this paper, namely:

a) Integrating all the information obtained from the potential users into the system specification.
b) Development of a first system design.
c) Testing the first prototype derived from this design using WOZ experiments and role-playing to obtain information about the usage context. Integrating such context information together with the social, cultural and economical context information extracted from the survey, will allow us to develop the user model for the system.

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