From “Design for All” Towards “Design for One” – A Modular User Interface Approach

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Abstract. The paper describes an approach to specifically tailored user interface design, to adapt the user interface to the specific needs of mobility impaired travellers. Given a user has some interaction impairments or s/he is in a situation that causes an interaction impairment (i.e. noisy environment has the same consequences as hearing impairment), another modality is to be used or adapted to compensate this impairment. As sound has other interaction characteristics than graphical user interface elements (e.g. information can not be presented in parallel, but sequentially), rules for substituting some modalities through others are described.

Keywords: Design for all, mobility impaired people, user interface design, adaptive user interfaces.

1 Introduction

1.1 Universal Design and User Interface Adaptation

Universal design, being a design for all approach, aims at “... designing products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design” (Story et al. 1998).

What should a universally designed product fulfil according to this definition? All people should be able to use it, but maybe not the full functionality. This would be a real disadvantage for these people. The other requirements that can be derived from the definition are that adaptation and specialized design should not be needed to use the product. Why? Because there should not be any extra effort or burden for some people to use the product – adaptation normally implies tedious configuration procedures and often requires expert knowledge. This is where the research project ASK-IT aims to provide a solution.

1.2 ASK-IT Project

ASK-IT¹ is a research project, that aims to support mobility impaired people with information on accessible routes, travel information, guide them around, provide assistance - enable them to travel independently. Mobility impairment in ASK-IT is defined in a very broad sense: all people who are hindered in one way or another in their mobility are mobility impaired. This can be an impairment of the upper or lower limbs, as well as illiteracy, a visual impairment or deafness.

The main ASK-IT user groups are listed below. The names of the user groups refer to an impairment or difficulty that can limit the user's activity. To each of the named user groups 2 to 5 sub-groups have been identified (Simões & Gomes, 2005). As you can see, the user interface has to take into account very diverse interaction requirements.

1. Lower limb impairment.
2. Wheelchair users.
3. Upper limb impairment.
4. Upper body impairment.
5. Physiological impairment.
6. Psychological impairment.
7. Cognitive impairment.
8. Vision impairment.
9. Hearing impairment.
10. Communication producing and receiving difficulties.

The user interface design approach in the project ASK-IT aims to solve the problem of tedious configuration: the user interface is adapted automatically to the interaction requirements of a specific person: if this person is blind, the contents are given in audio, if the person is in a wheelchair, standard graphical user interface elements can be used.

One main challenge of the project is to provide an adapted user interface to the very heterogeneous interaction requirements mobility impaired people bring in. To achieve this in an economic way and to make sure that the overall system has a consistent look and feel, ASK-IT adopts a modular approach in user interface design: user interface elements for all modalities are developed, tested and defined and – given the specific interaction requirements of a person – combined to the individual user interface. This builds on the principles of Unified User Interface development (Stephanidis & Savidis, 2003).

1.3 Interaction Restrictions vs. Functional Requirements

Mobility impaired people bring in specific requirements for the design of applications and services. On the one hand they have specific functional requirements that need to be met. Thinking about travel planning, accessible routes and accessible places mean something different for different user groups: for a wheelchair user an accessible route means that s/he needs a route without steps, not too steep and without cobbled

¹ The project ASK-IT is funded by the EC in the 6th framework program, priority IST-2002-2.3.2.10 eInclusion. Contract no.: IST-2003-511298.

pavement. For a visually impaired person, an accessible route might be the one with good lighting, big direction signs and with handrails in staircases in buildings. So, for each user group, their specific functional requirements are used for calculating the best route for them. The issue what accessibility means for each of the user groups is dealt elsewhere (Wiethoff & Sommer, 2005).

The issue of this paper is how to consider the diverse interaction requirements of mobility impaired people in user interface design. It is easy to figure out that blind people do not profit from visually presented information and people with upper limb impairments often use assistive devices to interact with software applications. On the other hand, the solution for this issue is more complicated than simply replacing text display by speech output for blind or sounds with a vibration signal for deaf people. This replacement has to take into account context factors (e.g. privacy in public surroundings), as well as the interaction characteristics of the different modalities.

2 ASK-ITs Modular Approach for UI Design

The challenge to meet the requirements of the heterogeneous user (sub-)groups ASK-IT will support, requires a user interface that will be automatically configured, according to the user profile (Bekiaris & Gemou, in print). The aim is to develop user interface concepts and elements to support user preferences and context-driven services. Therefore the approach to user interface development is to develop generic user interface patterns, that fulfill a set of interaction requirements and to define a schema to allocate them to user group and context requirements. This schema is based on a suitability analysis of a range of user interface elements and an assessment of interaction characteristics of the respective user interface elements. The approach is sketched out in the following paragraphs.

2.1 Interaction Characteristic of Selected User Interface Elements

An overview on interaction characteristics of selected user interface elements of different modalities is provided in figure 1.

The term *interaction characteristics* refers to what a specific user interface element can be used for, concerning its *reaction potential* and the *complexity of information* that can be displayed.

The *reaction potential* can be either no specific potential to evoke reaction, e.g. simple display of information, that is noticed only when attention is especially paid to it. The other options are user interface elements that grab attention and others that have the potential to evoke alert. The difference between attention and alert is seen, if a change of some variable is noticed by the user or if the user understands that actions have to be taken immediately.

This can easily be understood on the example of the user interface elements used nowadays by a standard mobile phone. Text display and graphical elements are used to generally display information. If the user should pay attention to a system reaction, e.g. when there was a failure sending an intended text message, this message is not only given by text, but additionally supported by a sound signal. Sound and vibration elements are used to indicate when a new text message has been received. This would

		Visual display	Graphical icons	LEDs (e.g. traffic light)	Sound	Sound with vibration	Sound + language	Language	Visual display	Sound	Visual display	Sound with vibration
Interaction characteristics	Reaction potential	1	1	1	2	2	2	2	1	2	0	1
	Alert	0	0	0	2	2	0	2	0	0	0	0
Complexity of information that can be displayed	Binary type (i.e. present/not present)	-	-	X	X	-	-	X	-	X	-	-
	Information differing on one dimension (ordinary scale, i.e. timeline until event status), two distinct codes (i.e. status)	-	X	X	-	X	-	X	X	X	-	-
	Complex information (i.e. explanations)	X	-	-	-	-	X	-	-	-	X	X

Fig. 1. Interaction characteristics of different user interface elements: reaction potential and complexity of information that can be displayed (reaction potential: 0/red = UI element does not have respective reaction potential, 1/yellow = UI element partly has respective reaction potential, 2/green = UI element has respective interaction potential; complexity of information that can be displayed: - = respective information can not be displayed by UI element, X = respective information can be displayed by UI element)

probably be overseen by the user, because in most times the display of the mobile phone is not monitored for a change in information display. Not in all cases an immediate reaction is needed, but the attention grabbing characteristic of sound and vibration allows the user to check the information and react, if needed. If a phone call comes in, in most cases an immediate reaction (pick up the phone) is to be taken. Here, not only a text display on the caller and vibration elements to gain attention are used, but also the sound element that indicates the phone call can be personalised, to support not only attention, but also semantic interpretation and focused action. Additionally, the sound element is displayed, until the user has taken the appropriate action.

In figure 1, a selection of user interface elements are evaluated concerning their reaction potential: the scheme worked out, for indicating the reaction potential of a specific user interface element, uses three levels: “0” stands for user interface element does not bear this characteristic, “1” indicates that under specific circumstances the user interface element shows the specific characteristic, and “2” indicates that the specific characteristic is prominent in the respective user interface element. For a better overview, the levels are additionally colored, using the traffic light metaphor (red for “characteristic not supported”, yellow for “partially supported”, green for “fully supported”).

As indicated by the mobile phone example, all displays that target the visual channel (e.g. text display, graphical elements, LEDs) are useful to gain attention only under specific circumstances – only if the display is in the vision field and is actually paid attention to already or uses attention gaining mechanisms, like blinking. To gain attention, sound-related elements or vibration can be used.

The *complexity of information* that can be displayed is an indicator of how rich a specific user interface element is in displaying information. As a starting point, three levels of complexity have been defined: if “binary type” of information can be displayed, it means that the user interface element is either present or not present. An example for that are LEDs in cars, that indicate that there is either a problem with the battery or there is no problem. This type is easy to understand but works only for few pre-known events. The next level of complexity is “information differing in one

dimension” or in only “few distinct codes”. The first could be an ambient display, that codes the time until an event is due in a continuously changing color display from “yellow” via “orange” to “red”. The second could be acoustic icons, that stand for different events, e.g. new email, new appointment, reminder on event due. The highest level of complexity is “complex information”. The interaction with a system also requires displaying more complex information to the user, e.g. explanations. As indicated in figure 1, there are only a few user interface elements, which are suitable for this type of information, especially when the information is abstract in a way. These are text and speech output, Braille and sign language.

2.2 Assessment of Suitability of a User Interface Element Per User Group, Context, and Information Type

User interface elements can be understood as building blocks of the respective user interface. They can be split into categories, according to the sensory channels they address: “visual elements”, “acoustic elements”, “haptic elements”, and “olfactoric elements”. The user interface elements are divided in input and output interaction whereas some elements are only sensible as either input or output (e.g. only olfactoric output) (see table 1).

Table 1. User interface elements analysed for their suitability for user groups and context requirements

UI element category	UI elements analyzed
Visual elements	Text, graphical elements (icons), LEDs, ambient displays, gaze-based interaction
Acoustic elements	Acoustic icons, earcons, acoustic input (e.g. paraverbals, humming), speech input and output
Haptic elements	Touch, vibration, tactile displays, gestures, motion, pressure, interaction with tangible objects
Olfactoric elements	Smell & taste output

To define which user interface elements are used in the respective ASK-IT user interface for each impairment group and context of use, these UI elements have been assessed by their suitability for a) user requirements and b) context requirements.

2.3 Interaction Requirements Per User Group

The approach is illustrated by the following example: One UI element, using the visual channel, is the display of text. In the examination of suitability of UI elements for user groups, it turned out that text display is “suitable” for the following user groups:

- Lower limb impairment
- Wheelchair users
- Upper limb impairment
- Psychological impairment

For the following user groups it is “partly suitable”. That means it is either not suitable for all user sub-groups (e.g. it is suitable for some people with communication impairments but not suitable for users who can not read) or suitable only with

adaptation to specific requirements, like “only with adaptable text size”, “only very few and easy words”. Here specific guidelines for design have to be formulated:

- Upper body impairment
- Physiological impairment
- Cognitive impairment
- Vision impairment
- Hearing impairment
- Communication producing and receiving difficulties

In the next step, the “text output” for ASK-IT will be defined for the respective use cases and used in user interface design of all groups, for whom the user interface element is suitable or partly suitable. In this case, the type of adaptation needs to be defined additionally. Sharing of interaction requirements leads therefore to common UI patterns.

An example for a UI element being “not suitable” for a specific user group is the haptic element “Gesture input”. “Gesture input” is not suitable for people with upper limb impairment. Accordingly, the user interface for people with upper limb impairments should not contain gesture input, but e.g. speech input. Speech input itself would not only be suitable for this user group but also e.g. for people with severe vision impairment.

2.4 Interaction Requirements per Context of Use

The requirements are not only shared by user groups. The context of use also brings in interaction requirements. The following contexts of use are to be considered for nomad device applications:

- Car
- Home
- Public place (e.g. public park, shopping mall, pedestrian zone)
- Transportation station (e.g. airport, train station)
- Transportation means (e.g. bus, train)

In table 2 the interaction requirements, in terms of interaction limitations for the different contexts of use, are described:

Table 2. Interaction limitations of contexts of use

Context of use	Interaction limitations
Car	Parallel task driving/attention switching, hands and eyes mostly involved in primary task, noisy, vibrations
Home	None
Public place (e.g. shopping mall, pedestrian zone)	Can be noisy, no privacy
Transportation station	Very noisy, no privacy
Transportation means	Very noisy, no privacy, vibrations

The suitability of user interface elements, for a given context of use, has therefore be assessed in a similar way than for user groups.

In the car context, none of the user interface elements really seems to be ideal, because the visual sense, as well as the haptic sense, are involved in the primary task of driving. How noisy it is in the interior and how good the ability of the person will be to distinguish different sounds depends on the car and the actual speed. The same holds true for vibration outputs. Additionally, vibration can cause an alert reaction, which is not wanted in the context of car driving. As a consequence, the user interface in the car will consist of a combination of adapted visual and acoustic-related elements. Adapted means that, compared to the user interface the respective ASK-IT user uses being not in the car, s/he will have bigger interaction elements and louder acoustic signals – the same holds true for a person with light visual and hearing impairments.

Whereas the home as usage context usually does not imply impairing interaction characteristics, public places and especially transportation related contexts bear challenges for interaction design. They can be quite noisy and in transportation means also vibrations are prominent. This makes interaction using haptic senses more difficult and vibration output is often not noticed – only if the vibration is at the body it may be noticed. The characteristic of reduced privacy leads to some restrictions in speech output, depending on what output is given. For that, visual user interface elements are very suitable. But for gaining attention, providing alerts and for people with severe visual impairments, other solutions have to be found. For ASK-IT, it is planned to implement on the one side sounds for information presentation, e.g. for navigation support for blind people. They are less intrusive than speech output and allow a higher level of privacy. If it is too noisy, an earphone can be used and a combination with haptic elements, placed suitably at the body, needs to be considered.

2.5 Interaction Requirements of Information Type

The information offered by the ASK-IT system has to be displayed, according to the underlying requirement, each by single messages to the user. This is especially true, if an immediate reaction is required or if it is the system reaction to a user-triggered request. Table 3 gives an overview on the requirements, based on the characteristics of each information type. More information can be found in Gemou & Bekiaris (in print).

Table 3. Interaction requirements of information type

Information type	Example	Characteristics	Requirements
Pushed information	Information provider sends according to user interests	Non-critical, not urgent, importance low, attention level low	Attention and complex information
Information (non-critical)	Pull information, i.e. get train timetables	Non-critical, not urgent, importance high, attention level high	Complex information
Critical information	Get of the bus the next station	Critical, not urgent, importance high, attention level low	Attention/Alert and some information
Emergency	Get of the bus immediately!	Critical, urgent, importance high, attention level not specified	Alert and some information

For a modular approach in UI design, the respective UI elements have to be carefully chosen and combined to only replace UI modalities, that have similar interaction characteristics. E.g. if a person is deaf, the allocation schema should not allow to provide notifications in very big visual elements, because they will only be noticed in the vision field, in contrast to acoustic elements.

3 Integrated User Interface

The integrated user interface, to be developed in the ASK-IT project, contains all user interface elements used in the ASK-IT application and develops rules for combination and substitution of these elements, to meet user and context requirements. This integrated user interface is not what a single user will be confronted with. The user will use the part and combination of UI elements that is suitable for him/her and that will allow fulfilling the interaction characteristics needed for the specific content. To sum up, the user interface for a specific user is firstly defined by his/her interaction range. Within this interaction range, the most suitable interaction for the given context is defined and the suitable building blocks for the information type are selected.

The user interface for a blind person would therefore use, e.g. acoustic elements, to indicate an important unforeseen event and explain that in more detail, in either speech output or Braille, depending on the context of use and the abilities of a person to understand Braille. For a deaf person, the attention could be gained by vibration feedback, while more information on the event is provided in text or graphical elements. For deaf and blind people, only a combination of haptic elements can be used, with the problem of how to display really complex information.

As a consequence, the design of adapted user interfaces is not as trivial as to substitute one user interface element by the other, because persons' impairment allows them not to understand all possible user interface elements. A substitution only makes sense for user interface elements that have the same interaction characteristics.

4 Next Steps

On the basis of the selected user interface elements, to be developed in ASK-IT, according to the suitability analysis of user and context interaction requirements prototypes are developed, tested, and optimized with users within the project. The prototypes show how the ASK-IT user interface will look and work in principle. This way ASK-IT follows a user-centered design process (ISO 1999), specifying requirements, building prototypes and optimizing them iteratively with users and implementing them when the requirements are met.

The prototypes cover a specific cutout of the whole ASK-IT system to target the user interface specification for all user groups, application domains and devices. The dimensions targeted in ASK-IT are shown in figure 2.

Fig. 2. Integrated user interface ASK-IT with relevant dimensions targeted

The approach of ASK-IT user interface development is modular and can be compared to a more-dimensional dice. The selected prototypes cover specific parts of the dice and the integrated user interface will then fill the remaining parts through transfer of the knowledge gained in prototypes development.

Therefore the prototypes are a:

- Selection of use cases
- Selection of user group related content and functionalities
- Selection of modality (depending on user and context requirements)
- Selection of device (depending on user and context requirements)

I.e. the prototypes show specific examples for the overall integrated ASK-IT user interface. Concerning pedestrian navigation, e.g. a prototype using graphical user interface elements (text and graphical elements) was developed. Another prototype shows how pedestrian navigation for blind people can be achieved with sound elements. For the integrated user interface, the conceptual integration of all user interface elements will be achieved. An analysis of replacement of different modalities according to user and context interaction requirements will be done, the learnings and principles of each prototype and the transferability to other user groups, devices, use cases, etc. will be discussed.

5 Conclusion and Outlook

In this paper, a modular approach to user interface design, using defined user interface elements, was presented, to fulfill very diverse interaction requirements. This design approach allows specific individual adaptation and therefore a “design for one”. This approach is not meant to be the opposite of a “design for all” approach, but to take the ideas in that approach a little further and solve arising problems with the help of self-adaptation mechanisms. The algorithms being the basis for that are dealt elsewhere (Ioannins & Savidis, 2006) – this paper provides the conceptual basis for the respective adaptation.

The advantage of the approach of defining user interface elements according to the interaction requirements is that, not only the useful schema for user interface development for mobility impaired people, but also for user interface adaptation to contexts of use: a person with hearing impairments has the same interaction requirement as a hearing impairing context of use – e.g. a train station.

Further systematic research still needs to be done in acoustic user interface elements and haptic interface elements. For using them not only as an enhancement of graphical user interfaces, but also for replacing these elements, systematic knowledge on how many elements can be distinguished, given a specific set of parameters, is needed. For haptic elements, it is especially important to know how to design haptic elements that they can convey more complex information and what restrictions have to be applied.

Acknowledgements. We wish to acknowledge to the ASK-IT IP project Consortium for their valuable contributions to this work. The ASK-IT IP project is partially funded by the EC.

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