Development of Open Platform Based Adaptive HCI Concepts for Elderly Users

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Abstract. This paper describes the framework and development process of adaptive user interfaces within the OASIS project. After presenting a rationale for user interface adaptation to address the needs and requirements of older users, the paper presents and discusses the architecture and functionality of the OASIS adaptation framework, focussing in particular on an advanced library of adaptive widgets, as well as on the process of elaborating the adaptation rules. The results of the adopted approach are discussed and hints to future developments are provided.

Keywords: Automatic user interface adaptation, Unified User Interface Design., adaptive widgets, adaptation decision-making.

1 Introduction

Over the last 50 years, the number of older persons worldwide has tripled - and will more than triple again over the next 50-year period as the annual growth of the older population (1.9%) is significantly higher than that of the total population (1.02%). The European Commission has predicted that between 1995 and 2025 the UK alone will see a 44% rise in people over 60, while in the United States the baby-boomer generation which consists of about 76 million people and is the largest group ever in the U.S., is heading towards retirement [7].

This situation asks for new solutions towards improving the independence, the quality of life, and the active ageing of older citizens. Although substantial advances have been made in applying technology for the benefit of older persons, a lot of work remains to be done. Notably, only 13% of people aged over 65 are Internet users, while the average in Europe is 51%.

Recent advancements in Information Society research have tremendous potential for meeting the emerging needs of older people and for further improving their quality

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of life. OASIS is an Integrated Project of the 7th FP of the EC in the area of eInclusion that aims at increasing the quality of life and the autonomy of elderly people by facilitating their access to innovative web-based services. OASIS stands for "Open architecture for Accessible Services Integration and Standardisation", which hints at the project's way towards making this vision a reality: OASIS aims at creating an open reference architecture, which allows not only for a seamless interconnection of Web services, but also for plug-and-play of new services. In order to give the OASIS architecture a critical mass for widespread implementation, the project consortium will make the reference architecture in question, and the related tools, available as open source. 12 initial services have been selected for prototype development in the project's lifetime. They are joined into three main categories considered vital for the quality of life enhancement of the elderly: Independent Living Applications, Autonomous Mobility, and Smart Workplaces Applications [8].

OASIS aims at creating an open system. Not only new Web services will be able to connect via the hyper-ontological framework. New applications, that process information from different Web services in an innovative manner, are expected to emerge frequently. One main advantage of this approach is that it enables developers to make any new Web service or application available to a large community of elderly users through the OASIS platform. The OASIS approach aims at delivering all such services in appropriate forms optimally tailored to diverse interaction needs through the OASIS advanced approach to user interface adaptation. This paper focuses on the R&D approach of the project towards ensuring high quality interaction for older users, building on personalisation and adaptation techniques. The chosen methods for automatic user interface adaptation and rules generation are introduced and discussed here. Their purpose is:

- to facilitate the development of interactive applications and services for different platforms;
- to develop various accessibility components that can be used across the range of interaction devices supported by the project;
- to enable the personalisation of interactions, as well as automatic tailoring-to-device capabilities and characteristics, thus offering an individualised user experience;
- to develop components that facilitate the rapid prototyping of accessible and self-adaptive interfaces for the project's range of supported devices.

2 Background

2.1 Older Users as a Target Group

Older people are increasingly becoming the dominant group of customers of a variety of products and services (both in terms of number and buying power) [7]. This user group, large and diverse in its physical, sensory, and cognitive capabilities, can benefit from technological applications which can enable them to retain their independent living, and ultimately reduce health care expenditure.

Although older people are not generally considered to have disabilities, the natural ageing process carries some degenerative ability changes, which can include diminished vision, varying degrees of hearing loss, psychomotor impairments, as well as reduced attention, memory and learning abilities. All of these changes affect the way older people use Information and Communication Technology (ICT), which must be accommodated to ensure that they are not disadvantaged when using ICT. This accommodation can only be realized after a thorough understanding of the changes associated with ageing and of their impact on the needs of older people concerning the interaction with technical systems.

2.2 Rationale for a User Interface Adaptation-Based Approach

According to ISO 9241, the usability of a technical system depends *inter alia* on the user and the context of use. This requirement becomes even more critical when designing for non–traditional and diverse user groups, such as the elderly. Therefore, appropriate, personalised, systematically-applicable and cost-effective interaction solutions need to be elaborated, and proactive approaches towards coping with multiple dimensions of diversity are a prerequisite. The concepts of Universal Access and Design for All [12], [13] have the potential to contribute substantially in this respect, as they cater for diversity in every dimension of human-computer interaction.

Recent approaches towards Design for All imply the notion of intelligent user interface run-time adaptation, i.e., the capability of automatically adapting to individual user characteristics and contexts of use through the realization of alternative patterns of interactive behaviour. The Unified User Interface design method has been developed to facilitate the design of user interfaces with automatic adaptation behavior [11] These efforts have also pointed out the compelling need of making available appropriate support tools for the design process of user interfaces capable of automatic adaptation.

In a parallel line of work to user-oriented adaptivity, user interface (UI) research has recently addressed the identification of, and adaptation to, the situational and technical context of interaction (see, e.g., [1] for an overview) – although most of the time, user- and context-oriented adaptivity are combined (e.g., see [3]). Adaptivity concerns systems that adapt to the form factor of the user's device, the actual interaction devices available to the user, the user's geographical location, etc.

In the context outlined above, OASIS aims to provide high-quality, ambient user interfaces by effectively addressing diversity in the following dimensions: (i) target user population and changing abilities due to aging; (ii) categories of delivered services and applications; and (iii) different computing-platforms and devices (i.e., PDA, smartphone, desktops, laptops).

In this context, new accessibility components and alternative interfaces are constructed within OASIS that will be used across the range of devices supported by the project, offering personalised, ambient, multimodal, and intuitive interaction. By design, the OASIS user interface will embed adaptations based on user, device and context characteristics. Furthermore, OASIS develops innovative tools to facilitate the rapid prototyping of accessible and self-adaptive interfaces for cutting-edge technologies and devices supported by the project.

3 User Interface Adaptation Methodology

The OASIS user interface adaptation methodology is decomposed into two distinct but highly correlated stages: the specification and the alternative design. During the specification stage, the conditionally adjustable UI aspects and the discrete dimensions that are correlated with the adaptation decisions (user- and context- related parameters) are identified. During the alternative design stage, a set of alternative designs is created for each UI component. These alternatives are defined according to the requirements posed by each adaptation dimension (e.g., visual impairment) and parameter (e.g., red-green colour blindness or glaucoma). These alternatives need to be further encoded into a rule set, loaded by a rule inference engine, evaluated and finally propagated from the concept layer to the actual presentation layer.

The OASIS project boosts adaptation by incorporating the above-outlined mechanisms into a complete framework that inherently supports adaptation. The Decision Making Specification Language (DMSL) engine and run-time environment [10] offer a powerful rule definition mechanism and promote scalability by utilizing external rule files while relieving the actual UI implementation code from any adaptation-related conditionality. The Adaptive Widget Library developed in OASIS (see section 3.1) encapsulates all the necessary complexity for supporting adaptation of user interface components (from evaluation request till decision application).

The OASIS adaptation platform infrastructure consists of the following components (see Fig. 1): the DMSL Server and the Adaptive Widget Library. The DMSL server is divided into the DMSL Engine Core and the DMSL Proxy. The Core is responsible for loading and evaluating the rules, while the Proxy acts as a mediator between the Core and external “clients”, by monitoring incoming connections, processing the requests and invoking the appropriate core methods.

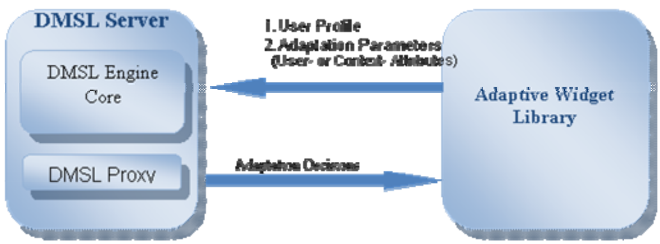

Fig. 1. The OASIS Adaptation platform infrastructure

3.1 The OASIS Adaptive Widget Library

The Adaptive Widget Library is a set of primitive (e.g., buttons or drop-down menus) and complex (e.g. file uploaders, image viewers) UI components that utilizes the DMSL Server facility to support adaptation. The library’s ease of use is ensured by relieving developers of the responsibility of manually adapting any widget attributes by offering a common “adapt” method. Each widget encloses a list of its adaptive attributes and when instructed to adapt itself, evaluates each attribute and applies the corresponding decision. Considering that the DMSL Server is a remote component, network connectivity is an essential precondition for the overall process; thus any lack of it should be handled beforehand. A fail-safe mechanism has been developed to minimize the side effects of potential connectivity loss, where the “last” known

Table 1. Adaptation steps in the OASIS framework

1. At compile time, the developer defines the rule file that the DMSL Server will load for the specific User Interface decision-making process and builds the user interface using the OASIS Adaptive Widget Library
2. At runtime, the application – when necessary – invokes the adapt method for each contained widget
3. Each widget asks the DMSL server to evaluate all the rules related to its subject to adaptation attributes
4. Upon successful evaluation, it applies these decisions and updates its appearance to meet user and context needs

configuration is stored and maintained locally to facilitate "static" user interface generation without supporting on-the-fly adaptation. The adaptation process in the OASIS framework is outlined in Table 1.

An example of user interface created using the Adaptive Widget Library is presented in Figure 2.

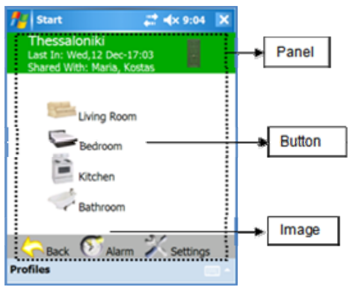

Fig. 2. An exemplary user interface developed with the Adaptive Widget Toolkit

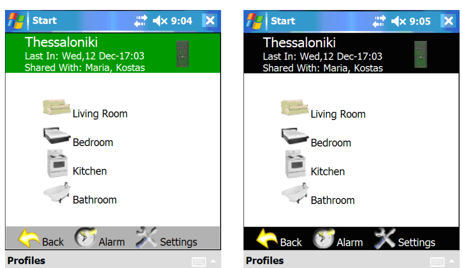

Fig. 3. A simple example of widget adaptation

The panel, button and image UI components which appear in this interface are available through the library. Figure 3 depicts how this interface is automatically adapted through DMSL rules. In the left part of the figure, the interface displays a color combination, while in the right part a greyscale is used for enhanced contrast. This type of adaptation can be useful in case of visual limitations of older users.

3.2 Interaction Prototyping Tool

To further facilitate adaptation design using the Adaptive Widget Library, a tool for rapid prototyping of interactions is being implemented to bind together all the components of the framework. This tool is intended to facilitate the connection of application task models (i.e., services) with accessibility solutions and adaptivity.

Specifically, it is going to enable interaction designers to:

- create rough interaction models,
- encapsulate preliminary adaptation logic and effects and
- specify how adaptations are effected in the interactive front-end.

This tool incorporates the facilities mentioned above in a form similar to reusable software design patterns. The output of the prototyping tool will facilitate further development of the interfaces, while preserving the possibility for full-cycle re-engineering of the modified output.

4 Adaptation Rules Elaboration Methodology

This section discusses the methodology adopted in the elaboration of the adaptation rules for the OASIS prototyping tool.

The major challenge in creating adaptation rules for self-adaptive user interfaces lies within the complexity of the resulting design space. Even a relatively simple adaptation design space including 3 different aspects of the interface, each of which will have three different alternatives, can in theory produce 27 different interface instantiations. Hence, iterative user interface development, involving repetitive user testing in the early phases, is not a very attractive method for creating adaptation rules. Instead, a more cost- and time-efficient solution is a theory based approach.

In the OASIS project the first step in the development of the adaptation routine was a review of general interface design guidelines (e.g., ISO 9241). This was primarily meant to ensure that the adaptation rules defined would not contradict existing standards. Afterwards, specific design guidelines for elderly users were examined (e.g., [4]), in order to determine where adaptations would be appropriate, according to the restrictions of the devices to be used. The result of this work is a matrix in which the lines contain the adaptation-trigger parameters (e.g. the user’s age or impairments profile) and the columns show the user interface elements to be adapted (e.g., font size and color profile). Parameters to be linked via an adaptation rule are indicated at the intersection of rows and columns. In the matrix, the trigger parameters are specified in a format that takes into account the exact definitions of these variables. This is meant to facilitate the translation of the rules into DMS.

As a subsequent step, the matrix was sent out to the OASIS consortium in order to collect feedback and to ensure that application-dependent issues are appropriately taken into account. The option of also collecting user-based feedback was discarded in this phase, based on the rationale that both the matrix and the underlying concepts would be difficult for the users to fully comprehend and comment upon. Users should rather be confronted with a prototype of the adaptive interface and provide a direct statement of approval or disapproval, e.g., via a validated measurement instrument for user satisfaction [6].

After updating the matrix according to the collected feedback, it was checked for possible conflicts between rules to be created. Finally, the adaptation rules were elaborated. Table 2 below summarizes the resulting adaptation trigger parameters, and Table 3 shows the user interface elements subject to adaptation in the context of OASIS. Table 4 displays two examples of adaptation rules.

Table 2. Trigger parameters

End devices:	Person-related parameters:	Context-related parameters:
• PCs (including laptops and tablet PCs) • PDAs • Symbian mobile phones	• All users o Language • Elderly users: o Age o Occupation / Life situation o Computer literacy o Speech impairment o Vision impairment o Mobility- / Motor impairment o Cognitive impairment o Hearing impairment • Caregivers o Profession • Others o User subgroup	• Location o Office o Home o Other points of interest • Ambient parameters o Illuminance o Noise level o Handling conditions • Occupation parameters o At work o Moving o Car o By feet o On bus / train • Device specification o Weight o Robustness

Table 3. User Interface elements subject to adaptation

Font size	Animation
Icon size	Voice control
Color-profile	Text-to-speech
Brightness	Touch screen
Audio volume	On-screen keyboard
Cursor	Touch less interface
Size of edit fields	Caution warnings

Table 4. Adaptation rules – examples

1	If	[Elderly user's age = 1 or 2 or 3] or [Elderly user's life situation = 2 or 3] or [Elderly user's computer literacy level = 0] or [Vision impairment = 1 or 2 or 3]
	Then	Resolution 640*480 pixels
2	If	[Elderly user's life situation =1] or [Elderly user's computer literacy level = 1]
	Then	Resolution 800*600 pixels

A further step to be accomplished is the final validation of the designed adaptations. Two approaches are under consideration towards this purpose:

Hypothesis driven: each single adaptation rule could be tested by presenting all possible variations of an interface element to test users and asking them for their preference – or doing a performance test with interface instances that only differ concerning one variable.

Comparison to standard device: one interface instance is considered as "standard" and each user in a user test is presented with both the standard and an adapted instance. This method will not tell the experimenter which adaptation is preferable, but it will show if all the adaptations together make sense.

4.1 Lessons Learned

Significant experience was acquired through the process of creating adaptation rules. For example, it was found that that the brief descriptions of some interface characteristics in the matrix could cause misunderstandings. When using such a matrix to collect feedback, each of the dependent parameters should be accompanied by a short description. The use of scenarios and personas can be very useful in order to explain why an additional parameter is needed and how it is supposed to behave. Furthermore, phrasing scenarios can help developers of the adaptation rules to keep a focus on the overall usability of the system and avoid losing orientation between a large number of more or less important and even partially contradicting adaptation indications.

Another important aspect of elaborating adaptation rules relates to the interpretation of existing design knowledge and guidelines. For many adaptation parameters, the literature does not provide precise thresholds for the trigger variables or the elements to be adapted. For example, older users are said to prefer bigger font sizes. Yet sources often do not give age-related cut-off-values, which is presumably due to the fact that the elderly are a very heterogeneous group. On the other hand, adaptation rules must be elaborated using precise thresholds, specifying, for example, at which user age the font size should grow, and to which extent. This issue was addressed by including adaptation rules with arbitrarily set thresholds based on design experience rather than excluding adaptations. It was assumed that the precision of the adaptation rules could still be fine tuned at a later stage through user testing. This decision was taken in order to allow the prototyping tool work with a rather large variety of rules. Corrective mechanisms will be included in the OASIS adaptation framework which support also the manual configuration of some interface aspects such font size or color profile. This empowers the user to reject any unwanted adaptation, resulting in an optimal personalisation of the UI.

5 Discussion and Conclusions

This paper has presented the OASIS approach to user interface adaptation in the context of Web services for older users, addressing in particular the elaborated adaptation framework, the role of the OASIS Adaptive Widget Library and the process of designing the adaptations embodied in such a library.

The design of user interface adaptation is a relatively novel undertaking. Although a general methodology is available, such as Unified User Interface Design, further research is necessary on how to best fine-tune various aspects of this methodology in different design cases. The work presented in this paper may serve as an example in this respect and offers hints for discussion. A first consideration that emerges is that tools are required in order to easily integrate adaptation knowledge into user interface development. The OASIS Widget Library has been developed in order to provide developers with fundamental support in applying adaptation. Through such a library, developers can easily embed user interface components' adaptations in their user interfaces without having to design them from scratch or to implement the adaptive behaviour.

However, it should be considered that adaptation not only affects the physical level of interaction, i.e., the presentation of interactive artifacts in the user interface, but also the interaction dialogue and overall structure. For example, the length of interactions, the number of interaction objects or options, the metaphors, wordings and operators, and the depth of menus are dialogue characteristics potentially subject to adaptation. Furthermore, additional adaptation triggers could also be considered, such as, for example, computer literacy and expertise. These aspects are not explicitly addressed in OASIS at the moment. However, it should be mentioned that the Unified User Interface Methodology provides techniques and tools for gradually expanding the types and levels of adaptation in a user interface, thus offering the opportunity to address increasing and evolving adaptation design requirements [2]. Additionally, the recent uptake of ontology-driven system development demands for general approaches targeted to linking adaptation to ontologies. A potential architecture for exploiting ontologies for adaptation purposes is presented in [9].

One fundamental challenge in creating self-adaptive interfaces lies in the difficulties encountered when translating the scientific state of the art into precise rules, as there are seldom concise thresholds defined for the triggers or even for the adaptive elements. Yet this challenge can be turned into a unique opportunity: adaptation rules are probably the most concise form of shaping theories about user behavior. Once a rule is established, it can be tested with specific user groups in experimental settings. If the results indicate that a rule improves interaction for certain user characteristics, than this rule is consolidated and can be re-used. If the rule turns out to be at least not generally right, it can be dropped. Eventually, the development of self-adaptive systems could bring new importance to basic research in human-computer-interaction.

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