From Adaptations to User Interfaces for All

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Abstract This paper provides an overview of research efforts in the area of accessibility over the past decade in Europe, and follows the evolution of Research and Technological Development work from solutions based on 'a posteriori' daptation to the notion of User Interfaces for All. The aim of the paper is to outline the beginning of an evolutionary path driving from reactive accessibility solutions to the requirement for Universal Access in the Information Society.

Keywords: *Accessibility of computer-based applications and services, adaptations, User Interfaces for All, Unified User Interface Development.*

1. INTRODUCTION

Amongst the ingredients of success of the emerging Information Society, *accessibility* is considered to be of paramount importance. The issue of accessibility concerns the right of *all* citizens to obtain and maintain access to a society-wide pool of information resources and interpersonal communication facilities, given the varieties of context (Stephanidis et al., 1998a). Over the years, accessibility has been addressed through various collaborative efforts. These fall into two main categories, which are distinctively characterised by their underlying focus and normative perspectives. The first, which is also referred as reactive approach, aims to adapt products so as to build the required accessibility features. The qualification of this approach as reactive results precisely from the 'a posteriori' adaptations that are delivered. The second and more recent approach aims to proactively account for accessibility by taking appropriate actions during the early phases of a product's life cycle.

This paper introduces and compares the two approaches, and provides an overview of some of the landmark projects in the study of user interface accessibility in Europe. The aim is to outline the beginning of an evolutionary path driving from reactive accessibility solutions, to the application of Universal Design in Human-Computer Interaction, and, ultimately, to the broader concept of Universal Access in the Information Society.

2. APPROACHES TO ACCESSIBILITY

2.1 The reactive approach to accessibility

The traditional approach to rendering applications and services accessible to people with disabilities, is to adapt such products to the abilities and requirements of individual users. Adaptations facilitate access to the interface via suitable mechanisms, such as, for example, filtering (e.g., Mynatt and Weber, 1994), dedicated interaction techniques, such as, for example, scanning (e.g., Savidis et al., 1997a), and specialised input/output devices (e.g., tactile display, switches, eye-gaze system). Typically, the results of adaptations involve the reconfiguration of the physical layer of interaction, and when necessary, the transduction of the visual interface manifestation to an alternative modality (e.g., auditory or tactile). The reactive approach to accessibility, although it may be the only viable solution in certain cases (Vanderheiden, 1998), suffers from some serious shortcomings, especially when considering the radically changing technological environment, and, in particular, the emerging Information Society technologies. Firstly, reactive approaches are not viable in sectors of the industry characterised by rapid technological change. By the time a particular access problem has been addressed, technology has advanced to a point where the same or a similar problem re-occurs. In some cases, adaptations may not be possible at all, without loss of functionality. For example, in the early versions of windowing systems, it was impossible for the programmer to obtain access to certain window functions, such as window management. In subsequent versions, this shortcoming was addressed by the vendors of such products, allowing certain adaptations (e.g., scanning) on interaction objects on the screen.

Finally, adaptations are programming-intensive, which raises several considerations for the resulting products. Many of them bare a cost-implication that amounts to the fact that adaptations are difficult to implement and maintain. The situation is further complicated by the lack of tools to facilitate ease "edit-evaluate-modify" development cycles (Stephanidis et al., 1995).

2.2 The proactive approach to accessibility

Due to the above shortcomings of the reactive approach to accessibility, there have been proposals and claims for proactive strategies, resulting in generic solutions to the problem of accessibility (i.e., universal access). Proactive strategies entail a purposeful effort to build access features into a product, as early as possible (e.g., from its conception, to design and release), thus minimising the need for a posteriori adaptations, and delivering products that can be tailored for use by the widest possible end-user population (Stephanidis, 1995). Universal access to computer-based applications and services implies more than direct access or access through assistive technologies, since it emphasises the principles that accessibility should be a design concern, and that the needs of the broadest possible end-user population should be taken into account in the early design phases of new products and services.

Universal Design in the Information Society has been defined (Stephanidis et al., 1998a) as the conscious and systematic effort to proactively apply principles, methods and tools, in order to develop IT&T products and services which are accessible and usable by all citizens, thus avoiding the need for a posteriori adaptations, or specialised design. The rationale behind universal design is that designing for the "average" user leads to products that do not cater for the needs of the broadest possible population, thus excluding categories of users (Bergman and Johnson, 1995). Contrasting this view, the normative perspective of universal design is that there is no "average" user and, consequently, design should be targeted towards all potential users.

Universal design often undergoes criticism concerning practicality and cost justification. In particular, it has been claimed that "many ideas that are supposed to be good for everybody aren't good for anybody" (see Lewis and Rieman, 1994, - Section 2.1, Paragraph 3). However, universal design in IT&T products should not be conceived as an effort to advance a single solution for everybody, but as a user-centred approach to providing products that can automatically address the possible range of human needs, requirements and preferences. Another common argument is that universal design is too costly (in the short-term) for the benefits it offers. Though the field lacks substantial data and comparative assessments as to the costs of designing for the broadest possible population, it has been argued that (in the medium- to long-term) the cost of inaccessible systems is comparatively much higher, and is likely to increase even more, given the current statistics classifying the demand for accessible products (Bergman and Johnson, 1995). What is really needed is economic feasibility in the long run, leading to economic efficiency (Lewis and Rieman, 1994).

3. SOME EVOLUTIONARY EFFORTS IN EUROPE: A RETROSPECTIVE

Having identified the main strands towards improving accessibility, we will now concentrate on some of the landmark projects[1] in the study of accessibility in Europe. These projects (see Acknowledgements) were funded by European Commission Programmes, have span across a decade, and have pursued an evolutionary path, initially adopting reactive, and subsequently advocating proactive strategies to accessibility. These projects show a progressive shift towards more generic solutions to accessibility. Most of them embodied both a reactive RTD component as well as a focus on proactive strategies and methods. The latter were initially oriented towards the formulation of principles, while later on emphasis was placed on the demonstration of technical feasibility. The main contributions and interconnection of these projects are briefly outlined in figure 1. A more in depth review can be found in (Stephanidis and Emiliani, 1999).

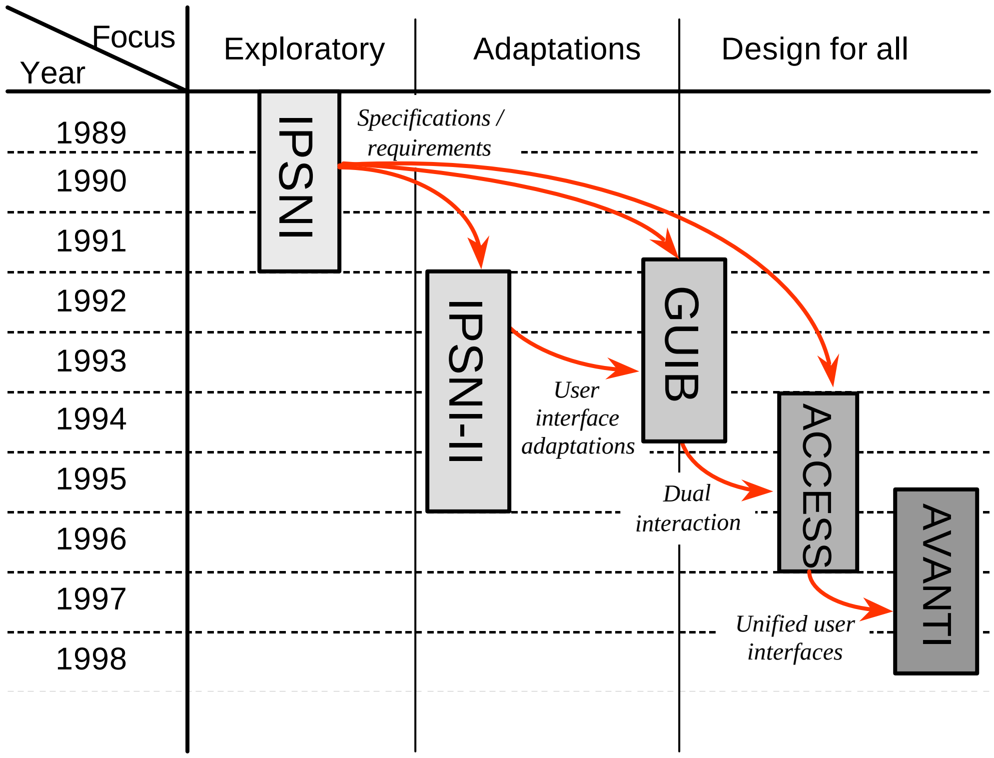

Figure 1. Chronological sequence and focus of the projects reviewed

3.1 Exploratory studies

The IPSNI project has investigated the possibilities offered by the multimedia communication network environment, and in particular B-ISDN (Broadband Integrated Services Digital Network), for the benefit of people with disabilities. Technological advances in this field include increased network bandwidth and reliability, as well as more powerful, more mobile, and less costly network terminals.

The starting point of the project was the consideration that increased bandwidth and reliability of the B-ISDN environment offers new opportunities for the provision of multimedia information, which additionally can be manipulated by the end-user through innovative interaction techniques and styles. The utilisation of network management techniques allows the application/service customisation according to the end-user needs and abilities and the provision of special services, where appropriate. As a consequence, the introduction of B-ISDN applications and services offers new opportunities for the socio-economic integration and independent living of disabled and elderly

[1] The authors had direct involvement in these projects in positions of responsibility.

people, including, but not limited to, distant learning, tele-working, tele-shopping, sophisticated alarm systems, etc.
In order to enable the accessibility of disabled people to the emerging telecommunications technology, the IPSNI project considered essential that the designers and/or providers of the services and terminal equipment take explicitly into account, at a very early stage of design, their interaction requirements. The project has addressed problems faced by people with special needs in accessing B-ISDN environments through an in-depth analysis of interaction requirements, based on human factors issues and ergonomics criteria. Several barriers have been identified which prevent people with special needs from having access to information available through the network. The identified barriers are related to accessibility of the terminal, accessibility of the anticipated services, and the perception of the service information.
In order to cope with these difficulties, different types of solutions have been proposed, which address the specific user abilities and requirements, at three different levels:
(i) Adaptations within the user-to-terminal and the user-to-service interface, through the integration of additional input/output devices and the provision of appropriate interaction techniques, taking into account the abilities and requirements of the specific user group.
(ii) Service adaptations through the augmentation of the services with additional components capable of providing redundant or transduced information.
(iii) Introduction of special services, only in those cases where the application of the two previously mentioned types of adaptation are not possible or effective.

3.2 Adaptation of telecommunication terminals

The IPSNI-II built on the results of the IPSNI project, and demonstrated the technical feasibility of providing access to people with disabilities to multimedia services running over a broadband network. Adaptations of terminals and services were implemented and evaluated. In particular, two pairs of multimedia terminals (one UNIX/X-Windows based and one PC/MS-Windows based) were adapted according to the needs of the selected user groups.
Special emphasis was placed on the adaptation of the user interfaces, and for this purpose, a user interface design and construction tool was designed, named INTERACT (Stephanidis and Mitsopoulos, 1995), which takes into account the interaction requirements of disabled users. INTERACT builds on the notion of separating an interactive system in two functional components, namely the application functional core and the user interface component, thus allowing the provision of multiple user interfaces to the same application functionality. It supports the "high-level" design of the interaction dialogue, i.e., independently from the presentation details and operational constraints of a particular technological platform (i.e., User Interface Toolkit). While INTERACT exhibits the majority of the characteristics of other state-of-the-art User Interface Builders, it also facilitates the development of graphics based applications for disabled users through the provision of enhanced user interface customisation possibilities.
The IPSNI-II project allowed an in-depth analysis of services and applications for the broadband telecommunications environment from the point of view of usability by disabled people, leading to the identification of and testing of necessary adaptations and/or special solutions. This work led to the conclusion that if emerging services, applications and terminals were designed considering usability requirements of disabled users, many of their access problems would be automatically reduced with a negligible expense. One of the conclusions was that, as a minimum, sufficient modularity and flexibility should be the basis of product implementation, in order to allow easy adaptability to the needs, capabilities and requirements of an increasing number of users.

3.3 Adaptation of graphical user interfaces

The TIDE-GUIB and TIDE-GUIB-II projects aimed to identify and provide the technological means to ensure continued access by blind users to the same computer-based interactive applications used by sighted users. The project starting point was the consideration that GUIs can be thought of as totally inaccessible by blind users, due to the fact that they have been designed to exploit the visual capabilities of sighted users and do not support non-visual interaction methods. On the other hand, multimedia user interfaces could potentially facilitate blind user interaction, provided

that appropriate design allows for easy installation and handing of special input-output devices and supports non-visual interaction methods, in addition, and in parallel, to the existing visual ones.
The short-term goal of the GUIB project was to improve adaptation methodologies of existing GUIs. Specific developments were carried out through the implementation of appropriate demonstrators enabling access to MS-WINDOWSTM (PCs) and to interactive applications built on top of the X WINDOW SYSTEM (UNIXTM based workstations). The GUIB approach to interface adaptation for blind users was based on a transformation of the desk-top metaphor to a non-visual version combining Braille, speech and non-speech audio. Access to basic graphical interaction objects (e.g., windows, menus, buttons), utilisation of the most important interaction methods, and extraction of internal information from the graphical environment were investigated. The system supports the specification of alternative output media for the various graphical interaction objects. The supported output media for non-visual interaction include speech and non-speech auditory cues, and Braille output. Input operations (e.g., exploration/selection of menu options, etc.) can be performed either by means of standard devices (keyboard or mouse) or through special devices (i.e., mouse substitutes, touch pad and routing keys of Braille device). An important feature of the method is that the whole graphical screen is reproduced in a text-based form and simultaneously presented on a monochrome screen which can be explored by blind users by means of Braille and/or speech output.

A tool was designed and implemented to facilitate the description of blind user interaction in a graphical environment and enable combinations of acoustic and tactile media for presentation and access to graphical objects (Mynatt and Weber 1994). Such a tool is mainly based on a formal language for the specification of appropriate interaction methods for the blind user, combining speech, sounds and Braille output (Weber et al., 1993). A screen reader configuration system (Stephanidis and Gogoulou, 1995) was developed to facilitate customisation of the non-visual environment.

3.4 High-level user interface development environments: Dual interfaces

A first step toward more generic and systematic solutions to the problem of accessibility was carried out in the already mentioned GUIB and GUIB-II projects. The goal of these efforts was the development of innovative user interface software technology aiming to guarantee access to future computer-based interactive applications by blind users. In particular, these projects conceived, designed and implemented a User Interface Management System as a tool for the efficient and modular development of user interfaces that are concurrently accessible by both blind and sighted users.
The concept of Dual User Interfaces (Savidis and Stephanidis, 1995a) has been proposed and defined as an appropriate basis for "integrating" blind and sighted users in the same working environment.
A Dual User Interface is characterised by the following properties: (i) it is concurrently accessible by blind and sighted users; (ii) the visual and non-visual metaphors of interaction meet the specific needs of sighted and blind users respectively (they may differ, if required); (iii) the visual and non-visual syntactic and lexical structure meet the specific needs of sighted and blind users respectively (they may differ, if required); (iv) at any point in time, the same internal (semantic) functionality is made accessible to both user groups through the corresponding visual and non-visual "faces" of the Dual User Interface; (v) at any point in time, the same semantic information is made accessible through the visual and non-visual "faces" of the Dual User Interface respectively.

The HOMER User Interface Management System (Savidis and Stephanidis, 1995a; Savidis and Stephanidis, 1998) has been developed to facilitate the design and implementation of dual interfaces. HOMER is based on a 4th generation user interface specification language. A non-visual toolkit to support non-visual interface development (Savidis and Stephanidis, 1995b; Savidis and Stephanidis, 1998), was developed and integrated within the HOMER UIMS. The non-visual library has been developed on the basis of a purposefully designed version of the Rooms metaphor, an interaction metaphor based on the physical environment of a room, and whose interaction objects are floor, ceiling, front wall, back wall, etc. Both the Athena widget set (for visual windowing interactions) and the non-visual toolkit have been imported within the HOMER UIMS maintaining the original (i.e., native) "look & feel" of their respective toolkit.

The HOMER UIMS has been utilised for building various dual interactive applications such as a payroll management system, a personal organiser and an electronic book with extensive graphical illustrations and descriptions (Savidis and Stephanidis, 1998).

3.5 Design for all in HCI

The concept of User Interfaces for all (Stephanidis, 1995, Stephanidis, 2001a) has been proposed, following the concept of *design for all,* as the vehicle to efficiently and effectively address the numerous and diverse accessibility problems. The underlying principle is to ensure accessibility at design time and to meet the individual needs, abilities and preferences of the user population at large, including disabled and elderly people.
The ACCESS project aimed to develop new technological solutions for supporting the concept of User Interfaces for all, i.e., universal accessibility of computer based applications, by facilitating the development of user interfaces automatically adaptable to individual user abilities, skills, requirements, and preferences. The project approached the problem at two levels: (i) the development of appropriate methodologies and tools for the design and implementation of accessible and usable user interfaces, and (ii) the validation of the approach through the design and implementation of demonstrator applications in two application domains, namely interpersonal communication aids for speech-motor and language-cognitive impaired users, and hypermedia systems for blind users.

The ACCESS project has proposed the concept of Unified User Interface development, with the objective of supporting platform independence and target user-profile independence, i.e., possibility of implementation in different platforms and adaptability to the requirements of individual users (Stephanidis et al., 1997a; Savidis, et al., 1997b; Akoumianakis et al., 2000; Stephanidis, 2001b; Savidis and Stephanidis, 2001a; Savidis and Stephanidis, 2001b; Savidis et al., 2001). Unified User Interface development provides a vehicle for designing and implementing interfaces complying with the requirements of accessibility and high quality interaction.
The Unified User Interface development method comprises design- and implementation-oriented techniques for accomplishing specific objectives. The design-oriented techniques (unified user interface design) aim towards the development of rationalised design spaces, while the implementation-oriented techniques (unified user interface implementation) provide a specifications-based framework towards constructing interactive components and generating the run-time environment for a unified interface.

In order to efficiently support the implementation of Unified User Interfaces, a development environment has been built, which includes a high-level language for User Interface specification, (Savidis and Stephanidis, 1997b), and a tool that automatically generates the implementation from such high-level specifications (Savidis and Stephanidis, 1997b; Stephanidis et al., 1997a, Savidis and Stephanidis, 2001c). The high-level language and the tool constitute a novel User Interface Management System for Unified User Interface development. Additionally, another tool has been developed, which enables the generation of platform independent toolkits (i.e., programming libraries) for unified interface implementation (Savidis et al., 1997a). Two toolkits have been generated as examples of the viability of the approach: an augmented version of the Windows interaction object library, including scanning techniques (Savidis et al., 1997b); and a toolkit for non-visual interaction (Savidis et al., 1997c). The adaptability of the User Interface to the specific needs, abilities and preferences of the target user group is achieved at design time by means of a user modelling tool (Akoumianakis and Stephanidis, 1997a; Akoumianakis and Stephanidis, 1997b, Akoumianakis and Stephanidis, 2001).

The Unified User Interface development method was validated in the ACCESS project in two application domains, namely the development of a hypermedia application accessible by blind people (Petrie et al., 1997) and the development of two communication aid applications for the speech-motor and language-cognitive impaired users (Kouroupetroglou et al., 1996). Additionally, the project contributed to non-technological areas such as legislation and standardization in Assistive Technology, by providing general and specific recommendations (Stephanidis, et al., 1997b)

The AVANTI project applied the unified user interface development in the implementation of an accessible Web browser for Web-based interaction with metropolitan information systems (Bini and Emiliani, 1997; Bini et al., 1997). The systems were targeted for the population at large, including people with disabilities. In particular, based on the U²ID methodology, a Web browser has been designed and implemented to act as the front end of the information systems, and provide accessibility and high quality of interaction to able-bodied, blind and motor-impaired users (Stephanidis, et al., 1998b, Stephanidis et al., 2001).

4. CONCLUSIONS

This paper has reviewed recent progress in the area of computer accessibility by disabled and elderly people. In particular, it presented a review of both 'reactive' and 'proactive' approaches in the context of EC funded RTD projects. The paper developed an argumentation for the proactive approach, and described how such an effort has been consolidated towards designing user interfaces for the broadest possible end-user population. From the results of the work presented, it becomes evident that accessibility in the Information Society is more of a challenge than a utopia: available know-how has reached a level of maturity that provides evidence of technological feasibility in the area of accessible computer-based products and services.

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- The IPSNI-II R2009 (Integration of People with Special Needs in IBC) project was partially funded by the RACE-II Programme of the European Commission (DG XIII, and lasted 48 months (1/ 1/1992 to 31/12/1995). Partners of the IPSNI-II consortium are: IROE-CNR, Italy; DUMC, United Kingdom; IRV, The Netherlands; CSELT, Italy; KUL, Belgium; Institute of Computer Science-FORTH, Greece; VTT, Finland.
- The GUIB TP103 (Textual and Graphical User Interfaces for Blind People) project was partially funded by the TIDE Pilot Action Programme of the European Commission, and lasted 18 months (1/1/1991 to 31/5/1993). The partners of the GUIB consortium are: IROE-CNR, Italy (Prime Contractor); F H Papenmeier GmbH & Co KG, Germany; IFI-University of Stuttgart, Germany; Institute of Computer Science-FORTH, Greece; RNIB, England; Institute of Telecommunications-TUB, Germany; Department of Computer Science-FUB, Germany; Vrije Universiteit Brussel, Belgium; VTT, Finland.
- The GUIB-II TP215 (Textual and Graphical User Interfaces for Blind People) project was partially funded by the TIDE Program of the European Commission (DG XIII), and lasted 18 months (1/6/1993 to 30/11/1994). Partners of the GUIB-II consortium are: IROE-CNR, Italy; Institute of Computer Science-FORTH, Greece; Vrije Universiteit Brussels, Belgium; Department of Computer Science-FUB, Germany; Institute of Telecommunications-TUB, Germany; IFI, University of Stuttgart, Germany; VTT, Finland; RNIB, England; F.H. Papenmeier Gmb & Co KG, Germany.
- The ACCESS TP1001 (Development platform for unified ACCESS to enabling environments) project was partially funded by the TIDE Programme of the European Commission (DG XIII), and lasted 36 months (1/11/994 31/12/1996. The partners of the ACCESS consortium are: CNR-IROE (Italy) - Prime contractor; ICS-FORTH (Greece); University of Hertforshire (United Kingdom); University of Athens (Greece); NAWH (Finland); VTT (Finland); Hereward College (United Kingdom); RNIB (United Kingdom); Seleco (Italy); MA Systems & Control (United Kingdom); PIKOMED (Finland).
- The AVANTI AC042 (Adaptable and Adaptive Interaction in Multimedia Telecommunications Applications) project was partially funded by the ACTS Program of the European Commission, and lasted 36 months (1/09/1995 to 31/8/1998). The partners of the AVANTI consortium are: ALCATEL Italia, Siette division (Italy) - Prime Contractor; IROE-CNR (Italy); ICS-FORTH (Greece); GMD (Germany), VTT (Finland); University of

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Thus, the user interface can be adapted in its: presentationâ€"the perceivable aspects, including media and interaction techniques, layout, graphical attributes; dynamic behaviour, including navigation structure, dynamic activation, and deactivation of interaction techniques; and content, including texts, labels, and images.Â One of the main reasons for the increasing interest in user interface adaptation is the device fragmentation stimulated by technological evolution, in particular in mobile devices. Device fragmentation concerns hardware and support for formats, browsers, audio/video playback/streaming, etc. Adaptation Example. The DOM adapter class LockingValidator used by the ATF State Chart Editor Sample contains this line in its OnNodeSet() method: m_lockingContext = this.Cast(); // required ILockingContext. This code is attempting to get an adapter for LockingValidator to the interface ILockingContext.Â You can adapt a DOM adapter to all interfaces implemented by a set of DOM adapters by doing the following: Define a set of DOM adapters for some type. Create DomNodes for that type or initialize all the DOM adapters. When you do this, you can adapt a DomNode defined for a type to any interface that any of the DOM adapters defined for that type implement. Adding Adapter Creators. You could use : Builder.RegisterAssemblyTypes(assemblies). .AsClosedTypesOf(typeof(ICommonMapper<,,>)); Where assemblies is a collection of the assemblies where your types belong. If you have a PersonMapper that inherits from ICommonMapper, Autofac will be able to resolve ICommonMapper.