Technology & Disability Journal, 1999, 10 (1), 21-44

‘Connecting’ to the Information Society: a European perspective

Constantine Stephanidis[1] and Pier Luigi Emiliani[2]

[1] Institute of Computer Science,
Foundation for Research and Technology - Hellas,
Science and Technology Park of Crete,
Heraklion, Crete, GR-71110 Greece
e-mail: cs@ics.forth.gr

[2] Institute of Research on Electromagnetic Waves "Nello Carrara" (IROE),
National Research Council,
Via Panciatichi 64, Firenze, I-50127 Italy
e-mail: ple@iroe.fi.cnr.it

Abstract

This paper addresses the critical issue of accessibility of interactive applications and services in the Information Society by disabled and elderly people, following two paths. Firstly, the paper develops an argumentation for proactive and generic strategies towards designing for the broadest possible end-user population, including disabled and elderly people, as opposed to reactive, adaptation-based approaches. To this end, the paper provides an overview of research and development work in the area of accessibility in Europe, and follows the evolution of research work from adaptation based solutions to the notion of universal access to the Information Society. The paper also reviews the current state of the art in the area of universal design, and elaborates on the contributions of the unified user interface development method towards the development of an accessible Information Society. Secondly, the paper discusses necessary steps to advance the available results beyond technological feasibility, towards the economic efficiency and efficacy needed in the long run. It concludes by pointing out the compelling need for international collaboration and discusses recent efforts in this direction.

Keywords: *Information Society, accessibility of computer-based applications and services, adaptations, User Interfaces for All, Unified User Interface Development, technology transfer, non-market institutions.*

1 Introduction and Background

The term Information Society, although difficult to define accurately, refers to the new socio-economic environment likely to occur as a result of the ongoing fusion of information technology, telecommunications, multimedia and consumer electronics. The main feature of the Information Society is the emergence of an intelligent distributed environment, where access to information in heterogeneous databases, and interpersonal communication, will be concurrently available through a variety of access technologies. These will include not only computers and computer-based telecommunication terminals, but also television sets, fixed-

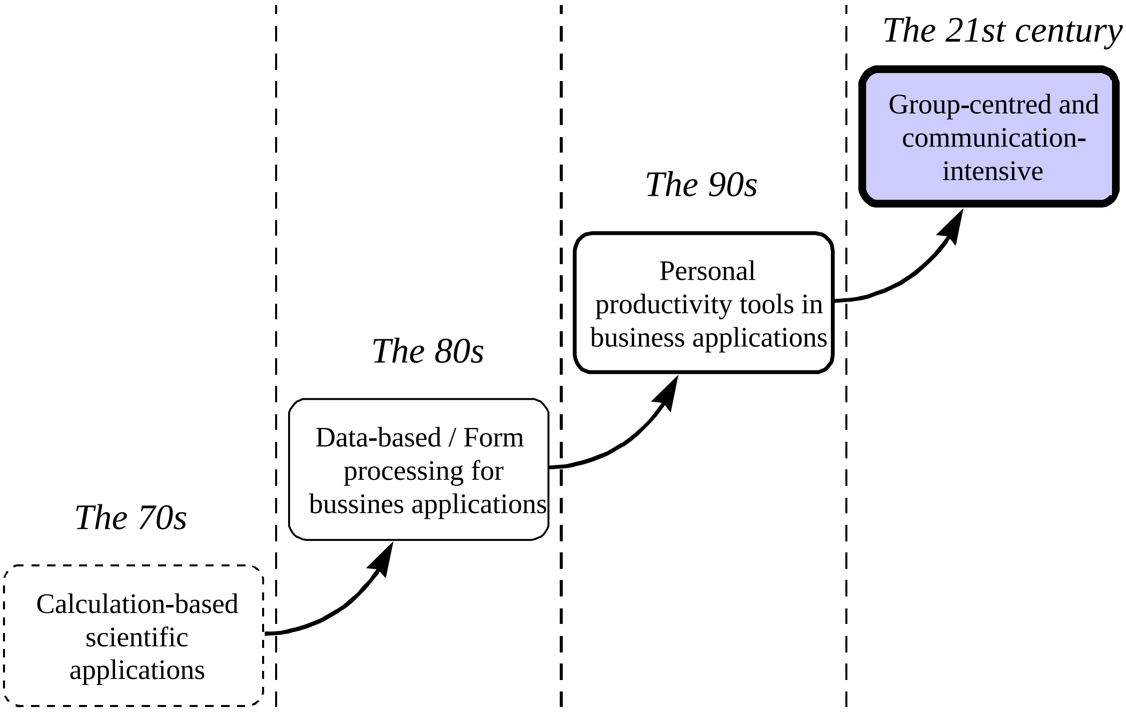


FIGURE 1. Shift in computer paradigms and forecast of trends for the 21st century (adapted from Stephanidis et al., 1998a)

point and mobile telephones, intelligent information appliances and consumer electronics products, etc..

The emergence of the Information Society is associated with radical changes in both the demand and the supply of new products and services. The changing pattern in demand is due to a number of characteristics of the customer base, including: (i) increasing number of users characterised by diverse abilities, requirements and preferences; (ii) product specialisation to cope with the increasing variety of tasks to be performed, ranging from complex information processing tasks to the control of appliances in the home environment; and (iii) increasingly diverse contexts of use (e.g., business, residential and nomadic).

On the other hand, one can clearly identify several trends in the supply of new products and services. These can be briefly summarised as follows: (a) increased scope of information content and supporting services; (b) emergence of novel interaction paradigms (e.g., virtual and augmented realities, ubiquitous computing); and (c) shift towards group-centred, communication-, collaboration-, and cooperation-intensive computing.

This general trend is exemplified by the shift in paradigm in the use of computers, leading to the present situation which is made possible by the fusion between information technology and telecommunications (Figure 1). As suggested by Figure 1, from the early calculation-intensive nature of work that was prevalent in the early 1960s, computer-based systems are progressively becoming a tool for communication, collaboration and social interaction, which are the main characteristics of the emerging intelligent information environment. From a specialist's device, the computer is being transformed into an information appliance for the citizen in the Information Society.

This process is expected to alter human interaction, individual behaviour and collective consciousness, as well as to have major economic and social effects (Danger et al., 1996). As with all major technological changes, this can have disadvantages and advantages. New opportunities are offered by the reduced need of mobility, due to the emergence of networked collaborative activities, and by the increased possibility of network meditated interpersonal communications. However, difficulties may arise in accessing multimedia services and applications when users do not have sufficient motor or sensory abilities. The complexity of control of equipment, services and applications, and the risk of information overload, may create additional problems.

The above mentioned problems are particularly relevant for people with disabilities, who have been traditionally underserved by technological evolution. Disabled and elderly people currently make up about the 20% of the market in the European Union, and this proportion will grow with the ageing of the population to an estimated 25% by the year 2030 (Vanderheiden, 1990; Gill, 1996). Not only there is a moral and legal obligation to include this part of the population in the emerging Information Society, but there is also a growing awareness in the industry that disabled and elderly people can no longer be considered as insignificant in market terms. Instead, they represent a growing market to which new services can be provided. However, due to the foreseen increase of citizens who will need to interact with the emerging technological environment, accessibility can no longer be considered as a specific problem of people with disabilities, but of the society at large, if suitable actions are not undertaken.

The normative perspective of this paper is that the Information Society has the potential to improve the quality of life of citizens and the efficiency of our social and economic organisation, to reinforce cohesion, and to offer new opportunities for all citizens in society, including disabled and elderly people. However, it may also introduce new barriers, human isolation and alienation, if the diverse requirements of all potential users are not taken seriously into consideration and an appropriate "connection" to computer applications and services is not guaranteed. As a consequence, it may lead to a "two-tier" society of "haves" and "have-nots", in which only a part of the population has access to the new technology, is comfortable using it and can fully enjoy the benefits (European Commission, 1994).

The paper is organised as follows. Section 2 outlines the main perspectives which have emerged to address accessibility and provides a retrospective account of some of the author's research and development project work which has facilitated a deeper insight into the issues involved, with particular emphasis on the aspects related to Human Computer Interaction (HCI). The following two sections elaborate on specific projects in chronological sequence and according to their respective focus (i.e., reactive versus proactive approach) and deliverables, emphasising the notion of *user interfaces for all* and how it has been facilitated by the unified user interface development methodology. The next section compares the reactive against the proactive approach and draws conclusions on their relative merits. Then, the paper discusses some of the non-technological conditions which are needed to guarantee the success of a proactive approach to accessibility, highlighting the inter-relationships between policy and Research and Technological Development (RTD), and identifying the critical role of non-market institutions. The paper ends with a summary and conclusions.

2. Accessibility

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 be "connected" (i.e., to obtain and maintain access) to a society-wide pool of information resources and interpersonal communication facilities, given the varieties of context.

2.1 Perspectives on accessibility

Over the years, accessibility has been addressed through various collaborative efforts. These fall into three 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. Though cost/benefit data are missing to assess the economic efficacy of proactive approaches, the attention devoted to the issue is increasing. Finally, the third perspective is that accessibility can be addressed by means of policy measures, such as legislation and standardisation. Each one of these approaches is briefly elaborated below, so as to set a 'global' scene on accessibility and to provide the framework for the argumentation of this paper.

2.1.1 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, Vernardos and Stephanidis, 1997), 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, based on a posteriori adaptations, though important to partially solve some of the accessibility problems of people with disabilities, 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. The typical example that illustrates this state of affairs, is the case of blind people's access to computers. Each generation of technology (e.g., DOS environment, Windowing systems, and multimedia) caused a new wave of accessibility problems to blind users, addressed through dedicated techniques such as text translation to speech for the DOS environment, off-screen models and filtering for the Windowing systems.

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. Minor changes in product configuration, or the user interface, may result in substantial resources being invested to re-build the accessibility features. The situation is further complicated by the lack of tools to facilitate ease "edit-evaluate-modify" development cycles (Stephanidis, Savidis and Akoumianakis, 1995).

2.1.2 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). Such an approach should aim to minimise the need for a posteriori adaptations and deliver products that can be tailored for use by the widest possible end-user population. In the context of Human Computer Interaction, such a proactive paradigm should address the fundamental issue of "universal access" to the user interface, namely how we can design systems that permit systematic and cost-effective approaches to accommodating all users (Stephanidis, 1995; Mueller et al., 1997).

Proactive approaches to accessibility are typically grounded on the notions of *universal access* and *design for all*. The term *design for all* (or *universal design*, the terms are used interchangeably) is not new. It is well known in several engineering disciplines, such as for example, civil engineering and architecture, with many applications in interior design, building and road construction, etc.. However, while existing knowledge may be considered sufficient to address the accessibility of physical spaces, this is not the case with Information Society Technologies, where universal design is still posing a major challenge. Universal access to computer-based applications and services implies more than direct access or access through add-on (assistive) technologies, since it emphasises the principle that accessibility should be a design concern, as opposed to an afterthought. To this end, it is important that the needs of the broadest possible end-user population are taken into account in the early design phases of new products and services.

Design for all 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 Information Technology and Telecommunications (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 grounded on the claim that designing for the "typical" or "average" user, as the case has been with "conventional" design of IT&T

applications and services, leads to products which 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, there is a line of argumentation raising the concern that "many ideas that are supposed to be good for everybody aren't good for anybody" (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 (Vanderheiden, 1990; Bergman and Johnson, 1995). What is really needed is economic feasibility in the long run, leading to versatility and economic efficiency (Vernadakis, Stephanidis and Akoumianakis, 1997).

2.1.3 Policy initiatives

In addition to RTD efforts aiming to provide solutions to accessibility problems (following either reactive or proactive approaches), there have been also some policy initiatives. In the recent past, the principles and practice of design for all have been progressively adopted and advocated by an increasing proportion of the research community (i.e., research consortia in the context of various RTD Programmes of the European Commission such as TIDE[1], RACE[2], ACTS[3], TAP[4], COST[5]), industrial consortia (such as the USA Telecommunications Policy Roundtable), scientific and technical committees (e.g., USACM[6]), as well as national legislation (e.g., Americans with Disability Act and the 1996 Telecommunications Act in the USA), and international directives (e.g., United Nations General Assembly Standard Rules of 1995).

In addition, there are several on-going efforts to promote accessibility in national and international standardisation bodies and industrial consortia (e.g., the World Wide Web Consortium - W3C). The majority of these efforts aim to formulate accessibility guidelines, either general (e.g., HFES/ ANSI Draft, Section 5[7]), platform specific (e.g., for Graphical User Interfaces or the Web[8]), or domain-specific guidelines (e.g., for text editing, graphic

---

1 Telematics for Disabled and Elderly people (http://www2.echo.lu/telematics/disabl/disabel.html).

2 Research and Development in Advanced Communications Technologies in Europe (http://www.analysys.co.uk/race/).

3 Advanced Communications Technologies & Services (http://www.uk.infowin.org/ACTS/).

4 Telematics Applications Programme (http://www2.echo.lu/telematics/home.html).

5 European Co-operation in the fields of Scientific and Technical Research (http://www.stakes.fi/cost219/index.html).

6 The ACM U.S. Public Policy Committee (http://www.acm.org/usacm/).

7 The following is an example of general guidelines: Software should enable as many input and output alternatives as possible (ANSI/HFES, 1997).

8 The following is an example of platform specific guidelines concerning the Web: Document conversion

manipulation[9]). Such guidelines are typically documented on paper, and reflect previous experience gained and best practice available for designing accessible interactive software (also including content). The systematic collection, consolidation and interpretation of these guidelines is currently pursued in the context of international collaborative initiatives (e.g., W3C-WAI Initiative[10], ISO TC 159 / SC 4 / WG 5[11]), as well as national projects, such as the Universal Design Project (Story, 1998), and international scientific fora[12]. In this context, it is worth pointing out the efforts carried out by the W3C-WAI Initiative in the area of Web accessibility guidelines.

2.2 A retrospective of a decade of evolutionary efforts in Europe

Having identified the main strands towards improving accessibility, we will now concentrate on some of the landmark projects[13] in the study of accessibility in Europe. These projects were funded by European Commission Programmes[14], have span across a decade, and they have pursued an evolutionary path, initially adopting reactive, and subsequently advocating proactive strategies to accessibility. Their main contributions and interconnection are briefly outlined in figure 2, while their respective technical focus and achievements is summarised in Table 1.

What is important to notice in relation to these projects is the progressive shift towards more generic solutions to accessibility. In fact with the exception of early exploratory studies (e.g., IPSNI), which did not have an RTD development dimension, all remaining projects 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. Thus, early development efforts aimed to provide tools for ease adaptation of a hierarchical interaction model to alternative modalities. The INTERACT user interface design and construction tool (see section 3.2.1) was developed in the context of IPSNI-II and is representative of this effort. One of the shortcomings of this approach was its focus on translating a graphical user interface into an alternative non-visual manifestation. However, for blind users who are not familiar with graphical environments, it was difficult to grasp the inherently visual concepts (e.g., the pop-up menu). Such an observation, which was also supported by concurrent developments in the context of the GUIB project (first phase, see section 3.2.2), led to the realisation that adaptations cannot

---

algorithms should produce accessible markup (see http://www.w3c.org/WAI/).

9 The following is an example of domain-specific guidelines concerning graphic manipulation: Software should enable users to change graphic attributes of visual codes used to represent data, without changing the meaning of that data (ANSI/HFES, 1997).

10 World Wide Web Consortium - Web Accessibility Initiative (http://www.w3c.org/WAI/).

11 International Standards Organisation, Technical Committee 159 (Ergonomics) / Subcommittee 4 (Ergonomics of human-system interaction) / Working Group 5 (Software Ergonomics and human-computer dialogues).

12 E.g., the International Scientific Forum "Towards an Information Society for All" (Stephanidis et al., 1998).

13 The authors had direct involvement in these projects in positions of responsibility. Pier Luigi Emiliani was the Project manager of the projects IPSNI, IPSNI-II, GUIB, GUIB-II, and ACCESS, as well as the technical manager of the project AVANTI. Constantine Stephanidis was the technical manager of ACCESS and the Scientific Responsible for the research and development work reported in this paper, which was carried out at ICS-FORTH, Greece, in the context of these consortia.

14 A brief account of some of the European Commission Programmes that have funded these projects can be found in the Appendix.

provide an effective approach for a generic solution to the accessibility problems of blind users.

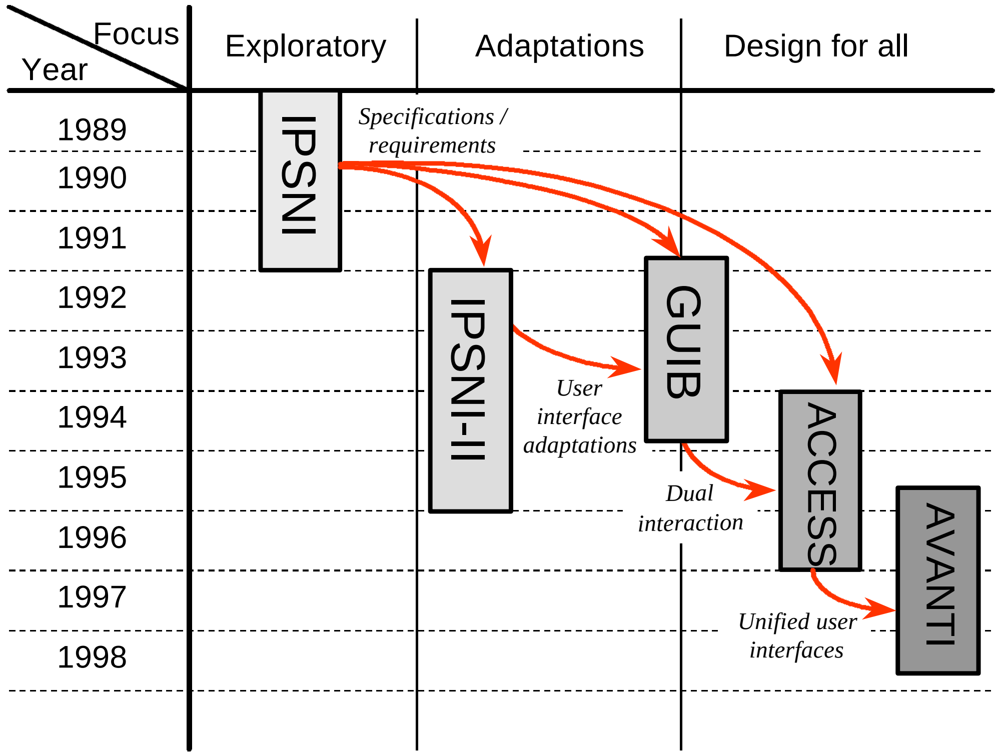


FIGURE 2. Chronological sequence, focus and some of the key outcomes of the projects reviewed

GUIB-II, building on the previous results, advanced a proposal for such a generic solution, which was based on the concept of dual interaction (see section 4.1). The HOMER User Interface Management System (UIMS), which provided an implementation platform for dual interaction, was the first ever practical demonstration of proactive strategies. Following this development, the approach was generalised and determined the focus and content of the ACCESS project (see section 4.2).

ACCESS delivered the unified user interface development methodology and several tools and prototypes to substantiate the viability of a universal design perspective into HCI. More recently, the principles of unified user interface development were applied in the context of the AVANTI project (see section 4.3), which developed web browsers inherently accessible by sighted, non-sighted and speech-motor and language-cognitive impaired users.

The above brief account of the issues involved, of the projects that dealt with them and of the systems that have been developed, is further elaborated in the following two sections, where each of these projects is discussed in some detail, and some of the key outcomes are presented.

Table 1. Main achievements of the EU funded projects IPSNI, ISPSNI-II, GUIB, GUIB-II, ACCESS and AVANTI

IPSNI January 1st, 1989 to December 31, 1991	• User requirements of people with disabilities for accessing telematic terminals, services and applications (IPSNI Consortium, 1991a) • User-to-terminal, and user-to-service interaction models (IPSNI Consortium, 1990) • Technical specifications for the development of adapted telematic terminals (IPSNI Consortium, 1991b)
IPSNI-II January 1st, 1992 to December 31, 1995	• Demonstrators of adapted telematic terminals for the MS-Windows and the X-Windows platforms (IPSNI II Consortium, 1993) • Prototypes of special purpose interaction peripherals, e.g., mouse emulators (IPSNI-II Consortium, 1992) • INTERACT: tool for developing user interfaces accessible by various user groups (prototype system supporting sighted, blind, low vision and motor-impaired users) (Stephanidis and Mitsopoulos 1995) • Demonstrators of special purpose services for people with disabilities (IPSNI II Consortium, 1994)
GUIB December 1st, 1991 to May 31, 1993 **GUIB-II** June 1st, 1993 to November 30, 1994	• BRAILLEX 2D: transitory Braille display (developed and commercialised) (Papenmeier, 1999a) • WINDOTS: screen reader for transitory Braille displays for the MS-Windows platform (developed and commercialised) (Papenmeier, 1999b) • GUIB-ERL: formal language for the specification of appropriate interaction methods for Blind users combining speech, sounds and Braille output (Weber et al., 1993) • Prototypes of speech-based screen readers for the MS-Windows (GUIB Consortium, 1994) and the X-Windows platforms (Weber, Kochanek, Stephanidis, Gogoulou, 1994) • Prototype system supporting spatialised 3D sound (Crispien, Wurz, Weber, 1994) • CONFIG: screen reader configuration system (prototype system that facilitates customisation of the non-visual environment) (Stephanidis and Gogoulou, 1995) • COMONKIT: non-visual toolkit (user interface toolkit for supporting non-visual interaction) (Savidis and Stephanidis, 1995b; Savidis and Stephanidis, 1998) • Definition of dual user interfaces, and specification of tools for supporting their development (Savidis and Stephanidis 1995b) • HOMER: user interface management system (prototype system for developing dual user interfaces accessible by both sighted and blind users) (Savidis and Stephanidis, 1998)

ACCESS January 1st, 1994 to December 31, 1996	• Definition of unified user interfaces and specification of a new methodology for supporting their development (Savidis et al., 1997) • A complete set of tools for developing unified user interfaces: USE-IT (Akoumianakis and Stephanidis, 1997a; Akoumianakis and Stephanidis, 1997b), G-DISPEC (Savidis and Stephanidis, 1997b), HAWK (Savidis, Stergiou and Stephanidis, 1997), MS-TOOL (Savidis, Vernardos and Stephanidis, 1997), PIM (Savidis and Stephanidis, 1997a) • I-GET: user interface management system (an integrated environment for designing and developing unified user interfaces) (Stephanidis and Savidis, 1997) • Application of the ACCESS technology and tools in the development of a demonstrator multimedia system accessible by blind people (Petrie et al., 1997) • ATIC: a novel architecture for developing inter-personal communication aids for people with disabilities (Kouroupetroglou et al., 1996) • Application of the ACCESS technology and tools in the development of a demonstrator communication system accessible by motor and cognitive disabled people (ACCESS Consortium, 1996) • Contribution to standardisation activities regarding accessibility; proposal of a new ISO work item on accessibility (Stephanidis and Akoumianakis, 1997)
AVANTI September 1st, 1995 to August 31, 1998	• Prototype system of a user modelling component for supporting adaptable and adaptive interaction (Fink, Kobsa and Nill, 1996; Fink, Kobsa and Nill, 1997) • Prototype system of an adaptable and adaptive Web browser (Stephanidis et al., 1998) • Demonstrator multimedia information systems with adaptable and adaptive information content and user interface (Bini and Emiliani, 1997; Bini, Ravaglia and Rella, 1997)

3. The reactive tradition

3.1 Exploratory studies

The IPSNI project[15] has investigated the possibilities offered by the multimedia communication network environment, and in particular B-ISDN (Broadband Integrated Services Digital

[15] The IPSNI R1066 (Integration of People with Special Needs in IBC) project was partially funded by the RACE Programme of the European Commission, and lasted 36 months (January the 1st, 1989 to December the 31, 1991). For the list of consortium partners see the Acknowledgements section.

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 offer 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 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 RTD efforts

3.2.1 Adaptation of telecommunication terminals

The IPSNI-II[16] 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

[16] The IPSNI-II R2009 (Access to B-ISDN Services and Applications by People with Special Needs) project was partially funded by the RACE-II Programme of the European Commission, and lasted 48 months (January the 1st, 1992 to December the 31, 1995). For the list of consortium partners see the Acknowledgements section.

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. More specifically, INTERACT supports different interaction styles through the utilisation of alternative interaction channels and media; the audio, visual and tactile modalities can be selected by the user interface designer, taking into consideration the characteristics of the target user group and the scope of the particular application. For instance, in order to support the development of graphics-based applications accessible by blind users, INTERACT enhances the graphical objects with additional attributes (e.g., presentation in auditory or tactile form) and provides facilities for the exploration of the graphical objects of the various applications (e.g., audio-based navigation). Figure 3 shows the stages in user interface construction that are supported by INTERACT.

The developed prototype addresses the needs and requirements of blind, low vision and motor-impaired users through the provision of appropriate interaction techniques, and the utilisation of suitable input and output devices for each user category. The supported interface styles include tactile-based user interfaces, speech based user interfaces, and combined speech and tactile based user interfaces. Also, it enables the incorporation of large size widgets, large size widgets with auditory cues, and large size widgets with speech, to facilitate the interaction for low-vision users. In this context, the IPSNI-II project has tested a number of special interaction peripherals and adaptation solutions (e.g., mouse emulators, screen keyboards, tactile and speech devices). Furthermore, it has developed special prototypes of services for disabled users, such as multimedia e-mail and computer based interviewing (i.e., a non real-time communication service based on structured multiple choice answers).

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 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.

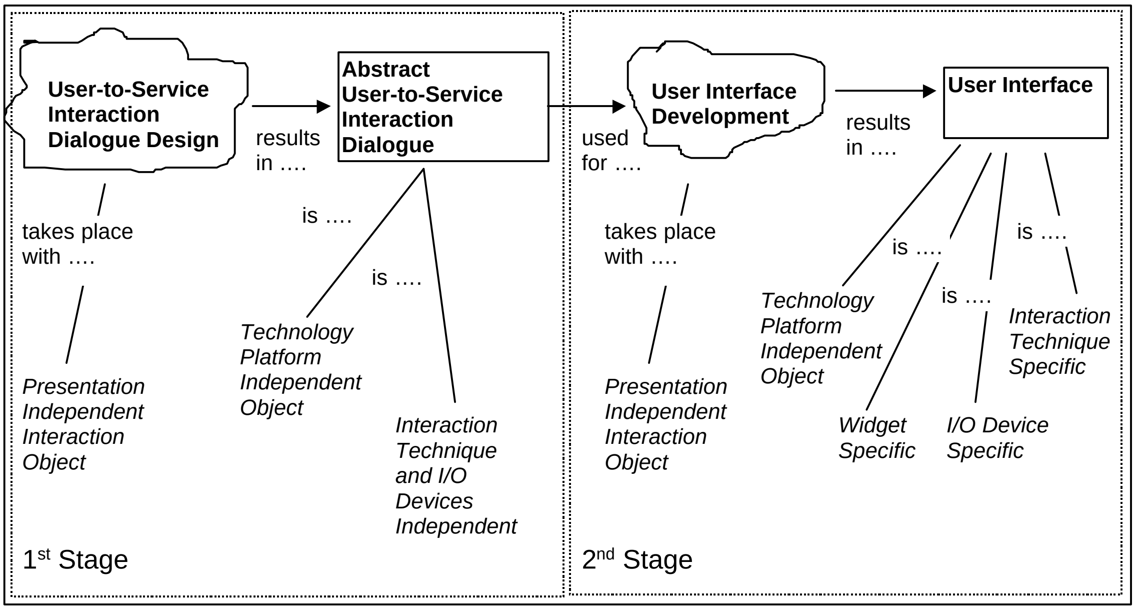


FIGURE 3. Process stages in adapting a user interface with INTERACT (adapted from Stephanidis and Mitsopoulos, 1995)

3.2.2 Adaptation of graphical user interfaces

The TIDE-GUIB[17] and TIDE-GUIB-II[18] 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 Graphical User Interfaces (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-WINDOWS™ (PCs) and to interactive applications built on top of the X WINDOW SYSTEM (UNIX™ 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

---

[17] The GUIB TP103 (Textual and Graphical User Interfaces for Blind People) project was partially funded by the TIDE Programme of the European Commission, and lasted 18 months (December the 1st, 1991 to May the 31, 1993). For the list of consortium partners see the Acknowledgements section.

[18] The GUIB-II TP215 (Textual and Graphical User Interfaces for Blind People) project was partially funded by the TIDE Programme of the European Commission, and lasted 18 months (June the 1st, 1993 to November the 30, 1994). For the list of consortium partners see the Acknowledgements section.

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. Additionally, sounds help navigation and provide spatial relationships between graphical objects. It is important to note that the text-based reproduction facilitates co-operation with sighted colleagues.

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) Filtering of internal graphical data. Appropriate filters in MS Windows provide data about text appearing on the screen (fonts, size, and colours), mouse pointer and cursor positions, position and size of windows, icons, menus and buttons. Additionally, information about more complex objects such as dialogue boxes and scrollbars is collected.

(b) Provision of a representation mechanism for synchronisation of both static and dynamic filtered data.

(c) Definition of a formal language for the specification of appropriate interaction methods for the blind user, combining speech, sounds and Braille output. The developed language called GUIB-ERL (Weber et al., 1993), is based on a formal language, called Event Response Language (ERL) (Hill, 1986), for modelling graphical user interfaces. GUIB-ERL supports easy handling of special input/output devices (Braille display, speech synthesiser, and sound generator) in addition to the handling of the conventional keyboard and pointing devices.

(d) Provision of a front-end module (i.e., a screen reader configuration system) that hides the complexity of GUIB-ERL from the end user and enables easy and quick customisations of the screen reader in order to conform to user preferences and specific application peculiarities. Selection of devices and media, definition of key bindings, activation of monitors and modification of the modelling of graphical objects constitute the basic functionality of the front-end module.

The CONFIG screen reader configuration system (Stephanidis and Gogoulou, 1995) was developed to facilitate customisation of the non-visual environment (see Figure 4). The development of the screen reader configuration system mainly focused on the provision of

facilities which enable the selection and combination of different non-visual interaction techniques, and the configuration of the utilised media, thus addressing the individual needs, abilities and preferences of the target end-user group (blind users). The configuration of the utilised media is performed by appropriately setting the associated parameters. For example, the system enables the specification of different speech parameters (e.g., language, voice) to be used according to the different modes of non-visual interaction (e.g., navigation in the graphical environment, interaction with menus, etc.). Additionally, the CONFIG system

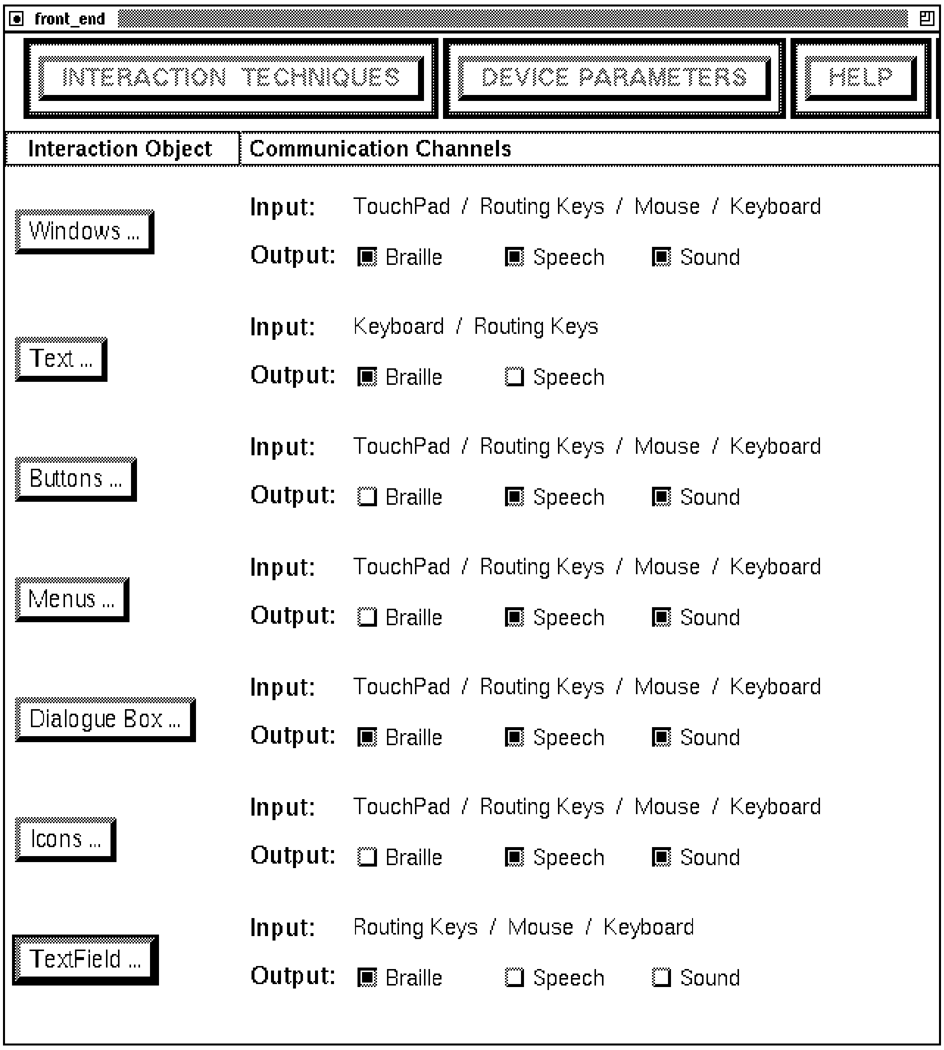


FIGURE 4. Dialogue customisation using CONFIG
(adapted from Stephanidis and Gogoulou, 1995a)

provides an on-line help facility for the seven classes of objects (Windows, Text, Menus, Buttons, Dialogue Boxes, Icons and Text Fields). The help facility describes the main characteristics of the object, as well as basic features of non-visual interaction, by considering the available input/output media.

The GUIB project also investigated a variety of issues related to user interaction in a graphical environment, particularly for blind users. For example, the project investigated different input methods that can be used instead of the mouse. It also studied the problem of how blind users can efficiently locate the cursor on the screen, and examined issues related to combining spatially localised sounds (both speech and non-speech) and tactile information in order to present available information. Finally, the project addressed the design and implementation of real-world metaphors in a non-visual form and the development of an optimal method to present graphical information from within applications.

3.3 Discussion on the reactive approach to accessibility

The described projects have mainly addressed accessibility of computer based applications and services to disabled and elderly people through an *a posteriori* adaptation of interactive software. This amounts to a *reactive* approach, whereby Assistive Technology experts attempted to react to contemporary technological developments by building accessibility features into interactive applications, as a result of specific user requirements. Such efforts to account for accessibility are, however, mainly governed by intuition and usually follow ad hoc procedures, which need to be proven in practice; often, they may lead to sub-optimal solutions with respect to user requirements. As a result, it has been argued that despite the long tradition of concern, in the Assitive Technology field, for access to computer systems by people with disabilities, in practice, much of the progress in this area has been slow (Mueller et al., 1997).

Despite the undoubted value and usefulness of the adaptations-oriented approach and the accumulated body of knowledge, the current state of the art clearly neglects aspects of accessibility, which become promptly relevant and important in the context of the emerging Information Society. (Stephanidis et al., 1998a; Stephanidis et al., 1999; Mueller et al. 1997) The inadequacy of the reactive approach stems directly from the shortcomings of adaptations. In particular, with rapid technological change, each new wave of technology introduces a new generation of access problems. By the time suitable adaptations have been devised, the technology is substituted by a subsequent generation, thus introducing the same problem all over again. It follows, therefore, that adaptations provide solutions that lag behind, at least one technological trajectory. But even if this were acceptable, adaptations-oriented solutions would still not guarantee adequate interaction quality to their users. Currently, for instance, access to GUIs for blind people is solely based on translating the visual manifestation of the interface to an alternative display medium (e.g., auditory, tactile). This, however, results in a non-visual reproduction of the dialogue, which hardly addresses the real interaction requirements of the blind users (Savidis and Stephanidis, 1995a).

4. The proactive approach

In the context of Human-Computer Interaction (HCI), the present situation shows that the vast majority of software firms have adopted mainstream development approaches that do not address the needs of people with disabilities. This is largely due to the fact that the perceived investment cost to provide accessibility ‘for all’ is considered unacceptable, mainly as a consequence of the lack of appropriate tools (Stephanidis, Savidis and Akoumianakis, 1995). It is believed that, if tool developers are provided with the necessary technological methods to build such tools in accordance with the "User Interfaces for all" principle, then software firms will be able to employ these tools in developing software products accessible to all. Using

existing tools one needs to develop dedicated User Interfaces for each different target user (group). Moreover, the pluralism of available graphical environments (i.e., platforms) and operating systems increases the complexity of the problem and the already high development cost.

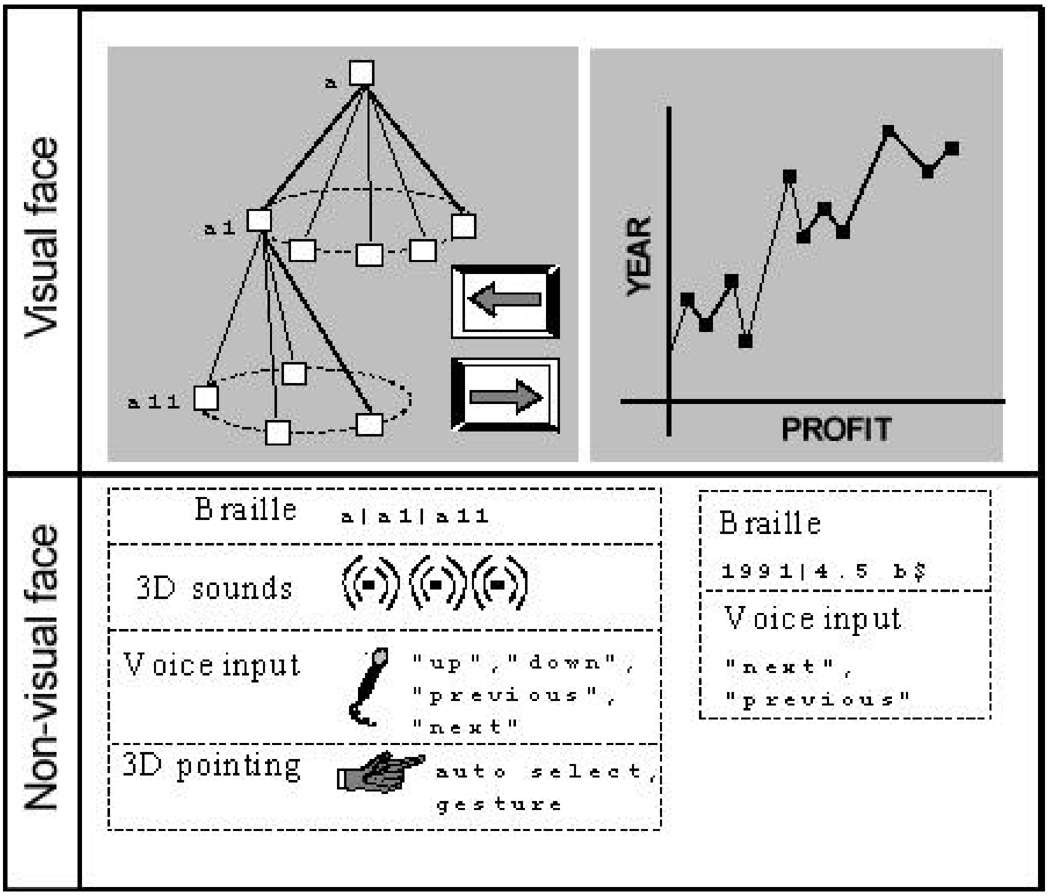


FIGURE 5. Examples of dual interfaces
(adapted from Savidis and Stephanidis, 1998)

4.1 High-level user interface development environments: Dual interfaces

A first step toward the development of tools aimed to the implementation of 'user interfaces for all' 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. Figure 5 shows the concept of Dual User Interfaces.

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 (the HOMER language), which supports: (i) abstraction of interaction objects, i.e., representation of objects based on their abstract interaction roles and syntactic / constructional features, decoupled from physical presentation aspects; (ii) concurrent management of at least two toolkits, so that any modifications effected on the interface by the user through the objects of one toolkit are concurrently depicted in the objects of the second toolkit; (iii) meta-polymorphic capability for abstract objects, i.e., abstract objects can be mapped to more than one toolkits, or to more than one object classes within a specific toolkit; (iv) unified object hierarchies supporting different physical hierarchies, so that alternative mappings of -portions of- the unified hierarchy to -portions of- physical hierarchies are possible; (v) ability to integrate different toolkits; (vi) object-based and event-based model support for dialogue implementation, i.e., the dialogue model can be defined either on the basis of the individual objects that participate in it, or on the basis of interaction events that originate from those objects; and, (vii) declarative asynchronous control models (e.g., preconditions, monitors, constraints), as opposed to syntax-oriented control models (e.g., task notations, action grammars), or alternative control techniques (e.g., event-based models and state-based methods); the rationale behind the adoption of declarative control models concerns the desired independence from specific syntactic models, which allows for differing models, supported by different toolkits, to be supported.
A non-visual toolkit to support non-visual interface development, called COMONKIT (Savidis and Stephanidis, 1995b; Savidis and Stephanidis, 1998), was developed and integrated within the HOMER UIMS. The COMONKIT 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.. The COMMONKIT library provides efficient navigation facilities, through speech / Braille output and keyboard input. Two different non-visual realisations of the Rooms metaphor have been assembled: (i) a non-spatial realisation, supporting Braille, speech and non-speech audio output with keyboard input; and (ii) a direct-manipulation spatial realisation, combining 3D audio (speech and non-speech), 3D pointing via a glove and hand gestures, keyword speech recognition and keyboard input (Savidis et al., 1996). In both realisations, special sound effects accompany particular user actions such as selecting doors (e.g., "opening door" sound), selecting the lift (e.g., "lift" sound), pressing a Button or a Switch object, etc..

The Athena widget set (for visual windowing interactions) and the COMONKIT toolkit (for non-visual Rooms dialogues) have been imported within the HOMER UIMS, maintaining the original (i.e., native) "look & feel" of their respective toolkit. The toolkit integration mechanism of the HOMER language has been practically demonstrated by importing together the Athena toolkit, (complying to the desktop windowing metaphor), and the COMONKIT library (realising the Rooms metaphor).

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).

4.2 Design for all in HCI: User Interfaces for All and the Unified User Interface Development paradigm

The concept of *User Interfaces for all* (Stephanidis, 1995) 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[19] 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 approach enables designers to deal with problems of rehabilitation and access to technology in a consistent, systematic and unified manner.

The ACCESS project has proposed the concept of *Unified User Interface development* (U^2ID), 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, Savidis and Akoumianakis, 1997; Savidis, et al., 1997; Akoumianakis, Savidis and Stephanidis, 1999). Unified user interface development provides a vehicle for designing and implementing interfaces complying with the requirements of accessibility and high quality interaction.

A unified user interface (figure 6) comprises a single (unified) interface specification, targeted to potentially all user categories. In practice, a unified user interface is defined as a hierarchical construction in which intermediate nodes represent abstract design patterns de-coupled from the specific characteristics of the target user group and the underlying interface development toolkit, while the leafs depict concrete physical instantiations of the abstract design pattern. 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.

To achieve the above, unified user interface design aims at: (i) initially identifying and enumerating possible design alternatives, suitable for different users and contexts of use, using techniques for analytical design (such as design scenarios, envisioning and ethnographic methods); (ii) identifying abstractions and fusing alternatives into abstract design patterns (i.e., abstract interface components that are de-coupled from platform-, modality-, or metaphor-

---

[19] The ACCESS TP1001 (Development platform for unified ACCESS to enabling environments) project was partially funded by the TIDE Programme of the European Commission, and lasted 36 months (January the 1st, 1994 to December the 31, 1996). For the list of consortium partners see the Acknowledgements section

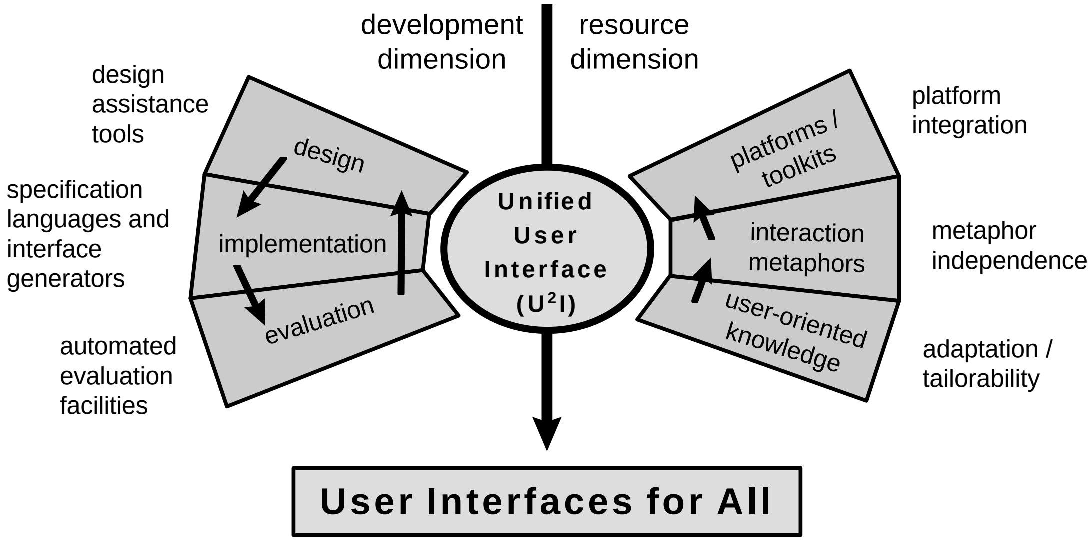


FIGURE 6. The concept of unified user interfaces
(adapted from Stephanidis, Savidis and Akouminakis, 1995)

specific attributes); and, (iii) rationalising the design space by means of assigning criteria to alternatives and developing the relevant argumentation, so as to enable a context-sensitive mapping of an abstract design pattern onto a specific concrete instance.

The result of the design process is a unified user interface specification. Such a specification can be built using a dedicated, high-level programming language and results in a single implemented artefact which can instantiate alternative patterns of behaviour, either at the physical, the syntactic, or even the semantic level of interaction. The unified implementation, which is produced by processing the interface specification, undertakes the mapping of abstract interaction patterns and elements to their concrete / physical counterparts.

In particular, the process of unified user interface implementation involves two distinctive steps, namely *platform integration* and *interface specification* (Akoumianakis, Savidis and Stephanidis 1999). Platform integration refers to the process of building a unifying programming layer on top of the interface toolkits which comprise the physical interaction resources (i.e., they provide the concrete means – in the form of buttons, menus, etc., through which physical interaction actually takes place). This unifying layer is necessary for transforming a unified user interface to a physical interface instance, given a target user, platform and usage context. Interface specification, on the other hand, entails the use of appropriate tools for: (a) the construction of a unified user interface as a composition of abstractions at different levels of interaction; (b) the manipulation and management of the physical resources; and (c) the establishment of the relationships between the involved abstractions and the available physical resources (Savidis, Stephanidis and Akoumianakis, 1997). The detailed architectural abstractions of a supporting tool environment that realises these steps have been presented in (Stephanidis, Savidis and Akoumianakis, 1997; Akoumianakis, Savidis and Stephanidis, 1999).

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, called G-DISPEC (Savidis and Stephanidis, 1997b), and a tool called I-GET (Savidis and Stephanidis, 1997b; Stephanidis, Savidis and Akoumianakis, 1997) that automatically generates the implementation from such high-level specifications. The G-DISPEC language and the I-GET tool constitute a novel User Interface Management System for Unified User Interface development. Additionally, another tool has been developed, called PIM (Savidis, Stephanidis and Akoumianakis, 1997), which enables the generation of platform independent toolkits (i.e., programming libraries) for unified interface implementation. 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, Vernardos and Stephanidis, 1997); and a toolkit for non-visual interaction (Savidis, Stergiou and Stephanidis, 1997).

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 called USE-IT (Akoumianakis and Stephanidis, 1997a; Akoumianakis and Stephanidis, 1997b). This tool takes the appropriate decisions regarding the lexical characteristics of the dialogue, based on: (a) knowledge about the user characteristics, abilities and preferences, and (b) knowledge about the structure of the lexical level characteristics with respect to the various target user groups (i.e., interaction objects, interaction techniques, devices, etc.). The unified User Interfaces, which are developed by utilising the tools of the U^2ID framework, automatically inquire the adaptability decisions generated by the USE-IT tool, and apply these decisions during user-computer interaction.

4.3 Applications of the proactive approach to HCI

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[20] 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, Ravaglia and Rella, 1997). The systems were targeted for the population at large, including people with disabilities. In particular, based on the U^2ID 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., 1997a).

The AVANTI project adopted the U^2ID methodology as a proactive approach in the development of the user interface of a Web browser, that takes into account the requirements and preferences of *all* potential users, in early stages of the development life cycle. Specialised mechanisms have been developed to support the adopted approach, employing adaptability and adaptivity at the user interface level.

[20] 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 (September the 1st, 1995 to August the 31, 1998). For the list of consortium partners see the Acknowledgements section.

Figure 7 depicts the overall architecture of the AVANTI system, focusing on the architecture of the unified browser and showing the different modules that are utilised in the provision of adaptable and adaptive interaction. The main components of each information system are (Stephanidis et al., 1998b): (i) a collection of multimedia databases which are accessed through a common communication interface (Multimedia Database Interface - MDI); (ii) the User Modelling Server (UMS), which maintains and updates individual user profiles, as well as user stereotypes (Kobsa and Pohl, 1995; Fink, Kobsa and Nill, 1996; Fink, Kobsa and Nill, 1997; Schreck and Nill, 1998); (iii) the Content Model (CM), which retains a meta-description of the information available in the system; (iv) the Hyper-Structure Adaptor (HSA, Kobsa and Pohl, 1995; Schreck and Nill, 1998) which adapts the information content, according to user characteristics; and, (v) the User Interface component (browser).

Adaptability and adaptivity[21] at the user interface level are applied to tailor the browser to the end user abilities, requirements and preferences, both during the initiation of a new session and throughout interaction with the system (Stephanidis et al., 1997a). This is supported through the co-operation of the user interface and the user modeling server; the former monitors user interaction and notifies accordingly the latter, which, in turn, draws inferences on the situation the user is in, successively updating its knowledge. The updated knowledge is used by the user interface to decide upon and perform self-adaptation.

Decision making in the AVANTI user interface follows a rule-based approach. Specifically, adaptation rules have been defined and associated with each user task, providing the mechanism for the selection, and configuration, of alternative user interface components. Rules and corresponding decisions are based on a number of ‘static’ and ‘dynamic’ user characteristics, which were selected during the user requirements analysis phase of the project. The selected static user characteristics include: *(a)* physical abilities; *(b)* the language of the user (the system supports English, Italian and Finnish); *(c)* familiarity of the user with:

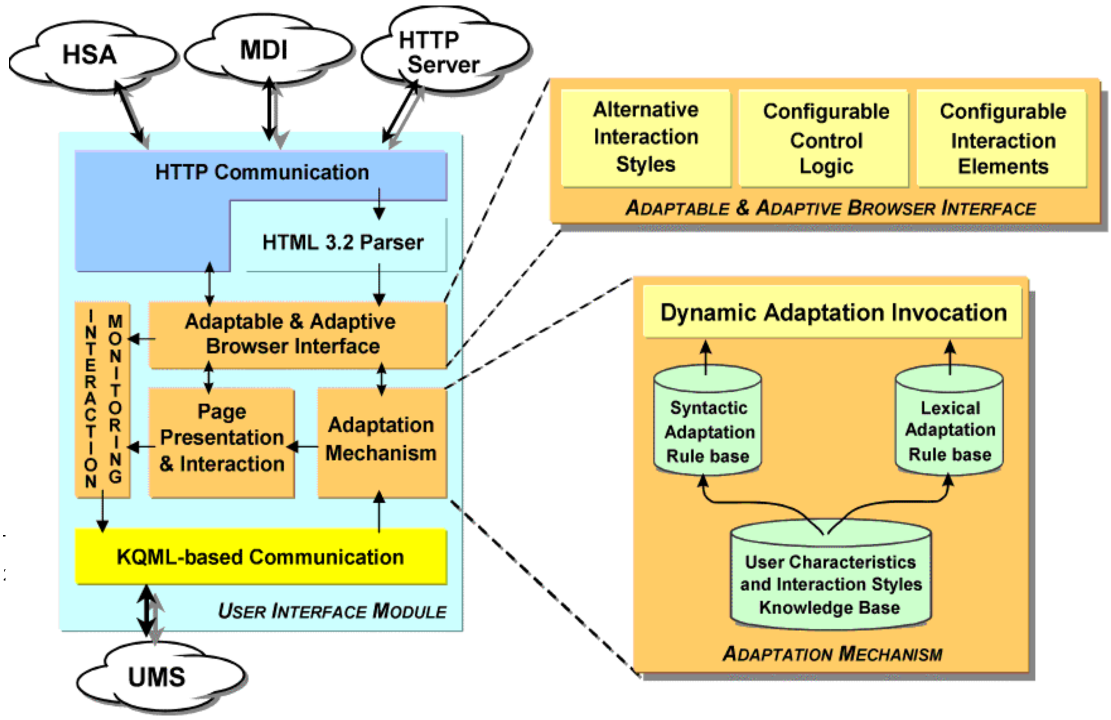


FIGURE 7. The architecture of the AVANTI browser (adapted from Stephanidis et al., 1998b).

computing, networking, hypermedia applications, the Web and the AVANTI system itself; *(d)* the overall usage target: speed, ease of use, accuracy, error tolerance; and *(e)* user preferences regarding specific aspects of the application and the interaction. The dynamic user situations that are taken into account concern: *(a)* familiarity with specific tasks (i.e., the user's ability to successfully initiate and complete certain tasks); *(b)* ability to navigate using the documents' navigation elements; *(c)* error rate; *(d)* disorientation; *(e)* user idle time; and *(f)* repetition of interaction patterns (Stephanidis et al., 1998b).

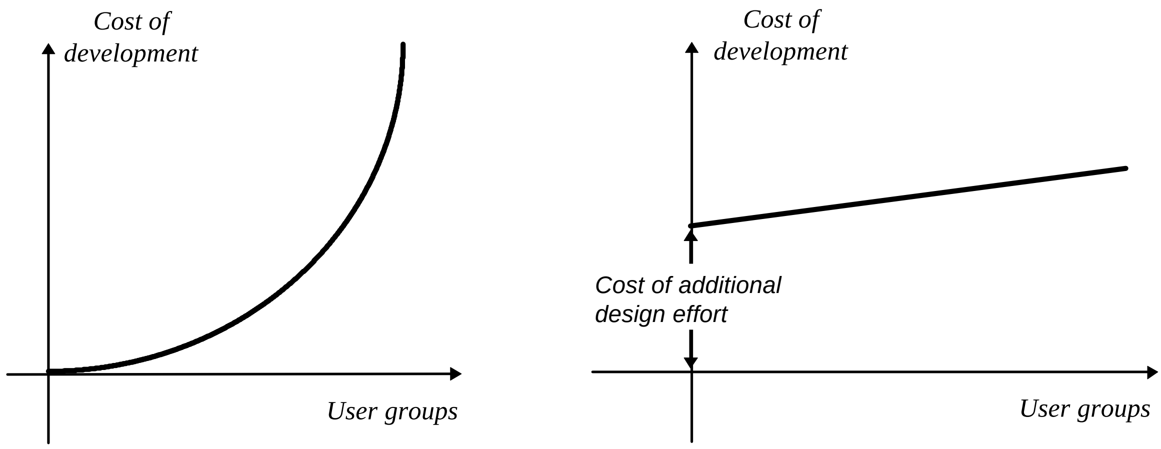
Special purpose input/output devices have been integrated into the system to support blind and motor-impaired individuals, including: binary switches, speech input (command recognition), joystick and touch-tablet input, Braille display output, speech output, digitised audio output, and special keyboard functionality (Stephanidis et al., 1998b).

5. Contrasting the two approaches

Granting access to an interactive application by users with diverse abilities, skills, requirements and preferences is currently a programming intensive task. This may be demonstrated with the following example, involving an interface built with currently available tools. The interface is to present a menu of options from which the user is to make a selection. With current technology, and the available tools, this would be a trivial task. Moreover, it would be possible to enhance and individualise the interaction with the menu by providing support for either *adaptive ordering* of options (based on frequency of use data), *adaptive prompting* (based, for example, on contextual information resulting from a model), or *guidance* (with help of an agent).

Let us now consider the case that the same system is to be used by a blind user, for whom it is not possible to make a selection in the visual (graphical) modality. Instead, the blind user perceives containment through real world concepts, such as the chapter within a book, or the room within a house. The question is how would the above strategies for enhancing interaction suit this new user more, and more generally, how today’s user interface software technologies cope with such radical departures from a predetermined interaction paradigm grounded on the visual embodiment of the desktop computer. Clearly, in order to allow access, the interface needs to be re-engineered and re-implemented to provide an interaction environment (at the device, syntax and language levels) suitable for the blind user. If we now assume that the interface is to be accessed also by a motor-impaired user, then it follows that yet another implementation is required, as the non-visual version does not suffice. From the above, it becomes evident that programming-intensive development paradigms, which are increasingly challenged anyway in the HCI field (Winograd, 1995) are not suitable for designing for different user groups, as the cost of interface development increases exponentially with the number of different target user groups (see Figure 8).

Unified user interface development makes two claims which radically change the way in which interfaces are designed and developed, while having implications on both the cost and maintenance factors. The first claim is that interfaces may be generated from specifications, at the expense of an initial design effort required to generate them. The second claim relates to the capability of the unified user interface to be transformed, or adapted, so as to suit different contexts of use. For example, in the cases of blind and motor impaired users, the problem of accessibility of the menu can be addressed through a sequence of steps, involving:



(a) Providing access through programming-intensive efforts

(b) Cost model for unified interface development

FIGURE 8. Cost implications of designing for the broadest possible population

a) the unification of alternative concrete design artefacts (such as the desktop menu, the 3D acoustic sphere likely for the non-visual dialogue, etc.) into abstract design patterns or unified design artefacts (such as a generalised container);

b) a method to allow the instantiation of an abstract design pattern into the appropriate concrete physical artefact, based on knowledge about the user; and

c) the capability to dynamically enhance interaction by interchanging or complementing multiple physical artefacts at run-time (see adaptivity examples in the AVANTI system, section 4.3).

It follows, therefore, that unified user interface development results in a revised cost model for user interfaces, where there is an initial effort to design, while development cost of alternative versions of an interface and maintenance costs are minimised.

In conclusion it should be noted that, given the lack of any real cost/benefit data on the viability of proactive versus reactive approaches - a point made earlier in section 2.1 - the above line of argumentation seeks to be only illustrative of the focus of the two approaches. In fact, whether or not the prevailing programming-intensive paradigm for HCI is likely to outweigh proactive alternatives is a subject in its own right. Nevertheless, it is worth pointing out that the shift from programming-intensive efforts to design-oriented tools is an indication of a sectors maturity level. Recent developments in the IT industry offer provide sufficient evidence to justify this claim. For example, GUIs did not really take off until visual programming environments and tools for designing graphical interactions became available (Winograd, 1995). More recently, the primary constraint impeding Java's diffusion is the lack of tools (Regan, 1998).

It is therefore evident that as the sector matures, it strives to provide tools which reduce design resources and productive design work. Though, this is not yet the case for the area of accessibility, trends in this direction are already evident (e.g., Active Accessibility by Microsoft and Java Accessibility by Sun). It is therefore expected that in the future, the initial design cost implied by universal access in HCI, will be reduced, as tools become available that ease the task of designers.

6. Non-technological conditions for success

The previous efforts have clearly indicated the technological trajectories through which advances for disabled and elderly people have progressively given rise to user interface software and technology that facilitate the design and development of user interfaces that can accommodate the requirements of the broadest possible end-user population. It is, therefore, obvious that designing for all in HCI is more of a challenge than a utopia. In this section, we set out to briefly address some of the issues related to the economics and management of technologies, such as those described in the previous section. In particular, the section argues that while technological feasibility efforts are clearly necessary, they do not constitute a sufficient condition for success, i.e., lead us to an accessible Information Society. For there are additional requirements for accompanying measures to ensure adoption, acceptance and diffusion of these technologies.

6.1 Co-operative RTD versus policy initiatives

In a previous study (Vernadakis et al., 1997), the likelihood of design for all was assessed against different technology transfer mechanisms. The main outcome from that investigation is that design for all is likely to proliferate when advanced mechanisms are involved. The types of such mechanisms that were considered appropriate included: co-operative RTD (M1); joint venture RTD agreements (M2); joint ventures that aim at keeping partners informed (M3); cross-licensing - referring to separate product markets (M4); and large-small firm agreements (M5). Table 2 summarises each alternative in terms of a small set of criteria which include: the level of technology involved (C1); the size and technological capabilities of firms involved (C2); and the nature and degree of technical character of products to be developed (C3).

Table 2: Assessment of technology transfer mechanisms with respect to Design for All

	C1	C2	C3
M1	High	Both source and recipient are very large	Strongly standardised; existence of significant technological complementarities.
M2	Same as above	Large firm, international oligopolist	Not very standardised, with significant technological complementarities
M3	Same as above	Same as above	Same as above
M4	Same as above	Oligopoly	Technological complementarities and/or special sectors in sub markets
M5	High and rapidly changing	The small firm is knowledge intensive	Same as above

In recent years, we have experienced attempts towards design for all, building directly upon some of the above mechanisms (cf. project descriptions and results presented in the previous sections), or calling upon such mechanisms to meet pressures introduced by legislation or other policy initiatives. In contrast to the USA, which has followed the latter approach by introducing legislation (Americans with Disabilities Act; 1996 Telecommunications Act) and / or facilitating national standards (e.g., Draft HFES/ANSI 200, Section 5), the European Commission has explored primarily the co-operative RTD alternative through successive Framework Programmes and the corresponding RTD sectors[22].

Though each alternative has its advantages and disadvantages, neither seems to be by itself capable to facilitate the intended objective of creating an Information Society accessible to all citizens. Policy initiatives by themselves cannot always guarantee acceptability in the long run. In industries where this has been the case, there was usually a solid RTD basis. As an illustrative example, we may refer to the case of alarm telephones service diffusion in Finland, where state interventions led to wide adoption of the technology for the benefit of disabled and elderly people (Vernardakis, Stephanidis and Akoumianakis, 1995a; Vernardakis, Stephanidis and Akoumianakis, 1995b). In contrast, where a solid RTD basis is lacking, as in the case of designing for all in HCI, policy initiatives are unlikely to bring about by themselves the expected results. In such cases, the likelihood is that the majority of the industries will find means to either oppose, or by-pass the legislation, or, in the best of cases, meet the absolute minimum requirements.

On the other hand, co-operative RTD offers no guaranteed solution. Though it may facilitate the consolidation of a sound RTD base, initiate proactive technological intervention, raise awareness and establish a common ground, it seldom exceeds the technological feasibility stage. In the past, co-operative RTD projects funded by the European Union have demonstrated their capability to be at the technological frontiers by being multi-disciplinary, collaborative, user-involved, trans-national and pre-competitive RTD activities, where technological feasibility is demonstrated in selected application domains, or pilot case studies. Though such attributes constitute necessary ingredients for socially desirable innovation, in the sense that without them the generation of such innovation may be hard to attain, they are clearly not sufficient to assure diffusion.

First of all, technological feasibility, though very important, does not necessarily imply economic efficiency and efficacy, which is what is really needed in the long run. Secondly, the adoption and diffusion of socially desirable innovation, depends on additional parameters. These include the degree to which the environment is favourable to such innovation, the commitment of firms to appropriate the resulting benefits, sectorial characteristics, such as industry composition, competitive strategies, the nature of the sector (e.g., producer versus recipient of technology), as well as prevalent practices in regulation and in particular standardisation (e.g., de facto industry standards) and legislation.

It is, therefore, apparent that only a sound RTD basis, complemented with the required policy initiatives, may bring about the desirable outcomes. To this end, the role of non-market institutions is crucially important in funding *appropriate* RTD project work, promoting

[22] This commitment is likely to continue in the 5th Framework Programme of the European Commission (1998-2002).

awareness, establishing directives, legislative acts and standards, assuring the diffusion of technology and its adoption by a wide proportion of the industry. Finally, non-market institutions can directly and explicitly contribute towards the creation of an environment favourable for ‘designing for all’, by acting as a catalyst for overcoming the technological threshold factors associated with the availability of adequate infrastructure (i.e., networks, terminals, etc.) to the various communities of end users.

6.2 The role of non-market institutions

In recent years, a number of studies have reached the conclusion that non-market institutions can play a catalytic role towards universal design, especially in sectors of the industry that are known to be recipients, as opposed to natural generators of innovation (e.g., Vernardakis, Stephanidis and Akoumianakis, 1997). In general, there is a broad range of actions non-market institutions can undertake. Some of them have been identified in (Stephanidis et al., 1998a) and are reproduced in Table 3.

Table 3. Potential role of non-market institutions

- Establish effective strategies and legal frameworks
- Act as catalyst in bringing about a shift in perspectives
- Provide funding for RTD initiatives
- Provide incentives to both large industries and SMEs
- Regulatory role aiming to support accessibility in scientific, technical and social terms
- Identify technological potential
- Promote coherence in the market
- Support actions for standardisation and legislation
- Adopt policy measures ensuring that industries *design for all*
- Guide industry towards *design for all*
- Promote the generation of the required knowledge and facilitate access to research results
- Encourage strategic alliances
- Act as technology transfer intermediary
- Develop standards and guidelines
- Establish an international usability assurance scheme to facilitate consumer confidence of product usability

Consequently, non-market institutions could and should provide effective means for undertaking research and demonstrating technological feasibility, as well as for assuring economic efficiency and efficacy in the long run. This can be achieved by introducing Programmes that, in addition to targeted RTD for the purpose of demonstrating technological feasibility, include support measures for technology transfer, exploratory awards, best practice and experience, process improvement experiments, and policy interventions.

7. Summary and Conclusions

This paper has investigated 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 EU funded RTD projects. It has been argued that, though the reactive approach may bring benefits in the short term, it is insufficient to provide appropriate and long-lasting solutions for the broader accessibility challenge posed by the emerging Information Society. On this basis, the paper developed an argumentation for the proactive approach, and described how such an effort has been consolidated in the field of HCI towards designing for the broadest possible end-user population, including disabled and elderly people. A second line of argumentation in the paper was that technological progress, though necessary, it is not a sufficient condition for an Information Society acceptable to all citizens. In particular, a conscious effort is additionally needed to create an environment favourable to an Information Society 'for all', by advancing the available results beyond technological feasibility and towards economic efficiency and efficacy needed in the long run. The complementary role of co-operative RTD and policy initiatives was discussed, in the light of recent experiences from the USA and the European Union, to conclude that neither is sufficient in itself to guarantee accessibility of the Information Society.

The main conclusions from this paper are twofold. First of all, it became evident that accessibility in the Information Society is more of a challenge than a utopia. This means that the currently 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. However, as already pointed out, technological feasibility is not enough. What is really needed is economic efficiency and efficacy in the longer term. To this end, non-market institutions such as the European Commission in Europe, MITI in Japan and the National Science Foundation in the USA, etc., can play a critical and catalytic role. This can be achieved by funding *appropriate* RTD project work, establishing suitable measures to promote awareness, facilitate adoption and diffusion, and, in general, to create an industrial environment favourable to social innovation.

The second conclusion from this paper is the compelling need for international collaboration in a wide area of technological and non-technological fields. Such collaborations should aim to establish a common ground, and a holistic approach covering scientific, technological and policy issues, for the advancement of an Information Society that is acceptable to *all* citizens. Moreover, efforts in this direction need to be carried out in a co-ordinated and timely fashion, so as to provide input to current and future initiatives across the world, such as the Fifth Framework Programme of the European Commission and the National Information Infrastructure in the USA. These objectives constitute part of the mission of the International Scientific Forum "Towards an Information Society for *All*" (Stephanidis et al., 1998a) which was formed to pursue a range of goals related to the development of an Information Society acceptable to all citizens.

Finally, it is important to point out that, despite the recent success stories in the development of appropriate technological paradigms and demonstrators, and in particular the application of universal design principles in the area of HCI, there is much more research and development work that is needed to address the remaining challenges[23]. Such efforts are required not only to provide a deeper understanding of human information seeking and processing behaviour in computer-mediated human activities, but also to enable the development of tools which will ease designers in constructing accessible and high-quality interaction to facilitate an Information Society for all.

Acknowledgements

The RTD work reviewed in this paper has been carried out in the context of the following European Commission funded projects. The authors wish to acknowledge the cooperation of all the partners of these consortia.

- IPSNI (R1066), partially funded by the RACE Programme of European Commission (DG XIII). Partners of the IPSNI consortium are: IROE-CNR, Italy; KUL, Belgium; IRV, The Netherlands; CSELT, Italy; Institute of Computer Science-FORTH, Greece; Technical Research Centre of Finland, Finland.

- IPSNI-II (R 2009), partially funded by the RACE Programme of European Commission (DG XIII). 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.

- GUIB (TP103), partially funded by the TIDE (Technology Initiative for the Disabled and Elderly People) Pilot Action Programme of the European Commission (DG XIII). 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.

- GUIB-II (TP 215) project, partially funded by the TIDE Programme of the European Commission (DG XIII). 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.

- TIDE - ACCESS (TP 1001) project (Development Platform for Unified Access to Enabling Environments) partially funded by the TIDE Programme of the European Commission. 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).

[23] Stephanidis et al., 1998a; Stephanidis et al., 1999.

- ACTS-AVANTI AC042, partially funded by the ACTS Programme of the European Commission. 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 Siena (Italy), MA Systems and Control (UK); ECG (Italy); MATHEMA (Italy); University of Linz (Austria); EUROGICIEL (France); TELECOM (Italy); TECO (Italy); ADR Study (Italy).

References

ACCESS Consortium (1996) “Report on the implementation of the demonstrator interpersonal communication aid”, TIDE TP-1001, ACCESS Project, Deliverable 2.6, December 1996.

Akoumianakis D., Stephanidis C. (1997a) “Knowledge-based Support for User-Adapted Interaction Design”, Expert Systems with Applications, vol. 12(2), pp. 225-245.

Akoumianakis, D., Stephanidis, C. (1997b) “Supporting user adapted interface design: The USE-IT system”, International Journal of Interacting with Computers, vol. 9(1), pp. 73-104.

Akoumianakis, D., Savidis, A., Stephanidis, C. (1999) “Encapsulating Intelligent Interactive Behaviour in Unified User Interface Artefacts”, to appear in the International Journal on Interacting with Computers, special issue on “The Reality of Intelligent Interface Technology”, 38 pages.

Bergman, E., Johnson, E. (1995) “Towards Accessible Human-Computer Interaction”, in Nielsen, J. (Ed.), “Advances in Human-Computer Interaction”, Volume 5, 87-113, New Jersey, Ablex Publishing Corporation.

Bini, A., Emiliani, P. L. (1997), "Information about mobility issues: The ACTS AVANTI project", 4th European Conference for the Advancement of Assistive Technology (AAATE '97), Porto Carras, Greece, 29 September - 2 October 1997.

Bini, A., Ravaglia, R., Rella, L. (1997), "Adapted Interactions for Multimedia based Telecommunications Applications", Conference Neties 1997, Ancona, Italy, 1-3 October 1997.

Crispien, K., Wurz, W., Weber, G., (1994), "Using spatial audio for the enhanced presentation of synthesised speech within screen readers for blind computer users, In proceedings of 4th /International Conference on Computers for Handicapped Persons, 14-16 September 1994, Wien, in Zagler, W.L., Busby, G. and Wagner, R.R. (eds), Computers for Handicapped Persons, Lecture Notes in Computer Science 860, Heidelberg: Springer, pp. 25-31.

Danger S., Huizing N., Walker A., Rowland A., Anderson R., Sciaccaluga R. (1996) “EU Information Society Guide”, Brussels, Belgium, The EU Committee on the American Chamber of Commerce in Belgium.

ETSI (1996) “ICT Standardisation and Disability in Europe”, European Policy Workshop, European Telecommunications Standards Institute.

European Commission (1994) “Recommendations to the European Council: Europe and the global information society - The Bangemann Report”, Brussels, Belgium, available electronically at http://www.ispo.cec.be/infosoc/backg/bangeman.html).

Fink J., Kobsa A., Nill A. (1996), "User-Oriented Adaptivity and Adaptability in the AVANTI project", Conference "Designing for the Web: Empirical Studies", Microsoft, Redmond, WA, 1996.

Fink J., Kobsa A., Nill A. (1997), "Adaptable and Adaptive Information Access for All Users, Including the Disabled and the Elderly", The Sixth International Conference on User Modeling, Chia Lagun, Sardinia, Italy, 1997.

Gill J. (1996) “Telecommunications: the Missing Links for People with Disabilities”, COST 219, European Commission, Directorate General XIII, Telecommunications, Information Market and Exploration of Research.

GUIB Consortium (1994) “Report on the MS-Windows demonstrator”, TIDE 215, GUIB Project, Deliverable 14.2, November 1994.

HFES / ANSI (1997) “Draft HFES / ANSI 200 Standard, Section 5: Accessibility”, Santa Monica, USA, Human Factors and Ergonomics Society.

Hill R.D. (1986) “Supporting concurrency, communication and synchronization in Human - Computer Interaction - the Sassafras UIMS”, ACM Transactions on Graphics, Vol.5, No. 3 pp.179 - 210.

IPSNI Consortium (1990), “WP 2.2: Potential Solutions for accessibility of IBC Terminals for PSN Users”, RACE R1066 IPSNI Deliverable, CEC -DG XIII, RACE Central Office, Brussels, Belgium, June 1990, 156 pages.

IPSNI Consortium (1991a), "WP4: A Guide for engineers to people with disabilities and access to telecommunications", RACE R1066 IPSNI Deliverable, CEC -DG XIII, RACE Central Office, Brussels, Belgium, December 1991, 116 pages.

IPSNI Consortium (1991b), “WP 4: IBC Terminal Functional Specifications”, RACE R1066 IPSNI Deliverable, CEC -DG XIII, RACE Central Office, Brussels, Belgium, December 1991, 277 pages.

IPSNI-II Consortium (1992), “WP 1: Proposed terminal access solutions” RACE R2009 IPSNI II Deliverable, CEC - DG XIII, RACE Central Office, Brussels, Belgium, December 1992.

IPSNI-II Consortium (1993), “WP 2: Hardware and Software specifications of adapted terminal emulators for PSN”, RACE R2009 IPSNI II Deliverable, CEC - DG XIII, RACE Central Office, Brussels, Belgium, June 1993.

IPSNI-II Consortium (1994), “WP 3: Identification of special services for PSN users”, RACE R2009 IPSNI-II Deliverable, CEC - DG XIII, RACE Central Office, Brussels, Belgium, December 1994.

Kobsa A., Pohl W. (1995) “The user modelling shell system BGP-MS”. User Modelling and User-adapted interaction, 4(2), pp. 59-106.

Kouroupetroglou G., Viglas C., Anagnostopoulos A., Stamatis C., Pentaris F., (1996) “A novel Software Architecture for Computer-based Interpersonal Communication aids”, In the proceedings of 5th ICCHP’96 (International Conference on Computers and Handicapped People), Linz, Austria, 17-19 July, pp. 715-720.

Lewis C., Rieman J. (1994) “Task-Centred User Interface Design: A Practical Introduction”, available at http://www.syd.dit.csiro.au/hci/clewis/contents.html.

Mynatt, W. E., Weber, G. (1994) “Nonvisual presentation of graphical user interfaces: contrasting two approaches”. In the Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI’94), Boston, Massachusetts, USA, pp. 166-172.

Mueller M. J., Wharton C., McIver W. J., Kaux L. (1997) “Towards an HCI Research and Practice Agenda Based on Human Needs and Social Responsibility”, In the proceedings of ACM Conference on Human Factors in Computing Systems (CHI’97), Atlanta GA, USA.

Papenmeier (1999a), "BRAILLEX 2D Screen Braille Display, The Two-dimensional Braille Display For Personal Computers", URL: http://www.papenmeier.de/reha/products/2de.htm, accessed January 1999.

Papenmeier (1999b), "WinDOTS 2, The Ultimate Braille Access Software for Microsoft® Windows™ 3.x and Windows™ 95", URL: http://www.papenmeier.de/reha/products/windotse.htm, accessed January 1999.

Petrie H., Morley S., McNally P., O’Neill A-M., Majoe D. (1997) “Initial design and evaluation of an interface to hypermedia systems for blind users”, In the Proceedings of Hypertext97, Southampton, UK, 6-11 April, pp. 48-56, New York: ACM Press.

Regan B. (1998) “Java: One Year Out”, available from http://www.webreference.com/content/java/.

Savidis A., Stephanidis C. (1995a) “Developing Dual User Interfaces for Integrating Blind and Sighted Users: the HOMER UIMS”, 1995 ACM Conference on Human Factors in Computing Systems (CHI '95), Denver, USA, 7-11 May, pp. 106-113.

Savidis A., Stephanidis C. (1995b), “Building non-visual interaction through the development of the Rooms metaphor”, 1995 ACM Conference on Human Factors in Computing Systems (CHI '95), Denver, USA, 7-11 May, pp. 244-245 (Companion Proceedings).

Savidis A., Stephanidis C., Korte A., Krispien K., Fellbaum K. (1996) “A Generic Direct Manipulation in 3d-Auditory Environment for Hierarchical Navigation in Non-Visual Interaction”, 2nd ACM-SIGCAPH Conference on Assistive Technologies (ASSETS '96), Vancouver, Canada, 11-12 April, pp. 117-123.

Savidis A., Stephanidis C., (1997a) "Unifying and Merging Toolkits: A Multi-Purpose Toolkit Integration Engine", HCI International '97, San Francisco, USA, 24-29 August 1997, pp. 457-460.

Savidis A., Stephanidis C., (1997b) "Agent Classes for Managing Dialogue Control Specification Complexity: A Declarative Language Framework", HCI International '97, San Francisco, USA, 24-29 August 1997, pp. 461-464.

Savidis A., Paramythis A., Akoumianakis D., Stephanidis C. (1997) "Designing user-adapted interfaces: the unified design method for transformable interactions", ACM Conference on Designing Interactive Systems: Processes, Methods and Techniques (DIS '97), Amsterdam, The Netherlands, 18-20 August, pp. 323-334.

Savidis A., Stephanidis C., Akoumianakis D. (1997) "Unifying Toolkit Programming Layers: a Multi-Purpose Toolkit Integration Module", 4th Eurographics Workshop on Design, Specification and Verification of Interactive Systems (DSV-IS '97), Granada, Spain, 4-6 June, pp 177-192.

Savidis A., Vernardos G., Stephanidis C. (1997) "Embedding Scanning Techniques Accessible to Motor-Impaired Users in the WINDOWS Object Library", HCI International '97, San Francisco, USA, 24-29 August, pp. 429-432.

Savidis, A., Stergiou, A., Stephanidis, C., (1997). Generic containers for metaphor fusion in non-visual interaction: The HAWK Interface toolkit. In the Proceedings of the Interfaces '97 Conference, Montpellier, France, 28-30 May, pp. 194-196.

Savidis A., Stephanidis C. (1998) "The HOMER UIMS for Dual User Interface Development: Fusing Visual and Non-visual Interactions", International Journal of Interacting with Computers, accepted for publication.

Schreck, J., Nill, A., (1998) "Prototype of User Model Server", ACTS-AVANTI AC042 Project Deliverable 022, February 1998.

Stephanidis C. (1995) "Towards User Interfaces for All: Some Critical Issues", HCI International '95, Panel Session "User Interfaces for All - Everybody, Everywhere, and Anytime", Tokyo, Japan, 9-14 July, pp. 137-142.

Stephanidis C., Gogoulou R. (1995) "Enhancing Non-visual Interaction in a Graphical Environment through a Screen Reader Configuration System", RESNA '95 Conference, Vancouver, Canada, 9-14 June, pp. 467-469.

Stephanidis C., Mitsopoulos Y. (1995) "INTERACT: An interface builder facilitating access to users with disabilities", HCI International '95, Tokyo, Japan, 9-14 July, pp. 923-928.

Stephanidis C., Savidis A., Akoumianakis D. (1995) "Tools for User Interfaces for all", 2nd TIDE Congress, Brussels, Belgium, 26-28 April 1995, pp. 167-170.

Stephanidis C., Paramythis A., Savidis A., Sfyrakis M., Stergiou A., Leventis A., Maou N., Paparoulis G., Karagiannidis C. (1997a) "Developing Web Browsers Accessible to All:

Supporting User-Adapted Interaction", 4th European Conference for the Advancement of Assistive Technology (AAATE '97), Porto Carras, Greece, 29 September - 2 October, 233-237.

Stephanidis C., Savidis A. (1997), "Final Report on the I-GET tool", TIDE TP1001 ACCESS Project, Deliverable D.1.4.2, January 1997, 62 pages.

Stephanidis C., Akoumianakis D. (1997), "Report on issues in Standardisation", TIDE TP1001 ACCESS Project, Deliverable D.4.2.3, January 1997, 48 pages.

Stephanidis, C., Savidis, A., Akoumianakis, D. (1997) "Unified Interface Development: Tools for Constructing Accessible and Usable User Interfaces", Tutorial Notes 13, 7th International Conference on Human-Computer Interaction (HCI International '97), San Francisco, California, USA.

Stephanidis C., Akoumianakis D., Ziegler J., Feahnrich K.-P. (1997b) "User Interface Accessibility: A Retrospective of Current Standardisation Efforts", HCI International '97, San Francisco, USA, 24-29 August 1997, pp. 469-472.

Stephanidis C., Akoumianakis D., Paramythis A. (1998), "User Interaction in Digital Libraries: Copying with Diversity through Adaptation", 2nd European Conference on Research and Advanced Technology for Digital Libraries (2ECDL), Heraklion, Crete, Greece, 21-23 September 1998.

Stephanidis C., Salvendy G., Akoumianakis D., Bevan N., Brewer J., Emiliani P. L., Galetsas A., Haataja S., Iakovidis I., Jacko J., Jenkins P., Karshmer A., Korn P., Marcus A., Murphy H., Stary C., Vanderheiden G., Weber G., Ziegler J. (1998a) "Towards an Information Society for All: An International R&D Agenda", International Journal of Human-Computer Interaction, vol. 10(2), pp. 107-134.

Stephanidis C., Paramythis A., Sfyrakis M., Stergiou A., Maou N., Leventis A., Paparoulis G., Karagianidis C. (1998b): "Adaptable and Adaptive User Interfaces for Disabled Users in the AVANTI Project". In: Trigila, S., Mullery, A., Campolargo, M., Vanderstraeten, H., Mampaey, M. (eds.): Proceedings of the 5th International Conference on Intelligence in Services and Networks (IS&N '98), "Technology for Ubiquitous Telecommunication Services", Antwerp, Belgium, 25-28 May 1998. Lecture Notes in Computer Science, Vol. 1430. Springer-Verlag Haidelberg Germany, 153-166.

Stephanidis C., Salvendy G., Akoumianakis D., Arnold A., Bevan N., Dardallier D., Emiliani P.L., Iakovidis I., Jenkins P., Karshmer A., Korn P., Marcus A., Murphy H., Opperman C., Stary C., Tamura H., Tscheligi M., Ueda H., Weber G., Ziegler J. (1999) "Towards an Information Society for All: HCI challenges and R&D recommendations", to appear in the International Journal of Human-Computer Interaction, vol. 11(1), 27 pages.

Story, M. F. (1998) "Maximising Usability: The Principles of Universal Design", Assistive Technology, vol. 10, pp. 4-12.

Vanderheiden G.C. (1990) “Thirty-something million: Should they be exceptions”, Human Factors, 32, pp. 383-396. Also available at: http://www.trace.wisc.edu/text/univdesn/30_some/30_some.html.

Vanderheiden G.C. (1998) “Universal Design and Assistive Technology in Communication and Information Technologies: Alternatives or Complements?”, Assistive Technology, Vol. 10.1, pp. 29-36.

Vernadakis N., Stephanidis C., Akoumianakis D. (1995a) “On the impediments to innovation in the European Assistive Technology industry”, International Journal of Rehabilitation Research, vol. 18(3), pp. 225-243.

Vernadakis N., Stephanidis C., Akoumianakis D. (1995b) “The use of analytical tools in analysing the demand of assistive technology products: The case of Alarm Telephones”, 2nd TIDE Congress, Brussels, Belgium, 26-28 April, pp. 211-214.

Vernadakis N., Stephanidis C., Akoumianakis D. (1997) “Transferring technology towards the European AT Industry: Mechanisms and Implications”, Assistive Technology Journal, vol. 9(1), pp. 34-46.

Weber G., Kochanek D., Stephanidis C., Homatas G. (1993) “Access to Selected Interaction Objects in MS Windows”, 2nd European Conference on the Advancement of Rehabilitation Technology (ECART-2), Stockholm, Sweden, 26-28 May 1993, 3 pages.

Weber G., Kochanek D., Stephanidis C., Gogoulou R. (1994), “Report on the XWindows demonstrator”, TIDE-GUIB II Deliverable No 15.2, GUIB-II Consortium, November 1994, 71 pages.

Winograd T. (1995), “From Programming Environments to Environments for Designing”, Communications of the ACM, 38(6), 65-74.

APPENDIX

Some European Commission Programmes that have funded Assistive Technology Project work

COST

European co-operation in the field of Scientific and Technical research
(1971 -)

COST is an open and flexible framework for scientific and technical co-operation in Europe, including also countries outside the European Union. The main focus of COST activities is the co-ordination of national research on a European level. COST Actions consist of basic and pre-competitive research as well as activities of public utility. In contrast to other European Commission funded research Programmes, this form of collaboration does not require an agreed overall research policy. It focuses on specific themes for which there is particular interest in the COST countries. COST funding covers only the co-ordination expenses of each Action. The signatory countries have to ensure that the means necessary for research cooperation are actually provided.

For more information see: http://www.cordis.lu/cost/

COST Action 219 (1986 to 1996) promoted research into the telecommunications field with the aim of proposing solutions to problems faced by disabled and elderly people in ensuring access to the emerging telecommunications infrastructure and telematics services. The main objectives of the Action were: to survey the state of the art regarding user requirements as well as technological developments; to review ongoing research and development efforts that could impact the socio-economic integration of people with disabilities; to stimulate activities in the Assistive Technology field; to consider the anticipated impact of emerging technologies on people with disabilities; and to act as an incubator for new research projects in the Assistive Technology field.

For more information see: http://www.stakes.fi/cost219/COSA130.HTML

COST Action 219 bis (1996 to 2001) is a continuation of the COST 219 Action. The main objective of this Action is to increase the availability of telecommunication services and equipment that are accessible by disabled and elderly people. This objective is pursued through three parallel lines of activity: (a) explicitly taking into account the specific requirements of people with disabilities, early in the design phase; (b) providing guidelines for adaptations to existing services and equipment; and (c) providing specifications for the establishment of supplementary, special-purpose, services and equipment. Moreover, the Action seeks to promote the principles of “Design for all” in the development of future telecommunications infrastructure and telematics services.

For more information see: http://www.stakes.fi/cost219/COSA120.HTML

RACE
Research and development in Advanced Communications technologies in Europe
(1987 to 1995)

RACE was a collaborative European research and development Programme. It received a financial contribution from the European Commission of 1,103 MECU, which represents less than 50% of the overall effort estimated at 2,500 MECU. The overall objective was the introduction of Integrated Broadband Communication (IBC) technologies, taking into account the evolving ISDN (Integrated Services Digital Network) and the various national introduction strategies. A small proportion of resources was devoted to access problems encountered by disabled and elderly people in the emerging telecommunications environment. This was the first systematic attempt in Europe to introduce the requirements of disabled and elderly people during the initial development stages of a new technology, instead of following the traditional adaptation approach after the technology has been deployed.

For more information see: http://www.analysys.com/race/

ACTS
Advanced Communications Technologies & Services
(1994 to 1999)

The ACTS Programme was the continuation of the RACE Programme under the Fourth Framework Programme of the European Commission, supporting research and development activities in advanced communications. ACTS research and development projects were conducted in the context of usage trials to ensure end-user relevance of the results and to encourage a broadening of awareness of the benefits that advanced communications may bring. The Programme had a budget of 671 million ECU, which was about 5% of the total budget available for European research under the Fourth Framework Programme. Given the global nature of the communications business, ACTS encouraged participation from non-EU countries. ACTS continued the policy of its predecessor Programme (RACE) in devoting a small proportion of resources to the access problems facing disabled and elderly people.

For more information see: http://www.infowin.org/ACTS/

TIDE
Technology Initiative for Disabled and Elderly people
(1991 to 1999)

The TIDE Programme is a pre-competitive technology research and development initiative in the field of assistive technology for the elderly and disabled. TIDE covers a broad range of technologies, including information, communication and control technologies. The main objective of the Programme is to stimulate the creation of a single market in assistive technology in Europe with a view to enable disabled and elderly people to live more independent lives and become more integrated in the society.

Project work funded by the TIDE Programme has addressed five main principles: (a) market orientation; (b) technology adaptation and innovation; (c) multi-disciplinary approach; (d) technology verification; and (e) user-focused approach. The principle of market orientation, i.e., development of assistive technology products that would reach the market, proved to be one of the Programme's strengths. At the same time, it was one of the Programme’s weak points since it mostly favoured projects that addressed “easy” problems which could be partially addressed by simple adaptations of available technology, instead of considering the “real”, and usually complex, problems faced by disabled and elderly people.

TIDE started as a pilot action outside the Commission’s Framework Programmes and, following a number of phases, it is currently completing a cycle under the Telematics Application Programme - Disabled and Elderly Sector - within the Fourth Framework Programme. In the period 1991 - 1999 TIDE has funded project work of the order of 200 MECUs.

For more information see: http://www2.echo.lu/telematics/disabl/disabel.html

AIM
Advanced Informatics in Medicine
(1988 to 1994)

AIM was a two-phase Programme, with the objectives to:

(a) exploit information technology and telecommunications (IT&T) in order to improve health care within the European Union;

(b) stimulate the development of harmonized applications of information and communication technologies in health care and the development of a European health-care information infrastructure taking into account the needs of users and technological opportunities.

In the context of the AIM Programme some activities related to the rehabilitation technology have been carried out. These activities mainly addressed problems connected to movement assessment and multimedia databases of rehabilitation techniques.

The AIM Programme's total funding was approximately 120 MECUs, out of which only a very small proportion was allocated to project work on Rehabilitation Technology.

For more information see: http://www.ehto.be/aim/