# Designing for *all* in the Information Society:

## Challenges towards universal access in the information age

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## 1. Introduction

The present report seeks to advance a proposition for an *inclusive* Information Society, by reviewing the current state of the art in prominent Information Society Technologies (IST), and elaborating on a proposed roadmap towards such an objective. The main line of argumentation is that the emergence of an Information Society signifies the creation of a broad range of new virtualities that will increasingly characterise the way in which humans undertake and engage in societal activities. Several metaphors, some generic (e.g., information highway) and others more specific (e.g., digital cash, virtual organisation), have been employed to convey the essence of the transformation of contemporary society to one based on information. Clearly, the hardest target to achieve in this process will be the *design* of such virtualities so as to empower *all* citizens and augment human problem solving capabilities. In this respect, Human-Computer Interaction (HCI) is particularly important, as citizens in the Information Society experience technology through their contact with the *user interface* of interactive products, applications and telematic services.

Recent research and development efforts, in Europe and world-wide, have demonstrated the compelling need for a human-centred protocol, whereby technological developments meet the requirements of end-users. Despite this widely held view, very little is currently available in terms of corresponding practical insights. On the contrary, the intensive competition and the commitment to minimising the time-to-market criterion has given rise to products and services which hardly embody the necessary qualities of human-centred development. At the same time, there are countries, nations, and geographic regions where the promise of an Information Society is less immediate, or appears very distant, due to the lack of the necessary infrastructure that constitutes the necessary technological performance threshold. For those geographic regions above such a threshold, infrastructure is a necessary but not sufficient condition. To define precisely the additional criteria requires an insight into what type of society is envisioned, its underlying principles and values, as well as the norms that are needed to prevail.

The present report advocates the need for an *inclusive* Information Society that values and respects citizens irrespective of social status, gender, age or (dis)ability. It thus, seeks to establish *universal accessibility* as a first-order design objective and a compulsory quality target in the emerging Information Society. The realisation of such a vision demands long-term commitment to principled objectives, inter-disciplinary efforts and quantifiable yardsticks to measure and assess progress. Most of all, however, what is needed is a research agenda on universal access that will provide a common and unifying frame of reference for subsequent endeavours. The report highlights such a tentative research agenda with the intention to establish a shared vocabulary amongst ERCIM institutes and an evolving space of collaborative research and development. The thematic scope of the proposed agenda is intentionally broad and complex. It spans from theoretical propositions to technical and research policy issues. By this account, it aims to highlight opportunities for both *technological* and *induced* innovation.

*Universal Access* concerns the right of *all* citizens to obtain and maintain access to a society-wide pool of information resources and interpersonal communication facilities, given the varieties of context. In recent attempts to formulate a definition of universal accessibility, in terms of measurable yardsticks, it is customary to assign a numerical value (e.g., 90 % of the target / total population) to depict the threshold of universal accessibility for certain products and services (e.g., telephony, e-mail). In this report we will not follow this tradition, since it is not always easy to define either the target or the total population of a product or service. It is however our intention to point out some of the technology performance thresholds that need to be overcome before universal access in the Information Society becomes a viable objective.

To this effect, the proposed research agenda calls for a concentrated effort at different levels, including the advancement of relevant theory, technology and policy. The recommendations for theoretical research are grounded on the compelling need to establish firm links with developmental sciences in order to provide a *design-oriented science base* and a consolidated body of knowledge that can inform the "construction" of new virtualities. The Research and Technological Development (RTD) part of the agenda outlines areas of technological research and development focusing on the provision of large-scale prototypes, *tools* and technical frameworks facilitate the development of applications and services accessible to the broadest possible end user communities. Finally, the research policy component identifies accompanying measures that are needed to guide research efforts as well as to create an environment favourable to industrial innovation towards universal access.

It should be noted that the proposals made are not intended to be either exhaustive or conclusive. They do however postulate a *proactive* account of the relevant issues, which is believed to be the only pathway through which the desired effects can be brought about. Furthermore, no account is provided as to the possible implementation mechanisms that could see to the realisation of the agenda. Nevertheless, it is argued that the propositions made are relevant at different levels, and they concern national, European and international research policy, and that they demand close collaboration and coordination.

## 2. The Information Society

The radical technological changes in the Information and Telecommunications industries have contributed towards a more information- and interaction-intensive paradigm for human-computer interaction. This trend, which is expected to continue, raises a whole new range of social, economic and technological considerations, regarding the structure and content of societal activities at the turn of the 21st century.

The term *Information Society*, although attributed with different connotations and meanings, is frequently used to refer to the new socio-economic and technological paradigm likely to occur as a result of an all-embracing process of change that is currently taking place.

The Information Society is neither the mere effect of radical technological progress, brought about by RTD work, nor the result of incremental demand-driven innovation in a particular sector of the industry. Instead, it is a product of a technology-fusion of information and telecommunications technologies, capable of revolutionising markets. This far-reaching effect of combining incremental technical improvements from several previously separate fields of technology is known to bring about radically new opportunities and market windows. Fumio Kodama, in (Kodama, 1992) reports that:

> *"… marrying optics and electronics technologies produced optoelectronics, which gave birth to fiber-optics communications systems; fusing mechanical and electronics technologies produced the mechactronics revolution, which has transformed the machine tool industry."*

In a similar fashion, the fusion of information and telecommunications technologies is likely to revolutionarise the Information Technology industry, creating new markets as well as far-reaching organisational and institutional changes in all aspects of human activity such as daily living, workplace, leisure, shopping, commerce, education, etc.

Figure 1 depicts critical trends associated to the emergence of the Information Society. The main feature of the Information Society is the evolution 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-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.

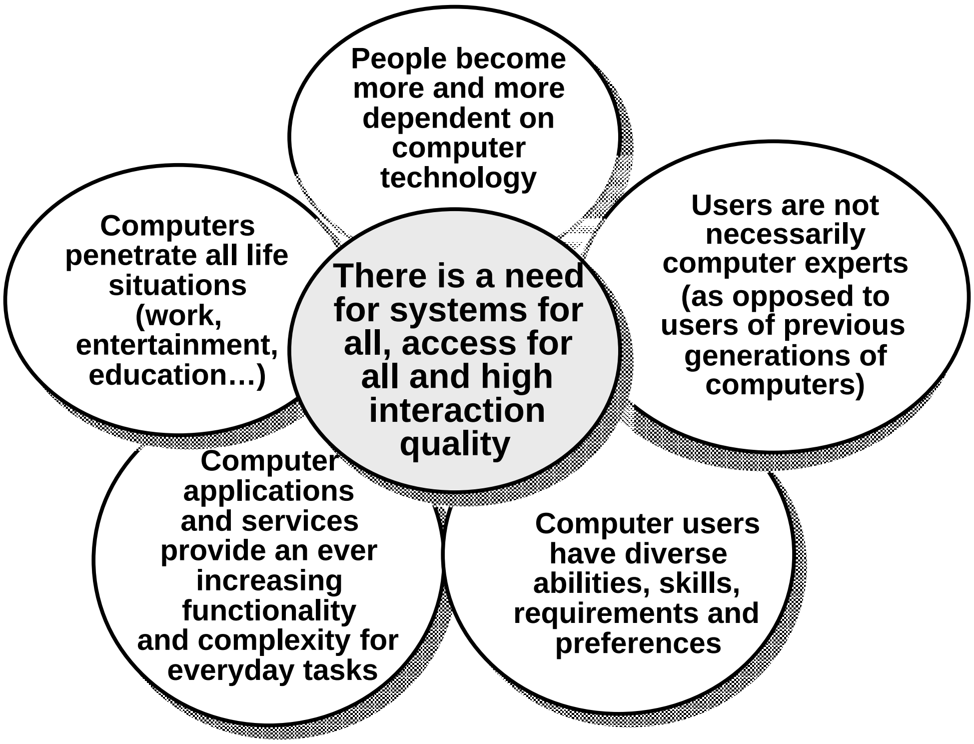


**Figure 1: Critical trends towards the emergence of an Information Society**

The Information Society has the potential to improve the quality of life of citizens, the efficiency of our social and economic organisation, and to reinforce cohesion. 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, as with all major technological changes, it can also have disadvantages. 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. These difficulties may lead to a “two-tier” society of “cans” and “can-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. It is in this context that the notions of *Universal Access* and *Design for All* become important for ensuring social acceptability of the emerging Information Society.

This report focuses on the concept of *Design for all* as a proactive approach to the accessibility of IST, and reviews current efforts towards the development of generic solutions to the problem of accessibility, including Active Accessibility® by Microsoft, Java™ Accessibility by Sun, the Unified User Interface development methodology and tools, and the FRIEND21 Guidelines for the Human Interface Architecture. The report also briefly summarises policy initiatives by international collaborative research and industrial consortia and standardisation bodies aiming at promoting proactive approaches to accessibility and *Design for all*. The aim is to point out the challenges posed by Design for All, particularly in the field of HCI, which relate to both the design and the development of user interfaces, and to sketch a research agenda for meeting the identified challenges. The field of HCI is particularly important to the issue of *acceptability* of IST by the broadest possible user population, as citizens in the Information Society experience technology through their contact with the *user interface* of interactive products, applications and telematic services.

## 3. Universal access in the Information Society

The acceptability of the emerging Information Society to all citizens ultimately depends on its accessibility and usability. Therefore, it is important to develop high quality user interfaces, *accessible* and *usable* by a diverse user population with different abilities, skills, requirements and preferences, in a variety of contexts of use, and through a variety of different technologies. *Universal Access* concerns the right of *all* citizens to obtain and maintain access to a society-wide pool of information resources and interpersonal communication facilities, given the varieties of context. To this end, HCI plays a critical and catalytic role.

In the context of the emerging Information Society, *universal access* becomes predominantly an issue of design, namely how is it possible to design systems that permit systematic and cost-effective approaches to accommodating all users (Mueller et al., 1997; Stephanidis, 1995b). "Universal design" or "design for all" (the two terms are used interchangeably in the present context) has long been a topic of discussion and debate. It grew out of demographic, legislative, economic and social changes among older adults and people with disabilities throughout the 20th century (Story, 1998). But, despite its origin, its focus is not specifically on people with disabilities, but on *all* people. This is clearly evident from the practice of universal design in certain engineering disciplines, such as housing, interior design, architecture, and consumer products, where universal design delivers a code of design that respects and values the requirements of the broadest possible end-user community. In this report, the term *universal design*, following (Stephanidis et al., 1998), is used to reflect a new concept or philosophy for design that recognises, respects, values and attempts to accommodate the broadest possible range of human abilities, requirements and preferences in the design of IST-based products and environments. Thus, it promotes a design perspective that eliminates the need for "special features" and fosters individualisation and end-user acceptability.

*Design for all* does not imply a single design solution suitable for all users. Instead, it should be interpreted as an effort to design products and services in such a way so as to suit the broadest possible end-user population. 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 Information Technology and Telecommunications (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 & 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.

D*esign for all* is already practised in several engineering disciplines, such as, for example, civil engineering and architecture, with many applications in interior and workplace design (Mace, 1998), housing (Mueller, 1998), etc. This is not to say, by any means, that the built environment we all live in has been designed for all, but merely points to the fact that *universal design* is not specific to the IST and the respective sectors of the industry. However, the distinction that should be made is that, whereas the existing knowledge may be considered sufficient to address accessibility of physical spaces (in our built environment), this is not yet the case with IST, where *universal design* still presents numerous challenges.

It should be noted that universal design has often attracted criticism regarding its 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 & Rieman, 1994 - Section 2.1, Paragraph 3). However, as already mentioned, 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 and a code of practice aiming to provide products that can automatically address the possible range of human needs, requirements and preferences. Another common argument is that universal design is too costly (in the short-term) for the benefits it offers. Though the field lacks substantial data and comparative assessments as to the costs of designing for the broadest possible population, it has been argued that (in the medium- to long-term) the cost of inaccessible systems is comparatively much higher, and is likely to increase even more, given the current statistics classifying the demand for accessible products (Bergman & Johnson, 1995; Vanderheiden, 1990). What is really needed is economic feasibility in the long run, leading to versatility and economic efficiency (Vernardakis et al., 1997).

## 4. State of the art

Over the years, the issue of access to computer-based applications and services 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, at present, to assess the economic efficacy of proactive approaches, the attention that is being devoted to the issue is rapidly increasing[1]. 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.

### 4.1 Reactive efforts to accessibility

The traditional approach to accessibility is to adapt applications and services to the abilities and requirements of people with disabilities. As a result, such an approach mainly reflects a *reactive* attitude, whereby Assistive Technology solutions addressed problems introduced by a previous generation of technology (Stephanidis & Emiliani, 1999). This reactive approach entails primarily *adaptations* that facilitate access to the interface via suitable mechanisms, such as filtering, dedicated interaction techniques (e.g., scanning) and specialised input/output devices (e.g., Braille displays, switches, eye-gaze systems). Typically, the result of adaptations includes the reconfiguration of the physical layer of interaction, and when necessary, the "translation" of the visual interface manifestation to an alternative modality. For example, access to a Graphical User Interface (GUI) by a blind user requires "filtering" of the contents of the screen, using appropriate software (e.g., screen reader), so as to present them in an alternative modality (e.g., tactile, audio).

[1] For example, the 1st International Conference on Universal Access in Human-Computer Interaction will be held in New Orleans, Louisiana, USA, August 5-10 2001 (http://hci2001.engr.wisc.edu).

Despite the undoubted value and usefulness of the adaptations-oriented approach and the accumulated body of knowledge, it clearly neglects aspects of accessibility which become promptly relevant and important in the context of the emerging Information Society (Mueller et al. 1997; Stephanidis et al., 1998b; Stephanidis et al., 1999a). Firstly, reactive approaches are not viable in sectors of the industry characterised by rapid technological change. By the time a particular access problem has been addressed, technology has advanced to a point where the same or a similar problem re-occurs. In some cases, adaptations may not be possible at all, without loss of functionality. Secondly, adaptations introduce a programming-intensive approach towards accessibility, which increases the cost of implementing and maintaining accessible software. Technological progress may render adaptations harder to implement. Finally, it is increasingly recognised that in the context of the emerging Information Society, accessibility should no longer be considered as mere translation of visual interface manifestations to alternative modalities (e.g., a posteriori adaptations), but as a requirement demanding a generic solution (Mueller et al., 1997; Stephanidis et al., 1998b; Stephanidis et al., 1999a). As a result, there have been several efforts in the direction of advancing and articulating the principles of universal design to address a range of quality attributes, including accessibility, in the context of the emerging Information Society.

## 4.2 Proactive efforts towards accessibility

Recently, there have been a number of initiatives by mainstream actors (Microsoft, Sun, IBM, Apple, etc) and research consortia to develop technological frameworks that provide more adequate support for accessibility and easier integration of assistive technology applications. These efforts aim to overcome the problems identified above and provide accessibility tools as integral components of mainstream interaction platforms and environments. Three promising alternatives are the Active Accessibility® initiative by Microsoft, Java™ Accessibility by Sun and the Unified User Interface development platform developed by ICS-FORTH[2] in the context of the ACCESS consortium of the Commission of the European Union. An important contribution has been also represented by the FRIEND21 project in Japan.

### 4.2.1 Active Accessibility®

Active Accessibility® is one of Microsoft's most strategic initiatives to improve the accessibility of applications and computer software in general[3]. It is a developer technology mainly indented to render computer programs more accessible to people who use accessibility aids (e.g., screen readers). In particular, it enables applications and objects to communicate more effectively and to actively co-operate with accessibility aids, providing information about their current status, the contents of the screen, and the ability for utilities to automate control of the application.

Active Accessibility® is based on OLE and the Component Object Model (COM), which are both Microsoft's standards for software component communication and inter-operation. These were designed to be able to handle new roles, which have now been applied to accessibility.

Using these foundations, an application creates "objects" representing elements on the screen. These objects provide the specific information needed by accessibility aids, such as the name

[2] http://www.ics.forth.gr/proj/at-hci/.
[3] http://www.microsoft.com/enable/msaa/default.htm

and type of the object, and where it is located on the screen. Most importantly, this information is standardised across all applications, so an accessibility aid should be able to work with any application that supports Active Accessibility.

The main contributions of Active Accessibility® to the accessibility of applications and services can be briefly summarised as follows:

- *Common Methods and properties*: Applications and objects can use COM and OLE Automation to expose a standardised set of basic methods and properties. This allows utilities to work with a wider range of applications, and ensures that the application provides sufficient functionality to support a wide range of tools and accessibility aids.

- *Object From Window or Location*: A set of functions that allow utilities to initiate communication with the COM or OLE Automation objects underlying a particular window, user interface element, or location on the screen. Thus, utilities are not required to know in advance which objects they will address.

- *WinEvents*: A mechanism that allows the system and applications to notify interested software about a wide range of state changes.

- *Off-Screen Model*: An enhancement planned for the future, the Microsoft Off-Screen Model (OSM) will be a centralised manager that client utilities can query about the text and objects on the screen and their screen presentations.

By supporting some or all of these methods, an application can provide information about on-going operations to accessibility aids, so they will no longer be dependent upon how the application's user interface is actually implemented. This allows software vendors to innovate in their user interface and implementations (e.g., by introducing new, non-standardised interaction elements), without sacrificing accessibility.

From the user's perspective, Active Accessibility® is entirely invisible. The required files get installed on the system when an accessibility aid is installed, or they may be installed as part of the operating system. Once it is installed, applications that use it will work with accessibility aids and other tools, and accessibility aids that use it will work with more applications, and should come to market more quickly.

From the developer's perspective, Active Accessibility® is a set of new Windows functions, and provides a solution to some hard compatibility problems that in the past have been impossible to resolve.

### 4.2.2 Java™ Accessibility

In the recent release of the Java™ Development Kit (JDK 1.2, also termed Java 2), the Java Foundation Classes incorporated several new features that have further enhanced a developer's ability to deliver scaleable, commercial, mission-critical applications. The features most relevant to accessibility include[4]:

[4] http://java.sun.com/products/jfc/jaccess-1.2/doc/guide.html

➪ *New high-level components*: these components (nicknamed “Swing components”) are written in Java, without window-system-specific code. This facilitates a customisable look and feel, without relying on the native windowing system, and simplifies the deployment of applications;

➪ *Pluggable look and feel*: this feature gives users the ability to switch the look and feel of an application without restarting it and without the developer having to modify the entire set of interactive components;

➪ *Accessibility API*: The Accessibility API provides a clean interface that allows assistive technologies to interact and communicate with interface components; development of this API has followed an open design process based on input from experts in the assistive technology field.

The Java™ Accessibility API defines a contract between the individual user interface elements that make up a Java application or applet, and an Assistive Technology product (e.g., screen reader, screen magnifier) that provides access to that Java application / applet. If a Java application / applet fully supports the Java Accessibility API, then it should be compatible and interoperate with Assistive Technology products. The accessibility contract defines a taxonomy of the various user interface elements used in Java programs, and further defines a set of queryable attributes –as well as the mechanism for making these queries– that exist on these user interface elements.

Combining the API with the accessibility features built into the Java Foundation Classes (JFC - a new library of interactive elements for the Java platform) enables accessibility to Java applications by users with disabilities and benefits both Assistive Technology Vendors (ATVs) and Independent Software Vendors (ISVs) alike.

In particular, ATVs benefit because the API allows them to quickly determine how to make their technologies Java savvy. ISVs benefit because the JFC enables them to maximise the information exposed to assistive technologies while, helping them meet legislation requirements for product accessibility in the countries where these hold. Finally, users benefit because the tight integration between the API and JFC allows their assistive technology products to operate on the user interface more reliably than was possible before.

In practice, Java™ Accessibility provides the means through which assistive technologies obtain accessible information about the user interface objects in the Java Virtual Machine. The Java™ Accessibility API is designed to allow assistive technologies such as screen readers, screen magnifiers, speech recognition systems and Braille terminals to access Java applications. For example, a developer can create a single application to be used by users with and without disabilities at the same time. As another example, using the Java™ Accessibility API to refine speech recognition capabilities will enable developers to create nomadic applications that do not rely on either touch or vision.

### 4.2.3 FRIEND21: Guidelines for the human interface architecture

FRIEND21 was a visionary five-year Japanese project aimed to provide guidelines for the next generation of user interface software and technology. In particular, FRIEND21 was tasked to achieve a technological revolution by replacing the conventional idea of a machine-oriented interface with a human-oriented interface. It has therefore proposed two new concepts of "human interface architecture", namely metaware and the agency model, and has concentrated its research and development efforts to implementing these concepts in real systems. The results of the FRIEND21 project have been published in a series of symposia, and in a comprehensive book by the Institute for Personalised Information Environment (PIE, 1995).

Though FRIEND21's rationale was not based on the concept of accessibility by disabled and elderly people, it was perhaps one of the first efforts in the late 1980s to acknowledge the new information processing paradigm shift and the implications for human interfaces. The results of the project offer a new understanding of how humans can interact with information artefacts and novel perspectives on the architectural components that should be embodied in the next generation human interface architectures. In this section, we provide a brief and informal account of FRIEND21 and its contribution to a more accessible information environment.

Some of the premises of FRIEND21 were (PIE, 1995):

- Enjoyable and useful information must be made available by the system on a daily basis, and anyone must be able to use it in a simple manner.
- Anyone must be able to easily access such information from anyplace at anytime.
- People-to-people communication must be broadened through the medium of information, and the means of communication must become more versatile, more user-friendly and appropriate to the needs in question.
- Anyone should be able to use these means of communication without difficulty, and if new forms of information or new functions are provided, very little time and effort should be required to learn them.

To shed light into the above issues, FRIEND21 proposed a set of guidelines and a conceptual depiction of architectural components for the next generation human interface. The key concepts in this effort were the notions of *metaware* and *the agency model*.

*Metaware*: The purpose of metaware is to provide a design framework for adapting the computer to the environment, so as to support the wide range of situations appearing in everyday life. Metaware is an effort towards a prescriptive theory for the use of multiple representations (multiple metaphors) in any one setting. This entails that the computer can exhibit adaptive behaviour in the sense that it can select and present appropriate images to assist the user in executing tasks, based on functions for identifying task intentions and the context of use, as this is provided by the user's personal operation history, preferences and dislikes.

*Agency model*: This is a computational mechanism for implementing metaware. The agency model provides for three functionally different agent groups that co-operate with each other in a distributed fashion via a shared blackboard interface called studio. These three agent groups are metaphor-environment agents and drive representations, function agents that execute tasks, and management agents that co-ordinate the interaction between the first two agent groups. The studio where agents exchange information acts as a framework for achieving a multimedia and multimodal operation environment, enabling the operation of multiple agents in parallel. Moreover, the studio is conceived as a flexible framework that can adapt to system extensions (i.e., system modifications and plug-in upgrades). Figure 2 shows an overview of the agency model.

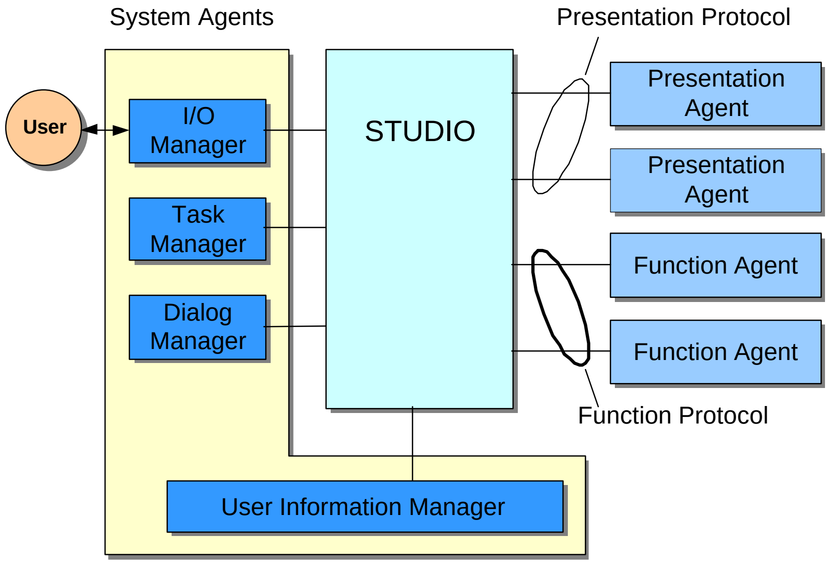


**Figure 2. The Agency Model in the FRIEND21 project (from PIE, 1995)**

### 4.2.4 User Interfaces for All and Unified interface development

The concept of *User Interfaces for All* was originally introduced in 1995 (Stephanidis, 1995b), following the results of several research initiatives in the context of collaborative project work co-funded by the European Commission (a review is available in Stephanidis & Emiliani, 1999). *User Interfaces for All* is rooted in the concept of *Design for All*, and aims at efficiently and effectively addressing the numerous and diverse accessibility problems (Stephanidis ed., 2000). The underlying principle is to ensure accessibility at design time, and to meet the individual requirements of the user population at large, including disabled and elderly people. 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. Such an approach, therefore, eliminates the need for a posteriori adaptations and deliver products that can be tailored for use by the widest possible end-user population.

The ACCESS[5] project, in the course of a three-year effort, 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 capable of automatically adapting themselves to individual user abilities, skills, requirements, and preferences. The project developed the *Unified User Interface* development methodology (chapters 19 to

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[5] 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). 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).

25 in Stephanidis, 2000; Stephanidis et al 1997b; Stephanidis et al. 1999b), and delivered a novel user interface development platform (Akoumianakis & Stephanidis 1997; Savidis & Stephanidis 1997, Savidis et al., 1997a; Savidis et al., 1997b; Savidis et al., 1997c; Stephanidis et al., 1997a). The methodology and supporting tool environment went through thorough validation and evaluation to demonstrate technical feasibility and reliability. In particular, the Unified User Interface development tools were used to develop accessible user interfaces in the application domains of communication aids for speech-motor and language-cognitive impaired users (Kouroupetroglou et al., 1996) and hypermedia for the blind (Petrie et al., 1997).

Subsequently, in the AVANTI[6] project, the unified interface development methodology was applied in the domain of the World Wide Web to provide adaptable and adaptive browsing technology for access to metropolitan information systems by users with diverse abilities, skills, requirements and preferences. The systems were targeted for the population at large, including people with disabilities. In particular, based on the Unified User Interface development 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 rest of this section provides a brief overview of the approach adopted by Unified User Interface development and highlights some of the novel properties underpinning this effort. For more details on the technical properties of unified interface development the user is referred to chapters 19 to 25 in (Stephanidis, 2000) and to (Akoumianakis & Stephanidis 1997; Akoumianakis et al., 2000; Stephanidis et al., 1999b; Savidis and Stephanidis, 1997; Savidis et al., 1997a; Stephanidis et al., 1997a; Stephanidis et al., 1997b).

Unified User Interfaces seek to convey a new perspective on the development of user interfaces which provides a principled and systematic approach towards coping with diversity in the target users groups, tasks and environments of use. The notion of a Unified User Interface originated from research efforts aiming to address the issues of accessibility and interaction quality for people with disabilities. The intention was to articulate some of the principles of *Design for All* in a manner that would be applicable and useful to the conduct of HCI. Subsequently, these principles were extended and adapted to depict a general proposition for HCI design and development, which was complemented by specific methodologies, techniques and tools.

A Unified User Interface is defined as an interactive system which comprises a single (i.e., unified) interface specification, targeted to potentially all user categories and contexts of use (see Figure 3). Such a specification can be built using either a traditional programming language, or a dedicated language.

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[6] 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). 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).

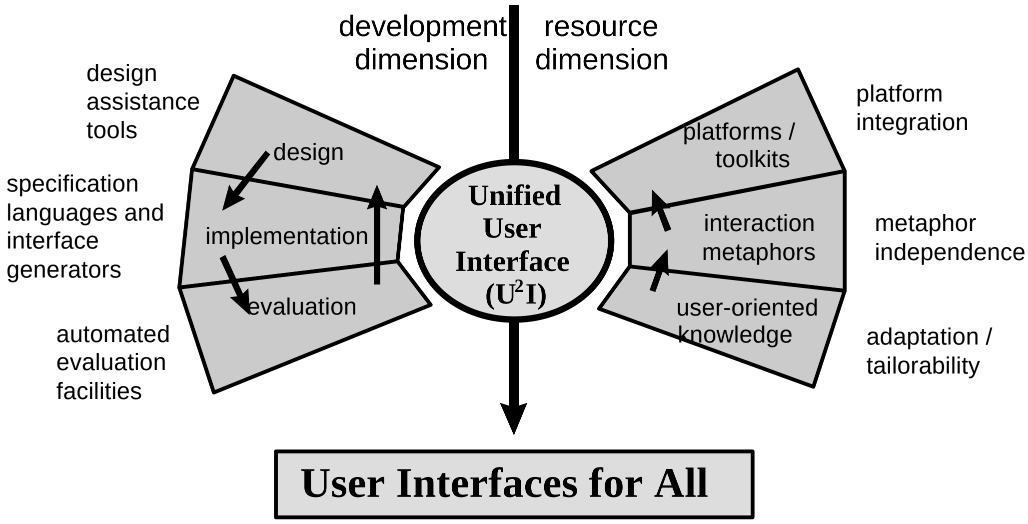


**Figure 3. The concept of unified user interfaces**

The distinctive property of a Unified User Interface is that it can realise alternative patterns of interactive behaviour, at the physical, syntactic or even semantic levels of interaction, by automatically adapting to accommodate specific user- and context-oriented requirements. Typically, such alternative interactive behaviours encompass interaction elements available in different toolkits or interaction platforms (e.g., Windows95, toolkit for non-visual interaction), suitable for the different target user groups (e.g., sighted and blind users respectively).

The design of interactive software applications and telematic services accommodating the requirements of "all" users in different contexts of use introduces the need to take into consideration the diverse attributes that characterise the users and the envisaged contexts of use. These varying user- and usage-context- attribute values give rise to different design requirements, which, in turn, affect the design of dialogue artefacts. As a result, alternative dialogue artefacts have to be constructed at various points of the interface design process, as dictated by the differing user- and usage-context- attribute values.

When trying to map the outcomes of such design processes into an implemented interactive application, a key issue is how the various alternative dialogue artefacts will be "packaged". The production of alternative interface versions requires prohibitive resources for development, maintenance, upgrading and distribution (since all distinct versions should potentially be made available for concurrent "execution"), which turns out to be practically unrealistic. This is particularly evident in the case of non-desktop computer systems, such as public access terminals, that anyone should be able to use. Consequently, the "packaging" of the various alternative dialogue patterns into a single software application has been considered the most promising approach. In this context, packaging may not necessarily imply the construction of a monolithic software system incorporating all the various dialogue artefacts; rather, it can be instantiated as a logical collection within a single resource. For example, a repository can be made directly accessible by a single software application which encompasses adaptation capabilities, thus being able to select the most appropriate dialogue patterns for a particular end-user and target usage context. In order to facilitate such a capability, interactive applications should encompass information about individual users, as well as alternative dialogue patterns in an implemented form.

The need for an appropriate development strategy for Unified User Interfaces has led to the introduction of the Unified User Interface development paradigm, targeted to the development of Unified User. The Unified User Interface development paradigm entails inter-disciplinary processes driving the production of automatically adapted software applications and services. It is general enough, so as not to exclude particular design and implementation practices, while, at the same time, it offers sufficient details to drive the engineering process of Unified User Interface software. As any new development paradigm, it naturally requires some initial investment to be effectively adopted, assimilated and applied. However, if the constructed software products are intended to be used by user populations with diverse requirements, operated in different usage contexts, the gains will heavily outweigh the overhead of additional resources that need to be invested.

Schematically, the phases of Unified User Interface development are depicted in the diagram of figure 4. Unified design entails an early account of the broadest possible range of end-user requirements and contexts of use, so as to develop effective representations depicting the global task execution context. Unified implementation, on the other hand, requires the capability to encapsulate design alternatives into suitable dialogue patterns and to map abstract design components to corresponding implemented (interaction platform-specific) options.

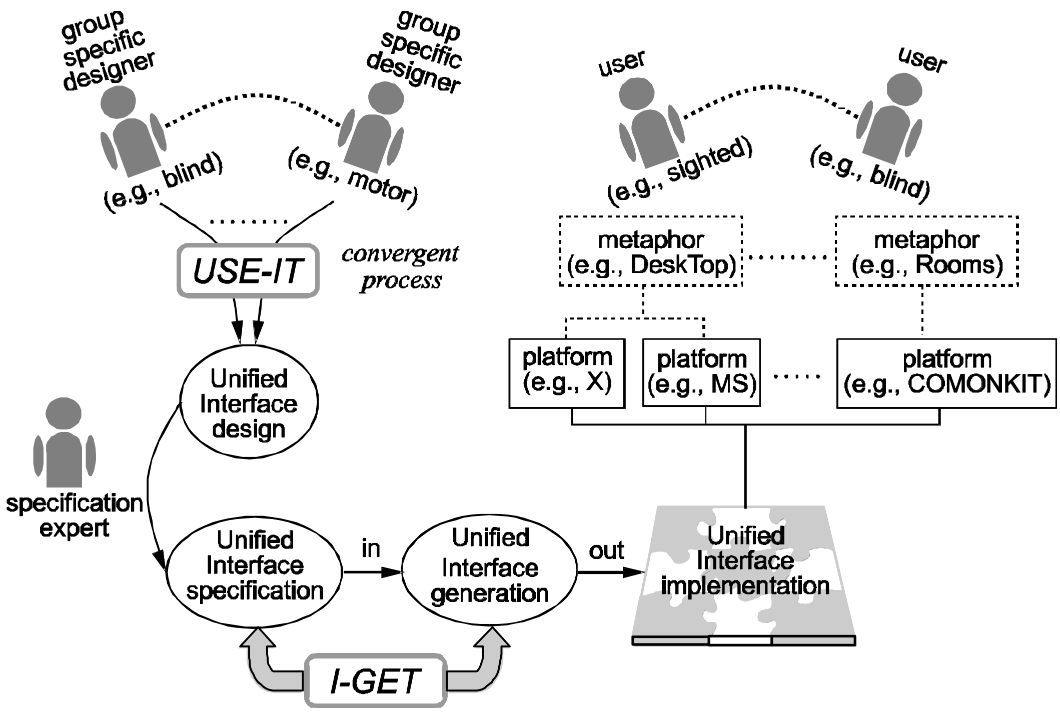


**Figure 4. The design and implementation phases for Unified User Interfaces**

Two distinctive requirements characterise Unified User Interfaces. The first is the requirement for an analytical design activity leading to the representation of the design knowledge required to reveal and differentiate amongst plausible design alternatives. The second requirement is that of encapsulation of the corresponding dialogue patterns into a (conceptually) single interactive entity. In this context, representation implies the use of suitable notations to capture and encode both design artefacts and accompanying design rationale. On the other hand, encapsulation entails the use of suitable dialogue specification techniques (programmatic, declarative, etc.) to manipulate interactive artefacts in a manner that is not dependent on a particular target interaction platform (e.g., by avoiding direct “calls” to the platform’s interactive facilities).

The design of a Unified User Interface entails three distinctive iterative tasks, namely *enumeration of design alternatives*, *abstraction* towards reusable unified design components and *rationalisation* of the design space. Enumeration of design alternatives can be attained through techniques which foster an analytical design perspective (such as design scenarios, envisioning, ethnographic methods) and facilitate the identification of plausible design options for different user groups (i.e., design space).

Abstraction entails the identification of abstract interaction components that can be used to encapsulate alternative concrete artefacts. Such abstract components are de-coupled from platform, modality, or metaphor specific attributes to provide a kind of reusable design “library”. Such an abstract element can be subsequently mapped to any particular concrete instance, given a specific user and context of use. Moreover, abstract components may be used to compile composite interface elements suitable for different users and contexts of use.

Finally, rationalisation of the design space implies the explicit encoding of the rationale for mapping an abstract design element to a concrete artefact. This is typically achieved by assigning criteria to design alternatives and providing a method for selecting the maximally preferred option.

To facilitate encapsulation, Unified User Interface development requires techniques that enable: (i) the grouping of alternative dialogue patterns (e.g., implemented design alternatives, catering for different user requirements) on the basis of an abstraction model; and (ii) the context-sensitive mapping of abstract components to suitable concrete artefacts. To this effect, the process of Unified User Interface implementation involves: (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 (e.g., various toolkits); and, (c) the establishment of the relationships between the involved abstractions and the available physical resources.

The unified implementation undertakes the mapping of abstract interaction elements to concrete / physical resources available in the target toolkits. This is achieved through specific functionality or tools which allow to connect (or link) with the underlying platform(-s) in order to utilise the available interaction resources in a platform-independent manner (Akoumianakis et al., 2000).

The Unified User Interface development paradigm is supported by a set of development tools, which have been built to provide an integrated framework that efficiently supports the design and implementation of Unified User Interfaces. The main characteristics of this framework are (Akoumianakis et al., 2000):

(i) Platform independence, intended to address the pluralism of interaction platforms and graphical environments (e.g., MS-Windows™, the X Windowing System), offering the versatility required for the management of different environments.

(ii) Metaphor independence, so as to cater for the interaction needs and characteristics of diverse target user groups, which may necessitate the coupling of different interaction metaphors to different categories of users and usage situations.

(iii) Automatic adaptation capabilities, so that the resulting user interfaces are adaptable and adaptive to the individual user abilities, requirements, skills and preferences.

(iv) Unified interface specification, which aims to reduce the overall development costs for Unified User Interfaces through the introduction of specification-oriented (rather than implementation-oriented) interface construction techniques.

The Unified User Interface development platform provides a number of tools to facilitate the above novel objectives, including. a high-level language for User Interface specification, (G-DISPEC, Savidis & Stephanidis, 1997), and a tool that automatically generates the implementation from such high-level specifications (I-GET, Savidis & Stephanidis, 1997; Stephanidis et al., 1997a). Additionally, another tool has been developed, (PIM, Savidis et al., 1997a), 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 et al., 1997b); and a toolkit for non-visual interaction (Savidis et al., 1997c). The adaptability of the User Interface to the specific needs, abilities, skills and preferences of the target user group is achieved at design time by means of a User Modelling Tool called USE-IT (Akoumianakis & Stephanidis 1997).

### 4.2.5 Discussion

The premise of Unified User Interface development is that of studying the global execution context of tasks and human activities, to identify suitable alternatives to accommodate individual requirements. This calls for analytical insight and pluralism in the respective outcomes, as no single solution is likely to be acceptable to all users. Such a focus contrasts the prevailing HCI design philosophy and supporting methodologies, which are primarily single-artefact oriented. It follows that Unified User Interfaces require a broader scope of design to explicitly account for context-oriented phenomena, as well as a powerful development framework to enable the generation of user interface implementations through specifying, rather than programming, interactive dialogues.

Such an approach necessitates a shift of perspective, in relation to design and development practices. In particular, the design of Unified User Interfaces requires explicit means to account and model context-oriented parameters. However, such contextual insights can only be facilitated by adopting more suitable units for analysing and modelling interactions (e.g., activity), than contextually isolated user actions (or keystrokes) which have been the primary focus of cognitive models. Additionally, the focus of design is on populating design spaces, rather than identifying a single best fit. Table 1 summarises some of the major differences between unified and traditional design practices.

**Table 1: Contrasting traditional and Unified User Interface design**

| Design Criteria | Traditional development paradigm | Unified User Interface development |
|---|---|---|
| Focus | Single artifact that fits all | Analytical insights to populate design spaces |
| Outcome | Single object hierarchy | Polymorphic task hierarchy |
| Process | Top down or bottom up | Middle out |
| Scope of design representation | Implicitly bound to the object hierarchy | Bound to rationalized design spaces; explicit in the run-time behavior |

Moreover, unified development requires corresponding means to provide the basis for user interface implementation. This challenges traditional practices with regards to both the architectural model according to which unified artefacts become embedded into user interface implementations, and the mechanisms offered for context-sensitive processing of alternatives towards the selection of a maximally preferred option. In Table 2, we contrast traditional and Unified User Interface development.

**Table 2: Contrasting traditional and Unified User Interface development**

| Design Criteria | Traditional development paradigm | Unified User Interface development |
|---|---|---|
| Implementation model | Programming as the basis for generating the user interface implementation | Generation from specifications |
| Premise of run-time code | Making direct calls to a platform | Linking to the platform |
| Platform utilization | Multi-platform environments | Multiple toolkit environment |
| Platform independence | Generalization across platform properties | Platform abstraction mechanism |

### 4.3 Guidelines

In addition to the above RTD efforts, there have been several attempts, some of which are still on-going, to consolidate the existing wisdom on accessible and/or universal design in the form of best-practice principles. Such materials become increasingly available either as general and context-free guidelines or as platform- or user-specific recommendations. Figure 5 shows the different levels of guidelines according to their generic vs. specific nature.

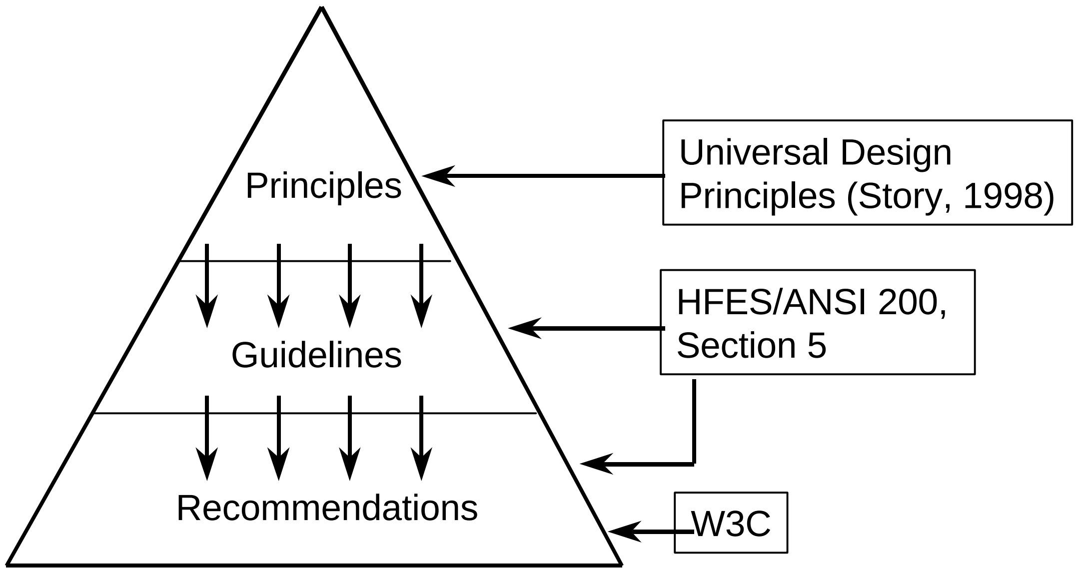


**Figure 5. Different levels of guidelines**

### 4.3.1 General guidelines: The principles of universal design

A recent publication by the Centre for Universal Design at North Carolina State University, U.S.A has summarised its long standing experience in the area of universally accessible built environments in a collection of Universal Design principles (see Table 3).

**Table 3. The Principles of Universal Design (Version 2), Source: Story, 1998**

| Principle | Brief explanation |
|---|---|
| Equitable Use | The design is useful and marketable to people with diverse abilities |
| Flexibility in Use | The design accommodates a wide range of individual preferences and abilities |
| Simple & intuitive Use | Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level |
| Perceptible information | The design communicates necessary information effectively to the users, regardless of ambient conditions or the user's sensory abilities |
| Error Tolerance | The design minimises hazards and the adverse consequences of accidental or unintended actions |
| Low physical effort | The design can be used effectively and comfortably and with a minimum of fatigue. |
| Size and space for approach and use | Appropriate size and space is provided for approach, reach, manipulation and use regardless of the user's body size, posture or mobility. |

It should be noted that general guidelines such as those depicted in Table 3 require substantial interpretation to become context-specific, which is one of their practical limitations.

### 4.3.2 Accessibility guidelines for Assistive Technologies

There have been several publications (e.g., HFES/ANSI 200 Draft, Section 5 on accessibility[7]; Bergman & Johnson, 1995; Church & Glennen, 1992; Thoren, 1993) which propose a collection of guidelines intended to facilitate access by people with disabilities to computer-based equipment and services. These documents consolidate the large body of knowledge regarding people with special needs and alternative assistive technology access in an attempt to formulate ergonomic design guidelines that cover a wide range of disabilities. Similarly, there have been proposals of physical accessibility guidelines of consumer product controls (see for example http://trace.wisc.edu/docs/consumer_product_guidelines/consumer.htm; Rahman & Springle, 1997).

### 4.3.3 Platform-specific accessibility guidelines

In recent years there has also been a trend for major software vendors to provide accessibility guidance as part of their mainstream products and services. In fact all major actors, such as Microsoft, IBM and Sun provide documentation and insights as to the accessibility guidelines applicable to their own platforms or products. Moreover, with the advent of the WWW, the issue of WWW accessibility recurred and was followed up by an effort undertaken in the context of W3C to provide a collection of accessibility guidelines for Web-based products and services[8].

### 4.3.4 Platform requirements for universal access

In a slight different tone, the ACCESS project proposed a set of critical requirements that user interface development platforms should possess in order to provide the required support for the development of universally accessible applications. These requirements are platform integration, platform augmentation, platform abstraction and orthogonality. The definition and rationale for each of those requirements is summarised in Table 4 (Stephanidis et al., 1998a).

## 4.4 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[9,] RACE[10], ACTS[11], TAP[12], COST[13]), industrial consortia (such as the USA Telecommunications

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

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

[10] Research and Technology Development in Advanced Communications Technologies in Europe (http://www.analysys.co.uk/race/).

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

[12] Telematics Applications Programme (http://www2.echo.lu/telematics/home.html).

Policy Roundtable), scientific and technical committees (USACM[14]), 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).

**Table 4. User interface development platform requirements for universal access**

| ***R*** | ***Definition*** | ***Rationale*** |
|---|---|---|
| **Integration** | Ability to import any interaction platform that may be required for the development of interactive applications | In cases where the interaction elements originally supported by a particular interaction platform do not suffice, it is important to be able to utilise interaction elements from alternative sources |
| **Augmentation** | The process through which additional interaction techniques are injected within the original collection of interaction elements of a particular platform | It is desirable to be provide extended interaction facilities, beyond the original collection, which could be useful in specific contexts of use (e.g., voice-control of windowing application, scanning, etc) |
| **Abstraction** | Ability to specify interactive behaviours by means of abstract interaction objects | Different interaction platforms offer different programming interfaces and calling conventions, thus complicating the use development of an interface that makes use of several such platforms |
| **Orthogonality** | Ability of a platform's run-time libraries to expose and make use of information produced by external software tools | When a user interacts with a particular application there are issues that relate to the specific contexts of use and which can only be determined during the interactive session. In such cases the interaction platform should provide the means to expose and receive information relevant to the context of use. |

Finally, efforts towards universal design in the fields of IT&T have met wide appreciation by an increasing proportion of the international research community, thus leading to the foundation of working groups and scientific fora.

The ERCIM Working Group on *User Interfaces for All*[15] (Stephanidis, 1995a) started its activities in 1995, and has held a Workshop on the topic each year since then. It builds on the background of the recent European R&D activities discussed in the previous sections, which have analysed the requirements, identified the viability, and demonstrated the feasibility of constructing 'user interfaces for all', and aims at investigating alternative, technologically more powerful and methodologically more systematic approaches to tackle the problems of accessibility and quality of interaction for all potential users and in a holistic way. The ERCIM

[13] European Co-operation in the fields of Scientific and Technical Research (http://www.stakes.fi/cost219/index.html).
[14] The ACM U.S. Public Policy Committee (http://www.acm.org/usacm/).
[15] http://www.ics.forth.gr/proj/at-hci/UI4ALL/index.html.

Working Group on *User Interfaces for All* aims at planning a path that, apart from meeting technical objectives, will bring closer together researchers and teams working in the different ERCIM organisations (but also organisations beyond ERCIM or the European boundaries), who share common interests and aspirations, and would like to contribute to the endeavours towards making the emerging 'Information Society' equally accessible to all. The Working Group has organised 4 workshops on *User Interfaces for All*: 1st ERCIM Workshop on "User Interfaces for All", Heraklion, Crete, Greece, 30-31 October 1995; 2nd ERCIM Workshop on "User Interfaces for All", Prague, Czech Republic, 7-8 November 1996; 3rd ERCIM Workshop on "User Interfaces for All", Obernai, France, 3-4 November 1997; and, 4th ERCIM Workshop on "User Interfaces for All" Stockholm, Sweden, 19-21 October 1998. The 5th ERCIM Workshop on "User Interfaces for All" is scheduled to take place in Dagstuhl[16], Germany, 28 November - 1 December 1999.

The International Scientific Forum "Towards an Information Society for All" is a *Network* for collaboration and exchange of experience between researchers, industrialists and policy makers, aiming to advance the existing wisdom and stimulate new developments towards universal access and social acceptability of the emerging Information Society. The Forum held its 1st meeting during the Seventh International Conference on Human-Computer Interaction (HCI International '97), in San-Francisco, USA, and its 2nd meeting in Crete, Greece, June 15-16, 1998. The 3rd meeting of the Forum has been held during the Eighth International Conference on Human-Computer Interaction (HCI International '99), in Munich, Germany. The Forum addresses the need for closer collaboration across disciplines and aims to offer holistic approaches covering scientific, technological and policy issues, facilitating a common research and practice agenda, for the advancement of an Information Society that is acceptable to all citizens. The first two meetings produced two white papers which have been published in the International Journal of Human-Computer Interaction (Stephanidis et al., 1998b; Stephanidis et al., 1999a).

## 5. Sketching the HCI challenges

To address universal accessibility in HCI in the context of the emerging Information Society, several obstacles need to be alleviated, including: (a) the lack of a consolidated theory to guide and facilitate universal access; and (b) the intuitive and ad hoc character of the majority of recent development efforts in the field of Assistive Technology. These two shortcomings give rise to a wide range of issues, which, for the purposes of this report, will be classified into design and development challenges.

### 5.1 The design challenge

The lack of consolidated theories to guide and facilitate universal access is evident from the limited input and impact that prominent HCI design strands, such as *Human Factors evaluation* and *Cognitive Science*, have had on the study of (universal) accessibility.

In particular, Human Factors evaluation has delivered a wide range of general and platform specific guidelines for HCI design, as well as a rigorous scientific approach to systems' evaluation. The available collections of guidelines cover a variety of topics and application

[16] http://fit.gmd.de/5-UI4ALL-Workshop/call.html

domains. Some of them provide insights and recommendations towards accessible design of computer-based equipment (e.g., HFES/ANSI, 1997), while others offer principles of good practice and examples of universal design (Story, 1998). However, such accessibility guidelines, though useful to start with (when applied), suffer from well-known shortcomings, related both to the relevance of their actual human factors input to universal design, and to their practical use by designers (Akoumianakis & Stephanidis, 1999). At the same time, the scientific ground of experimental paradigm of Human Factors, though sound and rigorous, raises high demands on the practitioner. These factors, in combination with the prevailing industrial focus to satisfy the *minimal-time to market* criterion, have impeded the adoption of human factors practices by design teams.

Similarly, cognitive models, such as GOMS, have had minor impact, both on the design of systems accessible by people with disabilities, and on the study of universal access. One study, by Horstman and Levine (1990), concentrated upon a word prediction task in an augmentative communication system. Their work, however, has come under fire by Newell and colleagues which has resulted in a lively exchange (Horstman and Levine, 1992; Newell, Arnott & Walter, 1992a, 1992b), regarding the suitability of cognitive user modelling in augmentative and alternative communication.

In general, the models produced by Cognitive Science are designed to capture the generalities of a population rather than individual differences, or the requirements of small specialised groups of users. This is due to the need for collecting statistically valid data to justify the models. On the other hand, universal access stresses the importance of individual differences and seeks to develop models and tools for accommodating them throughout a product's life cycle.

The realisation of the shortcomings underpinning the previous two design approaches led many researchers to approaches focussing upon the requirements of end-users, and providing early feedback to design. The term coined to characterise this approach was *user-centred design*, and the first comprehensive collection of papers on the topic appeared in (Norman et al., 1986). The normative perspective of user-centred design is to fulfil the need for usability by providing techniques that foster tight design-evaluation feedback loops, iterative prototyping, early design input, and end-user feedback. In subsequent years, and due to the compelling need to cost-justify usability throughout a product's life-cycle, the field moved towards a variety of techniques, generally referred to as *inspection-based evaluation* (Nielsen, 1993) which, though inexpensive, are less formal in their conduct and deliverables. Following several success stories in the use and cost justification of these techniques, the consolidated experience gave rise to a generally applicable process-model for constructing human-centred systems. Human-centred design is documented in an ISO document (ISO 13407, 1999) which provides a principled approach and guidelines for attaining usability.

In addition to the developments leading to user-centred design, there have been several proposals for remedying the shortcomings of Human Factors evaluation and information-processing psychology. These proposals stem from the social sciences, and aim to improve the experimental grounds for HCI design by emphasising the need for analytical, prescriptive frameworks for studying users in specific contexts of use. Existing attempts towards the above objective make suggestions for:

- Better exploitation of the existing knowledge and science base by utilizing the experimental ground of developmental approaches to psychology (e.g., cultural / historical / work psychology) and the social sciences (e.g., anthropology, sociology, humanities).

- Broadening the range, or even extending the scope of information processing psychology with concepts from developmental approaches to HCI, such as *activity theory* (Bødker, 1989, 1991), *language / action theory* (Winograd, 1988), *situated action models* (Suchman, 1987) and *distributed cognition* (Norman, 1991).

The normative perspective adopted in these efforts is that interactions between humans and information artefacts should be studied in specific *social contexts* and take account of the distinctive properties that characterise them. Despite this common commitment to the study of context, the above alternatives differ with regards to at least three dimensions, namely the unit of analysis in studying context, the categories offered to support a description of context, and the extent to which each approach treats actions as structured prior or during human activities (Nardi, 1996).

In the context of Universal Access to the Information Society, user-centred design, as well as the above mentioned emerging approaches, have several contributions to make. First of all, the human-centred protocols and tight design-evaluation feedback loop of user-centred design provide a new insight into how interactive systems can be developed. Such an insight aims to replace the techno-centric practices of the current paradigm with a human-focus, which will help and guide designers to identify and attain accessibility, usability and other *quality of use* targets. To this effect, however, user-centred design needs to advance the current collection of tools so as to provide the means to study context and to complement existing artefact-oriented practices with analytical and process-oriented instruments.

Developmental approaches to HCI design, rooted in cultural psychology, the social sciences and the humanities, hold the promise to provide contributions in this direction by offering richer tools for analytical design and prescriptive frameworks for studying varieties of context of use.

## 5.2 The development challenge

The above picture is further complicated by the lack of practical means to guide developments towards universal access systems. In the past, the issue of accessibility has been primarily addressed through programming-intensive efforts resulting in re-engineering or re-implementation of the user interface. In the field of HCI, part of the problem is attributed to the lack of tools to ease the task of creating accessible interactive software, which in turn, resurfaces one of the issues that has long been of concern to the HCI community, namely the user interface architecture (Mueller et al., 1997; Stephanidis et al., 1998b).

In particular, existing architectural abstractions for user interface software, such as the Seeheim meta-model (Ten Hagen, 1991), the Arch meta-model (The UIMS Tool Developers Workshop, 1992), or the PAC model (Coutaz, 1990) fail to provide sufficient guidance towards building universally accessible applications. First of all, they do not explicitly account for the notion of accessibility of an interactive application. Thus, they do not address issues such as multiple platform environments, toolkit integration, platform abstraction, etc., which arise from the proliferation of novel interaction platforms and diversity in usage patterns.

Secondly, these models offer no account of user interface adaptation (Dieterich, Malinowski, Kuhme & Schneider-Hufschmidt, 1993), which is a central theme in *Design for All* in HCI. As a consequence, key decisions such as what and when to adapt are not addressed, while the components that are needed to drive adaptations at the level of the user interface are totally missing. Thirdly, existing architectural models offer implementation-oriented views of user interface architectures; this limits the role of design by not addressing how design knowledge can be propagated to the development and implementation phases. As a result, the application of these models in current HCI practices leads to re-implementations (reactive approach) rather than instantiation of an alternative design (proactive approach).

## 6. Towards a new HCI research agenda

Having pointed out the constraints that undermine the choice of a scientific and technological base for studying (universal) access, we now briefly outline a tentative research agenda for meeting the challenge. This agenda was developed in the first meeting of the ISF "Towards a Information Society for all" (Stephanidis et al., 1998b) and it was subsequently refined specifically in the context of HCI (Stephanidis et al., 1999a).

The agenda points out a broad range of required actions relevant to three main themes, namely technology and user-oriented issues, critical application domains and services, and support measures. Under the theme of technology and user-oriented issues, the agenda highlights the need for additional work covering the development of critical technologies, the advancement of suitable design frameworks and the evolution of powerful user interface architectures. Critical application domains and services include life-long learning, public information systems, terminals and information appliances, transactions services, social services and electronic commerce, as well as global issues such as security, reliability, etc. Support measures that would facilitate a favourable environment towards an Information Society for *all* should cover the articulation of demand for universal design, support to industry, awareness raising and knowledge dissemination, and technology transfer.

In a subsequent effort, the above main themes were further elaborated to provide a roadmap for HCI research activities. Four main research clusters were identified; the first three are proposed as RTD topics whereas the fourth is proposed as a support measure, or "horizontal" activity: (i) Promote the development of environments of use; (ii) Support communities of users; (iii) Extend user-centred design to support new virtualities (and novel usage contexts); (iv) Establish suitable accompanying measures. The four topics are interrelated. Thus, recommendations under one topic link with recommendations under a different topic. The type of actions envisaged, with the exception of the accompanying measure cluster, cover of all phases of technological development, ranging from feasibility studies, to basic and applied research, and demonstration. In what follows, we present a brief description of the meaning and rationale for each one of the four high level recommendations.

### 6.1 Promote the development of environments of use

Environments of use imply integrated systems sharable by communities of users. They should, in contrast to the traditional notion of computers as productivity tools, allow for richer communications and signifying the progressive integration of the computing environment with the physical environment. Moreover, in contrast to tools, which enhance the productivity of individuals, environments of use would promote the concept of loveable systems suitable for a broad range of communication and collaboration intensive activities amongst groups of people. Such environments should be characterised by sympathy and care for users and non-users[17] and should be accessible by anyone, anytime, anywhere. Finally, they should provide unobtrusive means for supporting social activities.

Environments of use are likely to become integral components of daily activities amongst communities of users and facilitate the establishment of new forms of social endeavours. Consequently, they should be conceived and designed as community-centred, sharable, expandable, co-operative, collaborative and responsive media, catering through user and environment monitoring, for a broad range of human needs for both users and non-users. Additionally, they should offer voluntary and context-specific user support, and facilitate error tolerant behaviour and preventive actions against unforeseen circumstances and / or misuse.

Possible area of action concerning the development of environment of use are:

- The investigation desirable properties of environments of use (e.g., augmented capabilities on user's demand, multimodality, cooperativity, intelligence, adaptation, etc); actions in this area should aim to (a) identify requirements of different user groups (including people with special needs) and non-users, (b) determine quality attributes such as loveability, usability, accessibility, unobtrusiveness, etc, that characterise environments of use, and (c) map user requirements to technical characteristics.

- The development of novel architectures for interactive systems for managing collective experiences of users and non-users; actions in this area should strive to introduce and validate new architectural models for interactive software; define desirable architectural properties (e.g., adaptation, co-operation, collaboration, portability, interoperability, scalability, modifiability) and produce guidelines on how they can be met.

- The development of architectures for multiple metaphor environments; actions in this area should aim to: (i) explore alternative metaphors for interaction; (ii) develop interactive computer-embodiments of metaphors; (iii) determine properties of multiple metaphor environments (e.g., adaptive change, user awareness, context sensitive processing, intelligence); (iv) provide experimental evidence and illustrate face validity of proposals; (v) develop demonstrators of multiple metaphor environments; and (vi) compile recommendations and guidelines for building and supporting multiple metaphor environments.

- The development of multi-agent systems and components to support co-operation and collaboration; actions in this area should strive to support and facilitate the co-operation and collaboration between humans in the new environments of use. Of particular interest is the construction of systems and components that will facilitate the coexistence of humans and software entities.

- The support of individualisation and user interface adaptation (e.g., adaptability and adaptivity) in environments of use; actions in this area should aim to: (i) provide methods

[17] The term “non-user” is used to refer to members of a community who, though not interacting with the environment themselves at a particular point in time, are being affected by this environment, or its use by other active users.

to facilitate the design of adaptations; (ii) construct tools to support adaptable and adaptive behaviour; (iii) evaluate and assess adaptation strategies; (iv) develop instruments for evaluating adaptable and adaptive behaviour; (v) explore alternative architectural models for user interface adaptations; and (vi) assess user's opinion towards individualised interactions.

## 6.2 Support communities of users

Another critical trajectory en route to an Information Society is the one that progressively shifts the focus of attention from individual users to communities of users. The important element in this trajectory is the emphasis on social interaction in virtual spaces. To design interactions in such virtual worlds, it is pertinent to enhance the currently prevailing interaction paradigms [e.g., Graphical User Interfaces (GUIs) and the World Wide Web (WWW)] to support the broad range of group-centric and communication-intensive computer-mediated human activities.

Such a community-wide design perspective requires that activities amongst members of communities of users become the primary unit of analysis, as opposed to an individual's keystrokes, or performance measures. Moreover, the design focus should be on the cumulative experiences of the community's users with the shared resources, as well as on the way in which communities move from early formation to maturity. To this end, there is a compelling need to study and understand how such communities (e.g., the virtual city) are formed, evolve, grow and intra- / inter- operate in order to synthesise methods that facilitate the design of suitable virtualities and computer-mediated activities for all potential community users.

Possible areas of action for the support of communities of users include:

- The management of individual / collective intelligence and community knowledge; actions in this area should strive to facilitate capturing community-generated wisdom and collective experiences; support social awareness, collaboration, knowledge sharing and persistence, and the exchange of experiences.

- The development of methodologies for collecting / analysing requirements and understanding virtual communities; actions in this area should aim to: (i) develop an understanding of virtual community life-cycles; and (ii) investigate how on-line communities are formed, operate and grow.

- The provision of means to access community-wide information resources; actions in this area should aim to (a) ensure accessibility and usability of community-based information resources by *all* potential users, (b) develop suitable interaction techniques that meet the requirements of individual members of communities of users, and (c) establish demonstrators of good practice.

- The development of models to support social interaction amongst members of on-line communities; actions in this area should aim to explore novel concepts for embodying information spaces (e.g., the virtual theatre, the virtual city, the virtual market place) and assess their relevance to the design of virtual communities; provide experimental evidence to support novel design concepts for community-based activities (e.g., collaborative concept creation, community-based learning).

## 6.3 Extend user-centred design to support new virtualities

In order to facilitate the design of new virtualities likely to be encountered in the Information Society, the existing inventory of methods, techniques and tools for user-centred design should be suitably applied and enhanced. To this end, attention should be drawn upon the accumulated knowledge and results in the social sciences (e.g., human communication theories, language theories, action theories, etc), to promote and facilitate the use of developmental approaches[18] to the study of computer-mediated human activities. In all cases, the tight evaluation-feedback loop advocated by user-centred design should provide the primary channel for timely input into design processes, so as to ensure that deficiencies are corrected at an early stage, while updates are less costly to make.

Areas of action in this direction include:

- The development of suitable foundations for design, by applying, integrating and extending existing user-centred design methods to facilitate the design of new virtual spaces. Actions in this area should strive to assess potential HCI design contributions rooted in disciplines that focus on human communication in social contexts (e.g., developmental psychology, the social sciences, the humanities, etc); extend existing analytical design approaches (e.g., design space analysis techniques) with social constructs to provide new methods for studying virtual spaces.

- The development of metrics for important quality attributes (e.g., usability, accessibility, adaptation, intelligence, etc); actions are needed to (a) extend the available range of metrics to cover additional quality attributes such as accessibility, adaptation, intelligence, etc, likely to determine the outcome of computer-mediated human activities in the emerging Information Society, (b) embed such metrics into tools for automatic evaluation and measurement, and (c) establish (technology-independent) protocols for measuring quality attributes of systems, taking account of the various contexts of use and the new virtualities that such systems are intended to support.

- The provision of computation support for usability engineering (e.g., computer-supported usability platforms); actions in this area should aim to investigate characteristic properties of, and to provide for, computer-supported usability engineering platforms comprising inter-operable software components, and covering the broad range of usability engineering tasks within a user-centred design protocol.

- The extension of existing requirements engineering methods to facilitate the elicitation of requirements in novel contexts of use and different user groups. Actions in this area should strive to provide improved means for eliciting, capturing and consolidating requirements for a broad range of computer-mediated human activities in the Information Society, including the development of tools to facilitate the mapping of requirements to design concepts.

[18] The term *developmental approach* to studying computer-mediated human activities is used to refer to various established theoretical strands within the social sciences and / or psychology that take explicit account of, and model development in human behaviour and capability. Such developmental approaches have recently started to progressively find their way into HCI. Examples include *activity theory* (Bødker, 1989; Bødker, 1991; Nardi, 1996), *situated action plans* (Suchman, 1987), *distributed cognition* (Hutchins, 1995), *language / action theory* (Winograd, 1988), etc.

- The promotion of user involvement and the development of protocols for effective user participation in design activities. Actions in this area should aim to: (i) establish new methods and tools for managing user participation in design projects which are intended to be accessible to the broadest possible end-user population, including people with special needs; and (ii) promote practice and experience of participatory design and develop suitable models.

- The investigation and provision of design recommendations for alternative interaction modalities and their combinations. Actions in this area should aim to establish a basis for designing for alternate interaction modalities and combinations of modalities, as well as to demonstrate the benefits of developing multimodal and multimedia systems for communities, groups and individual users.

## 6.4 Establish suitable accompanying measures

Support measures cover a whole range of multi-disciplinary and cross-sector actions that are needed to facilitate the development of an industrial environment favourable to an Information Society for the broadest possible end-user population. Actions are needed to promote and facilitate the adoption and diffusion of good practice in the areas of accessibility and usability, so as to ensure quality in the use of products and services. To this end, it is important that accompanying measures are initiated to articulate demand (Kodama, 1992) for universal design, support the industry in adopting novel methods and practices, raise awareness, promote knowledge dissemination and transfer technology in the form of know-how and know-why.

***Articulating demand for design for all.*** Support measures are needed in the direction of raising consumer awareness on the value of accessibility and usability, educating consumers and producers in the need to include requirements for usability and accessibility in product specifications, as well as helping them evaluate usability and accessibility when making design, or purchase, decisions. Such actions would help towards building a public expectation for accessible and usable products and services, and intolerance of inaccessible forms of technology. Additionally, until a certain maturity level is reached and more effective end-user input into the design process can be attained, procurement guidance is necessary with regards to accessible and usable technology.

Subsequent steps required for demand articulation concern the translation of market data to product concepts and the decomposition of product concepts to development projects. In this respect, it is important that a range of questions are addressed, including: (i) what product types are needed in the market; (ii) how they could be produced; (iii) through which technologies; and (iv) what other characteristics should the envisaged technologies exhibit.

***Supporting the industry.*** This line of action should be targeted towards the creation of an environment favourable to industrial innovation. At the core of such activities should be the provision of incentives towards *design for all*. Industrial incentives need not necessarily be of a financial type, though this would be critical for Small and Medium size Enterprises (SMEs). They should also include access to research results that would be difficult to obtain otherwise, provision of a suitable infrastructure, collaborative R&D activities for technology transfer (see also later section on "Technology Transfer"), as well as other policy initiatives, such as the establishment of an Accessibility / Usability certificate.

There is also a compelling requirement for speeding-up current standardisation processes, as well as for more intensive international co-ordination of standards in the long-term. To this end, actions are needed to facilitate co-ordination across efforts initiated in the context of research consortia (e.g., the W3C - WAI[19] project and the ERCIM Working Group on "User Interfaces for All"[20]), as well as in national (e.g., HFES / ANSI[21]) and international standardisation bodies (e.g., the new work item on accessibility by ISO 9241 / TC 159 / SC 4 / WG 5).

Legislation is also needed to provide the framework of operation, and the required incentives for both the consumer base and the industry. To this effect, recent experience in the USA with the Americans with Disabilities Act of 1993 and the Telecommunications Act of 1996 should be assessed, and similar actions should be encouraged internationally. Such efforts could also draw upon general rules and recommendations compiled by industrial consortia (e.g., The Telecommunications Policy Roundtable in USA), technical committees (e.g., the Association of Computing Machinery (ACM) Public Policy Committee) and international organisations (e.g., the United Nations General Assembly Standard Rules of 1995).

***Awareness and knowledge dissemination.*** One of the critical impediments to the adoption of universal design practice is the lack of qualified practitioners who understand what the requirements for universal access and quality in use are. To overcome this, it is recommended that, in the short-term, accessibility, usability and quality in use are introduced as mandatory components of university education.

Additionally, efforts should be devoted to the collation and dissemination of comprehensive information on the practical resources available for user-centred design, usability and accessibility. This would include information on the available methods, techniques and tools for user-centred design, usability and accessibility, the skills required to adopt, internalise and appropriate the benefits of the methods, as well as their socio-economic benefits and costs. Such efforts would necessarily build upon the accumulated wisdom[22] collected through past and on-going collaborative project work in the context of trans-national projects.

Dissemination methods could include guidance and reference documents, lists of resources and provision of tutorials and workshops. Ideally, such activities could be supported through the sponsorship of a network of excellence that would adopt the above targets as part of its global function.

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[19] World Wide Web Consortium - Web Accessibility Initiative (1997). For more information please refer to http://www.w3.org/WAI/

[20] For more information please refer to http://www.ics.forth.gr/proj/at-hci/UI4ALL/index.html

[21] See also (HFES/ANSI, 1997)

[22] The European Commission has funded several projects aiming to collect, consolidate and disseminate available knowledge and experience. Examples include: INUSE ("European Usability Support Centres", Telematics Applications Programme, Telematics Engineering Sector, 1996-1998); RESPECT ("Requirements Engineering and Specification in Telematics", Telematics Applications Programme, Telematics Engineering Sector, 1996-1998); MEGATAQ ("Methods and Guidelines for the Assessment of Telematics Application Quality", Telematics Applications Programme, Telematics Engineering Sector, 1996-1998); BASELINE ("Data for User Validation in Information Engineering", Telematics Applications Programme, Telematics Engineering Sector, 1996-1998) INCLUDE ("INCLUsion of Disabled and Elderly people in telematics", Telematics Applications Programme, Telematics Engineering Sector, 1996-1998); ACCESS ("Development Platform for Unified Access to Enabling Environments", Technology for the Disabled and Elderly (TIDE) Programme - Bridge Phase, 1994-1996), USER ("User Requirements Elaboration in Rehabilitation and Assistive Technology", Technology for the Disabled and Elderly (TIDE) Programme - Bridge Phase, 1994-1996).

***Technology transfer.*** Effective and efficient technology transfer is another critical target, requiring a range of support measures to be effected. To facilitate successful transfers of technology, suitable mechanisms are needed in the short-term, to the effect of targeted and purposeful exchange of knowledge, know-how and know-why. It is recommended that, from the broad range of technology transfer mechanisms which can be considered, emphasis is on advanced measures (such as co-operative R&D, joint venture R&D agreements, joint ventures aimed at keeping partners informed, large / small firm agreements), rather than simpler ones (such as licensing, technical advice, technical support, contract of R&D). This is because the latter cluster is better suited for the type of transfers (e.g., know-how and know-why) that is required. In this context, it is important to mention that collaborative, inter-disciplinary, multi-national, multi-cultural and cross-industry R&D activities, involving industry and research institutions, are of primary importance.

## 7. Critical application domains

The wider diffusion and adoption of Design for all also depends on the identification of the critical application domains that are of wide societal impact in the Information Society. These are likely to concern sensitive areas of human activity, where design-for-all is expected to revolutionise current practices, by granting all citizens equitable and high quality access. The significance of the application domains does not only reflect their role in establishing a coherent and socially acceptable Information Society, but also the diverse range of human activities likely to be penetrated, as a result of the fusion in the IT&T sectors of the industry.

*Life-long learning* is a critical area where emphasis should be placed, in the "knowledge" society of the future. It entails a continuous engagement in the acquisition of knowledge and skills to facilitate and sustain equitable participation in the Information Society (European Commission, 1997). New technologies may play a catalytic role in providing new educational mechanisms and structures, thus allowing learning to become an inseparable part of life-long human activities in the context of knowledge-intensive *learning communities*, and social interaction amongst groups of people.

Another important application area and a critical short-term target is the development of general-purpose *public information systems*, *terminals* and *information appliances*, (e.g., information kiosks for access to community-wide information services). These are expected to be used in increasingly different contexts, including public places, homes, classrooms, etc, and provide the means for ubiquitous and nomadic access. *Environmental control* will also become increasingly important. *Smart environments* will progressively penetrate a wide range of human activities in hospitals, hotels, public administration buildings, etc. Tele-operation of such environments will also gain increasing attention to facilitate responsiveness to unforeseen events, enhanced mobility and security.

A broad range of *transaction services* (e.g., banking, advertising, entertainment), *social services for the citizens* (e.g., administration, health care, education, transport), and *electronic commerce* applications, will also become increasingly important in reshaping business and residential human activities. These should also be addressed within a short- to medium-term time horizon.

Finally, a particularly important area in which Design for All is expected to play a significant role is Health Telematics. Advances in information technology and telecommunications will inevitably bring about a revolution in Health Telematics, characterised, amongst other things, by the digitisation and interlinking of previously disconnected health information sources, the remote provision of health-related services, the establishment of an environment favourable to collaboration between geographically dispersed practitioners, as well as by the placement of emphasis on services targeting the community or the individual. The opportunities offered by the emerging technological infrastructure are numerous. In the immediate future, it will be possible to attain high quality health services, offering timely access to critical health information, facilitating the management of such information, while, at the same time, reducing the overall costs involved.

Health care, in particular, is characterised by large collections of data, which, in turn, raises numerous challenges regarding their organisation and management. With recent technological advances, both the type and content of such data have been gradually changing to facilitate the increasingly demanding information seeking behaviour of the users. Thus, traditional paper-based artefacts are being stored and manipulated digitally, enabling more effective and efficient information management. At the same time, the prime concern in Health Telematics has shifted away from capturing and storing data, to effectively accessing the medical collections to facilitate informed service provision. Such a compelling need has driven the development of new visualisation techniques and advanced interaction technologies, aiming to increase the usefulness of health-related information by rendering them more easily, effectively and efficiently attainable and manipulable by all actors involved.

However, despite recent advances, user access to medical information remains a challenge, due to the considerable *diversity* that is a characteristic of Health Telematics, evident in: different types of data (from alphanumeric, administrative data to complex, memory- and bandwidth-demanding high-resolution sequences of images); different application areas (e.g., primary care systems, clinical departmental and support systems, institutional, hospital and nursing information systems, medical knowledge and decision support systems); different organisational structures and roles of end-users (e.g., doctors, nursing staff, administrative staff, management, patients); different user groups with different skills, requirements and preferences (e.g., computer experience and expertise, education, physical abilities); different contexts of use (e.g., desktop access, mobile access, Internet access, kiosks); and, different interaction technologies (e.g., speech-based interaction, pen-based interaction, advanced visualisations, variety of access terminals). From the above, it is evident that Universal Design principles are necessary to address the challenge of ensuring accessible and usable Health Telematics services.

Independently of any particular application domain or service, there are certain quality attributes and added-value functionality that should be accommodated into future services. For instance, *security*, *privacy* and *control*, *intuitive operation* and *ease of use*, as well as well as functionality to allow users to create, store and tailor available data into added-value information, and leave traces of their experience, are central themes in the evolution of a socially acceptable Information Society and should receive immediate attention. At the same time, they will increasingly constitute more complex targets to accomplish, as they span across different levels of the telecommunications infrastructure, from network services to application services (such as business transactions and entertainment), terminals and information appliances.

## 8. Summary, Discussion and Conclusions

This report has outlined the concept of *Design for all* as a proactive approach to the accessibility of IST technologies in the emerging Information Society, and reviewed current efforts towards the development of generic solutions to the problem of accessibility, including Active Accessibility® by Microsoft, Java™ Accessibility by Sun, the Unified User Interface development methodology and tools, and the FRIEND21 Guidelines for the Human Interface Architecture. The report has also briefly summarised policy initiatives by international collaborative research and industrial consortia and standardisation bodies aiming at promoting proactive approaches to accessibility and *Design for all*. The performed analysis of the state of the art in the field of *Design for All* has shown 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. It also has shown that *Design for All* is rapidly expanding, attracting the interest of the academic, research, industrial, standardisation and legislation communities. Nevertheless, much more research and development work is needed to address the challenges posed by *Design for All* in the HCI field, which relate to both the design and the development of user interfaces. This report has outlined those challenges, and sketched a research agenda for meeting them. The agenda is articulated around four clusters: (i) the development of environments of use; (ii) the support of communities of users; (iii) the extension of user-centred design to support new virtualities; and (iv) the establishment of suitable accompanying measures.

The issue arises, then, to identify an appropriate strategy for the implementation of such a research agenda, as well as for establishing a favourable environment for the wider diffusion and adoption of *Design for All* by mainstream industry. In a recent study (Vernardakis et al. 1997), the feasibility of design for all practices was assessed against different technology transfer mechanisms. The main outcome from that investigation was that design for all is likely to proliferate when 'advanced' technology transfer mechanisms are involved. The types of such mechanisms that were considered appropriate included co-operative R&D, joint venture R&D agreements; joint ventures that aim at keeping partners informed; cross-licensing - referring to separate product markets, and large-small firm agreements.

In recent years, the field of HCI has experienced attempts towards design for all building directly upon some of the above mechanisms (e.g., collaborative R&D) or calling upon such mechanisms to meet pressures introduced by legislation or other policy initiatives. In contrast to the U.S.A., which has followed the approach of introducing legislation (Americans with Disabilities Act, 1993; Telecommunications Act, 1996) 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 sector[23].

Though these alternative pathways towards effective support measures may share common objectives, they differ in a number of dimensions (see Table 5). In particular, each alternative may potentially turn out to be ineffective since, as shown in table 5, there are strong conditions placed upon them.

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[23] This commitment appears to continue and increase in the 5th Framework Programme of the European Commission (1998-2002).

**Table 5: Comparative assessment**

| Policy instruments | | | |
|---|---|---|---|
| **Criteria** | **Legislation** | **Standardisation** | **Co-operative R&D** |
| Target | ♦ Reinforcement | ♦ Consolidation of knowledge<br>♦ Guidance | ♦ Establish common R&D agenda<br>♦ Provide a solid basis for R&D<br>♦ Promote cohesion |
| Pre-requisites | ♦ Demand already articulated<br>♦ Commitment | ♦ Solid R&D base<br>♦ Timely intervention | ♦ Cross-industry focus<br>♦ Reciprocal investments<br>♦ Willingness and commitment<br>♦ Favourable conditions for transfers |
| Potential shortcoming | ♦ Difficult to guarantee compliance, due to industry opposition, tendency to by-pass, lack of user demand, lack of awareness | ♦ Lock-on effect<br>♦ Appropriate recommendations<br>♦ User involvement<br>♦ Industrial participation<br>♦ Not possible in highly competitive industries | ♦ Exploitation capability<br>♦ Technology must be emerging<br>♦ Conditions for sources and recipients<br>♦ Conditions on mechanism used |
| Role of non-market institutions | ♦ Initiate and sustain<br>♦ Monitoring application | ♦ Funding<br>♦ Disseminate knowledge | ♦ Funding R&D work<br>♦ Facilitating collaboration<br>♦ Offering guidance<br>♦ Undertaking technological forecasting<br>♦ Provision of incentives<br>♦ Establishing favourable conditions |

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. 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, on its own, may not necessarily offer guaranteed solutions. Though it may facilitate the consolidation of a sound RTD base, initiate proactive technological intervention, raise awareness and establish a common ground, it may not exceed the technological feasibility stage. In the past, co-operative RTD projects funded by the European Commission 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, sectoral 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 RTD project work, promoting awareness, establishing directives, legislative acts and standards, assuring the diffusion of technology and its adoption by a wide proportion of the industry. 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. One possible option is that national governments fund the required RTD policy mechanisms. However, many of the items and recommendations of the proposed R&D agenda have either an explicit international dimension, or can be more effectively addressed at an international level. As a result, what is needed is international collaboration and co-operation, which, in any case, would provide the necessary input to national and trans-national RTD policy fora.

In this direction, the ERCIM Working Group on *User Interfaces for All* has initiated activities aiming to consolidate current practice and experience in the area of universal design. In the short- to medium-term, work can be directed towards the identification of key accessibility criteria or requirements to be met by products and services. These activities can be consolidated into an appropriate form that would guide subsequent efforts by both research/academic organisations and industry towards interactive products and services *accessible* and *usable* by the broadest possible end-user population. Furthermore, such activities can help industry to gain a renewed focus on the issue of universal design, and facilitate justification for the costs and benefits of alternative technologies. Additionally, they can stimulate new developments, and establish the ground whereby universal design informs and improves practice.

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