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Technology and inclusion – Past, present and foreseeable future

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Abstract. The paper considers the Information and Communication Technology sector to discuss some general characteristics of the activities meant to favour inclusion through the use of technology, as well as of the attitudes of actors in this sector. The paper does not claim to give a comprehensive description of the technological applications in the field of eInclusion. Rather, it focuses on a set of examples, reviews some lines of development, and uses these to explore the present situation and potential developments in the near future. Observations include: (i) technology has been very useful to improve the situation of people with activity limitations (AT); (ii) interesting new improvements are possible using available and emerging technologies (improvement of present AT and new products, services and applications); (iii) however, innovation is not very well served due to internal problems in the field; (iv) Design for All could be very useful, but there are business difficulties for its deployment; (v) despite this, many mainstream developers are moving in the direction of producing new products and living environments that will be more usable by people with activity limitations and facilitate their inclusion.

Keywords: Assistive Technologies, Design for All, eInclusion

1. Introduction

It is commonly accepted that technology can be an invaluable support for the inclusion of people with activity limitations, both producing inclusive mainstream equipment and/or services and offering the possibility of implementations aimed to the specific support of people (Assistive Technology – AT). This has been particularly emphasized in the eInclusion sector, where information and communication technologies (ICT) are used to support the inclusion of people in the Information Society, offering them access to information, interpersonal communication and environmental control. This paper focuses on the ICT sector as an instance to discuss some general characteristics of the activities meant to favour inclusion through the use of technology, as well as of the attitudes of people active in this sector, most of which can be generalised to other sectors.

There are several reasons why ICT is of particular interest: (i) ICT has developed very fast in recent years and is accelerating its development, thus offering the possibility of very innovative products and applications; (ii) it has a very important impact on the organisation of society, up to the point that society is currently described by many as in transition from an industrial society to an information society; (iii) it impacts many different areas of life that are key to independence including information, interpersonal communication and environmental control, which are becoming more crucial every day given the emerging technological environment; (iv) it is challenging from the perspective of applications, due to the complexity produced by the fusion of different technologies with the emergence of new classes of products and/or services and applications; (v) it is based on infrastructures that require a general analysis and careful planning, with the contribution of all citizens including those with activity limitations.

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Even constraining itself to only ICT, the present paper does not claim to give a comprehensive description of the technological applications in inclusion. Rather it focuses on a set of examples from eInclusion, reviews some lines of development, and uses these to explore the present situation and potential developments in the near future. Observations include: (i) technology has been very useful to improve the situation of people with activity limitations (AT); (ii) interesting new improvements are possible using available and emerging technology (improvement of present AT and new products, services and applications); (iii) however, innovation in this field is not very well served due to internal problems in the field; (iv) Design for All could be very useful, but there are business difficulties for its deployment; (v) despite this, many mainstream developers are moving in the direction of producing new products and living environments that will be more usable by people with activity limitations and will facilitate their inclusion.

2. The situation today

Traditionally, Assistive Technology (AT) refers to the technologies (devices or services) used to compensate for functional limitations, to facilitate independent living, to enable older people and people with activity limitations to realise their full potential. Some technologies, even if not purposely designed for people with activity limitations, can be configured in such a way as to provide assistance or assistive functions when needed. The term AT covers any kind of equipment or service capable of meeting this definition. Examples include wheelchairs, prosthesis, communicators and telecommunication services. In eInclusion, AT includes, for example, equipment and services for access to information (e.g., for seeing, hearing, reading, writing), interpersonal communication and control of the environment [1,2]. Low technology, as for example simple optical devices for vision, simple manipulation devices for environmental control or communication boards for AAC (Augmentative and Alternative Communication), are not considered in the paper.

2.1. *Special purpose equipment* (*based on ICT*)

AT products for seeing comprise mainly image-enlarging and contrast enhancing video systems. The existing technology is based on video cameras that catch the image of the object (newspapers, books, maps etc.) to be accessed and transmit it to a monitor or to a PC, which displays the enlarged and/or enhanced image.

Assistive products for hearing include devices for amplifying and/or modulating sounds for a person with hearing problems. They include, e.g., hearing aids with built-in tinnitus masking and induction coil devices.

Access to reading can be provided in different forms. Personal character-reading machines, based on desktop scanners that read text from any printed page, are devices for reading and transforming written text into alternative forms of visual, auditory and/or tactile communication. The acquired text is processed by OCR (Optical Character Recognition) software that outputs text as synthetic speech or by means of a Braille display, or records it, e.g., in MP3 format. Another class of product is talking book readers. Another example is multimedia reading materials systems, such as handheld dictionaries and thesauruses that include a spelling corrector, grammar guides and educational games.

The class of assistive products for drawing and writing includes devices that help a person to convey information by producing figures, symbols or text. Electronically operated portable note-taking devices for Braille are an example. These devices can take different form, including different sized Braille displays (1, 12, 20, 40 or more refreshable Braille cells), and different functions (taking notes; reading an audio book while walking; taking appointments and transfer them to a PC; recording sounds and voices; storing addresses and phone numbers; making calculations; sending and receiving SMS; listening to music; reading audio books in the DAISY[1] format; make connections to a mobile phone through Bluetooth; checking time and temperature; etc.). Even standard word processing software that is usually considered a mainstream writing product rather than an assistive technology, in fact, allows writing, organizing and storing text in a more easily way than by handwriting. Spell check, grammar check and multimedia features can further assist with writing activities. There are also purpose-built word-processing software programs that have alternative ways of controlling their use built-in, e.g., by means of scanning selection or virtual keyboard and special output, e.g., Braille or speech synthesis.

Assistive products for face-to-face communication focus on helping people to communicate with each other in the same space. The main group of products related to ICT is composed of dialogue units, i.e., elec-

[1] http://www.daisy.org, last visited on 14 March 2011.

tronic devices that support Augmentative and Alternative Communication (AAC), addressing the expressive communication needs of people with speech impairments. Dialogue devices can be portable or non-portable, with recorded and/or synthetic speech output, and alphabet-based or symbolic input and output.

An example of assistive products for remote communication is the text telephone (TTY or TDD), a device for text communication via a telephone line. These devices are designed for use by people with hearing and/or speech difficulties. The text is transmitted in real time to a compatible device, i.e., one that uses the same communication protocol. More recently, video-telephony has become important. Its quality has increased to the point where it is now possible its use for communication using sign language and lip reading. Finally, mobile telephones allow text communication through SMS, now largely used because of their ubiquity in all phones despite the fact that they do not provide a real-time dialogue.

Typical assistive products for alerting, indicating and signalling are: (i) e.g., indicators with visual and/or acoustic signals that provide visual alerts and/or amplified audible signals for end-users or carers; (ii) personal emergency alarm systems, i.e., devices either operated by the user or activated automatically in case of personal emergency, such as, e.g., insulin alarms, seizure alarms for people with epilepsy, and fall alarms; (iii) monitoring and positioning systems, i.e., devices for monitoring the position of a person, such as, e.g., general positioning systems (GPS) as wandering alarm.

2.2. *The ubiquitous PC*

With the development and widespread adoption of personal computers, increasing efforts have been devoted to enabling access to them by people with activity limitations.

Many input devices for interaction with computers of persons with different residual abilities exist. They include special or adapted keyboards, mice, joysticks and alternate input devices. The standard keyboard functions can be performed in different ways by means of Braille keyboards, modified keyboards (with different arrangement of keys); simplified keyboards with a reduced number of keys (only letters, numbers and essential functions); enlarged, reduced, with or without grid, programmable keyboards (tablets where different zones can be assigned programmable functions as: inputting characters, words, or sentence), scanning keyboards (allowing users to type in text using only one or two switches), and alternative keyboards (chord, one hand, etc.). Scanning keyboards are often coupled with a prediction system to speed up text input. Input software can be used to change the properties of the keyboards. Modifications include, the "sticky keys" function that allows a one handed typist or mouth stick users to activate shift, control and function keys in combination with other keys and bouncing suppression, the inhibition of repeatedly pressed keys due to tremors and the control of repetition time when a key is pressed.

Many mouse emulators have also been developed, such as trackballs of different forms and dimensions with programmable push-buttons; mouse emulators operated through an array of push-buttons; using head pointing and clicking by puffing or sipping a suitable switch; moving an appropriate device using the mouth or virtually any part of the body that can be detected by means of an analogue transducer or a video camera.

More recently, alternate input devices have become available which allow input of data to a computer without the use of a keyboard and/or a mouse. Examples are eye tracker systems that detect eye movements; speech recognition systems that allow input of words or control of the functions to be performed by the computer; touch screens and touch tablets with a programmable sensitive surface that allow to perform input functions e.g. mouse emulation, keyboard emulation, and/or input of words, sentences and commands, simply touching a predefined zone of the tablet; data gloves and direct brain interfaces.

Screen magnifiers are software applications able to present the computer graphical output contents enlarged on the screen, suitable for visually impaired people with some residual vision. Increasingly one is provided as part of the operating system, even if these systems may not have all the functionalities of commercially available specialised screen magnifiers.

An example of output system for blind people is the refreshable Braille display, an electro-mechanical device for displaying Braille characters, usually by means of raising metal or plastic pins through holes on a flat surface. Alternatively, a speech synthesiser can be used. In both cases, a screen reader is used, i.e., a software application that attempts to identify and recognize what is being displayed on the screen. Screen readers are useful to people who are blind, visually impaired, or learning disabled, often in combination with other assistive technologies such as screen magnifiers. On the market there are already available screen readers for mobile devices (PDAs and mobile phones) with synthesized speech of good quality. These systems offer to blind and visually impaired persons the possibility of performing a number of tasks on the move (e.g., taking notes, sending and receiving e-mail, browsing the Web). When a paper copy is necessary, a Braille printer, or embosser, i.e., an impact printer that renders text as Braille, can be used.

2.3. Telecommunications services and applications

The Telecommunications Relay Service, also known as TRS, Relay Service, or IP-Relay, is an operator service that allows people who are deaf, hard–of–hearing, speech disabled, or deaf blind to place calls to standard telephone users via TDD, TTY, personal computers or other assistive telephone devices. It is a real-time manned service which translates in both directions from text to voice and voice to text. Relay services for video telephony have been available since 1997. They are primarily used for relaying telephone calls between a deaf person using sign language and a talking person. As the communication (voice and video) over IP and using 3G telephony mobile telecommunications systems is becoming popular and widespread, voice and video relay services can be more effectively merged and delivered by means of the common network infrastructure.

2.4. Assistive Technology for Cognition (ATC)

Traditionally, in AT the main emphasis has been on the support to people with sensory and/or motor disabilities. More recently, research has started also in the direction of using technology to effectively facilitate participation of persons with cognitive limitations in many activities that would otherwise not be possible. Technological interventions have been developed to assist with tasks requiring cognitive skills as diverse as complex attention and prospective memory (i.e., remembering tasks that need to be performed and carrying out these tasks at the appropriate time, self-monitoring for the performance of specific desirable behaviours, inhibition of undesirable behaviours, sequential processing, and understanding of social cues).

3. Innovation: Technology development and new methodologies

In this section, innovation meant to increase the eInclusion possibilities of people with activity limitations is considered from two complementary perspectives. The first is the presentation of some technological developments that could be used to produce better assistive technology in terms of functionalities, usability, usefulness, and cost [1,3]. The second is the presentation of a new methodology (Design for All or Universal Design) [4–6], also supported by the United Nations (UN CONVENTION on the RIGHTS of PERSONS with DISABILITIES[2]) that aims to mainstream at least some of the needs, requirements and preferences of all people.

3.1. Technological developments

The main limitations of the current image-enlarging video systems are their large dimensions and heavy weight. Possible solutions are displays that can be rolled up and projected image systems. Rollable displays are flexible displays often based on organic electronics. This technology provides a large display available when in use, which can be rolled up into a small space when not in use. Another approach is to project images that appear to float in space in front of a person. With special glasses or goggle-based systems, only the user can see the image floating there. Some systems use optics and a more traditional display while other systems project the image directly onto the retina. Motion sensors can cause the displays to move with the user's head, or stay stationary. These technologies could also be used to make available a wide display for symbolic communicators. Using a projector and camera, products have been produced that can project anything from a keyboard to a full display and control panel that the person can interact with onto a tabletop, a wall, or any other flat surface. Moreover, miniaturization can help to make the products for face to face communication more portable, and eye movement recognition and gesture recognition can make easier the use of such devices. Special vibrating materials can be used to make tiny portable devices for alerting people, for example a wristwatch that gives different vibration cadences depending on the occurrence of various events, such as a telephone, door, fire, baby, pager, etc.

Some new wireless technologies may someday replace or provide options to older AT technologies. For example wireless local area networks (e.g., Wi-Fi) and personal area networks (e.g., Bluetooth, ZigBee) are becoming widely available and can be used to substi-

[2] http://www.un.org/disabilities/convention/conventionfull.shtml, last visited on 14 March 2011.

tute the inductive loop as soon as the hearing aids or alarm devices will support them.

An approach to reading and accessing graphic information can be represented by software systems based on machine vision that allows blind or visual impaired people to access the content of a display. An image of the display panel is captured by the system or using a digital camera incorporated in a mobile device. The captured image is processed in order to detect the numeric, alpha-numeric and iconographic information. Finally the information is transmitted to the user using text to speech technology.

The DAISY standard for digital books is opening new opportunities for control in reading books while still offering backward compatibility. Since DAISY books store audio in MP3 files, they can be read in any MP3 player or mobile phone. However, until mainstream MP3 players on the market make full use of the DAISY structure information users will be limited in the control of their reading. However, for those people who want to read a book from the beginning to the end at its normal speed any MP3 player can be used, though ease of use may be inhibited by breaking the audio part of a book into multiple pieces of MP3 files. DAISY readers are available (hardware and software) that can give better control for those that want it.

Prototypes of voice-input voice-output communication aids have been presented. For example, VIVOCA is a prototype system for people with disordered or unintelligible speech, initially conceived for people with dysarthria. VIVOCA is intended to recognize and interpret an individual's disordered speech and speak out an equivalent message in clear synthesized speech [7].

Natural interaction systems like gesture recognition, eye movement recognition and speech recognition are starting to provide alternatives to the mouse-keyboard approach for interaction. Eye tracking is a general term for techniques for measuring the point of gaze – where one is looking – or for determining eye/head position. Today a number of methods exist for measuring eye movements, using image processing. Gesture recognition is an attempt of interpreting human gestures via mathematical algorithms. The term gesture means any bodily motion or state, but commonly originates from face or hands. It enables hands-free or device-free interaction with a computer and may allow people who can only control limited part of their bodies to interact with a computer. Gesture recognition has already found applications in the mainstream world, and has been integrated into mobile phones (e.g. for dialling) and into video consoles (e.g. Microsoft's KINECT add-on to the Xbox 360).

Brain-computer interfaces (BCI) have been identified as a possible extra channel between the brain and the external environment to transmit information bypassing the spinal and peripheral neuromuscular systems [8]. External electrodes in the form of a band or cap are available today as commercial products for elementary direct control from the brain. It is easy to figure out that the potential of such a way of interaction is enormous, but, in this case, research is still far from a robust and affordable solution of the related problems.

The evolution of PDAs supporting screen readers with good quality synthetic speech output and special interfaces can allow blind people to use mainstream products. With the enhancement of speech recognition technologies, inputting text via voice is becoming sufficiently affordable to compete with keyboard typing for all users. This possibility is offered as a standard facility, e.g., in the Microsoft Windows 7 Operating System for the English language.

With respect to remote interpersonal communication, there is a rapid diversification taking place in the ways people can communicate. Video conferencing allows simultaneous text, visual, and voice communications. Chat and other text technologies have started integrating voice and video capabilities. In particular, video can be used for sign language, lip reading and generally for showing objects or feelings in order to ease communication. In addition, technology to cross-translate between modalities is maturing. The ability to have individuals talking on one end and reading on the other is already available using human agents in the network (see relay services). In the future, the ability to "translate" between sensory modalities may become common for all users. One of the potentials of multimodality is to adapt the type of interaction to the abilities and preferences of the user, e.g., allowing voice interaction if the user is blind or cannot look at the display, or providing gesture interaction when the user is not able or prefer not to speak.

Mobile text communication through GSM, like SMS, has gained worldwide popularity, and is often used as an alternative to phone conversation. The methods currently available for text entry on small mobile devices exhibit poor performance in terms of input speed, which present a potential barrier to acceptance and growth. A likely solution is the combination of use of language modelling and careful interaction design and verification [9]. Another difficulty is that communication using SMSs is not real-time, even if, in principle, real time exchange of text information could be made possible. This does not appear of outmost importance for young deaf people, but it is apparently not well accepted by people who presently use text telephones that allow real time communication. However, the use of SMS would allow text communication with any mobile telephone until such time as ubiquitous real-time text communication arrives on phones with VoIP.

Captioning is very important for deaf people. A possible evolution is captioning by means of voice recognition, which in some environments is becoming a reality. By means of voice recognition IBM has developed an ingenious system called SiSi (Say It Sign It) that automatically converts a spoken word into British Sign Language (BSL), using an animated digital character or avatar.[3] Deaf people may soon be able to get help understanding a telephone conversation from an electronic face that they can lip-read as it speaks the words they can't hear. For example, the prototype talking-head telephone, Synface[4], provides lip-reading support for people with hearing impairments. This is also connected with the possibility of implementation of relay services without operator. These services are supposed to be based on voice recognition technology for replacing the human operator with voice to text equipment. The system recognizes speech and transforms it into text. The vice versa transformation can be obtained using a speech synthesizer.

3.2. *Design for All*

In addition to the improvement of traditional AT with the use of the above exemplified technological developments, the Design for All (or Universal Design in the USA) methodology has been proposed to mainstream some of the problems of integration of people with activity limitations.

This approach, which has elicited interest, not only in the field of eInclusion [4–6] but also in some industrial environments [10], has been defined as: "The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design[5]". According to this methodology, products should not be designed for the "average" user, but the needs, requirements and preferences of all potential users should be taken into account in drafting their specifications. This means that, as far as possible, all users should be taken into account in the production of mainstream products.

Much debate has been going on about the use of the approach. From one side it is recognised that it is coherent with the user centred design principle and the new WHO approach to classification of activity limitations, which emphasizes the social and contextual components of exclusion, but at the same time it has been considered by some actors in the field too complex and expensive. Technical approaches for the implementation of Design for All in ICT have been proposed. At the European level, a network (EDeAN – European Design for All eAccessibility Network) has been set up for discussing about related problems, and a Coordination Network (IST CA 0033838 DfA@eInclusion – Design for All for eInclusion) has been funded to organise and disseminate material needed to inform interested actors. Interested readers are referred to the EDeAN Resource Centre[6] and to the DfA@eInclusion[7] web site, where a set of documents summarize the situation and propose how the approach can be further developed.

A parallel and complementing trend to Design for All can be observed in some application areas where personalized user interfaces are increasingly replacing the one-size-fits-all approach for user interfaces. Personalization as can be observed on popular Websites such as Amazon.com is currently restricted to content extension ("customers who bought this item also bought..."), and tailored layouts for different browser and device platforms (desktop version, mobile version, TV version). However, it is foreseeable that this trend will facilitate personal user interfaces for Websites and any applications in the future, and may become the basis for an advanced Design for All approach that provides alternative and personal user interfaces in an economically feasible fashion.

4. Innovation issues

Unfortunately, when it comes to eInclusion, irrespective of the on-going technological developments, the sector is not very innovative, considering both its assistive technology and Design for All components. There is of course an almost unlimited number of technical ideas, but this often does not lead to products and ap-

[3] See http://www-03.ibm.com/press/us/en/pressrelease/22316.wss, last visited on 02 June 2011.
[4] See http://www.speech.kth.se/synface/, last visited on 02 June 2011.
[5] http://trace.wisc.edu/world/gen_ud.html, last visited on 02 June 2011.
[6] http://www.edean.org, last visited on 02 June 2011.
[7] http://www.dfaei.org, last visited on 02 June 2011.

plications, and accordingly to transformations of social systems from the perspective of people with activity limitations.

One of the main problems in introducing innovation in e-Inclusion, which implies innovation at the technical and organisational levels, lies within the multiplicity of involved stakeholders (industry – big, medium, assistive technology industry –, service delivery organisations, end users, research community) and their integration into the context of social service provision.

Simplistically, innovation is introduced in the market due to the competition of companies in order to attract clients who are looking for the best possible products at the minimum price. This model does not seem to apply in the eInclusion sector, where it may be difficult to define who the real customer is, and where the market is often based more on the creation of protected niches than on competition. The limited market size for some products due to market fragmentation and the high cost to introduce new products are significant hurdles, particularly for new players. The societal systems regarding disability, accessibility and eInclusion do not provide enough incentives to change. Technical innovation does not lead to societal innovation due to factors which are reluctant to change. Some examples are discussed below.

Assistive technology enterprises are limited in their ability to support innovation. First of all, they normally are small companies, which cannot invest in research and development and often find difficulties in learning about or getting rights to research results obtained, for example, in project supported by the European Commission. A mechanism should probably be studied according to which results obtained in European Consortia and not used by the involved partners for a predefined period of time are made freely available. Then, due to the fact that assistive technology is often paid by public delivery service organizations, heavy bureaucratic procedures must be carried out in many countries before a new product is inserted in the list of products that can be delivered and/or funded by the public service. This implies investments with a return in times incompatible with the economic sustainability of a small company. Only for products that offer improvements important enough to be immediately perceivable by end users and for which they are willing to pay personally, could the company run the economic risk. Moreover, the cost argument is not strong enough in the sector to lead to market competition. As in many other market segments today, the price of products is mainly determined by the perception of how much the client (the service delivery organization in this case) is ready to pay for solving the problem of a group of users. The normally small assistive technology companies are more interested in finding their protected niche sector than in competing. Finally, they often perceive Design for All as a risk for their very survival.

Big enterprises (producing basic technology, e.g., Microsoft, IBM, Oracle, SUN, HP etc.) are aware of what eInclusion means and would be able to use this knowledge to make their products accessible without special add-ons, either using the Design for All approach or offering AT functionalities embedded in the operating system. However, they are afraid to be accused of cannibalising the market and killing the AT industry. Therefore, they often offer the minimum necessary to comply with the American laws, i.e., only basic functionalities. Most big and medium enterprises that use the basic technology for the production of equipment and services do not know (or pretend not to know) user needs and the existence of approaches for accommodating non-standard users. For example, some of them[8] present minor adaptations of their products as innovative DfA achievements. Normally, the fact of being forced (e.g., by legislation) to take into account all users is considered by them an undue interference in their goal (serving the mainstream customer and maximizing profits). This situation is slightly changing because elderly people start to be perceived as a market, even if not a market where it is easy to get money from public delivery systems.

Many companies, in particular in the consumer electronics and entertainment sector, regard the user interface of their product as an essential part of their corporate branding. Therefore, an approach that would allow for significant changes in the user interface, including its substitution by 3rd parties, does not fit their business plans.

Public Service Delivery Administrations are not always in favour of fast innovation in the sector. They are not normally organised to react to new and fast changing approaches to assistive services. Any innovation produces the need of adapting the structure of the organisation, the procedures for evaluation, the structure of the budget, etc. This is not compatible with bureaucracy that normally likes smooth changes and adaptations. Also some dislike Design for All approaches, i.e., mainstreaming. Service delivery organisations

[8] see for example the Digital Europe documents, http://www. digitaleurope.org, last visited on 02 June 2011.

control the distribution of large amounts of money and, therefore, they have considerable power. Some worry that any mainstreaming of the support of their clients (DfA) could reduce the importance of the organization itself.

Some service providers for people with disabilities have also been reluctant in exploiting the full potential of ICT and AT, as their role and incentives is based on having clients come to them for evaluation and fitting of special assistive technologies.

End users can be hesitant with respect to innovation, particularly to the DfA approach, because, as discussed above, in most countries the service delivery organisations can pay only for selected AT products. Products are paid by subsidy, i.e., public care and health services or insurance payments. If products would change too fast, this could create problems and delays in the selection procedure. Also, some funding agencies flatly refuse to pay for mainstream devices used in an assistive way, even if much less expensive than purpose built devices. Users are also not very interested in incremental innovation, but only in breakthroughs that really improve significantly their possibility of accessing information, communicating and control the environment. Incremental innovation is often used in the market to characterize the individual products and get loyalty to the brand. This is perceived as dangerous by people with activity limitations, who would like to have products adaptable to their needs, but with consistent functionalities and interaction approaches. They are also suspicious about Design for All and mainstreaming. If products would be made accessible by DfA, no subsidy would probably be granted for them.

Finally research organizations are only marginally active in this sector. eInclusion is not recognized at the academic level and most of the researchers see eInclusion only as one of the possible (normally marginal) application of their research activities. For example, while advances in robotics and computer vision have important implications for eInclusion, the two fields so far have shown limited collaboration at the level of identifying the real needs, requirements and preferences of people with activity limitations.

5. The future

Mainstreaming eInclusion of all citizens can be seen from two different perspective, the AT perspective and the DfA one. Due to the present economic crisis, there is an emphasis on the reduction of cost of AT. To reach low price AT devices will have to be based on mainstream devices. As an example, the possibilities offered by new mainstream smartphones equipped with a variety of sensors and a GPS antenna, can be considered. They offer communication, localisation, availability and access to information, and "intelligence" (increasing in time). This intelligence can be used to offer additional functionalities, including support to the users, e.g., in terms of adaptations of the interface, guidance in the environment, and support to memory. Therefore, facilities already available in mainstream products can be used to replace special purpose technology.

Mainstreaming can also be seen from the Design from All perspective, whereby products are produced to be usable by all. Recently, scepticism about the DfA approach appeared due to the increased emphasis worldwide about profit. The main underlying idea is that people with limitations should be a duty of the welfare system in the different countries and should not be an obstacle to the main aim of industry, i.e., to the generation of profit. According to this approach any increase, even if marginal, of cost due to the need of taking care of needs of "non-standard" users cannot be justified, irrespective of the fact that the group of people over 65 is supposed to become a large proportion of the European society and there will also be a significant increase in the number of people over 80.

However, it seems that the developments of technology itself and its integration in the information society will lead to mainstream products and living environments with capabilities and features that will be inclusive and useful for all users including people with activity limitations, even if designed without explicitly taking in consideration their needs, requirements and preferences.

Some examples of mainstream technological developments, both at the level of single technology and of their integration in complex systems, which could be instrumental in favouring the integration of people in the Information Society, are given in Sections 5.1 and 5.2. Then, Section 5.3 presents two specific instantiations of the previous statement that there are mainstream developments not connected to eInclusion but potentially useful to people with activity limitations.

5.1. Examples of potentially useful technological developments

5.1.1. Computer technology – cost, dimensions and performances

One of the main technological trends is that the computational power is ever-increasing while the size, power consumption and cost of the corresponding components are decreasing. Even if the Kurzweil prediction that by 2020, $1,000 will purchase the computational power of the human brain [11] may probably be disputed, it is clear that the "intelligence" of computer based systems will grow in the near future. The cost of computing drops by a factor of 10 approximately every 4–5 years. It is not uncommon to find children's video game consoles that have more computing power than supercomputers of just 10–15 years earlier. Considering dimensions, e.g., personal digital assistants have shrunk from the size of paperback books to credit card size, and now to a function that runs in the back of a cell phone. Cell phones have shrunk from something just under the size and weight of a brick to cigarette-lighter size, most of which is occupied by the battery. Therefore, mainstream inexpensive platforms start to offer functionalities up to now used in AT and the necessary intelligence for producing applications.

This will be favoured by the improvement of speech and natural language-enabled technologies and intelligent agent software embedded in mainstream products. For example, speech synthesis is no longer a significant cost factor and can be added with little or no hardware costs. Network-based services can further reduce costs by putting intelligence and memory in the network and allowing a new device to pick up where the last one left off.

International initiatives, such as for example "Raising the floor" (RtF) (http://raisingthefloor.org/) and its Global Public Inclusive Infrastructure (GPII.org), could contribute, offering ways for companies to innovate faster, have a ready open marketplace for AT similar to iPhone and Android markets, and make it easier for users to identify and use access technologies across different technologies. Since one of the main goals of RtF and its GPII is to enhance AT and built in access development – and another is to grow the market, such efforts could help overcome some of the barriers to innovation described above.

The trend toward wearable technologies can also be helpful for meeting the need for people with activity limitations to carry devices, leaving their hands free for other tasks. This will be particularly helpful for people who use canes, walkers, and service animals, and generally already have at least one hand in use. People who have a cognitive disability that makes it difficult to remember such devices, and who might therefore leave them behind, will also benefit from wearable technologies. Very sophisticated communication and health monitoring technologies can now be worn on the wrist or woven into clothes.

Moreover, nanotechnology is also developing very fast. It is very likely that this will have impact on many different aspects of technology, particularly in the sector of sensors, which will become not only wearable but also implantable and able to navigate through the human body.

5.1.2. Artificial intelligence

Artificial intelligence principles and techniques are starting to reach applications in different environments. One of them is natural language processing. The capability of technology to process human speech continues to evolve. Although full, open topic natural language processing is not yet available, natural language processing for constrained topics is being used on the telephone and may soon allow people to talk successfully to machines.

Artificial intelligent agents are a second very important sector of fast developing applications. Websites are available that allow users to text chat with a virtual person, who helps them find information on the site. Research on task modelling, artificial intelligence, and natural language are targeted toward creating agents users can interact with, helping them find information, operate controls, etc. Often the subject of science fiction, simple forms of intelligent agents are reaching the point of becoming a reality in everyday use applications.

In combination with the virtual companion, the proactive agent can also provide an innovative and user-friendly interface in the form of a customizable avatar. Therefore a user interaction support module can be designed to support natural interaction with the user and also to provide user-friendly presentation mechanisms through the use of a virtual companion. The user interface will seamlessly integrate communication with other persons and service providers, as well as with the local environment. Content will be presented to each user in a personalised manner, adapted according to user habits, personal profile or environment features.

5.1.3. Image processing and pattern recognition

As a further example of possible short-medium time improvements connected to the use of technology, the potential impact of emerging image processing and pattern recognition technology can be considered. Several functions can be performed using this technology, if enough computer power is available to implement the required complex algorithms and enough intelligence allows the extraction and organisation of data.

A first very important function is the localization of humans and objects. This is considered particularly important, and therefore mainstreamed for security reasons, and has an important potential to support people with functional limitations in everyday life. Even if, due to the possible moderate quality of the sources and the distance of the cameras from the targets, it may be difficult to perform object recognition, e.g., identify the user by face recognition, object localization can be based on detecting visual differences on the images. The main challenge is to guarantee a high level of robustness despite variability of environmental conditions (e.g., changes of illumination, single or multiple subjects, stillness or motion etc.). This can be addressed by the development of algorithms with the ability to automatically learn from and model the appearance of the environment from its variations during the day, integrating information over time and from different sources (several cameras sharing the same environment) and compensate for such variations during the detection of the targets. We can also count on the continued and rapid increase in the resolution of imaging technologies.

Such technologies are meant to allow: (i) distinguishing a person from other persons or objects in the same environment, based on a combination of measurements of simple features such as user height or silhouette shape, walking pattern, and face patterns; (ii) visually localizing humans and objects in the environment; this is essential in scenarios where the user has social contact with other persons in the home or when more than one older people are living in the same home; (iii) discovering elementary spatio-temporal patterns, such as sitting up/down, walking from one place to another, grasping an object etc.; (iv) tracking over time of the localized objects and computation of motion attributes computed from their measurements of velocity, acceleration, trajectory. Movements of the crucial points of the human body (hands, feet, head and centre of gravity) can be analysed in order to detect simple actions such as walking, bending down or displacing an object.

Using the previous approach passive alarm and control systems and services can be set up able to monitor the activities of different persons in the same environment, to draw inferences about the type and quality of activities (e.g., movement) in order to anticipate possible difficulties, and to infer their emotional status. This would be an important contribution to the implementations of living environments offering increased possibilities of independent living.

5.1.4. Personal user interfaces

The Universal Remote Console (URC) framework, as standardized in the 5-part International Standard ISO/IEC 24752:2008, allows the separation of products into user interfaces and application, thus allowing for really personal user interfaces that can be plugged into a "user interface socket" provided by a mainstream product. The idea is that the manufacturer of a mainstream product provides user interfaces for the most popular control platforms, covering the abilities of most users (but not necessarily all). Then, specialized third parties can fill the gap in providing additional, alternate user interfaces for special user groups (including people with disabilities and older people), possible using specialized control devices (assistive technologies).

Thus a new market of user interfaces can evolve, that allows for downloading specialized user interfaces from a cloud-based resource server on demand. This one-size-fits-one approach will provide for a better fit of user interface technologies for people with disabilities than the traditional all-in-one approach. Moreover, it will allow all parties to concentrate on what they do best, i.e. the product manufacturers to make functional products, and assistive technology and Human Factors specialists to provide usable and accessible user interfaces. This will result in an ecosystem that allows for economically sustainable solutions for all users, beyond the 5th and 95th percentile.

The URC approach has been prototypically implemented in research projects, including smart home solutions for elderly people and people with disabilities [12]. This technology has also gained recognition in the European eInclusion domain [13].

5.2. Integration of technology in ambient intelligence environments

Ambient Intelligence (AmI), which is widely recognised as one of the most likely evolutions of the Information Society, has the potential to offer a global vision of the possible organisation of human activities related to access to information, interpersonal communications and environmental control [14].

Following two originators of the AmI vision [15], Ambient Intelligence is defined as an environment where: (i) Technology is embedded in the physical and social environment of people; (ii) technology is context aware – employing machine perception a model of activities of people and their social and physical context can be obtained; (iii) technology is personalized – addressing each user as an individual person; (iv) technology is adaptive to context and activities of the person; (v) technology is anticipatory – predicting user's needs and taking action to support them.

It is particularly interesting that the above considerations are made not at the level of single technologies, (intelligent) objects, and interaction, but at the level of systems and services. This brings about the idea that analysis at the user level must be carried out through the identification of functionalities users need to access information, communicate and control the environment and their integration in the environment. First, it is necessary to discover what the users need at a functional level, and then how and up to what point the needed functionalities can be granted through available technology and harmonised in an intelligent system.

These properties are obviously very important from the perspective of eInclusion, as they allow implementing environments which can support users with functional limitations in their everyday activities.

One such environment is the smart home. A smart home is populated by domestic equipment, including, e.g., heating systems, cooking, white appliances (dish washer, washing machine, freezer etc.), home entertainment devices (radio, TV, Video recorders etc.), telecommunications devices (telephone, video telephone, fax,), safety alarm systems, health monitoring systems, home safety monitors and sensors (water, smoke, fire, stoves, movement, etc), special furniture (e.g., electrically adjustable beds, cupboards and washbasins), and environmental control systems (door telephones, doors, curtains, windows, lights etc.). This kind of equipment, which is becoming itself intelligent, is interconnected to offer applications to the inhabitants in cooperation with services and applications made possible by the availability of (broadband) networks.

With a focus on the functionalities available to the user five hierarchical classes of smart homes have been proposed [16] that can be generalised to any AmI-like environment: (i) Environments which contain intelligent objects – environments contain single, standalone applications and objects which function in an intelligent manner; (ii) environments which contain intelligent, communicating objects – environments contain appliances and objects which function intelligently in their own right and which also exchange information between one another to increase functionality; (iii) connected environments – environments have internal and external networks, allowing interactive and remote control of systems, as well as access to services and information, both within and beyond the environment; (iv) learning environments – patterns of activity in the environments are recorded and the accumulated data are used to anticipate users' needs and to control the technology accordingly; (v) attentive environments – the activity and location of people and objects within the environments are constantly registered, and this information is used to control technology in anticipation of the occupants' needs. Learning and attentive environments are particularly important to offer technological support for people.

So far most of AmI research has focussed on introducing intelligence in individual objects, on interconnecting them and on developing natural interactions with the objects themselves and with the environment through them. Since broadband is becoming more widespread, available smart environments are shifting within the hierarchy from environments which contain intelligent, communicating objects to connected environments. This is considered also by CENELEC, the European Committee for Electro-technical Standardization, as the minimum level to have a substantial contribution to the quality of life, since this is necessary for the delivery of telecommunication services to the environment [17].

However, it is clear from the discussions in the paper that this is not enough. The environment cannot be useful if a "purposeful" communication and control of its single parts (objects and available services) is not available. This means that "intelligent" control must be available and the usefulness of the environment increases with the available intelligence. So far, most of the control systems available in AmI-like environments are essentially deterministic systems, which take decisions about actions on the basis of physical measurements and with the support of pre-determined algorithms. The real intelligence lies with people in alarm and control services, in health care units, and in the environment itself. A typical rule may be: if the body temperature is higher than 37°C, then call the health care service. It is obvious that it is not advisable to aim at completely automatic systems, because even if they would be feasible, contact with other human beings is more important than any technical support in many situations. However, the possibility exists of moving toward the final goal of transforming the environments in learning and attentive environments.

A smart environment may provide an extremely large number of choices and some of them may be quite complex. An interface that directly offers all the possibilities to the user may result cumbersome and difficult to understand and use. On the contrary, the user interface should act as an intelligent intermediary between the complex system and the user. This is the reason why Artificial Intelligence methods and techniques are starting to be used for the development of adaptive intelligent interfaces. It must be considered that accessibility and usability represent the two most important user-related dimensions according to which the success or failure of a technological application or service can be determined and assessed. Intelligent interfaces are supposed to be able to adapt to the user physical, sensorial and cognitive capabilities, some of which may be restricted due to aging or impairments and/or may change along the day, due, e.g., to fatigue and changes in motivation. To this end, the interface must embed a model of the users and be able to make assumptions about their actual situation from the current value of a number of parameters as measured by sensors and/or made available by the evolving interaction behaviour. However, adaptive intelligent interfaces may also have problems; the most important one is the possibility of errors in adaptation. The adoption of erroneous assumptions about the user may make interaction impossible, by, e.g., activating interaction modalities that they are not able to use due their varying (e.g. by fatigue) personal activity limitations or contextual factors.

Another important characteristic of the human interfaces for smart environments is their spatial dependency. The interaction model is not any more based on the assumption that a person is interacting with a computer or a terminal. Therefore, many aspects of interaction depend on the position of the user. For instance, a simple command such as "switch on the lights" must be interpreted differently according to the place where is has been issued. Provided that the user is located with enough precision, the interface needs a spatial model to be able to decide which the lights to be switched on are.

5.3. Two real examples

This section briefly describes two mainstream developments that have the potential of being inclusive without investments that could lead to reduction of profit.

5.3.1. The intelligent kitchen

In eInclusion, an intelligent home environment, where all components are interconnected through an intelligent control and also communicate with the external world, has been considered important for supporting people, e.g., elderly people, favouring their independent living. This has been discussed at least for the last fifteen years. However, the creation of such an environment for inclusion motivations has not been considered viable. Now it is resurfacing due to increasing interest for reducing the cost of household equipment maintenance and for environmental problems.

Firstly, a continuous monitoring of equipment in the kitchen is now considered important for introducing preventive maintenance practices, in order to plan more carefully and economically interventions on the equipment before their breakdown, or to intervene as fast and efficiently as possible when the breakdown has occurred. This needs intelligent appliances and their interconnection with a control centre and the possibility of monitoring their performance and reasoning about the possibility of a breakdown. Additionally, the need of saving energy is considered of paramount importance. First of all, this implies introducing intelligence in the equipment in order to allow them to decide the right program to use. For example, a washing machine should be able to know (or, better, understand) the type, colour, quantity of laundry in order to optimise the quantity of water, its temperature, the quantity of washing powder and the washing time as a function of the real washing task to be carried out. An oven should know what it is cooking to control temperature and cooking time. Then, the kitchen system should be connected with the energy provider. As matter of fact, it is becoming common that the cost of electric energy is a function of the time and/or the fluctuations of use. Therefore, the equipment should be able to connect with the energy provider in order to optimise the cost of energy.

Concurrently, the market of electronic components has significantly changed. Not only computer CPUs are one of the cheapest electronic components, but it is necessary to standardize the production around a few types of chips to increase the production scale. Therefore, producers of household appliances, who up to now have used simple controllers for their products, find now more economic, in order to reduce hardware and software development costs, to use general purpose computer CPUs and general software development systems. Thus, their products become intelligent interconnected equipment with an intelligent control and coordination system. Moreover, the intelligence available in equipment is normally much more than what is necessary for the above described tasks.

This means that the intelligent interconnected environment discussed several times in the context of inclusion as a possible support to people with activity limitations is being produced for mainstream applications. Some of its resources are freely available for other applications, including support of users. Interest has been demonstrated (e.g., in Italy) for applications for people with activity limitations, particularly because there is support by the European Commission and national Governments (Ambient Assisted Living – AAL initiative[9]) for these developments with minor investment by industry.

5.3.2. Total conversation

A second example of mainstream development which will have an important impact on people with activity limitations is the Total Conversation service. It is a telecommunications service enabling voice, real-time text and video communication simultaneously. This service is feasible when telecommunications services are based on Internet Protocol (IP) and the capacity and capability of networks and terminal equipment is sufficient to provide satisfactory quality for multimedia services. Standards for multimedia services have been developed in international standardization organizations such as International Telecommunication Union (ITU)[10], Internet Engineering Task Force (IETF) and 3rd Generation Partnership Project (3GPP) and are generally available. The IP Multimedia Subsystem (IMS) is envisaged to be the architectural framework to support this service both in fixed and mobile environments.

A Total Conversation service based on IP and IMS will probably supersede the current separate voice, text and video services based on circuit switched technologies. However, the transition period is rather long, requiring a major upgrade of networks and terminals. It is expected to take 5–10 years in mobile environment and 3–5 years in the fixed broadband environment. The implementation timetables will significantly vary from country to country, and they may go beyond the indicated periods [18].

At the end of development this will make available a system able to accommodate the communication needs of most of people with activity limitations.

6. Conclusions

Even though innovation in Assistive Technologies is currently limited by market and other constraints, development both in the mainstream world and innovations like the Global Public Inclusive Infrastructure can help open up markets in access technologies, and anticipate future directions. As mainstream technologies increase in intelligence and flexibility, it is easier for them to present different interfaces to different users. With the greying market on one end and young buyers on the other, there will be increasing motivation to create products that can serve both. However, the focus on profits that all companies must maintain will continue to focus them on the "bulk" of both. This creates the danger that these markets will leave unserved those on the edges, eg., those with more severe disabilities. Thus, it will remain important to build infrastructures which can ensure that it is possible and profitable for industry to reach and serve all people who have functional limitations that affect their ability to use ICT.

This will probably happen, not because Design for All will become the normal industrial practice, but because all people, due to the changing lifestyles and the trend of giving access to information and interpersonal communication in any context of use, need to and want to carry out activities considered normal in everyday life under constrained conditions; and also finally, because we maintain and develop a healthy and innovative AT market.

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