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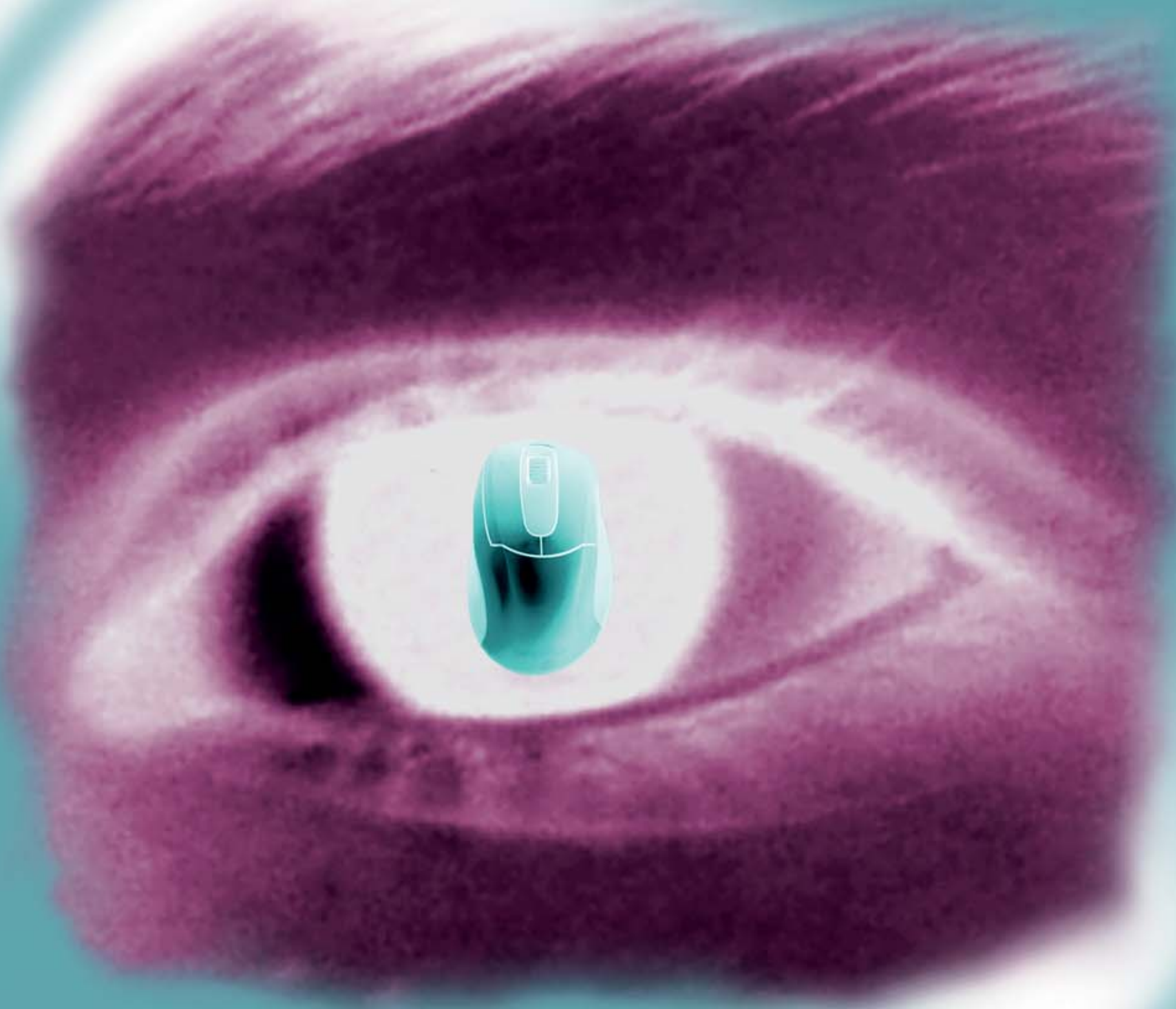

Information Technologies for Visually Impaired People

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Vol. VIII, issue No. 2, April 2007

Monograph: Information Technologies for Visually Impaired People (published jointly with Novática*)

Guest Editors: *Josep Lladós-Canet, Jaime López-Krahe, and Dominique Archambault*

UPENET (UPGRADE European NETwork)

CEPIS NEWS

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Editorial

Our Training as European Professionals

The field of ICT seems to have survived the devastating consequences of the implosion of the technological bubble that clouded the start of this new century. New generations of short-lived businesses, languages, and devices have brought in the last five years a tremendous challenge for IT professionals whose altogether slower rate of renewal requires them, both as individuals and as a group, to make a major and costly effort to keep up.

In the current climate of globalization and offshoring, academic learning is not enough to meet, either quantitatively or qualitatively, the production needs of a sector in the midst of a profound change and the personal needs of a group of professionals who can expect forty long years of exercising their chosen profession in a sea of continual challenges. There are those who fear that in our training we are using professional profiles that look towards the east, while we are neglecting the profiles that are essential to our European working environment that originate here or are imported from further west.

CEPIS has been preparing to help address this situation with the aid of its splendid *de facto* watchdog group of 300,000+ active professionals. In this five-year ICT 'trough', CEPIS has been in the frontline of European Certification concerns regarding e-skills, the in-depth study of their shortcomings, the analysis of their misadaptations, and the way to overcome them by professionalism.

One of the most important results of this effort has been the massive relaunch of EUCIP, the European Certification of Informatics Professionals, which provides three interlinking cer-

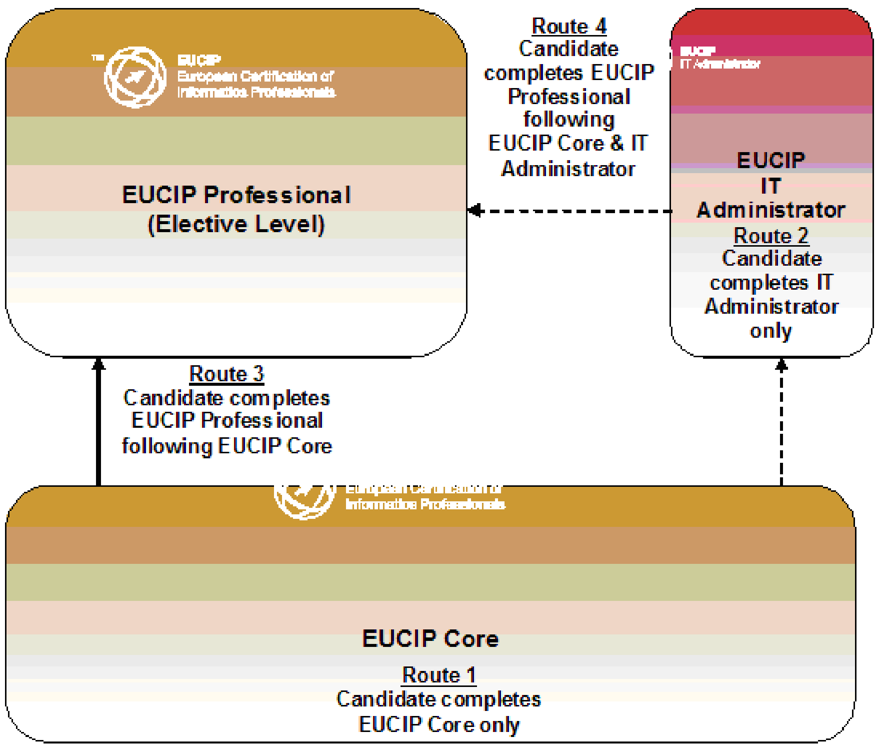

Figure 1: The EUCIP Interlinking Certification Options.

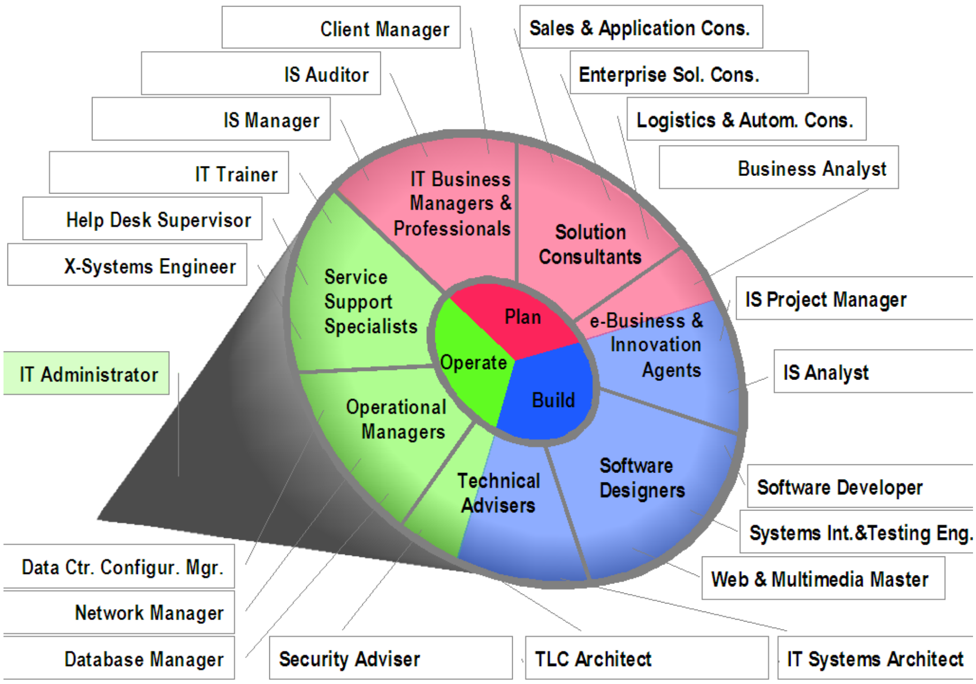

Figure 2: The twenty one Advanced Training Profiles of EUCIP Professional Certification.

tification options EUCIP Core, EUCIP Professional and EUCIP IT Administrator (see Figure 1). Several years of pilot projects in relatively classical profiles have been combined with the large scale training experiences (different but convergent) provided by several million ECDLs and ICDLs (*European and International Computer Driving Licences*). This work has resulted in a certification suite suitable for IT professionals at any stage in their career.

EUCIP Core offers a broad basis covering aspects of planning, building and operating IT Systems. This certification can then lead to EUCIP Professional, a certification which allows candidates to choose from 21 advanced training profiles geared towards actual professions (see Figure 2). The EUCIP Professional profiles cover the tasks that professionals will be required to perform in their actual careers, striking the right balance between management, development, and operational aspects which employers demand, enabling IT professionals to consolidate, update, and certify their irreplaceable experience, the benefit of which is so often lost due to a lack of continuity. In addition, EUCIP IT Administrator has been developed to cover the essential role of an IT Administrator to be found in so many small to medium sized companies or regional offices of larger organisations.

With this unprecedented international effort that has involved thousands of hours of work, CEPIS invites us to our future, to a programme that provides a wonderful opportunity to certify what we know and know that what we certify will be useful to us in the future.

Presentation

Introduction to Assistive Technology for the Blind

Jaime López-Krahe

The two fundamental problems facing blind people are the difficulty of knowing where they are and getting about, and the impossibility of having direct access to information, whether in written or in electronic form.

The evolution of assistive technologies for the blind saw a boom at the end of the last century, opening the doors to exciting new prospects for the present day.

Several articles of this monograph look at the current situation and the research outlook for these issues. In this introduction we will take a historical look at the evolution of assistive technology for the blind from the 18th century to the end of the millennium in the hope that it will help readers have a better understanding of this monograph .

According to the World Health Organization (WHO), blindness is a visual acuity of 20/400 or 0.05% in the better eye and with the best possible correction. The problem of helping the blind to integrate in everyday life has been addressed in some way or another since time immemorial. But where once only the most basic form of aid or merely compassion was offered, now a more autonomous concept of life for the visually impaired is pursued.

The greatest problems facing the blind to acquire this autonomy and their solutions fall into two main categories:

- The possibility of getting around independently; in other words, mobility and navigation aids.
- Access to written information and the social memory. This includes accessibility to digital information on computers by means of specialized digital interfaces.

1 Mobility Aids

The White Cane

Apart from those natural human aids (or rather guides) popularized in Spain by the fictional character Lazarillo, the first technical and intuitive aid is the simple stick. It allows the user to explore the cone of space within its reach although it cannot detect obstacles above ground level (overhanging or projecting objects, etc.) while hazards caused

The Guest Editors

Jaime López-Krahe is Chair Professor and Dean of the faculty of Mathematics, Computing and Information Science and Technology of the *Université de Paris 8*. He has authored about a hundred publications. His research work is focused on image analysis, form recognition, discrete geometry, Hough transformation, etc., and their application in the world of the disabled. Since 2001 he has promoted and directed the first Master in "Technology and Disability" at the *Université de Paris 8*.<jlk@univ-paris8.fr>.

Josep Lladós-Canet received his degree in Computer Sciences in 1991 from the *Universitat Politècnica de Catalunya* and his PhD in Computer Sciences in 1997 from the *Universitat Autònoma de Barcelona* (Spain) and the *Université Paris 8* (France). He is currently an Associate Professor in the Computer Sciences Department of the *Universitat Autònoma de Barcelona* and a staff researcher of the Computer Vision Center, where he is also the deputy director. He heads the Pattern Recognition and Document Analysis Group (2005SGR-00472). His current research fields are document analysis, graphics recognition, and structural and syntactic pattern recognition. He has headed a number of Computer Vision R&D projects and has published several papers in national and international conferences and journals. J. Lladós-Canet is an active member of the Image Analysis and Pattern Recognition Spanish Association (AERFAI), the Spanish chapter of the IAPR, and is currently chairman of the IAPR-ILC (Industrial Liaison Committee). Prior to that he served as chairman of the IAPR TC-10, the Technical Committee on Graphics Recognition, and he is also a member of the IAPR TC-11 (reading Systems) and IAPR TC-15 (Graph based Representations). He serves on the Editorial Board of the ELCVIA (Electronic Letters on Computer Vision and Image Analysis) and the IJDAR (International Journal in Document Analysis and Recognition), and is also a PC member of a number of international conferences. Josep Lladós-Canet also has experience in technological transfer and in 2002 he created the company ICAR Vision Systems, a spin-off from the Computer Vision Center, specializing in Document Image Analysis, after winning the Catalonian Government's entrepreneurs award for business projects involving Information Society Technologies in 2000.<josep@cvc.uab.cat>.

Dominique Archambault has a PhD in Computer Sciences and is an Associate Professor at the *Université Pierre et Marie Curie*, Paris. Since 1996 he has been working in the field of assistive systems for visually impaired people. He focuses on projects concerning non visual interfaces, Web accessibility, and educational tools for blind children. One of his main topics of interest is the way in which computer technologies can be used as a tool for children's development, particularly in the case of visually impaired children with additional difficulties (problems arising from their visual impairment or additional disabilities). He has coordinated 2 IST European projects (TIM - IST-2000-25298 and Vickie - IST-2001-32678). <dominique.archambault@upmc.fr>.

Figure 1: *Parable of the blind leading the blind*. 1568: P Bruegel the Elder, Pinacoteca di Capodimonte, Naples, Tempera on canvas 86 x 154 cm.

by level changes (stairs, holes in the ground) are only detectable if they are specifically explored. This "device" dates back a fair way as we can see in Bruegel the Elder's dynamic and almost cinematographic painting "Parable of the blind leading the blind" (see Figure 1) in which we see a number of blind people guiding one another, with the leading ones falling over and bringing the ones behind down with them.

After the catastrophe of the First World War the number of blind people grew considerably and the white cane came to be an instrument with a dual function: firstly it was to help blind people get around more easily and secondly to let the people around them know that the person using the white cane was visually impaired. This invention has been attributed to George A. Bonham of the Peoria Lions Club, Illinois, USA in 1930 and its use rapidly became widespread.

The proper use of the white cane, and in particular of the long cane, requires special training by mobility instructors to optimize its usefulness.

The Guide Dog

The use of animals as mobility aids is relatively recent. By way of an anecdote, reproduced below is a photograph, probably from the late 19th century, showing a blind man being led by two hens (see Figure 2); the information conveyed by the photo is minimal and we can only assume that the level of training that a pair of hens can attain is also minimal to say the least.

The first attempts to train guide dogs apparently occurred in Austria in the late 18th century according to references by Leopold Chimani who in 1827 mentions the case of Joseph Resinguer who had trained dogs for his own use. Later the rigid harness (Johann Wilhelm Klein, 1819) appeared but its use was ignored for practically a century <http://www.nodo50.org/utlai/perros.htm>.

We had to wait for the consequences of the Second World War before the appearance of dog training establishments in a number of countries, often as a consequence of individual initiatives (Gerhard Stalling in Germany, Paul Corteville in France and later in Spain).

We should also mention here the efforts of the Lions Club which has encouraged the development of this mobility and safety aid in many countries for people with visual impairment, including of course the ONCE.

Electronic Mobility Aid Devices

Late in the 20th century electronic mobility aids began to appear based on interferometer systems [1]. The first technologies used were based on the emission and reception of infrared rays which allowed obstacles to be detected by reflection up to a distance of 3 to 4 metres (Tom Pouce, Teletact)[2] (see Figure 3).

Later laser technology devices were used allowing a greater range and better processing of the information. These devices may take the form of canes or glasses which interface with the user in one of two ways; by touch or by sound. A tactile module enables the user to obtain information about obstacles. Acoustic systems provide information by means of tonal differences (higher or lower frequency) depending on the location of the obstacle and varying loudness to inform users about how far away the obstacle is. One of the difficulties preventing these devices from being more widely adopted is the need for specialized training in their use.

The use of satellite positioning (GPS) and orientation devices open up further perspectives, although there are still some unresolved problems since in built-up areas the presence of buildings can interfere with satellite signals, especially on pavements. These devices can also be linked to mobile telephones capable of transmitting images, which enables users to summon remote human aid.

2 Information Access Systems

Direct Transduction

Direct transduction devices convert visual information into information that is accessible to the blind. They do not use intelligent processing systems, but depend simply on energy transformation. This technology is often referred to as sensory substitution.

Tactile Stimulation

The first intuitive was in this sense to convert visual information directly into tactile stimulation, thereby respecting the two dimensions of shapes. The sense of touch is made up of nerve endings that can detect various sensations (cold, heat, pressure, etc.). It is important to know the exact nature of these nerve endings so as to be able to optimize their stimulation. One important feature is their spatial distribution frequency, especially of pressure sensitive receptors. In 1 cm^2 the fingertip there may as many pressure receptors as in 200 cm^2 of any other part of the body. Another important feature is that tactile sensory cells act on an On/Off basis, emitting an action potential when they are stimulated and also when they cease to be stimulated (for example, they "notice" when you put on a pair of glasses or a hat, and when you take them off, but not while

Figure 2: Blind Man Led by two Hens.

Figure 3: Teletact.

you are wearing them). For this reason stimulation must be effected by prompting an exploration with movements or by making the stimulators vibrate.

Around 1880 Camile Grim presented his "Anoculoscope", a prototype of 64 (8x8) light sensitive selenium cells which used electromagnets to activate an identical number of stimulating tactile pins according to the light that fell on matrix of cells[3].

Later other experiments focused on stimulation of the user's back or tummy as can be seen in Figure 4 [4].

In the seventies another device appeared; the Optacon (see Figure 5), developed by Telesensory Corp. This was a device comprising a camera with 6x24 receptors connected to a screen with an identical number of vibrating pins that allowed the user to feel the shape by stimulating a finger. It was successfully marketed until the turn of the century. It enabled users to access documents, for example, after a basic training course, although reading speed remained slow and the process was tiring. A miniaturized camera was located on two rollers to make it easy to move along the line and it was equipped with a zoom and an adjustable tactile screen (frequency and intensity of vibration, inverse stimulation, etc.).

Some research going on today in the field of visio-tactile sensory substitution is focusing on stimulating the underside of the tongue[5].

Acoustic Stimulation

Another possibility of stimulation, although of a more abstract nature, is acoustic stimulation . In this case the idea is to transmit bi-dimensional information via a one dimensional channel such as hearing. However, by analyzing the frequency of such signals we can achieve a pseudo two dimensional encoding. The first research into this type of sensory substitution is attributed to Fournier d'Albe [6], who invented and perfected [7] the "Optophone" for which reading speeds of up to 60 words a minute were claimed [8]

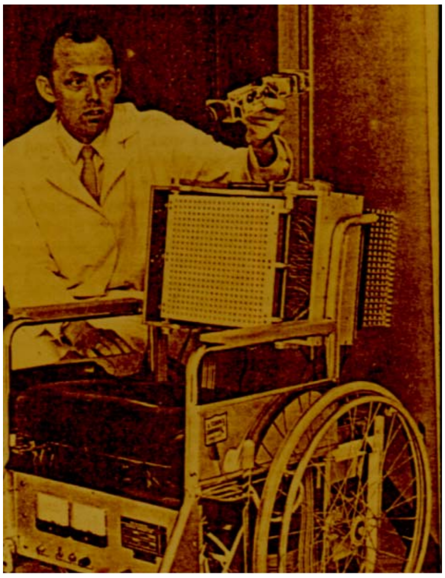

Figure 4: Transmission of Information by Dorsal or Ventral Stimulation.

(although such a claim may be optimistic). Later other devices based on this principle were marketed, such as the "Visotoner" or its subsequent, more developed version, the "Stereotoner". It worked by means of a camera that projected an image onto an array of photo-receptors, each of which was associated with a rising or falling frequency depending on the position of the image. By passing the camera over a line of text a user would hear sounds representing the shape of each letter; for example the letter "v" would be represented by a tone that started high, then fell, and then rose again. Mauch Labs. Inc. ceased to manufacture these devices in 1977.

Access to Written Information

Braille

The most commonly used method of reading for the blind is braille, invented in 1827 by Louis Braille in France when he was just 18 years old. It consists of a binary information system using a cell of six raised dots (2x3) which is well adapted to tactile exploration. A well trained blind person can achieve reading speeds akin to those of sighted people. The main drawbacks to the system was the space it occupied, its difficulty to learn, and the cost of producing texts.

It was an indirect system of access to the written word insofar as it required someone else to manually transcribe the text (although a number of copies could be made at the same time by putting two or three sheets in at the same time and pressing harder).

In order to make reading faster and save space, some countries developed a kind of shorthand braille. There are specific coding systems to transcribe music scores or mathematical texts, which need to overcome the problem caused by the fact that braille is a linear system and music and maths require multi-dimensional information to be represented (matrices, fractions, five line staves). This information is represented by a system of operators and parentheses.

Reproduction difficulties became a thing of the past with the appearance of the braille printer and the thermoformer – a kind of embossing photocopier.

The First Refreshable Braille Devices

In the mid seventies O. Tretiakoff invented an electronic system of refreshable braille on a 12 character display. By combining this display with a and audio cassette machine and a 6-key braille keyboard he produced an innovative device: the Digicassette. The braille was recorded on a cassette and could be read on the 12 character braille display (which was later increased to 20). This system made copying easy and solved the problem of the sheer volume to be stored. Later another US company came up with another, similar system, the VersaBraille (see Figure 6), which was equipped with a serial interface that allowed it to be connected to a computer. The early cassette based recording systems of Digicassette and VersaBraille were later upgraded to floppy disk. These computer connectable refreshable braille displays represented a major step towards Internet accessible systems.

Generation of Interface Devices

Until relatively recently the quality of speech synthesis was too poor to be used in assistive technology for the blind. Today that problem no longer exists and an ever increasing number of blind people are turning to this solution, which is not incompatible with Braille and, while it falls short in some areas, has some other very interesting advantages such as ease of access, ease of indexing, and the possibility of increasing reading speed. Today speech synthesis is a cheap and simple way of electronically accessing any text document.

The refreshable braille systems used in Digicassette and VersaBraille paved the way for modern day devices employed as a means of accessing computerized systems directly via a braille interface (see Figure 7).

Today practically all printed information is transmitted through electronic media which, once legal and administrative problems have been overcome, allows direct access either by speech synthesis or by braille.

Figure 5: Use of the Optacon.

This means that we have to take the needs of blind people into consideration when generating Web documents or pages. We need to take into account and respect W3C – WAI (Web Accessibility Initiative, <http://www.w3.org/WAI/>) recommendations to ensure that Web sites are accessible to everyone. A lack of awareness of these basic rules often prevents access to this type of information. Webmasters need to be aware of these initiatives and learn how to provide simple options for visually impaired people (contrast inversion, page amplification, etc.) It is more a problem of culture and unawareness than a lack of willingness so any information in this regard can only be welcome.

Advances in Form Recognition

The first reading machine based on intelligent character recognition was designed by Kurzweil who in the early eighties marketed a device that enabled blind people to access printed text automatically. It was a machine (like a large photocopier) which processed an image and outputted a speech synthesis in English. It was specifically designed for the blind and its high price meant that its use was mainly limited to specialized centres and libraries .

More recently, thanks to the widespread use of office applications, the cost of hardware and software has come down so much (computer, scanner, OCR package, speech synthesis or braille line) that it is now a reasonable option in terms of achieving direct access to the printed word.

Moving towards the present day, we should look at such inventions as the KNFB reader, also invented by Kurzweil, which is the first portable automatic reading device to read printed texts. It is based on a combination of numerical photography, PDA, and speech synthesis with a considerable memory. The device detects the edges of the document, indicates when the photo can be taken, and in a matter of seconds the text can be heard.

These small computers equipped with cameras can also be used to identify everyday objects; cans of drink, caned foods, medicines, etc.

Low Vision

The definition of blindness that we saw earlier involves the total absence of vision, but in many cases the use of residual vision is also an option, provided that the right equipment is available. From conventional magnifying glasses to electronic magnifiers sometimes linked to a computer and character recognition systems, there are solutions available to help those with low vision access information. Depending on the nature of the residual vision, such devices can allow users to alter the presentation, colour, size, etc. of the text they wish to read.

Figure 6: VersaBraille.

Figure 7: Refreshable Braille Interface Device.

3 Conclusion

The purpose of this brief historical overview is to introduce the subject of this edition and give readers a better understanding of the assistive products available to help the blind and partially sighted integrate into the information society and achieve autonomy.

In the following articles readers will be able to see the current trends, the state of the art, the direction that research is taking, and the developments we can expect in the matter of assistive technology.

Two clear trends can be identified:

- A specific development, the need for which arises at a specific moment in time, such as braille displays.
- The use of general purpose technologies that can be developed as technology advances.

If it is impossible to avoid using special interfaces, it would seem logical to ensure that such devices are produced in such a way as to be integratable with conventional technology by using standard connection methods and protocols. Otherwise the result will be products that are too costly, hard to maintain, and with a tendency to become quickly obsolete, to the consequent frustration of their users. Thus, the development of general purpose OCR, with its falling cost and increasing reliability, is causing information access devices of a more special purpose nature to gradually disappear.

Digicasette, VersaBraille, Optacon, Stereotoner and other such devices have given way to an ever changing information technology and an (accessible?) Internet with specially adapted but minimalist interfaces that integrate perfectly and make use of existing general purpose systems.

*Translation by **Steve Turpin***

References

[1] C. Jacquet, Y. Bellik, Y. Bourda. Electronic Locomotion Aids for the Blind: Towards More Assistive Systems. In Studies in Computational Intelligence, Intelligent Paradigms in Assistive and Preventive Healthcare, ISBN: 3-540-31762-7, N. Ichalkaranje, A. Ichalkaranje, L.C. Jain (Eds.), Springer-Verlag, Vol. 19, 2006, pp. 133-163.

[2] R. Farcy, R. Damaschini, R. Legras, R. Leroux, Y. Bellik, C. Jacquet, J. Greene, P. Pardo, L. Agro, J.M. Murienne et A. Zoghaghi. *Perception de l'espace et locomotion des non-voyants par profilométrie laser: aides électroniques à la locomotion*, J3eA - Vol. 3, Hors-Série 1 - 5 (2004). DOI: 10.1051/bib-j3ea:2004605.

[3] Gallois. *Anoculoscope*. Bulletin Le Valentin Haüy, Paris, Octobre 1883.

[4] P. Bach-y-Rita. A tactile vision substitution system based on sensory plastic, in Visual Prosthesis. Ac. Press, 1971.

[5] P. Bach-y-Rita, S.W. Kercel. Sensory substitution and the human-machine interface. TRENDS in Cognitive Sciences, Vol. 7, No. 12, December 2003.

[6] E.E. Fournier d'Albe, The Type Reading Optophone. Nature, Vol. 94, pp 4, London, September 1914.

[7] E.E. Fournier d'Albe. The Optophone: an instrument for reading by ear. Nature, Vol. 105, London, May 1920, pp. 295-296.

[8] J.C. Nye, P. Bliss. Sensory Aids for the blind:a challenging problem with lessons for the future. Proc. of the IEEE. Vol. 58, No. 12, December 1970.

Computing Blind

Carmen Bonet-Borrás

Disabled people should be able to play their part in our information society using new technologies under the same conditions as any other citizen. There are now tools that, to a greater or lesser extent, can alleviate the difficulties arising from visual impairment, and there are also design standards for Web pages that make Internet access possible for the visually impaired who, in turn, should commit to accessibility by using and helping to develop the new solutions.

Keywords: Accessibility, Assistive Technology, Braille, Braille Display, Character Recognition, Design for All, Functional Diversity, Low Vision, Screen Reader, Text Magnifier, Visual Impairment.

Author

Carmen Bonet-Borrás. I was born in Bellreguart (Valencia, Spain) in November 1955 into a family of 4 siblings. Due to my blindness, caused by congenital infantile glaucoma, my early schooling was spent in ONCE centres; four years in Alicante and four in Madrid. I continued my education in a regular school where I studied sciences before changing school to study for my university entrance exams. I studied Mathematics at the *Universidad Complutense de Madrid* and after selling ONCE lottery tickets for 4 years I began my training in IT on a course delivered by IBM where I embarked on my career as a Systems Technician working in Applications Development, Networking, and other fields. I am about to complete my 25th year in this profession. <carmen.bonet@es.ibm.com>.

1 What Is Blind?

If we start by consulting the *Dictionary of the Spanish Royal Academy* (DRAE) we find this definition of "blind": "*Deprived of sight*".

Or in the Seco dictionary [1] "*adj 1 Deprived of the sense of sight. Also, referring to people. DPlaja Literatura 213: 'Each person Lázaro serves is the butt of his mockery: he sees the evil that resides in the blind man.'* ". In spite of being a dictionary of usage, this dictionary, like the DRAE, has very little to say on the subject. Moreover, I think that, given the vast number of references to be found in literature, the one chosen can hardly be said to be the most fortunate example.

Going back in time a little, to the first half of the 20th century, the María Moliner dictionary, also a dictionary of usage, defines blindness as: "*Physiologically incapable of seeing*". This definition is not exactly over-explanatory either, but I prefer it.

Another longer leap backwards in time. The *Diccionario de Autoridades*, the first dictionary produced by the Spanish Royal Academy in the 18th century which backed up its definitions with examples of real usage: "*Deprived of sight, like a man born without it, or who lost it later, through accident or illness: also used for animals. From the Latin 'caecus' with the same meaning*".

And going back a little further in time to the early 17th century and another dictionary, one which nowadays may seem a trifle exotic as it is a compilation of the personal knowledge of just one man. It was the first formal dictionary of Spanish and the criteria used to decide its entries are varied in the extreme. There are a great many personal comments and opinions, it is entirely subjective as we can see by the definition of "blind", and sometimes his definitions are almost encyclopaedic; he tells us everything he knows related to the word in question. I am referring to Sebastián de Covarrubias's *Tesoro de la lengua castellana o española*: "*A man or animal that lacks sight. The man may have been born blind and may never recover [his sight], unless by a miracle; or may have lost his sight due to an accident*".

These last two definitions give us some more information, but let's keep looking. Moving away from the purely academic and returning to more modern times, we find other contributions: *"Blind! Mother of God! the worst thing that could happen to me!*". That's what some passers will invariably say to us when they generously offer us their arm to help us across the street. And then they might add: *"I do so admire you people!*". We hear this kind of intrinsically contradictory comment about our blindness regularly. If blindness makes us admirable, what's all the fuss about?

What is objectively true is that blindness in a person is a condition that's easy to see. As for most generalizations, there are exceptions, but not many. Normally, if you have a visual impairment, sooner or later the people in your circle are going to notice. I am also convinced that blindness is something which very few people view with indifference. The proof of this that there cannot be many people who, at one time or another, have not closed their eyes to try and imagine what it's like to be blind. Do you remember the children's game 'Blind Man's Bluff'? From Homer, epic poet of ancient Greece, of whom it was said he was blind, to the current day, we find references to blindness in literature: *El Lazarillo de Tormes*, *El concierto de San Ovidio*, or *El Túnel* are all important literary works featuring characters who are blind.

For this reason I think now would be a good moment to clarify a number of points before centring in on the topic of this article. From the perspective of my more than fifty years' experience, or perhaps a little less, depending on how you look at it, since while I have been blind since birth, I had no clear awareness of being blind until I reached more or less the "age of reason" (can that be a coincidence?), to this day I still don't know whether blindness makes a *quantitative* *or a qualitative difference*. And I'm beginning to suspect that the answer to this dilemma is for ever going to remain in the pending file of my life.

However, what I am in no doubt about, is that blindness is a characteristic that sets us apart, that creates group identity, and causes a major change in the way we relate to our human, social, and physical environment.

Leaving aside any possible value judgements, I will try to limit myself to the more objective aspects. Oh, and by the way; closing your eyes is not much like being blind at all.

The term 'visually impaired' covers a wide range of problems. You may be able to see nothing at all or you may see a little. And if you see a little, what you do see may vary both in quantitative and qualitative terms from person to person. You may see only light and vague shapes, or you may see enough to walk along a street without using a white cane, for example, but only when there's not too much light, or using only the middle part of the eye, as if you were looking down a tube, etc.

The two parameters that are most commonly used to express these differences are visual acuity and visual field. Visual acuity refers to the distance at which a person sees an object clearly. A visual acuity of 1 means normal vision and the figure goes down as the size of the object in question needs to be increased to be seen at the same distance. For example, a person has a visual acuity of 0.5 if he or she needs the size of the object to be doubled or, of course, the distance to be halved. Thus we can speak of:

- Total congenital blindness: does not even know what seeing is, therefore has no notion of light and darkness, or of colour, cannot see black, simply does not see.
- Total acquired blindness: all visual function is lost due to illness or accident, but some memories remain as intellectually manageable concepts.
- Visual impairment: when there is some usable residual vision that can be optimized by using technical aids.

In the first two cases we are talking about the blind, while in the third case we are referring to the visually impaired.

In addition to the visually impaired whose degree of impairment qualifies them as legally blind, there is another group of people who "cannot see properly". These people are said to suffer from "low vision". This is a concept based on functionality and is therefore difficult to define with complete precision. These are people who, after appropriate treatment and standard refractive correction, have in their better eye, a visual acuity of between 0.1 and 0.3, or a visual field whose extent in all directions around the fovea (i.e., around the physiological centre of the visual field) is less than 10 degrees (i.e., a diameter of less than 20 degrees) in the eye with the field of greater central extent, but who uses, or is potentially able to use, vision for various tasks. Obviously, there is no strict dividing line between visual impairment and low vision, regardless of whether the condition falls inside or outside the threshold of legal blindness.

This is a relatively new field of care which is mainly the responsibility of optometrists who attempt to provide more or less effective solutions through the use of optical devices for the conditions that medical science still cannot cure. Low vision occurs more frequently among the elderly, but it can affect any age group, which is why technology is so important as a source of optical aids.

2 Does Being Blind Create a Lot of Complications?

In every facet of life a blind person makes use of a set of capabilities that are different from those enjoyed by the majority of society and, therefore, each facet will be complicated or not depending on whether he or she has the necessary resources with which to act. For example, if it's a matter of reading a book and that book is available in a format that a blind person can handle (braille, sound) there's no problem. The problem only arises when the book is in a format that is inaccessible to a blind person. I would like to underline this difference. This is a true case of functional diversity. Minorities characterized by some kind of functional diversity will find things more or less difficult depending on to what extent society is capable of responding to those functional diversities. I am referring of course to the strictly physical aspects. The emotional side is beyond the bounds of this article.

The visually impaired are a diverse and varied group, depending on the degree of vision they have (if any), the nature of that residual vision, any skills they may have had before they first encountered visual problems, their economic and social status, any rehabilitation they may have received, etc.

So what we need to do is to look for flexible solutions and, depending on how successful we are, we will be able to mitigate the difficulties facing the visual impaired.

3 Market and Technology

In western society, the frame of reference used in this article, the blind and visually impaired represent around 1.5% of the population. In other words, it's a relatively small group of people and, as such, does not carry much weight when it comes to influencing market priorities which tend to be based on profitability criteria and gravitate towards a supply that will reach the highest number of consumers possible.

Meanwhile, technological advantages depend on the interests of the entities that fund research, and once again people with functional diversity are not a priority. In view of this scenario, what tends to happen is that, more often than not, technological advances tend to exclude these groups, either wholly or partially. However those same technological advances often give rise to opportunities that, when properly realized, can provide interesting solutions capable of addressing some of the difficulties caused by disability

Also, bearing in mind the longer life expectancy of the population, an increasing number of people reach an age at which a variety of functional limitations begin to make an appearance. As this group of people grows, so does their economic importance, and they begin to become more interesting from a business point of view.

4 Active Participation

The visually impaired must not be excluded from the information society and the new technologies. That would only add to their functional differences by making tools used by the sighted majority inaccessible to them.

I therefore believe that it is our responsibility as a group to get involved and participate, claiming our rights as users but also contributing with our collaboration in all processes where it may be of use: from the prototype design phase to the market launch of the finished product. With an open mind and an active will we need to find the way to become directly involved in the processes of research, manufacture, and design so that our problem is taken into consideration from the very moment an idea is first conceived. In that way the idea can be developed and brought to fruition as a product that meets "design for all" or "universal design" criteria.

Modifying something already on the market so as to make it usable by a blind person requires much more work and added expense than if those modifications had already been included in its conception, design, and manufacture stages. Also, when something is designed using design for all principles, it invariably ends up benefiting all users, whether disabled or not.

5 Technology and Visual Impairment

In my opinion it is a legitimate aspiration of all the various groups of people with functional diversity to enjoy the benefits provided by technology. To achieve this we need to ensure that technological advances incorporate features that enable them to be used by the blind or visually impaired, and use such advances to address the problems inherent to their visual impairment. We will use this new technology both to improve available resources and to replace visual information by auditory or tactile information; i.e. to make use of our other senses when there is no residual vision.

Whenever possible we should apply general purpose technological advances to disability related applications. Only when it is strictly necessary should we develop technology for the specific use of people with functional diversity, what is known collectively as assistive technology. The reasons are obvious: general purpose technology will always be more economical and will evolve according to the dictates of the market, while assistive technology will always be more expensive and will evolve less or at a slower pace.

6 Information Technology

Information technology plays an undeniably important role in society. The Internet is a very significant source of information and of business tool. From merely looking up information, to buying tickets, performing bank transactions, etc., it is practically impossible to find a reason for not getting involved in IT. If the visually impaired are to take part in this wonderful world, we need to ensure that both hardware and software are accessible to them while guaranteeing the accessibility of Web pages.

One of the most fundamental aspects of this area of work is that of standardization, or the definition of standards to help facilitate communication between all the various elements, both hardware and software. The closer any element of hardware or software comes to conforming to the applicable standard, the more useful and interesting it will be in terms of accessibility. Among the most important features are: operating system independence, portability (weight and size), versatility of communication, and capability of evolving with the environment.

It is also very important to maintain the functionality of assistive tools. When a new version of a product comes out, it should not lose compatibility with screen readers and other assistive technology tools, something which unfortunately happens all too often (if it happens once that is one time too often). What tends to happen is that when a new version of a product comes out, technical aids lose some of their functionalities while others are improved. Of course, tools need to evolve, but if they evolve on the assumption that the latest version of the product is already in common use, these tools will always arrive late, badly, or never to the consequent detriment of users.

Price is nearly always a sticking point when marketing new assistive technology. To overcome it we need to try and join forces and avoid competing in a market that is already too small. We also need to try and get state authorities involved to help with funding and in particular to promote the culture that products should be accessible from conception.

Among the technology currently available on the market there are a number of solutions that are already up and running. The first problem we need to overcome in order to make use of them is how to handle the mouse and the screen reader.

6.1 Mouse Handling

Not being able to see where the mouse is pointing makes handling the mouse an impractical proposition. The solution is to use the keyboard, a skill which is not particularly difficult for a blind person to learn. However, if this is to be viable, the operating system and the application to be used should be designed for that purpose. If this possibility is not provided for internally, the application will be inaccessible. For every function a mouse can perform there should be a sequence of keystrokes equivalent to the corresponding mouse clicks.

6.2 Screen Magnifiers

For people with a considerable degree of residual vision, the ideal solution is to provide them with the possibility of magnifying the image and altering the colours so as to adapt the presentation to their visual capability. These features are available in software that normally goes by the name of "screen magnifier".

6.3 Screen Readers

For blind people we need to resort to voice and/or braille. Nowadays there a excellent sound card based speech synthesizers which form the basis for what are known as "screen readers", programs that read out load whatever is on the screen, provided that the operating system considers it as text. A screen reader is normally built around a basic module which interacts with the operating system and a number of profiles that act as links for the various applications. They are designed to be able to tailor the function of reading to each user's needs, always by using the keyboard. A user might require the program to repeat a phrase, spell out a word, say the colour of a character, change the speed of reading or the tone of voice, etc. They are highly versatile programs which provide user-friendly management of the contents of the screen .

However, there are times when a user may wish to read content that the operating system does not identify as text, but rather as a graphic. In this case, screen readers are incapable of capturing or interpreting that information. A graphic is always a graphic. Whether it is a photo of someone or somewhere, or the page of a book, it will always be an image that the screen reader cannot interpret.

6.4 OCR

A type of software known as OCR (*Optical Character Recognition*) has been developed based on a general purpose tool, the scanner, the purpose of which is to scan the graphics on a page and convert them into text. Naturally, if the scanned page contains no characters, there will be nothing to convert. Generally speaking excellent results can be obtained with a minimal error rate, although much depends on the print quality of the graphic to be scanned. Nowadays there are even OCR programs capable of working directly with PDF files.

There are also scanners that come equipped with their own OCR and operate as an independent device with a voice output and their own storage capacity. Or programs that are compatible with certain scanners, but work through a PC. These resources are an enormous help when it comes to accessing the printed word, which has always been one of biggest obstacles facing the blind or the visually impaired.

6.5 Talking Browser

A screen reader will invariably have a profile enabling it to be used with one of the standard Internet browsers. However, there is also the possibility of an Internet browser that can be operated using a keyboard and with a voice output. However, there is a substantial price difference between a voice browser and a screen reader, which is much more expensive due to its greater functionality.

Other software tools have been brought out that enable users to alter the "aspect" of a standard browser by changing sizes and colours. These tools are available through links to the supplier on the page that the end user wishes to visit, thereby providing added value for that page.

6.6 Braille Display

This is a hardware device used for converting the content on a screen into braille. At present these devices usually run under screen reader software, although they have a degree of functionality that enables the user to read "according to taste", to change line, to use a 6 or 8 dot braille, etc., using its own keyboard. They may vary greatly in size depending on the number of characters they can display, from 20 to a maximum of 80, among other factors. There are also significant differences in the way they connect with the computer. Today some devices connect via Bluetooth; they are very compact displays and convenient to carry around.

The price still needs to come down as they are very expensive devices, partly due to the cost of some of the materials used in refreshable braille displays, and partly because of the fact that this is assistive technology for an especially small market. However, it is a vitally important device – braille is, after all, the blind person's reading and writing system - and we therefore need to promote and facilitate its use [2].

6.7 Braille Printer

These are used for printing in braille. They are normally used for text, but there are some printers that enable simple graphics to be printed.

6.8 Personal Notetaker

For a number of years now, it has been possible to acquire notetakers that can be used as standalone devices for word processing, storing a certain amount of data, as calculators, etc. and they have enjoyed great success among blind users. They are easier to use than a computer, their size and compactness makes them ideal to carry around anywhere and, in short, they are a highly useful tool. If they can also be used for exchanging information with a computer, then we are talking about a truly valuable resource. Input to nearly all models is provided by a braille keyboard while output is by voice, although there are devices with a braille output that are less widely used, perhaps due to their considerable extra cost.

6.9 Web Pages

In order to browse the Internet, it is not enough to have tools enabling a blind person to handle a computer. If a Web page has not been designed in accordance with the WAI (*Web Accessibility Interface*) standards recommended by the W3C (*World Wide Web Consortium*), the page is likely to be totally inaccessible. Pages designed with plenty of graphics, movement and so on with the idea of appealing to visitors, are often also very tedious and deficient on certain browsers, types of terminal etc., and tend to be a headache for screen readers. Ideally designers should meet WAI standards from the initial design stage, but that doesn't mean they have to abandon their aesthetic aspirations; an accessible page does not have to be an unsightly page. And forget any ideas of providing a "text-only version" as a solution. Firstly, because there is no reason why a text version should necessarily be any more accessible than the page it replaces, and even if it were, it means twice the work to produce a page that may well be obsolete within the month, making it a complete waste of time.

At this point it should be made clear that when we speak of accessible Web page design we are talking about accessibility in terms of the principle of design for all, not just for the blind or visually impaired which, while being particularly sensitive to this problem, are not the only people with functional diversity that need to be considered.

In fact nowadays we should also be speaking of routine accessibility practices. Web pages should be designed to be accessible, but we should also be applying usability and accessibility principles in our day-to-day work. By way of an example, think of the way the changes made to a document which several different people are working on are marked with different colours. The use of different colours to indicate changes is fine, but it's no help to blind people. Let's add, say, a double asterisk, and, hey presto, problem solved.

Leaving aside commercial considerations, governments should strive to ensure that, on the one hand, its Web pages are usable by *all* its citizens and, on the other, that the society being built is an inclusive one. Governments thus bear a heavy burden of responsibility when it comes to enacting laws to promote universal accessibility.

7 Other Areas of Technological Action

7.1 Medical Science

Technological advances play an important role in medical science. Major advances in surgery have been made while neurological research is entering territory that some years ago would have been thought of as science fiction. Any battles that medical science can win in the fight against visual impairment, from curing diseases to the neurological emulation of the visual function of the brain, a field in which interesting progress is being made, will very more than welcome. The role of stem cells also appears to be promising.

7.2 Optical Science

The field of optical science has a great deal to offer. From the simplest magnifying glass to the most sophisticated video magnifier that allows you to adjust the magnification, colour contrast, reflections, etc., there is a wide range of products on the market today.

7.3 Digital Books

The new technologies have brought about a radical change in the matter of accessibility to books. While it is true that braille is the reading and writing system of the blind, for various reasons some form of voice technology has very often been used for the purpose of reading. In the past there were cassette recordings of books, recorded by real people. Playback was necessarily sequential and there were scant opportunities to "play" with the content of a book. This situation has changed dramatically.

Firstly, there is a great deal of literature in directly digitized formats that can be handled by a blind person with the tools currently available. The book can be "opened" and the reader can move around inside it with ease. It will be read either by speech synthesis or braille, depending on the user's hardware and software environment. Reading by speech synthesizer through a screen reader is a little shocking at first - the voice sounds a little metallic and robotic - but with practice and with the optimal quality that these media can now achieve, the reading standard is now more than acceptable. It may not be the best way to read Antonio Machado or Pablo Neruda, but it is at least possible. In any event, if you have a braille display or a braille printer you can read in the more literal sense of the word.

The other method is to listen to recordings made in a digital format on a CD. Books recorded in this way will preserve all the advantages of the human voice but will also allow you to access the book via software capable of searching the book by chapter, pages, etc. Add to this the ease and low cost of making copies, which allows users to have their own copy (the traditional method involved borrowing from libraries), we can now justify the use of the term bibliography in the broadest sense of the word.

7.4 Solid Braille

This is the name given to the use of raised dots to form braille letters which are produced by means of a series of droplets deposited on the surface on which we wish to write, which then adhere to it before finally solidifying to form an integral part of that surface. This system has been used in trials for visiting cards, for example. It can be a magnificent solution for labelling consumables, pharmaceuticals, clothing, etc. This is no simple task; you need a material that is of sufficient consistency, clean, and tough, and a mechanism capable of performing this kind of precision writing at a reasonable cost. What I am trying to say here is that the problem of labelling is no trivial matter. Every day we come across packaged products - food, cleaning, leisure products, etc. – which need to be easily and clearly identifiable if the blind are to enjoy autonomy and quality in their day-to-day life.

7.5 GPS

This is a relatively new resource which is very appealing to blind people. The possibility of knowing exactly where you are while walking around places you are unfamiliar with is really very interesting indeed. If it also provides details of the location of specific buildings, shops for example, it will solve one of the most common problems facing the blind. To date, all I know is that there is a GPS service that can be used via a mobile phone, a device which, by the way, will need to be equipped with its own screen reader.

8 Conclusion

While we are waiting for that miracle to which our 17th century dictionary compiler, Sebastián Covarrubias, referred, that we will get our sight back (and it is highly unlikely that we will), let us try to make use of the aids that technology affords us and help improve the quality of life as far as is humanly possible. We cannot afford to miss this boat, as there won't be another one. Let's get down to work do what we can to help.

Translation by ***Steve Turpin***

References

[1] Manuel Seco, Olimpia Andrés, Gabino Ramos. *Diccionario del español actual*. Aguilar, 1999.

[2] Carmen Bonet Borrás. *El braille y el placer de la lectura: los ciegos queremos seguir leyendo con los dedos*. Novática, No. 169, July-August 2004, pp. 67-72. <http://www.ati.es/novatica/2004/169/nv169sum.html>.

Assistive Technology for the Blind and Visually Impaired

José Antonio Muñoz-Sevilla

A decade ago, actions aimed at improving the living conditions of disabled and elderly people, including access to culture-related goods and services, were no more than a generous, paternalistic concession. That request, based on "cultural charity", has now become a fundamental demand within the rights of citizens to full integration and access to information. This article analyses how technology is being used by people with visual impairment as a channel to access information, and describes some research lines identified by ONCE (the Spanish National Organization for the Blind) as priority in the field of technical aids.

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He has collaborated in a number of articles and books on the subject, such as "*Apoyos digitales para repensar la educación especial*" (Digital aids to rethink special education) Editorial Octaedro, 2001; White Book "*I+D+I al servicio de las personas con discapacidad y las personas mayores*" (RD&I in the service of the disabled and the elderly*)* Instituto de Biomecánica de Valencia, 2003; "*Touch, Blindness, and Neuroscience*" Universidad Nacional de Educación a Distancia (UNED), 2004; "*Tecnología y discapacidad visual*" (Technology and visual impairment) ONCE , 2004. <jmsv@once.es>.

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1 Introduction

To say that we live in a highly technological society will surprise no one. However, it may come as a surprise to know that not everyone enjoys the same rights under the law. The right to information is one of the pillars of social development which should apply to everyone but sadly this is not the case. When information is generated, universal design principles are not always applied; therefore, much of the information generated is inaccessible for a number of people due to their lack of knowledge, age, physical characteristics, psychological characteristics, etc. One highly illustrative example is the way content is posted on the Internet. Content is not always accessible by disabled people, even though there are clearly defined standards and principles governing the design of Web pages and content in place to prevent access discrimination (W3C-WAI standards [1]).

The technology used in the field of visual impairment has all too often been developed specifically to address these accessibility problems without actually solving them. We will go on to analyse the role of the principal players involved in this process and look at what is being done to ensure that the visually impaired can access digital information.

2 The User

We must all have come across people with a more or less serious visual impairment. However, probably not very many of us are able to define with any accuracy exactly what blindness is. Functionally speaking we might say that *a person is blind if he/she has perception of light only, without projection, or has no sight whatsoever.*

The World Health Organization [2] defines blindness as "*visual acuity of less than 3/60, or corresponding visual field loss to less than 10 degrees, in the better eye with best possible correction*" (ICD-10 visual impairment categories 3, 4 and 5) and low vision as "*visual acuity of less then 6/18, but equal to or better than 3/60, or corresponding visual field loss to less than 20 degrees, in the better eye with best possible correction*" (ICD-10 visual impairment categories 1 and 2).

In functional terms, we may consider a person to be visually impaired if he/she has serious vision problems and, in order to function properly in his/her daily life, may require a visual rehabilitation programme and/or optical or electronic aids to mitigate the negative aspects of their disability.

The disabled come from all walks of life but all have one thing in common; to a greater or lesser extent they all need additional guarantees if they are to enjoy their full rights as a citizen or participate in the economic, social, and cultural life of the country on an equal footing with their fellow citizens [3] [4].

On the international scene there is a great awareness and sensitivity regarding equal opportunities issues and non-discrimination on the grounds of any personal or social condition or circumstance. Thus, the United Nations Organization (ON), the European Council, and the European Union, among other international organizations, are currently working on the preparation of policy and legal documents on the protection of the rights of disabled persons.

In Europe, the most interesting developments in the field of accessibility are to be found in the *e-Europe* 2002 action plan [5] (now superseded by *e-Europe* 2005 [6]), which has as one of its primary goals the adoption and recommendation of a number of Web accessibility guidelines in member states.

It was precisely this idea of accessibility that spawned the *Web Accessibility Initiative* or WAI. This is an initiative led by the W3C which aims to improve information access for the disabled by developing accessibility guidelines, improving Web accessibility evaluation and training tools, implementing an educational and awareness-raising programme on the importance of Web page design accessibility, and opening up new research fields in Web accessibility.

We must all be aware of how the development of information and communication technology has brought about a substantial change in the way information is produced, managed, and accessed. Such a change has undoubtedly given rise to a huge increase in the volume of information in circulation, but this does not always mean that that information is accessible.

All too often when information is generated no thought is spared as to whether the format or the medium used to disseminate it is apt for everyone who may want to access it. This is when we run the risk of creating a situation of "digital exclusion", a term that has unfortunately had to be coined to describe a situation in which we are in danger of excluding certain sectors of society from the information society due to disability or even social disadvantages.

Technical aids have had an enormous impact on those suffering from visual impairment. There can be no doubt that, in most cases, such aids are, and will continue to be, the way people with a severe visual impairment can overcome their disability and realize their potential.

3 Technical Aids

Assistive technology for the visually impaired comprises electronic and/or computerized devices and aids that are specifically designed for the blind. They may be highly specialized (requiring a specific training course before they can be used properly) or of a lower level of specialization (simple enough not to require any prior training). These products are intended for the blind and the deaf-blind.

Aids for people with residual functional vision are referred to as low vision products. These are mechanical or electronic optical aids used to correct, improve, or optimize a person's visual acuity.

4 The Services

There are a number of services and resources that can be provided and, when appropriate, acquired to help the visually impaired achieve personal independence:

- Specific devices, aids, and technology.
- Specially adapted material.
- Material in accessible media (braille, recorded material, and information technology).
- Optical aids.
- Non-optical and electronic aids.
- Training and family support.
- Guidance to other institutions to ensure the accessibility and adaptation of physical environments.
- Training and guidance for external professionals, voluntary workers, etc.

For the purpose of this article we will concentrate on the first four aspects and we will analyse how technical and human resources are employed in Spain to ensure that the visually impaired enjoy a good level of personal independence.

Among its main missions, the ONCE (the Spanish National Organization for the Blind) [7] is committed to ensuring that all its members and, in special cases, people who are not members but have needs due to visual impairment, can access, be trained in, and handle information technologies under optimal conditions and with the aid of any technical and human resources that they might require. The resulting independence opens up more and better opportunities in the fields of culture, education, work, leisure, etc.

But, in order for this mission to be achievable, we must deliver the means to constantly upgrade technical aids; that is to say, we must work collectively on the universal design of products and services and, where that is not feasible, we must redouble our research efforts to develop the appropriate technical resources.

With regard to the public sector, those involved in assisting people with visual impairment who are registered with ONCE provide their services under the auspices of that same organization. The goods and services provided by ONCE related to communication and access to information are described below:

- **Shop-Showroom:** In each city there is a showroom for displaying assistive products and for handling the orders made by ONCE members. These showrooms are run by ONCE's administrative branch offices and departments. They are specialized shops where people with visual impairment go to find the range of assistive products available in Spain.
- **Professionals:** All activities related to training, guidance, and technical support for products for the blind and deaf-blind are carried out by technicians specializing in devices and aids for the visually impaired. There are 85 such technicians, and they are spread all over Spain so as to be able to provide individual attention to users wherever they may be. These professionals receive basic computing and training skills before going on to learn more specialized techniques and methods through ongoing training and refresher courses organized, coordinated, and delivered by ONCE's research centre, the *Centro de Investigación Desarrollo y Aplicación Tiflotécnica* (ONCE-CIDAT). Later in this article we will be taking a closer look at the workings and structure of this research centre, which is also responsible for the design of the organization's intervention strategy.
- For users with residual functional vision there are

122 technicians throughout Spain working out of 44 centres. These are responsible for training, guidance, and technical support for low vision aids, tools to aid users in their day-to-day lives, and spatial orientation aids .

- **Assistive technology classrooms:** all of ONCE's regional branch offices, administrative departments, and centres (45 in total) have a training classroom with the infrastructure and the specialized hardware and software required to deliver training and support to the users registered at each centre. These classrooms represent the hub from which the aforementioned 85 professionals pursue their activity and provide the appropriate technical support to regular education establishments, training centres, companies, and basically anywhere where there may be blind users, together with ergonomic and functional studies to adapt work and study places.

5 The Research

Organizationally, the CIDAT research centre [8] comes under ONCE's *Dirección General Adjunta para Servicios Sociales* (General Directorate for Social Services) and works in close coordination with the dependent department of that directorate, the *Dirección de Autonomía Personal y Bienestar Social* (Personal Independence and Social Welfare Department) (see Figure 1).

CIDAT is engaged in research and development, the evaluation, maintenance, and repair of products, the training of trainers, the provision of guidance, the import/export of goods, the production, distribution, and marketing of assistive products, and the provision of a personalized service to users of technical aids for the visually impaired.

The research centre is headed by a general manager and has five dependent departments (General Resources, Production and Maintenance, Sales and Marketing, User Care, and Research and Development, as well as a consulting service to provide guidance in the use of technical aids for visual impairment). The total headcount of all the departments, including both skilled and unskilled workers, is around 80.

Focusing now on the Research and Development Department, as part of ONCE's ongoing quest for progress in the removal of physical and digital barriers, this department develops many national and European projects, putting into practice its accumulated know-how and experience in the definition of specifications and in the validation of trials and products.

The Research and Development Department's Action Plan calls for collaboration with companies which, generally speaking, act as subsidiaries for the provision of R&D services and the manufacture of products commissioned by, or in support of, ONCE.

With regard to research of a more academic nature, we would highlight the research agreements in place with a number of Spanish universities. This collaboration is formalized through institutional collaboration agreements at various levels: education, work, etc. Thus, for example, in the field of IT engineering, the framework agreement is aimed at collaboration in technological research and innovation through the promotion of technical support, IT development, and the dissemination of IT, to ensure the social integration of the disabled.

6 Plan of Research of ONCE-CIDAT

CIDAT's [9] main lines of research are aimed at developing products and services related to:

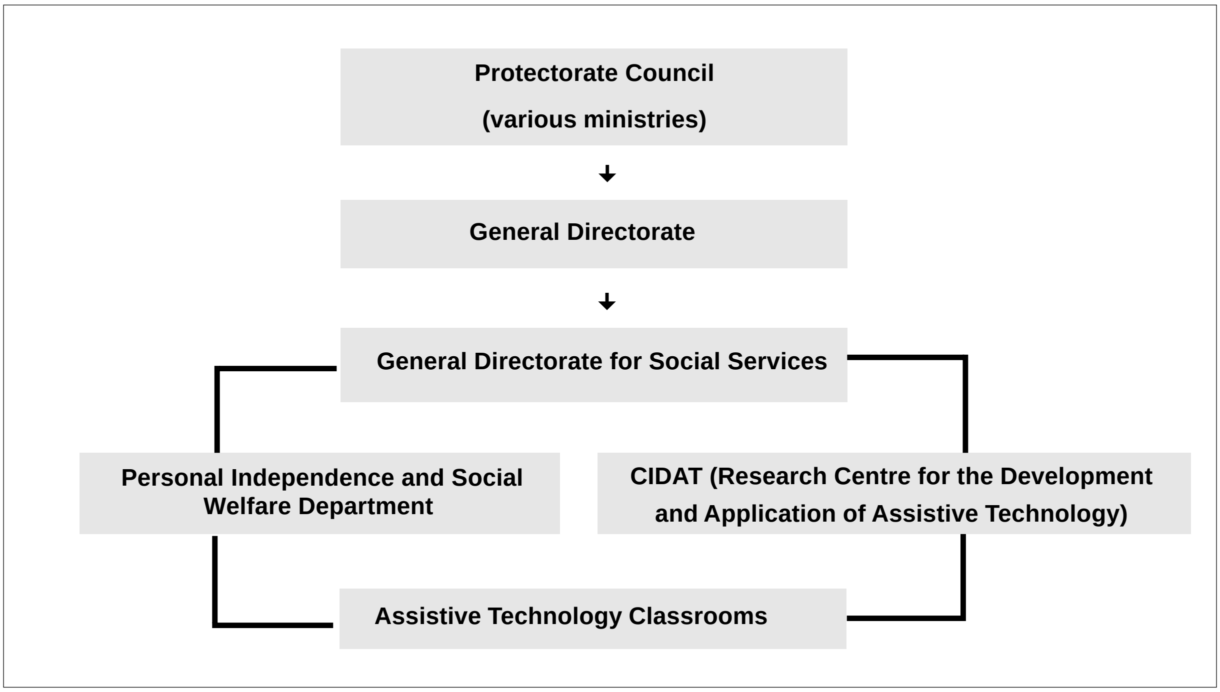

Figure 1: Basic Hierarchy of ONCE-CIDAT.

■ **Resources facilitating access to computer-based information.** This line of research centres on the continuous upgrading of screen magnifiers and readers to enable users to access the most commonly used operating systems and applications. This equipment needs to be accompanied by modern information access devices such as braille displays (cell, line, or full-page) and other tactile representation devices with improved functionality and design. Research is also conducted into the integration of speech synthesizers that improve on current performance in terms of speech quality and range of languages (official languages in Spain), and into speech recognition technologies insofar as they help provide access to information for the blind and the visually impaired (screen readers, magnifiers, braille displays, PAC Mate, Plextalk PTN1, Victor Reader). Meanwhile research is also being conducted in the field of *virtual reality* as a source of tools capable of opening up new channels of access to information (projects such as GRAB[10], INMU, etc.).

■ **Access to paper-based information, and data conversion and processing applications.** In this field, CIDAT works on the ongoing evolution and improvement of optical character recognition, and keeps a watchful eye on the market for any products using this or similar technology that might be useful to ONCE and its members. The centre also researches into systems capable of reading *ID codes on banknotes and products* (barcodes, PDF, magnetic strips, inks, etc.).

In the field of *specific technology for people with residual functional vision* research is conducted into the most advanced optical techniques to develop high performance, portable, and inexpensive enlarging devices.

Meanwhile, for those who may wish to process the information retrieved by the above mentioned technologies, CIDAT is conducting ongoing research into the development of braille conversion systems, musical and mathematical notation, PDF, and the recording and playback of formats such as Daisy, mp3, etc. (symbolic braille, Bluetype keyboard, Lectotext, etc.).

■ **Braille printers and print control software.** In order to continue to exploit the market potential created by ONCE with the manufacture of new printers and the upgrading of existing ones, CIDAT is researching into ways of maintaining ONCE's current competitive level while meeting the needs of its members. This hardware is complemented by print driver, spooler, and adjustment software which is upgraded constantly to meet the requirements of the printers and the demands of the market. (Braille display, Linux printer drivers, Quickbraille).

■ **Educational and recreational software.** As technology is acquiring an increasingly more significant role in the world of education and is also an important tool in the educational development of blind and visually impaired students, researchers at CIDAT believe that it is essential to pay the maximum attention to this line of research. One aspect of this work is to ensure accessibility to the operating systems, content, and content management systems used by each of the Spanish Autonomous Communities.

CIDAT has also developed other educational applications and devices (dictionaries, encyclopaedias, interactive courses, concept tables, etc.) covering educational needs from infant school right up to university.

Meanwhile the centre continues to develop adapted games, not only for PC environments but also for mobile telephony and even educational board games (Lambda, BME, English course, accessibility to Spanish Royal Academy, bilingual dictionaries, Espasa dictionary, ONCE-Larousse, tutorials...), games ("*Invasión alienígena*" [Alien invasion], stories, "*La pulga Leocadia*" [Leocadia the flea"], "*Aventuras en el tiempo*" [Adventures in time]…), etc.

■ **PDA's and mobile telephony.** These two fields, PDA's and mobile telephony, are undergoing a permanent evolution towards convergence in which their separate identities are becoming blurred, therefore for the purpose of research into assistive technology the two are treated as one. CIDAT's research is focused on continuing the progress already made in accessibility to these devices, with the development and/or adaptation of GPS applications, office automation utilities, games, etc., while looking for new ways to provide accessibility to other products via these devices.

At the same time CIDAT is researching into accessibility to new PDA models and into accessibility to third generation telephony (MSP – screen reader for PDA's -, Wayfinder).

■ **Professional tools and occupational training.** In response to the ever-changing market for the tools that drive a company's business activity, researchers at CIDAT study the viability of adapting these tools to the needs of the blind and visually impaired for activities such as remote assistance, accessibility of the equipment used in physiotherapy, distance learning applications and the adaptation of telephone switchboards. At CIDAT we are aware that this is a sector which offers great possibilities in terms of the integration of people with disabilities into the job market.

The continuous advances made in telephony technologies in the service of the workplace makes it necessary to identify and apply solutions that will ensure their integration in the shortest time possible, while optimizing the cost of this type of solutions. For this reason, research efforts are mainly focused on accessibility to computerized switchboards.

■ **Accessibility to home automation and household appliances.** The development of solutions providing accessibility to household appliances is centred on the communication capabilities provided by Bluetooth technology and ONCE's relationship with expert companies in that field and with household appliance manufacturers, mainly using mobile phones or PDA's as access terminals, However the use of other technologies as a means to access such appliances is also under study.

Also, given the continuing development of home automation systems in our society, CIDAT also researches into technologies to provide accessibility to such systems.

■ **Public transport.** Public transport is one of the main barriers facing the disabled. It is therefore essential that all the players involved in this sector, whether public or private, identify and provide accessibility solutions wherever they are needed. In spite of the fact that the provision of greater accessibility does not strictly depend on technological research, the various technologies used in the field of assistive technology may be of great help in adapting public transport to the requirements of the blind and visually impaired and so give them a greater independence in terms of mobility. For this reason CIDAT works in collaboration with public transport companies, the Public Administration, and the ONCE Foundation, providing guidance and research in systems that improve accessibility to public transport.

■ **Audiovisual media.** The widespread use of audiovisual systems such as DVD, and the high expectations aroused by digital television, make these fields highly interesting from an accessibility point of view, since the development of these media, which were designed under universal accessibility criteria, can open up a world of disabled-friendly information and services. For this reason, CIDAT collaborates with companies and the other areas of ONCE involved in the study of and research into systems which ensure optimal accessibility to these communication media (Digital TV).

■ **Manufacture, prototyping, and adaptation of specialized devices and equipment.** In this field CIDAT is involved in processes of design, prototyping, production, and manufacture of canes, braille writing tools, the mechanical parts of various assistive aids, and special adaptations of other equipment. The centre also researches into the manufacture of new canes that substantially improve the quality of those in current use to meet the highest demands of our members, using state-of-the art materials to produce solid, stable, and durable canes.

7 Collaboration with Third Parties and Participation in Major Events

Our centre regularly collaborates with and participates in any national and international events that may bring us into contact with new technologies or help disseminate our products and activities.

With regard to international events, in addition to taking part in meetings with the manufacturers of specific solutions, we also participate in international assistive technology trade fairs such as CSUN (*California State University at Northbridge*) [11], SightCity (Germany) [12], etc.

Here in Spain, as well as the various exhibitions we attend or organize to make our products known to users, we also collaborate with other enterprises in a wide variety of events of a less specific nature, such as SIMO [13] or the *Semana de la Ciencia* (Science Week) [14].

We also regularly collaborate with companies or public or private organizations in presentations, discussion sessions, workshops, etc.

We attend and often collaborate in the organization of events for two reasons. Firstly to keep up to date with the new products and solutions that are constantly being released and, secondly, to disseminate our activities and raise society's awareness of the needs of the visually impaired and the solutions that they require when faced with the new technologies.

Translation by ***Steve Turpin***

References

[1] W3C, Web Accessibility Initiative <http://www.w3.org/WAI/>.

[2] World Health Organization. *International Classification of Functioning, Disability, and Health: ICF*, 2001.

[3] Law 51/2003, of December 2, on equal opportunity, non-discrimination, and universal accessibility for people with disabilities.

[4] Law 34/2002, of July 11, on information society services and electronic commerce.

[5] European Commission. eEurope2002. <http://europa.eu/scadplus/leg/es/lvb/l24226a.htm>.

[6] European Commission. eEurope2005. <http://europa.eu/scadplus/leg/es/lvb/l24226.htm>.

[7] ONCE (National Organization for the Blind). <http://www.once.es/>.

[8] ONCE-CIDAT. <http://cidat.once.es>.

[9] ONCE-CIDAT. ONCE-CIDAT R&D action lines: partially published in the *Plan Nacional de I+D+I 2004-2007* (National RD&I Plan 2004-2007) as part of the National Programme for health and welfare technologies: national sub-programme of technologies to assist the disabled and the elderly.

[10] GRAB Project. <http://www.grab-eu.com/>.

[11] California State University. <http://www.csun.edu/cod/conf/2006/exhibit/2006DirectoryofExhibitors.htm>.

[12] Sight City. <http://www.sightcity.net/index-e.html>.

[13] SIMO. <http://www.ifema.es/ferias/simo/default.html>.

[14] *Semana de la Ciencia de Madrid* (Madrid Science Week) <http://www.madrimasd.org/semanaciencia/2006/default.aspx>.

An Overview of Handheld Computerized Technologies For People with Visual Disabilities

Philippe Foucher

Handheld computerized tools can be used to provide technical assistance to improve the autonomy of people with visual impairments. Many projects have brought solutions to the special needs of blind people everywhere. Those handheld tools use mainly non-specific devices such as PDAs and smartphones. Speech interfaces (synthesis or recognition) and/or haptic-enabled communication between user and device. Applications concern the daily life situations of blind people: mobility and written or symbolic information access. Concerning the mobility of blind people, many systems have been implemented: outdoor/indoor navigation (GPS/ GSM/WLAN/Bluetooth/RFID), travel assistance (planning, urban public transport access), video remote assistance, and adapted assistance. Written or symbolic information access is based in embedded OCR software, RFID tags identification, objects pattern recognition by using artificial vision.

Keywords: Handheld Computers, Information Access, Information Processing, Visual Disabilities.

1 Introduction

People use mainly visual information for indoor/outdoor navigation, public transport information, textual or symbolic indications access (bus lines, posters, packaging). Performing those daily tasks is very difficult and sometimes impossible for people with visual disabilities. They must perceive and interpret information by other senses (hearing, smelling, touching) and/or asking sighted people to help them. This human assistance is often welcome but is not always possible in real time and does not correspond to the precise needs of sight-impaired people.

Technical assistance has given partial autonomy to people with visual impairments in their daily life. Thus, urban devices installations (audio or haptic) and computer tools improvements (speech synthesis, Braille console), have brought some help to blind people. The boom of handheld devices such as PDA (*Personal Digital Assistants*), cellular phones, smart phones and IP cameras, has also opened the possibilities of many applications to help partially and totally non-sighted people at any time.

This contribution aims to provide a state-of-the-art review of handheld computerized tools for helping people with visual impairments. This article concerns only non-invasive technological tools which enable the identification of real objects or give information about localisation or environment. Concerning navigation systems, two complementary approaches are considered [1]:

- Obstacle avoidance systems and ultrasonic obstacle avoiders have been developed to assist visually-impaired travellers through the immediate or local environment. Those systems have been widely described in literature [2] [3] [4] and will be not detailed in this article.
- Navigation through the distant environment concerns location by GPS, GIS, GSM, Bluetooth, WLAN, RFID technologies.

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After this introduction, this article is composed of four sections and a conclusion. Section 2 presents the problem of technical help for blind people. Section 3 presents the technical description of existing tools. Section 4 presents the applications which facilitate the mobility of visually-impaired people. Section 5 describes the research into visual information access (text, pictograms, environment).

2 Issue of Technical Assistance for Blind People

The issue of technical help for blind people consists of two aspects:

- The computerized assistance tool must give supplementary information to blind people. These supplements must be accurate, reliable and widely available. It is thus a question of defining the types of assistance according to daily life situations: area accesses, position knowledge, navigation, information access, travel planning. Knowledge of the advantages and drawbacks of technological tools enables the development of aids adapted to each need.
- How shall the aids communicate with blind people? Blind people must have Input/Output (speech recognition/

synthesis, tactile keyboard/screen) access to give indications and receive information. The adaptation of devices, human machine interface and contents is essential to obtain a usable and efficient assistance.

3 Technical Description of Aids

3.1 Location Tools

The choice of location methods depends often on the blind person's environment (urban or rural areas, outdoor/ indoor situations). All the methods are generally used complementarily to combine accuracy, signal reception level and reliability in many areas.

The main location methods are based on a trilateration (a process analogous to triangulation) measurement between satellites and receiver device [5]. At the moment, only the GPS (*Global Positioning System*) enables geolocation by satellites. The European system Galileo will soon be operational (2008-2009). Trilateration calculates the electromagnetic signal's propagation time between mobile receiver location and at least three satellites. Location information given by GPS is free and receiver devices are ubiquitous and inexpensive. Location information corresponds to latitude and longitude coordinates and navigation software such as GIS (*Geographical Information System*) or Map Matching is generally proposed with GPS to navigate on a map.

Some factors have an influence on GPS receivers in terms of accuracy (location given by GPS is very close to real location) and satellites reception level (GPS is accessible anywhere).

- GPS signals are deflected and reflected as they pass through the Earth's atmosphere. This introduces a location error.
- GPS receivers can only see satellites which are above the horizon, and obstructions caused by vegetation, buildings, mountains, or canyon walls can block satellite signals. A study has revealed very poor reception conditions in dense urban areas [6]. In this urban environment pedestrian navigation may be thus problematic because of the walls of large buildings.
- Canyons, both natural and urban are also notorious for the multipath (the reflection of signals off canyon walls). GPS receivers work by calculating the time it takes for signals to be received from GPS satellites, so signals bouncing off canyon walls are delayed slightly, thereby introducing error.
- There is no GPS signal reception for indoor location.

Some methods have enhanced GPS measurement and satellites reception level. DGPS (*Differential Global Positioning System*) corresponds to Global Positioning System (GPS) with an additional correction (differential) of the location. DGPS compares the GPS location at a fixed station with the actual known location of the station. It transmits then this difference to mobile GPS receiver which automatically correct the positioning. AGPS (*Assisted Global Positioning System*) refers to a system where resources other than satellites, such as a fixed assistance server and reference network, GSM (*Global System for Mobile Communications*), UMTS (*Universal Mobile Telecommunications Systems*), help a GPS receiver calculate its position. The receiver can operate more quickly and efficiently than it would unassisted, because a set of tasks that it would normally compute is shared with the assistance server. For example, the assistance server can take into account precise GPS satellite information (orbit and clock), initial position and time estimation. This information is computed by the assistance server and communicated to the receiver through the mobile network. AGPS also works when signal reception is low. It is thus particularly interesting in dense urban areas or in buildings. Moreover, the use of AGPS decreases necessary time computation for position calculation.

In general, GPS Location gives the most accurate results. However, other location systems, using mobile networks (GSM, UMTS) and terrestrial stations enable greater location accuracy in urban and indoor environments.

Those positioning systems are based on different location methods [7]:

- The basic location method is Cell Identification (Cell-ID). It is based on the fact that mobile networks can identify the approximate position of a mobile handset by determining which cell beacons the mobile device is using at a given time.
- Specific antennas arrays and location receivers in Base Transceiver Stations (BTS) determine the angle of arrival of the signal from the mobile device. The intersection of apparent arrival directions determines the mobile device location. This method needs at least two BTS but three or more BTS stations are generally used to increase the accuracy of the system.
- The Mobile device signal is received by three or more BTS which measures the Time of Arrival. Trilateration computation determines the mobile device location.

This technology is supported by all mobile handsets but the location accuracy highly depends on the environment. It is much higher in urban areas than in rural areas. The same methods (Triangulation or IP Address Identification) are used for location using WLAN (*Wireless Local Area Network*), Bluetooth networks. These technologies are available on standards PDA. Triangulation of Infrared or Ultrasonic signals is also used for location especially for indoor location. Research by Pandya *et al.* [8] has evaluated location accuracy by Bluetooth or WLAN networks. Location by Bluetooth seems to give better results than location by WLAN network.

RFID (*Radio-Frequency Identification*) systems are composed of RFID microchip (RFID tags) mounted on or inside a support and a RFID reader which read and/or write RFID microchip information by a remote activation (10 meters) [9]. The data derived from accurate RFID tag locations can be used to determine the location of the RFID reader. This method is generally used for indoor location or navigation. A complete navigation system could consist of GPS for outdoor locations and RFID systems for indoor navigation [10].

All location systems (GSM, UMTS, WLAN Bluetooth, RFID), excluding GPS, are usable in urban areas or indoor places. However, those systems need a large number of terrestrial stations or antennas to obtain good location accuracy. Figure 1 below, sums up the advantages and limitations of systems.

For pedestrian applications, the use of inertial units with other positioning systems (GPS or GSM) improves the accuracy [11]. The basic idea of inertial unit is dead reckoning navigation. It determines successive positions by estimating the distance and the angle the person has moved since the previous computed position. The computation takes into account thus the characteristics of the person's gait. Inertial units are composed of embedded sensors such as accelerometers which measure acceleration rate, gyroscopes to measure angular speed and magnetic compasses to indicate the direction. A drawback is that computed positions are likely with time to deviate from real positions (cumulative errors) since inertial units are based on relative positioning. An advantage is that it does not depend on terrestrial stations or antennas.

3.2 Information Access

The adaptation of visual information content and a judicious choice of devices, information processing software and human-machine interfaces are necessary to implement systems usable by blind people. Information Access tools concern handheld computerized devices and adapted software used to help blind people everywhere and in many situations.

Cellular phones and PDAs are standard, autonomous, non-specific, handheld and increasingly cheaper devices. PDAs are real and powerful computers. A standard PDA is composed of a microprocessor with a frequency over 600Mhz and extensible RAM of 128 MBytes. Cellular phones are less powerful than PDAs but are more widespread. Smartphones combine PDA and cellular phone functionalities. The microprocessor power and storage capacity enhancement and wireless transmission have facilitated applications integrations: GIS outdoor navigation, RFID readers, data processing systems (text, audio, image, signals). Moreover, most standard PDAs are equipped with a GPS receiver, WLAN or Bluetooth access, Multimedia tools (Input/output audio systems, camera…) and GSM or UMTS networks for smartphones.

Computers research has improved human-machine interfaces so that they may be used by people with visual disabilities. Speech recognition or synthesis and haptic interfaces can be implemented on handheld devices. A haptic interface is an interactive communication system which enables to the user to "perceive" the texture of 2D objects. The system is an interface which can be similar to a pen or a mouse [12].

Lastly, the knowledge of visual information (text/pictograms) can be essential to identify objects (posters, products, places) in many situations (at home, outside, at shopping)… A first approach consists in tagging objects with barcodes or RFID and storing information in a data basis (Bar code is a read only memory, while RFID tag contains erasable and repeatedly writable memories in it). A handheld device with barcode or RFID reader is then used to get information identifying the objects. The second approach is the visual information processing using pattern recognition methods. This approach presents the interest to be applied for a high number of applications (location, public trans-

Systems	**Advantages**	**Limitations**
GPS / DGPS	Accuracy (< 10 meters) Available in non urban area	No indoor Navigation Canyon walls Specific systems
GSM / UMTS …	Indoor /outdoor navigation Non specific systems (Cell-phone)	Low accuracy in non- urban area
Wireless / bluetooth	Indoor /outdoor navigation	Low accuracy in non- urban area
RFID	Indoor /outdoor navigation Environment information	RFID tags equipment Accuracy

Figure 1: Advantages and Limitations of Location Systems.

port information, text / pictograms reading…) without any equipments such as stations, RFID tags, etc.

4 Mobility of Visually Impaired People: Handheld Computerized Assistance

This section presents handheld computerized assistants to facilitate the mobility of visually impaired people.

4.1 Urban Guidance and Pedestrian Navigation

Many research projects have been proposed for people with visual impairments. Loomis *et al.* [13] and Brusnighan *et al.* [14] are considered to be the first research works on GPS navigation for blind people commenced in the nineteen-eighties. In Brusnighan's experiment, the GPS system located the blind person's position and calculated the distance and the time to go to a previously defined place. It was the first urban guidance system but the research was conducted during the early deployment of GPS. However, the poor positioning accuracy and technical limits of handheld devices were incompatible with assistance for visually impaired people. Makino *et al.* [15] used a mobile phone to transmit blind pedestrian GPS coordinates to an assistance server which returned the position vocally using speech synthesis. The cost, the weight and the computer power of the handheld device was thus highly reduced.

Urban guidance systems became more and more competitive with the technology's enhancement (geolocation, data processing, speech synthesis). A methodology was proposed by Gaunet and Briffault [16] to define specifications. The first commercial GPS-based system proposed by the Arkenstone Foundation [17] provides both information about the locations of nearby streets and points of interest and instructions for travelling to desired destinations.

MoBIC project (*Mobility of Blind and Elderly People Interacting with Computers*) [18] consists of two interelated components:

- *MoBIC Pre-Journey System* (MoPS) to assist blind users in planning journey by storing information such as local maps, public transport timetables, opening hours of facilities, notes on the traversability of routes, specific surfaces, user preferences and address.

- MoODS (*MoBIC Outdoor System*) to help the user to navigate. The system is composed of a GPS/DGPS location system, magnetic compass and GIS software. The blind user asks a question via a handheld keyboard: where am I? Public transport timetable? Answers are received aurally through speech synthesis.

The entire journey is memorized to improve the database. The interface works on a cellular phone but the size and the weight (6 kilograms, mostly due to the batteries) is a critical factor in the acceptability of the MoODS system [19]. The guidance system of Guillet et al.[20] considers the trip length and specfic impairments to propose an adapted path. The navigation integrates GPS, mobile phone and GIS.

In the Drishti project [21] [22], the researchers integrate several technologies to implement a navigation system. It consists of an outdoor navigation system by GPS/DGPS and an indoor navigation system by ultrasonic signals triangulation. The location information is processed and speech-synthesized by an assistance server using WLAN network. Moreover, Drishti is a dynamic system which adapts the trip according to environment situation (traffic congestion, route blockage) or according to a changed decision of the user (new destination). The device is composed of a very light wearable computer, headphones and microphone. Willis and Helal [23] proposed an outdoor/indoor navigation system on a PDA with a RFID reader. They estimate that the concept of setting up RFID Information tags is economically feasible in buildings, in college campuses and corporate parks. RFID guidance is also studied by Ceipidor et al. [24]. They installed an RFID reader on a white cane. Collected data are transmitted to a PDA by Bluetooth and are processed and speech-synthesized by an assistance server using WLAN network. Bellotti *et al.* [25] have experimented with the use of RFID tags at the Euroflora 2006 exhibition. The system is composed of a PDA with embedded speech synthesis software. The RFID tags enabled navigation in the exhibition hall and a description of each stand. The 120 blind testers were satisfied by the system's utility and usability. However, the system will need to be made more accurate by increasing the number of RFID tags. Kulyukin *et al.* [26] have developed a Robot-assisted indoor navigation system for visually impaired people. A robotic guide moves automatically using RFID tags. Experiments have been undertaken in two indoor environments. All participants reached their destinations without a problem. In their exit interviews, the participants especially liked the fact that they did not have to give up their white canes and guide dogs to use robotic guide. Human-robot interaction, especially speech synthesis system is still problematic. Other limits concern robot velocity, the non-detection of route blockages and the static environment after the RFID tags are deployed.

Some research integrates both relative positioning by dead reckoning systems and absolute positioning by GPS [27]. This combination enables the commercialisation of a specific and lightweight (400 grams) device for visually impaired people. The system is called PNM: *Pedestrian Navigation Module*.

Other commercial projects have resulted in autonomous navigation devices for blind people. Navworks (in France)[28] and Smarteyes (in Greece)[29] projects aim at developing computerized and handheld systems to vocally guide people with visual disabilities. The systems use both GPS and GSM modules. The intent of the "Free Mobility Assistance" project [30] is to install RFID tags to help blind people to be directed in the city using vocal and audio messages. The city of Kobe (Japan) have experimented with a system by installing 4000 RFID tags. The Sendero Group society [31] has implemented a specific wearable device for GPS location for blind people. The HumanWare society [32] has commercialised the Trekker using a standard PDA with GPS receiver. This product proposes a tactile interface for blind people.

4.2 Public Transport and Journeys

Public transport access is essential to improve blind people's autonomy. The purpose of research work is mainly to communicate public transport information in real time to blind people. The Rampe project [33] [34] aims at making available an interactive system to assist people with visual disabilities to obtain public transport information. The project considers only bus and street car stations or stops. The user carries a smart handheld device (PDA) which communicates by a wireless connection with fixed equipment in the bus or streetcar stations. The information is vocally communicated to the user and indicates the proximity of a station, the bus lines, the timetable and alterations to arrival and departure times (public works, bus stop changes). A complementary project could be Ubibus [35]. In this project three entities interact by WLAN or Bluetooth: bus, bus stop/station and PDA of the user. The application allows the user to request in advance the bus of his choice to stop and to be notified when the correct bus has arrived.

Underground navigation system for blind people is also proposed using Bluetooth technology. The Blueeyes system [36] is composed of fixed Bluetooth stations deployed in the underground area and mobile phones with Bluetooth receivers. The user is located in the underground by Bluetooth and a message is sent to indicate his/her position and possible directions. The method works step by step and indicates the path by real-time computing. However, all underground stations and connections must be equipped with Bluetooth bases to inform the blind user.

NOPPA [37] navigation and guidance system is designed to offer public transport passenger and route information for the visually impaired. The system provides an unbroken trip chain for a pedestrian using buses, commuter trains and trams in three neighbouring cities. The Noppa system is implemented in a standard mobile phone and presents the following characteristics: Speech interface (speech and recognition), journey planning, real time information on public transport, real time information on geographical environment and, GPS location for outdoor navigation and Bluetooth and WLAN location for indoor navigation. The limits are that map data may include outdated information or inaccuracies, positioning may be unavailable or inaccurate, or wireless data transmission is not always available.

4.3 Remote Assistance

The 3G mobile phone using UMTS technology allows video assistance. Research in Brunel University [38] consists in a navigation system with two distinctive units:

- A Mobile Navigation Unit (MNU) carried by blind user. This unit is composed of a camera, a GPS receiver and an adapted interface on a smartphone.
- A stationary Navigation Service Centre (NSC) at the site of a sighted person (the guide). The NSC is composed of workstations with GIS data basis and a monitor to display the real time video image and the user's location on a digital map; these are the input information used by the sighted person to provide the vocally guided service.

Hestnes *et al*. [39] [40] have proposed a service through which visually impaired persons can obtain information on what is present in their surroundings with the help of persons who can see and act as guides. They have undertaken a series of studies which examined whether a mobile videophone (an "eyephone") can be a real help for people who are blind or severely visually impaired. 10 blind or severely visually impaired users have tested the system in 5 situations (bank, shopping, at a bus stop, finding something lost on the ground, being lost). All the tasks were accomplished with success and the satisfaction rate was very high. The system presented some problems in reading documents and finding very small objects. Lighting conditions must be sufficient.

4.4 Communication Interfaces

Representing and perceiving the environment brings some significant indications to help visually impaired people to move in this environment. In this way, the development of specific interfaces contributes to improve this representation and perception.

The Äänijälki project [41] is a platform for visually impaired people to exchange information about museums and exhibitions. The intention is to motivate visually impaired people to visit museums by providing a tool to get information about museum spaces, access, opening hours. The service is composed of two main elements: a handheld device (PDA) with tactile screen to be used in museums or exhibitions and an Internet website to obtain information. The PDA is equipped with headphones to receive audio comments in museums and exhibitions.

The goal of Coroama and Röthenbacher's [42] project is to use alternative means to present continuously and vocally the environment to the visually impaired user. It gives thus some of the information which the user would otherwise miss. The prototype is composed of the following elements:

- A large number of environment objects which are RFID-tagged,
- A device interacting with tagged objects when the user moves into the object environment,
- A real-world tagged object which has a virtual representation containing its information.
- Communication interface by Bluetooth and WLAN

All these methods allow visually impaired people to increase their autonomy in navigation and trip information processing. Some assistance projects also involve visual information processing to access textual data, pictograms, signboards and street name information.

5 Visual Information Processing

In this section, two approaches are proposed: object identification using RFID or barcoded tags and object recognition by artificial vision.

5.1 RFID and Barcode Methods

The purpose of the Trinetra [43] is to develop a cost-effective solution to assist the blind and visually impaired with the task of grocery shopping. In the Trinetra-scenario, the blind shopper should not need to ask for assistance from a store clerk, and should be able to locate and browse products within the store on his/her own. Two solutions are proposed; the identification using barcodes on tagged individual products and RFID identification which holds more product information and is not yet prevalent in stores. The device is composed of a smart phone with Bluetooth and a text-to-speech module, a RFID reader, barcode reader and a remote assistance server with RFID database and barcodes database. In future developments, the authors would like to embed RFID tags into the environment to identify the correct aisle, rack and shelf in the grocery store. The use of artificial vision technologies (OCR systems) instead of barcodes or RFID is also investigated.

Tatsumi *et al.* [44] propose two solutions using PDA for textual information access:

- Information access via a notice board. A blind student uses a PDA equipped with a barcode scanner to read a bar code printed on the notice board. The bar code is sent to the server which automatically and vocally sends the notice board information back.
- Messaging systems between students and teacher using RFID tags on the teacher's office door. The blind student uses his/her PDA equipped with RFID scanner to read and/or write messages on RFID tags.

Coughlan *et al.* [45] propose an assistive technology system based on a camera cellular phone held by the blind user) to find and read specially designed signs in the environment. The signs are barcode locations on office or restroom doors. The use of distinctively coloured areas next to barcodes allows the rapid location of barcodes. A specific and robust algorithm has been implemented to read barcodes with poor resolution and in dim lighting. Preliminary tests have shown that blind users are able to locate barcodes using a standard cellular phone. The authors would like future developments to read barcodes at greater distances.

These solutions are attractive but the identification concerns only tagged objects with barcodes or RFID and the corresponding information must be regularly updated in the databases.

5.2 Computer Vision

The first application based on image processing methods is OCR (*Optical Character Recognition*). Kurzweil National Federation [46] presents a portable device to read textual documents anywhere. The device is composed of a PDA with a digital camera to scan any documents (restaurant menu, text, announcements), Text is decoded by embedded OCR software and audio converted by a text-to-speech software. Data are entirely processed by the PDA.

Dumitras *et al.* [47] present a handheld text recognition system to extract written information from a wide variety of sources. They use a smartphone (with an embedded camera) which sends the photograph of the object to an assistance server using a GPRS network. The server sends the extracted textual information back to the smartphone where it passes through a text-to-speech converter.

The iCare-reader [48] is also a portable reading device. It is composed of a digital camera mounted in a spectacle frame and connected wirelessly to a PDA. OCR software decodes the text and a speech synthesizer converts it into audio format. New challenges concern the interaction between the reader and the user. A specific interface would required to allow the reader device to train the user in pointing the camera at the reading material by head movements.

The portable device of Nakajima *et al.* [49] recognizes phrases on signboards and menus and translates them into other languages. A picture of a signboard or menu is taken by the camera of a PDA or cellular phone. It is then wirelessly sent to an assistance server for OCR decoding. The system resolves the difficulty of character sets such as Japanese and Chinese by using a language translation module.

Gaudissart et al. [50] [51] have developed a text recognition system on a PDA equipped with a camera for the imaging of textual documents (banknotes, CDs). Embedded OCR software translates text within image files into editable text files and information is transferred to a text-to-speech module for audio output. The system, called Sypole, gives encouraging results for text with uniform backgrounds but is not efficient enough for text detection in outdoor situations.

Image processing tools do not concern only communication and information accessibility using text recognition. Shape recognition algorithms could indeed be implemented on handheld devices to detect elements in the city such as pictograms, pedestrians' traffic lights, crosswalks where text data are totally lacking. In those situations, the mobility of visually impaired people could be facilitated by different types of electronic aids.

In order to help partially sighted people, Everinghan *et al.* [52] have proposed a technology combining the field of virtual reality with advanced artificial vision methods to create an enhanced image from an urban scene image. In this contribution, an eight-level grey scale image presenting objects of the scene classified in eight categories (road, sky, pavement, buildings, vehicle, vegetation, obstacles) is displayed to the low vision user on a head mounted screen. Methods have also been developed to help totally blind people. In this way, different methods have been proposed to detect crosswalks and stairs. Molton *et al.* [53] have developed thus a robotic system based on sonar and stereovision sensors for detection of obstacles whereas Se *et al.* [54] described an algorithm based on edge detection followed by a Hough transform. In this second contribution, the distinction between crosswalks and stairs is evolved by vanishing line methods. Those two papers do not discuss on the way to give information to the blind user.

The research of Snaith *et al.* [55] concerns a system using computer vision techniques to facilitate centre-path travel and to recognize doorways. The detection is based on recognition of characteristic patterns of near- vertical and near-horizontal lines for doorways and the determination of dominant vanishing lines make possible the detection of main direction along a path.

The identification of pedestrian traffic lights is also taken into account in the literature. Some research works have shown an interest in this topic by presenting traffic light recognition systems. The first one [56] is based on a two step algorithm: extraction of candidates for the traffic light regions by colour analysis and shape recognition by using affine invariant moments. The results are highly encouraging but the authors do not propose a portable and cheap system (such as a PDA) and they do not give any information for transfering the output to visually impaired people. The second one [57] deals with the analysis of the colour histograms without calculating any shape features. The decision depends only on the colour criteria, making possible misclassification due to the lights of parked cars or others similar colour sources. The use of single colour information seems insufficient to detect the correct silhouette. The colour information is highly dependant on the colour illumination and similar colour (red or green) could be present at the scene. The combination of colour information and shape information seems preferable.

The researchers of the THIM laboratory have presented a PDA-based tool to recognize pedestrian traffic lights. Their algorithms use both shape information (by structural methods [58] or Fourier descriptors [59]) and colour information with very encouraging results (70% of good classification for red traffic light and 80% for green traffic light). The researchers have shown the complexity of a problem (recognize pedestrian's traffic light) that could be appear fairly simple [60]. For instance, locating the object of interest is not an easy task.

6 Conclusion

The growing volume of research into handheld computerized applications for persons with visual impairments is really interesting and encouraging. However, all the projects propose a partial solution to the needs of blind people: navigation/location, remote assistance, visual information and public transport. There is not yet a universal handheld tool to assist people with visual impairments in all conceivable situations.

At long-term vision, it seems to the author that the potential of artificial vision allows to elaborate very interesting, robust useful applications on portable devices for blind people assistance. Artificial vision could bring reliable solutions for location/navigation, visual information access, etc.

References

[1] N.A. Bradley, M.D. Dunlop. Investigating context-aware clues to assist navigation for visually impaired people. Proceedings of Workshop on Building Bridges: Interdisciplinary Context-Sensitive Computing, University of Glasgow. 2002.

[2] S. Shoval, I. Ulrich, J. Borenstein. Computerized Obstacle Avoidance Systems for the Blind and Visually Impaired. En Intelligent Systems and Technologies in Rehabilitation Engineering. Editores: H.N.L. Teodprescu, L.C. Jain, CRC Press, pp. 414-448, 2000.

[3] E. Pissaloux, F. Maingreaud, R. Velasquez. *De la perception au mouvement : réflexions autour de la conception des aides électroniques aux déplacements de déficients visuels*, Signaux, 98, pp. 23-32, December 2003.

[4] C. Jacquet , Y. Bellik, Y. Bourda. Electronic Locomotion Aids for the Blind: Towards More Assistive Systems. Intelligent Paradigms for Assistive and Preventive Healthcare. N. Ichalkaranje, A. Ichalkaranje, L.C. Jain, editores. Springer-Verlag. pp. 133-163, April 2006.

[5] B. Hofmann-Wellenhof, H. Lichtenegger, J. Collins. GPS: Theory and Practice (Fifth Revised Edition). Springer Wien NewYork, 2001.

[6] J. Chao, Y. Chen, X.D. Wu Chen, Z. Li, N. Wong, M. Yu. An Experimental Investigation into the Performance of GPS-based Vehicle Positioning in Very Dense Urban. Areas. Journal of Geospatial Engineering 3, 1, pp. 59–66, 2001.

[7] G.M. Giaglis, V. Zeimpekis, G. Lekakos. A taxonomy of indoor and outdoor positioning techniques for mobile location services. ACM SIGECOM Exchanges, 3(4), pp. 19-27, 2003

[8] D. Pandya, R. Jain, E. Lupu. Indoor Location estimation using multiple wireless technologies. Proc. of the 14th IEEE international Symposium on Personal Indoor and Mobile Radio communication, pp. 2208-2212, 2003.

[9] T. Tsukiyama. Global navigation system with RFID tags. Proceedings of SPIE Volume: 4573 Mobile Robots XVI, pp. 256-270, 2002.

[10] M. Kourogi, N. Sakata, T. Okuma, T. Kurata. Indoor/Outdoor Pedestrian Navigation with an Embedded GPS/RFID/Self-contained Sensor System. Proceedings of the 16th International conference on Artificial Reality and Telexistence (ICAT 2006), pp. 1310-1321, 2006

[11] P.-Y. Gilliéron, Q. Ladetto, D. Buchel, I. Spassov, C. Hagin, M. Pasquier. *Navigation pédestre: le futur en marche*, Géomatique, 31,1, pp. 6-13, 2004.

[12] E. Lecolinet, G. Mouret. TactiBall, TactiPen, TactiTab. Actes 17e conf. francophone sur l'Interaction Homme-Machine (IHM'05). ACM Press. September 2005.

[13] J.M. Loomis, R. Golledge, R.L. Klatzky. GPS-based navigation systems for the visually impaired. En W. Barfield & T. Caudell, (Eds.), Fundamentals of wearable computers and augmented reality. NJ. Mahwah: Lawrence Erlbaum Associates, pp. 429-446, 2001.

[14] D.A. Brusnighan, M.G. Strauss, J.M. Floyd, B.C. Wheeler. Orientation aid implementing the Global Positioning System. In S. Buus (Ed.), Proceedings of the

fifteen ²th Annual Northeast Bioengineering Conference. Boston: IEEE, pp. 33-34, 1989.
[15] H. Makino, I. Ishii, M. Nakashizuka. Development of navigation system for the blind using GPS and mobile phone connection. En Proceedings of the 18th Annual Meeting of the IEEE EMBS, Amsterdam, The Netherlands, pp. 506-507, October-November, 1996.
[16] F. Gaunet, X. Briffault. *Méthodologie de spécification pour un système informatique de guidage verbal: le déplacement des déficients visuels en ville*. ÉPIQUE 2001, Actes des Journées d'étude en Psychologie ergonomique, Nantes, IRCCyN, France, pp. 133-143, Octubre 2001.
[17] J. Fruchterman. Arkenstone's orientation tools: AtlasSpeaks and Strider. Presentation at Conference on Orientation and Navigation Systems for Blind Persons, University of Hertfordshire, 1995.
[18] H. Petrie, V. Johnson, T. Strothotte, A. Raab, S. Fritz, R. Michel. MoBIC: Designing a travel aid for blind and elderly people, Journal of Navigation 49(1), pp. 45-52, 1996.
[19] T. Strothotte, S. Fritz, R. Michel, A. Raab, H. Petrie, V. Johnson, L. Reichert, A. Schalt. Development of dialogue systems for a mobility aid for blind people: initial design and usability testing. Proceedings of the second annual ACM conference on Assistive technologies, pp. 139-144, 1996.
[20] V. Guillet, B. Rumpler, J. Pinon. Providing Help for Visually Impaired People's Navigation in an Urban Environment Using GPS. Computer Helping People with Special Needs: 8th International Conference, ICCHP, Linz, Austria, pp. 429-436, July 2002.
[21] S. Helal, S. Moore, B. Ramachandran. Drishti: An Integrated Navigation System for Visually impaired and disabled. Proceedings of the 5th International Symposium on Wearable Computer, Zurich, Switzerland, pp. 149-157, October 2001.
[22] L. Ran, S. Helal, S. Moore. Drishti: An integrated Indoor/Outdoor Blind navigation system and Service. Proceedings of the 2nd IEEE Pervasive Computing and Communications Conference. Orlando USA, pp. 23-30, March 2004.
[23] S. Willis, S. Helal. RFID Information Grid for Blind Navigation and Wayfinding. Proceedings of IEEE International Symposium on Wearable Computers, pp. 34-37, 2005.
[24] U. Biader Ceipidor, C.M. Medaglia, F. Rizzo, A. Serbanati. RadioVirgilio/Sesamonet: an RFID-based Navigation system for visually impaired. Mobile guide 2006, Turin, Italy. <http://mobileguide06.di.unito.it/programma.html>, Last visit on January 29th 2007.
[25] F. Bellotti, R. Berta, A. De Gloria, M. Margarine. Guiding visually impaired people in the exhibition, Mobile guide 2006, Turin, Italy. <http://mobileguide06.di.unito.it/programma.html>, Last visit on January 29th 2007.
[26] V. Kulyukin, C. Gharpure, J. Nicholson, S. Pavithran. RFID in Robot-Assisted Indoor Navigation for the Visually Impaired. Proc. Of International conference on Intelligent robot and systems, 2, pp. 1979-1984, 2004.
[27] Q. Ladetto, B. Merminod. 2002 In Step with INS: Navigation for the Blind, Tracking Emergency Crews. GPSWorld, pp. 30-38, October 2002.
[28] F. Gaunet, X. Briffault. *Aide à la mobilité des piétons aveugles : vers un système informatique de guidage verbal portatif localisé*, Proc. Handicap 2002, Paris, 2002.
[29] Altivis. SmartEyes : guidage par satellite au service des aveugles <http://www.altivis.fr/SmartEyes-guidage-par-satellite-au,1283.html>. Last visit on January 29th 2007.
[30]ITS. "Free Mobility Assistance" Project. <http://www.its.go.jp/ITS/2006/006.html>. Last visit on January 31th 2007.
[31] Sendero Group. <http://www.senderogroup.com> (Last visit on January 29th 2007).
[32] Trekker. <http://www.humanware.ca/web/en/p_DA_Trekker.asp> (Last visit on January 29th 2007).
[33] J. El Sayah, G. Baudoin, O. Venard, B. El Hassan. Simulation using OMNet++ of the RAMPE system - an Interactive Auditive Machine helping blinds in Public Transports, Proc. Conference IEEE EUROCON 2005, Belgrado, Serbia y Montenegro, November 2005.
[34] G. Baudoin, O. Venard, G. Uzan, L. Rousseau, Y. Benabou, A. Paumier, J. Cesbron. "The RAMPE Project : Interactive, Auditive Information System for the Mobility of Blind People in Public Transports", ITST'2005 – IEEE, The 5th International Conference on ITS Telecommunications, pp. 389-392, 27-29 July, Brest, France.
[35] M. Banatre, P. Couderc, J. Pauty, M. Becus, S. Brewster, M. Dunlop. International symposium on mobile human, 6, Glasgow, vol. 3160, pp. 310-314, 2004.
[36] BlueEyes. <http://www.blueeyes.fr/>. Last visit on January 29th 2007.
[37] A. Virtanen, S. Koskinen. NOPPA Navigation and guidance System for the Visually Impaired. <http://www.cemt.org/topics/handicaps/FIN-Noppa.pdf>.
[38] Z. Hunaiti, V. Garaj, W. Balachandran, F. Cecelja. An Assessment of 3G Link in a Navigation System for Visually Impaired Pedestrians. Proc. of the 15th IEEE International Conference on Electronics, Communications, and Computers (CONIELECOMP 2005), pp. 7-9, 2005.
[39] B. Hestnes, P. Brooks, S. Heiestad. Videotelephony for blind people – case studies with high quality prototype and 3G mobile systems. 20th International Symposium on Human Factors in Telecommunication, 2006
[40] B. Hestnes, P. Brooks, S. Heiestad, M. Tollefsen. "Eye-phone" – case study results from the application of videotelephony for blind people. Proc. 19th. International Symposium on human Factors in Telecommuni-

[41] M. Salgado, A. Kellokoski. Äänijälki: Opening Dialogues for Visually Impaired Inclusion in Museums. International Workshop. Re-Thinking Technology in Museums: Towards a New Understanding of People's Experience in Museums, Limerick, Ireland, 2005.
[42] V. Coroama. Experiences from the design of a ubiquitous computing system for the blind. Extended abstracts of Conference on Human Factors in Computing Systems, CHI '06, pp. 664-669, 2006.
[43] P. Narasimhan. Assistive Embedded Technologies, IEEE Computer, pp. 85-87, July 2005.
[44] H. Tatsumi, Y. Murai, M. Miyakawa, S. Tokumasu. Use of Bar code and RFID for the visually impaired in Educationnal Environment. 9th International Conference ICCHP, pp. 583-588, 2004.
[45] J. Coughlan, R. Manduchi, H. Shen. Cell Phone-based Wayfinding for the Visually Impaired, 1st International Workshop on Mobile Vision, Graz, Austria, 2006.
[46] Kurzweil – National Federation of the Blind. <http://www.knfbreader.com/>. Last visit on January 29th 2007.
[47]T. Dumitraþ, M. Lee, P. Quiñónez, A. Smailagic, D. Siewiorek, P. Narasimhan. Eye of the Beholder: Phone-Based Text-Recognition for the Visually-Impaired. Proc. of the 10th IEEE International Symposium on Wearable Computers. pp. 145-146, 2006.
[48] H. Nakajima et al. "Portable Translator Capable of Recognizing Characters on Signboard and Menu Captured by Built-in Camera", In ACL Interactive Poster and Demonstration Sessions, pp. 61-64, 2005.
[49] T. Hedgpeth, M. Rush, V. Iyer, J. Black, M. Donderler, S. Panchanathan. iCare-Reader - A Truly Portable Reading Device for the Blind. The 9th Annual Accessing Higher Ground: Accessible Media, Web and Technology Conference, University of Colorado, November 2006.
[50] V.Gaudissart, S.Ferreira, C.Thillou, B. Gosselin. Mobile reading assistant for blind people, Proc. 13th EUropean SIgnal Processing Conference, EUSIPCO, Antalya, Turkey, 2005.
[51] J.P. Peters, C. Thilllou, S. Ferreira. Embedded Reading Device for Blind People: a User-Centred Design. Proc. of Emerging Technologies and Applications for Imagery Pattern Recognition. (AIPR), Washington D.C., USA, 2004
[52] R. Everingham, R.T. Thomas, T. Troscianko. Head-mounted mobility aid for low vision using scene classification techniques. International Journal of Virtual Reality, vol. 3 (4), pp. 3-12, 1999.
[53] N. Molton, S. Se, S. Brady, D. Lee, P. Probert. Robotic Sensing for the partially sighted, Robotics and Autonomous systems, 26, pp. 185-201, 1999.
[54] S. Se, M. Brady. Road Feature detection and estimation, Machine Vision and Applications Journal, Vol. 14 (3), pp. 157-165, 2003.
[55] M. Snaith, D. Lee, P. Probert. A low-cost system using sparse vision for navigation in the urban environment, Image and Vision Computing 16 (4), 1998, pp. 225-233.
[56] T. Shioyama, H. Wu, N. Nakamura, S. Kitawaki. Measurement of the length of pedestrain crossings and detection of traffic lights from image data. Measurement Science and Technology 13(9), 2002, 1450-1457.
[57] J. Aranda, P.Mares. Visual system to help blind people to cross the street. Proceedings of the 9th International Conference ICCHP, Paris, 2004, pp. 454-461.
[58] D. Moreno Eddowes, J. Lopez Krahe. Pedestrian Traffic Light Recognition in a scene using a PDA. Proceedings of the 4th IASTED International Conference on Visualization, Imaging and Image Processing. Marbella, Spain, 2004, 578-583.
[59] P. Foucher, D. Moreno Eddowes, J. Lopez Krahe. Traffic light silhouettes recognition using Fourier descriptors. Proceedings of the 5th IASTED Conference on Visualization Imaging and Image Processing, Benidorm, Spain, pp. 186-190, 2005.
[60] P. Foucher, G. Uzan, J. Lopez Krahe. Mobile Interface to recognize pedestrian traffic lights: Needs and propositions. Human07: International Conference on Human Machine Interaction- IEEE, Timimoun, Algeria, March 2007.

Abbreviations and Acronyms

AGPS: Assisted Global Positioning System.
BTS: Base Tranceiver Station.
DGPS: Differential Geographical Positioning System.
OCR: Optical Character Recognition.
GPRS: General Packet Radio Service.
GPS: Geographical Position System.
GSM: General System for Mobile Communications.
MNU: Mobile Navigation Unit.
MoBIC: Mobility of Blind and Elderly People Interacting with Computers.
MoODS: MoBIC Outdoor System.
MoPS: MoBIC Pre-Journey System.
NOPPA: Nakovammaisten Opastusjarjestelman Pilotti Projekti [Navigation and Guidance System for the Visually Impaired].
NSC: Navigation Service Centre.
PDA: Personal Digital Assistant; a handheld electronic device providing database and communications facilities.
PICRI: Partnerships Institution-Citizens for Research and Innovation [France].
PNM: Pedestrian Navigation Module.
RFID: Radio Frequency Identification.
THIM: Laboratory, Paris 8 University (Technologies, Handicaps, Interfaces and Multimodalities).
UMTS: Universal Mobile Telecommunications System
WLAN: Wireless Local Area Network.

Access to Scientific Content by Visually Impaired People

Dominique Archambault, Bernhard Stöger Donal Fitzpatrick , and Klaus Miesenberger

The study of Mathematics and Sciences has always been difficult for visually impaired students. In this paper we will describe the research undertaken during the past 20 years to support scientific work for blind and partially sighted people. We will first describe the modalities that can be used to render mathematical contents, and describe speech and Braille solutions, together with the inadequacies of these solutions. Then we will present a number of research projects organised in 3 categories: conversion based on Braille, conversions based on speech and navigation, and communication tools. We will then propose our views on the future research that needs to be carried out now, focusing on support functions for understanding and editing ("doing Maths"), and on communication between sighted and visually impaired people.

Keywords: Accessibility, Mathematics, Mathematical Braille, Speech, Visually Impaired People.

1 Introduction

The study of Mathematics has always been particularly difficult for blind people and especially for pupils in early classes who have to learn its specific notation. This is also the case for students who have to deal with very complex mathematical content. Most mathematical concepts are better explained using drawings and notes which illustrate the main content. These include graphics such as curves or geometrical figures, graphical notes (strokes, underlines or surrounding circles highlighting some parts of the material links between terms as illustrated by Figure 1, or textual material related to a specific part of the content. Additionally the mathematical notation itself uses two dimensions in order to convey more rapidly the general structure of the formula, which makes it easier to understand its semantic. One "pictures" the basic mathematical content at a glance, which helps to read the details in a more efficient way, since the role of every part of the expression is already assimilated.

When the visual modalities are not available, it is another story, indeed the other communication channels that are available to convey Mathematical contents (audio and tactile) do not offer the same possibility of getting a rapid overview. That makes it much more difficult for blind people to learn mathematical concepts than for sighted people. We can observe that a large majority of blind pupils do not succeed in Maths studies. To date in the Republic of Ireland, no totally blind student has been in a position to complete the Leaving Certificate (pre-university examination) at the higher level, and further evidence [1] demonstrates this fact. Clearly we assume that there is no reason that mathematical semantics can not be understood for reasons

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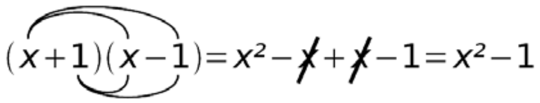

Figure 1: Extra Graphics Used to Illustrate a Calculation.

of blindness, rather the biggest barrier is the notation used for doing Mathematics. As this notation is essentially visual, it is quite difficult to transmit its contents using other modalities. Blind pupils often fail in Maths because of the way information is presented. A key feature which is present in the visual reading process is the role of the printed page. This medium affords the reader not only the facility to act as an external memory, but also facilitates a highly refined control over the flow of information. In the case of graphical content, tactile drawings can also be made. To some extent, this applies fairly to representation of curves and bidimensional geometrical figures. Even if great progress has been made in the technologies that allow the production of tactile drawings, there are limitations due to properties of tactile sense. It is also possible to render a curve using audio, by modelling a sound according to the shape of the curve, or using an haptic device like the Senseable Phantom [2].

In this paper we will focus on methods of access to mathematical formulas, which are the basis for all calculations and are used in all areas of mathematics and more generally in the sciences. Considering the two communications channels that have been cited above, formulas can be represented is a tactile form, usually based on Braille, or they can be spoken.

1.1 How People Read Mathematics

One of the key decisions which must be made when considering the manner in which mathematics, originally prepared using the visual modality, is depicted in either an audio or tactile one, is to firstly ascertain what information to present, followed by how to present this material. It is therefore important to understand the reading process, in order to fulfil the dual purpose of determining both **what** and **how** to present the relevant information to the user. In the subsequent paragraphs, the discussion is placed in terms of both auditory and Braille reading. and where there are discrepancies they will be highlighted.

A feature which is present in the visual reading process is the role of the printed page. This medium affords the reader not only the facility to act as an external memory, but also facilitates a highly refined control over the flow of information. In his Ph.D. thesis, Stevens states that Rayner [3] describes reading as: "... the ability to extract visual information from the page and comprehend the meaning of the text" [3]. Stevens [4] also tells us that reading can be divided into three main domains.

1. The input of information from a physical, external source, into the reader's memory via the visual system;

2. The recognition of words and their integration into higher level structures such as sentences;

3. The process of understanding what has been read.

It would appear that there exists a point at which the process of listening and reading converge. This would seem to indicate that, once the information has been absorbed by the reader, it is both syntactically and semantically decomposed in the same manner, though the processes of actually retaining the material are quite different depending on which means the reader uses to read. It would appear that many readers hear a voice inside their head whilst reading. This voice articulates what is being read, giving the reader both a phonological and sub-localised impression of the document.

Stevens [4] defines the *phonological code* as "the auditory image kept in working memory during reading". It can be said that the written text is converted to this phonological code, which contains all the features of natural speech, such as pitch, rhythm etc. The notion of *inner speech* is quite speculative, but Rayner states that "Some proponents of inner speech have argued that reading is little more than speech made visible" [3]. The above appears to suggest that the visual component of reading is converted to an audio version, seeming to suggest a point where the two converge. After this point, the comprehension of the information should be the same. It is clear that the only differences in the reading process are the mechanical means of obtaining the information.

One aspect in which listening and reading differ significantly is the role of paper as an external memory. The manner in which the eye can relate to this external memory is a very powerful tool to aid in the retention and comprehension of written information. It can rapidly scan over the printed words, and by virtue of the juxtaposition of characters or symbols on the printed page, semantically interpret those symbols to produce the underlying meaning. Once the information is lost from the short term memory, it can be easily refreshed by the rapid movements of the eye.

There are a number of steps involved in the visual reading of a document. A skilled reader will normally read at a rate of 250-300 words per minute. The eye does not actually start at the top of a page and continue in a linear fashion until the end of the material is reached; rather the reading process consists of several distinct movements. Stevens tells us that there are a number of tasks which the eye performs in order to gain informational input. The reading process can be broken down into a series of **sacades** (jumps) and **fixations**. He tells us that:

"The sacades move the point of fixation in accordance with how much information has been or can be apprehended.

$$\frac{x+1}{x-1} \qquad x+1\ /\ (x-1)$$

Figure 2: Linearisation of a Very Simple Fraction.

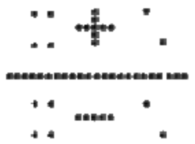

Figure 3: The *F*ormula (1) *R*endered *U*sing DotsPlus *T*echnology[1].

Forty nine percent of reading time is taken up with fixations. The rest of the time is taken up with the selection of which portion of the text to next fixate and the move to that location." [4].

In the Braille representation, while the *refreshable Braille Display* or printed page acts as an external memory, it is not possible for the finger to rapidly regress over material and assimilate it.

It is the absence of this external memory that is so different when the information is being read using audio. The facility of the paper as an external memory source is not present, and as the speech signal is transitory, the listener cannot easily recapitulate over already read material. Further, a vastly increased load is placed on the short term memory, thereby detracting from the ability to comprehend the material which could otherwise be easily understood.

An important distinction which must be made between reading and listening is the method by which the information is assimilated by the reader. When listening, the speech signal flows past the reader [4] [5]. The process can therefore be described as a serial exchange of information from the audio device to the passive listener. Visual reading, on the other hand involves rapid movements of the eye over a visual stimulus, and the acquisition of information through the visual cues which are inherently part of any document. Even the most rudimentarily written document consists of various forms of visual cue.

Firstly, the use of white space can determine the ends of both sentences, and other sectional units (such as paragraphs). This use of visual enhancement becomes more pronounced as the complexity of the material being presented increases. Finally, when a point is reached when mathematical (or other such technical information) is included, the use of the innate visual cues becomes more and more important to aid the visual reader in distinguishing the diverse types of content from the main body of the material. Consequently, material which is important can be easily recognised by virtue of the visual characteristics which have been imparted to it. The listener on the other hand is reliant on

$$x+\frac{1}{x-1}\ (3) \qquad x+\frac{1}{x}-1\ (4) \qquad \frac{x+1}{x}-1\ (5)$$

Figura 4: Problems of Ambiguity when Speaking a Formula.

the prosodic features which form a part of all spoken output, while the Braille reader relies on a highly structured linear presentation in order to apprehend the information.

1.2 Linearisation

In both tactile or speech cases, the non visual representation necessitates linearising the formula. Any formula can be linearised, in most cases this linearisation generates a much longer representation, which is more difficult to understand than the graphical one.

For instance the very simple fraction in Figure 2 is usually written with a visual layout (1) that allows a very quick understanding of its semantics. The reader understands at first glance that the formula is a fraction and that the numerator and the denominator are rather short. The same formula written in a linear way (2) needs a bit more thought to be understood. Additionally it is written using many more symbols (11 while the first one only necessitates 7).

1.3 Tactile Representations

From this linear representation it is possible to print a Braille version using specific Braille characters for mathematical symbols (for example the square root). As Braille is based on a six-dot pattern, it only allow 64 different symbols, which is not enough to represent the large variety of Maths symbols necessary. Consequently most symbols are represented using several Braille characters, which makes the formulas even longer. For instance the formula in Figure 3 requires up to 19 Braille characters, depending on the Braille code used (see below). Note that this example is quite simple but in the case of complex formulas the number of symbols increases dramatically.

During the twentieth century, various strategies have been developed to reduce the length of formulas, which led to the design of specific Braille notations for Maths. These specific notations are usually context sensitive, which allows large reductions in the length of the formulas. These notations will be described further in the section 2 below.

There exist some representations based on an eight-dot Braille pattern: the Stuttgart Maths Braille Notation[6], which is used locally in Germany, and the lambda-code, designed by the EU-sponsored project of the same name [7], that will be described below. The advantage of eight-dot Braille is that 256 different characters can be represented, and therefore the length of formulas can be reduced even further. Unfortunately eight-dot Braille cannot be read by a simple horizontal motion of the finger. Indeed the surface-area of sensitive skin on the end of the finger is just sufficient to apprehend the six-dot pattern (except maybe in exceptional cases). Then it is necessary for the reader to move the finger vertically on each character, which makes the reading process very slow, so the benefit of reducing the length of the formula is lost.

Another tactile representation which deserves mentioned here, it is the so-called "dots plus"[1] developed by View

[1] <http://www.viewplus.com/products/braille-math/dotsplus/>.

Plus[8]. Using a "graphical" embosser the formulas are represented using a mix of Braille characters and graphics, in a way which is close to the graphical layout. Braille characters are used to represent the basic elements, like digits and letters, while the mathematical symbols are represented graphically: fraction bar, square root, arithmetic operators.

Additionally this representation keeps the graphical layout of the formula (for instance a fraction is represented by a graphical line with the numerator above and the denominator below).

This representation is quite interesting to help pupils to understand the meaning of a formula, but unfortunately it is based on paper printouts and therefore can only be used to read, rather than to write or edit a formula.

1.4 Speech

Speaking a formula is the other option. The linear version of the formula is said by a human speaker or by a speech synthesiser. In this case there are some non trivial problems of ambiguity. For instance if we consider the formula 1, it will be naturally spoken like the following sentence: *"x plus 1 over x minus 1''*. However, there are 3 other ways in which this sentence can be understood: see formulas in Figure 4.

Another obstacle to comprehension of audio-based mathematical information is the increase of the mental work involved in the retention and comprehension of audio-based mathematical information. Indeed whereas the reader can use the printed page as the external memory and an aid to retention, the listener has only their memory of the spoken utterance, thus making the comprehension of syntactically rich data extremely difficult.

Much of the investigation into the intelligibility of synthetic speech has been carried out using lists of single words, separated by pauses [9]. It was demonstrated that when the length of the pause was reduced, the retention was degraded far below that of natural speech. Waterworth conjectures that the reason for this is that listeners are exhibiting a recency or primacy effect [9]. It is inferred that the listener's working memory is concerned with either analysing and interpreting the acoustic input, or rehearsing material which is already present.

Coupled with this, Pisoni [10] has shown that the comprehension of synthetic speech depends on the quality of the system, and varies over a wide range; from 95.5% in the case of natural speech, to 75% when poor quality synthetic speech was in use. It can be further inferred that the intelligibility of spoken output is determined by:

- Whether the spoken output is synthetic or natural.
- The quality of synthetic speech.
- The level of prosody contained in the spoken utterance.

The prosodic component of speech [11] is that set of features which lasts longer than a single speech sound. The term *prosody* can be traced back to ancient Greek where it was used to "refer to features of speech which were not indicated in orthography, specifically to the tone or melodic accent which characterised full words in ancient Greek'' [12]. The term *prosody* remained almost forgotten until the 1940s, when it was revived as an approach to the study of linguistic analysis.

Another major factor in the understanding of synthetic speech is the *fatigue effect* which is primarily brought about by the monotonous quality of synthetic speech. It has been found that the introduction of prosodic cues into spoken output has increased intelligibility significantly. One possible reason for this is the relieving effect that the inclusion of prosodic features, such as alterations in the pitch range, and changes in the rate introduce a rhythm more akin to natural speech, hence relieving the tedium of the monotonous voice.

This fact has major implications for the presentation of syntactically complex material such as mathematical equations. Three sets of rules are known to exist for the production of spoken mathematics. The first is provided by the *Confederation of Taped Information Suppliers* (COTIS), the second is a set of guidelines written by Larry Chang [13], and the third is devised by Abraham Nemeth [14]. These rules attempt to alleviate the problem of syntactically rich material through the addition of lexical cues, adding to the mental workload of the listener.

Also, both these sets of guidelines are aimed at the human reader. Consequently, they are flexible enough to permit the semantic interpretation of the material, or to read the various symbols as they occur. In addition, the fact that both sets of rules are intended for human use assumes that the human reader can employ all features of natural speech when speaking the material. Such semantic interpretation is not available to any automated system; necessitating the development of a tighter set of rules to unambiguously present the material.

1.5 Computer Tools

During the past 3 decades, considerable progress has been made in the field of access to information for the group of blind and visually impaired people. Thanks to modern information technology in the mainstream and to very specialised adaptive and assistive technologies, blind and visually impaired people are now able to deal independently and efficiently with almost every piece of information that is composed of pure text.

Despite current strong trends towards graphical presentation, text still covers the majority of relevant contents for private and professional life, such that information access for this target group is currently accomplished to a very large extent.

On the other hand, blind and visually impaired people are still excluded from an efficient usage and handling of graphical content. Since Mathematics is presented in a highly graphical way most of the time, this exclusion implies considerable restrictions in access to Mathematics.

The problems faced by the target group with respect to Mathematics fall into four basic categories [15]:

1. Access to mathematical literature (books, teaching materials, papers etc.).

2. Preparation of mathematical information (presenting school exercises, writing papers etc.).

3. Navigation in mathematical expressions and communication between blind and sighted people.

4. Doing Mathematics (carrying out calculations and computations at all levels, doing formal manipulation, solving exercises).

We will present in Section 3 various published works which address the first two problems at least in a satisfactory manner (to some extent). In Section 7 we will focus on a few approaches that are now addressing the third one. Unfortunately until now almost nothing has been achieved to support the target group in solving tasks relating to the last category [16] [17] [18].

1.6 iGroupUMA

To address these challenges, 6 organisations having expertise in the field of Mathematics for the Blind have decided to join their efforts, creating the *International Group for Universal Math Accessibility* (iGroupUMA). They have been since joined by a seventh organisation.

The iGroupUMA members are:

- University of Texas at Dallas, United States.
- Dublin City University, Ireland.
- University of South Florida at Lakeland, United States.
- Johannes Kepler University of Linz, Austria.
- New Mexico State University, United States.
- University Pierre et Marie Curie in Paris, France.
- University of Kyushu, Japan.

2 Braille Mathematical Notations (BMNs)

2.1 General idea for BMNs

Braille is a linear writing system and consequently, it is necessary to linearise formulas to represent them in Braille. We have seen in Section 4 that the first "natural" way of writing formulas is to translate them to a non specific linear form, and then to use specific Braille characters for mathematical symbols, however this method makes formulas very long and quite difficult to handle for blind students.

In order to reduce the length of these formulas as far as possible specific Braille notations for Mathematics, and more widely for Scientific content, have been developed during the second half of the twentieth century. These very high level notations have been designed in order to improve the readability for the blind, mainly by significantly reducing the number of symbols necessary to represent a formula. To achieve this brevity, they have been based on context sensitive grammars which allow the use of the same symbol strings with different meaning depending on the context.

In counterpart these notations are quite difficult to learn (and to teach). The reason is that blind pupils have to deal with 2 learning difficulties at the same time: the Mathematical content itself and the Math code which is at least as difficult as the content. Currently only very proficient Braille users are able to do it, while average sighted pupils succeed much easier.

To further complicate things, these Braille Mathematical notations have been developed in different areas, according to the linguistic and cultural history of these countries. Therefore, while the mainstream (visual) representation of formulas is identical in every language, the same is not true for Braille notations. Indeed each Braille mathematical notation is widely used in its zone of linguistic influence, while it is completely unknown in other areas. In other words, a Braille formula written using the British notation is not understandable by a German speaking reader. This problem is quite important since the number of available Braille documents is very small compared to the number of ordinary Maths books.

The main Braille Mathematical notations are the following:

- In France, the Braille Mathematical code was first adapted to Mathematics in 1922 by Louis Antoine. This code was revised a first time in 1971. It was then deeply revised in 2001[19], in the goal of improving the collaboration between sighted and blind and facilitating automatic transcription. Nevertheless a lot of Braille readers still use the version devised in 1971.
- Marburg is used in German speaking countries. It was designed in 1955 in the Marburg school for the Blind in Germany by Helmut Epheser, Karl Britz and Friedrich Mittelsten Scheid. A heavily reworked and revised edition was published in 1986 [20].
- The Nemeth Code for Braille Mathematics was published and accepted as the standard code for representing math and science expressions in Braille in 1952. It was designed in 1946 by Abraham Nemeth so that he could complete his PhD in mathematics. The 1972 revision [21] is the current official code in use in the US. Note that Nemeth was adopted officially in a number of Southeast Asian countries (like India, Thailand, Malaysia, Indonesia, Cambodia, Vietnam).
- The British notation [22] is used in United Kingdom and in Ireland. It was first designed in 1970, and a deeply revised version was published in 1987. This was slightly revised in 2005.
- The current Japanese Mathematical Braille notation was published in 2001 by the Japan Braille Committee. It is an important revision of the 1981 formal specification of Japan Mathematical Notation, itself based on the notation published in 1956 by Japan Braille Research Group ("Nihon Tenji Kenkyukai'').
- Italy, Spain and many other countries have developed their own Mathematical notations.

Additionally some countries where no specific notations had been designed decided to officially adopt one of these notations. For instance Greece is using the Nemeth notation.

Finally a set of countries does not use such specific notations, like the European Nordic countries, but they use simple linearisation of formulas, with a set of specific symbols for Mathematical symbols that do not exist in the ordinary alphabet.

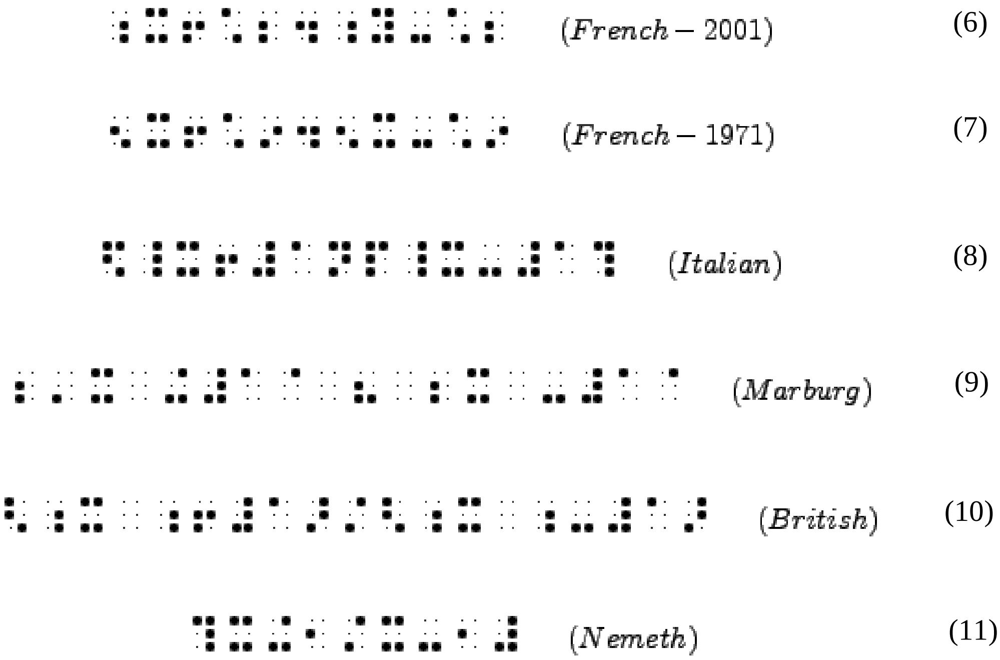

Figure 5: Transcription of Formula (1) in several Braille Mathematical Notations.

2.2 Main Strategies

Let us consider the transcription of formula (1) in Figure 2 in several Braille Mathematical notations (see Figure 5).

The number of available Braille symbols is quite reduced: 6 dots which can be combined in a maximum of 64 different patterns. Therefore it is necessary to use multiple Braille characters to code most Mathematical symbols. The various Braille notations implement different strategies for dealing with that problem. In Italian, the digits and the letters are always written using 2 symbols, the first indicating whether it is a digit or a letter and in the latter case which kind of letter (in the formula (8) for instance, "1" is

the first symbol standing for digit, while "x" is

where the first symbol means it is a Roman letter). British uses the same rule, but users will omit the prefix in the case of a symbol which cannot be a number (numbers are represented by the 10 first letters), like 'x' here

().

In Marburg the prefix for Latin letters is used only the first time, like a switch, indicating that any other instance of 'x' in the formula is of the same type (lower case Roman for instance here). Digits are always preceded by the

symbol. Finally in French the most frequent case is always assumed (lower case Roman), and there is a prefix before each other (upper case, Greek, etc.). There is also a special way to represent digits adding the dot '6' to the corresponding letter traditionally used: instead of

the single symbol

is used (this is called the 'Antoine' notation for digits). This make simple formulas shorter. Nemeth differentiates also the digits from letters by using different Braille patterns. Here the numbers that are written in the lower part of the Braille cell: 1 is represented by

 .

Let us now consider the fraction itself. Block markers identify the numerator and the denominator. In French, Marburg and British notations the blocks are always the same; making it necessary to reach the fraction symbol to determine that this is in fact a fraction. The fraction structure itself uses 5 symbols, 2 pairs of block markers and a fraction mark (for example in French:

).

On the contrary in Italian the numerator and the denominator markers are not the same; there is no fraction symbol and the fraction structure uses only 4 symbols

(),

and additionally the reader knows he/she is reading a fraction immediately from the first symbol. In the same kind of idea, Nemeth uses 3 Braille characters: the beginning of fraction, the fraction bar and the end of fraction

().

In order to reduce the length of simple numerical fractions, in Marburg and British notations, the denominator is written with lower numbers, that is, numbers that are written in the lower part of the Braille cell. For instance `1/4` will be

.

3 Conversion to/from Mathematical Braille

In the last twenty years, various projects have been developed in the field of Mathematical Braille notations, mainly with the aim of facilitating the written communication between sighted people and Braille readers in the field of Mathematics. We will first focus on converters that allow conversions to be performed between mainstream mathematical formats like LATEX and MathML and Braille notations.

These converters are used for different purposes. One is to facilitate the production of scientific Braille documents. Indeed it is much easier to produce a Mathematics document in LATEX or to use a word processor that supports MathML than to write a document in Mathematical Braille. Additionally a lot of resources are available in both these formats. In the reverse conversion (from Braille notations to mainstream formats) they allow sighted teachers or peers to access to formulas written by blind students.

3.1 Labradoor

Labradoor (*LAtex to BRAille DOOR*) converts a full LATEX document including Mathematical formulas into Marburg Braille or into HRTEX(see below). In addition, it offers a rich variety of formatting capabilities, enabling the production of Braille hard copies out of formatted LATEX documents [23]. As for conversion, one may choose between two options: The mathematical contents of a LATEX document may be converted either to Marburg Braille Notation, or to *Human Readable TeX* (HRTEX). The latter is a code developed at the University of Linz, with the intention to supply teaching materials in a way more easily readable than TEX or LATEX notation.

HRTEX is derived from TEX, although not compatible with it. These are some of the most important differences:

- Many symbols are abbreviated. For example, the symbols for Greek letters are composed of the first two characters, e.g., instead of `\alpha` we just write `\al`, instead of `\beta` we write `\be`, etc.
- The names of standard functions are written like variables, but in upper case letters, e.g., we write SIN instead of `\sin`, `LOG` instead of `\log`, etc.
- Alternative notation for fractions: The fraction bar is represented by two slashes `-//-`, and the whole fraction is written as a group. For instance, instead of `\frac{a+b}{c+d}` we write `{a+b // c+d}`.

As for formatting, Labradoor supports two output modes, one for Braille hard copies, and one for electronic text. In Hard Copy mode, elaborate text formatting algorithms suitable to represent paragraphs, lists, tables etc. in an attractive Braille layout are available. The table formatter deserves special mention, because it is able to represent tables in a variety of ways. Apart from the attempt to render a table in Braille according to its natural layout, tables may be dissolved according to their rows or columns. In Electronic Text mode these sophisticated formatting tools are disabled.

3.2 MathML to Braille Converters

Various converters from MathML to Braille have recently been developed. They allow transcribers to design Mathematical content using mainstream Maths editors.

Bramanet [24] converts formulas from MathML to French Braille. It is an application based on the XSLT technology. It allows various settings including the possibility to edit the output Braille table in order to fit with any hardware. It comes with a script which automatically makes a conversion from a document containing Maths formulas to a document ready to be embossed in Braille.

math2braille [25] is a "self-contained Module'' which takes in a MathML file and outputs a Braille representation of the same Maths. It is based on protocols and procedures that have been developed in a previous project about access to music. It produces Braille code in use in the Netherlands.

Stanley and Karshmer [26] propose a translator from MathML to Nemeth Braille Code. The translation is performed in 2 phases. First the MathML elements are translated to Nemeth codes.

Then syntactic rules that are inherent to Nemeth code are applied, such as the use of the numeric indicator, additional spaces, and some contractions. These rules were fashioned by Dr Nemeth to direct the conversion of Mathematics into the Braille code.

3.3 Insight

Based on the MAVIS project [27] which was the first solution to back-translation from Nemeth Braille code to LATEX, the Insight project [28] proposes a complete system to translate Maths documents with mixed Grade II Braille text and Nemeth code to LATEX. The back-translator is based on language semantics and logic programming.

The system processes an image of a Braille sheet (for instance a scanned page) and recognises the Braille dots to produce an ASCII Braille file. Text and Nemeth code are automatically identified and separated to be separately translated. Finally a single LATEX document is produced to be read by a sighted individual.

3.4 MMBT

MMBT (*Multi-Language Mathematical Braille Translator*) [29] was an open-source project allowing transcriptions from and to LATEX, MathML, French (revisions 1971 and 2001), British and Italian Braille notations. MMBT has been developed in Java to be used within the Vickie user interface (see the Vickie project below). In order to permit transcription from and to any of the supported formats, MMBT was based on a specific central language. It was discontinued and replaced by UMCL which uses the standard MathML as central language.

3.5 Universal Maths Conversion Library (UMCL)

One problem that transcribers have to deal with is the fact that most conversion tools are attached to one specific Braille code. For instance a French transcriber who looks for a tool to convert LATEX documents to Braille will find Labradoor, but this will be useless since it produces only Marburg.

One of the goals of the iGroupUMA has been to produce a programming library encapsulating various converters for various Braille codes in a single library usable through a simple and unique API. This library will also be useful for transcription tools (from mainstream notations to Braille and vice versa) as well as for software that needs real-time conversions (like formula browsers or editors). It will also make it possible to convert a document from one Braille national notation to another, increasing de facto the number of documents available for students and allowing blind mathematicians from various countries to exchange documents.

The UMCL (*Universal Maths Conversion Library*) [30] is an open-source portable library which allows such conversions. It was developed in standard "C" and has wrappers to different programming languages.

To make this possible without increasing the complexity, it was necessary to adopt an architecture based on a central representation of the formula, and to develop parsers to generate this central representation from the different input formats, and output generators for each output format [15] [31] [32].

The iGroupUMA has decided to use MathML as the central language. The architecture of UMCL is quite simple. It includes a main module and as many input and output modules as Maths codes are available. Input and output modules are independent and can be installed later on. The main module detects the available input and output modules and calls the modules necessary to perform the conversions according to requests. In other words it is possible to add input or output modules to any application using UMCL, at any time when a module becomes available.

Most output modules (MathML to Braille) are developed as XSLT stylesheets. Note that this is not mandatory, since input or output modules can be developed in any language. Interfaces for input and for output modules have been published.

In order to simplify the development of output modules, and to speed-up the processing time, we have developed a subset of MathML, that we call Canonical MathML [33]. Canonical MathML is a tentative attempt to unify MathML structures in a deterministic way in order to simplify transcription into Braille. All Mathematical structures that are necessary to perform a correct transcription into Mathematical Braille are recognised and rewritten in a unique way. Additionally Canonical MathML is valid MathML so it can be used with common tools which handle MathML. An input module for MathML allows the conversion from any MathML document to Canonical MathML. Currently output modules have been developed for the French notations (revisions 1971 and 2001) and Italian. Beta versions of Marburg and British code are also already available.

4 About source documents

Whatever the quality of the converter, it has to be mentioned here that converters can only transform what they are given! This seems obvious but one main problem encountered by transcribers is the poor quality of sources. Indeed, most documents come with formulas split in parts. For instance, for some reason there is often a character in between that is not included in the Mathematical material, because it looks nicer that way. This is also the case with LATEX input and with documents designed with word processors including Equation objects.

Additionally documents should be properly structured. Arrabito [34] states that without a degree of semantic markup, the production of a TEX based Braille translator, and indeed a universal Braille translator, is impossible. He points out that using the TEX primitives, authors can control the visual modality of their document, with no regard for the overall structure of their material. They could, for example, define various characters or symbols in terms of line segments, or use environments to achieve display styles for which they were not intended. Fitzpatrick [11] confirms this conjecture. Using the TEX language, some authors often use the "display’’ environment to display textual material, as opposed to the mathematical content for which it was designed.

In this respect LATEX is much better than TEX since it is based on semantic mark-up. When using a word processor, it is important to use styles to define the structure, since these styles can be processed.

5 Infty

Another project deserves to be highlighted here. Infty [35] is a large project aimed at giving access to printed mathematical content. It is base on a core module (InftyReader) which is an OCR specialising in Mathematical documents [36]. It is able to extract mathematical formulas from a scanned document and to recognise the mathematical structure and the symbols. It produces a topological representation of the formulas in an XML format. Then this representation can be converted into various formats: MathML, LATEX, HTML, HRTEX, KAMS, and into Unified Braille Code (English) and Japanese Braille code.

Some additional tools have been developed by the same group, in order to extend the possibility of the system. InftyEditor allows the output of InftyReader to be edited. It proposes also a handwriting dialog in which users can write formulas by hand, to be recognised automatically. ChattyInfty [37] is adding speech output to the system. It allows visually impaired users to access expressions with speech output, and to also author and edit them.

6 Conversion to Audio

6.1 ASTeR

One of the most important attempts to produce accessible technical documents to date is the ASTER system [5]. ASTER (Audio System for Technical Reading) aims to produce accurate renderings of documents marked up in the TEX family of languages. ASTeR uses both spoken and non-speech audio to assist in this process. The tool used by the ASTER system to produce the audio output, is a language devised by the author known as *Audio Formatting Language*, or AFL. This language, an extension to LISP can be described as "... the audio analogue of visual formatting languages such as Postscript" [5]. The aim of this language is to provide mechanisms to control the multiple aspects of the audio presentation, such as speech-based, and non-speech sounds. The output produced by the audio-formatter in ASTER represents the various components of the audio presentation using *audio space*, which is derived by taking the sum, or cross product of the various individual dimensions of the audio space. Examples of these dimensions would be the spoken utterance, and the earcons[2] which enhance the spoken output. The output from the *audio formatter* is altered by adjusting the dimensions (parameters which may be changed) of each individual aspect of the audio space. Such dimensions would include the pitch and rate of the voice, the means by which these characteristics change to reflect alterations in the visual appearance of the text, etc.

Raman has observed that there is little in the way of similarity between the evolution of a written mathematical notation, and the audio counterpart. He points out: "Any notational system is a combination of conventions and intuitive use of the various dimensions that are provided by the perceptual modality and the means available to produce appropriate output for that modality.".

Raman [5] also points out that the traditional mathematics notation uses a set of primitive layout cues to achieve highly complex and often nested structures. The main aim of ASTeR's audio representation of mathematics is to produce a non-visual counterpart to the highly complex visual writing of mathematics. The system used in this particular software approach is to offer the listener the option to obtain highly descriptive renderings of the mathematics, or conversely purely notational. The former can be used when new material is being perused, while the latter can be utilised when familiar content is encountered.

[2] audio equivalents of icons.

6.2 The Maths Project

MathTalk [4] is another example of a system designed to render algebra more accessible to blind students. Unlike the ASTeR system described in the previous section, this system is aimed at students who are still at school, and is particularly aimed at those between the ages of 16 and 18. Accordingly the form of presentation, and its interface, are deliberately simpler and more intuitive to use. The design principles on which this work are based attempt to render the algebraic formulae in a non-interpretive fashion. This contrasts totally with the approach taken in ASTeR, where the mathematical content was rendered to make it more intelligible. The MathTalk program uses a vastly different prosodic model to convey both the content and structure of algebraic formulae. Stevens uses the following list to summarise the general rules implemented in MathTalk for the provision of lexical cues.

- For Latin letters, MathTalk only prefixes uppercase with a tag.
- For sub-expressions, MathTalk uses only the tag "quantity".
- MathTalk speaks simple fractions (those with a single term in both numerator and denominator) with only the word "over" between the two terms.
- Complex fractions (those with more than one term in either numerator or denominator) are bounded with lexical cues.
- Roots are enclosed with the lexical tags "the root" and "end root".
- Simple roots are spoken without an end tag.
- Initially MathTalk used the cue "to the" to indicate exponents. Later this was replaced by "super" (shortened from "superscript") to comply with minimal interpretation.
- The word "all" can be used with the opening superscript cue, when the superscript governs a complex object [4].

6.3 The TechRead System

The TechRead system [38] [39] departed from the premises described in the preceding systems. This approach aimed to produce a rendering of mathematics without using non-speech audio; rather relying on the prosodic features found in synthetic speech to convey the material. The core idea involved the use of alterations in the pitch, speaking rate and amplitude of the voice to convey the content, and the introduction of strategically placed pauses to convey the structure.

The paradigm on which the spoken mathematical presentation is based [40], is that of converting a sequence of juxtaposed symbols, delimited by both white space and other visual cues (such as parentheses) into a serially transmitted linguistic approximation. In order to achieve this, a parallel was drawn between the structure found in mathematical expressions and the inherent composition of English sentences [11].

The two methods used to imply the grouping of terms into sub-expressions, (and by extension of sub-expressions into the whole formulae) is to insert pausing, and alter the speaking rate at strategic points within the presentation. This is not an arbitrary process but is based on both the mathematical components preceding and following the point at which the pause is needed. For example, the expression

$$a + b + c$$

a simple, linear concatenation of three quantities, separated by two relational operators, irrespective of whether the material is being read visually or auditorily. However, the expression

$$\frac{a}{b} + c$$

or non-linear in the print medium, but linear in the audio domain.

Accordingly, something must be introduced to indicate to the listener that the fractional component of the expression merely encompasses the first two elements, and that the final one is not contained therein. The method whereby this is achieved, is to speak the expression as follows: "a over b, plus c"'. Using this method, it can be clearly seen that the distinction between the fractional component of the expression and the remaining relational operator and quantity is evidenced. If one also adds a slight quickening of the speaking rate of the utterance of the fraction, then the distinction becomes even more apparent to the listener.

The fundamental core of the prosodic model used in TechRead is that of relative rather than absolute change. The alterations in the pitch and speaking rate, and the duration of the pauses are all calculated in terms of a starting point rather than as fixed quantities. This facilitates use of the system by both experienced and novice users, and also enables a high degree of flexibility in the model used.

6.4 MathPlayer

MathPlayer is a plug-in for MS Internet Explorer[3] [41]. MathPlayer works with screen readers using MS Active Accessibility interface (MSAA). It actually sends to the screen reader a string containing the relevant sentence to read with a speech synthesiser. A MathZoom feature allows expressions to be magnified. Built-in speech rules try to minimise the number of words used to speak the math while producing an unambiguous rendering of the math.

MathPlayer ability to use prosody is severely limited by MSAA, which only allows a string to be sent to the screen reader. Nevertheless MathPlayer provides an interface for screen readers to get round this problem.

7 Navigation and Communication Tools

7.1 The Vickie Project

The Vickie Project[4] [42] aims at facilitating the inclusion of visually impaired pupils and students in mainstream education.

A unified user interface has been developed to enable visually impaired pupils and students to access documents using specific devices, while a synchronised graphical display supplies sighted teachers with a view of the same document. This interface is an application built on the framework of Mozilla[5]. The interface actually presents 3 views of the same document:

- A graphical view of the document, including images and mathematical formulas.
- This view is called the teacher's view.
- An adapted view to partially sighted users, with adjustable print and colours.
- A Braille view. The libbraille library [43] is used to write directly on Braille devices.

The mathematical formulas are stored in documents in the MathML standard, and then can be displayed easily in a graphical way thanks to Mozilla's MathML rendering engine. This rendering engine permits the setup of the size of print and the colours for the adapted view.

The formula is automatically converted into Braille in real-time thanks to the MMBT converter [29] (see above). This software will also convert formulas written by the pupil in Braille to MathML in order for it to be displayed for the teacher.

In the Vickie project all documents are stored on a server [44] using the dtbook DTD format[6]. The mathematical formulas are included in the dtbook documents in MathML, thanks to the module mechanism of the dtbook DTD. Then the MMBT is also used to convert documents from a specific Braille notation that is used in France for printing (BrailleStar). Numerous documents are stored in that format and can then be imported into the Vickie server.

7.2 Math Genie

The Math Genie [45] is a formula browser that facilitates understanding of formulas using voice output. It has recently been augmented to provide Braille output on refreshable Braille displays. It has been designed to convey the structure of the mathematical expression as well as its contents. It can be used by a blind student together with a sighted teacher who does not need to have any specific knowledge in Braille. Indeed the teaching material can be prepared for both sighted and blind students using any Math editor able to produce MathML. The graphical rendering is synchronised to the audio which makes communication easier with the teacher. It is based on SVG (Scalable Vector Graphics), which allow the Math Genie to support magnification, in order to give support to partially sighted individuals, and colour-contrasted highlighting, in order to support individuals with dyslexia. It should be remarked that this project is based on research in cognitive psychology, in

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[3] MathPlayer is a free download from <http://www. dessci.com>.
[4] The Vickie Project is funded by the European Commission, on the IST (Information Society Technologies) Programme 2001 (FP5/IST/Systems and Services for the Citizen/Persons with special needs), under the reference IST-2001-32678.
[5] The Mozilla project: <http://www.mozilla.org>.
[6] The dtbook Document Type Definition (DTD) is part of the NISO Z39.86-2002 standard, also known as DAISY 3.0.

order to enhance the way voice synthesis reads mathematical formulas [46]. The Math Genie offers blind students several ways of reading the formulas, from default reading from left to right to an abstract way that highlights the hierarchical structure while "folding" away the sub-expressions. The user can navigate in the mathematical structure, moving by way of meaningful "chunks". This is based on lexical clues, which represent the structure of the mathematical content.

Additional features provided by the Math Genie are:

- the possibility to let the user to add so-called "voicemarks" to expressions, that is to record audio bookmarks attached to any sub-expression.
- an online dictionary of mathematical terms accessible during navigation in mathematical expressions through simple keyboard shortcuts gives contextual support to the blind users.

The current version supports English, French and Spanish for speech, and offers facilities to add any local language provided that a speech synthesiser is available with the requested interface. The Braille output currently supports the Nemeth code [26] (see Section 3.2).

7.3 Lambda

Lambda [6] is a mathematical reading and writing system designed for blind students. The software was developed in a project of the same name, whose meaning is in full: "Linear Access to Mathematics for Braille Device and Audio Synthesis". The Lambda software is mostly referred to as the "Lambda Editor’’. It is an editor that enables a blind student to input and to edit mathematical expressions in a rather comfortable way.

The main characteristics of the Lambda project is that it is built on a new code. This code is an XML code specifically designed for supporting the Braille transcription into 8-dot pattern national codes. Each Lambda national code has the lambda structure and a Braille character dictionary as close as possible to the official national code.

Within Lambda, mathematical formulas may be input in several ways:

- through keyboard shortcuts.
- from a structured menu.
- from an alphabetic list.
- from a toolbar (for sighted users mainly.).

As for output, Lambda supports these modalities:

- Braille output in a special, though customisable 8 dot code.
- speech synthesis - mathematical symbols are verbalised in a descriptive language.
- visual presentation in a linear code (a specific font in which each Braille character is represented by a visual symbol).
- graphical rendering - not synchronous to input, the graphical rendering is built when the user presses a key. This view is then static. The graphical view is obtained by conversion of the Lambda code to MathML.

Lambda offers several tools to support a student in editing mathematical expressions. The most important among these utilities is the manipulation of blocks: Every structure with an opening and a closing tag, i.e., an expression in parentheses, a root, a fraction, an index, or an exponent, is considered a block. The Editor has functionality to select a block, to enlarge or diminish the selection according to structural levels, to delete a block, and to copy it to a different place in the document.

As for navigation support, Lambda offers collapse and expand functionality, which is also organised along the block structure of a mathematical expression.

8 Future Challenges

Nowadays, the significant efforts made around the MathML language and the progress made by rendering programs (like Mozilla for instance) and the equation editing software (like MathType) allow us to develop very useful software that might help blind users to deal with the intrinsic complexity of Mathematical Braille notations. We have seen in this paper a few examples that provide such help (Math Genie, Lambda).

8.1 Needs

One of the central objectives of works in this field is now collaborative work between blind and sighted individuals, most typically in a mainstream teaching environment, where one blind pupil needs to be able to collaborate with his/her sighted teacher and, perhaps, several sighted fellow students.

This requires synchronisation of 2 representations using 2 different modalities, one dedicated for the blind and one dedicated for the sighted. Each of these representation must be the natural representation, that is the representation the readers are used to. In the case of sighted people it has to be the natural graphical view. In the case of blind readers it has to be the official Braille notation in use in their environment.

The synchronisation must allow each one to point a location on the formula to show it to the other, in order to highlight an idea or to explain an error. On the graphical view this pointing must be done using the mouse by clicking on the desired location. Then the specified location is highlighted on the Braille display. On the other direction the Braille user can click on a cursor routing key and then make appear the selected location with a different background on the screen.

Additionally it is necessary to be able to collapse/expand some branches of the Maths expression in order to get overviews of the formulas. Obviously this has to be synchronised too.

Actually carrying out mathematical calculations is even more difficult than reading and writing formulas. The problems in doing formal manipulations happen because of the complex structures that arise during a calculation: whereas sighted people may organise a computation such that it can be easily surveyed and navigated, blind people tend to get lost quickly within a formal structure. There is a need for powerful editing tools that pupils can use to do calculations more easily.

There is also a tremendous need for tools providing contextual support on the Braille mathematical code and doing calculations. These tools should provide support with respect to the Braille notation itself and not mathematical content. The aim is to reduce the gap between blind pupils and their sighted peers induced by the complexity of mathematical Braille notations.

8.2 MAWEN

We are currently developing a prototype application based on MathML which implements all these features. MAWEN, which stands for "Mathematical Working Environment", is currently being developed in co-operation between the Johannes Kepler University of Linz, Austria, and the University Pierre et Marie Curie in Paris, within the MICOLE project, funded by the European Commission. It is a comprehensive, collaborative, bi-modal software solution designed to address all the basic problems outlined in this paper.

The system is designed:

- To work on documents of mixed content - textual and mathematical.
- To simultaneously represent formulas in a Braille Mathematics code of the user's choice (MAWEN potentially supports any official Braille code - as soon as it is implemented in the UMCL library), and in natural visual rendering.
- To support bi-directional pointing possibilities.
- To support navigation through formulae by collapse and expand functionality, synchronised with both views.
- To input/edit this mixed content, and especially mathematical formulas, such that the above-mentioned simultaneous representation persists.
- To support the student in doing mathematical manipulation.

In order to achieve this objective we have developed a model which is based on MathML - actually on Canonical MathML and which supports synchronisation and all features described above. The choice of a standard (MathML) as work representation ensures the timelessness of the system.

9 Conclusion

The study of Mathematics is crucial in most science disciplines. The difficulty inherent in the particular notation they use clearly disadvantages blind and partially sighted pupils. Therefore there is a urgent need for software tools which help them to overcome the difficulty due to their impairment. Considering the current trends which encourage more and more such pupils to attend mainstream schools it is necessary that these tools are usable by teachers who do not have a specific knowledge of Braille. Today the development of inexpensive but powerful computers allows to have an optimistic view on the future.

Indeed we have seen in this paper that a lot of partial solutions have been developed in the past decade. The involvement of multidisciplinary teams to have a better knowledge about the way individuals understand and represent Math content will help to make these tools more efficient and useful.

The development of tools based on MathML (which is now the standard for representing Mathematics contents) allows the development of tools that will better integrate visually impaired people into the mainstream. Indeed these tools allow, for instance, the production of documents with mainstream software. Additionally we can access software tools which allow high quality graphical rendering of MathML formulae. The development of converters from MathML to various Braille code in a portable and modular form will allow to integrate the natural representation of formulae for each user in an efficient work environments, giving some support on the math code to the blind users.

References

[1] K. A. Ferrell, M. Buettel, A. M. Sebald, R. Pearson. American printing house for the blind mathematics research analysis. Technical report, National Center on Low-Incidence Disabilities - University of Northern Colorado, 2006.

[2] W. Yu, S. Brewster. Evaluation of multimodal graphs for blind people. Journal of Universal Access in the Information Society, 2(2):105-124, 2003.

[3] K. Rayner, A. Pollatsek. The Psychology of Reading. Prentice Hall, 1994.

[4] R. D. Stevens. Principles for the Design of Auditory Interfaces to Present Complex Information to Blind People. PhD thesis, Department of Computer Science, The University of York, Heslington, York, UK, 1996.

[5] T. V. Raman. Audio Systems for Technical Reading. PhD thesis, Department of Computer Science, Cornell University, NY, USA, 1994.

[6] W. Schweikhardt. *Stuttgarter mathematikschrift für blinde. Universität Stuttgart, Institut für Informatik*, 1998.

[7] W. Schweikhardt, C. Bernareggi, N. Jessel, B. Encelle, M. Gut, LAMBDA: A European System to Access Mathematics with Braille and Audio Synthesis. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), volume 4061 of LNCS, pp. 1223-1230, Linz, Austria. Springer, 2006.

[8] J. Gardner, C. Herden, G. Herden, C. Dreyer, G. Bulatova. Simultaneous braille tactile graphics and ink with tiger ink attachment and duxbury. In Proc. CSUN'04 (19th Annual Conference "Technology and Persons with Disabilities"), Los Angeles, California, USA, 2004.

[9] J. A. Waterworth. The psychology and technology of speech, symbiotic relationship. In J. A. Waterworth,

editor, Speech and Language Based Interaction with Machines: Towards the Conversational Computer. John Wiley, 1987.

[10] J. V. Ralsten, D. Pisoni, S. E. Livel, B. G. Green, J. B. Moulinix. Comprehension of synthetic speech produced by rule. Human Factors, 33(4):471-491, 1991.

[11] D. Fitzpatrick. Towards Accessible Technical Documents: Production of Speech and Braille Output form Formatted Documents. PhD thesis, School of Computer Applications, Dublin City University, 1999.

[12] E. Couper-Kuhlen. An Introduction To English Prosody. Edward Arnold Ltd, 1986.

[13] L. A. Chang. Handbook for Spoken Mathematics (Larry's Speakeasy). Lawrence Livermore Laboratory, The Regents of the University of California, 1983.

[14] A. Nemeth. Tips for Reading Math Out loud to Blind Students. <http://www.rit.edu/ easi/easisem/talkmath.htm>.

[15] M. Batusic, K. Miesenberger, B. Stöger. Parser for the marburg mathematical braille notation. In C. Stephanidis, editor, Universal Access in HCI - Inclusive Design in the Information Society, Vol. 4, pages 1260 - 1264, Mahwah, New Jersey, USA. Lea, 2003.

[16] H. Guo, A. Karshmer, C. Weaver, J. Mendez, S. Geiger. Computer processing of nemeth braille math code. In Vollmar, R. and Wagner, R., editors, Proc. ICCHP 2000 (International Conference on Computers Helping People with Special Needs), Universität Karlsruhe, Germany. Österreichische Computer Gesellschaft, 2000.

[17] A. Karshmer. Access to mathematics by blind students. In K. Miesenberger, J. Klaus, W. Zagler, editors, Proc. ICCHP 2002 (International Conference on Computers Helping People with Special Needs), Vol. 2398 of LNCS, Linz, Austria. Springer, 2002.

[18] B. Stöger, K. Miesenberger, M. Batusic, D. Archambault. Multimodal interaction with mathematical formulae: Access, communication and support for blind people in doing mathematics. In Stephanidis, C., editor, Proceedings of HCI International 2005 Conference, Las Vegas, Nevada. 10 pp. (proceedings on CD-Rom).

[19] Commission Évolution du Braille Français. Notation mathématique braille. INJA and AVH, Paris, France, 2001.

[20] H. Epheser, K. Britz, F. M. Scheid. *Neufassung und vervollständigung des systems der internationalen mathematikschrift für blinde.* Marburg/L.: *Ständige Arbeitsgemeinschaft "Mathematikschrift", Deutsche Blindenstudienanstalt e.V.*, 140 pp.

[21] A. Nemeth. The nemeth braille code for mathematics and science notation, 1972 revision. American Printing House for the Blind, USA, 1972.

[22] Braille Autority of the United Kingdom. Braille mathematics notation. RNIB, Peterborough, UK, 2001.

[23] M. Batusic, K. Miesenberger, B. Stöger. Labradoor, a contribution to making mathematics accessible for the blind. In A. Edwards, A. Arato, W. Zagler, editors, Proc. ICCHP 98 (6th. International Conference on Computers Helping People with Special Needs), Oldenbourg, Wien, München.

[24] F. Schwebel. *BraMaNet logiciel de traduction des mathématiques en braille*, 2003. <http://handy.univ-lyon1.fr/projets/bramanet/>.

[25] D. Crombie, R. Lenoir, N. McKenzie, A. Barker. (2004). math2braille: Opening access to mathematics. In K. Miesenberger, J. Klaus, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 (9th. International Conference on Computers Helping People with Special Needs), Vol. 3118 of LNCS, pp. 670-677, Berlin. Springer.

[26] P. B. Stanley, A. I. Karshmer. Translating mathml into nemeth braille code. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp. 1175-1182, Linz, Austria. Springer, 2006.

[27] A. I. Karshmer, G. Gupta, S. Geiiger, C. Weaver. Reading and writing mathematics: the mavis project. In International ACM Conference on Assistive Technologies (ASSETS), pp. 136-143, Marina del Rey, CA, USA, 1998.

[28] A. Annamalai, D. Gopal, G. Gupta, H. Guo, A. Karshmer. (2003). INSIGHT: a comprehensive system for converting Braille based mathematical documents to Latex. In C. Stephanidis, editor, Universal Access in HCI - Inclusive Design in the Information Society, Vol. 4, pp. 1245 - 1249, Mahwah, New Jersey, USA. Lea.

[29] V. Moço, D. Archambault. Automatic translator for mathematical braille. In C. Stephanidis, editor, Universal Access in HCI - Inclusive Design in the Information Society, Vol. 4, pp. 1335 - 1339, Mahwah, New Jersey, USA. Lea, 2003.

[30] D. Archambault, D. Fitzpatrick, G. Gupta, A. Karshmer, K. Miesenberger, E. Pontelli. (2004). Towards a universal maths conversion library. In K. Miesenberger, J. Klaus, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 (9th. International Conference on Computers Helping People with Special Needs), Vol. 3118 of LNCS, pp. 664 - 669, Berlin. Springer.

[31] A. Karshmer, G. Gupta, K. Miesenberger, E. Pontelli, H.-F. Guo. The development of a tool to enhance communications between blind and sighted mathematicians, students and teachers: A global translation appliance. In C. Stephanidis, editor, Proceedings of the UAHCI'01 conference — Universal Access in Human-Computer Interaction (joint with 9th International Conference on Human-Computer Interaction) — Towards an Information Society for All, pages 929 - 932, New-Orleans, Louisiana, USA. Lawrence Erlbaum Associates, 2001.

[32] B. Palmer, E. Pontelli. Experiments in translating and navigating digital formats for Mathematics (a progress report). In C. Stephanidis, editor, Universal.

[33] D. Archambault, V. Moço. Canonical mathml to simplify conversion of mathml to braille mathematical notations. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp. 1191-1198, Linz, Austria. Springer.

[34] R. Arrabito. Computerized Braille Typesetting: Some Recomendations on Mark-up and Braille Standard. Technical report, The University of Western Ontario, 1990.

[35] M. Suzuki, T. Kanahori, N. Ohtake, K. Yamaguchi. An Integrated OCR Software for Mathematical Documents and Its Output with Accessibility. In K. Miesenberger, J. Klaus, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 (9th. International Conference on Computers Helping People with Special Needs), Vol. 3118 of LNCS, pp. 648-655, Berlin. Springer, 2004.

[36] R. Fukuda, N. Ohtake, M. Suzuki. Optical recognition and braille transcription of mathematical documents. In R. Vollmar, R. Wagner, editors, Proc. ICCHP 2000 (International Conference on Computers Helping People with Special Needs), pages 711-718, Universität Karlsruhe, Germany. Österreichische Computer Gesellschaft.

[37] T. Komada, K. Yamagushi, F. Kawane, M. Suzuki. New Environement for Visually Disabled Students to Acess Scientific Information by Combining Speech Interface and Tactile Graphics. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp. 1183-1190, Linz, Austria. Springer, 2006.

[38] D. Fitzpatrick. Mathematics: How and What to Speak. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp. 1199-1206, Linz, Austria. Springer, 2006.

[39] D. Fitzpatrick, A. Karshmer. Multi-modal mathematics: Conveying math using synthetic speech and speech recognition. In K. Miesenberger, J. Klaus, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 (9th. International Conference on Computers Helping People with Special Needs), Vol. 3118 of LNCS, pp. 644 - 647, Berlin. Springer.

[40] A. Monaghan. Intonation in a Text-to-Speech Conversion System. PhD thesis, University of Edinburgh, 1991. Access in HCI - Inclusive Design in the Information Society, Vol. 4, pp. 1245 - 1249, Mahwah, New Jersey, USA. Lea, 2003.

[41] N. Soiffer. Advances in accessible web-based mathematics. In Proc. CSUN'05 (20th Annual Conference "Technology and Persons with Disabilities"), Los Angeles, California, USA, 2005.

[42] D. Archambault, D. Burger. The vickie project. In K. Miesenberger, J. Klaus, W. Zagler, editors, Proc. ICCHP 2002 (International Conference on Computers Helping People with Special Needs), Vol. 2398 of LNCS, pages 90 - 97, Linz, Austria. Springer.

[43] S. Sablé, D. Archambault. libbraille: a programming library for easy access to Braille displays. In G. Craddock, L. McCormack, R. Reilly, H. Knops, editors, Assistive Technology - Shaping the future, Proceedings of the AAATE'03 Conference, Dublin, Ireland, pp. 435 - 440, Amsterdam, The Netherlands. IOS Press. Schwebel, 2003.

[44] B. Guillon, J.-L. Monteiro, C. Chécoury, D. Archambault, D. Burger. Towards an integrated publishing chain for accessible multimodal documents. In J. Klaus, K. Miesenberger, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 in Paris (International Conference on Computers Helping People with Special Needs), LNCS, Linz, Austria. Springer, 2004.

[45] A. Karshmer, G. Gupta, S. Geiger, C. Weaver. Reading and writing mathematics: The mavis project. Behavior and Information Technology, 18(1):2-10, 1998.

[46] A. Karshmer, D. Gillan. How well can we read equations to blind mathematics students: some answers from psychology. In Stephanidis, C., editor, Universal Access in HCI - Inclusive Design in the Information Society, Vol. 4, pp. 1290 - 1294, Mahwah, New Jersey, USA. Lea, 2003.

Computer Games and Visually Impaired People

Dominique Archambault, Roland Ossmann, Thomas Gaudy, and Klaus Miesenberger

The accessibility of computer games is a challenge. Indeed, making a computer game accessible is much more difficult than making a desktop application accessible. In this paper first we define game accessibility, then we present a number of papers published in the last decade: specific games (audio games, tactile games etc), games designed for all, and a few words about game accessibility and then we will describe the work that we are currently carry out in order to propose a framework to allow mainstream games accessibility.

Keywords: Accessibility, Computer Games, Visually Impaired People.

1 Introduction

Computer games have become an important part of child and youth culture, and most children, in developed countries, have a considerable experience of such games. Additionally these games are used by a growing part of the population, especially young adults (in average 25 years old, including 40% of women[1]) but the proportion of players is also growing in other age groups.

Indeed the mainstream commercial market for computer games and other multimedia products have shown a rather impressive development in recent years. For instance in 2002, costs for the development of a games could vary between 300,000 euros for a game on a wearable device, to 30 millions for the biggest productions (involving nearly a hundred of employees) [1] [2] [3]. Since 2002, the anticipation by players for more impressive games have caused budgets to increase, with increased use of new technologies.

People who cannot use the ordinary graphical interface, because they are totally blind or because they have a severe visual impairment (sight rated < 0.05), do not have access or have very restricted access to this important part of the youth culture [4]. This is particularly unfortunate for two main reasons. The first is that this group of people is probably the one who can benefit the most from technology. Indeed, technological tools benefits them in a lot of situations in their daily lives, at school as well as at work or at home, in mobility, etc. Therefore it seems important that children get used to using technology as early as possible. A second reason is that handicapped children can benefit a lot from the use of computer games for their psychomotor and cognitive development [5].

[1] TNS Sofres, *Le marché français des jeux vidéo* (The market of video games in France). afjv, November 2006. <http://www.afjv.com/press0611/061122_marche_jeux_ video_ france.htm>.

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To give people with visual disabilities the chance to have access to multimedia games should be seen as an important issue for better inclusion and participation in society.

Designing games that work for visually impaired children is quite a challenge since the main feedback channel in games is usually visual. Indeed even if audio is more and more used in mainstream games, it has only a complementary role in a huge majority of cases. It improves the experience of the player but it is usually not bringing necessary pieces of information that the player would not get visually. For instance most of these games can be played efficiently with sound switched off.

This is probably the reason why very few computer games are accessible and very few have been developed for the visually impaired. Before 2000, the only accessible games that one could find were developed by the Swedish Library of Talking Books[2].

2 Game Accessibility

Accessibility of games is a more complex problem than software accessibility in general. First, and it seems obvious, it is very important that accessible games still be games.

Accessible games must still be games!

2.1 Computer Access

Computer access for visually impaired people started to develop largely during the 80s, thanks to the appearance of personal computers. It was made possible by the development of speech synthesis and by the appearance of Braille refreshable displays. These tools allow to render information using alternative modalities (namely audio and touch).

To access desktop application, blind people have to use specific software applications, called screen readers, which literally reads the information on the screen to render it in an appropriate way using speech and/or Braille, according to the user settings. These applications were relatively simple when we were using console operating systems (text only on screens showing 25 lines of 80 characters), but became extremely complex with the development of graphical user interfaces. Nowadays screen readers are able to deal with multiple windows, to access client contents as well as menus, dialog boxes, etc. They allow a trained user to access efficiently most desktop textual applications (word processors, spreadsheets, Internet browsers, email software, etc), as well as system information and settings.

The improvement of screen technology during the 90s has allowed the development of enlargement software (screen magnifiers), which enlarge text or pictures up to 32 times, which is often a necessity for partially sighted people. Furthermore it is possible to change colours, resolution and also to redesign the organisation of information on the screen. Used alone, or in combination with speech synthesis, these software solutions enables people with really low vision to use the graphical display in an efficient way.

Additionally a number of specific devices which use the tactile modality or the haptic modality can be used together with specific software. First tactile boards are devices on which overlays can be inserted. The device transmits to the computer the location where it is pressed. Usually they are used to adapt computer games for young children. Indeed the overlays can support very rich tactile representations and therefore be very attractive for children. Tactile overlays may be prepared using various technologies, like thermoform, swallowed paper, polymerised glues etc, or simply by sticking different kinds of material. However, the major limitation with this kind of device is that is that overlays are static and not so easy to insert properly in the device.

Other tactile devices have appeared recently. These are tactile graphical refreshable displays which use the same kind of pins than Braille displays, to represent a graphic surface, with 16x16 pins or more[3]. These are still very expensive and for now mainly used in research labs, but they might come to the market in the next decade.

Other experimental devices called tactile transducers use the principle of deforming the skin by tangential traction [6]. An experimental device was designed comprising a 6x10 actuators array with a spatial resolution of 1.8x1.2 millimetre. It was successfully tested by subjects who were asked to detect virtual lines on a smooth surface.

Haptic devices include a variety of devices like vibrato tactile joysticks and gamepads, or the Senseable Phantom[4]. The Phantom is an input/output device which looks like a mechanical robot arm that is holding a stylus. When holding the stylus in the hand it is possible to touch, feel and manipulate virtual objects with 6 degrees of freedom. It uses only one point of interaction (the stylus), which means that the user will access the virtual environment through this single point, like touching objects with a stick [7].

Finally switches are very simple input devices which are used by people with very reduced motor capacities. They allow only to send one event (when pressed). They are very sensitive and allow a lot of precise settings.

2.2 Computer Accessibility

Unfortunately these specific access software applications (screen readers and screen magnifiers) are not able to access all software regardless of how it was developed. Indeed access software applications need to collect accessible information from the applications in order to render it using alternative modalities. This accessible information is mainly textual which means that all graphics that have a function must have alternative texts, but it is also necessary to get the information when something happens on the screen (when a dialog box appears, when some information arrives somewhere in the client window, etc...). If this information is not present in an application, the use of screen

[2] TPB, <http://www.tpb.se/english/computer_games>.
[3] See for instance Handytech GWP (*Graphic Window Professional*): <http://www.handytech.de/en/normal/products/for-blind/gwp/index.html>.
[4] Senseable Technologies Inc.

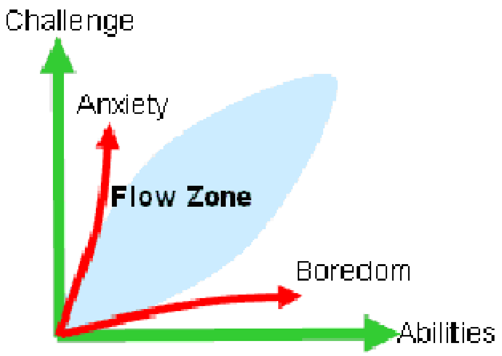

Figure 1: About Flow in Games.

readers with this application is at the best very difficult and in the most cases completely impossible.

To make applications accessible, accessibility frameworks have been developed and are available in the main environments. For instance, Microsoft has developed Microsoft Active Accessibility[5], which is a COM-based technology that provides assistive technology tools with access to the relevant information. On one side it is a collection of dynamic-link libraries that are incorporated into the operating system, on the other side is a COM interface and application programming elements.To make their applications accessible, application developers have to implement the IAccessible interface.

There exist similar frameworks on Mac[6] and on Linux desktop environments: Gnome accessibility project[7], KDE accessibility project[8].

Furthermore specific development frameworks need to support accessibility. For instance the Java Accessibility API[9] or Access Mozilla[10].

2.3 Accessibility of Contents

It is not enough that applications respect accessibility standards. In most cases the contents must be accessible too.

For instance in the case of a web site, the accessibility of web browser is necessary but the web contents must be accessible too. Graphical elements for instance must have textual alternatives, and this depends on the content itself. In that respect, the W3C launched the Web Accessibility Initiative to developed guidelines for Web Accessibility: WCAG[11]. (*Web Content Accessibility Guidelines*). These guidelines indicate how to use each of the HTML tags to make a web site accessible. For instance to support graphics, it is requested to insert alternative text within an "ALT" attribute on each IMG element.

2.4 Differences in the Case of Games

These accessibility solutions work satisfactorily for desktop applications but not for computer games. First the notion of "working satisfactorily" is a) not enough and b) not easy to define in that context.

Indeed, the results of a game can not be easily quantified unlike classical desktop applications. In word processing software, it is easy to measure the time needed by a user to write a document or to edit a document produced by a colleague. In a game we can observe if a player succeeds, and measure the time to finish a level or any case relevant for the game considered, but this is not enough. Unlike others software, games have to provides special feelings to players. There are likely to be some emotional factors to consider in the desktop applications, but they are usually not taken into account, or at least unless they affect the productivity. In the case of a game these factors are the most important.

It is not easy to describe the nature of these types of feelings: it is a large field of research and studies that describes it through two main concepts: the concept of presence and the state of flow. Both describe a state where the player feels totally immersed in the game universe. The presence concept is the ability of the game to provide the illusion for the player that he/she is in the virtual environment [8]. The presence sensation can be evaluated according to the goals of the game [9]. The efficiency of the interaction is also an essential point [10]. There are many others ways to approach this particular type of sensation felt by the player.

The other concept is the state of flow. This concept could appear very similar to the presence concept, but it is more oriented to a sensation of intense pleasure rather than an illusion of being elsewhere. It can be defined as a state of concentration, deep enjoyment and total absorption in an activity [11]. Flow is the result of the balance between two different psychological states, anxiety and boredom, themselves produced by the gathering of two aspects of gaming: the challenge of a task versus the abilities of the player [12] (see Figure 1).

In other terms, as we stated at the beginning of this section: Accessible games must still be games! Adults in work situations accept relatively large constraints on usability in order to be able to use the same software as their sighted colleagues and to work on the same documents.

The example of ord processing software provides a quite interesting way to illustrate this. Usually the simple access to character properties (like knowing if a word is in bold face or not) necessitates some complex manipulations. What is immediate by sight on any WYSIWYG word processing application, necessitates selecting the word, opening a dialog window and then navigating the various boxes of the character properties dialog in order to check the various settings currently selected. There exist other software solutions for word processing, like LaTeX, which allow much

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[5] <http://msdn.microsoft.com/at>.
[6] <http://www.apple.com/accessibility/>.
[7] < http://developer.gnome.org/projects/gap/>.
[8] < http://accessibility.kde.org>.
[9] <http://www-03.ibm.com/able/guidelines/java/javajfc.html>.
[10] <http://www.mozilla.org/access/>
[11] <http://www.w3.org/TR/WAI-WEBCONTENT/>.

simpler access to this kind of information for a blind person, but they are usable only if the colleagues of this person use the same software! Otherwise, it's always more important to be able to use the same software as the others even if the usability is not so good.

This is not the case for children, especially when playing. In other words it is not enough to find a technical way of allowing to access to all information needed in the interface, the result must be as interesting and as usable as the original game.

Another important reason, which is as important as the previous one, is that it must be possible to succeed! Once again it seems obvious. In the example of a screen reader with a desktop application the user has to explore the content of the screen or of a window to know its contents. In the case of a game, let us consider a shooting game for instance, if an enemy enter the screen, a sighted person will perceive it visually within seconds, together with its location. But if a blind user needs to scan the screen to get the same information, the enemy will have plenty of time to defeat him/her and the game will be over very soon.

In the current mainstream market a huge majority of computer games are totally inaccessible to blind users as well as to most partially sighted users, and also to people having a large variety of other impairments.

2.5 Playable Alternative Modalities

To handle the special needs of the impaired players, new ways of interacting and communicating have to be found. The different modalities available for visually impaired users have to be studied in order to see what kind of interaction can be made with each device and how.

2.5.1 Audio

The first modality which comes to mind is obviously the audio. Considerable progress has been made in audio possibilities of computers, and what has largely contributed to this progress is the need for the development of computer games. These audio possibilities have been used for a quite large number of audio games, games that rely only on audio. We'll see a number of them in Section 3.1.

Unfortunately these developments have been exclusively driven by use cases where the audio is a complement to a visual experience, which is supposed to enhance the feeling of the situation for the player.

2.5.2 Tactile

The tactile modality can be used to design tactile or audio-tactile games. We'll see in Section 3.2 some games using tactile boards. Braille devices are usually not used to design games. Nevertheless some research is currently carried out in order to find models to represent a 2D space on a linear Braille display [13]. A few experimental games were designed in order to evaluate these models, for instance a snake game and a maze game.

2.5.3 Haptics

Sjöström [14] studied the possibilities offered by haptic technologies for creating new interactions usable by blind people. He worked especially with the Senseable Phantom.

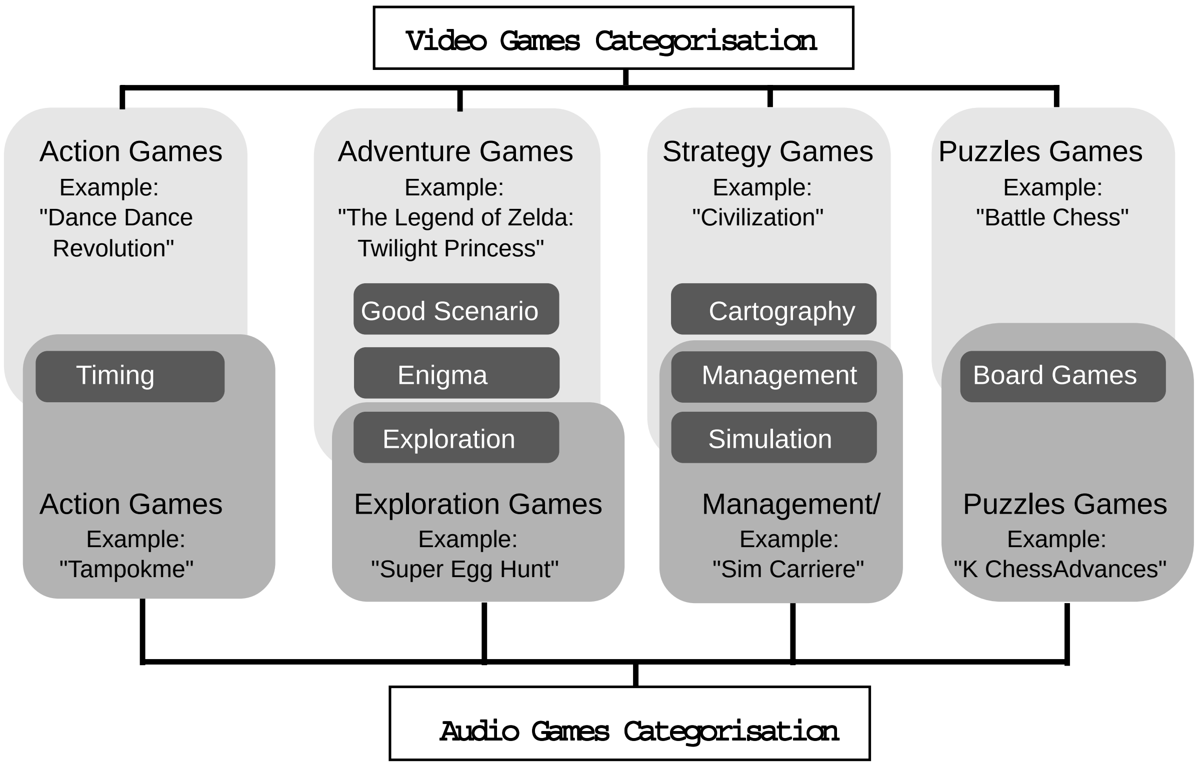

Figure 2: Comparison of Video Games Categorisation and Audio Games Categorisation.

Johansson and Linde [15] used an inexpensive force feedback joystick in a virtual maze. Wang et al. [16] have designed an experimental memory game in order to assess the possibilities of their tactile transducers. Raisamo et al. [17] present the same kind of memory game using a low cost vibrato-tactile device (a force feedback gamepad). In these three cases, the interest of the researchers is not in the game development itself, but the use of the game as a tool to study the haptic perception. Nevertheless the players were able to successfully play the games and showed an interest in the devices, so use in future accessible games would be possible.

Evreinov et al. [18] designed a vibro-tactile pen and software to create tactons and semantic sequences of vibro-tactile patterns on mobile devices (iPAQ pocket PC). They propose special games to facilitate learning and manipulation by these tactons. The techniques are based on gesture recognition and spatial-temporal mapping for imaging vibro-tactile signals.

The Phantom was used in several game experiments. Aamisepp and Nilsson [7] built a plugin for an open source 3D game engine (Crystal Space) that allows navigation in the 3D environment and to touch the surroundings with the Phantom. The authors conclude that their system can be used with 3D environments specially built for the haptic environment but that it would not really work with existing environment used in 3D games like Half-life or Quake. The reason is that the Phantom uses a single point of interaction, which makes it very difficult to understand a 3D shape.

Crossan and Brewster [19] describe research about the possibility of using two hands with two different devices. They were using their dominant hand to move a cursor with a phantom and their other hand to receive tactile information from a device offering a 4x8 array of pins[12]. A maze game was designed for the experimentation. They conclude that most users could solve the task with little training, which tends to show that such combination can be used to make accessible games or accessible versions of games.

The Phase project [20] is an experimental game using haptic feedback. It has been successfully played by visually impaired people in various exhibitions. The game refers to function of a phonograph: Phase offers visual stereoscopic landscape wherein a player moves a kind of play head that produces sounds, according to its position over the landscape. It can be used as a musical toy that users just listen to or as a challenging game. To beat the game, players have to increase speed by trying to reach the lowest location of the landscape. The haptic device (Senseable Phantom) allows the user to feel the relief and to find acceleration zones. It enables visually impaired players to successfully handle the game.

About the Phantom, we must also mention BattlePong, which is a pong game where the players use a Phantom to handle the racket. BattlePong was presented at the Experimental Gameplay Workshop at GDC 2004 (*Game Developers Conference*).

3 Specific Games

This section focuses on games specifically designed for visually impaired people. These games are usually funded by foundations or non-profit organisations. Most of them are very nice for visually impaired people but have little interest for the mainstream, except maybe a few of the audio games.

3.1 Audio Games

Audio games are games, in which the main play modality is audio, which includes three different concepts. The first involves mainstream video rhythm games like "guitar hero II"[13]. The second is related to artistic musical experimentations. The web site audiogame.net refers interesting interactive works. In this paper we will focus on the third concept - audio games which can be played with audio only and without visuals which are therefore accessible to visually impaired players.

In 10 years, over 400 audio games have been developed, which is a very small number as compared to video games. Indeed, compared to the market of computer games, audio games are a tiny market, profitability of such projects is smaller and development teams contain generally only between one and four persons. Nonetheless, the production rate has dramatically increased those last few years and the community of players and developers strengthens with sites such as Audio games.net, which seems to imply that this new medium is in a very promising phase of expansion.

Researchers could have an important role to play in that expansion process, by contributing to develop innovative features like a more pleasant audio rendering, by projecting audio games in a futuristic point of view by using uncommon technology like GPS for instance and by participate in the elaboration of games which can interest both the sighted and visually impaired community [21]. There exist a few visual audio games which can be very impressive and playable as well with or without sight. "Terraformers"[14] [22] was developed with accessibility as part of the original concept of the game. On the other hand, "Audioquake" [23] (see Section 5.5) was developed as a research project to make a non accessible game accessible.

3.1.1 Audio Games Categorisation

Audio games, like video games, can be categorised. The categorisation of audio games provides conceptual tools allowing to comprehend better the interaction mechanisms used for the players to have fun. In order to categorise audio games, we use a categorisation of video games as a theoretical basis of thinking [3]. Natkin distinguishes four main types of games that can be played alone: action games, adventure games, puzzle games and strategy games. These

[12] Virtouch VTPlayer.

[13] <http://www.guitarherogame.com>.

[14] <http://www.terraformers.nu>.

categories will be described more precisely below. Natkin mentions that these types of games can be mixed together and it is true that numerous video games belong to several categories.

The categorisation of audio games proposed in [24] looks similar, with four matching categories, but they are not exactly the same as video games categories (see Figure 2). Indeed audio games do not have the same history as video games. They have not had the same evolution. Audio games owe their existence to video games but also to textual games. Without the visual, texts are the best means to give the players the rules of the game. Audio games with more complex rules, such as parlour games or management/ simulation games, are therefore naturally more textual than audio. Games with more simple rules, such as action and exploration games, have more recourse to non-verbal sounds. Most of the games that are more non-verbal audio than textual can be considered as a mixture at different levels of the interaction mechanisms of action and exploration games. Some interactions have to be based on a precise timing (temporal dimension of the interaction) and some interactions permit the exploration of a geographic space. Thus, current audio games can be studied with three factors: their dependency on verbal information, their dependency on interaction mechanisms based on timing and their dependency on the interaction mechanisms of exploration.

3.1.2 Action Games

Action games directly refer to games coming from and inspired by arcade games and requiring good dexterity from the player. One example of such games is "Dance Dance Revolution" (DDR). DDR is the first of an important series of musical video games. Playing these games requires a good synchronisation with a tempo given by the music. They are not accessible because the kind of action to be done is given visually. The visual information allows the player to anticipate the time of the interaction. The tempo of the game can be rather fast and really challenging. The concept of timing is very important but it depends at the same time on audio and visual perception.

There are also audio action games, where the success of the player depends on an interaction based on a precise timing. "Tampokme"[15] is such an accessible audiogame. The principles of the game are very simple compared to DDR. There is no possibility of anticipating but timing is essential. The player has to identify various kinds of audio signals and react accordingly and in fixed time. The state of flow is not as intense as in DDR but the potential for improvement is high and it is fully accessible to visually impaired people as well as to people who have mobility troubles (it can be played with a single button).

3.1.3 Adventure Games/Exploration Audio Games

Adventure games allow players to take part in a quest. This type of game combines three essential features: an interesting scenario, the exploration of new worlds and riddle solving. A typical example is the series "Zelda". The enigmas and the scenarios of this kind of game are important but not as much as the action of moving around of the avatar of the player in a virtual environment.

There are also adventure audio games, though the scenarios of these games, as compared to video games, are still very little developed and that the activity of puzzle solving is clearly secondary. The primordial aspect of these games is, most often, the exploration of a new geographic environment. That is why we call this category "exploration games" in the case of audio games.

"Super Egg Hunt"[16] focuses on the move of the avatar on a grid, where the players must locate objects only from audio feedback. A quite clever use of stereo, volume and pitch of the sounds allows an easy and pleasant handling.

3.1.4 Strategy Games/Management-simulation Audio Games

Strategy games require that the players control an army, a territory and resources by manipulating maps. The game "Civilization" allows the player to control a large number of characters, spread across a large number of places. The player manipulates a lot of parameters in order to ensure that the population survives and develops.

There are a few strategy audio games but the manipulation of maps is rather difficult without the visual aspect. It is still possible: galaxy ranger and AMA Tank Commander are two audio games that offers an interesting approach of strategy games, but they are isolated [25]. The aspects that are the most prominent for these games are the management of resources and simulation.

The game "simcarriere"[17] ignores the map aspect and focusses on the simulation/management side. The player has to manage a lawyer's office by buying consumables, hiring personnel, and choosing the kind of cases to defend.

3.1.5 Puzzle Games

Finally puzzle games are inspired from traditional games. There are puzzle audio games which directly refer to parlour games that are not accessible in their usual material form. Nevertheless audio and video puzzle games are quite similar in their principles.

The game "Battle Chess" is an adaptation of the Chess game into a video game. "K-Chess advance"[18] is also an adaptation of the Chess game, but focussing on audio. In those cases, the feeling of flow does not rely on principles of reactivity in front of audio or video signals, but on entertaining principles that have stood the test of time before the advent of computers.

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[15] Tampokme, the audio multi-players one-key mosquito eater, CECIAA/CNAM CEDRIC/UPMC INOVA, <http://www.ceciaa.com/?cat=lois&page=action>.

[16] Egg Hunt, LWorks, <http://www.l-works.net/egghunt. php>.

[17] <http://www.simcarriere.com/>.

[18] KChess Advance, ARK_Angles, <http://www.arkangles.com/kchess/advance.html>.

3.2 Tactile Games

Tactile games have inputs and/or outputs that are carried out with tactile boards or Braille displays, usually in combination with audio feedback.

As mentioned in Section 2.5.2, the use of Braille displays for gaming is only experimental at the moment so we will only discuss projects that involve tactile boards.

Back in 1999, we developed a first software workshop[26] allowing to design software games using a tactile board for the input. A scripting language was used to define regions on the tactile board and to attach sounds to these regions. It was also possible to design several scenes and to link them together, which allowed the design of audio/tactile discovery games as well as matching games, quizzes and interactive stories.

Then during the TiM project [27] we developed several tactile games. One was an accessible version of "Reader rabbit's Toddler", where the children can feel tactile buttons on the tactile board, and then drive the game from this board. This adaptation has been designed with the support of the publisher of the original game.

This work allowed us to realise how important it is to compensate the lack of visual information in order to ensure that the adapted game has enough attractive feedback for the visually impaired children[28]. Indeed in a first version we had only adapted the tactile interfaces, so the game was usable by the children, but all the audio outputs were the original ones. It was clearly not enough, the children did not consider it as a game. In a second version we added a lot of audio content, which had been written by a professional author. This version was much appreciated by the children.

Another game developed within the TiM project was FindIt, which was a very simple audio/tactile discovery and matching game. It is intended for very young children or children with additional disabilities. The player must associate sounds with pictures on the screen or tactile information on a tactile board. Recorded comments and clues are associated with the items. From this game we developed a game generator [29] which is currently being evaluated by practitioners working with visually impaired children. The generator allows educators and teachers who work with visually impaired children to design their own scenarios and to associate them with tactile sheets that they design themselves manually.

Tomteboda resource centre in Sweden has published a report in which they try to stimulate parents and educators to develop their own games using tactile boards [30].

4 Games Designed for All

The goal of games being developed under the title of "designed for all" is to give players with a wide variety of abilities or disabilities the opportunity to play these games. This requires a very advanced game setting and configuration.

4.1 UA-Chess

UA-Chess[19] (*Universally Accessibility Chess*) [31] is a universally accessible Internet-based chess game that can be concurrently played by two gamers with different (dis)abilities, using a variety of alternative input/output modalities and techniques in any combination. It was developed by the Human-Computer Interaction Laboratory of ICS-FORTH in close cooperation with the Centre for Universal access and Assistive Technologies.

The game supports a collection of possible input devices like keyboard (including switch devices), mouse and even speech recognition (recognise more then one hundred words). With these input devices, several configuration and combinations are possible. For example the keyboard can be used, beside the standard input, for input scanning. Furthermore, keyboard shortcuts help the gamers to control the game and the game menus quickly.

The two possible output channels are visual and auditory through speech synthesis. An integrated screen reader makes it possible to play the game without visual information. The player can decide which information he/she wants to be read. UA-Chess gives the opportunity to save these customised information in profiles.

The game provides a default, a blind and two switch-input profiles. Furthermore, two user profiles will be supported. Certainly, each of the two players can select their own profile. As already mentioned, it is a two player game, which can be played together on one computer or over the Internet.

The programming language and technique is Macromedia Flash MX Professional 7. Flash was chosen because the plug-in is available for all important web browsers on several operating systems (Windows, Mac OS, Linux and Solaris). Flash does not support speech input or output, so to support speech recognition and synthesis *Speech Application Language Tags* (SALT) technology[20] was used.

4.2 Access Invaders

Access Invaders[21] is a designed-for-all implementation of the famous computer game Space Invaders, with the target groups of people with hand-motor impairments, blind people, people with deteriorated vision, people with mild memory/cognitive impairments and novice players [Grammenos et al., 2006]. Furthermore people belonging to more than one of the previous groups. Like UA-Chess, this game is developed by the Human-Computer Interaction Laboratory of ICS-FORTH. Universal Access will be achieved by supporting alternative input/output modalities and interaction techniques that can co-exist and cooperate in its user interface, in combination with configurable player profiles. Each game parameter can be adapted both based on the player's profile and the current game level. Non-visual gameplay is also supported by full acoustic rendering of game information and a built-in screen reader.

[19] <http://www.ics.forth.gr/hci/ua-games/ua-chess/>.
[20] <http://www.saltforum.org>.
[21] <http://www.ics.forth.gr/hci/ua-games/access-invaders>.

Multi-player games are available, where people with different (dis)abilities can play cooperatively, sharing the same computer. In this case, the game's interaction parameters can be independently adjusted for each player. An unlimited number of concurrent players is supported. This is reached by the concept of the so called *Parallel Game Universe*. Different kinds of aliens (varied by amount and strength) belong to the different players. A player just can kill aliens belonging to him/her and vice versa.

Future development will cover the support of tactile output through a Braille display and a force feedback joystick and stylus. Furthermore, an interactive editor for user profiles and dynamic gameplay adaptation, which includes monitoring the player's actions and dynamically adjusting the gameplay to better match the player's skills.

4.3 Tic Tac Toe

The approach of Ossmann et al. [33] was not to develop a new game designed for all players. It was decided to make an already published game accessible and show, if this is possible and how big the effort is. An open source implementation of Tic Tac Toe was chosen. The accessible functionality bases on *Guidelines for the Development of Accessible Computer Games* (see Section 5.2) and was a good test for the usability and completeness of these guidelines. The so called *Descriptive Language* was used to realise the accessible features during the implementation.

This language connects alternative input/output devices with the game engine with the possibility to use several input devices simultaneously and present the game output on several output devices. This means that, as an example, the game player can decide if he/she wants to have all graphical objects presented on screen, described over speaker or be on both output devices. Additionally the Descriptive Language covers the option for an extensive configuration of the game, so that the game can be customised to the special needs of a (dis)abled person. This configuration ranges from game speed to the number of opponents to many other game options, depending on the kind of game. The Descriptive Language is, as the Tic Tac Toe game itself, still under development and this game is the first example, using this language.

The game provides, beside the already mentioned full sound output of all objects on the game field, also the possibility to use input scanning in connection with (one) switch devices. The future development will cover the support of visual impairments and full accessible game configuration.

5 Game Accessibility

The goal of games accessibility is to bring the idea of accessible games (or games designed for all) to the mainstream and show different approaches. Here is an overview of papers about research work and development on this topic.

5.1 Accessibility in Games: Motivations and Approaches

[34] is a white paper published by the Games Accessibility Special Interest Group[22] (GA-SIG) of the IGDA (*International Game Developer Association*) in 2004. Firstly they give the following definition of games accessibility: "Game Accessibility can be defined as the ability to play a game even when functioning under limiting conditions. Limiting conditions can be functional limitations, or disabilities such as blindness, deafness, or mobility limitations." Furthermore definitions of the different kinds of (dis)abilities are given followed by statistics about (dis)abilities in the population and the possibilities of game based learning.

The paper also covers a collection of hints, suggestions and guidelines for the development of accessible games. Moreover there is a collection of accessible games with a short description of each game and a categorisation of the (dis)abilities supported. A listing of assistive technologies and an overview of state of the art research completes the paper.

It is the first famous publication that woke up the mainstream game developers and showed them that it is possible and necessary to include more users in the mainstream games.

5.2 Guidelines for the Development of Accessible Computer Games

Guidelines are an important tools to bring games accessibility to the mainstream. Ossmann and Miesenberger [35] show a set of guidelines[23], based on the already mentioned guidelines from IGDA and a set of guidelines from the Norwegian company MediaLT[24], and their development process. The guidelines are a collection of rules, hints and suggestions as to how to develop accessible computer games, divided into the categories of level/progression, input, graphics, sound, and installation and settings.

The guidelines have, beside the rules themself, a categorisation in three classes of priorities: a) must have, which means, that it is absolutely necessary for the listed group of gamers. Otherwise the game is not accessible for them, b) should have, which means, that it is a big help for the listed group of gamers and c) may have, which means, that it is a helpful feature for the listed group of gamers. Furthermore there are four groups of (dis)abilities: visual, auditory, mobility and cognitive (dis)abilities. These (dis)abilities are allocated to the priorities, e.g. one rule can have priority 1 for visually impaired people and priority 3 for auditory impaired people. The next steps will be adding code samples and best practice methods to fulfil the rules. Another step will be making a stronger integration of assistive technologies in the guidelines, specially adding an input device section to them.

The future goal is to have a useful and usable set of guidelines for game development like the web accessibility guidelines for web pages.

[22] <www.igda.org/accessibility>.
[23] <http://gameaccess.medialt.no/guide.php>.
[24] <http://www.medialt.no>.

5.3 Computer Games that Work for Visually Impaired Children

Archambault et al. [28] describe the work on computer games for blind or severely visually impaired children from 3 to 10 years old. The research and development work was done during the TiM project, which was a co-operation of several European institutes and organisations, funded by the European Commission. Various mainstream games had been studied and several of them were adapted to be playable for the target group. Also new ones were developed. Several case studies were accomplished, one with the game "Reader Rabbit's Toddler". In the original version of this game, the player can have access to 9 different educational activities. From these 9 different activities in the original version, 4 could be adapted plus the navigation in the main menu.

All output was converted to alternative modalities (basically audio in this game) and for the input, a device called tactile board was used. This is an input device on which a rectangular sensitive area is divided into 256 cells. On top of the sensitive area, a tactile overlay may be inserted. Rich tactile overlays were designed, using pieces of various materials, stuck on a robust PVC sheet, and Braille labels.

A second game, called Mudsplat, which based on the classic arcade game "Space Invaders", was developed. The game has a various degrees of difficulty and traditional features of arcade games were implemented (like high score, extra lives, levels, bonus objects, bonus levels,...).

Furthermore the paper includes 14 rules for games, being developed for the already mentioned target group. These rules based on the results of research and test cases with children, including information about the game play itself, about the navigation in the menus and about content for the sighted.

5.4 Internet and Accessible Entertainment

[36] is based on a project, which is aimed at adapting and developing entertainment software for young people with (dis)abilities, including those with mental (dis)abilities, or a combination of severe motor handicaps and perceptual losses. Entertainment was chosen, because entertaining software may provide good motivation e.g. for learning assistive devices and standard computer skills. During the project, a new product should be developed following the principles entertaining, simple (not childish), accessible and flexible.

Internet games using Macromedia Flash were used based on the following considerations: support for different platforms, no client installation and only one source to maintain in combination with Flash's built-in tools for creating graphics and animations, use of mp3-files for music, the accessibility support is fairly good and the easy distribution to different medias like Internet and CD-ROM. The developed game (called "HeiPipLerke") can in short be described as a music composer adjusted to meet the requirements of the target group. It provides input scanning and audio output by default.

Some problems and challenges occurred, e.g. the implementation of input scanning and speech output, which was not available in Flash. Furthermore pointing to, and selecting items on the screen using a touch screen, followed by some problems changing the colours of all objects for people with visual impairments. The game based on the Guidelines for Accessible Games (see Section 5.2) and "Best Practices for Accessible Flash Design" guidelines. The future work on the game will include more content and support for the hearing impaired by including sign language in addition to speech.

5.5 Making the Mainstream Accessible: What's in a Game?

Atkinson et al. [23] describe the work of the AGRIP project - an effort to develop techniques for making mainstream games accessible to blind and visually-impaired gamers. *AudioQuake* is the first adaption of an existing mainstream game (Quake from id-Software) designed specifically for sighted people that has been made playable for blind gamers by adding an "accessibility layer". During the development of this layer, one of the issues to be solved was navigation. Navigation issues were divided in global navigation towards one's ultimate goal (e.g. the red team's flag, ...) and local navigation (e.g. how do I get out of this room?). At the low-level game accessibility stage of the project's development, the primary concern was to develop the support of effective local navigation.

One "tool" that was implemented for the local navigation was the EtherScan Radar. It warns players of nearby enemies and team mates using a RADAR-like metaphor: sounds emanate from the position of the enemy and have a gain and repetition speed proportional to the players distance from them. Another topic is serialisation. It reduces multidimensional problems into single-dimensional problems, which is important for the two most popular accessible output formats — speech and 1-dimensional Braille displays. Serialisation has a close connection to prioritisation. This means, that different kinds of information (enemies, walls, ...) will get different kinds of priorities when being serialised. Several priority paradigms are discussed there.

6 Game Accessibility today

We have seen (Section 3) that a number of games have been developed specifically for visually impaired users. These are mostly audio games but a few tactile games exist. These games have two points of interest: firstly of course they are of tremendous interest for visually impaired players (especially since the number of such games is extremely limited regarding the number of mainstream games), and secondly in the research field there are many experiments or demonstrations of how to render various interaction situations with alternative modalities. This can be completed by a number of research papers about new uses of modalities in the game play (Braille devices, haptic...) described in Section 2.5.

In the specific case of audio games some more progress could be achieved. Indeed they still don't use the specific musicality aspects of sounds. Multi-player audio games are required for better communication between players [25]. In order to progress it is necessary that audio games start to interest a larger community of players.

Then in Section 4 we have presented 3 research projects focussed on games designed for all. These games must be seen as good practice examples, demonstrating that Universal Access is a challenge and not utopia. In these projects we have to admit that the alternative access to these games requires more development than the rest of the game.

We assist the way to a general awakening to accessibility needs by the mainstream game developers. Some first efforts were started to improve accessibility of mainstream games, with particular guidelines supported by the International Games Developer Association. If they are ever partially implemented we can expect that the general accessibility level will be raised, which means that for a large number of people having a slight to moderate visual impairment, more games will be playable.

If we want to go further in this field, which means we want to make more mainstream games accessible, and if we want to make them accessible to all, we need support for accessibility included in the mainstream games themselves. This is the only way that will allow the building of accessible interfaces for mainstream games.

For now, considering Windows desktop applications, we have seen in Section 2.2 that it is necessary to have accessibility support embedded in the applications in order to make them accessible to alternative interfaces, supporting alternative modalities, like screen readers. This was achieved through the Microsoft Active Accessibility, but if this technology is well suited to desktop text-based applications it is clearly not enough for games (see Section 2.4).

In the close future we need to design a framework that will allow development of accessible solutions for games, that we call *Active Game Accessibility* (AGA). The goal of AGA is to allow mainstream game developers to offer support to accessibility solutions without significantly increasing the development charge for those games. This support will be used by Accessibility specialists to design accessibility solutions. These solutions will be various, depending on each game.

For instance AGA will allow the design of some kind of game screen readers which will make the most simple games accessible. The AGA framework will concern a much larger group than visually impaired people with support for all kind of disabilities. Then specific access software for various types of disability can be developed.

These generic accessibility software solutions will be necessary but will not be enough to make any kind of games accessible. Indeed in the most complex cases it will still be necessary to develop specific interfaces to the games. We have seen in Section 3.2 that in most cases it is necessary to at least add some audio feedback in order to compensate the lack of visual information. In more complex games it will be necessary to adapt the game-play itself. The AGA framework will allow the design of such interfaces that can communicate with the mainstream games themselves.

Today more and more actors of the game industry are aware that something must be done in the near future to improve the accessibility of computer games. We can be reasonably optimistic since we set up collaborations with specialists of Game Accessibility (for all disabilities), with several companies working in the mainstream, and with Assistive Technology providers. The game is not over yet!

References

[1] S. Natkin, C. L. Prado, V. Gal, L. Vega. *Quelques aspects de l'économie du jeu vidéo*. In *Actes des journées d'étude: Internet, jeu et socialisation*, Paris, France. Ossmann et al., 2006.

[2] F. Fries. *Propositions pour développer l'industrie du jeu vidéo en france*. Rapport à l'attention de M. Francis Mern Ministre de l'Économie, des Finances et de l'Industrie, et de Mme Nicole Fontaine, Ministre déléguée à l'Industrie, 2003.

[3] S. Natkin. Video games and Interactive Media: A Glimpse at New Digital Entertainment. AK Peters.

[4] A. Buaud, H. Svensson, D. Archambault, D. Burger. Multimedia games for visually impaired children. In K. Miesenberger, J. Klaus, W. Zagler, editors, Proc. ICCHP 2002 (International Conference on Computers Helping People with Special Needs), Vol. 2398 of LNCS, pp 173 - 180, Linz, Austria. Springer.

[5] A. Hildén, H. Svensson. Can All Young Disabled Children Play at the Computer? In K. Miesenberger, J. Klaus, W. Zagler, editors, Proc. ICCHP 2002 (International Conference on Computers Helping People with Special Needs), Vol. 2398 of LNCS, Linz, Austria. Springer, 2002.

[6] Q. Wang, V. Hayward. Compact, Portable, Modular, High-performance, Distributed Tactile Transducer Device Based on Lateral Skin Deformation. In Symposium on Haptic Interfaces For Virtual Environment And Teleoperator Systems, pp 67-72, Arlington, VA. IEEE VR, 2006.

[7] H. Aamisepp, D. Nilsson. Haptic hardware support in a 3d game engine. Master's thesis, Department of Computing Science Lund Institute of Technology, 2003.

[8] B. G. Witmer, M. J. Singer. Measuring presence in virtual environments: A presence questionnaire. Presence, 7(3):225-240, 1998.

[9] A. Gaggioli, M. Bassi, A. D. Fave. Quality of experience in virtual environments. In G. Riva, F. Davide, W. IJsselsteijn, editors, Being There: Concepts, Effects and Measurments of User Presence in Synthetic Environments, chapter 8, pages 121-136. Ios Press, Amsterdam, The Netherlands, 2003.

[10] X. Retaux. *Presence in the environment: theories, methodologies and applications to video games*. PsychNology Journal, 2003.

[11] D. Johnson, J. Wiles. Effective affective user interface design in games. Ergonomics, 46(14):1332-1345, 2003.

[12] C. Jenova. Flow in games. MFA Thesis, University of Southern California. <http://www.jenovachen.com/flowingames/>, 2001.

[13] A. Sepchat, N. Monmarché, M. Slimane, D. Archambault. Semi automatic generator of tactile video games for visually impaired children. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp 372-379, Linz, Austria. Springer.

[14] Sjöström. The sense of touch provides new computer interaction techniques for disabled people. Technology and Disability, 1999.

[15] A. Johansson, J. Linde. Using Simple Force Feedback Mechanisms as Haptic Visualization Tools. In Proc. of the 16th IEEE Instrumentation and Measurement Technology Conference, 1999.

[16] Q. Wang, V. Levesque, J. Pasquero, V. Hayward. A Haptic Memory Game using the STRESS2 Tactile Display. In CHI2006, Montréal, Québec, Canada. ACM.

[17] R. Raisamo, S. Patomäki, M. Hasu, V. Pasto. Design and evaluation of a tactile memory game for visually impaired children. Interacting with Computers, 19(2):196-205, 2007.

[18] G. Evreinov, T. Evreinova, R. Raisamo. Mobile games for training tactile perception. In ICEC 2004 - Third International Conference on Entertainment Computing, volume 3166 of LNCS, pages 468-475, Eindhoven, The Netherlands. Springer.

[19] A. Crossan, S. Brewster. Two-handed navigation in a haptic virtual environment. In Extended Abstracts of CHI2006, Montréal, Québec, Canada. ACM.

[20] X. Rodet, J.-P. Lambert, R. Cahen, T. Gaudy, F. Guedy, P. Mobuchon. Study of haptic and visual interaction for sound and music control in the Phase project. In Proceedings of the 2005 conference on New interfaces for musical expression, pages 109-114, Vancourer.

[21] E. Velleman, R. van Tol, S. Huiberts, H. Verwey. 3D Shooting Games, Multimodal Games, Sound Games and More Working Examples of the Future of Games for the Blind. In K. Miesenberger, J. Klaus, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 (9th. International Conference on Computers Helping People with Special Needs), Vol. 3118 of LNCS, pp 257-263, Paris. Springer.

[22] T. Westin. Game accessibility case study: Terraformers – a real-time 3d graphic game. In Proc. of the The Fifth International Conference on Disability, Virtual Reality and Associated Technologies, Oxford, UK, 2004.

[23] M. T. Atkinson, S. Gucukoglu, C. H. C. Machin, A. E. Lawrence. Making the mainstream accessible: What's in a game? In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pages 380-387, Linz, Austria. Springer.

[24] T. Gaudy, S. Natkin, D. Archambault. *Classification des jeux sonores selon leur type de jouabilité*. In Proceedings of Handicap 2006 Conference, pp 221-226, Paris.

[25] M. Feir. A Decade's Accessible Gaming: An Old Editor's Anniversary Observations, 2006. Audyssey, 49.

[26] D. Archambault, D. Burger. Development Tools for Non Visual Education Applications. In Proc. CSUN'99 (14th Annual Conference "Technology and Persons with Disabilities"), Los Angeles, California, USA, 1999.

[27] D. Archambault. The TiM Project: Overview of Results. In K. Miesenberger, J. Klaus, W. Zagler, D. Burger, editors, Proc. ICCHP 2004 (9th. International Conference on Computers Helping People with Special Needs), Lectures Notes in Computer Science 3118, pp 248 - 256, Berlin. Springer.

[28] D. Archambault, D. Olivier, H. Svensson. Computer games that work for visually impaired children. In C. Stephanidis, editor, Proceedings of HCI International 2005 Conference, Las Vegas, Nevada. 8 pages (proceedings on CD-Rom).

[29] A. Puret, D. Archambault, N. Monmarché, M. Slimane. A simple game generator for creating audio/tactile games. Technology and Disability, 18(4):227-236, 2006.

[30] J. Hammarlund. Computer play for children who are severelly visually impaired: Using an alternative keyboard with tactile overlays. Technical Report 20, Tomteboda resource centre, Stockholm, Sweden, 1999.

[31] D. Grammenos, A. Savidis, C. Stephanidis. Ua-chess: A universally accessible board game. In Salvendy, G., editor, Proceedings of the 3rd International Conference on Universal Access in Human-Computer Interaction, Las Vegas, Nevada, 2005.

[32] D. Grammenos, A. Savidis, Y. Georgalis, C. Stephanidis. Access invaders: Developing a universally accessible action game. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pages 388-395, Linz, Austria. Springer.

[33] R. Ossmann, D. Archambault, K. Miesenberger. Computer game accessibility: From specific games to accessible games. In Proceedings of CGAMES'06 Conference (9th International Conference on Computer Games), Dublin, Ireland, 2006.

[34] IGDA, I. G. D. A. Accessibility in games: Motivations and approaches. <http://www.igda.org/accessibility/IGDA_Accessibility_WhitePaper.pdf>, 2004.

[35] R. Ossmann, K. Miesenberger. Guidelines for the development of accessible computer games. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp 403-406, Linz, Austria. Springer.

[36] M. Tollefsen, A. Flyen. Internet and accessible entertainment. In K. Miesenberger, J. Klaus, W. Zagler, A. Karshmer, editors, Proc. ICCHP 2006 (10th. International Conference on Computers Helping People with Special Needs), Vol. 4061 of LNCS, pp 396-402, Linz, Austria. Springer.

Computer Vision Tools for Visually Impaired Children Learning

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Computer Vision is an area within Artificial Intelligence devoted to the definition of artificial cognitive models to process visual information. Computer Vision can be used to develop useful tools for visually impaired people. This is because it allows the extraction of information associated with visual inputs, by means of optical sensors as digital cameras or scanners. In this paper we present two software tools developed for visually impaired children or children with low vision. The first is a system to translate scanned Braille texts. The second applies techniques of on-line shape recognition to interpret simple geometric shapes drawn using a digital tablet. This tool allows children to learn, in an autonomous way, basic concepts of graphical shapes and spatial relations.

Keywords: Document Image Analysis, Graphics Recognition, Sketching Interfaces.

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Figure 1: a) Translation System Braille-View. b) Translation Results.

1 Introduction

Computer Vision is a computer based technology devoted to studying ways of extracting information from images in order to understand them. One of the functions of Computer Vision is Document Image Analysis which combines techniques of image processing and shape recognition to process and interpret electronic documents [1]. Electronic documents range from scanned images of paper documents to those already generated by a digital process as e.g. pdf files, e-mails, web documents or graphics and diagrams drawn by a design software. This research line is divided in two main sub areas of interest: the recognition of textual information (OCR *Optical Character Recognition*) and the recognition of graphical information which appears in plans, diagrams, maps, etc. OCR is one of the pioneer activities of the Pattern Recognition domain and early works in this area come from the 50's [2]. Graphics Recognition, however, can be considered a more recent activity, with an increasing interest in recent years. It initially arose from the need to digitize plans and maps to automatically embed them into CAD and GIS systems, and lately is much used with new devices based on hand drawn interaction, as Tablet PCs or PDAs [3] [4].

Computer Vision has an increasing interest as a support technology for visually impaired people. Some examples, such as bar code readers to identify products in supermarkets, color identifiers to select clothes, or document readers, are applications that, combined with speech synthesis mechanisms, are useful tools. This paper describes two Computer Vision applications for visually impaired children and their teachers and families. These applications are currently being developed at the Computer Vision Center (CVC) of the *Universitat Autònoma de Barcelona* (UAB) in collaboration with the *Centre de Recursos Educatius Joan Amades* of the Spanish Blind People Association (ONCE). The first application consists of a translator from Braille to *view*. View is the name used to refer to the regular printed information in hard copy among non-visually impaired people. It is used as an opposite term of Braille, the touching-based format popular among some visually impaired people. Thus we use the above two terms to refer the two ways to present information in paper documents, visual or relief-based. Translating texts from Braille allows children to share their homework with other people without their needing to know Braille notation; moreover it allows duplication of Braille texts without retyping them. The second application allows visually impaired children and children with low vision to learn, in an autonomous way, how to draw geometrical shapes or capital letters or to retrace them, all using a digital tablet. This learning paradigm is useful in different ways. For example, to follow parallel lines is a step in the learning of reading Braille, as to do it the child needs to follow the Braille characters that appear placed in parallel lines. To learn to write short texts in *view* mode can help them to communicate with other people or to give them notes. Finally, with this tool children are able to draw simple scenes or reality concepts, e.g. the human body or a landscape. It allows them to understand scale and spatial

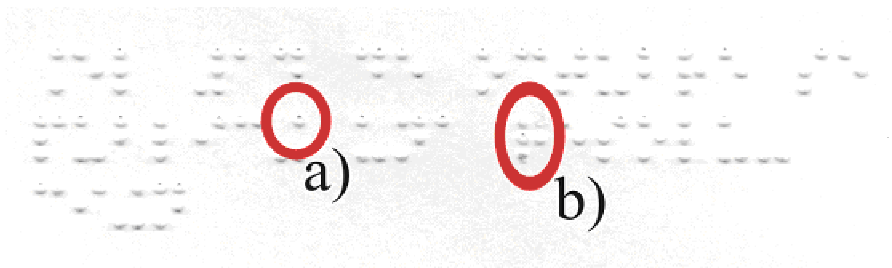

Figure 2: Imperfections in Braille Dots.

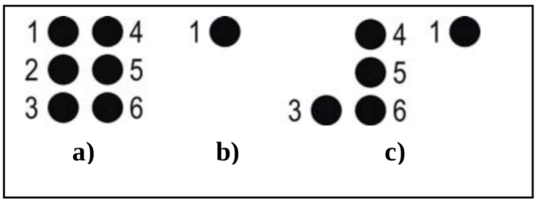

Figure 3 : Structure of a Braille Character. a) Generator Symbol, b) Letter "a", c) Number "1".

concepts of reality. Moreover, the system cleans up the introduced hand drawn predefined shapes, improving the final appearance of an edited document.

From a scientific point of view both applications belong to the two main lines of the Document Analysis research field stated in the above paragraphs: text and graphics analysis. The aim of the translation of Braille texts is a particular case of OCR named OBR (*Optical Braille Recognition*) [5] and the interactive recognition of graphical shapes designed by means of a digital tablet, is a case of graphical symbol recognition [3].

In the rest of the paper we further explain both applications and their technological basis. Section 2 presents the Braille translator, Section 3 explains the application of graphical shape recognition, and finally Section 4 is devoted to the conclusions.

2 Translator from Braille to View

In this section we present the framework wherein the application has been developed and some of the technological principles forming the basis of its construction.

2.1 Purpose and Application Framework

Unlike the majority of other published systems which use papers made by a Braille printer, the system presented in this paper works with handwritten documents by means of a Perkins typewriter, see Figure 1. Nowadays, a visually impaired child who has not yet started to use a computer to create his/her documents, uses this kind of typewriter. When the child is integrated into a school where neither teachers nor students are able to understand Braille, someone has to translates these documents, in order for them to be shared or evaluated. This task is done by assistant teachers who go to the schools periodically. A simultaneous translation of these papers allows the children to share them with their environment in a more dynamil way. Their teachers can correct their homework or exams in a more direct and agile way, and they can give their marks at the same time as the rest of the students. Their classmates can understand their homework and this facilitates the integration of the child with them. Finally their families can also follow up the progress of their children as they can understand their homework. The system presents another more generic advantage, the possibility to "photocopy" a Braille text. To duplicate a Braille text means that it has to be reprinted with its relief necessitating recognition of the original text and reprint it with relief. Nowadays this process can only be done by manually retyping the text, but with this system it is possible to scan, analyze and save the text in a digital format without retyping it.

The system consists of a personal computer connected to a scanner. Directly from the application it is possible to scan a Braille document, recognize the Braille characters and translate them. The Braille notation has different interpretation styles. Thus it allows writing, apart from plain text, music, chemical symbols, mathematical formulae, etc. Each of these domains has its own symbols and placement rules, and some common symbols that have different meanings depending on the domain in which they appear. It allows a code based in six dots to have a high representational power (There is another codification based on eight dots which is not considered in this paper). However, since the analyzed documents are made by little children using a Perkins typewriter, the possibility exists of having some imperfections such as "deleted" points, i.e. points flattened that are not "read" by the fingers but usually visible in the scanned image, see Figure 2 b). It is also possible that a paper read (i.e. touched) several times, can have some stains on it. Sometimes the sheets are taken out of the typewriter to be read and then reintroduced to continue typing; this may result in some misalignments in the characters and in their separation with the rest of the lines. Finally the pressure exerted when the child is enthusiastically tapping the keys can create some little holes in the Braille relief points, these holes will appear as additional shadows in the image, see Figure 2a). As a result there are papers with different kinds of imperfections: stains that can be misunderstood with real Braille points, "deleted" points that can appear as non-deleted points, double points produced by the holes in the paper, misalignment of lines and rows, etc.

2.2 OBR Technology

An OCR application is software that converts a digital image of text, acquired by a scanner or digital camera, to a text file that can be edited by a text editor [6] [7]. Nowadays there are a number of commercial OCR tools, sometimes distributed with scanners, which perform this function. OCR avoids the need to retype printed texts. From a technological point of view, an OCR system consists of three phases: low level process, segmentation/detection of the document structure and character recognition or classification. The low level process applies techniques of image processing to enhance digital images acquired from paper (using contrast enhancement, filters to delete shadows, stains and different kinds of noise etc.). The segmentation process separates and labels the components forming the physical structure of the document which are structured in a hierarchical way as: paragraphs, lines, words and characters. Finally, the recognition or classification step identifies, for each image zone containing a character, which character it is. The latter process compares a set of features extracted from the image [8] with the models or patterns previously

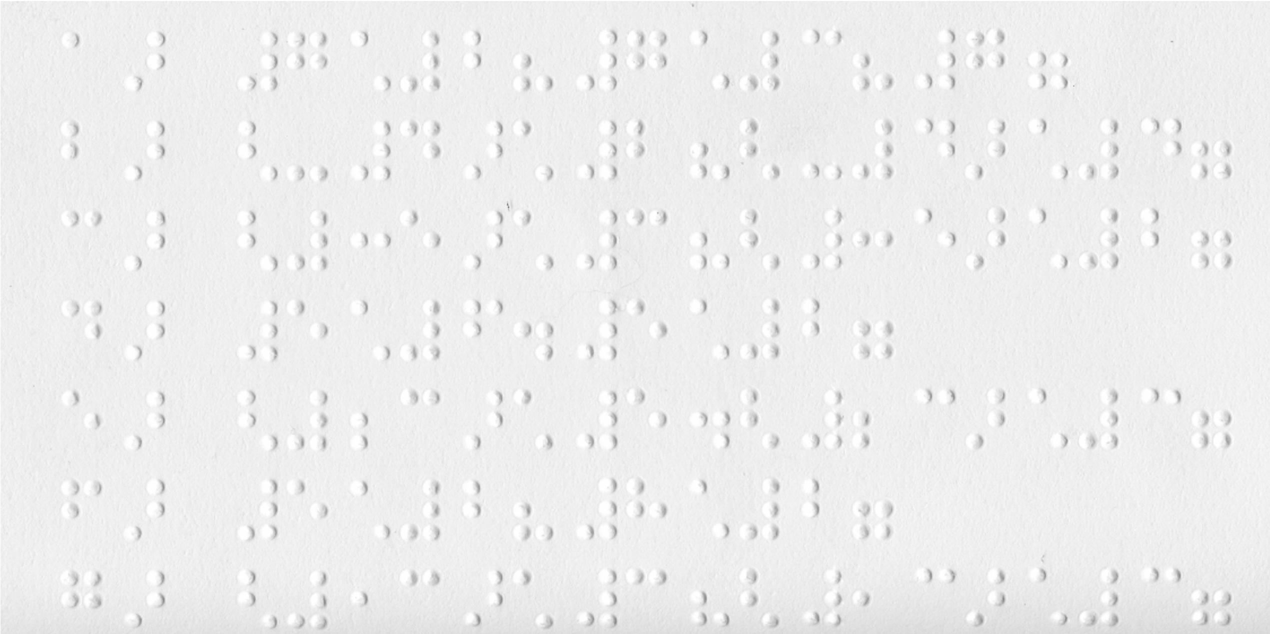

Figure 4: Scanned Image of a Braille Document.

learned that are stored in a reference database. From a scientific point of view, optical character recognition is a mature problem. Nevertheless, there are still some open research lines such as omnifont recognition, that is, OCR capable of recognising printed texts in any typography; or the recognition of handwriting, called ICR (*Intelligent Character Recognition*). *Optical Braille Recognition* (OBR), is a particular case of OCR. It has two main differences from the classical OCR solutions. First the text is not printed, but it is marked with relief dots that in terms of a visual process, result in shadow dots. We have to take into account that Braille documents are there to be touched and not seen. It implies that the paper used can have some visual marks that can increase the difficulty of the artificial vision process. Examples of that are stains or characters or points deleted resulting in false shadows. Secondly, the typography is not formed by a set of symbols like letters or numbers, but the characters are formed by a matrix of six points distributed in three rows and two columns, or a sequence of them. This matrix is the generator symbol, see Figure 3a**)**. The codification of each character is based upon which points are active each time and in their context. For example, the symbol used to indicate the letter **a** and the number **1**, Figure 3b) and Figure 3c) respectively, is the same, but in the second case there is a previous character indicating that the following character has to be interpreted as a number. Ac-

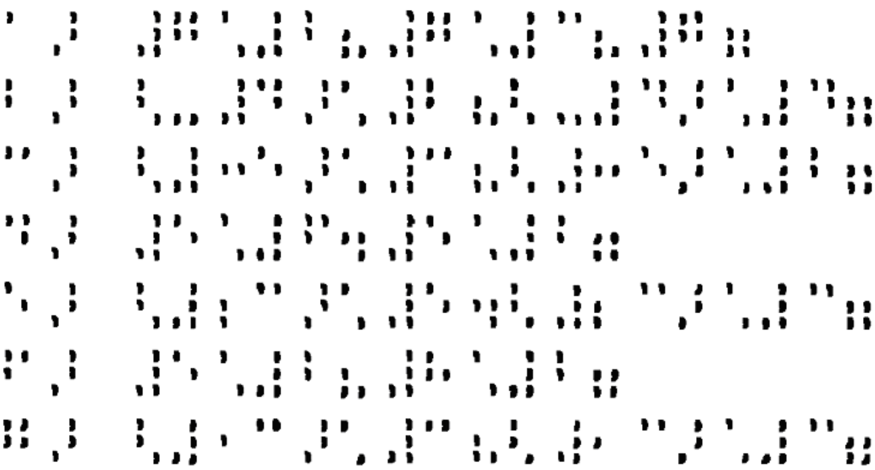

Figure 5: Extraction of Dots from the Original Image Appeared in Figure 4.

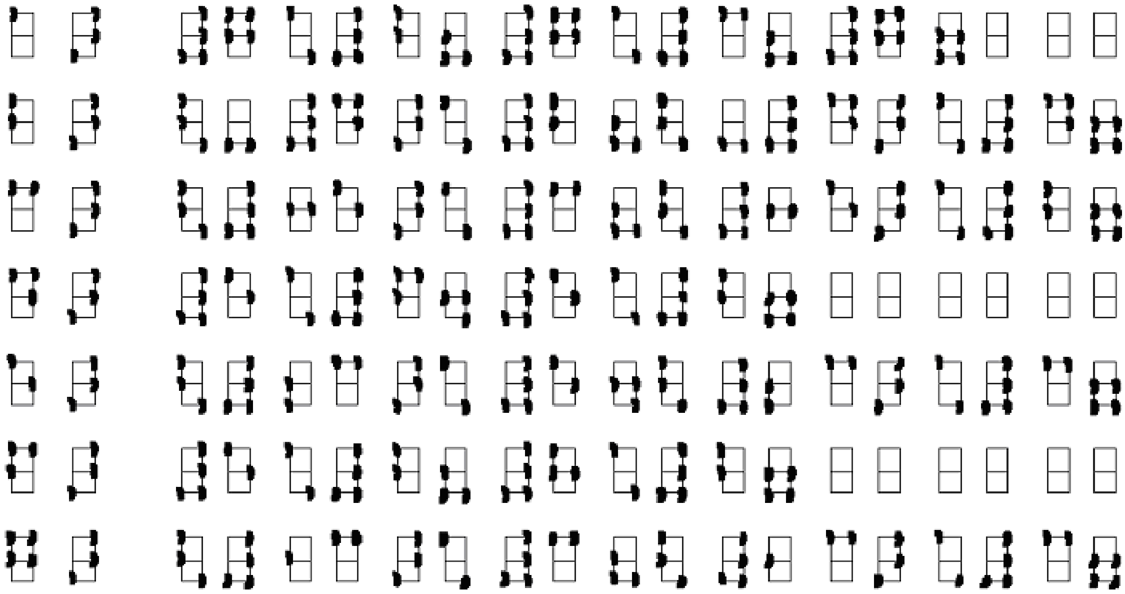

Figure 6: Groups of Dots Forming Characters Found in the Image of Figure 5.

cording to this, to segment Braille characters means to find and to group the points that are forming a character, which will appear as little shadows due to their relief and the scanner illumination. Once the Braille characters are segmented, to interpret them involves firstly to classify them according the active points they have, and then to analyze their context to give them an interpretation.

There are several published papers concerning Braille recognition, see [5]. The system presented in this paper has the following steps:

a) Image scanning: The image is obtained by scanning a sheet of paper with typed text in Braille with a standard flatbed scanner. The recommended scan resolution is 200 dpi, to have enough information for subsequent analysis. Likewise, the pages are expected to be scanned in a vertical position, although they can have a small deviation of ±3 degrees due to manual placement. If the resolution is not high enough there will be not enough information to analyze the image, but if it is too high the image will be too big. See Figure 4 as an example of scanned image.

b) Image filtering: The image of the scanned document presents the Braille points as shadows but also some marks as little holes, stains and other not desired marks. In this process the extraneous marks are deleted as far as possible. At the end of the process a binary image is obtained with two values representing the background and the dots respectively. To obtain it some image filtering techniques are used: first an adaptive binarization is done to classify pixels as background or foreground (Braille dot). Then pixels are grouped in connected components, using techniques of mathematical morphology, and the area of each region is computed. At the end, depending on their area the regions are selected as possible Braille dots. Figure 5 shows an example.

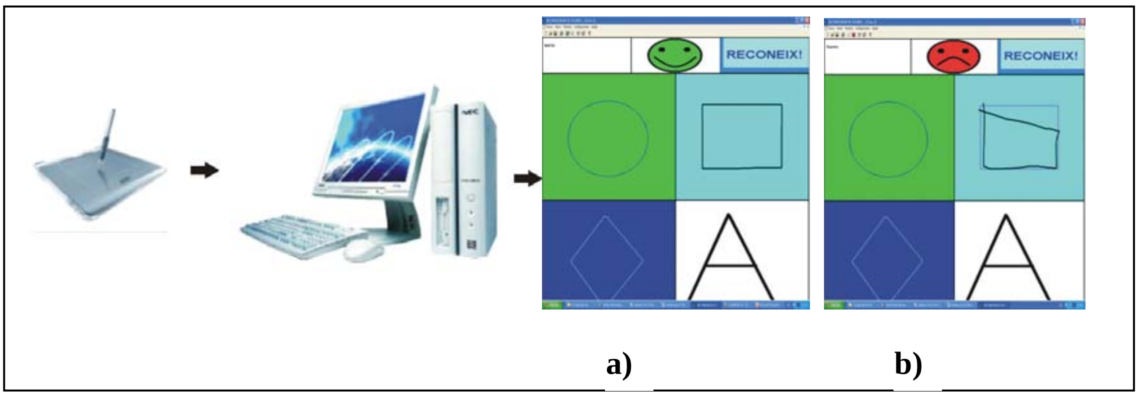

Figure 7: Graphical Recognition System. a) Correct Answer, b) Wrong Answer.

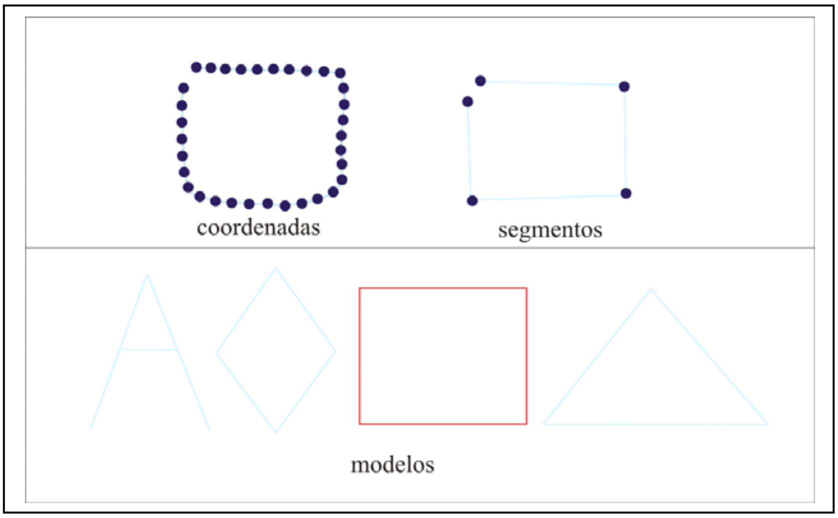

Figure 8: Presentation of Coordinates Introduced by means of a Digital Tablet, the Extracted Segments and the Possible Models to Be Compared. The Selected Model is Marked in Red Color.

c) Extraction of the position of the characters: Once the image is binarized and the pixels forming Braille points are found, it is necessary to determine how these points are placed in lines and rows, and then to group them following the generator symbol shown in Figure 3a). Figure 6 shows an example of groups of six position structures found in a document. Generally speaking, the documents written in Braille have predefined horizontal and vertical distances among points belonging to the same character and also between two consecutive characters. These distances have been selected to make documents in Braille more comfortable to read. For that reason, if the scan process is always done using the same resolution these distances can also be preset. However, as the image shows the shadows of the points and not the points themselves, there are some deformations and variations in these parameters. Moreover some errors may appear due to the gauge of the Perkins typewriter, and the fact that people can introduce and extract the sheet of paper from the typewriter may also generate distortions in the alignment of the points.

Some of the techniques used in this step are: the Hough transform [9] to find the alignment of points in the image, and the analysis of the histogram of the map of distances among points, to automatically compute the horizontal and vertical distances among dots inside a character and between two different characters.

d) Character recognition: Once the points have been grouped into characters they are classified following the position of these points. A lookup table with an entry for each possible combination of points indicates is a valid codification and the valid possible interpretations according to the different modes. Current possible modes are: text or mathematics, Spanish or Catalan, capital or non capital letters. In future versions new modes will be added, as other languages, and other special languages as the musical or chemical ones. The distinction among languages is necessary for special characters as the ñ or the ç, and the accented or with dieresis vowels, etc. The special languages such as mathematics, chemistry and music have special symbols and combination of symbols with their own special meanings, similar in concept to those shown in Figure 3b) and Figure 3c).

e) Translation of the character sequence: Once the possible translations of the Braille character found in the image are obtained from the translation table, the correct translation is selected following the active mode of the document at that moment. There are some special characters that represent an alteration in the mode. At the start we assume non capital letters and a predefined language, for example Spanish, and then when some special characters appear the mode is changed to capital letters or cursive or mathematics and so on. The valid sequences of Braille characters that can appear in a document are modeled by a grammar. In the grammar the changes of modes are also modeled when certain special symbols or sequences of symbols are analyzed. Following the grammar and taking into account the active mode, the Braille character is analyzed using the translation table and the active mode, or changing the mode when the character is the special one for that purpose. If a syntactical error is found in the transcription, for example a missing parenthesis in a mathematical formula, it is possible to give an error message and continue with the rest of the transcription. This error tolerance is important, as the analyzed documents are made by children and they can contain some errors, but it is necessary to continue translation to allow their teachers to make any corrections with the pupil present.

3 Sketch Understanding

In this section we describe the tool for understanding sketched drawings, its applications and the pattern recognition techniques used in it.

3.1 Purpose and Application Framework

Usually, visually impaired children use a plastic sheet to make drawings so that the drawings can be seen but also perceived by touching the relief. Also, computers can "see" the drawings input by touching devices like a digital tablet or a tablet PC. Our idea was to join both drawing modes by adding a plastic sheet on the screen of a digital tablet. Thus, while the strokes made by the user are digitally acquired by the electronic device as a sequence of 2D coordinates, they are also marked in relief in the sheet so can be touched by the user.

Our system allows teachers to define new forms as exercises to practice with the sketching input possibilities. These forms can be designed to interactively learn geometric shapes, graphical symbols and diagrams, letters, or any other symbol consisting of strokes. In addition, our system can be used to include diagrams in documents after cleaning up. Forms have different zones with associated functions. For example a zone can have a drawing and the associated function of aligning the input strokes with the lines of it. The aim would be to measure the ability of the user to follow (redraw) the lines of a given drawing. In addition this activity zone has two audio messages depending whether the action is right or not.

Once the form has been designed, it can be printed with a special printer that makes the reliefs of the Braille dots and associates textures to colours. The form is printed on a plastic sheet that is placed on the digitizing tablet during the activity. Thus the child can "read" the instructions by touching the relief and interact with the system by touching the cells and getting audio feedback, or drawing with the digital pen on the tablet by following the drawing, or copying it into another cell, etc.

The double system, relief plastic sheet and digital tablet, allows the visually impaired user first to touch the figure, and then to draw it with the digital pen. Digital strokes are captured from the computer and interpreted and the computer gives audio feedback accordingly. Thus, for example the system compares the input figure with a database of models like square, circles, animal silhouettes, capital letters, etc.

The teacher, when designing the forms, can record audio responses or visual ones like emoticons associated to activity actions. Visual outputs allow the system to be used by non-visually impaired or low vision users. An outline of the system is shown in Figure 7**.** An interesting survey on similar interfaces can be found in [10].

3. 2 A Framework Based on a Sketching Interface

The technological basis of our system is the recognition of graphical symbols. It can be defined as the identification and interpretation of visual shapes depending on the domain. It means that the same symbol can have different meanings depending on the context in which it appears. According to the input mode, we can classify the recognition of graphical symbols in two categories, namely *off-line* or static recognition, and *on-line* or dynamic recognition. The former uses a scanned document and only works with the spatial information of the image strokes. The latter interactively obtains the document, using an input device as a digitizing tablet or Tablet PC, so it additionally has dynamic information of the temporal sequence of strokes, speed, pressure, etc. Our work is based on on-line recognition of hand drawn graphical symbols by a digitizing tablet. Such type of man-machine interfaces are called *sketching* (or calligraphic) *interfaces*.

Related works can be read in [11] [12]. *On-line* recognition consists of three steps: acquisition, primitive recognition and interpretation. The acquisition step consists of extracting the strokes from the graphic device and encoding them as a sequence of coordinates or lines approximating the input as well as dynamic information such as speed, pressure, etc. Primitive recognition consists of associating the strokes with basic graphic structures as polylines, circumference arcs, basic geometric shapes, etc. Finally the interpretation step aims to associate a semantic meaning to the graphical structure consisting of basic primitives. This step requires the use of semantic knowledge of the working domain. Let us further describe these steps in our system.

a) Acquisition of drawing strokes: when the user draws on the digitizing tablet, the electronics of it convert the input to a sequence of coordinates that are sent to the computer. Thus, each stroke of the drawing is encoded as a sequence of coordinates, see Figure 8. Taking as curves such sequences of coordinates, singular points as maximum curvature points, crossings, end points, etc. are detected. It allows conversion of the strokes in sequences of segments as Figure 8 illustrates.

b) Primitive recognition: The extracted segments are grouped into primitives. These primitives depend on the application domain. For example, in flowchart diagrams primitives can be squares, circles, arrows, etc. In our case, the alphabet of primitives consists of the valid shapes as squares, diamonds, circumferences, etc. In the example shown in Figure 8 the detected primitive is an open polyline identified as a square

c) Interpretation: The last step is the validation of the drawing after comparing it with possible models. For example, in the case of forms requesting a particular drawing, the input is compared with the ideal pattern with a distortion tolerance allowed for due to the hand drawn input, and an acceptance decision is made. In Figure 8 we show a shape that was drawn and recognized as square, and the corresponding model of Figure 7a). On the contrary in Figure 7b), we can see another square but with a high degree of distortion regarding the model and that has been rejected. In freehand drawings, each input shape is compared with all the models in the database and is recognized as the model with minimum distance, under a given threshold. The models are generated using a set of examples that allows definition of the primitives and topological relations among them. The comparison between shapes is formulated in terms of both shape and topological relation similarities.

4 Conclusions

This paper presents two systems based in Computer Vision that are used for the learning activities of visually impaired children. The first one uses OBR techniques to translate Braille documents and integrates a module of speech synthesis to be able to communicate with the child. This system helps the integration of the child in a school. The second applies graphical symbol recognition techniques in a tool that allows the child to learn graphical shapes in an autonomous way. Both systems have additional benefits. The first one allows to "photocopy" the Braille texts that are only in a sheet of paper, while the second one allows the reshaping of hand drawn designs to render them suitable for introduction into documents. Nowadays both systems are in a developing phase after the creation of a first prototype.

Acknowledgements

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References

[1] T. Sakai. "A history and evolution of document information processing", Proceedings of 2nd International Conference on Document Analysis and Recognition, Vol. 1, pp. 377-384, October, 1993.

[2] V.K. Govindan, A.P. Shivaprasad. "Character Recognition - A Review". Pattern Recognition, Vol. 23, No. 7, pp. 671-683, 1990.

[3] J. Lladós, E. Valveny, G. Sánchez, E. Martí. Symbol recognition: current advances and perspectives, in "Graphics Recognition: Algorithms and Applications", Y.B. Kwon, D. Blostein eds. Lecture Notes in Computer Science, Vol. 2390. Springer-Verlag, 2002.

[4] W. Liu. "On-Line Graphics Recognition: State-of-the-Art". In book "Graphics Recognition. Recent advances and Perspectives", J. Lladós and Y.B. Kwon (eds). LNCS-3088, Springer-Verlag, 2004. pp. 289-302.

[5] R.T. Ritchings, A. Antonacopoulos, D. Drakopoulos. "Analysis of Scanned Braille Documents". In book "Document Analysis Systems", A. Dengel, A.L. Spitz (Eds.). World Scientific Publishing Co., 1995, pp. 413-421.

[6] H. Bunke, P.S.P. Wang. "Handbook of Character Recognition and Document Image Analysis". World Scientific, 1997.

[7] T. Pavlidis, S. Mori. "Optical Character Recognition". Special Issue of Proceedings of the IEEE, Vol. 80, No. 7, 1992.

[8] O.D. Trier, A.K. Jain, T. Taxt. "Feature Extraction Methods for Character Recognition - A Survey". Pattern Recognition, Vol. 29, No. 4, pp. 641-662, 1996.

[9] P.V.C. Hough. Method and Jeans for Recognising Complex Patterns. Technical Report, 1962. U.S. Patent No. 3069654.

[10] H.M. Kamel, J.A. Landay. "Sketching Images Eyes-free: A Grid-based Dynamic Drawing Tool for The Blind." In ASSETS 2002: Proceedings of the Fifth International ACM SIGCAPH Conference on Assistive Technologies, Edinburgh, Scotland, July 2002.

[11] J. A. Landay, B. A. Myers. "Sketching Interfaces: Toward More Human Interface Design." IEEE Computer, Vol. 34, No. 3, March 2001, pp. 56-64.

[12] T. Stahovich, R. Davis, J. Landay. Proceedings on 2002 AAAI Spring Symposium Sketch Understanding. Stanford University, Palo Alto. March, 2002.

Technology and Education in the Field of Visual Impairment

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In this article we look at the use of Information and Communication Technologies (ICT) in the education of visually impaired learners with a view to ensuring that they achieve the maximum degree of independence in society. We start by looking at the present situation, mentioning the tools used (hardware and software) and the working methodology from early childhood up to adulthood. We reflect on the difficulties that we encounter and their possible solution, and we consider how the design of assistive tools in accordance with accessibility guidelines can help the visually impaired.

Keywords: Accessibility, Digital Tools, Educational Portals, Low Vision and Blindness, Magnifier, Screen Reader, Usability.

1 Introduction

Learners with visual impairment need to acquire basic competencies in the communication and information society [1] and enjoy the same learning opportunities in ICT as their sighted counterparts.

Sighted children observe, imitate, and are constantly surrounded by technology. They press buttons, touch computers and "play" on them whenever they are allowed to. However, visually impaired children need help and support at this initial stage. They require existing resources to be adapted to their needs and presented to them by others.

Thus it is difficult for visually impaired learners to access technology at an early age. **As professionals we need to be creative, innovative, and find alternative ways for these children to access computers in these early stages.**

We will divide our approach into two stages: from early childhood up until 7 or 8 years old we will use "guided applications" (applications that can be used without a screen reader), and from 8 years old on, "unguided applications" (applications that require screen reading software and/or hardware).

2 Working Methodology and Basic Resources in the First Stage

When visually impaired children reach school age at the age of three, they attend a regular school where their spe-

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Lucía Melchor-Sánchez worked as a support teacher in integrated education programmes for visually impaired children from 1992, forming part of blended learning teams and the compulsory education team of the Joan Amades Educational Resources Centre (CREc). In 1998 she began to study Psychopedagogy (Educational Psychology) at the *Universitat Oberta de Catalunya* (UOC), where she used all the Internet-enabled tools available to students. Between 1998 and 2005 she researched into the possibilities afforded by the Web in terms of helping the blind become more independent, focusing especially, though not exclusively, on the field of education. Since 2005 she has formed part of ACCEDO group of the Joan Amades Educational Resource Centre, where she has participated in a great many training courses, delivered either to other professionals in the field of education or to visually impaired learners. She has taken an active part in various conferences, sessions, round tables, and forums related to technology for the visually impaired. <lms@once.es>.

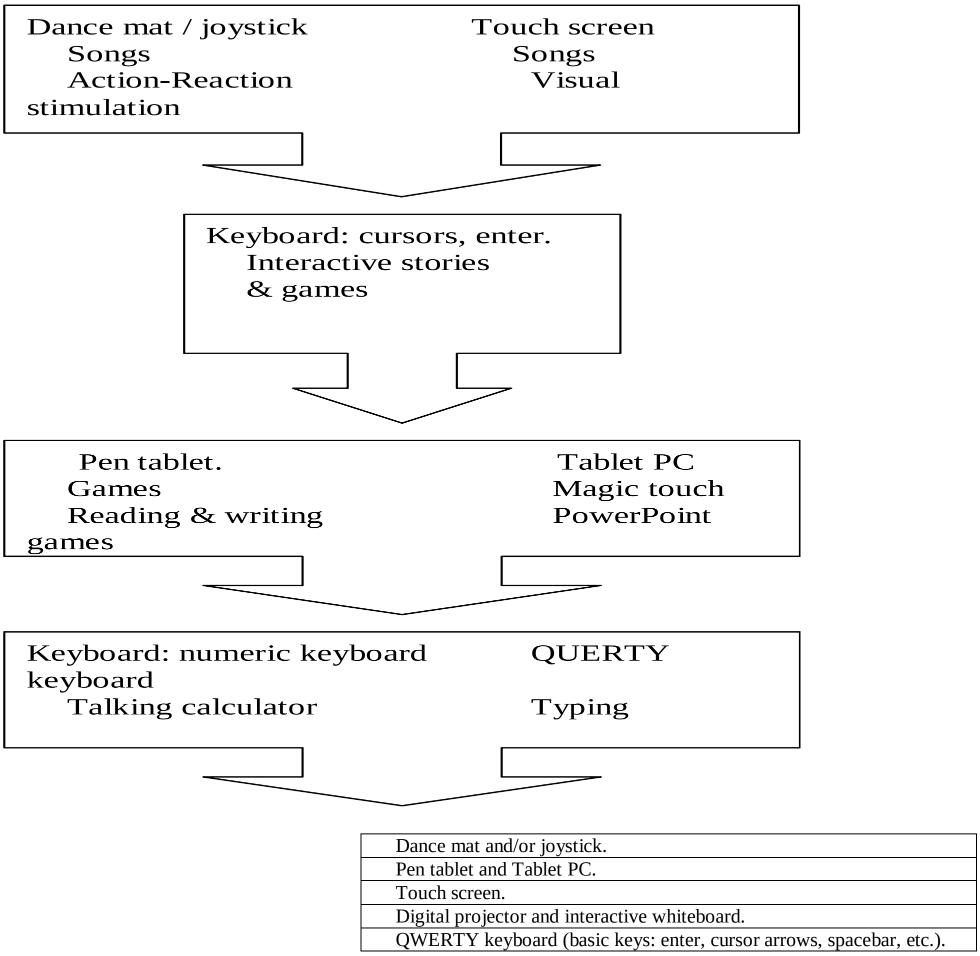

Figure 1: Tools Selected for the First Stage.

cial training is provided by their classroom teachers and support teachers from ONCE. Every so often they attend ONCE's Educational Resource Centre in Catalunya where they receive special training in a number of subjects, including assistive and adaptive technology for the visually impaired.

The selection of the appropriate resource for a blind learner or one with low vision depends on many variables at the same time: the learner's maturation process, their learning capacity, when ICT is first introduced, the priority given to learning Braille, and other aspects. Teachers must bear in mind and take advantage of the recreational and motivational value of ICT, the children's integration with their classmates, and the opportunity to reinforce learning with play.

We go on to show how we introduce peripherals and software, based on our experience at the Resource Centre and at regular schools.

2.1 Tools

The tools selected (see Figure 1) are basically the following:

- **Dance mat or dance pad.**

A dance mat is a game device that works like a joystick which allows little ones to access computers as it can be operated with either the feet, the hands, or any part of the body. This device, used in conjunction with open educational software for creating stimulus-action-reaction activities, enables visually impaired learners to access computers and play.

Objects and different textures can be placed on the surface of the mat to encourage visually impaired children to explore and investigate the play area which emits an audio response whenever an object is touched. We use this game to work on concepts of action-reaction, spatial orientation, motivation, and educational concepts such as children's songs, animal noises, colours, etc. [2][3].

- **Pen tablet and Tablet PC.**

The pen tablet is a communication peripheral which replaces the keyboard and allows embossed overlays to be placed over its surface in order to provide a schematic representation of what is on the screen. The visually impaired learner operates the application's controls by moving an optical pen over the area represented by the embossed overlay and so is able to interact with the computer.

The pen tablet allows users to work with any software – Internet games, PowerPoint presentations, educational games – provided that these applications meet two requirements: they must be guided applications (i.e. they must be equipped with sound to guide the learner), and the screens used in the activity must not change too often. An example of these activities can be seen in [4].

To find out about making and adapting the overlays, see the guide in [5].

Tablet PC enables learners with low vision to work with an application using an optical pen instead of mouse. Windows Journal provides an easy way for pupils to start learning reading and writing skills by transforming the information directly to a word processing program.

- **Touch screen.**

This peripheral is an indispensable ally for learners with very low vision as it provides computer access to learners who cannot yet control a mouse. The hand is a direct prolongation of what they see with their eyes and they don't need to perform the necessary hand-eye coordination via any intermediary device.

- **Digital projector and interactive whiteboard.**

The digital projector is a basic tool in a visual stimulation room. It allows us to project the image of a computer screen wherever and as large as we want. This tool, used in an appropriate working environment with dim lighting and sound etc. and with appropriate visual stimulation software, allows professionals working with learners with low vision to evaluate the visual acuity of their charges and conduct visual training exercises.

Examples include the EVO program *(Estimulación Visual por Ordenador* or Computer Generated Visual Stimulation) [6] and EFIVIS.

- **QWERTY keyboard.**

From 7-8 years old, learning the QWERTY keyboard is fundamental to accessing computers and their applications. This learning process is structured in stages. First the basic keys are introduced (cursor arrows, enter, spacebar) by means of interactive games such as stories (Sleeping Beauty, Little Red Riding Hood, etc.) [7]. Next the numeric keyboard is introduced, using talking calculator software or specific games, for example. Finally, the whole keyboard is learned using traditional typing instruction methods (for example, learners with low vision can use Teclado 2.0 software which lets you alter letter fonts and background colours, and blind learners can use word processing and a screen reader, or ONCE's DIO interactive typing program). Strategy and skill games that are controlled by the keyboard may also be used [7].

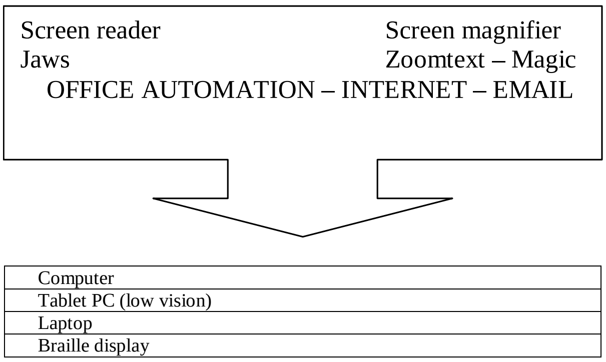

Figure 2: Tools Selected for the Second Stage

3 Working Methodology and Basic Resources in the Second Stage

In the second stage, once learners with visual impairment have learned how to use the QWERTY keyboard, they can go on to use most of the applications included in the curriculum. Some specialized applications are now introduced (the JAWS screen reader and screen magnifiers), and the use of standard (computer, laptop) and special (braille display) devices.

Below we show how we introduce peripherals and software based on our experience at the Resource Centre and at regular schools.

3.1 Tools

The tools selected (see Figure 2) are basically the following:

- **Laptop.**

Once the learner has learned how to use the QWERTY keyboard, we introduce the use of the laptop in the classroom as a tool that provides access to information and the day-to-day work in an effective and independent manner. For blind learners we use laptops with the JAWS screen reader, and for learners with low vision we use laptops with screen magnifiers.

- **JAWS screen reader.**

This program captures information from the computer and delivers it to the user as voice and/or braille output.

- **Zoomtext or Magic screen magnifiers.**

These magnify the characters and enable the colours to be configured according to the needs of low vision users.

- **Braille display.**

This is a device that is connected to a computer and converts the information on the screen, line by line, into braille for blind users.

At [8] interested readers can obtain further information and download demos of the abovementioned programs.

3.2 Working Methodology

Since learners with low vision generally have no difficulty following the set curriculum in spite of having to use a screen magnifier, our working methodology will concentrate on blind learners.

It is important to bear in mind that, while the tools we use are fairly standard, the way we teach them is necessarily special, since the graphical environment provided by the Windows operating system, and practically all applications, enable most normally sighted people to use them in an almost intuitive manner whereas the visually impaired, and especially the totally blind, find them difficult to use.

Specialist teachers in visual impairment use special methods to teach these applications, so that children can learn use them without assistance in the shortest time possible. Among the skills learned are familiarity with the screen, use of hotkeys only when the application is to be used continuously, navigation using an application's toolbars, use of the computer and of the application's functions solely via the keyboard, etc.

Although hotkeys allow users to navigate faster, it is advisable to teach learners how to access an application's tools and functions via the toolbar. It is better if learners do not memorize the hotkeys for a particular application but rather come to think of navigating through menus as the norm, as this will help them be more independent when using a variety of applications.

Thus, our work focuses on three fundamental aspects:

1. Direct intervention to show learners how to use the computer in day-to-day classroom work, and to show them the usefulness of the computer in daily life.
2. To identify any resources that might be of use to achieve the first objective mentioned in point 1 above.
3. To draw up a basic plan that can be adapted to the needs of each individual learner.

The work schedule employed up until now covers the following topics:

- Basic concepts of the Windows Operating System.
- Microsoft Word or whichever word processing program is applicable.
- Dictionaries and encyclopaedias: Microsoft Encarta.
- Internet navigation: browsing, search engines (Google), information search and transfer to a word processor, etc.
- Email via a web page, creation of an address using servers such as Yahoo or Hotmail, Microsoft Outlook.
- Microsoft Excel spreadsheet: workbooks, simple formulae, graphs, combination with other Office applications.
- Microsoft Access database management: creation and management of tables, queries, reports, etc.
- Business management applications: Facturaplus, Contaplus, etc. Blind learners are taught strategies for using these applications with a screen reader.
- Graphic design applications are used by learners with low vision in conjunction with a screen magnifier. Blind learners do not have access to these graphical applications.

4 Main Challenges in the Future

The main challenges we face in the future are as follows:

- **Use of standard tools versus specialized tools**

Specialized tools are necessary in many areas but in education most of the professionals at the Educational Resource Centre favour the use of standard tools that are already equipped with the necessary accessibility features, for the following reasons:

- In the case of blind learners who write in braille, the laptop facilitates the exchange of material with teachers and classmates. It enables work to be corrected immediately and encourages classroom teachers to have a more active attitude towards learners. Standard tools are integrative.

- The price of standard tools and applications tends to be lower than specialized tools given that they are aimed at a larger market.

- The teachers at regular schools are familiar with standard tools, which makes it easier for them to help when a learner gets into technical difficulties.

- New versions of standard applications are released more often than specialized tools since specialized tools ultimately depend on innovations introduced in standard tools.

- Notwithstanding this preference for standard tools, they cannot always be used by visually impaired learners since they may not have the required accessibility features: voice synthesis, screen magnifiers, virtual keyboard, configurable colour, font, and size of characters, etc. Ideally, designers of new tools would follow universal design criteria and then we would not have to be thinking about specialized applications to make those new tools "accessible".

- **Lack of accessibility and usability of the applications and portals used in education.**

We live in a technological world in which visual aesthetics are all important. The appearance of new applications, educational portals, thematic search engines, etc. are opening up an increasing number of possibilities and teachers are including these tools in their classes to an ever growing extent.

The Internet has made it possible for the visually impaired to perform a great many activities independently which previously required the help of others (parents, teachers, co-workers or classmates): educational activities (online dictionaries and translators, museums, etc.), work-related tasks, leisure (online shopping, reading the newspaper, chatting, online banking, etc.)

However, none of this is possible if web pages are not accessible. It is necessary for web page developers to follow accessibility criteria and use all the available accessibility tools in their design programs (for example, the accessibility features of Macromedia Flash) so that visually impaired learners are not excluded from the technological society in which live and to prevent the "digital divide" from widening.

It is not enough merely to meet internationally recognized criteria in this respect, such as the WAI guidelines developed by the W3C Consortium [9]; usability criteria also need to be adopted and recommendations such as those described in [10] need to be followed.

- **Educational digital content and widespread use of the Internet.**

It would appear that the future trend in the field of education will be the ever-increasing use of digital content in classrooms and the widespread use of the Internet. This means that visually impaired learners must have unimpeded access to these materials if they are not to be left behind by the education system.

Consequently, these materials must not only be accessible via a screen reader but must also meet usability criteria. For this reason ONCE's Education Department has developed a set of guidelines with the aim of ensuring that visually impaired users have access to digital content [10].

Generally speaking, following these guidelines neither involves a greater programming effort nor any additional cost.

Some of the most common examples of inaccessible pages that blind people come across when using the Internet with their screen reader, and which the abovementioned set of guidelines aims to address, are:

- Images without alternative text.
- Videos without a text or audio description.
- Forms that cannot be navigated logically using the tab key.
- Browsers which do not support all keyboard commands.
- Non-standard document formats that cause problems for screen readers.

■ **Introduction of other operating systems and applications (Linux, OpenOffice, etc.).**

Almost since the very birth of computing there has been constant research into how to provide visually impaired users with access to computers, to the point that nowadays any blind or partially sighted person is able to use a computer without help from others. This has been achieved mainly due to the widespread use of the Windows Operating System and its office productivity suite, Microsoft Office, which is accessible to screen readers and magnifiers.

With the appearance of other operating systems and new applications that do not follow Microsoft Windows standards, we are faced with the problem that, as yet, there is no tool powerful enough to achieve the levels of accessibility, independence, and control provided by the JAWS screen reader or the Zoomtext magnifier, both of which work only with Microsoft Windows. While other accessibility tools do exist (the Orca screen reader, magnifier, etc.) these devices are still a long way from providing the levels of accessibility achieved within Windows environments.

■ **Research into computer applications for use in the fields of mathematics, music, physics, chemistry, etc.**

Although there are some editors for mathematics (Lambda[11], Latex, Excel), music (BME [12]), physics and chemistry (Latex [13]) which can be used with screen readers, some of them are still at an experimental stage and they are not yet available to blind learners in the classroom. This means that learners cannot use computers in these subjects and are obliged to use the Perkins Brailler as a means to write.

5 Conclusions

Through our designs and our technical and digital developments, all we professionals and designers should be doing all we can to help young, visually impaired learners to have access to technology by creating whatever adaptations those learners may require before they move on to the use of standard technology. As part of its standard specification this standard technology should include universal accessibility features which not only provide computer access to the visually impaired but also to other large sectors of society (the elderly, etc.).

Translation by ***Steve Turpin***

References

[1] *Xarxa Telemàtica Educativa de Catalunya. Competència básica TIC* (in Catalan) <http://www.xtec.es/escola/tec_inf/tic/index.htm>.

[2] *Xarxa Telemàtica Educativa de Catalunya. Materiales educativos de Joaquin Fonoll* <http://www.xtec.es/~jfonoll/>.

[3] *Xarxa Telemàtica Educativa de Catalunya. Alfombra mágica*. <www.xtec.es/dnee/jornada/tecnica/alfombra.pps>.

[4] Ministry of Education and Science. *Internet en el aula*. <http://ares.cnice.mec.es/infantil/index.html>.

[5] ONCE. *Guía de adaptaciones especiales del CRE de Pontevedra*. <http://educacion.once.es/appdocumentos/educa/prod/CREP%202005-01-19%20guia%20 sencillas%20adaptaciones.doc>.

[6] ONCE. *Programa EVO de Estimulación Visual por Ordenador*. <http://educacion.once.es/home.cfm?id=136&nivel=2&orden=4>.

[7] ONCE. Software – Stories and games. <ftp://ftp.once.es/pub/utt/tiflosoftware/06_Juegos _Cuentos/>.

[8] ONCE. Assistive software for the visually impaired. <ftp://ftp.once.es/pub/utt/tiflosoftware/Indice%20Tiflosoftware.html>.

[9] W3C. Web Accessibility Initiative. <http://www.w3.org/WAI/>.

[10] ONCE. *Pautas para el diseño de entornos educativos accesibles para personas con discapacidad visual*. <http://www.once.es/appdocumentos/once/prod/SS-ED%20Pautas%20de%20diseno%202005.doc>.

[11] IST programme. Lambda Project. <http://www.lambdaproject.org/ASP/index.aspx?IDMenuAPP=0> .

[12] Braile Music Kit. Braile Music Plug-In. <http://www.dodiesis.com/asp/download.asp?language=2>.

[13] *El Paraíso de las Matemáticas*. LaTex. <http://www.matematicas.net/paraiso/latex.php>.

SAW: a Set of Integrated Tools for Making the Web Accessible to Visually Impaired Users

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In this paper a System for Accessibility to the Web (SAW) for visually impaired people is introduced. SAW consists of a set of integrated tools designed to be used by both Web designers and end users. The foundation of SAW is an ontology that allows the definition of the entire set of elements that can belong to a Web page. This ontology also represents the relationships between elements and the accessibility attributes of elements and relationships. From the point of view of the designer, an editor is provided for making semantic annotations to Web pages based on the information stored in the ontology. From the point of view of the end user, a multimodal navigator is provided which also makes use of the ontology for its configuration and interpretation of Web pages. This navigator incorporates a speech synthesizer, voice recognition software, a haptic (tactile) mouse, an accessibility evaluator and an e-mail management system.

Keywords: Libre Software, Multimodality, Ontology, Semantic Web, Visually Impaired People, Web Accessibility.

1 Introduction

Web accessibility can be defined as the fact that *anyone using any kind of Web browsing technology must be able to visit any site and get a full and complete understanding of the information contained there, as well as have the full and complete ability to interact with the site* [1].

Accessibility can be analysed from different points of view, such as normative, legislative and technological. From a legislative viewpoint, the USA led the way in 1998 with a law that requires public sites to be accessible. Europe is now gradually adapting its legislation.

The legislative context is essential but insufficient. It is necessary to rely on normative guidelines that help us to overcome existing obstacles. There are three main barriers for the visually impaired user: hardware, software and the information itself [2]. In this sense, various guidelines exist on designing accessible hardware, browsers and content. The Web Content Accessibility Guidelines, WCAG <http://www.w3.org/TR/WCAG20/>, specify in detail how to make information accessible.

From the technological point of view, there are several tools; some of these are intended for users and others for designers; some are aimed at overcoming hardware barriers and others are designed to overcome software or content barriers. This technological disparity, variety of manufacturers and lack of an integrated tool hinders real accessibility. It was precisely this situation that led to the creation of SAW, a System for Accessibility to the Web that takes into account the end user as well as the designer. SAW combines different tools in order to overcome the three main barriers to accessibility: hardware, browser and content.

2 The SAW Project

SAW[1], System of Accessibility to the Web, is an ontology-based group of software components that aim to make the Web accessible. The system also incorporates a special mouse that allows blind users to surf the net. The relationships between these elements are shown in Figure 1.

The *ontoSAW* ontology represents the attributes and re-

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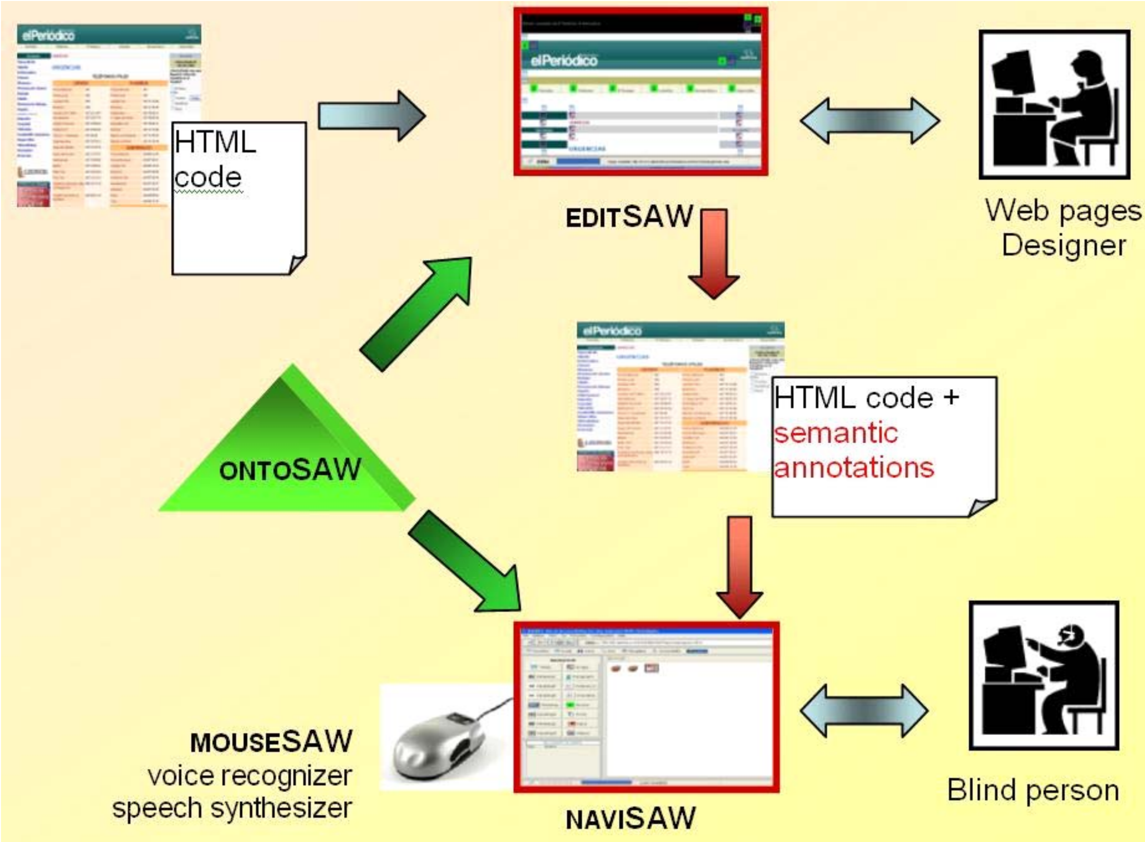

Figure 1: SAW Components and Relationships.

lationships between Web page components, including accessibility properties, according to the normative WAI guidelines. This representational framework is used by the SAW software modules as a common outline to identify the characteristics of the different Web elements. One of these elements is the Web page editor editSAW, which allows the designer to carry out semantic annotations within HTML code, adding special accessibility elements. These annotations together with the outline defined in ontoSAW are used by the naviSAW browser to display information to the user. The toolset also contains a speech synthesizer, voice recognition software and mouseSAW, a special mouse with Braille cells. Each component of the SAW architecture is detailed in the following sections.

3 Using an Ontology to Identify Accessible Web Elements

One of the contributions of SAW is the fact that it identifies the attributes of Web page elements relating to Web accessibility and represents them in an ontology [3] named ontoSAW. In order to build ontoSAW, a detailed study of the W3C specifications was carried out. OntoSAW contains the basic structural elements that may appear on pages written in HTML and Extended HTML (XHTML), such as paragraphs, images, tables, links, objects, etc. OntoSAW also takes into account the WAI's recommendations that determine the attributes of these elements to make them accessible on the Web. Moreover, ontoSAW incorporates additional attributes that enable naviSAW to offer blind people some

```
< table
   OntoSAW:resume="Price table of MP3 player"
   OntoSAW:rows=3        ontoSAW:columns=3
   OntoSAW:braille="http://quercusseg.unex.es/MP3player/table567/fictable567.bra"
   OntoSAW:voice="http://quercusseg.unex.es/MP3player/tabla567/fictable567.wav"
   width="100%" height="114" border="0">
 <tr> <td>Product</td> <td>Price</td> <td>Currency</td> </tr>
 <tr> <td>Player P1</td> <td>43</td> <td>Euro</td> </tr>
 <tr> <td>Player P2</td> <td>68</td> <td>Euro</td> </tr>
</table>
```

Figure 2: Simple Example of Annotated HTML Page.

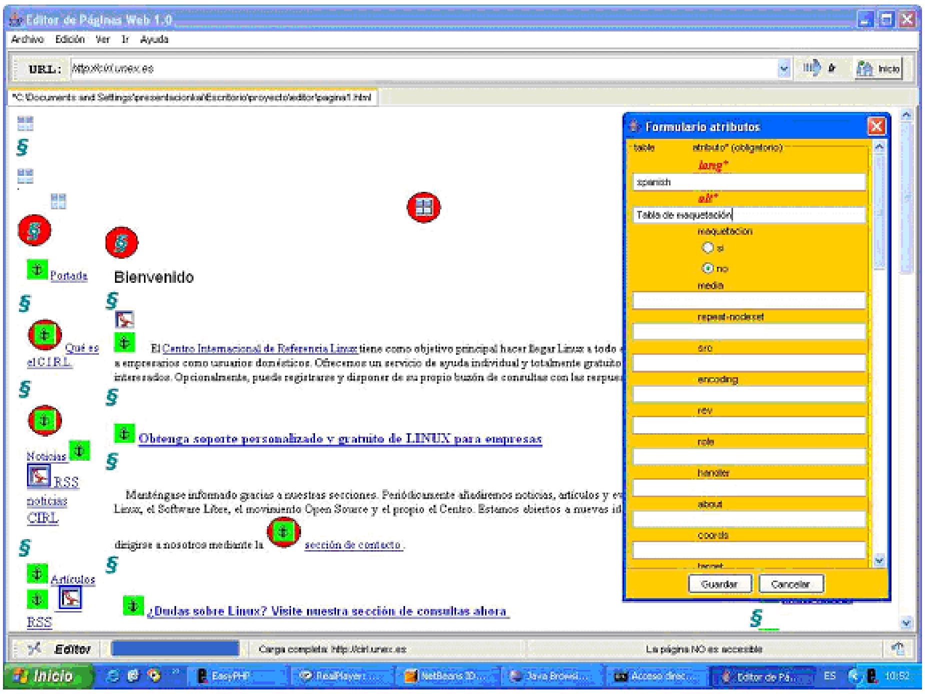

Figure 3: Editing Accessibility with EditSAW.

special perceptual possibilities, such as linking each Web page element to a voice file or Braille file that describes the content or functionality of these elements.

4 EditSAW: Accessibility Editor for Web pages

One contribution of the SAW project is the transformation of existing Web pages into accessible Web pages by using the software tool editSAW, which is based on the ontoSAW specifications. In order to do this, it adds semantic annotations [4] to the elements that appear on existing Web pages to be interpreted by naviSAW.

EditSAW can be used not only to identify which elements of the Web page lack accessibility, but also to permit the designer to modify these elements to incorporate attributes that will make the page fully accessible. It provides added value by allowing the incorporation of other characteristics that improve the perception of these page elements by blind users (voice files, etc).

Figure 2 shows an example of an element type *Table*, into which the attributes ontoSAW:resume, ontoSAW:rows, ontoSAW:columns, ontoSAW:Braille and ontoSAW:voice, with their corresponding values, have been incorporated.

In order to make a Web page accessible, editSAW first connects to the ontology via the Internet. If the ontology has incorporated new elements and attributes according to the latest W3C or WAI recommendations, these new characteristics will therefore be considered dynamically by editSAW. After identifying the URL Web page that the designer wants to use, its content will be analysed and the elements which are not accessible will be displayed (in Figure 3, these are shown with a circled icon). The designer will be able to modify the attributes of these and other elements simply by selecting the appropriate icon and entering values for the corresponding attributes. Once no more circled icons remain (that is, all Web page elements have their attributes with appropriate values for accessibility),

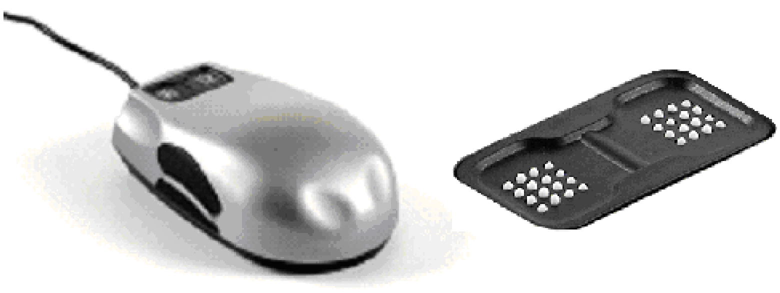

Figure 4: MouseSAW and Close-up of its Pin Cells.

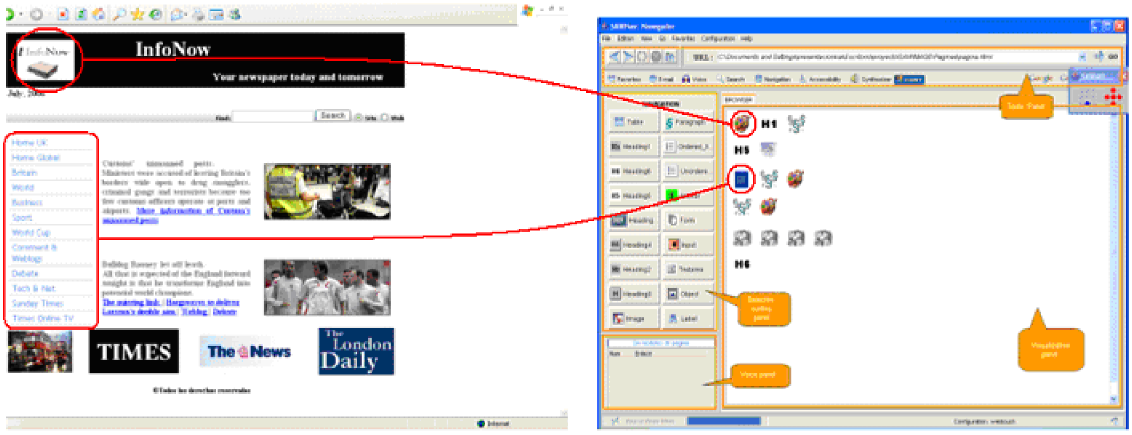

Figure 5: a) Web Page of a Digital Newspaper in a Conventional Browser. b) The same Page in NaviSAW.

the new accessible page can be saved.

To sum up, editSAW modifies the HTML code of original Web pages, incorporating labels that make elements accessible and others that will help naviSAW to provide added accessibility options. These special annotations that editSAW carries out form perfectly valid pages. Standard browsers (Mozilla and Explorer) ignore these labels although they show all the other attributes of the elements in a conventional way. However, naviSAW will use these annotations to offer improved accessibility to impaired users, as described in Section 6.

5 The Braille Mouse: MouseSAW

Visually impaired users have the ability to overlap different conceptual maps. mouseSAW uses this ability to manage the browser as well as the contents represented within it [5].

The mouse is shown in Figure 4. The main ideas have been extracted from the VTMouse [6]. It was originally designed for computer games, but has been configured and programmed in our laboratory to represent useful information in a haptic manner.

This mouse behaves in the same way as a conventional mouse, but two cells of pins have been added. One of the cells informs the user which panel is currently active. The other one represents the element beneath the mouse pointer (a table, an image, etc).

6 The Multimodal Browser: NaviSAW

NaviSAW is a multimodal browser that allows users to access Web pages using different modes: visual, auditory and tactile. All these modes are optional and compatible with each other. The browser assists in selective surfing based on the class of elements stored on a Web page, according to the previous classification made in ontoSAW.

Figure 5 shows the normal appearance of a Web page in a conventional browser and the final result, after being transformed and displayed in naviSAW. Each element of the original page is defined with an icon on the transformed page. Take the Web page logo, for example.

Originally, it was positioned in the top left hand corner. This element is classified as an "image" and transformed into a specific icon. It maintains its original position, the top left hand corner, on the transformed page. Another example is the page menu, a list of links. This menu has been transformed into a "list". In this case, the element contains other elements, the links. We can access these items using the "expand" action defined for this type of element in ontoSAW.

The naviSAW interface is divided into four panels, with movement being restricted within each panel. If the user wants to change the active panel, he has to use a combination of keys or, alternatively, a voice command if the speech synthesizer has been activated. Each panel has different functionality; some of the panels are explained below:

- Navigation panel. This contains the URL, "back", "go to", "refresh", "stop" and *"home*" buttons, and also the browser add-ons, such as the speech synthesizer, voice recognition software and mailSAW, which is used for reading mail.
- Selective navigation panel (on the left of the screen). This contains a button for each type of Web page element. The element types are defined in the ontoSAW ontology. When one of the buttons is pressed, a filter is activated over the content of the page displayed.
- Visualization panel (in the centre of the screen). The Web page is represented in this panel. Each element of the original Web page is represented as an icon. This icon stores its position on the page in terms of rows and columns. mouseSAW can surf through these elements, obtaining haptic information from them. When the mouse pointer is positioned over an element, a contextual menu appears. This menu, called the "accessibility menu", could be read out by the speech synthesizer. Its content is dynamically obtained

from ontoSAW. The user can select an item by using the mouse or his voice.

■ Voice shortcuts panel. Using editSAW, the designer can associate spoken words with the activatable elements on a Web page (buttons, links, urls, etc.). An activatable element is one that can be accessed via its term by using the voice recognition software.

7 Conclusions and Future Work

In this paper a System for the Accessibility to the Web (SAW) for visually impaired people has been introduced. The following goals have been achieved: a) the elements and accessibility attributes that can appear on a Web page have been represented in an ontology; b) based on this ontology, we have developed editSAW, an editor able to make semantic annotations in order to associate accessibility attributes to elements of Web pages; c) we have also developed naviSAW, a navigator able to obtain and interpret the semantic annotations of Web pages so as to provide this information in a multimodal manner. The navigator uses a speech synthesizer, voice recognition software and mouseSAW, a special mouse with tactile cells. Other hardware devices such as Braille lines can be easily integrated.

The prototype has just been completed and is now being tested. Our current work is focused on migrating this prototype to a mobile environment. The objective is to allow visually impaired users to surf the Web from a PDA or mobile phone, based on the same architecture as that used in SAW.

References

[1] C. Letourneau. Accessible Web design: a definition. Last updated 26/08/2003. <http://www.starlingWeb.com/Webac.htm>.

[2] J. Brewer. W3C Working group internal Draft. How people with disabilities use the Web. 05/05/2005. <http://www.w3.org/WAI/EO/Drafts/PWD-Use-Web/>.

[3] S. Studer, R. Benjamins, D. Fensel. Knowledge Engineering: Principles and Methods. Data and Knowledge Engineering, 25, (1998). pp. 161-197.

[4] T. Berners-Lee, J. Hendler, O. Lassila. The Semantic Web. Scientific American, Volume 284, 5th May 2001. Pp. 34-43.

[5] O. Lahav, D. Mioduser. Multisensory virtual environment for supporting blind persons acquisition of spatial cognitive mapping – a case study. Cyber Psychology and Behaviour, 2001.

[6] <http://www.accessible-devices.com/tactilemouse.html>.

Automatic Adaptation to the WAI Standard

Juan Manuel Fernández-Ramírez, Vicenç Soler-Ruiz, Jordi Roig de Zárate

Today it is hard to find a website that meets World Wide Web Consortium (W3C) standards. These standards are intended to help users access all the information available on the website in a user-friendly manner. It is even harder to find sites that meet the standards for people with disabilities. These standards, published by the Web Accessibility Initiative (WAI), improve access to the information in a website for those with disabilities and also for those without. In an attempt to change this situation, we have created the Automatic Conversion Tool for an Accessible Web *(ACTAW), a tool which automatically adapts Web pages to WAI standards.*

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Keywords*:* HTML, WAI, WCAG, Web Accessibility.

1 Introduction

As things stand today, the needs of people with disabilities are not taken into account by software and website developers. This makes it really difficult for these people to integrate into the job market and to access all the information available on the Web. The way software and websites are designed today, much of the great potential afforded by the Web as an instrument of integration and standardization is lost. The *Automatic Conversion Tool for an Accessible Web* (ACTAW) offers a new approach to the problem of Web accessibility and tries to make the largest possible number of Web pages accessible to users with disabilities.

A set of standards to ensure the correct development of all the elements involved in Web browsing does exist. These standards have been drawn up by the *World Accessibility Initiative* (WAI) [2] which forms part of the *World Wide Web Consortium* (W3C) [1]. In this article we will focus on *Web Content Accessibility Guidelines* 1.0 (WCAG) [3] which provides guidelines to follow for accessible website design and implementation. This set of standards defines a number of points to which website developers should pay special attention to ensure that their websites' content is accessible to everyone.

The W3C is an organization whose mission is to lead the Web to its full potential. This organization draws up standards for the various technologies used in the Web. In particular, it specifies the grammar of HTML, the most commonly used language on the Web. This grammar is the basic standard for this language, although it is rarely used properly. This makes it even more difficult to achieve Web accessibility, since if Web designers are not capable of following the basic rules of the language they use, they are unlikely to follow recommendations to make their designs accessible.

Meanwhile, it is often the case that websites are designed with specific browsers in mind which may not implement HTML grammar properly [5]. This situation means that the presentation of a website may vary greatly depending on the browser used.

The infrequent use of proper HTML grammar is to a large extent due to this habit of designing websites for a particular browser, since Web pages so created are only checked with that browser and are not checked with the W3C validation system [4]. Add to this the fact that today's Web editors and browsers add their own tags and attributes and it is easy to see how when we try to include another feature, such as accessibility, proper website development becomes a very complicated proposition.

The application presented in this article attempts to solve this problem by analysing and modifying a website's XHTML/HTML code so that it meets the WAI standard. It also analyses the presentation of the Web page, i.e. the various style files (CSS), to adapt those files to the standard as well.

By analysing and modifying the website we can adapt it not only to the WAI standard but also to HTML grammar. In this way we help improve Web browsing for people with or without disabilities since the content will be available in a more user-friendly manner.

2 Structure and Analysis of a Website

2.1 HTML Grammar

An HTML document is organized as a tree structure in which each tag has a parent tag and may have an indeterminate number of children tags. There are cases where this does not occur, such as when an image is included in the document. This tree structure makes for quick and easy representation.

In addition to tags there are various attributes which allow different aspects of the tag to which they belong to be altered or defined. The combination of tags and attributes allows for a wide range of possibilities, and provide us with a complete and, occasionally, complex language.

2.2 Cascade Style Sheet

The style of a Web page should not be marked up using HTML. This language is for creating the structure and content of the website but not for styling it. For this purpose we have CSS, which allows us to separate presentation from content. This separation is necessary if we bear in mind that in many cases the style will not be rendered or may prevent access to the information contained in the website.

2.3 Use of CSS and HTML

The proper use of CSS and HTML allows browsers to adapt the style to meet their needs or ignore it completely without losing the content of the website. Also, structuring a website in this way allows the developer to work faster and with greater ease. The designer can modify the content of an HTML document without altering the way it is displayed, or can change the style of an entire website solely by correcting a CSS file.

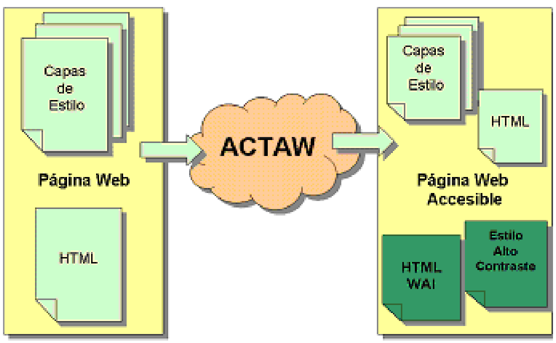

Figure 1: Diagram Showing how ACTAW Works.

The way CSS and HTML are used nowadays is far from correct, as in many cases the style is defined using HTML, which prevents it from being subsequently eliminated or altered by the user. In other cases we find CSS styles embedded in HTML documents. And finally, there is one situation which makes for a high degree of inaccessibility; the combined use of CSS and HTML to set the desired style. In this case if we replace the original CSS original with one created specially by a disabled end user, the style set with HTML will interact with the user's style and prevent it from displaying the information the way the user needs in order to access it.

An HTML document is organized as a tree structure and contains a number of elements that are defined in the grammar, and therefore we might say that these are "known" elements. The reality, however, is different. 95% of all pages on the Web [6] are not able to pass the W3C HTML validation test. This means that the proper analysis of an HTML document depends on more than just the grammar.

2.4. How ACTAW Works

First and foremost, ACTAW takes a an HTML document and the files associated with the target Web page and creates an accessible HTML document with properly modified CSS files. It will also create CSS files in which the colours contrast properly while being as faithful as possible to the original style. Thus we make it possible for the Web page to be visited either with the original style or with a high contrast style.

As we commented earlier, the analysis of a document does not only depend on the grammar defined by the W3C, so any attempt to analyse a document based on this grammar would be fruitless since a large number of Web pages cannot be analysed in this way. This requires us to look for some element that is common to all Web pages and which will enable us to analyse them.

The answer is to analyse the document's tags and attributes. These elements must be present as they are responsible for delivering the information to the user. Although some tags and attributes are not specified in the grammar, these are in a minority and their use is relatively easy to work around. However, if the elements of an HTML document are not properly structured and there are structure-related implementation errors, it is really complex job to implement an analyser

So, ACTAW implements an HTML analyser that is not based on HTML's grammar structure but rather on the document's tags and their attributes. Thus, we can create a tree with the content of the HTML document. Each node will correspond to a tag with its attributes, irrespective of whether it is in the right place or whether it is defined properly. In the code below we can see an example.

```
<HTML>
<BODY>
<B>Hello<U> World<I> !!!</H1></U>
This text is also in italic type.
```

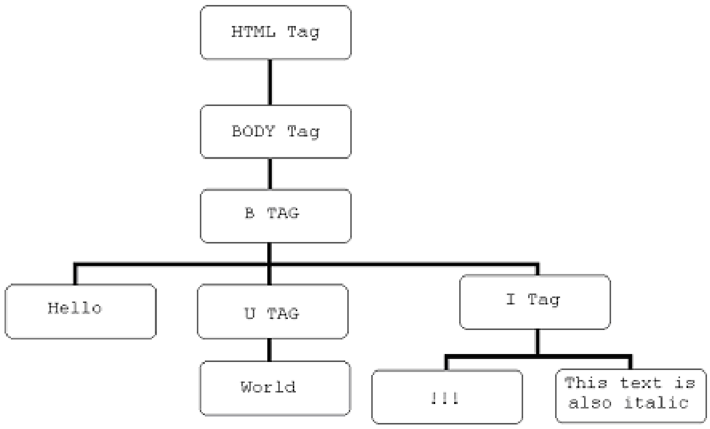

Figure 2: Tree Created for the above Example.

```
</BODY>
</HTML>
```

This code would generate a tree like the one shown in Figure 2. When the document is reconstructed the application generates a properly designed document:

```
<HTML>
<BODY>
<B>Hello<U> World<I> !!!</I></U>
<I>This text is also in italic type.</I></B>
</BODY>
</HTML>
```

If we come across a tag that is not specified in the standard, we cannot process it to adapt it to the standard as there will be no recommendations for it, but neither can we eliminate it, as we would also be eliminating information for the end user. In this case the tag or attribute is treated as unknown and is added to the set of known tags while we run the application. This enables us to treat any other appearances of this unknown element as a known element but one which cannot subsequently be processed.

As we have seen, we are not affected by the correctness of the document we are processing. This allows us to significantly broaden the application's scope of action, which is one of the strengths of this application. The HTML document analyser is capable of processing documents even if

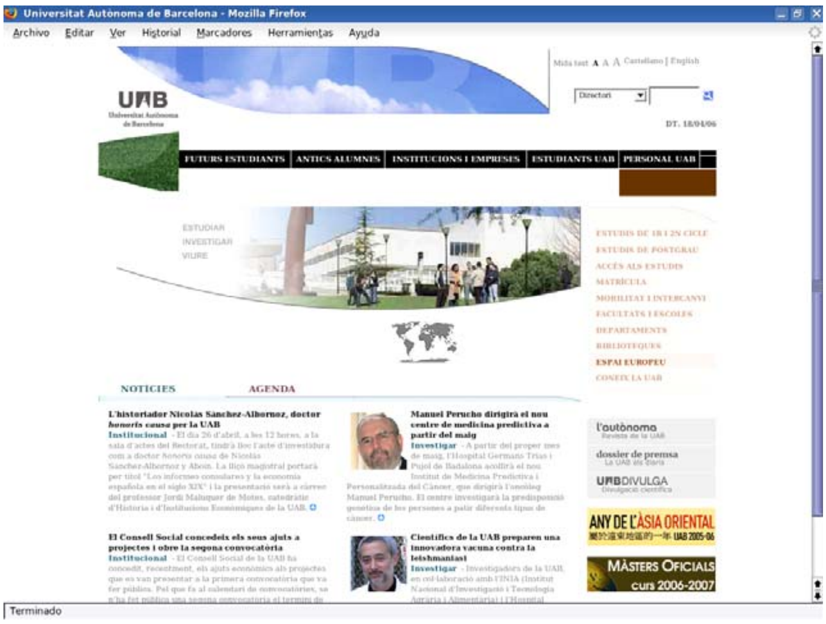

Figure 3: Original Web Page.

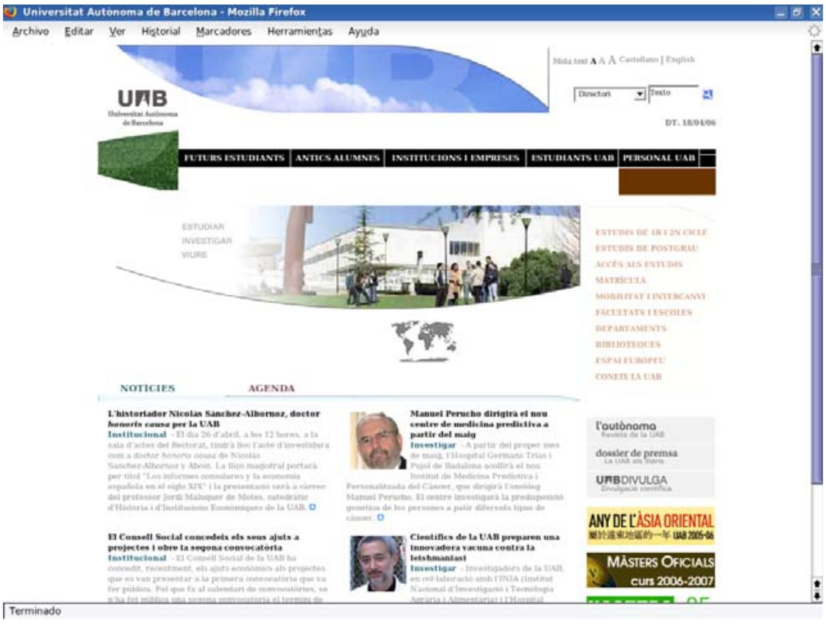

Figure 4: Web Page Processed by ACTAW.

they do not follow the grammar rules. Given the huge number of improperly designed Web pages there are, this makes the analyser a highly versatile tool.

To improve the resulting code, situations that, while not incorrect, are not recommended are replaced. This is done by unifying criteria to specify colours, converting all definitions to a hexadecimal format instead of using a decimal format or the name of the colour. A large number of special characters are replaced by their equivalent HTML character so that they can be seen correctly using any browser. An example is the carácter '*ñ*' which would be replaced by the identifier "*&ntilde*".

The analysis of cascading styles is similar to that of HTML. A CSS document is analysed without any defined element other than the basic style definition structure. All the information is stored separately; i.e. multiple definitions are broken down into simple definitions. By applying the WAI standard we can modify, in a totally independent manner, the various elements that initially were the same, and so adapt the solution to each specific case.

3. Application of WAI Standards: Proposed Solutions

We have analysed the various possible situations and how they match up against the guidelines proposed by WCAG, and we have applied the WCAG recommendations. It should be noted that the WAI standard is intended for website developers who know the semantic meaning of the content of a given HTML document; that is to say, people who are able to provide information not described by HTML tags, such as the meaning of an image. This makes the application of standards a truly arduous and complicated task. Some of the guidelines cannot be implemented a posteriori without knowledge of the Web page's content of the page and its meaning. To obtain this information we need to perform a semantic analysis of the content of the page, which is a time-consuming process. Work is currently underway on possible solutions to this problem which may, in the future, deliver improvements to the application and Web accessibility in general.

We go on to comment on a number of solutions proposed by some of the guidelines. To comment on all existing proposals and guidelines would be an overly lengthy and tedious task, so we have limited are comments to the guidelines we think will be of the most interest to our readers.

Guideline 1: Provide equivalent alternatives to auditory and visual content

Elements affected by this guideline are images, image maps, and embedded objects. Alternative texts are provided for these elements with all the information that can be ob-

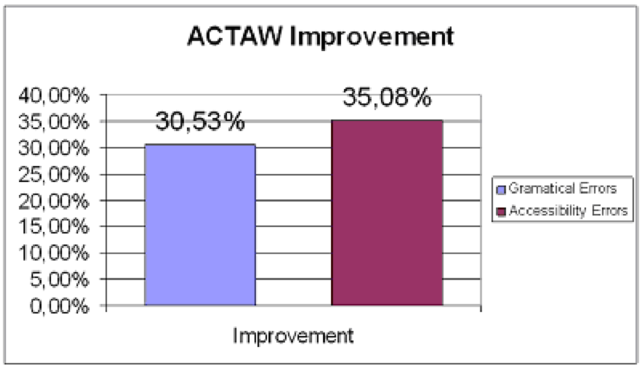

Figure 5: Improvement of Grammatical and Accessibility Errors using ACTAW.

tained from the HTML code. These alternative texts contain indications that tell us if they are used as links, if the reference does not exist, and what type of element we are dealing with. This enables us to differentiate an image used as a link from one that has no additional function.

Alternative texts are also described for frame-based Web pages. These texts tell us the number of rows and columns and their position. Information is also included for browsers that do not support frames.

Guideline 2: Don't rely on colour alone

Colours defined in the style sheets of the Web page are checked. If the colours do not meet the W3C colour contrast threshold, a new CSS document will be created with colours that contrast properly. The algorithm applied tries to ensure the greatest possible similarity between the original document original and the standardized one, since combinations of colours can provide information. The result of the CSS will not contain all the possible information, but it will allow it to be accessed.

Guideline 3: Use markup and style sheets, and do so properly

For this guideline the tags that markup visual effects are replaced by equivalent tags that markup emphasis for example. Contextual clues are added to be able to follow a list properly, regardless of whether it is nested.

The application cannot detect text included in images, which means that any such text will not be available to voice browsers. Also, the coherence of headings and the proper use of tags that identify them depends on how well the creator of the document did his or her job, since it is impossible to know whether the start of a section is actually being indicated, or whether that section is more or less important than the one preceding it.

Guideline 4: Clarify natural language usage

Since the only source of information we have is the HTML code, the language used is identified and indicated by looking in the metadata. We are currently working on an agile and fast language detection system. In the event of any doubt, this system will also be able to determine the language with the help of other data, such as the topic of the website.

Guideline 5: Create tables that transform gracefully

All possible information contained in tables is provided, such as their size in the window or the number of rows and columns. Columns are grouped together according to their headings, if they have any. However, since we cannot obtain information about the content of tables, no specific measures are taken to ensure the proper alignment of tables, which may confuse users. We are currently looking for an effective algorithm to address this problem and so be in a position to offer users a fully user-oriented system.

Guideline 6: Ensure that pages featuring new technologies transform gracefully

For device dependent actions, keyboard and mouse equivalents are provided. However, no type of solution can be offered for elements created using JavaScript, since there is no analyser available for this type of code and so we are unable to modify it properly.

We have already commented on the situation regarding frame-based pages, but there is one situation which is highly inaccessible; when one of the frames is an image. In this situation the image will be replaced by an HTML document which will contain the image together with all the information it is possible to include. This allows the user to obtain information about the image that would otherwise have been inaccessible.

Guideline 7: Ensure user-control of time-sensitive content changes

Animated images and embedded elements cannot be halted without losing information. Therefore special care needs to be taken when creating this type of content so as not to violate the standard.

The application does however replace moving or blinking text if it was created using HTML. This change is performed using equivalent CSS and HTML techniques but may be disabled by the user from the browser. Any automatic refreshes and redirects in the page are also eliminated, thereby preventing end users from losing control over the pages they visit and over the content of those pages.

Guideline 10: Use interim solutions

This guideline deals with situations such as opening a new window with a link. Users may be confused when a new window appears without prior warning. The elimination of links that display information in new windows could lead to a loss of information, for example if a user wishes to return to the information contained in the previous Web page and that page depended on a user session. In view of this situation, we decided not to eliminate such links but rather to inform users when a link will open up in a new window. In this way users will have prior warning that a new window is to open and will be able to treat it like any other window and navigate around it properly.

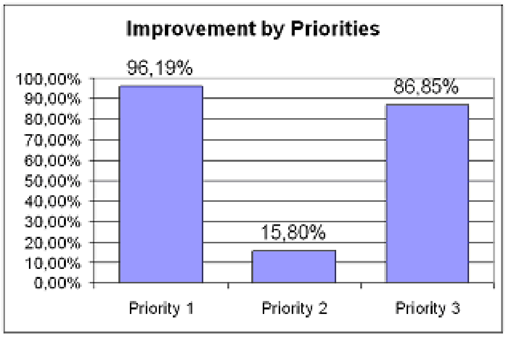

Figure 6: Analysis of the Improvement by Priorities.

This guideline also recommends that logically related links should be grouped together, and that each control should be properly positioned with its associated tag. We encountered the problem of not being able to analyse the relationships between a text and the various links included, or the relationship between a text and a specific control, so we were unable to provide a satisfactory solution.

Finally, help is provided for people with cognitive disabilities so that they can navigate through a form. The edit boxes or text areas of a form are filled in with either "Write here" or "Text" depending on the size of the space. If an image replaces a button, the type of action to be carried out will be indicated.

Guideline 11: Use W3C technologies and guidelines

All obsolete or deprecated HTML tags or CSS style tags will be replaced by their recommended equivalents. Sizes are modified by changing from a number to a CSS format. Finally, the "!Important" tags in an CSS document are eliminated so that the user is not prevented from disabling any part of the style.

Guideline 13: Provide clear navigation mechanisms

The basic mechanism of Web navigation is the link. To ensure that these links are as clear as possible, alternative texts are added with the name and target of the link. If the link is to a section or to an email, or indicates a frame or window into which the link is to be loaded, this should be indicated in a clear and concise manner so as to provide users with all possible information about the link so that they can decide whether or not to follow it.

Guideline 14: Ensure that documents are clear and simple

All HTML document style definitions have been moved to CSS documents so that they comply with the principle of separating structure and presentation. The use of styles allows us to show the alternative texts to be sure that this information is also available visually. Finally, various styles indicating the type and tone of voice have been indicated, to be used for headings and elements that indicate emphasis and similar effects. Although current voice browsers are capable of performing this analysis automatically, these additional styles are included to ensure that older browsers are able to inform users properly.

4 Implementation and Results

The application has been developed entirely in Java as this allows it to be run on a variety of platforms, thereby avoiding restrictions on its use. This is important as the end user could be a system administrator but could equally well be a user with only a basic knowledge of computing.

The application has been put through a series of tests involving 60 Web pages. The topics of the pages are random but include a large proportion of all possible types. Thus we may find anything from leisure and game sites to Web pages belonging to banks and not-for-profit associations. The Wiki format is also represented in our test bed.

In order to pass a Web page processed by our application as accessible, it must retain its original style while eliminating all deprecated and inaccessible elements. The proposed solution should also improve accessibility in general. Finally, the result must be validated by W3C validation tools and CTIC's Web Accessibility Test (Spanish acronym: TAW) [7].

We can see an example of a successfully processed page in the images below. Figure 3 shows the original page. As readers will see. It is a complete and complex Web page; i.e. it contains a number of different elements and a large amount of information.

Figure 4 shows the result after using our application. The presentation of the Web page is identical to the original. There are some added elements, such as an explanatory text in the search box and additional information is provided in the alternative texts accompanying the images to allow users to know what function each image has. There is also a notification that the page has been processed to meet the WAI standard. Thus users are aware that they are not viewing the original page and that deprecated elements may have been disabled or eliminated.

Our test bed returns some very good results. 100% of our test bed pages are analysed correctly. In Figure 5 we see the improvement in terms of accessibility and grammar errors. In the case of accessibility the improvement is 35.08%, a result which may seem low, but if we analyse the improvement by priorities we see that it is a very good result indeed.

When we analyse the improvement by priorities (Figure 6), the result is very good in two of the three priorities. In the case of priority 1 the improvement is 96.19% which is very good, especially if we bear in mind that this priority includes all elements that make it impossible to access information. Thanks to this improvement, 71.67% of our test bed pages achieved level A accessibility; in other words, they contained no element that made access to the information contained in the Web page impossible.

Meanwhile the improvement achieved in priority 2 is the lowest since this priority includes solutions for which it is necessary to know the semantics of the website's content of the website. This priority concerns elements that make it difficult to access information. Finally, the application also scores highly for the third priority, achieving an improvement of 86.85%. This priority includes elements that make it somewhat difficult to access information.

As we can see, the overall results are really very good. We need to take into account the difficulty of obtaining information from a page that is not designed with accessibility in mind. But even so, the application achieves a significant improvement in accessibility. Perhaps the most important aspect of the results is the high number of pages that achieved level A accessibility.

It should also be noted that the presentation of the pages after running the application is practically the same as before, which means they can be navigated by anyone, whether disabled or not.

4 Conclusions

By meeting WAI standards we can provide Web access to disabled users and improve it for people without any disability. The automatic conversion of documents is a very important step in the quest to make the Web more accessible. A tool of this nature can also be used by organizations wishing to make all their existing information accessible at a really low cost in terms of both time and money.

The standardization provided by ACTAW requires a broad scope of action if it is to be useful. The HTML analyser we have designed is capable of processing all types of HTML documents. Thanks to this versatility the tool can deliver some very good results and improve the quality of the Web by providing pages that use proper HTML grammar.

However, we should not forget that the guidelines proposed by the WAI are intended for developers, which means that applying them a posteriori is a complex and costly task. Thus, in order to improve the proposed solutions and enhance accessibility we need to build a semantic analyser. Such an analyser would allow us to understand the content of a Web page and apply better solutions on the basis of that information, and work is already underway on its design. Work is also underway on systems that will ensure the correct alignment of tables, improve orientation in tables and frames, and detect the language used in the website.

The application that we present in this article represents a further step along the road to improving Web accessibility. The fact the tool can be used by either end users or website administrators has the advantage of allowing end users to access the information on a Web page even if the original page did not meet Web accessibility criteria. The ACTAW tool also addresses the issue of accessibility from a global viewpoint and attempts to improve all possible aspects while respecting both the Web developer's original style and the W3C standard.

Translation by ***Steve Turpin***

References

[1] World Wide Web Consortium. <http://www.w3.org/>.
[2] Web Accessibility Initiative. <http://www.w3.org/wai/>.
[3] Web Content Guidelines Working Group. Web Content Accessibility Guidelines 1.0. <http://www. w3.org/TR/WCAG10/>.
[4] The W3C Markup Validation Service. <http://validator.w3.org/>.
[5] The Web Standards Project. <http://www.webstandards.org/>.
[6] Chen Shan, Hong Dan, Vicent Shen. An Experimental Study on Validation Problems with Existing HTML Web pages. International Conference on Internet Computing. Proceedings, 2005.
[7] CTIC Foundation. Web Accessibility Test 3.0. <http://www.tawdis.net/>.

Helping Authors to Generate Accessible Content: two European Experiences

Carlos Rebate-Sánchez and Alicia Fernández del Viso-Torre

*This article aims to describe the experience obtained and the lessons learned in two European projects: VISUAL (*Voice for Information Society Universal Access and Learning*) and ENABLED (*Enhanced Network Accessibility for the Blind and Visually Impaired*). The two projects share a number of common features: their target public (the visually impaired), their goals (to help authors generate accessible Web content that is compatible with the most common technical aids) and their funding (both projects were funded by the European Commission within the 5th and 6th Framework Programmes).*

Keywords: Accessibility, Accessible Software, Authoring Tools, ENABLED, Human-computer Interaction, VISUAL, Visual Impairment.

1 Introduction

In this article we present our experience in the development of tools to help authors generate accessible content. This experience is the result of our participation in two European research projects: VISUAL [*Voice for Information Society Universal Access and Learning* (IST-2001-32495)] and ENABLED [*Enhanced Network Accessibility for the Blind and Visually Impaired* (FP6-2003-IST-2-004778)].

Before looking at each project individually perhaps we should explain why we decided to describe the two experiences and the lessons learned from them in the same article. It is a proven fact that developing tools to meet user expectations is a complicated task. Users are often fickle characters who try the patience of developers and never seem to be happy with the outcome. Unfortunately, it is impossible to build good software without listening to the users. It is vitally important to know the needs of users and involve them in the development of the product, since the ultimate success of any development will depend directly on the degree of commitment that developers and users jointly put into the software creation process. All the above is doubly important in the development of authoring tools for generating accessible content where we have two groups of users: the users of the authoring tools themselves, and the users of the content generated by those tools.

Another point that we need to make is that it is possible to find authoring tools that, in spite of meeting W3C accessibility guidelines for authoring tools [1] are not properly accessible to the author, and Web pages which meet content accessibility guidelines [2] but are not properly accessible to the end user. Compliance with guidelines is no guarantee that the end product will be accessible.

If we cannot rely exclusively on existing guidelines - de facto standards - for the creation of authoring tools and accessible content this makes it all the more necessary to involve our end users to check whether the software we are producing is truly accessible and can be used in a real environment. This is a major problem since we do not only depend on users for producing and testing a product's functional specifications but we also rely on them to know whether the software is really accessible from a purely technical point of view.

Authors

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Alicia Fernández del Viso-Torre graduated as a Technical IT Engineer from the *Universidad de Oviedo* (1998), and has a Master in the Information and Telecommunications Society from the *Escuela de Organización Industrial* (EOI) of Madrid. She has worked in SOLUZIONA since 1999. From 1999 to 2001 she worked as a software engineer on the development of a package of *utilities* known as v10. In 2001 she obtained Sun certification in Java. Since 2001 she has taken part in the presentation and coordination of national and international projects in the field of e-Inclusion, such as VISUAL (*Voice for Information Society Universal Access and Learning*), ENABLED (*Enhanced Network Accessibility for the Blind and Visually Impaired*), FAA (*Formación Abierta y Accesible*), EU4ALL (*European Unified Approach for Assisted Life Long Learning*) and ALPE (*Accessible eLearning Platform for Europe*). <afernandezde@soluziona.com>.

In order to address this situation, people with visual impairment and with sufficient technical knowledge were involved in both projects in order to provide guidance during their development, with the aim of ensuring that the end product was accessible from a formal point of view (compliance with the relevant W3C accessibility guidelines) and from a functional point of view (that users were able to interact with the software in an effective manner).

Lesson 1: *If you want to be successful, always involve your end user in the design of your product.*

2 Two European Experiences

2.1 VISUAL

The VISUAL project is an international project coordinated by SOLUZIONA and funded by the European Commission IST (*Information Society Technologies*) programme under the 5th Framework Programme. Its aim was to develop technology based on voice interaction [3] [4] to improve access to the Information Society for the visually impaired.

VISUAL began in October 2001 and ended in September 2004. It enjoyed the participation of two universities (*City University* and *Katholieke Universiteit Leuven R&D*), national blind organizations from four European countries – United Kingdom (*Royal National Institute of the Blind*), France (*Fédération des Aveugles et Handicapés Visuels de France*), Italy (*Unione Italiana Ciechi*) and Germany (*Deutscher Blinden- und Sehbehindertenverband e.V.*) – and the European Blind Union.

The basic goal of the VISUAL project was to **allow visually impaired people to create their own Web content** with aid of an authoring tool which, in turn, would encourage and teach users to **create accessible Web content** in a user-friendly and intuitive manner. Target users need to be familiar with the use of technical aids and have a basic grasp of HTML.

The authoring tool had to be conceived with **accessibility in mind** from the outset and not, as is the case of most tools that claim to be "accessible", designed first and then fiddled with to meet the appropriate guidelines and recommendations. We had a great opportunity in front of us.

Creating a tool in the knowledge that most of the Web authors that were going to use it would be blind was an enormous challenge. The first step was to carry out an exhaustive study of commercial and free tools (Amaya, DreamWeaver, HomeSite, FrontPage, HotMetal Pro, etc.) to look for their strengths and weaknesses (which often included not being accessible at all!). Most of them had a major visual component; they were clearly based on Web authors "seeing" what they are creating (to see in order to do) – hence the success of the famous WYSIWYG (*What You See Is What You Get*) view. We had to discover our own form of WYSIWYG; a way of enabling blind people to create a mental model of the page of being built while allowing them to access, locate, place, and navigate between elements using a keyboard. The task of discovering our "user view" became the focal point of all our discussions.

The view would be the cornerstone of the tool, around which the entire Web creation process would revolve, which

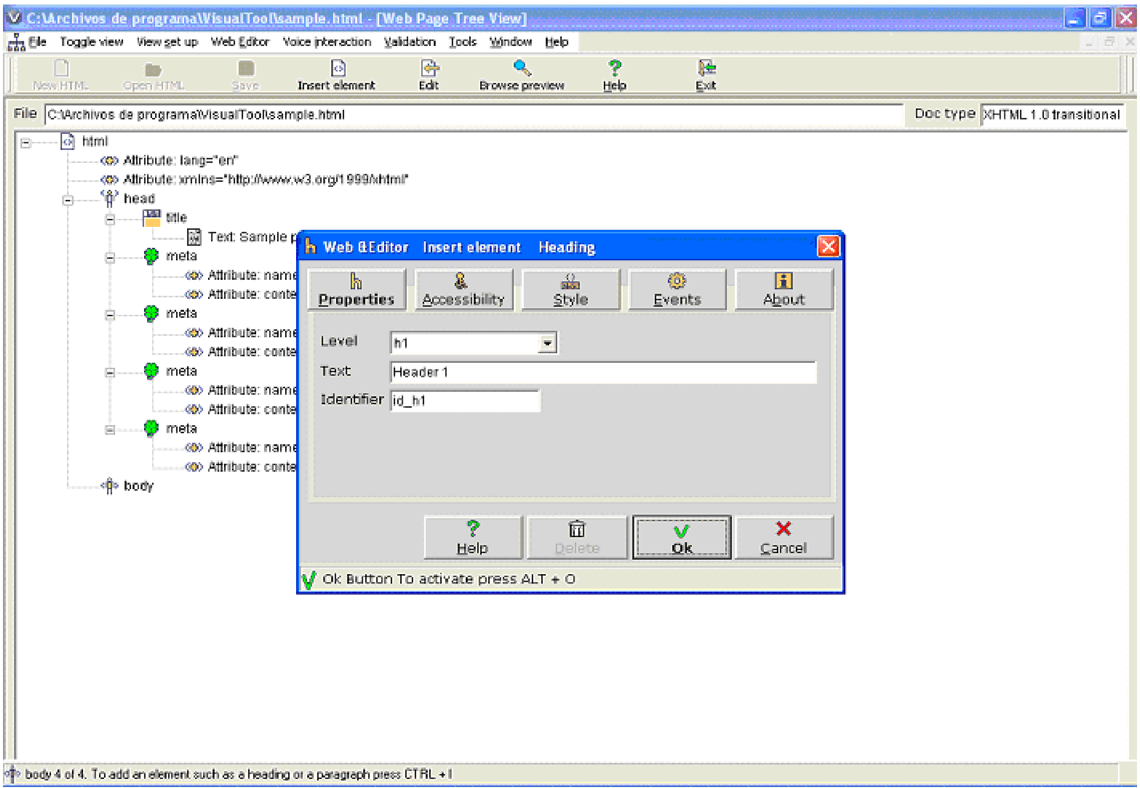

Figure 1: User Interface of the VISUAL Authoring Tool.

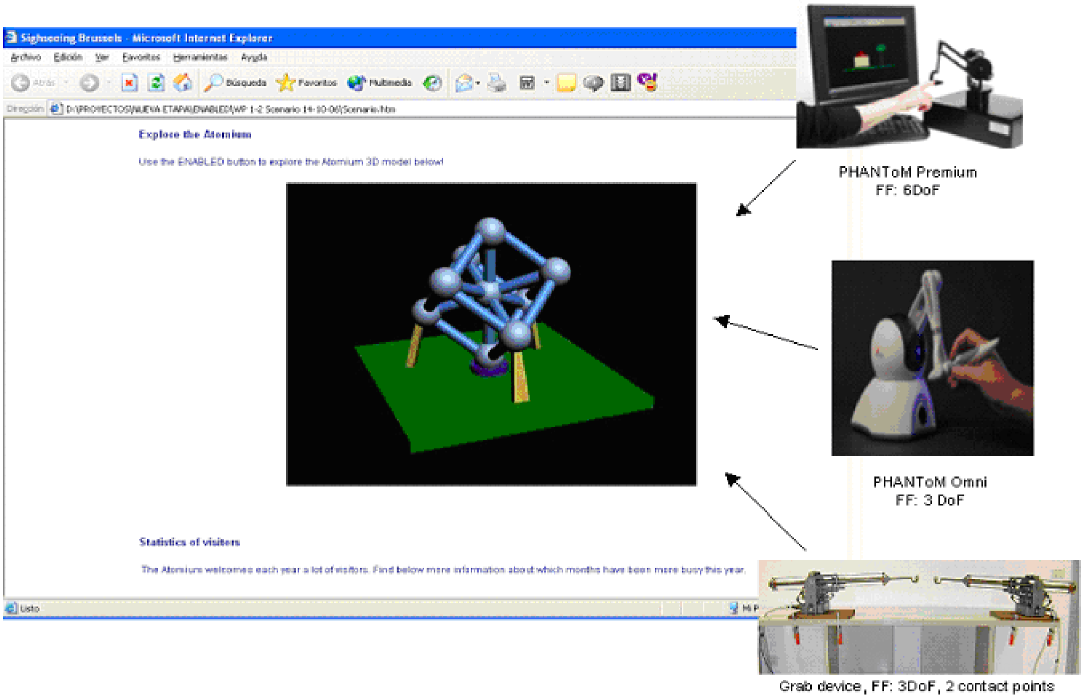

Figure 2: Insertion of an Element 3D Annotated for Haptic Exploration.

was why it was so important to find the right mechanism. After the consortium held several meetings to try and decide upon a method of interaction that would help users to navigate around the page content, we were set on the right track by a fact that had hitherto escaped us all. Discussing how users in general resist change, someone made a comment about how the arrival of Windows had been received with a certain degree of opposition by users of assistive technology accustomed to working with MS-DOS in text mode which, by using a simple screen reader, enabled them to receive the same information as a user looking at the screen output. The Windows operating system, more visual and more colourful, was a step in exactly the wrong direction for users of assistive technology. In principle, the idea of having a load of windows that opened, closed, emerged, and used icons to identify the various elements had little to recommend it to those that up until then had been used to having text as the only source of information about what was happening on the screen. Nowadays users of assistive technology have no option but to use Windows and many of them are more than happy to use Windows file explorer which shows users the content of the local and network units to which they are connected and which allows them to navigate up and down the file structure, changing its content, adding, deleting, and even renaming folders with the aid of hotkeys, all by using nothing but the keyboard.

This reflection on the usefulness of the file explorer combined with the fact an HTML Web page is ultimately a perfect hierarchical structure, provided that it is well formed (XHTML), led us to choose the file explorer model as our means of interaction for users creating a Web page with the aid of our tool. For users of VISUAL, the Web page would be represented as a tree in which each node would correspond to an HTML element or to an attribute of that element. In order to interact with the tree you only need to use the keyboard and its hotkeys in the same way as with file explorer. To interact with the XHTML tree you use the hotkeys that display the dialogue windows in which you can then input the data corresponding to each element (texts, images, links, etc.).

One of the strong points of the VISUAL tool was its user-friendliness and innovative interface (see Figure 1). However one of its weaknesses was the result of one of its objectives: **the creation of accessible content only**. For more experienced Web designers this was a drawback since Web designers are habitually less than scrupulous in their compliance with XHTML syntax rules. Having long been accustomed to using HTML elements freely without taking syntax into account, Web developers saw the tool as "not very flexible". Paradoxically this was actually one of the strengths of the tool as it meant that **it is impossible to create Web content with it that is not (formally) accessible**.

Now we had a philosophy to follow: a tree view (hierarchical representation of the Web page) with the use of *wizards* and dialogue windows to act as a guide in the creation of accessible Web content. All combined with an accessible user interface via a keyboard, compatible with assistive technology, in which the tool's own speech synthesis system combines with the synthesis provided by the assistive technology or can even replace it if so desired. It also includes a "code cleaner" [5] and an integrated accessibility validator to debug existing pages.

The tool was evaluated by 24 people with visual impairment (13 of them blind): 5 from the *Unione Italiana Ciechi*, 5 from the *City University*, 5 from the *Fédération des Aveugles et Handicapés Visuels* in France, 4 from the *Royal National Institute of the Blind*, and 5 from the *Deutscher Blinden- und Sehbehindertenverband e.V.* together with a number of experts in accessibility from the various organizations in the consortium.

2.2 ENABLED

ENABLED [6] [7] is a large scale European project involving 14 entities from 10 countries including major companies, universities, and research centres. Led by *Queen's University of Belfast* (United Kingdom), ENABLED enjoys the participation of SOLUZIONA and the LABEIN Foundation in Spain, the Lund University in Sweden, SCALAB in Italy, Tekever in Portugal, Siemens, OFIS and CAS in Germany, NetUnion in Switzerland, and British Telecommunications (BT) in the United Kingdom.

The goal of the ENABLED project, which began in 2004 and is scheduled to finish this year, is to improve Internet access for the visually impaired in two ways:

- By developing technologies that make it possible to create **accessible Web content**.
- By creating **tools to provide users with access to information** and available Web services through the use of **adaptive and interoperable interfaces**.

Unlike VISUAL, ENABLED limited its scope to delivering accessibility to one particular type of content, non-text content (images, graphics, maps, 3D objects, etc.). The web is full of non-text content which cannot be accessed by the blind and for which a text description is often insufficient. Unlike VISUAL, the ENABLED project is not aimed exclusively at Web authors but also addresses the problem of interaction with non-text content from a dual perspective:

1) On the one hand, the Web author, by using the right tools for annotating this content so that all the information can be conveyed to users in a non-visual manner.

2) On the other hand, the users, who can access those annotations using available tools or devices to allow them to access the information contained within the image via other alternative senses such as touch or hearing. The project goes even further and enables users to obtain information and interact with the content (depending on the device used).

If with VISUAL the greatest difficulty was finding a means of interaction that would be familiar to users and would allow them to use their "own" tools when creating Web pages, with ENABLED the difficulty resided in having users use new means of interaction which would not permit them to use "their own tools" but would instead require them to use new devices or new interfaces of which they had no prior experience.

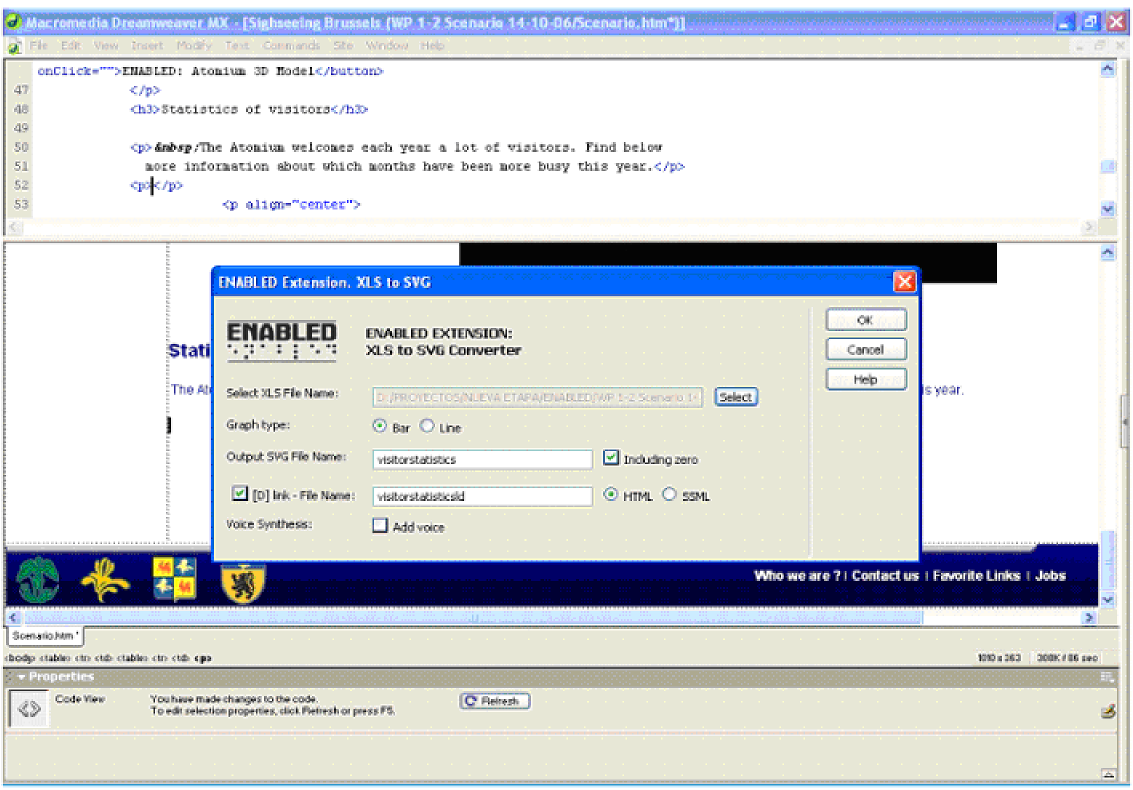

Figure 3. Extension of DreamWeaver for the Creation of a Vectorial Graphic (SVG) Annotated to an Excel Spreadsheet.

Thus the great challenge was to gather user requirements that could be used to guide the development of these tools in the knowledge that users had no idea of what those tools were going to be like. It was like "let's play at inventing" a means of interaction. In order to limit the scope of the problem, user requirements were ascertained by asking users to talk about the known reality and therefore about their present day access problems. Thus by identifying, with the aid of the users, the areas of improvement which we needed to focus on, it was the project's job to come up with innovative ideas or approaches to address these problems. Below we show two examples: Exploration of 3D figures with haptic devices[1] (see Figure 2) and the creation and insertion of vectorial graphics (SVG) annotated to Excel spreadsheets (see Figure 3).

3 Lessons Learned

As we had already anticipated, the first lesson is that users need to play a key role in the process. For this reason, in both projects we used an iterative and incremental model, alternating the release of various versions of the tools with evaluation periods.

The data gathered from each evaluation is standardized by the experts who took part in the user requirements gathering process, and are converted into recommendations for future versions of the tools. In the case of ENABLED, prototypes were also used to enable concept tests to be performed to check whether the chosen way was the right one before incorporating new features to more advanced developments.

With regard to the evaluation of prototypes, in both cases predefined scenarios were evaluated in order to be able to compare results with subsequent evaluations, and to involve the user in what was to be a day to day use of the tool.

From the evaluations performed in the two projects by users and experts we can deduce a list of desirable features that any accessible interface should have regardless of its purpose or future use:

- Visibility of system status: the system should always keep the user informed about what is going on by appropriate means (speech synthesis, text, etc.)
- Match between the system and real world: avoid using technical terms to refer to real world entities. Use concepts that are familiar to the user rather than system-oriented concepts.
- User control: the user should have control over the application at all times, and be able to undo, repeat, or return to a previous state whenever he or she so desires.
- Consistency and standards: the user should not be made to wonder whether different actions, terms, or situations mean the same. The conventions established for each platform should always be observed.
- Error prevention: the system should prevent users from making a mistake due to the incorrect use of the interface.
- Do not rely on recall: the user should not always have to be remembering what to do. The instructions for use of the system should be visible and intuitive.
- Flexibility and efficiency: the system should be tailored to the experience of the user so that more experienced users can use shortcuts to actions that they are familiar with.
- Less is more: avoid including irrelevant information in user dialogues or any extraneous information that will be rarely needed. Any unnecessary information competes with information that is really important, with the risk that the user may miss the part that is really important.
- Help recognize, detect, and solve errors: error messages should be expressed in natural language indicating what to do next to solve the problem.
- Help and documentation: necessary help and documentation should be provided so as to explain to users in natural language the steps required to carry out any particular task.

Translation by ***Steve Turpin***

References

[1] W3C. Authoring Tool Accessibility Guidelines. <http://www.w3.org/TR/WAI-AUTOOLS>.

[2] W3C. Web Content Accessibility Guidelines. <http://www.w3.org/TR/WAI-WEBCONTENT>.

[3] C. Rebate, A. Fernández del Viso et al. "*ConPalabras*". Novática, no. 161, January-February 2003, pp 38-42.

[4 C. Rebate, A. Fernández del Viso et al.. "A web voice solution: *ConPalabras*". Upgrade, Vol. IV, no. 1, February 2003, pp 65-70.

[5] SourceForge. <http://tidy.sourceforge.net>.

[6] ENABLED Project. <http://www.enabledweb.org>.

[7] C. Rebate, A. Fernández del Viso. "Technical notes: Accessibility". Interview on *Intereconomía TV*, December 12 , 2006.

[1] <http://en.wikipedia.org/wiki/Haptic>.

ICT Prospective

Inline or Online?

Steve Kennedy

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It's five years in the future and more and more people are working from home. It can be cheaper for businesses as they now don't have to rent expensive offices just to seat people. Of course there can be hidden expenses that can increase costs considerably (a company basing an employee from home has to ensure that their working environment is similar to the workplace environment, including all the health and safety requirements), but, ignoring those aspects, what technologies will be at use?

Keywords: Future, Homeworking, Network, Wireless.

21st Century Network

BT should have pretty much rolled out its 21st century network (aka 21CN), the all IP network going into the home and business.

Initially the home worker won't notice anything different, their BT phone line won't change (though in the background as soon as the analogue call goes into the local exchange it gets converted to Voice over IP).

As part of 21CN, ADSL2+ will also be introduced, allowing 24Mb/s download speeds (to urban areas at least). BT is also considering putting DSL (Digital Subscriber Line) equipment into the green boxes in the street, which will then be connected using fibre back to BT's core network and using technologies such as VDSL2 or VDSL2+ where speeds of up to 100Mb/s can be delivered.

With these kinds of bandwidths available, delivering voice as an analogue service becomes irrelevant, so it's likely BT will just package a router into every house and the customer just gets an ethernet/LAN connection into which they can plug their PC, IP phone and so on.

Delivering all kinds of service over a single IP fabric means BT will need to provide quality of service (QoS) or voice calls will degrade when the user watches a video, for example. BT's 21CN core already provides this (using internet protocol/multi-protocol label switching) and end-user QoS can be provided in the DSL router.

So everything will come into the home over a single IP connection with QoS enabled. You'll be able to have multiple lines, watch video and do video conferencing all using the same connection.

Of course if you want QoS, BT currently want you to use BT's services to guarantee that QoS. You'll be able to use anybody else's VoIP or IPTV service too, it's just unlikely to have QoS over BT's network.

Author

Steve Kennedy is currently a consultant (NetTek Ltd) specialising in Internet, telecoms, wireless and mobile. He also freelances (journalism) for various trade publications and web sites. Until March 2005 he was employed by THUS Plc as Head of Product/Technology Futures. Mr Kennedy had overall responsibility for evaluating and providing technical insight into future technologies (both in the Internet and voice/data areas) and how they could be utilised in the development of new products and services. He also owned THUS's product roadmap. Mr Kennedy's previous experience includes over ten years in a variety of internal and external consultancy roles in electronic, software and network engineering. Mr Kennedy holds a BSc in Microelectronics and Information Processing. He is a member of the Institution of Engineering and Technology (IET), the British Computer Society (BCS), the Institute of Electrical and Electronic Engineers (IEEE, US) and a Fellow of the Royal Institution. <steve@nettek.co.uk>.

WiMAX is just around the corner

Though wired broadband allows high speeds, they're only possible if you're near an exchange, which is alright for densely populated urban areas, but not for rural areas.

Unfortunately WiMAX requires licensed spectrum to work well, and (in the UK at least) spectrum is a valuable commodity as there isn't very much available. There are currently two networks offering WiMAX services on licensed spectrum: PCCW (UK Broadband) at 3.4GHz and Pipex Wireless on 3.5/3.6GHz. These services are only available in limited areas.

Ofcom is planning to make more spectrum available and there'll be an auction for 2.5GHz in the near future. Although originally designated a 3G band, Ofcom are going to make it available for any kind of use, including WiMAX. There's certainly going to be a lot of interest in that spectrum and BT have already stated it is interested in it.

WiMAX will allow speeds of about 100Mb/s to end-users, which is certainly good enough to deliver BT's 21CN requirements (and any other network operator's) which is good news for people who don't live in city centres

Wireless

Wireless will permeate the home: you've got 802.11/a/b/g and now 802.11n (well draft 2.0 now, but in five years' time they'll have settled their arguments and the actual specification will have been released, by then it will be 802.11n+ or turbo). This will allow speeds of up to a couple of hundred megabits per second between devices. Since it uses MIMO (multiple in, multiple out) the beams can be steered, allowing higher transmission speeds and distances with less interference between devices.

A new wireless standard will also be available called UWB (ultra wideband). UWB devices are already starting to appear in the US. Unfortunately the FCC has adopted a slightly different specification to that in Europe (which has just been approved), so it will be a while before European-approved UWB devices appear.

UWB works by sending data over large amounts of spectrum, by splitting data into chunks that are sent over different frequencies. The data is also duplicated so if various frequencies are interfered with, the original data can be resurrected (i.e. there's error correction). UWB uses extremely low transmission levels which means if it interferes with something else using some of the frequencies they just 'hear' background noise and can generally ignore it, and if UWB is interfered with (frequency wise) it just uses its error correction techniques to put the data back together again.

UWB will offer short-range transmission rates of hundreds of megabits per second – the US equipment coming out now is designed for wired USB 2.0 replacement, which operates at 480MB/s.

Why do people need these high speeds? It's all about replacing wires.

802.11n for longer range in-home connectivity and UWB for very short range. Many vendors are looking at in-home video distribution, so your Sky box will sit in one room, but can deliver a high-definition video stream to any TV in the building (using 802.11n). UWB will also be used to replace cables out of the PC, meaning you can sit your PC under your desk and the monitor, keyboard, mouse, printer, scanner etc will all connect wirelessly.

Femto Cells

Femto cells are low power GSM or 3G cells that use broadband to connect back to an operator. As both GSM and 3G use licensed spectrum only the operators will be able to offer in-building services, but on the GSM side 12 new licenses were awarded last year and they are starting to offer services.

Femto cells should cost around $100 (probably including a broadband router) which means they should be affordable for home use. When in range of the cell, your phone will use that instead of the normal network cell and as it uses broadband for connectivity call pricing should be reduced, it's likely that mobile calls when in range of a local femto cell could be as cheap as current landline calls. It also allows news services to be offered, like your phone becoming part of your office phone system. So no more deskphone, just your mobile.

The Future and Beyond

Wireless is definitely going to play a major part of any new technologies in the future and that future is going to be all IP.

Now I think I'll go and jack myself into my virtual world (3rd life?) but must remember to eat. Being in-line doesn't mean my real body stops working.

The future's bright, the future's IP and wireless.

CEPIS Projects

Next Milestones and Events

Harmonise has now entered the last, but certainly most important, months of its life. For a few months, the project partners have been putting together the different areas of study to create a unified and consistent final report that will be presented to the European Commission in September.

With the purpose of sharing the latest findings of the study, CEPIS and its partners gathered in Milan on the 4th. and 5th. June 2007. In order to ensure a high level of quality in the project outcome, the Harmonise Consortium decided to gather external experts in the shape of a working group to whom the results of the study will be presented. Our guests will then be able to comment on the findings. The working group will meet on 4th. September 07. CEPIS will also organize a final event to present publicly the results of the research. This event will take place in Brussels on 18th. September 07. Should you be interested in joining one of these two events or in receiving more information about the project, please contact François-Philippe Draguet <draguet@cepis.org>. You can also visit the project website <www.cepis-harmonise.org>.

The Euro-Inf Consortium finalized the first drafting phase. In order to reach this general agreement by the stakeholders on the Draft Framework for Accreditation of Informatics in Higher Education, various meetings were organized, a workshop was set up by CEPIS in Brussels gathering representatives from industry, accreditation agencies, CEPIS member societies and many rounds of feedback were monitored. The final draft version of the framework is now online. You can download it from <www.euro-inf.eu> in the “news” section. The project is now testing the draft framework in various volunteer universities. The first accreditation visit will take place in Tuzla at the end of June. Other visits will be organized in the autumn to other universities. This testing phase will lead to a refining phase of the framework. It will then be tested again and retuned according to the feedback. Should you be interested in joining the accreditation team or in having more information on the project, please contact François-Philippe Draguet <draguet@cepis.org> or check the project website <www.euro-inf.eu>.