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@Science: a network about science accessibility for university students

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Abstract

At present, visually impaired students are strongly discouraged to attend university scientific studies, especially because of the lack of scientific resources fully accessible through assistive technologies, the difficulty to attend scientific university lectures based on explanations employing transparencies with mathematical expressions as well as graphical representations and the tools to work on mathematical expressions, which are often partially usable or incomplete for advanced subjects. Furthermore, the variety all over Europe of national braille codes to represent mathematical expressions and the language dependence of audio books recorded by human readers make difficult a cross country exchange of knowledge and resources. Some universities have been working on the improvement of assistive technologies in science learning for many years and they have collected best experiences, tools, accessible scientific resources and effective and efficient methods. Unfortunately, up to now many of these best practices and educational resources haven't got widespread all over Europe. In order to share knowledge among universities about science accessibility by visually impaired people and to produce guidelines and to document best practices, the @Science thematic network was established. It is supported for two years by the European Union eContent-Plus Programme. It involves six founding members from five European countries: Italy, Austria, Slovakia, Belgium and France. In the project lifetime, collaboration actions will be undertaken so as to involve in the thematic network other universities, software and hardware manufacturers, publishers, associations for visually impaired persons and students themselves. In so doing, each group will contribute with its experience and will gain knowledge from other experiences. Moreover, the guidelines and best practices will be the result of a two years exchange of knowledge among experts and end users. At first, this paper will introduce the main barriers which affect blind students in going through scientific studies. Then, it will present the objectives and the methodology of the @Science network.

1 Introduction

Braille and speech assistive technologies have brought several advantages to visually impaired students, especially as for the greater availability of educational resources accessible through auditive and tactile perception, the improvements in tools for reading and writing and the possibility to better communicate with sighted people (e.g. teachers, schoolmates, etc.). So far, the benefits brought by assistive technologies have only partially affected scientific studies. That is due mainly to two factors: the features of scientific documentation and learning processes, and the existence of many local specificities which prevent students and institutions from easily sharing methods and resources. An example of the former issue concerns the use of images in scientific documentation. They have to be adapted in alternative formats to be understood by visually impaired students. Many of the available techniques are expensive, time consuming and reusability of the results is often not guaranteed. An example of the latter issue concerns the existence of many national Braille codes to represent mathematical expressions. Many Braille codes are not complete for advanced studies and they are sometimes not officially approved by Braille authorities, but nonetheless they are used by many students. Furthermore, there exist many local experiences and projects which came to worthwhile results. Some of these projects and results are often not known worldwide. In the following sections, some of the main problems about access to scientific studies by visually impaired people will be illustrated. Subsequently, the proposal of a transnational network about science accessibility by visually impaired students will be presented.

2 Speech and tactile access to scientific documentation

2.1 Scientific documentation

Text, mathematical expressions and graphics are the chief means used to describe and communicate concepts and procedures in scientific branches of learning. As for input, expressiveness, structure and understanding, these documentation forms present peculiarities and differences.

Text is the printed representation of natural language. It can be written on paper by pencil and it is easy to input it in a digital form by a computer keyboard. Actually, a lot of editors and word processors exist and they are proven to be advantageous in many writing activities, including taking notes, preparing drafts and documents. Tools and techniques to work on text are widespread (e.g. text marking, cut and paste, search and replace, etc.). Text is generally organized according to a rather simple structure (e.g. words, sentences, paragraphs, sections, chapters, etc.), consequently the exploration of its visual rendering can proceed either from left to right or browsing the tree structure of the parts. The mental workload to understand textual information is usually not high as it is often enough to get the gist of what is written to fully understand the meaning of a whole sentence. Therefore not all the written items have to be carefully read and remembered to understand properly a concept described through text.

Mathematical expressions are meant to unambiguously describe concepts and procedures. They are usually written on paper by pencil. There exist many tools to input mathematical expressions in a digital form, but they are mainly used to transcribe something written on paper for printing or displaying on a screen. Writing on paper is still widely regarded as a more straightforward technique to take notes, to simplify algebraic expressions and to understand symbolic manipulations. It is due above all to the difficulty to rely on effective, efficient and satisfactory input and edit techniques for mathematical notations exploiting two-dimensional representations (e.g. fractions, subscripts, superscripts, exponents, matrices, etc.). Mathematical expressions are potentially extremely structurally complex. For example a sum of nested fractions is easy as for operations to perform in simplifying it, but it is complex as far as the structure is concerned. In order to improve readability, the visual rendering of mathematical expressions exploits a two-dimensional layout. It induces horizontal and vertical exploration, as well as the necessity to directly access to specific building blocks (e.g. the numerator, the denominator, the subscript, etc.) precisely located on a two-dimensional plane.

Graphical descriptions are related to a large variety of representations, such as diagrams, flowcharts, drawings, and so on.

The images are extremely expressive. An image can convey synchronously much meaningful information. Actually, visual exploration of images is not a sequential process as text reading. Many meaningful informative units are instantly isolated by sight and mental processes, afterwards mutual relations are constructed. For example, watching the diagram of a sinusoidal function, the Cartesian axes are immediately isolated from the curve and mutual relations between the curve and the axes (e.g. intersections, position of some points in a certain quadrant, etc.) are rapidly understood.

The possibility to come effectively, efficiently and satisfactorily to a mental representation of text, mathematical expressions and drawings is a basic requisite to understand scientific documentation.

2.2 Tactile and Speech Assistive Technologies

Tactile and speech user interfaces are generally designed for visually impaired people and they are commonly implemented in assistive technologies, namely those tools which allow one to overcome difficulties due to a disability in achieving tasks (e.g. reading and writing documents, browsing web pages, etc.). They can be divided into two groups. The former group addresses the design of adaptations to mainstream programs in order to make them available to visually impaired users. The latter addresses the design of specialized applications, useful to enable visually impaired users to achieve a specific task (e.g. writing documents, reading books, exploring diagrams through sound, etc.).

Screen readers are the primary representatives of the first category. These are programs that make the information displayed in a visual interface, available in a different modality: either Braille through a Braille display or speech through a speech synthesizer. These programs are general purpose because they attempt to improve access to any information presented by programs within a particular operating system. This enables visually impaired people to use the same software products as their sighted colleagues. Nonetheless, interaction paradigms used in graphical user interfaces are sometimes unsuitable or even totally unusable by visually impaired users.

So, specialized programs are produced to fulfil needs and operative strategies not catered for by either mainstream software or general purpose screen readers. Advancements in graphical user interface design, in the early nineties presented great problems of accessibility for visually impaired computer users [1]. However, technical advancements in the design of screen readers greatly improved access to products employing graphical user interfaces such as Microsoft Windows. Yet, not all environments are fully accessible with the current screen readers. Screen readers mainly render only textual representations of natural language. Even if many screen readers are able to handle graphical objects such as icons, graphical buttons, bars, and so on, or also complex informative structures such as tables, lists, dialog boxes, pull-down menus, and so on, the description of these objects is almost exclusively textual. Textual representations are often enough to facilitate the construction of a mental image of what is displayed and to interact with the system. Nonetheless, as was mentioned previously, textual descriptions could not be enough to successfully describe, read and understand scientific documentation. In order to provide more effective, efficient and satisfactorily techniques to work with complex informative structures (e.g. images, mathematical expressions, scores, etc.), specialized applications are designed. Specialized software can be developed also when a need does not exist or has no relevance within the sighted community. For example, the audio description of diagrams [2] proper tactile embossing of two-dimensional structures [3], audio cues within descriptions of complex information [4].

2.3 Usability of scientific documentation through assistive technologies

Let us define usability to scientific documentation through assistive tools as the measure of effectiveness, efficiency and satisfaction with which blind students can achieve their learning tasks in an educational environment.

The factors which affect usability of scientific documentation through tactile and speech assistive technologies are manifold and they are strongly related to usability of text, mathematical expressions and graphics.

As was mentioned in advance, text does not present great problems as for tactile and speech exploration and editing. Many techniques were studied and they are currently implemented in mainstream screen readers. Therefore, text usability is generally high through mainstream speech and tactile tools.

On the contrary, mathematical expressions present challenging usability issues. Two main factors affect usability of mathematical expressions: how they can be read and understood, as well as how they can be written and manipulated. In order to comprehend how mathematical expressions can be read and understood through tactile and speech output, it is useful to compare visual reading and tactile and speech reading. A model for visual understanding of mathematical expressions was proposed in 1987 [5]. This model works as follows. A mathematical expression is visually scanned by the reader, whose gaze may rest upon the expression for a while. A mental representation of the surface structure of the expression is formed. This representation is checked for understanding, which involves checking that all symbols are known and checking that the complexity or length of the expression is manageable. If either of these two tests are failed the procedure is aborted and a smaller portion of the expression is gazed. Otherwise a syntactic analysis is undertaken in order to come to a tree representation. It is the initial part of this process that poses difficulties for a blind reader [4], as it implies the existence of an external memory (e.g. paper, a blackboard or a screen) which permanently displays the representation of the mathematical expression. The permanence of the structure to explore and understand relieves the reader of the mental workload in retaining the information to be accessed, so that further mental resources can be employed in the comprehension of the mathematical meaning, rather than in retaining the syntactical structure. Furthermore, the manner in which the information is presented (e.g. whether some portions are underlined or highlighted, how blanks are used to separate blocks, how the mutual relations among sub-expressions are marked, etc.) can also help in the process of reading and understanding by sight and the layout of the information can suggest transformations and procedures to perform a certain task. This high level understanding of the expression is an "overall glance", which can be gotten quickly by sight over the entire expression or over its parts (e.g. sub-expressions, building blocks, etc.). This ability to get different views allows planning and adapting to the purpose the reading process. The representation on an external memory can be effective only when its parts can be accessed quickly and accurately. A visual representation on paper or on a screen in conjunction with the control provided by sight allows effective and active understanding. Reading and understanding through speech output is affected by the lack of an external memory. The transient nature of the speech signal does not allow one to have a permanent representation of the structure to read. That causes an inability to get different views at a mathematical expression and to directly access specific portions. As a consequence, the listener tends to be passive. Reading by touch is a more active style of exploration. The external memory is not absent, but it is extremely reduced with respect to the one accessible by sight. It is generally made up of a line of about forty Braille cells. Although rightward, leftward, upward and downward movements allow one to update the external memory with new portions of the mathematical expressions, at any one time, only a small portion of it can be accessed. Moreover, under the fingertips, at most two Braille cells can be perceived at any one time. Consequently, it is difficult to get an overall tactile glance at the whole expression or at its sub-expressions, so planning the reading process is far more difficult than by sight. Input and editing techniques for mathematical expressions are of paramount importance to achieving high usability of mathematical notations, through speech and tactile devices. In particular, they affect the writing speed, which influences the overall efficiency, the ease in carrying out transformations and the prevention of typing mistakes, which influence both effectiveness and satisfaction. When a sighted person writes a mathematical expression, the flow of information is simultaneously controlled by sight. Not only what is being written can be read by sight, but also a rather large area around the focused piece of information. That allows one to have complete control over the input process and the transformations to carry out. Consequently, writing mistakes can be immediately located. Furthermore, during a step of simplification, a straightforward comparison with the previously written expression can be achieved by sight. Touch does not allow simultaneous control over what is being typed in, since the fingers are part of the typing process. Anyway, symbolic patterns can be accurately retrieved by tactile exploration. Hearing may allow synchronous control, but it does not allow the synchronous exploration of already written expressions. Therefore, the design of input and editing techniques which exploit both speech and tactile output are likely to optimally compensate for the lack of sight.

Graphics can be hardly usable through tactile and speech devices. In order to comprehend the reasons which complicate the understanding of graphics in a non-visual mode, first of all let us analyse how visual understanding works and which advantages come from a visual exploration of graphical representations. Literature about how sighted people explore and understand graphics, suggests some basic features which should be reproduced by whatever tool for the exploration of non-visual representations of graphics. In particular, two features of diagram understanding were regarded as important: easiness to search and immediacy to recognize. Localisation of related parts in diagrammatic representations reduces the need for searching, and consequently it facilitates understanding. It means that information represented over a two-dimensional plane can be more efficiently grouped and searched for meaningful items than text along a line. As for recognition, diagrammatic representations allow one to immediately understand meaningful shapes, namely relevant parts can be easily isolated and connected to related diagram components. For example, given a parabola, it is straightforward to recognize by sight which is the part in the first and second quadrant, when it is displayed, whereas it takes a longer time to get it from a textual description (e.g. through some points in a table). What is natural in the exploration by sight, often becomes difficult in the exploration through speech output and tactile devices. It is due mainly to the transient nature of the speech signal and to the possibility to explore by touch only small areas at any one time. Nonetheless, it may be supposed that a tool which has to improve usability of non-visual descriptions of graphics should have at least four exploration features:

- item the possibility to easily recognize basic components or clusters in the diagram;
- item the possibility to identify relationships between basic components or clusters;
- item the possibility to easily search for components, either clusters or the basic ones;
- item techniques to hierarchically explore the graphical representation;

2.4 The importance of assistive technologies for science learning

As a consequence of what previously introduced, specialized assistive technologies for accessing science are necessary. In particular they should enable the students to:

- write, read and process mathematical expressions both through the Braille display and the speech synthesizer [6];
- communicate with sighted assistants also through visual representations, in particular with teachers and schoolmates;
- access resources available in mainstream formats [7];
- produce and explore non-visual descriptions of graphical representations.

3 The @Science network

3.1 Objectives

In order to enhance the access to scientific educational resources during university studies for blind and visually impaired students a project called “@Science” has been established. The ongoing project has been developed within the framework of the European Union eContentPlus programme and is co-ordinated by the Università degli Studi di Milano in Italy. The project started in October 2006 and has a duration of 2 years. The aim of this project is to facilitate the access to digitally available scientific resources to visually impaired students and researchers both by collecting and sharing practices and by producing guidelines about accessibility to digital scientific resources. There exist many differences among European countries as for science communication to visually impaired students. Some of the national peculiarities may constitute a problem (e.g. language dependent educational resources or differences in Braille codes), whereas others may be shared (e.g. techniques to prepare tactile representations or programs to explore representations in specific knowledge domains such as graph theory). By fostering communication among universities and institutions about these specific problems, the @Science network aims to prepare guidelines to produce digital scientific documentation accessible by visually impaired students in university courses. The founding consortium consists of the coordinating Università degli Studi di Milano (Italy), the University of Linz, Institute Integriert Studieren (Austria), the Katholieke University Leuven

(Belgium), the Comenius University, faculty of Mathematics, physics and informatics (Slovakia), the Union of the Blind in Verona (Italy) and the Pierre et Marie Curie Université (France).

3.2 Methodology

The @Science network aims to achieve the objectives mentioned above by undertaking two kinds of activities: information actions and collaboration actions. Information actions are undertaken to widespread both general background information about the problem of science accessibility and specific solutions (e.g. emerging technologies, success experiences, etc.), especially through conferences and papers. Collaboration actions mean to involve individuals, institutions (e.g. universities, schools, associations for visually impaired, libraries) and companies (e.g. assistive technology manufacturers, publishers, online content providers) to discuss and share experiences about access to digital scientific resources and select and share the best solutions. Some of these activities are set through the @Science web portal. The @Science website is the access point to the thematic network @Science on Internet. It can be browsed at the address: http://www.ascience.eu. This website collects pages concerning the aims of the thematic network, how institutions can join the network, how to contact network members and how to subscribe to the services being delivered by the network (e.g. the newsletter). It is divided up into four sections: events, projects, articles and tools. The events section collects information about up-to-date events (conferences, workshops, etc.) about science accessibility issues. To many of these events @Science members contribute or participate and prepare reports on the emerging opportunities. The projects section collects reports about the latest ongoing projects on specific issues. Both international and local projects are analysed. The articles section contains both informative papers on specific issues developed by the network members and abstracts of useful papers available from other content providers. The tools section stores demo releases or free programs which can help visually impaired students overcome certain barriers in scientific studies. Furthermore, the web portal provides two collaborative tools to support exchange of experiences and of resources: a forum and a mailing list. The discussions being carried on in the forum or in the mailing list are supposed to be extremely useful to share existing solutions and to sketch new ones.

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