Mathematics on the web: emerging opportunities for visually impaired people

[@Science European Thematic Network]

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ABSTRACT

This paper discusses the state of the art of mathematics on the Web in the context of its accessibility to visually impaired people. It goes on to explain how the use of the MathML markup language to embed mathematical expressions in Web pages could improve the accessibility and usability of Web published scientific documentation when consulted with speech synthesis and/or Braille devices. This work was carried out as part of the @Science project. @Science is a thematic network funded by the European Commission eContentPlus Programme. Its goal is the preparation of guidelines and best practices for production and use of digital scientific documentation accessible to visually impaired university students.

Keywords

Web accessibility, science accessibility, mathematics accessibility, visually impaired

1. INTRODUCTION

Until recently mathematical expressions were published on the Web either as images depicting the expression or as PostScript or PDF files to be downloaded. Both of these solutions pose problems to browsing with speech and/or Braille. Images are seldom provided with alternative descriptions (e.g. LaTeX-like notations) and both PostScript and PDF viewers do not enable screen reading software to describe mathematical expressions in an alternative way. A promising direction to enhancing accessibility and usability of scientific documentation on the Web involves the use of MathML[1] to publish mathematical expressions and the improvement of browser extensions which translate MathML into speech or Mathematical Braille notations. This line of development is being pursued by the @Science thematic network in order to provide blind students at university with accessible scientific documentation.

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[1]http://www.w3.org/Math/

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2. THE @SCIENCE THEMATIC NETWORK

In order to enhance access to scientific educational resources for blind and visually impaired students undertaking university studies a project called "@Science" was set up. This ongoing research project is being developed within the framework of the European Union eContentplus Programme and is coordinated by the Università degli Studi di Milano in Italy. The project started in October 2006 and will last for 2 years. The aim of the project is to facilitate access to digitally available scientific resources for both visually impaired students and researchers by bringing together and sharing best practices and producing guidelines concerning the accessibility of digital scientific resources. The consortium is made up of the coordinating Università degli Studi di Milano (Italy), the University of Linz, the 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 Université Pierre et Marie Curie (France).

3. SPEECH AND BRAILLE ACCESS TO MATHEMATICS ON THE WEB

Speech and Braille understanding of mathematical expressions is somewhat different from visual comprehension. Mathematical notation usually uses two-dimensional structures (e.g. fractions, matrices, etc.). A two-dimensional layout can be understood at first sight with a rapid overall glance, providing information about the structural elements making up the expression, then by examining details, horizontally or vertically. The sighted reader can directly and accurately access specific parts of the expression when needed (see equation 1).

$$\frac{x+1}{x-1} \tag{1}$$

Reading and understanding a mathematical expression through speech output or Braille, on the other hand, is impeded by the lack of a solid representation of the structure to explore. These modalities necessarily linearise contents – see in figure 1 the linearised version (2) of equation 1, and then its Braille form in Italian (3) and Nemeth (4) Braille codes. This makes it difficult to achieve overall understanding and to directly access specific subexpressions. Reading a Braille representation of a mathematical expression is mainly a sequential process. The overall meaning of an expression is understood by finding mutual relations among readily understandable simple subexpressions. The possibility to plan further exploration and to access specific parts directly can be lost. Mathematical expressions can be understood effectively and efficiently through tactile and auditive perception, but only when the reader can rely on operations to rapidly access specific parts of the expression and to extract the overall structure.

Until recently mathematical expressions have been published on the Web either by embedding bitmap images in Web pages or by allowing the download of PostScript or PDF files. Neither of these techniques enable software agents to produce Braille or speech output. MathML has opened up new possibilities for generating speech and Braille representations and for giving readers the functions required for optimal understanding. If mathematical expressions are embedded in Web pages through MathML, software agents can parse the structure to generate speech or Braille alternative descriptions or to implement exploration functions. Moreover, MathML content can be accessed to output high quality speech (using prosody, for example). Again, the use of semantic annotations can help software agents to generate the right alternative descriptions in specific sub-branches of expressions. In the following sections the most relevant emerging tools which use MathML are described.

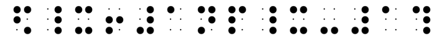
4. MATHPLAYER

MathPlayer [8] is a Web browser extension which interprets MathML and produces both a visual description of the mathematical notation and speech output[2]. It is especially useful for improving scientific communication between sighted and visually impaired people. Further development is planned to support multilingual speech output and Braille output. MathPlayer actually produces a string containing the relevant sentence to be read with a speech synthesiser, which is transmitted to a screen reader through MSAA (Ms Active Accessibility interface). A MathZoom feature allows partially sighted users to magnify expressions. Built-in speech rules try to minimise the number of words used to speak the maths while producing an unambiguous rendering of it. The ability of MathPlayer 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.

5. THE LAMBDA SYSTEM

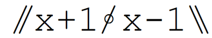
The LAMBDA system [7] is the outcome of a research project of the same name (Linear Access to Mathematics for Braille Device and Audio-synthesis), funded by the European Union IST program. It sought to develop a system

$$(x+1)/(x-1) \tag{2}$$

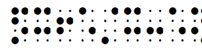


(3)

(4)



(5)



(6)

Figure 1: Equation 1 according to Italian national code (3), Nemeth code (4), Lambda code with visual font (5) and Lambda Italian Braille code (6).

to facilitate reading, writing and processing text and mathematical expressions through a Braille display and speech synthesiser. The LAMBDA system is made up of two components: a mathematical linear code and a multimodal mathematical editor.

There exist many different Braille codes to represent mathematical expressions. Some of them are 6-dot Braille codes, others are 8-dot. The 8-dot Braille codes in particular are often incomplete and not officially approved by national Braille authorities. Despite this, 8-dots Braille codes are often used and adapted by blind students on their Braille displays. Both 6-dot codes and 8-dot codes often lack symbols and rules to represent mathematical expressions. In order to overcome national particularities, a set of rules was defined to uniformly describe Braille mathematical expressions in a linear form. These rules did not impose a unique mathematical Braille code. Instead a markup language was developed to linearly represent mathematical expressions, enabling them to be easily rendered on a Braille display or through speech output. Dot combinations linked to markers are customised according to national Braille codes (see Italian version on figure 1 (6)). For example, a fraction is always represented with three markers: one to mark the beginning, one to mark the separation between numerator and denominator and one to mark the end. The dot combinations for the markers can be different depending on the country. A name and a description are also associated with each marker in order to output speech.

Based on this uniform set of rules the LAMBDA editor enables users to develop working strategies which exploit the structural elements of the expression. The editor provides the user with techniques to input mathematical expressions through keyboard short-cuts and context-based function with strategies for understanding the structure of the mathematical expression (e.g. to shrink or un-shrink the content between parentheses) and with editing functions able to extract meaningful parts from the expression (e.g. numerator, denominator, etc.). Communication with sighted people is ensured by using a special font which displays Braille specific markers as meaningful shapes and also through a MathML converter which transforms the expression being edited for display by a viewer (see figure 1 (5)).

The MathML converter also enables the system to ex-

[2]MathPlayer is available as a Ms Internet Explorer plug-in and can be freely downloaded from http://www.dessci.com

change documents with mainstream applications. In particular, it is possible to import a simplified XHTML+MathML document, process it with the assistive functions of the system and export it again to XHTML+MathML.

6. MATH GENIE

The Math Genie [5] is a formula browser that facilitates understanding of formulas using voice output. It was recently augmented to provide Braille output on refreshable Braille displays. It was 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 teacher who is not required to have any particular knowledge of Braille. Teaching material can be prepared equally for both sighted and Blind students using any Math editor able to produce MathML. Graphical rendering is synchronised to the audio, making communication with the teacher easier. It is based on SVG (Scalable Vector Graphics), which enables the Genie to support magnification, in order to give support to partially sighted individuals, and colour-contrasted highlighting, in order to support individuals with dyslexia. The project is based on research in cognitive psychology, in order to enhance the way voice synthesis reads mathematical formulas [4]. The Math Genie offers Blind students several ways of reading formulas, from default left to right reading to a more abstract way that highlights the hierarchical structure while "folding" away the sub-expressions. The user can navigate in the mathematical structure, moving through meaningful "chunks". This is based on lexical clues, which represent the structure of the mathematical content.

The current version supports English, French and Spanish for speech, and enables the addition of any other language provided that a speech synthesiser is available with the requisite interface. The Braille output currently supports the Nemeth code [9].

7. MAWEN

MaWEn, which stands for *"Mathematical Working Environment"*, is a prototype application developed by the Johannes Kepler University of Linz, Austria, and the Pierre et Marie Curie University in Paris, as part of the Micole Project, funded by the European Union. It is a comprehensive, collaborative, bi-modal software solution designed to address the following issues:

- To work on documents of mixed content - textual and mathematical.
- To simultaneously represent formulas in the 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, especially mathematical formulas, such that the simultaneous representation mentioned above is retained.
- To support the student in doing mathematical manipulations.

In order to achieve these objectives a MathML based model has been developed which supports synchronisation and all the features described above. The choice of the MathML standard ensures the duration of the system over time.

8. UMCL

One problem that users have to deal with is the fact that most mathematical software using Braille is associated with one specific Braille mathematical code. As Louis Braille did not originally develop any code for Mathematics many different codes were developed in various countries. So for instance, if one looks for a tool to convert LaTeX documents to Braille, one will find Labradoor[3], but this will be useful only if the reader knows the Marburg code.

To address this issue the UMCL (Universal Maths Conversion Library) was developed [1]. UMCL is a programming library encapsulating various converters for different Braille codes in a single library, usable through a simple and unique API. UMCL is an open-source project and is portable. It was developed in standard "C" with wrappers to different other programming languages. The library allows developers of Mathematical applications to support more varied Braille codes. The library can also be used together with 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 makes converting a document from one national Braille notation to another possible, increasing de facto the number of documents available for students and allowing blind mathematicians from different countries to exchange documents.

To make this possible without increasing the complexity, an architecture based on a central representation of the formula needed to be adopted. Parsers needed to be developed to generate this central representation from the different input formats, as well as output generators for each output format. MathML was chosen as the central language. The architecture of UMCL is quite simple. It includes a main module and as many input and output modules as there are Maths codes 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 needed 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 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 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[2]. Canonical MathML is an attempt to unify MathML structures in a deterministic way so as 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. It must be stressed that Canonical MathML is valid MathML so it can be used with common tools which handle MathML. An input module for MathML allows conversion of 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.

9. CONCLUSIONS

One common thread of the various projects cited in this paper is that whether or not they are based on MathML, they support it. To effectively support the work of Blind individuals, applications should provide users with their usual notation, so that the method of accessing mathematical content does not increase the inherent difficulty of its comprehension.

MathML allows graphical rendering of Mathematical expressions in two dimensions, which is the natural way for sighted users. Indeed many applications have been developed to display MathML graphically on a screen (Mozilla based applications, Amaya and diverse plug-ins for Ms Internet Explorer). MathML contents can also be enlarged in order to accommodate low vision users (this is not possible with bitmap images). Tools like UMCL enable applications to provide Braille experienced users with the notation they have been taught, so they do not have to learn another one. Finally beginners or people who have recently lost their sight can use speech enabled applications based on MathML.

The Daisy Consortium[6] also recently released the Mathematics Modular Extension for the DAISY Standard[3]. DAISY stands for Digital Accessible Information SYstem. DAISY was created to set up standards for digital talking books. The Maths extension is based on MathML. It gives great hopes for increasing the scientific literacy of people with print disabilities.

To conclude we believe it is important that the providers of online scientific documents or services (e.g. e-learning platforms, interactive Web-oriented tools for calculus, etc.) adopt the MathML standard widely. This seems to be the only way to make documents fully accessible to everyone, with whatever means they use to access contents. Several tools exist now that enable print impaired individuals to access MathML contents using Braille or speech synthesis, or to magnify the graphical rendering. Further tools will only be designed if mainstream applications are based on MathML.

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[3] http://www.daisy.org/news/news_detail.asp?NewsId=296, March 2007

[4] The contents of this paper is the sole responsibility of the authors an in no way represents the views of the European Commission or its services)