The Journal on Technology and Persons with Disabilities

Generating Nemeth Braille Output Sequences from Content MathML Markup

Samuel S. Dooley, Su H. Park
Pearson Assessments
sam.dooley@pearson.com, su.park@pearson.com

Abstract

The need for high-quality braille materials is one of the most challenging obstacles faced by visually-impaired students, especially for mathematical content. The need for visually-impaired students to communicate their work to sighted instructors often prevents them from participating in mainstream classrooms in STEM subjects. The goal of this current work is to provide a software system that supports the automatic generation of Nemeth Braille output in the context of a WYSIWYG equation editor designed for sighted math users. This software allows a sighted math user, who need not know Nemeth Braille, to produce high-quality braille materials for math in a fraction of the time, and at a fraction of the expense, of current best practices for print-to-braille translation. This software provides the basis for more immediate communication of mathematical content from sighted users to visually-impaired students, reducing communication barriers that inhibit visually-impaired students from participating in mainstream math and science classrooms.

Keywords

Mathematical User Interfaces; Equation Editors; Nemeth Braille; Content MathML; Braille Translation Software.

Introduction

The W3C Math Markup Language (Ion and Miner) has now been used for over fifteen years to represent structural forms (Content MathML) and print notations (Presentation MathML) for online mathematical expressions. Nemeth Braille (The Nemeth Braille Code for Mathematics and Science Notation) has now been used for over sixty years as a means to capture print math notation for tactile reading for low-vision and blind users. While Nemeth Braille has much in common with Presentation MathML in its intent to capture the appearance of print math notation, the design of its coding rules also shares much in common with Content MathML in its desire to preserve the structural form of the expressions it encodes.

Content MathML provides a common source representation that can be translated into multiple parallel output representations using an operator-based transformation rule framework to effect the translations (Dooley; 55-62). Using this framework, Content MathML can be transformed into Presentation MathML for print users, and can be transformed into Nemeth Braille for visually-impaired users, who may access the Braille output by means of refreshable braille devices or other tactile printing methods.

This framework enables the input from a sighted user to be displayed in a format that can be read by a visually-impaired user, where the simultaneous print and braille displays are updated upon receipt of each keystroke event.

Discussion

The similarities in design between MathML markup and Nemeth Braille codes encourage a specific means to represent math expressions within a software system in a format that is accessible to both print and braille users. A single source representation (Content MathML) can be translated into multiple parallel output representations using an operator-based transformation rule framework to effect the translations (Dooley; 55-62). Using this framework, Content MathML can be transformed into Presentation MathML for print users, whether for online or offline use, and can be transformed into Nemeth Braille for visually-impaired users, who may access the braille output by means of refreshable braille devices or other tactile printing methods.

A large majority of the encoding rules for Nemeth Braille are purely structural in nature, and can be implemented in a straightforward fashion using the same transformation rule framework used to generate Presentation MathML. These rules include virtually all of the most common mathematical operators (signs of operation, comparison, and special symbols) as well as many that are beyond the scope of Content MathML (arrows, shapes, circled and squared operators), but that can be represented using extensions to Content MathML, and processed just as any other operator.

Other Nemeth encoding rules are more contextual in nature, and require more specialized techniques. Nested structure indicators for fractions (which require an additional indicator from the inside out) and radicals (which require an additional indicator from the outside in) can be supplied by a special routine to traverse the content expression tree to determine the number of indicators. A similar procedure is used to determine the proper encoding for nested combinations of superscripts and subscripts, and over scripts and under scripts. More specific procedures are needed to determine the circumstances dictating the use of spacing rules, numeric and alphabetic indicators, and the multipurpose indicator. These contextual rules are mostly limited in application, but serve the important role of distinguishing between similar braille sequences that code different expressions. While rules to encode combinations of textual and mathematical content are outside the scope of this work, as are encoding rules for spatial arrangements and tactile graphics, these forms also could be addressed within the current framework, albeit with considerably more effort.

The operator-based transformation rule framework, augmented by special techniques for contextual encoding rules, is sufficient to encode all of the mathematical content addressed by the Nemeth Braille rules, to a high degree of precision. This framework has been implemented as an extension to an existing equation editor for Content MathML markup (Dooley; 55-62) that is currently used in an assessment platform to collect constructed math responses to high-stakes assessment items. The Nemeth Braille extensions described here will be used to provide access to the online assessment platform for low-vision and blind users.

The testing regimen for the transformation from Content MathML to Nemeth Braille was accomplished by means of a special test page that embeds the equation editor, which generates the Presentation MathML and the Nemeth Braille encodings for a sequence of test cases, each of which are displayed on the page so the correspondence between the presentation forms can be verified by a sighted user. In addition, hand-generated alternate text for each test case is displayed and marked so it can be announced by a screen reader, and the braille encoding is marked so it may be displayed on a refreshable braille device. Using this test page, a blind tester was able to verify the correspondence between the hand-generated alternate text, and the machine-generated braille output, for 948 separate test cases, within two days, and provide specific feedback to improve the generated braille.

Conclusions

As described in (Dooley; 55-62), operator-based transformations from Content MathML to Presentation MathML are well understood, and represent a specific case of the more general approach to the separation of structure and style found in other web languages. These transformations allow math content forms to be translated into any number of presentational forms, including Presentation MathML, and Nemeth Braille.

Further work on the operator-based transformation framework and the quality of the braille output it generates would include addressing a few remaining issues in the implementation of certain contextual rules, completing the list of known operators to include limits, derivatives, and integrals, and extending the framework to support markup for content that contains both literary and mathematical expressions.

As time goes on, more and more of the means and methods by which math and science are taught are being transformed into electronic and/or online forms. Online math instruction and assessment are now high-profile lines of business for major publishing companies and consortia, and are transforming education at all levels. Electronic textbooks and other materials are increasingly replacing paper-based alternatives, and teacher-student interactions are taking place using social media, online meeting rooms, and distance learning systems. As these transformations take place with increasing speed, the accessibility of these solutions lags behind due to the inherent difficulty of providing accessible math software in an online world. Online math software presents unique challenges that are not found in text-based software, further compounding the difficulty in making such software accessible. Moving forward, the need for access to online math content will override all other concerns related to the communication of mathematics. If visually-impaired students are to succeed in mathematics in the classroom at all grade levels, their participation needs to be fully online and fully interactive. By reducing the time and cost involved in braille translation, this work has the potential to produce a truly level playing field for visually-impaired students in mainstream STEM classrooms.

Works Cited

Dooley, S. S. Editing Mathematical Content and Presentation Markup in Interactive Mathematical Documents, in Mora, T., Ed., Proceedings of the 2002 International Symposium on Symbolic and Algebraic Computation, New York, 07–10 July 2002, ACM SIGSAM, ACM Press, pp. 55–62. Lille, France.

Ion, P., and Miner, R., Eds. Mathematical Markup Language (MathML) 1.0 Specification, W3C Recommendation, W3C, 07 April 1998. http://www.w3.org/TR/1998/REC-MathML-19980407/

The Nemeth Braille Code for Mathematics and Science Notation, American Printing House for the Blind, Louisville, Kentucky, 1972. https://nfb.org/images/nfb/documents/pdf/nemeth_1972.pdf

Journal on Technology and Persons with Disabilities

ISSN 2330-4216

LIBRARY OF CONGRESS * U.S. ISSN CENTER
ISSN Publisher Liaison Section
Library of Congress
101 Independence Avenue SE
Washington, DC 20540-4284
(202) 707-6452 (voice); (202) 707-6333 (fax)
issn@loc.gov (email); www.loc.gov/issn (web page)