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XML BASED LANGUAGES FOR REPRESENTING MATHEMATICAL AND SCIENTIFIC CONTENT*

Milko Tipografov, Vladimir Dimitrov

The purpose of this paper is to overview XML based languages for encoding and representing of mathematical and scientific content and data. It covers Mathematical Markup Language (MathML), OpenMath, Scalable Vector Graphics (SVG), Synchronized Multimedia Integration Language (SMIL), and Chemical Markup Language (CML).

Mathematical Markup Language (MathML)

What is MathML? W3C has brought together key players to fill an urgent need for mathematics on the Web. Out of this work has come the Mathematical Markup Language (MathML), a format enabling authors to present mathematical expressions on the screen, as well as forming the basis for machine to machine communication of mathematics on the Web. Designed as an XML application, MathML provides two sets of tags, one for the visual presentation of mathematics and the other associated with the meaning behind equations. MathML is not designed for people to enter by hand but specialized tools provide the means for typing in and editing mathematical expressions.

MathML is a low-level specification for describing mathematics as a basis for machine to machine communication. It provides a much needed foundation for the inclusion of mathematical expressions in Web pages.

MathML is intended to facilitate the use and re-use of mathematical and scientific content on the Web, and for other applications such as computer algebra systems, print typesetting, and voice synthesis. MathML can be used to encode both the presentation of mathematical notation for high-quality visual display, and mathematical content, for applications where the semantics plays more of a key role such as scientific software or voice synthesis.

MathML is cast as an application of XML. As such, with adequate style sheet support, it will ultimately be possible for browsers to natively render mathematical expressions. For the immediate future, several vendors offer applets and plug-ins which can render MathML in place in a browser. Translators and equation editors which can generate HTML pages where the math expressions are represented directly in MathML will be available soon.

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Why we are working in this area? Although the mark-up language HTML has a large repertoire of tags, it does not cater for math. With no means of using HTML tags to mark up mathematical expressions, authors have resorted to drastic means. For example, a popular method involves inserting images – literally snap shots of equations taken from other packages and saved in GIF format – into technical documents which have a mathematical or scientific content.

Current situation. Version 2.0 of the MathML specification was released as a W3C Recommendation on 21 February 2001. It adds new functionalities and improvements to MathML 1.01 (released in July 1999) such as a DOM, new character sets, and an interface to embed MathML in other XML-based documents such as XHTML.

A test suite for MathML 2.0 was released in December 2000. Version 2.0 of the test suite was released in September 2002.

The first MathML Conference was held on 20-21October 2000. The second was held on 28-30 June 2002.

The Second Edition of MathML 2.0 was published as a Recommendation on 21 October 2003. It provides a coherent whole containing corrections to all the known errata and clarifications of some smaller issues that proved problematic in MathML 2.0.

Role of W3C. W3C hosts a Math Working Group which currently includes representatives from the American Mathematical Society, Design Science Inc., Deutsche Forschungszentrum für Künstliche Intelligenz, Boeing, IBM, INRIA, MacKichan Software, MathSoft, Microsoft, NAG, Stilo Technologies, Stratum Technical Services, Universita di Bologna, University of Western Ontario, Waterloo Maple Inc. and Wolfram Research. The group is involved in:

- Maintenance of and encouragement of the use of the MathML 2.0 Recommendation
- Continued liaison with other Working Groups within the W3C to ensure that the potential of MathML is realized
- Talking to other organizations with a view to strengthen the position of MathML and the use of math on the Web
- Making sure that other newly developing W3C specifications promote the implementability and usefulness of MathML
- Working with Web Accessibility Initiative (WAI) experts on the realization of audio rendering of MathML
- Cooperation with the OpenMath effort, as realized in the European Esprit project and through the The North American OpenMath Initiative on the other side of the Atlantic
- Encouraging development of software that facilitates the creation of documents using MathML for math. Examples are translators from older encodings, such as TeX and ISO 12083, and customized input syntaxes and editors.

MathML in browsers and mathematics software. MathML 2.0 is currently supported by many applications, proving that not only is it the format of choice for publishing equations on the Web but also that it is a universal interchange format for mathematics. More than 20 implementations are listed on the MathML software page (http://www.w3.org/Math/implementations.html), showing that all categories of mathematical software can handle MathML:

- Browsers: all common browsers can display MathML equations, either through the use of plug-ins (like techexplorer or Mathplayer for Microsoft Internet Explorer) or native support (Mozilla, Netscape 7).

- Editors: MathType, Amaya, Publicon, TeX4ht, WebEQ.
- Converters: MathML to SVG (Custard), LaTeX2HTML.
- Software libraries for rendering Math: GtkMathView.
- Most "heavy-duty" mathematical software can export and import MathML: Scientific Workplace, Maple, MathCad, Mathematica.

Simple example of MathML. This simple example of MathML gives you an idea of how it works. The equation in question is:

$$\boldsymbol{x^2 + 4x + 4 = 0}$$

and below are two ways that this can be represented, first using presentational tags, then using semantic tags. The presentational tags generally start with "m" and then use "o" for operator "i" for identifier "n" for number, and so on. The "mrow" tags indicate organization into horizontal groups.

```
<mrow>
 <mrow>
   <msup> <mi>x</mi> <mn>2</mn> </msup> <mo>+</mo>
    <mrow>
     <mn>4</mn>
     <mo>&InvisibleTimes;</mo>
     <mi>x</mi>
 </mrow>
  <mo>+</mo>
  <mn>4</mn>
</mrow>
  <mo>=</mo>
  <mn>0</mn>
</mrow>
```

The semantic tags take into account such concepts as "times", "power of" and so on:

```
<apply>
 <plus/>
 <apply>
  <power/>
  <ci>x</ci>
  <cn>2</cn>
 </apply>
 <apply>
  <times/>
  <cn>4</cn>
  <ci>x</ci>
 </apply>
 <cn>4</cn>
</apply>
```

OpenMath

Overview. OpenMath is an emerging standard for representing mathematical objects with their semantics, allowing them to be exchanged between computer programs, stored in databases, or published on the worldwide web. While the original designers were mainly developers of computer algebra systems, it is now attracting interest from other areas of scientific computation and from many publishers of electronic documents with a significant mathematical content. There is a strong relationship to the MathML recommendation from the Worldwide Web Consortium, and a large overlap between the two developer communities. MathML deals principally with the *presentation* of mathematical objects, while OpenMath is solely concerned with their semantic meaning or *content*. While MathML does have some limited facilities for dealing with content, it also allows semantic information encoded in OpenMath to be embedded inside a MathML structure. Thus the two technologies may be seen as highly complementary.

Mathematical objects encoded in OpenMath can be

- displayed in a browser
- exchanged between software systems
- cut and pasted for use in different contexts
- verified as being mathematically sound (or not!)
- used to make interactive documents really interactive.

OpenMath is highly relevant for persons working with mathematics on computers, for those working with large documents (e.g. databases, manuals) containing mathematical expressions, and for technical and mathematical publishing.

The worldwide OpenMath activities are coordinated within the OpenMath Society, based in Helsinki, Finland. It is coordinated by an executive committee, elected by its members. It organizes regular workshops and hosts a number of electronic discussion lists. The Society brings together tool builders, software suppliers, publishers and authors.

Scalable Vector Graphics (SVG). SVG is a platform for two-dimensional graphics. It has two parts: an XML-based file format and a programming API for graphical applications. Key features include shapes, text and embedded raster graphics, with many different painting styles. It supports scripting through languages such as ECMAScript and has comprehensive support for animation.

SVG is used in many areas including Web graphics, animation, user interfaces, graphics interchange, print and hardcopy output, mobile applications and high-quality design.

SVG is a royalty-free vendor-neutral open standard developed under the W3C Process. It has strong industry support; Authors of the SVG specification include Adobe, Agfa, Apple, Canon, Corel, Ericsson, HP, IBM, Kodak, Macromedia, Microsoft, Nokia, Sharp and Sun Microsystems. SVG viewers are deployed to over 100 million desktops, and there is a broad range of support in many authoring tools.

SVG builds upon many other successful standards such as XML (SVG graphics are text-based and thus easy to create), JPEG and PNG for image formats, DOM for scripting and interactivity, SMIL for animation and CSS for styling.

SVG is interoperable. The W3C release a test suite and implementation results to ensure conformance.

Technical Details. SVG is a language for describing two-dimensional graphics in XML. SVG allows for three types of graphic objects: vector graphic shapes (e.g., paths consisting of straight lines and curves), images and text. Graphical objects can be grouped, styled, transformed and composited into previously rendered objects. Text can be in any XML namespace suitable to the application, which enhances searchability and accessibility of the SVG graphics. The feature set includes nested transformations, clipping paths, alpha masks, filter effects, template objects and extensibility.

SVG drawings can be dynamic and interactive. The Document Object Model (DOM) for SVG, which includes the full XML DOM, allows for straightforward and efficient vector graphics animation via scripting. A rich set of event handlers such as onmouseover and onclick can be assigned to any SVG graphical object. Because of its compatibility and leveraging of other Web standards, features like scripting can be done on SVG elements and other XML elements from different namespaces simultaneously within the same Web page.

Synchronized Multimedia Integration Language (SMIL). The Synchronized Multimedia Integration Language (SMIL, pronounced "smile") enables simple authoring of interactive audiovisual presentations. SMIL is typically used for "rich media"/multimedia presentations which integrate streaming audio and video with images, text or any other media type. SMIL is an easy-to-learn HTML-like language, and many SMIL presentations are written using a simple text-editor.

W3C's Synchronized Multimedia Activity has focused on the design of a new language for choreographing multimedia presentations where audio, video, text and graphics are combined in real-time. The language, the Synchronized Multimedia Integration Language is written as an XML application and is currently a W3C Recommendation. Simply put, it enables authors to specify what should be presented *when*, enabling them to control the precise time that a sentence is spoken and make it coincide with the display of a given image appearing on the screen.

Today, W3C's Synchronized Multimedia Activity is focusing on the design of a new language to cover all necessary aspects of timed text on the Web. Typical applications of timed text are the real time subtitling of foreign-language movies on the Web, captioning for people lacking audio devices or having hearing impairments, karaoke, scrolling news items and teleprompter applications.

SMIL Concepts Simply Explained Timing the components of a multimedia presentation. In SMIL, the author names media components for text, images, audio and video with URIs and schedules their presentation either in parallel or in sequence. A typical SMIL presentation has the following characteristics:

The presentation is composed from several components that are accessible via URIs, e.g. files stored on a Web server.

The components have different media types, such as audio, video, image or text. The begin and end times of different components are specified relative to events in other media components. For example, in a slide show, a particular slide is displayed when the narrator in the audio starts talking about it.

Familiar looking control buttons such as stop, fast-forward and rewind allow the user to interrupt the presentation and to move forwards or backwards to another point in the presentation.

Additional functions are "random access", i.e. the presentation can be started anywhere, and "slow motion", i.e. the presentation is played slower than at its original speed.

The user can follow hyperlinks embedded in the presentation.

The SMIL language has been designed so that it is easy to author simple presentations with a text editor. The key to success for HTML was that attractive hypertext content could be created without requiring a sophisticated authoring tool. The SMIL language achieves the same goal for synchronized hypermedia.

Chemical Markup Language (CML). Chemical Markup Language brings the power of XML to the management of chemical information. In simple terms it is 'HTML with Molecules', but there is a great deal more. CML, and associated tools, allows for the conversion of current files without semantic loss, structured documents including chemical publications, and precise location of information within files. CML has been designed carefully so that it is as easy as possible for the 'average chemist' to understand it. Like a lot of chemistry it's not trivial, but it's no harder than Cahn-Ingold-Prelog chirality rules, and easier than Huckel theory. It helps if you know something about HTML (the hypertext language of the WWW) and have tried to transfer data files between sites or programs. It's not magic, and doesn't do anything that isn't really just common sense, but it hides a lot of the hassle that we have at present.

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Milko Tipografov
e-mail: `mike00@abv.bg`

Vladimir Dimitrov
POB 1829, 1000 Sofia, Bulgaria
e-mail: `cht@fmi.uni-sofia.bg`

XML БАЗИРАНИ ЕЗИЦИ ЗА ПРЕДСТАВЯНЕ НА МАТЕМАТИЧЕСКО И НАУЧНО СЪДЪРЖАНИЕ

Милко Типографов, Владимир Димитров

Настоящият материал представлява обзор на XML базираните езици за маркировка и представяне на математическо и научно съдържание и данни. В него са включени Mathematical Markup Language (MathML), OpenMath, Scalable Vector Graphics (SVG), Synchronized Multimedia Integration Language (SMIL) и Chemical Markup Language (CML).