New Accessibility Features in MathJax

Volker Sorge

MathJax Consortium

(University of Birmigham, UK; Progressive Accessibility Solutions, Ltd.)

joint work with Davide Cervone and Peter Krautzberger

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Introduction

- Accessibility to Mathematics is essential for inclusive education
- TTS of Mathematics is a challenging problem
- Particular on the web as mathematics is badly supported
- MathJax is already a visual rendering solution
- Make it universally accessible
- Instead of relying on browsers or screen readers we have created an AT solution in MathJax

- Based on some work done in ChromeVox at Google and later extended in Benetech's MathMLCloud project
- Now supported by AMS and Sloan Foundation

What is MathJax?

- MathJax is a JavaScript library for rendering Mathematics in all browsers
- Can take LaTeX, AsciiMath, and MathML as input
- Generates browser output, e.g. HTML/CSS, SVG
- Standard Maths rendering solution for: stackexchange, wordpress blogs, mediawiki, etc.
- Internal format is (still, something close to) MathML

MathJax is the de facto rendering solution of (nearly) all Mathematics on the web (35 million unique daily rendering requests via CDN)

The State of Mathematics on the Web

- MathML is officially part of the HTML5 standard
- Mathematics should be formatted in (presentation) MathML.
- Generally this is not the case: Instead it is given as LaTeX or ASCIIMath.

- MathML has very limited support from Browser vendors
  - Two incomplete implementations: FireFox (Gecko), Safari (WebKit)
- MathML spec is seriously outdated
  - In particular it does not take modern web technology into account (HTML5, CSS)!
- There is no WAI-ARIA spec for Mathematics

Accessibility of Mathematics on the Web

- MathPlayer
  - Only until IE 9 on Windows (MathML and MathJax)
  - Somewhat in IE11 (not in Edge)
- ChromeVox in Chrome (works on MathML, and LaTeX and ASCIIMath via MathJax)
- VoiceOver has some support for MathML
- NVDA, Jaws via MathPlayer, now via MathJax and MathPlayer library

MathJax and Accessibility

- Maths will never be first class citizen in all browsers
- It is also too much to expect Maths solutions from general assistive technology providers

- MathJax is the Visual Rendering solution
- Turn MathJax also into an Assistive Technolgy solution
- Support users with a wide variety of print impairments
- Enable magnification, simplification, highlighting, aural rendering, etc.

MathJax's Renderers

- MathJax provides a variety of renderers
  - CommonHTML, SVG, HTML/CSS, native MathML, ...

```
<span class="math" id="MathJax-Span-7" role="math" style="width: 8.246em; display: inlin
  <span style="display: inline-block; position: relative; width: 7.115em; height: 0px; f
    <span style="position: absolute; clip: rect(1.457em 1000em 2.751em -999.997em); top:
      <span class="mrow" id="MathJax-Span-8">
        <span class="mi" id="MathJax-Span-9" style="font-family: STIXGeneral; font-style
        <span class="msubsup" id="MathJax-Span-10">
          <span style="display: inline-block; position: relative; width: 0.919em; height
            <span style="position: absolute; clip: rect(3.397em 1000em 4.151em -999.997e
              <span class="mi" id="MathJax-Span-11" style="font-family: STIXGeneral; fon
                <span style="display: inline-block; overflow: hidden; height: 1px; width
              </span>
              <span style="display: inline-block; width: 0px; height: 3.99em;"></span>
            </span>
            <span style="position: absolute; top: -4.415em; left: 0.488em;">
              <span class="mn" id="MathJax-Span-12" style="font-size: 70.7%; font-family
              <span style="display: inline-block; width: 0px; height: 3.99em;"></span>
            </span>
          </span>
        </span>

  ...
</span>
```

Trivialty of Presentation MathML

- MathJax uses Presentation MathML as internal format
- Mathematical information is rather trivial

Example: Quadratic Equation

$$ax^2 + bx + c = 0$$

is commonly represented in linear form in MathML:

```
<math>
  <mi>a</mi>
  <msup>
    <mi>x</mi>
    <mn>2</mn>
  </msup>
  <mo>+</mo>
  <mi>b</mi>
  <mi>x</mi>
  <mo>+</mo>
  <mi>c</mi>
  <mo>=</mo>
  <mn>0</mn>
</math>
```

Semantic Enrichment

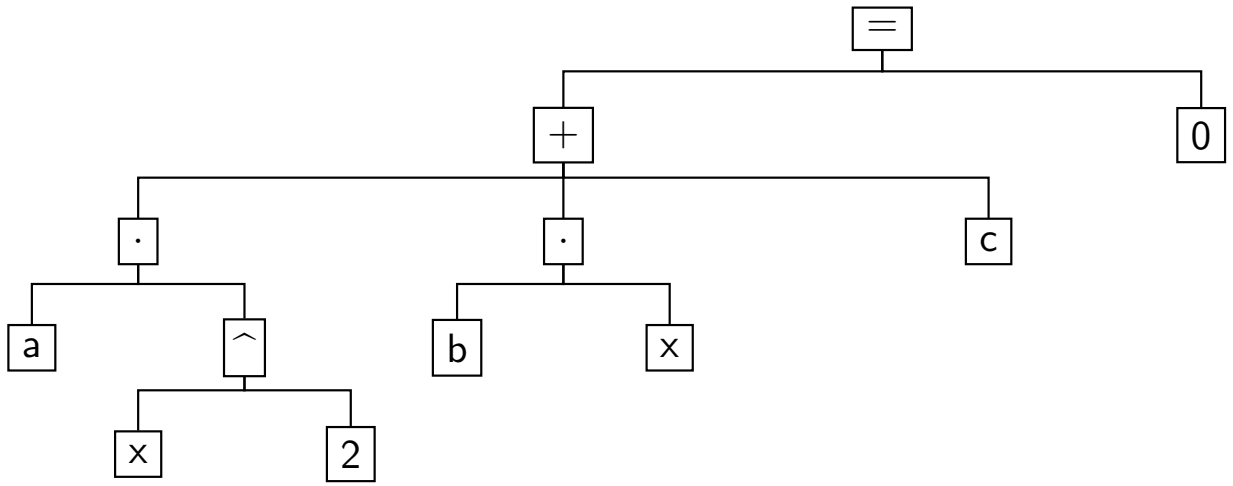
- Impose "light" semantic interpretation on MathML expression
- Rewrite syntax tree into a term tree using heuristics:
  - Combine operator and relation sequences,
  - Determine potential function applications,
  - break up symbol sequences into elided products,
  - combine bracketed expressions as much as possible,
  - recognise scope of big operators (e.g., sums, integrals),
  - ...
- Originally developed in ChromeVox for K-12 Mathematics
- Clean interpretation regardless of how horrible the MathML

Semantic Tree Example

$$ax^2 + bx + c = 0$$

is rewritten from its Presentation MathML representation into its semantic interpretation:

```
<math>
  <mi>a</mi>
  <msup>
    <mi>x</mi>
    <mn>2</mn>
  </msup>
  <mo>+</mo>
  <mi>b</mi>
  <mi>x</mi>
  <mo>+</mo>
  <mi>c</mi>
  <mo>=</mo>
  <mn>0</mn>
</math>
```



Combining Semantic and MathML

- MathML is internal representation in MathJax
- Embed the semantic interpretation directly using HTML5 data attributes
- Alternative view on the MathML element, by providing an orthogonal tree structure
- Data attributes are retained in the rendered expression regardless of the particular MathJax renderer used.

Assistive Technology Extension

- Responsive Equations and Abstraction
- Highlighting
- Interactive Exploration
- Speech Generation

UX the same regardless of the renderer.

Responsive Design

- Responsive design enhances a core feature of HTML: reflow
- Re-arrange, optimise, and transform content:
  - cropping images, abstracting icons, modifying tables
- Mathematics combines the properties of text, tables, and graphics into a single problem
- Content is usually created with print in mind: manual layout!

Responsive Equations

- Automatic reflow for simplifying layout, adapting to form factor of display and magnification
- Intelligent linebreaking by exploiting semantic enrichment
  - Don't break in the middle of an expression
- Chunking: Abstracting over large elements
  - collapsing mathematically meaningful sub-expressions

Example

$$I_\nu(\nu^{-1},1) = \underbrace{\frac{\pi^2}{4}\ln\left(\frac{(1+\nu)^{1+\nu}}{\nu^\nu}\right) - \frac{7\zeta(3)}{8}\nu}_{\text{Let this be C}} + 2\int_1^{\frac{1-\nu}{1+\nu}} \frac{\chi_3(v)}{(1+v)^2}\mathrm{d}v$$

$$= C - \frac{2\chi_3(v)}{1+v}\bigg|_1^{\frac{1-\nu}{1+\nu}} + 2\int_1^{\frac{1-\nu}{1+\nu}} \frac{\chi_2(v)}{v(1+v)}\mathrm{d}v$$

$$= C + (1-\nu)\chi_3\left(\frac{1-\nu}{1+\nu}\right) - \frac{7\zeta(3)}{8} - \quad 2\chi_2(v)\ln(1+v)\bigg|_1^{\frac{1-\nu}{1+\nu}} + \int_1^{\frac{1-\nu}{1+\nu}} \frac{\ln(1+v)\ln}{v}$$

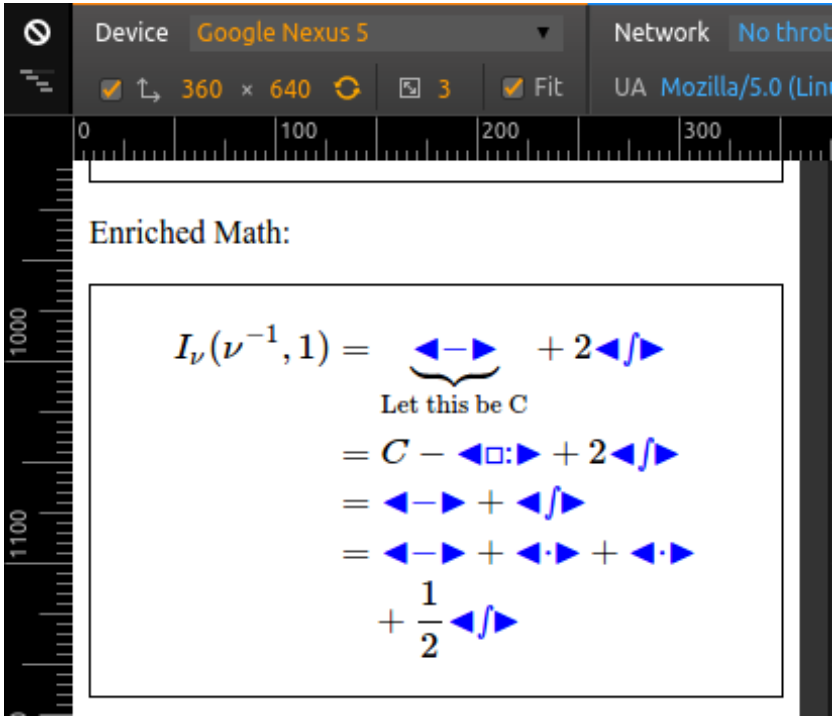
$$= C + (1-\nu)\chi_3\left(\frac{1-\nu}{1+\nu}\right) - \frac{7\zeta(3)}{8} + 2\chi_2\left(\frac{1-\nu}{1+\nu}\right)\ln\left(\frac{1+\nu}{2}\right) + \frac{\pi^2}{4}\ln 2$$

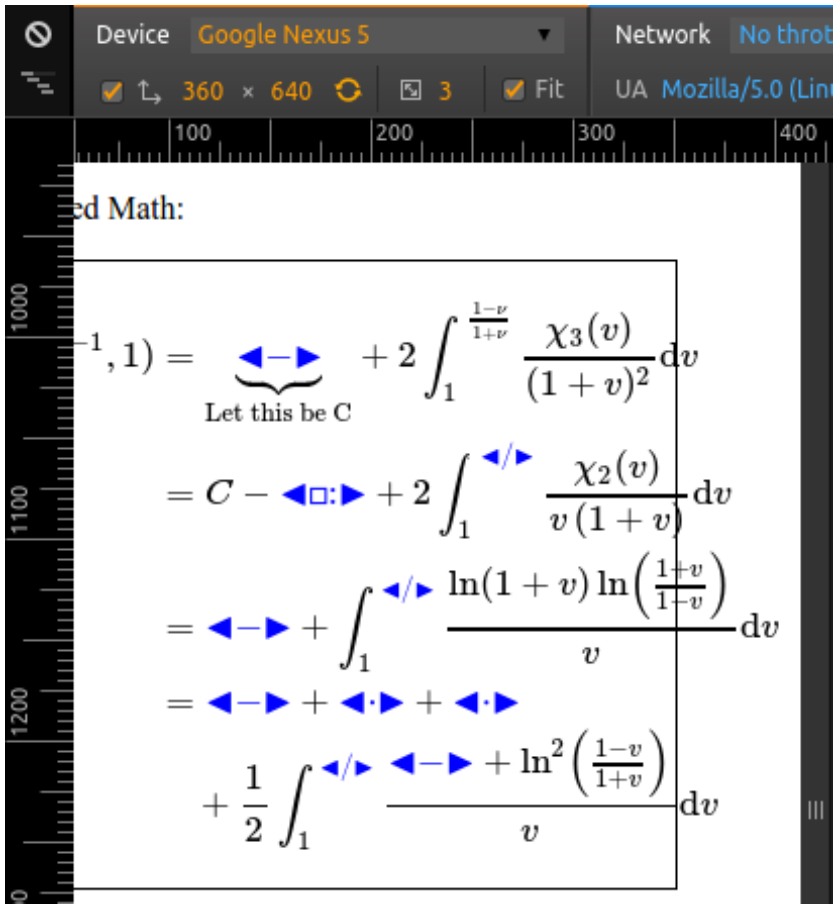
$$+ \frac{1}{2}\int_1^{\frac{1-\nu}{1+\nu}} \frac{\ln^2(1+v) - \ln^2(1-v) + \ln^2\left(\frac{1-v}{1+v}\right)}{v}\mathrm{d}v$$

Example of mathematics "in the wild" taken from math.stackexchange.com.

Exploring Equations

- Collapsed parts are represented by a simple meaningful Unicode construction, ◂X▸.
  E.g., ◂()▸,◂f()▸,◂+▸,◂$\sqrt{}$▸





Semantic Highlighting

- Dyslexia support via highlighting
- Customisation of fore- and background colours for high contrast
- Highlight mathematically meaningful expressions
- Syntactic highlighting:

$$I_\nu(\nu^{-1},1)=\frac{\pi^2}{4}\ln\left(\frac{(1+\nu)^{1+\nu}}{\nu^\nu}\right)-\frac{7\zeta(3)}{8}\nu+2\int_1^{\frac{1-\nu}{1+\nu}}\frac{\chi_3(v)}{(1+v)^2}\mathrm{d}v$$

- Semantic highlighting:

$$I_\nu(\nu^{-1},1)=\frac{\pi^2}{4}\ln\left(\frac{(1+\nu)^{1+\nu}}{\nu^\nu}\right)-\frac{7\zeta(3)}{8}\nu+2\int_1^{\frac{1-\nu}{1+\nu}}\frac{\chi_3(v)}{(1+v)^2}\mathrm{d}v$$

Interactive Exploration

- "Walkers" allow to interactively dive into mathematical expression
- Synchronised highlighting together with aural rendering
- Simple JavaScript extension for MathJax
- Different types of walkers: syntactic, semantic, collapsed
- Simple navigation model using arrow keys
- UX the same regardless of the renderer

Aural Rendering and Highlighting

- Speech strings are computed with Speech Rule Engine initially implemented in the context of ChromeVox and extended for MathMLCloud
- Currently uses the MathSpeak rules: verbose, brief, superbrief
  - special summarisations for collapsed parts
  - Other rule sets and localisations in the future
- WAI-ARIA and CSS to implement interactive exploration
  - Speech output by updating ARIA live regions
  - Colour/contrast changes by rewriting CSS properties
- Speech strings can be precomputed or generated on the fly
- Works for all renderers MathJax provides

System Testing

Tested with combinations of the main browsers, screen readers and platforms

- IE 10-11, Edge, Chrome, Firefox, Web
- NVDA, Jaws, WindowsEye, VoiceOver, ChromeVox, ORCA
- Windows (XP, 7, 8, 8.1, 10), MacOSX, Linux

Full support matrix at `https://github.com/mathjax/MathJax-RespEq/wiki/Support-Matrix-a11y-tool`

User Testing

- Responsive Equations
  - Feedback from experts and users of Stack Exchange
- AT extension: Collection of user feedback is currently in progress
  - With (blind) experts, users and accessibility support officers
  - Most critique currently focuses on MathSpeak and it's verbosity
  - Navigation generally viewed positively

Conclusion

- Current implementation is available as MathJax extension at `https://github.com/mathjax/MathJax-RespEq/`
- Should become permanent feature in 3.0 release

- Difficult to maintain due to reliance of third parties (browsers, screen readers, etc.)
- Proper implementation of standards by all would help
- There is a need for a WAI-ARIA specification for mathematics or STEM in general

Web References

- Demo:
  - http://mathjax.github.io/MathJax-RespEq/examples/Struik.html
  - http://mathjax.github.io/MathJax-RespEq/Semantics-Lab/TeX.html
  - http://mathjax.github.io/MathJax-RespEq/Semantics-Lab/TeX-linebreaking.html
- Systems:
  - https://github.com/mathjax/MathJax/
  - https://github.com/mathjax/MathJax-RespEq/
  - https://github.com/zorkow/speech-rule-engine/
  - https://github.com/mathjax/MathJax-node/