MathML in Browsers

Web Engines Hackfest - October, 2019

\[ \Gamma(t) = \int_0^{+\infty} x^{t-1} e^{-x} dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left( \frac{t}{e} \right)^t \]

Rob Buis (rbuis@)
Frédéric Wang (fwang@)
<table>
<thead>
<tr>
<th>Year Range</th>
<th>Event</th>
<th>Software/Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977-1984</td>
<td>Math typesetting rules</td>
<td>T_{\overline{E}}X typesetting system</td>
</tr>
<tr>
<td>1993-1995</td>
<td>Browser experiments</td>
<td>\texttt{&lt;MATH&gt;} Arena</td>
</tr>
<tr>
<td>1998-1999</td>
<td>MathML standard</td>
<td>MathML Gecko</td>
</tr>
<tr>
<td>2002-2003</td>
<td>Gecko/Mozilla</td>
<td>Mozilla 1.0</td>
</tr>
<tr>
<td>2006-2007</td>
<td>Presto/Opera, Microsoft Office</td>
<td>MathML 2</td>
</tr>
<tr>
<td>2008</td>
<td>MathML in HTML5!</td>
<td></td>
</tr>
<tr>
<td>2009-2011</td>
<td>WebKit/Safari</td>
<td></td>
</tr>
<tr>
<td>2012-2013</td>
<td>WebKit/Chrome, Blink fork</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>OpenType MATH</td>
<td></td>
</tr>
<tr>
<td>2015-2016</td>
<td>WebKit’s refactoring</td>
<td></td>
</tr>
<tr>
<td>2019-2019</td>
<td>Blink/Chrome, Edge switch</td>
<td></td>
</tr>
</tbody>
</table>

**HISTORY**
THE `<MATH>` TAG

Consider the equation:

\[ H(s) = \int_{0}^{\infty} e^{-st} h(t) \, dt \]

This can be represented as:

```xml
<math>
H(s) = \int_{0}^{\infty} e^{-st} h(t) \, dt
</math>
```

The mathematical symbols are given with their standard ISO operators, the subscript/superscript text is centered over the allow you to define more complex equations, as in:

\[ C \frac{dV_{out}}{dt} = l_b \tanh \left( \kappa \frac{V_{in} - V_{out}}{2} \right) \]

which is represented by:

```xml
<math>
C \frac{dV_{out}}{dt} = l_b \tanh \left( \kappa \frac{V_{in} - V_{out}}{2} \right)
</math>
```
MATHML IN MOZILLA

"One of the quietest open source achievers in Australia" - the SMH
I am currently driving an effort to enable MathML-in-HTML (apart from MathML-in-XHTML that we already support). I have a patch that serves the dual purpose of showing where things are going and the issues to ponder about.

Here is a [screenshot] https://bugzilla.mozilla.org/attachment.cgi?id=239771 which is a _live_ rendering of this testcase:
[mathml-in-html] https://bugzilla.mozilla.org/attachment.cgi?id=239769

Those interested in following this up can see bug 353926:
https://bugzilla.mozilla.org/show_bug.cgi?id=353926

Quick background:

At the Firefox engineering meeting in Mountain Views (last December 2005), I pleaded that we enable MathML in HTML5 to advance the cause
WEBKIT'S REFACTORING

"¡Qué horrible es esta implementación!" - alex@
Microsoft Edge: Making the web better through more open source collaboration

By Joe Belfiore / Corporate Vice President, Windows

For the past few years, Microsoft has meaningfully increased participation in the open source software (OSS) community, becoming one of the world’s largest supporters of OSS projects. Today we’re announcing that we intend to adopt the Chromium open source project in the development of Microsoft Edge on the desktop to create better web compatibility for our customers and less fragmentation of the web for all web developers.

As part of this, we intend to become a significant contributor to the Chromium project, in a way that can make not just Microsoft Edge — but other browsers as well — better on both PCs and other devices.
The min-content (respectively max-content) inline size of content is the maximum between the min-content (respectively max-content) inline size of the numerator's margin box and the min-content (respectively max-content) of the denominator's margin box.

If there is an inline stretch size constraint or a block stretch size constraint then the numerator is also laid out with the same stretch size constraint otherwise it is laid out without any stretch size constraint. The denominator is always laid out without any stretch size constraint.

The inline size of the content is the maximum between the inline size of the numerator's margin box and the inline size of the denominator's margin box.

NumeratorShift is the maximum between:

FractionNumeratorShiftUp (respectively FractionNumeratorDisplayStyleShiftUp) if the math

MATHML CORE

- Fundamental subset
  Ask CG members
  Analyze tools & use statistics
- Implementation details
  TeX/OpenType layout
  HTML5/CSS compatibility
- Browser-driven
  Gecko/WebKit/Blink
  Web Platform Tests!
EXTENSIBILITY

- MathMLElement IDL (1)
  - *EventHandlers
  - ElementCSSInlineStyle
  - HTMLOrForeignElement

- CSS/Houdini
  - CSS properties? (2)
  - Layout constraints? (3)
  - Font APIs? (4)

- New MathML elements
  - Overridable display (5)
  - Element.shadowDOM? (6)
  - Custom element? (7)
CSS COMPATIBILITY

• CSS layout
  Visual box model?
  Supported features?
  Interpretation?

• Math-specific
  Invalid markup
  New CSS properties
  OpenType parameters
  Special painting
  Text metrics
  Operator Stretching
TEXT METRICS

- Ink block metrics (1, 2)
  \[ x \quad x \]
  \[ y \quad y \]

- Italic correction (3)
OPERATOR STRETCHING

• Stretch constraints (1)
  Horizontal stretch size
  Vertical stretch size
  above/below baseline

• Parent layout (2, 3)
  Layout non-stretchy children
  Calculate stretch constraint
  Layout stretchy children

• Real-life operators
  Distort glyph
  Upper estimate of min/max (4)
The reported results do not necessarily reflect the true capabilities of each web browser, so they should not be used evaluate interoperability.

<table>
<thead>
<tr>
<th>Path</th>
<th>Chrome 78 Linux 18.04</th>
<th>Edge 78 Windows 10.0</th>
<th>Firefox 71 Linux 18.04</th>
<th>Safari 82 pre-macOS 10.15</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8488b4e</td>
<td>8488b4e</td>
<td>8488b4e</td>
<td>8488b4e</td>
</tr>
<tr>
<td></td>
<td>Sep 24, 2019</td>
<td>Sep 24, 2019</td>
<td>Sep 24, 2019</td>
<td>Sep 24, 2019</td>
</tr>
<tr>
<td></td>
<td>37 / 477</td>
<td>37 / 477</td>
<td>386 / 477</td>
<td>348 / 477</td>
</tr>
<tr>
<td></td>
<td>84 / 1502</td>
<td>84 / 1502</td>
<td>762 / 1502</td>
<td>723 / 1503</td>
</tr>
</tbody>
</table>

For information on the search syntax, view the help.
WEB PLATFORM TESTS

• ~2000 tests (1, 2, 3)
  Math layout
  Removed features
  DOM/CSS interaction

• Results (4)
  Igalia's Blink: ~99%
  Gecko: ~73%
  WebKit: ~72%

MathML Core - Implementation Report

Blink-MathML ☰ 1944/1971 (98.63%) +
Development build of Igalia's Chromium fork.

Blink ☰ 17/1971 (0.86%) +
Development build of Igalia's Chromium fork with the LayoutNG/HTML runtime feature disabled.
These results might contain false positives.

Gecko ☰ 1434/1971 (72.75%) +
Nightly build of Firefox.

WebKit ☰ 1418/1971 (71.94%) +
Development build of WebKitGTK.
PAST IMPLEMENTATIONS

Firefox/Gecko 2008

\[
\Gamma(t) = \int_0^{+\infty} x^{t-1} e^{-x} \, dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{\left(1 + \frac{1}{n}\right)^t}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left(\frac{t}{e}\right)^t
\]

Chrome/WebKit 2013

\[
\Gamma(t) = \int_0^{+\infty} x^{t-1} e^{-x} \, dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{\left(1 + \frac{1}{n}\right)^t}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left(\frac{t}{e}\right)^t
\]

Opera/Presto 2007

\[
\Gamma(t) = \int_0^{+\infty} x^{t-1} e^{-x} \, dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{1}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left(\frac{t}{e}\right)^t
\]
2019 IMPLEMENTATIONS

Firefox/Gecko
July release

\[ \Gamma(t) = \int_{0}^{+\infty} x^{t-1} e^{-x} \, dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left( \frac{t}{e} \right)^t \]

Epiphany/WebKit
Build r249360

\[ \Gamma(t) = \int_{0}^{+\infty} x^{t-1} e^{-x} \, dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left( \frac{t}{e} \right)^t \]

Chromium/Blink
Igalia's Branch

\[ \Gamma(t) = \int_{0}^{+\infty} x^{t-1} e^{-x} \, dx = \frac{1}{t} \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{1 + \frac{t}{n}} \sim \sqrt{\frac{2\pi}{t}} \left( \frac{t}{e} \right)^t \]
GECKO AND WEBKIT (1, 2)

- Standardize browser behaviors
  MathML3 interpretations
  "Hacks" for legacy content
- Unship features
  Counters & Deprecation (3)
  Runtime flag
- Tests
  Convert & synchronize
  More "pass" / Less "flaky"
- Enhancement and bug fixes
  Math DOM (4, 5)
  Math layout (6, 7, 8, ...)
  CSS compatibility
(IV) MATHML IN CHROMIUM
• Upstream mathml-dev!
• Non-Linux platforms?
• Automated WPT sync for WebKit 😊
IMPLEMENTATION ROADMAP

• Basic setup ✅
• Basic layout ✅
• Operator Dictionary ✅
• Stretchy operators: ✅
• Advanced style ✅
• HTML5 Compatibility ●
• Upstreamed & shipped ✗
CHANGESETS

Base Setup
- Runtime flag
- mathml.css
- Element classes
- New CSS
- New DOM/IDL

Low-level API
- Font parameters
- Glyph stretching
- Layout constraints
- Ink baselines

MathML
- Dictionary
- Attributes
- Painters
- Layout utils
- Layout classes
SIZE IMPACT

CHROME

- Binary: $\Delta < 320\text{KB}$
- Archive:
  - deb: $\Delta < 45\text{KB}$
  - rpm: $\Delta < 26\text{KB}$

CODE

<table>
<thead>
<tr>
<th>Folders</th>
<th>#Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>core/layout/ng/mathml</td>
<td>4977</td>
</tr>
<tr>
<td>core/mathml</td>
<td>3279</td>
</tr>
<tr>
<td>core/css, core/style</td>
<td>940</td>
</tr>
<tr>
<td>core/paint</td>
<td>285</td>
</tr>
<tr>
<td>platform/fonts, platform/graphics</td>
<td>268</td>
</tr>
<tr>
<td>core/layout, core/layout/ng</td>
<td>164</td>
</tr>
<tr>
<td>core/dom, core/html, core/svg</td>
<td>44</td>
</tr>
<tr>
<td>Total</td>
<td>$\Delta &lt; 10k$</td>
</tr>
</tbody>
</table>

Current SVG code size (only for core/svg, core/layout/svg) is $> 62k$
LAUNCHING FEATURES

- **Idea Phase**: explainer, *intent-to-implement*
- **Design Phase**: design doc & spec, TAG review, 
  *chromestatus entry*, chrome launch review
- **Implementation Phase**: implementation & tests, *intent-to-ship*, 3 LGTM
- **Post Launch**: crashes, regressions, bug fixes, interop, doc, 
  cleanup...
Example 1

Consider

\[ \int_0^{+\infty} (x^2 + x + 1)e^{-3x} \, dx \]

We consider \( f(x) = x^2 + x + 1 \) and \( g(x) = \frac{e^{-3x}}{3} \) that is \( f(x) = 2x + 1 \) and \( g'(x) = e^{-3x} \). The integral can be written \( \int fg' \, dx \) and hence we get

\[
\left[ (x^2 + x + 1)\frac{e^{-3x}}{-3} \right]_0^{+\infty} - \int_0^{+\infty} (2x + 1)\frac{e^{-3x}}{-3} \, dx = \frac{1}{3} + \frac{1}{3}\int_0^{+\infty} (2x + 1)e^{-3x} \, dx
\]

We now consider \( h(x) = 2x + 1 \), \( h'(x) = 2 \) the second integral can be written \( \int h'g \, dx \) and hence

\[
\int_0^{+\infty} (2x + 1)e^{-3x} \, dx = \left[ (2x + 1)\frac{e^{-3x}}{-3} \right]_0^{+\infty} - \int_0^{+\infty} \frac{2e^{-3x}}{-3} \, dx = \frac{1}{3} + \frac{2}{3}\int_0^{+\infty} e^{-3x} \, dx
\]

Finally,

\[
\int_0^{+\infty} (x^2 + x + 1)e^{-3x} \, dx = \frac{1}{3} + \frac{1}{3} \times \left( \frac{1}{3} + \frac{2}{3} \times \frac{1}{3} \right) = \frac{14}{27}
\]

Example 2

\[ \int_1^2 x^3 (2\ln x + 7\arctan x) \, dx \]

We let \( f(x) = 2\ln x + 7\arctan x \) and \( g(x) = \frac{x^2}{3} \). Hence \( f'(x) = \frac{2}{x} + \frac{7}{1+x^2} \) and \( g'(x) = x^3 \). The integration by parts gives:
<table>
<thead>
<tr>
<th>As rendered by TeX</th>
<th>As rendered by your browser</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^2 y^2$</td>
<td>$x^2 y^2$</td>
</tr>
<tr>
<td>$2F_3$</td>
<td>$2F_3$</td>
</tr>
<tr>
<td>$\frac{x + y^2}{k + 1}$</td>
<td>$\frac{x + y^2}{k + 1}$</td>
</tr>
<tr>
<td>$\frac{a}{b/2}$</td>
<td>$\frac{a}{b/2}$</td>
</tr>
<tr>
<td>$a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4}}}}$</td>
<td>$a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + \frac{1}{a_4}}}}$</td>
</tr>
<tr>
<td>$\left(\frac{n}{k/2}\right)$</td>
<td>$\left(\frac{n}{k/2}\right)$</td>
</tr>
<tr>
<td>$\left(\frac{p}{2}\right)x^2 y^{p - 2} - \frac{1}{1 - x} \frac{1}{1 - x^2}$</td>
<td>$\left(\frac{p}{2}\right)x^2 y^{p - 1} - \frac{1}{1 - x} \frac{1}{1 - x^2}$</td>
</tr>
<tr>
<td>$\sum_{0 \leq i \leq m} \sum_{0 \leq j \leq n} P(i, j)$</td>
<td>$\sum_{0 \leq i \leq m} \sum_{0 \leq j \leq n} P(i, j)$</td>
</tr>
<tr>
<td>$x^2 y$</td>
<td>$x^2 y$</td>
</tr>
<tr>
<td>$\sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} a_{ijk} b_{ik} c_{ki}$</td>
<td>$\sum_{i=1}^{n} \sum_{j=1}^{n} \sum_{k=1}^{n} a_{ijk} b_{ik} c_{ki}$</td>
</tr>
<tr>
<td>$\sqrt{1 + \sqrt{1 + \sqrt{1 + \sqrt{1 + \sqrt{1 + x}}}}}$</td>
<td>$\sqrt{1 + \sqrt{1 + \sqrt{1 + \sqrt{1 + \sqrt{1 + x}}}}}$</td>
</tr>
<tr>
<td>$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)</td>
<td>\varphi(x + iy)</td>
</tr>
<tr>
<td>$2^{2x^r}$</td>
<td>$2^{2x^r}$</td>
</tr>
</tbody>
</table>
Basic Integration

Ideas

If \( F \) is a primitive of \( f \) then \( \int_a^b f(x)dx = F(b) - F(a) \), provided the integrand and integral have no singularities on the path of integration. As a consequence, we can use a table of derivatives:

<table>
<thead>
<tr>
<th>Function</th>
<th>Derivative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linearity</td>
<td>( af + bg )</td>
</tr>
<tr>
<td>Leibniz rule</td>
<td>( f + g )</td>
</tr>
<tr>
<td>Reciprocal rule</td>
<td>( \frac{1}{f} )</td>
</tr>
<tr>
<td>Chain Rule</td>
<td>( f \circ g )</td>
</tr>
<tr>
<td>Inverse function rule</td>
<td>( f^{-1} )</td>
</tr>
<tr>
<td>Elementary power rule</td>
<td>( x^p )</td>
</tr>
<tr>
<td>Generalized power rule</td>
<td>( p^q )</td>
</tr>
<tr>
<td>Exponential</td>
<td>( \exp x )</td>
</tr>
<tr>
<td>Logarithm</td>
<td>( \ln x )</td>
</tr>
<tr>
<td>Sine</td>
<td>( \sin x )</td>
</tr>
<tr>
<td>Cosine</td>
<td>( \cos x )</td>
</tr>
<tr>
<td>Tangent</td>
<td>( \tan x )</td>
</tr>
</tbody>
</table>

Examples

Using linearity and elementary power rule:

\[
\int_0^1 (u^4 - 2u^3 + 5u^2 + 4u)\,du = \left[ \frac{u^5}{5} - \frac{2u^4}{4} + \frac{5u^3}{3} + 4u \right]_0^1 = 161 \quad \text{and} \quad 30
\]

Using linearity and sine/cosine:

\[
\int_0^\pi (2\cos(\theta) - 3\sin(\theta))\,d\theta = \left[ 2\sin(\theta) + 3\cos(\theta) \right]_0^\pi = 6
\]

Using Leibniz rule, Chain rule and Exponential/Power:

\[
\int_0^1 2xe^{-2x} - 3x^2e^{-3x}\,dx = \left[ x^2e^{-2x} \right]_0^1 = \frac{4}{e^2}
\]

Using the inverse function rule and tangent:

\[
\int_0^1 \frac{1}{1 + x^2}\,dx = \int_0^\tan^{-1}(x) \frac{1}{\sqrt{1 + x^2}}\,dx = \left[ \arctan(x) \right]_0^\frac{\pi}{4} = \frac{\pi}{4}
\]

Using linearity, reciprocal rule and logarithm:

\[
\int_0^1 \frac{1}{\sqrt{1 + x^2}}\,dx = \int_0^\frac{\ln(x)}{2}\frac{1}{1 + x^2}\,dx = -\left[ \frac{1}{2} \arctan(\ln(x)) \right]_0^1
\]
\[
\binom{(2k)}{m} = \frac{(n^2)(2k)!}{(n-k)!k!}
\]

\[
\sum_{m=0}^{n-k} \binom{(2k)}{m} \sum_{i=0}^{m} (-1)^i \binom{m}{i} \frac{1}{i+1} = \frac{1}{n!} \sum_{l=0}^{n} \binom{(2k)}{l} = (k)\zeta
\]
Padding, border and margin

\[
\Gamma(t) = \int_{-\infty}^{\infty} e^{-x^2} \, dx = \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{\sqrt{n\pi}} \sim \frac{\Gamma(t)}{\sqrt{\Gamma(t)}}
\]

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\Gamma(t) = \int_{-\infty}^{\infty} e^{-x^2} \, dx = \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{\sqrt{n\pi}} \sim \frac{\Gamma(t)}{\sqrt{\Gamma(t)}}
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\[
\Gamma(t) = \int_{-\infty}^{\infty} e^{-x^2} \, dx = \prod_{n=1}^{\infty} \frac{(1 + \frac{1}{n})^t}{\sqrt{n\pi}} \sim \frac{\Gamma(t)}{\sqrt{\Gamma(t)}}
\]
Custom display values

Flexbox and Grid

CSS Layout API

Click a B to toggle between multiscrrips and custom layout:

\[ \frac{1}{2} + \left( \frac{1}{2} \right)^{\text{num}} \cdot \left( \frac{1}{3} \right)^{\text{denom}} + \sqrt{7} + k \]
(VI) ¿QUESTIONS?