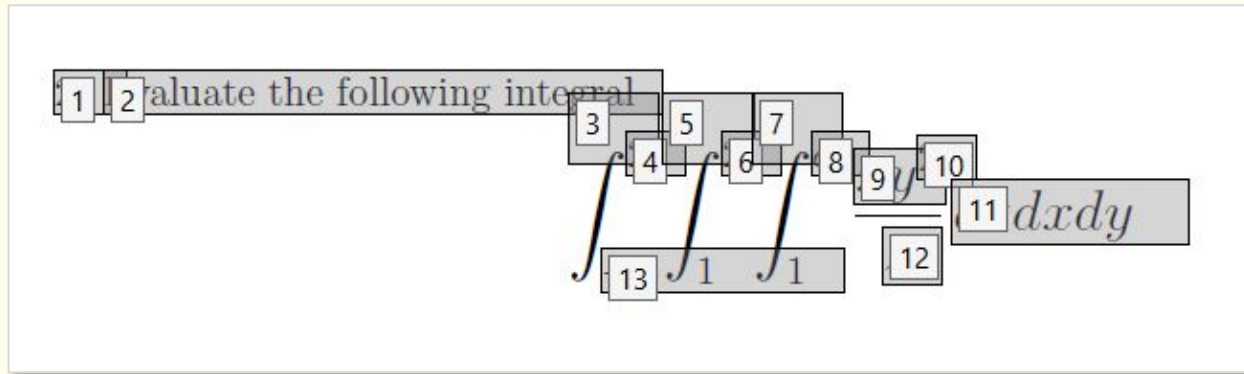


Accessibility for Special Materials: Math

Problem: PDFs Do Not Encode Math Accessibly

PDFs have no practical means of presenting accessible math:



Mathematical expressions become a series of glyphs that are meaningless to assistive technologies.

Problem: Simple Formulas as Text Will Not Work

- What's wrong with entering simple equations as text, “2 - 3 = -1”?
- Screen-reading software will not “know” the text is math. A screen reader will speak the numbers as numbers and some of the operators as ASCII characters:

2 to 3 equals dash 1

- By default, the verbosity settings in most screen-reading software will simply ignore many symbols
- The JAWS screen reader speaks “(x + 2)³ = 8” as:

X 2 3 equals 8



Problem: Text Formatting Does Not Work Either

- Superscripts and subscripts in text are not supported either, “ x^n ” will be spoken as:

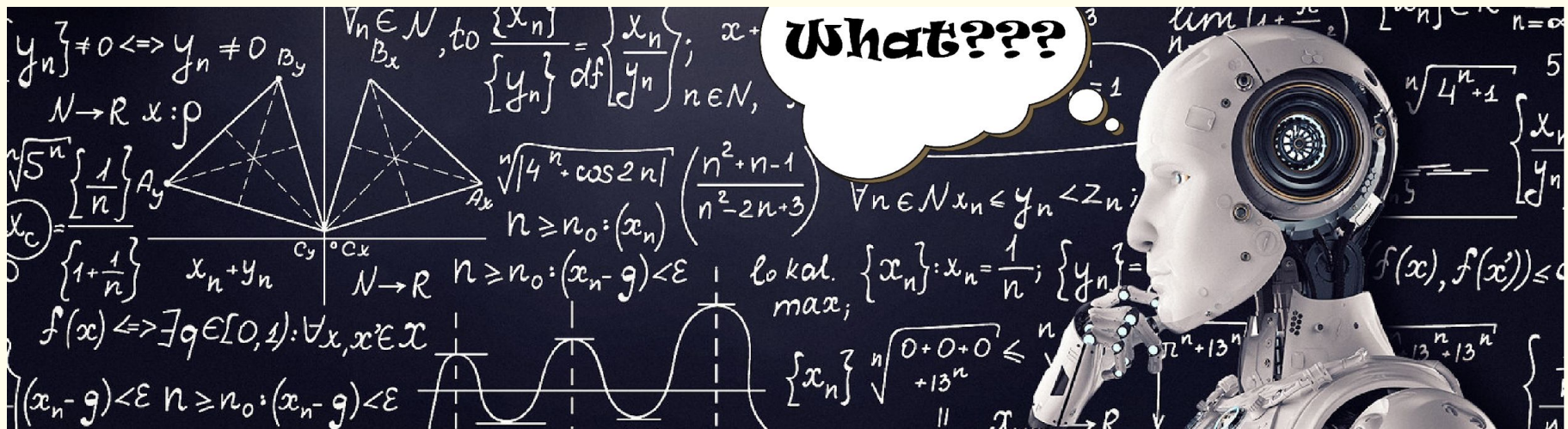
x n

The takeaway: Common symbols, superscripts, subscripts, etc. in text will not be treated as math, may be ignored, or misinterpreted by assistive technologies



Problem: Math Content is Often Published as Images

- Images are only effective for readers with normal vision and decoding capabilities
- Assistive Technology **will not** recognize math in images and speak it effectively any more than it will correctly describe images that are missing alt-text



How Should Math Be Spoken?

$$a + \frac{b}{c}$$

How Should a Screen-Reader Speak Math?

What phrasing or sonification needs to be added to “a plus b over c” to make these two examples unambiguous?

$$a + \frac{b}{c}$$

$$\frac{a+b}{c}$$

Problem: Image Alt-Text Is Not Suitable

What would you prefer? Exploring this equation with your

eyes:

$$\sum_{k=n_0}^n \left(\frac{A}{|k-c|+1} \cos(k \cdot 2\pi x - vt) \cos(r \cdot \pi x) + a \right) \frac{1}{\sqrt{2\pi s}} e^{\left(-\frac{(x-u)^2}{2s^2} \right)}$$

or hearing:

“the sum from k is equal to n sub 0 to n of; open paren; the fraction with numerator A; and denominator the absolute value of k minus c, end absolute value; plus 1; end fraction; cosine of; open paren; k times 2 pi x; minus v t; close paren; cosine of, open paren, r times pi x, close paren; plus a; close paren; times; the fraction with numerator 1; and denominator the square root of 2 pi s, end root; end fraction; e superscript open paren; minus; the fraction with numerator; open paren x minus u, close paren squared; and denominator 2 s squared; end fraction; close paren”

Navigating forward and back through the words of the linearized speech text would not be equivalent to how an individual with sight examines it.



Happily, the W3C Has the MathML Standard

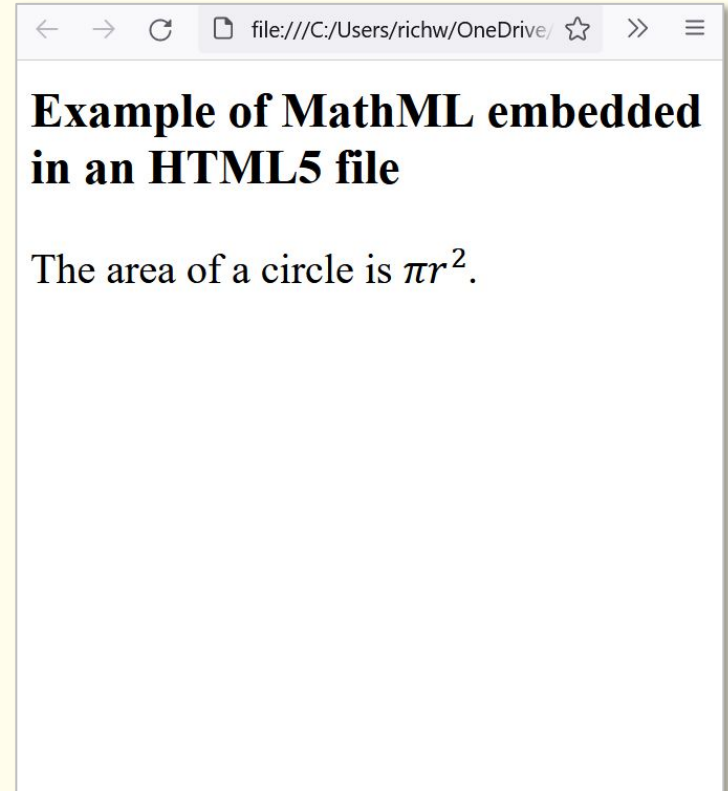
The World Wide Web Consortium (W3C) oversees the development of key standards that help make web pages and electronic documents accessible, including math:

- **MathML** = A low-level specification for marking up mathematical and scientific content as XML in web pages and other digital documents
- Often used “under the cover”
- MathML 1.0 was released in April 1998
- MathML 3.0 (current) was released April 2014
- <https://www.w3.org/Math/>



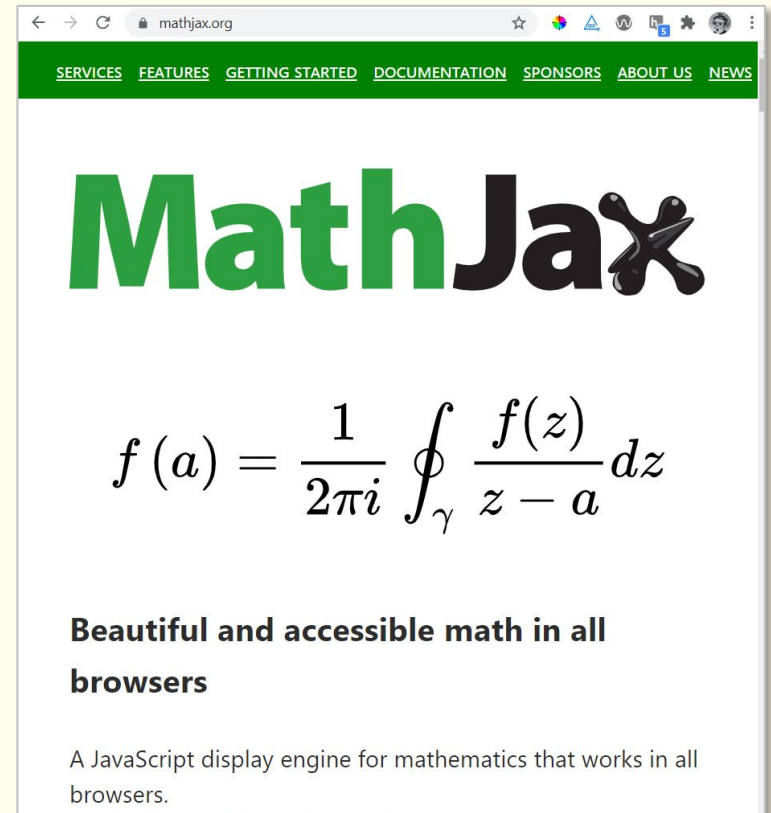
MathML Renders in HTML Technologies

```
<h1>Example of MathML
embedded in an HTML5
file</h1>
<p>The area of a circle is
  <math>
    <mi>&pi;</mi>
    <mo>&InvisibleTimes;</mo>
    <msup>
      <mi>r</mi>
      <mn>2</mn>
    </msup>
  </math>.
</p>
```



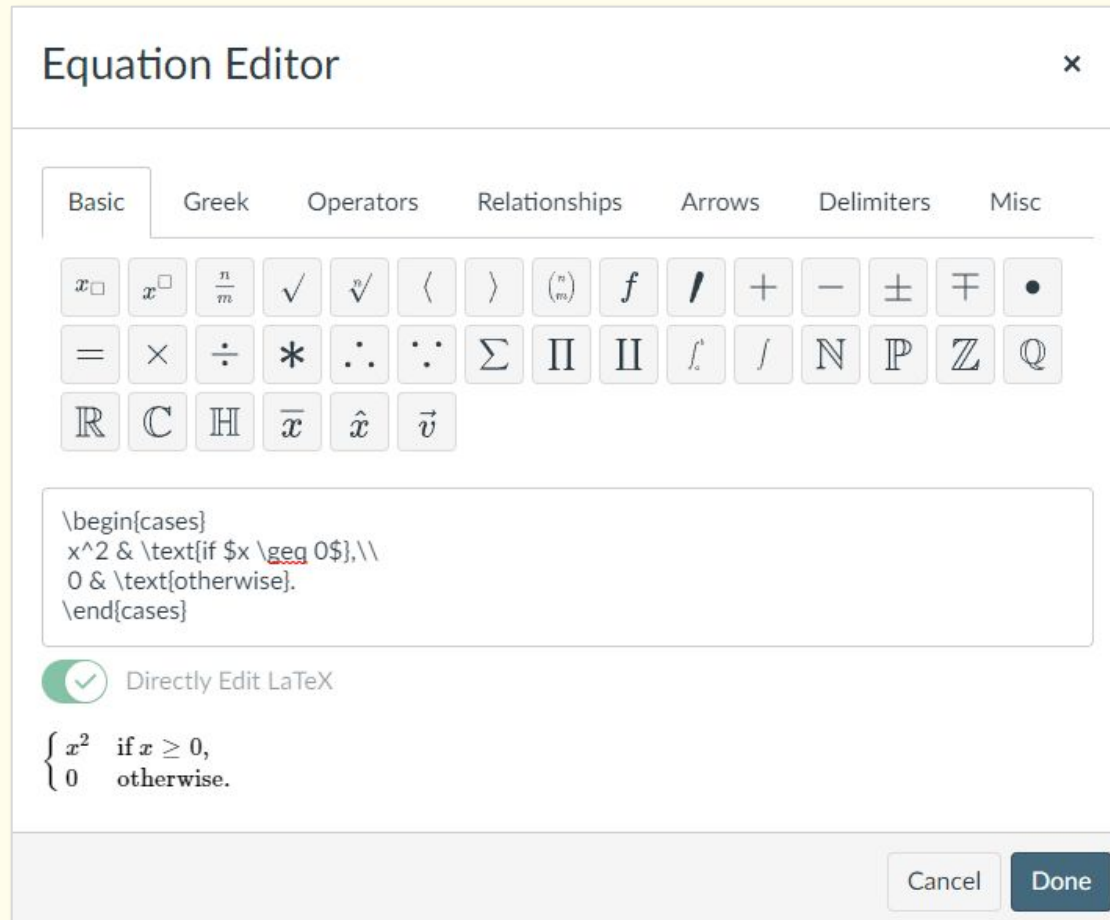
Many Websites Use the MathJax Display Engine

- MathJax is an open-source JavaScript library.
- MathJax will find math content in an HTML document and render it reliably and accessibly.
- Generates speech text, braille, is zoomable, and has an interactive expression explorer.
- <https://www.mathjax.org/>



Equation Editor in the Canvas LMS's RCE

The Canvas Rich Content Editor's Equation Editor creates accessible math objects:



The screenshot shows the "Equation Editor" window with the following components:

- Navigation Tabs:** Basic (selected), Greek, Operators, Relationships, Arrows, Delimiters, Misc.
- Symbol Grid:**
 - Row 1: x with a box, x^{\square} , $\frac{n}{m}$, $\sqrt{\quad}$, $\sqrt[n]{\quad}$, $\langle \quad \rangle$, $\binom{n}{m}$, f , $/$, $+$, $-$, \pm , \mp , \bullet .
 - Row 2: $=$, \times , \div , $*$, \therefore , \ddots , Σ , Π , \prod , \int , \int , \mathbb{N} , \mathbb{P} , \mathbb{Z} , \mathbb{Q} .
 - Row 3: \mathbb{R} , \mathbb{C} , \mathbb{H} , \bar{x} , \hat{x} , \vec{v} .
- Code Editor:** Contains LaTeX code for a piecewise function:

```
\begin{cases}x^2 & \text{if } x \geq 0, \\ 0 & \text{otherwise.}\end{cases}
```
- Options:** A checked checkbox labeled "Directly Edit LaTeX".
- Preview:** Shows the rendered piecewise function:
$$\begin{cases} x^2 & \text{if } x \geq 0, \\ 0 & \text{otherwise.} \end{cases}$$
- Buttons:** "Cancel" and "Done".

LaTeX Entered Directly into the Canvas RCE

LaTeX can be entered between delimiters in the body text of the RCE

Page Title

LaTeX in the RCE

Edit View Insert Format Tools Table

12pt Paragraph B I U A T²

- $\{ \dots \}$ should be used for inline expressions.
- $\$ \$ \dots \$ \$$ or $\{ \dots \}$ should be used for block expressions (centered on their own line).

The well known Pythagorean theorem $(x^2 + y^2 = z^2)$ was proved to be invalid for other exponents.
Meaning the next equation has no integer solutions:

$$\{ x^n + y^n = z^n \}$$

$\$ \$ \int_{x_1}^{x_1 + \Delta x} f(t) dt = f(c) \cdot \Delta x. \$ \$$

$$\{ x = a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + a_4}}} \}$$
$$\{ x = a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + a_4}}} \}$$

p | 120 words | </> ↗ ⋮

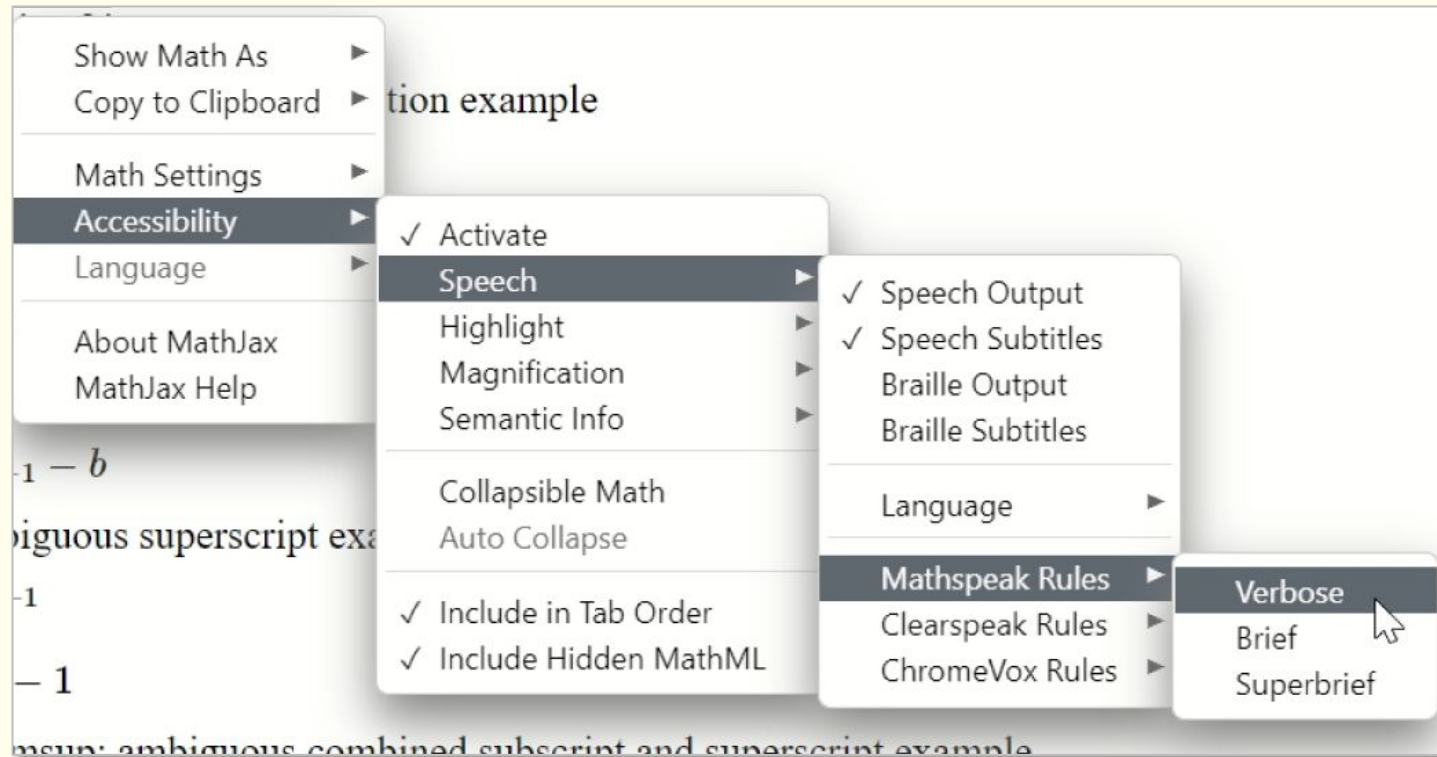
LaTeX in the RCE ↕

- $\{ \dots \}$ should be used for inline expressions.
- $\$ \$ \dots \$ \$$ or $\{ \dots \}$ should be used for block expressions (centered on their own line).

The well known Pythagorean theorem $x^2 + y^2 = z^2$ was proved to be invalid for other exponents.
Meaning the next equation has no integer solutions:

$$x^n + y^n = z^n$$
$$\int_{x_1}^{x_1 + \Delta x} f(t) dt = f(c) \cdot \Delta x.$$
$$x = a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + a_4}}}$$
$$x = a_0 + \frac{1}{a_1 + \frac{1}{a_2 + \frac{1}{a_3 + a_4}}}$$


MathJax Provides Grammars for Speaking Math



Many assistive technologies use one or more established grammars like ClearSpeak, MathSpeak and SimpleSpeak to speak math.

Example: Math Linearized into Speech Text

x equals StartFraction
negative b plus-or-minus
StartRoot b squared minus 4 a
c EndRoot Over
2 a EndFraction

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$



Example of a Matrix

$$\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

ClearSpeak (Medium verbosity):

the 3 by 3 matrix; row 1; 1, 0, 0; row 2; 0, 1, 0; row 3; 0, 0, 1;



Example of a Conditional

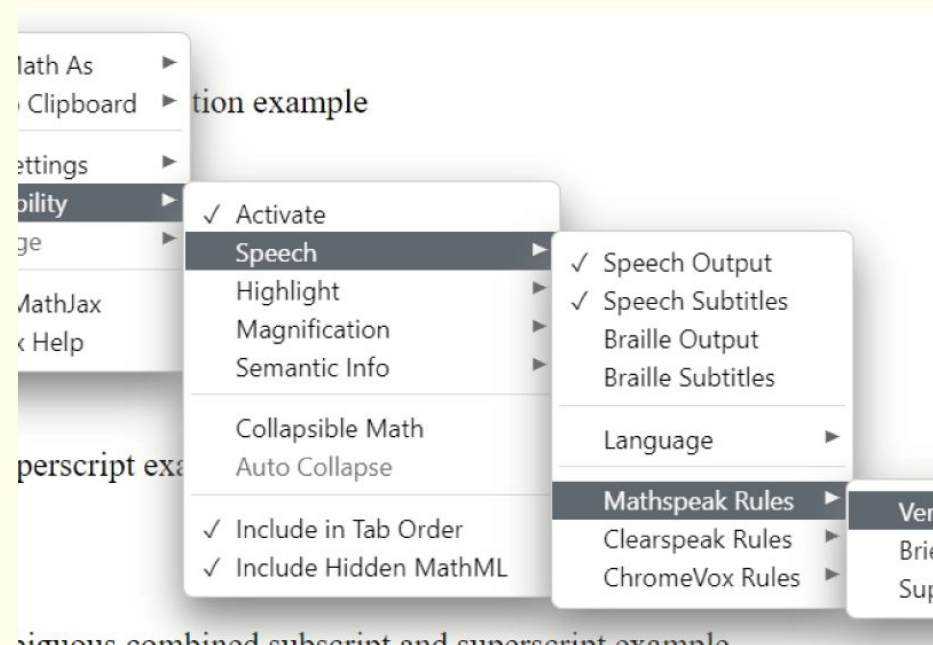
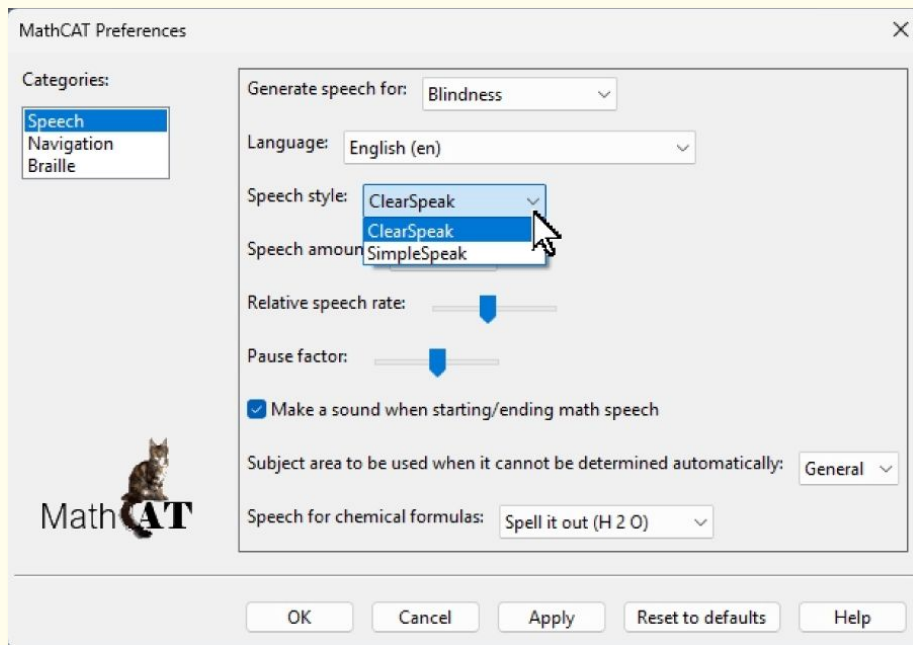
$$f(x) = \begin{cases} x^2 + 3, & x < 0 \\ x^2 - 3, & x \geq 0 \end{cases}$$

ClearSpeak (Medium verbosity):

f of x equals; 2 cases, case 1; x squared plus 3, comma, x is less than 0; case 2; x squared minus 3, comma, x is greater than or equal to 0;



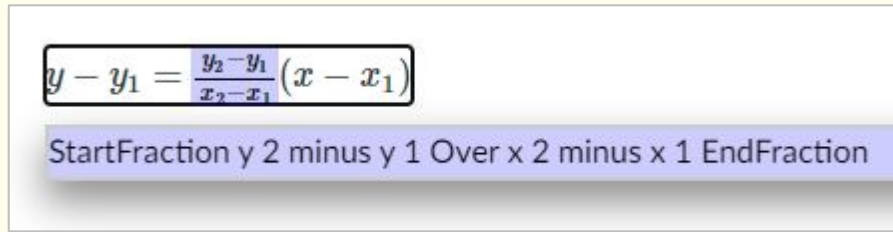
Grammars for Speaking Math



Many assistive technologies use one or more established grammars like ClearSpeak, MathSpeak and SimpleSpeak (along with preference settings) to speak math.



AT Users Can Navigate Using Expression Explorers



The image shows a screenshot of a math expression explorer. At the top, the point-slope formula is displayed: $y - y_1 = \frac{y_2 - y_1}{x_2 - x_1} (x - x_1)$. Below the formula, the corresponding code for the expression is shown: `StartFraction y 2 minus y 1 Over x 2 minus x 1 EndFraction`.

- Help pages for various equation explorers:
 - [MathCAT Navigation Commands and their Key Bindings](#)
 - [MathJax: Key Bindings for the Math Explorer](#)
 - [JAWS: Accessing Math Content with JAWS and Fusion](#)
 - [VoiceOver iOS: Read Math Equations](#)

PDF/UA-2 Was Recently Released with Support for MathML



ISO 14289-2 (PDF/UA-2), the “gold standard” for accessibility in PDF 2.0, has arrived

Based on WTPDF, ISO 14289-2 serves to assure institutions that the PDF Association’s requirements for creating and validating accessible PDF 2.0 files are now ISO-standardized.

About the author: The PDF Association staff delivers a vendor-neutral platform for PDF’s stakeholders, facilitating the development of open specifications and ISO standards for PDF technology. Staff members include: Alexandra Oettler (Editor), Betsy Fanning ... [Read more](#)



[PDF Association staff](#)

March 15, 2024

[Announcement](#)



Along with the Well-Tagged PDF Guidance

RESOURCE

Well-Tagged PDF (WTPDF)

Using Tagged PDF for Accessibility and Reuse in PDF 2.0

The primary purpose of this specification is to define how to represent electronic documents in PDF 2.0 files in a manner that allows the file to be reusable and accessible across a wide spectrum of possible use-cases.

There is a large overlap between the requirements for reuse and accessibility. However, some requirements are critical for reuse whereas others are critical for accessibility. This document clearly identifies the requirements for each use-case via a conformance level mechanism.

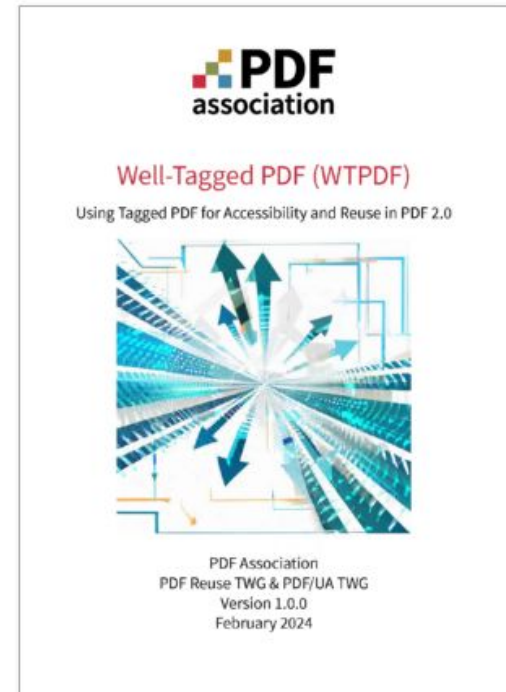
WTPDF identifies the components that shall, should or may be used in these contexts, as well as restrictions on their use. It includes a conformance level mechanism to empower software and document authors to target these use cases.

The specification is fully compatible with [ISO 14289-2 \(PDF/UA-2\)](#), so a file that conforms to the accessibility conformance level defined in this specification also conforms to the latest ISO standard for accessible PDF, and may be marked as such.

Both this document and PDF/UA-2 provide numerous improvements on PDF/UA-1, including:

- comprehensive requirements for the new structure element types introduced in PDF 2.0
- comprehensive requirements for structure element attributes;

RESOURCE INFO



[Download WTPDF](#)

Well-Tagged PDF (WTPDF) provides developers with comprehensive requirements for software that seeks to create fully reusable and accessible PDF 2.0 files in an interoperable manner.



Adobe Funded LaTeX Project Support for PDF/UA-2

Report on the L^AT_EX Tagged PDF workshop, TUG 2023

David Carlisle, Ulrike Fischer,
Frank Mittelbach

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1.2	Tagging commands and Tagging activation	267
1.3	Compatibility with older formats and legacy code	267
1.4	Tools	268
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2.1	Adapting packages and classes	268
2.2	acmart	268
2.2.1	Review of packages and commands	268
3	Tables	269

they are needed. It also requires more compilations to build the correct tagging structure.

Other workflows such X_qL^AT_EX or L^AT_EX–dvips are not recommended as real space characters can’t be inserted in these cases. In order for accessibility tools to distinguish inter-word spaces from inter-letter kerns and other spacing adjustments, words need to be separated by space characters (U+0020) even if the spacing is further adjusted. It is not feasible to add these space characters just using the macro layer, and currently only pdfL^AT_EX and luaL^AT_EX have engine-level support to add them.

When developing or updating packages or classes for tagging, one always needs to test tagging with at least pdfL^AT_EX and luaL^AT_EX. They use different methods to create the basic MC-chunks (called “marked-content sequences” in PDF reference manuals) and create the structure tree (namely, PDF literals in pdfT_EX and luaT_EX node attributes in luaT_EX).

1.2 Tagging commands and Tagging activation



Test Versions of LaTeX -> Tagged PDFs w/MathML Are Available Now

Automated tagging of PDF documents

We have now enabled new automatic tagging functionality for additional LaTeX elements, among them most display environments, standard sectioning commands and content, figure and table listings.

This can be activated through

```
\DocumentMetadata{testphase=phase-III}  
\documentclass{...} % article, book or report
```

In addition there is also a (very early) prototype for tagging formulas, which can be activated through

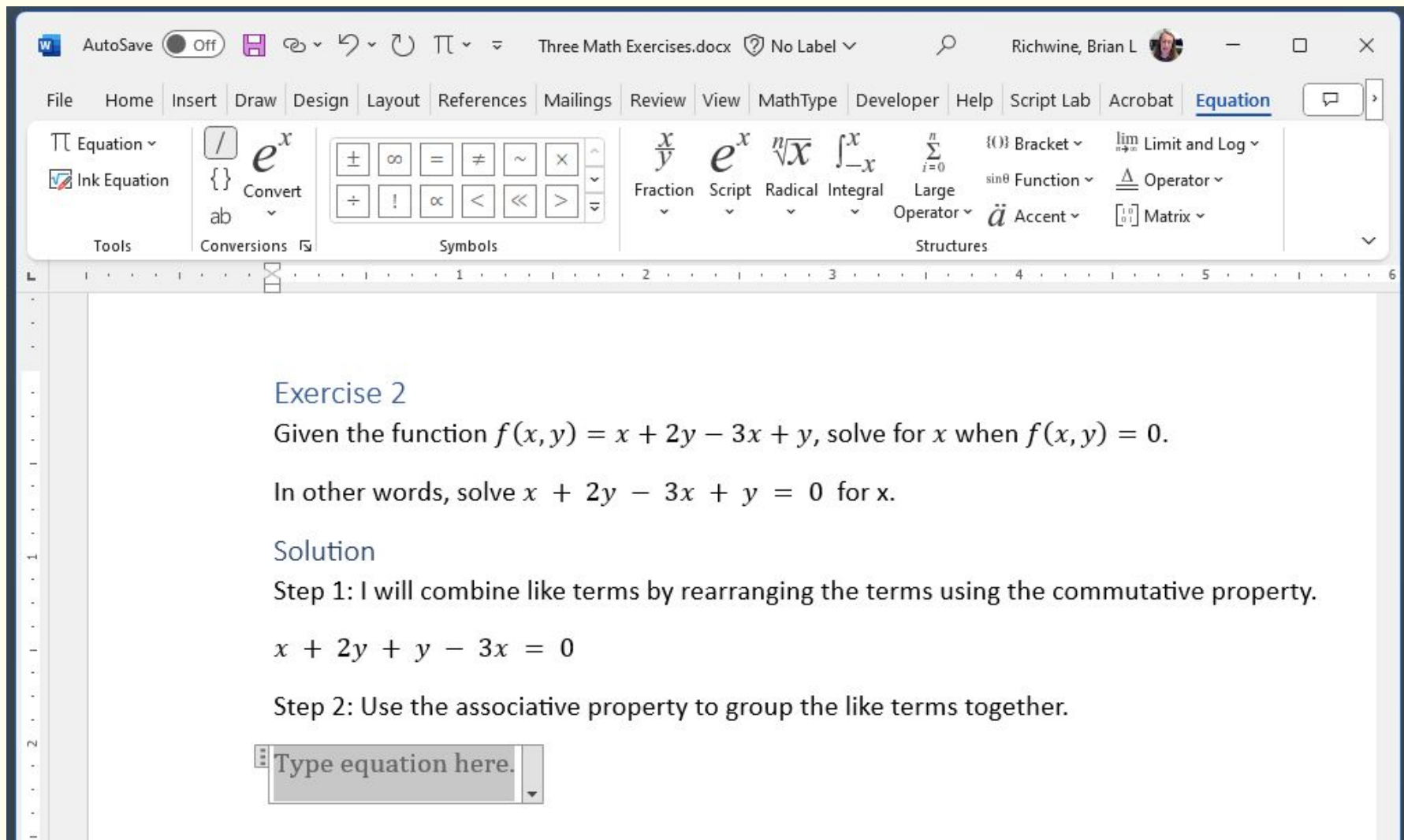
```
\DocumentMetadata{testphase={phase-III,math}}  
\documentclass{...}
```

It offers support for LaTeX's standard math environments but also for all environments provided through the `amsmath` package.

All of this automation is currently in a prototype state and restricted to the use of standard classes (`article`, `report`, and `book`) and it supports only a limited number of add-on package. See the draft version of the [LaTeX2e News Issue 37](#) newsletter for further details. It provides information how to submit feedback on the new functionality.



Listening Isn't Just for Reading: Create and Edit Math Using Microsoft Word Equations



The screenshot shows the Microsoft Word interface with the Equation ribbon selected. The ribbon includes options for Equation, Ink Equation, Tools, Conversions, Symbols, Structures, and various mathematical symbols and operators. The document content is as follows:

Exercise 2
Given the function $f(x, y) = x + 2y - 3x + y$, solve for x when $f(x, y) = 0$.

In other words, solve $x + 2y - 3x + y = 0$ for x .

Solution
Step 1: I will combine like terms by rearranging the terms using the commutative property.

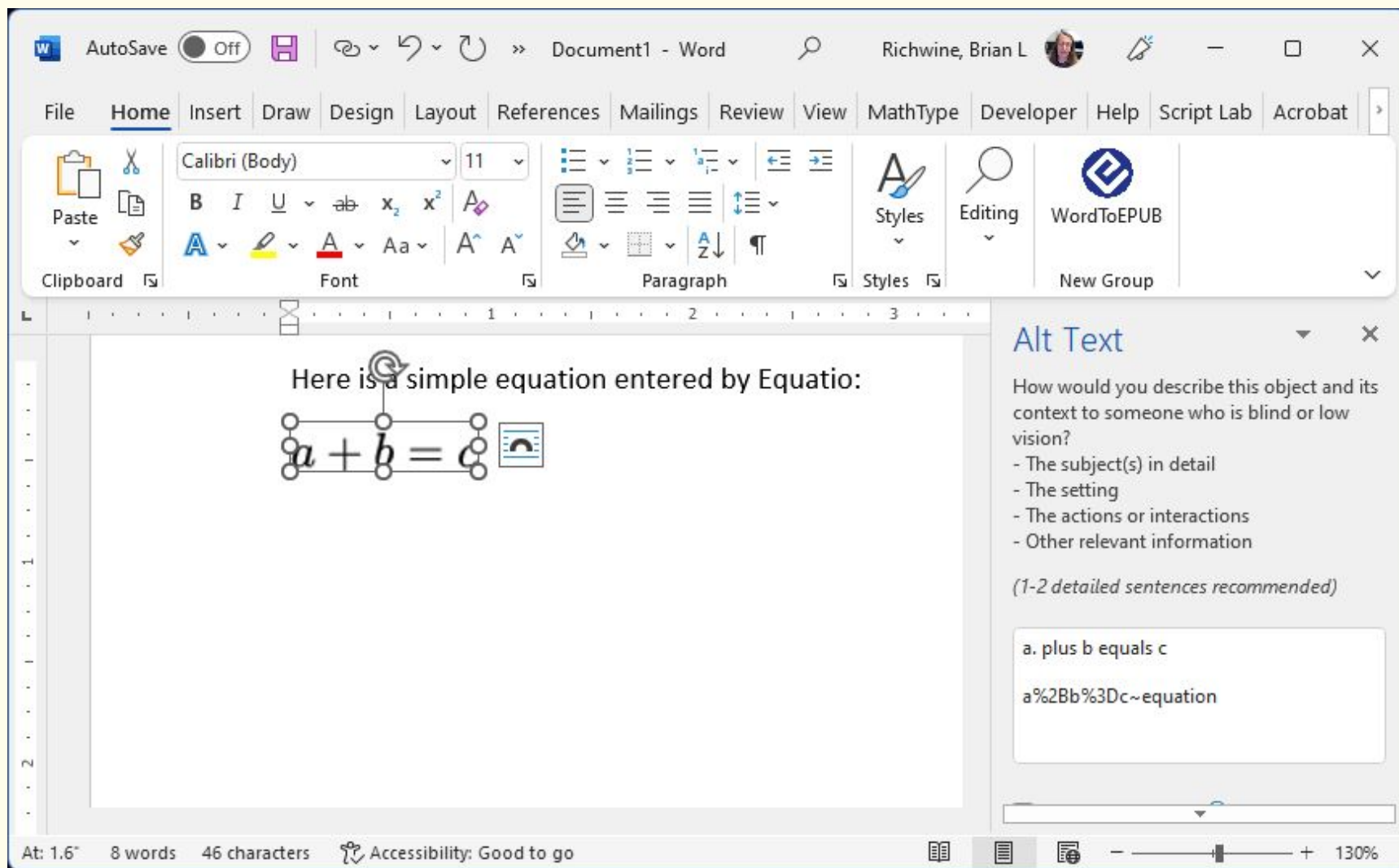
$$x + 2y + y - 3x = 0$$

Step 2: Use the associative property to group the like terms together.

Type equation here.



Check Math in Word: Images



The screenshot shows the Microsoft Word interface. The ribbon is set to the 'Home' tab. The text 'Here is a simple equation entered by Equatio:' is followed by the equation $a + b = c$. The equation is displayed with a bounding box and a small icon to its right. The 'Alt Text' pane is open on the right side of the window, showing the following text:

Alt Text

How would you describe this object and its context to someone who is blind or low vision?

- The subject(s) in detail
- The setting
- The actions or interactions
- Other relevant information

(1-2 detailed sentences recommended)

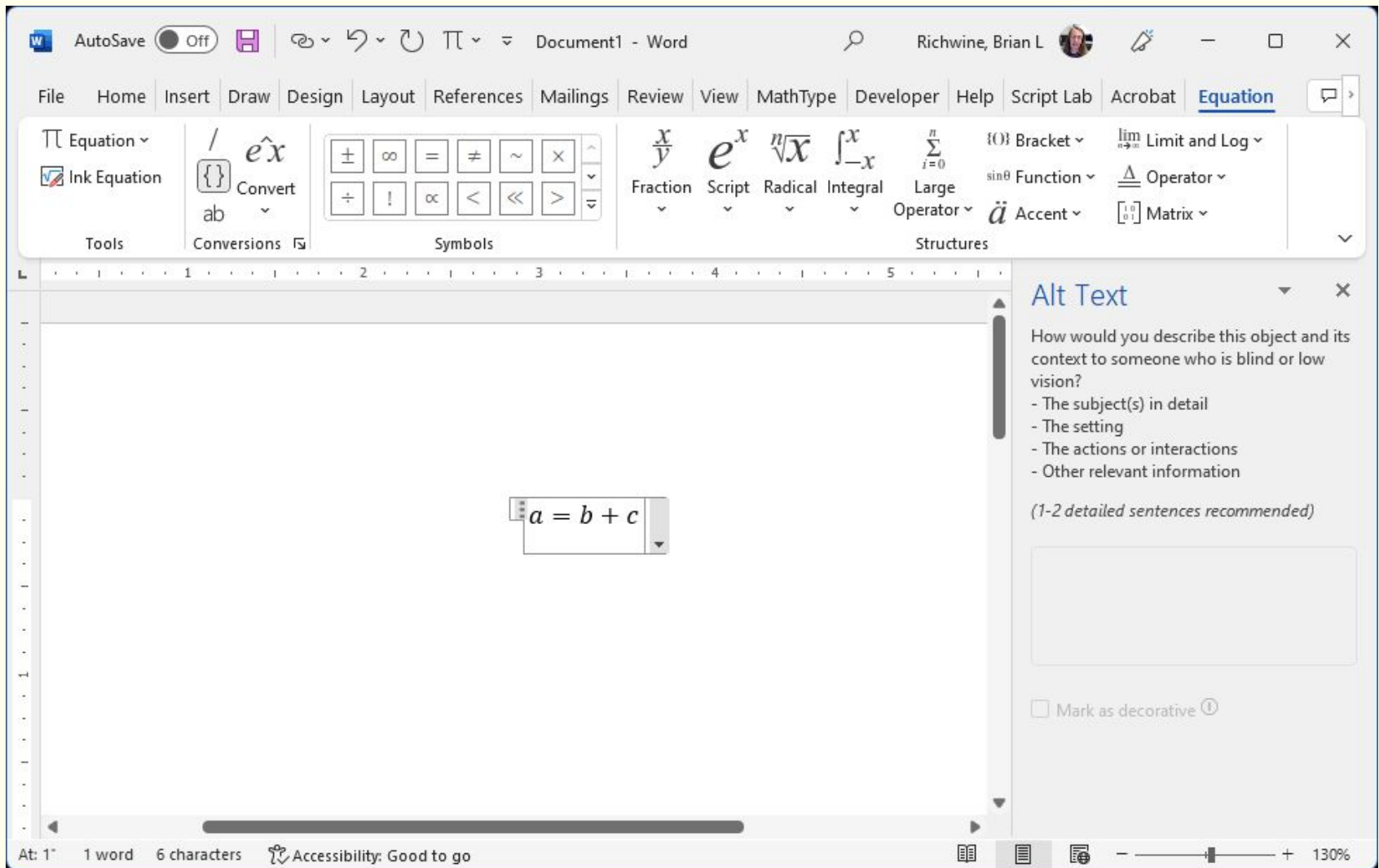
a. plus b equals c

a%2Bb%3Dc~equation

At: 1.6" 8 words 46 characters Accessibility: Good to go 130%



Check Math in Word: Built-in Math Object



The screenshot displays the Microsoft Word interface with the Equation ribbon selected. The ribbon includes sections for Tools, Conversions, Symbols, and Structures. The Structures section contains various mathematical symbols and operators. The main document area shows a math object containing the equation $a = b + c$. The Alt Text pane on the right side of the window is open, providing instructions on how to describe the object for accessibility. The status bar at the bottom indicates the current position (At: 1), word count (1 word), character count (6 characters), and accessibility status (Accessibility: Good to go).

Equation

Tools

Conversions

Symbols

Structures

Alt Text

How would you describe this object and its context to someone who is blind or low vision?

- The subject(s) in detail
- The setting
- The actions or interactions
- Other relevant information

(1-2 detailed sentences recommended)

Mark as decorative ⓘ

At: 1 1 word 6 characters Accessibility: Good to go 130%



AI-Powered Tools for Converting PDFs with Math into Other Formats (Word, HTML, etc.)

Viewing A RECURSIVE TRANSFORMER FOR 3D HUMAN POSE ESTIMATION

	A	B	C	D	E
1	2D Inputs	9	27	81	243
2	CPN	48.3	45.8	43.7	42.8
3	GT	34.6	33.1	28	24.8

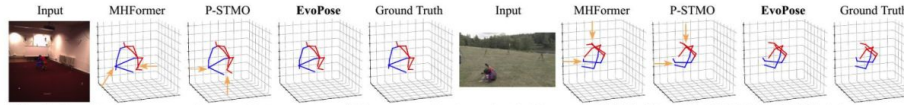


Fig. 2: Qualitative comparison with two state-of-the-art methods on both Human3.6M (left) and MPI-INF-3DHP (right) dataset.

Table 2: Results comparison with state-of-the-art methods on MPI-INF-3DHP. Bold: the best; Underline: the second.

Methods	N	PCK↑	AUC↑	MPJPE↓
PoseFormer (ICCV'21) [6]	9	88.6	56.4	77.1
MHFormer (CVPR'22) [13]	9	93.8	63.3	58.0
P-STMO (ECCV'22) [14]	81	97.9	75.8	32.2
EvoPose (Ours)	9	<u>97.8</u>	<u>81.9</u>	24.2
EvoPose (Ours)	27	<u>97.8</u>	83.7	21.9

Table 4: Ablation study on the number of input frames with MPJPE. CPN: cascaded pyramid network; GT: ground truth.

2D Inputs	9	27	81	243
CPN	48.3	45.8	43.7	42.8
GT	34.6	33.1	28.0	24.8

model components: SPR and the

Pipeline (RR)	MPJPE
✗	57.3
✗	47.9
✓	55.5
✓	45.8

to state-of-the-art methods. Following ground truth 2D poses as inputs of this dataset being shorter than setting of 27 frames. The results be seen that our method performs the other methods with improved PCK and 7.9 in AUC over the previous methods. This is our method in the real world.

Also show several visualization results on Human3.6M and MPI-INF-3DHP with ground truth 2D poses as inputs. It is

and ground truth 2D poses in Table 4. With the increase of the frame number, the results become more accurate.

To further explore the performance of our model, we conducted an ablation study on the Human3.6M under MPI-INF-3DHP. We choose the number of input frames as 9, 27, 81, and 243 in Table 3. The structure of the pipeline is shown in Figure 3. The cues in SPR and the cascaded pyramid network (CPN) are 9.4mm, while the performance to 55.5mm. When the structure of the pipeline is improved by a large number of input frames, it indicates that the structure of the pipeline is improved by a large number of input frames in RR to further improve the performance.

```

{
  "auto_rotate_confidence": 0.0046418966250847404,
  "auto_rotate_degrees": 0,
  "confidence": 0.9849104881286621,
  "confidence_rate": 0.9849104881286621,
  "data": [
    {
      "type": "asciimath",
      "value": "f(x)=[x^(2), \\ if \\<x<0],[2x, \\ if \\>x>=0:]"
    }
  ],
  "is_handwritten": true,
  "is_printed": false,
  "request_id": "eec691de4cad35bcf5cfad28d865278b",
  "text": "\\( f(x)=\\left\\{\\begin{array}{l} x^2 \\\\ \\text { if } \\<x<0 \\\\ \\text { if } \\>x>=0 \\end{array} \\right. \\)"
}
  
```

In this paper, we propose EvoPose, a novel recursive transformer for 3D HPE with kinematic structure priors.

$$f(x) = \begin{cases} x^2 & \text{if } x < 0 \\ 2x & \text{if } x \geq 0 \end{cases}$$

OCR Data Original Solver

Hide Original ^

$$\int_0^1 \langle t^3, 3t^2 \rangle - \langle 4t^3, 3t^2 \rangle dt = \int_0^1 (4t^{10} + 9t^4) dt = \left(\frac{4}{11} t^{11} + t^5 \right) \Big|_0^1 = \frac{4}{11} + 1 = \frac{15}{11}$$

$$\int_0^1 \langle t^7, 3t^6 \rangle - \langle 4t^3, 3t^2 \rangle dt = \int_0^1 (4t^{10} + 9t^8) dt = \left(4 \cdot \frac{t^{11}}{11} + t^9 \right) \Big|_0^1 = \frac{4}{11} + 1 = \frac{15}{11}$$

Copy MS Word Copy PNG Open DOCX Copy PNG Open PNG

`\begin{aligned} \int_0^1 \langle t^3, 3t^2 \rangle - \langle 4t^3, 3t^2 \rangle dt = \int_0^1 (4t^{10} + 9t^4) dt = \left(\frac{4}{11} t^{11} + t^5 \right) \Big|_0^1 = \frac{4}{11} + 1 = \frac{15}{11} COPIED`

`\begin{aligned} \int_0^1 \langle t^7, 3t^6 \rangle - \langle 4t^3, 3t^2 \rangle dt = \int_0^1 (4t^{10} + 9t^8) dt = \left(4 \cdot \frac{t^{11}}{11} + t^9 \right) \Big|_0^1 = \frac{4}{11} + 1 = \frac{15}{11}`

Confidence