

# Are figures accessible in mathematics academic journals?

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## Abstract

Are figures accessible in mathematics academic journals? An analysis of current image accessibility in highly cited mathematics journals.

## Keywords

Figures, mathematics, academic journals, accessibility

## 1. Introduction

In Science, Technology, Engineering and Mathematics (STEM) academic literature, mathematical formulae, diagrams and other two-dimensional structures are a critical information source (Sojka et al.). Even for many sighted students “math education poses a serious roadblock in entering technical disciplines” (Karshmer, Gupta, and Pontelli 664). The output of mathematics literature can create even greater barriers to visually impaired students ( Smeureanu, and Isaila) and students with learning disabilities (Lewis, Noble, and Soiffer), due to the technical notations they include, the large number of visual resources used (such as diagrams, graphs

and charts) and the inclusion of visual concepts, such as spatial concepts. Currently, the inclusion of visual information in academic research papers is a widespread practice. Efforts to convert academic literature in mathematics to accessible formats after their publication have been made (Sojka et al.). However, most research literature is not currently supported by a publishing process that produces accessible outputs of scientific documents (Gardner, Bulatov, and Kelly).

A solution for making the mathematics in electronic documents accessible is to provide alternative textual descriptions to critical graphical information (Webb), as the textual information can be rendered in speech by screen readers or in Braille. This solution “is directly analogous to the standard accessibility approach” (Cooper, Lowe, and Taylor 928) proposed by the “Web Content Accessibility Guidelines 1.0” and “Web Content Accessibility Guidelines (WCAG) 2.0”.

Several proposals exist on making standard statistical graphics accessible. Demir et al. and Ferres et al. have applied statistical and natural language processing techniques for the generation of spoken descriptions of statistical graphics. Doush et al. have proposed a multi-modal approach for accessing charts in Excel for visually impaired users.

The National Center for Accessible Media (NCAM) has created guidelines on how to textually describe diagrams and other standard graphics within Digital Talking Books (Gould, O’Connell, and Freed), with the aim of making them more accessible for students or scientists who are blind or visually impaired.

In this paper we aimed to review publishing practices, policies and submission guidelines concerning the accessibility of visual content in a sample of ten academic journals in mathematics. We checked the application of the accessibility policy in one article from each journal. In particular, we focused our analysis on the alternative textual means of accessing the underlying semantics of figures. As noted by Cooper, Lowe, and

Taylor, the design of appropriate textual descriptions of images is a challenging task and “this becomes more challenging as the complexity of the mathematics increases” (928). In order to address this issue, Splendiani, and Ribera suggests that “the function of the text alternative can be accomplished by any textual description presented within the context of the paper” (10) that openly refers to the image and properly describes its content. In consonance with this view we checked the presence of the image’s caption, the surrounding/adjacent text, mentions of the image in main text, image title and metadata and we advance insights into their relevance as appropriate information for image description.

Our research aimed to improve access to mathematics journals for researchers with disabilities by proposing the inclusion of accessibility policies in the journals’ submission workflow. A parallel objective was to show the need for guidelines to standardize the submission of images in scientific papers. Although standard submission guidelines according to international standards have been adopted by academic journals, as far as we are aware, no shared standard is currently available for manuscript submission to mathematics journals. We found general guidelines in how to write mathematical symbols (International Organization for Standardization) but they were not even cited in the journals’ guidelines for authors.

## **2. Method**

Ten mathematics journals with the highest impact factor according to the ranking of the Journal Citation Report<sup>1</sup> and with ISI SCR subject “Mathematics” were identified (Table I). The submission policy and accessibility policy (where available) of the journals were analyzed and documented. For each journal, the

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<sup>1</sup> According to the Science Edition 2012, accessed October, 1<sup>st</sup> 2013.

application of alternative text, caption, mention in the body of the text to figures in articles available online and published in 2013 (Table I) were analyzed and reported. A requirement for the selection of papers was the presence of figure(s) in the article. We also checked the presence of metadata in the articles, concerning the whole document and also the images within them, according to the Extensible Metadata Platform (XMP) specification.

<b>Journal</b>	<b>Impact Factor</b>	<b>DOI of the article</b>
Journal of the American Mathematical Society	6.311	10.1090/S0894-0347-2013-00777-8
Communications on Pure and Applied Mathematics	4.908	10.1002/cpa.21466
Annals of Mathematics	4.675	10.4007/annals.2013.178.2.1
Acta Mathematica	4.656	10.1007/s11511-013-0096-8
Bulletin of the American Mathematical Society	4.529	10.1090/S0273-0979-2013-01434-4
Inventiones Mathematicae	4.447	10.1007/s00222-012-0441-0
Foundations of Computational Mathematics	4.424	10.1007/s10208-013-9147-y
Journal of the European Mathematical Society	4.260	10.4171/JEMS/388
Publications Mathématiques de l'IHÉS	4.260	10.1007/s10240-013-0048-z
Fixed Point Theory and Applications	4.010	10.1186/1687-1812-2013-104

Table I Mathematics journals and article selected.

### 3. Results

No journal had an accessibility policy statement and only two journals made a reference to the inclusion of descriptive captions of figures in their submission guidelines for helping people with disabilities to access the graphical content of the images.

The analysis of the articles suggested that visual elements in mathematics papers had peculiar characteristics and treatment compared to figures in papers of other research areas (Splendiani, and Ribera; Splendiani et al.).

Nine papers out of ten included images in vector format (images in the article from “Foundations of Computational Mathematics” journal were in raster format), which is more suited to render technical graphics and diagrams. From an accessibility point of view, the use of vector format could potentially enable a multimodal access to visual features, since the information embedded could be defined semantically and described by metadata. Instead, as the analysis revealed, the PDF generated from original LaTeX documents by the use of conversion libraries lost their tags.

Generally speaking, vector images are reformatted in PDF and are represented as a content stream encapsulated into an object following the PDF model, as showed in figure 1. In other words, “PDF doesn’t really have the concept of a vector image, such as an EPS or EMF file” (Rosenthol 58).

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58 0 obj
<< /A << /D (cite.BT) /S /GoTo >> /Border [ 0 0 1 ] /C [ 0 1 0 ] /H /I /Rect [ 306.008 682.302 313.455 691.8 ] /Subtype /Link /Type /Annot >>
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<< /A << /D (cite.BT) /S /GoTo >> /Border [ 0 0 1 ] /C [ 0 1 0 ] /H /I /Rect [ 156.819 208.89 164.266 218.388 ] /Subtype /Link /Type /Annot >>
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63 0 obj
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stream
BT
/F79 7.9701 Tf 217.541 720.269 Td [(GALOIS)-250(THEOR)65(Y)-250(AND)-250(PR)40(OBJECTIVE)-250(GEOMETR)65(Y)-9419(1341)]TJ/F79 10.9091 Tf -91.015 -23.91
[(Morse)15(v)15(er)40(,)-282(I)]TJ/F58 7.9701 Tf 51.689 3.96 Td [(a)]TJ 0 -6.895 Td [(\027)]TJ/F57 10.9091 Tf 5.503 2.935 Td [(.)]TJ/F87 10.9091 Tf 4
[(Z)]TJ/F58 7.9701 Tf 7.964 -2.117 Td [(')]TJ/F57 10.9091 Tf 4.626 2.117 Td [(/)]TJ/F79 10.9091 Tf 7.077 0 Td [(and)-276(D)]TJ/F58 7.9701 Tf 26.637 3
[(\027)]TJ/F57 10.9091 Tf 5.504 2.935 Td [(.)]TJ/F87 10.9091 Tf 4.069 0 Td [(Z)]TJ/F58 7.9701 Tf 7.964 -2.117 Td [(')]TJ/F57 10.9091 Tf 4.626 2.117
Td [(/)]TJ/F80 10.9091 Tf 7.077 0 Td [(ax)37(e)]TJ/F79 10.9091 Tf 17.146 0 Td [(the)-276(standard)-275(abelian)-276(inertia)-276(and)-276(decompositi
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Figure 1 Example of source code of a vector image encapsulated into a PDF. Source: Bogomolov, and Tschinkel.

For this reason, vector images reformatted in PDF are not tagged as such and as a consequence no vector figure analyzed had an associated alternative text. Raster images in the article from “Foundations of Computational Mathematics” journal had no alternative text either.

In some cases figures appeared not to be treated as a specific element inside the article, rather as part of the text, as we found that they were not labeled as such, had no caption and no references in the main text of the article, as showed in the example in Figure 2.

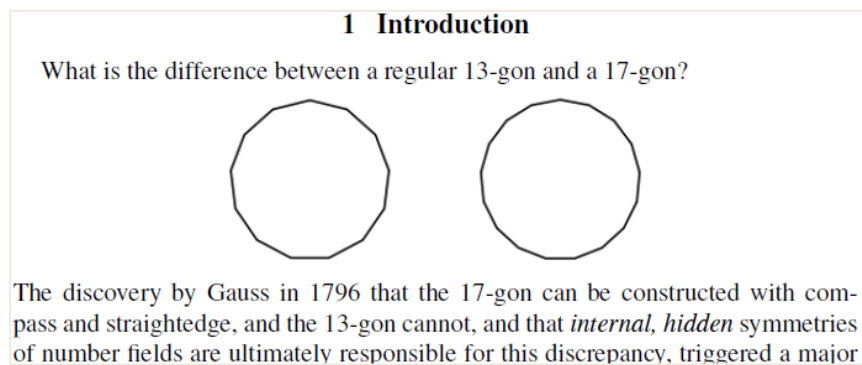


Figure 2 Example of figure without caption or mention in the text. Source: Bogomolov, and Tschinkel.

Most figures included math formulae and used a label font size lower than 12 pt, the minimum size to guarantee readability of labels and other textual information. All the journals adopted the font family that conforms to the ISO 80000-2:2009 (International Organization for Standardization) in formulae. Taking into account that accessibility guidelines for typography recommend the use of sans serif families, in this case the standard presented a mismatch with accessibility requirements. Sans-serif fonts, such as Verdana, Arial, Helvetica and Lucida, are generally considered more legible than serif fonts, such as Times, New Roman, Georgia) (Ranaldi, and Nisbet), especially for readers with learning disabilities, such as dyslexia (Rello, and Baeza-Yates).

A metadata analysis showed that XMP records associated with PDF documents included a very limited number of metadata compared to the amount of information that was possible to have been generated during the publishing workflow. Only the raster images in the article from “Foundations of Computational Mathematics” journal had XMP descriptive records associated with them: the name of the tool used to create the figure (XMP:Creatortool: “VTEX”) in one figure or (XMP:Creatortool:”Adobe Illustrator 8.0”) in another, the title of the figure (dc:title: “9147f02.eps”) and the entity primarily responsible for making the resource (dc:creator: “vtex vtex”) in the other figure. The images in the rest of the papers were generated from vector images and had no XMP associated with them.

## **4. Conclusions**

Our analysis showed a lack of common and clearly defined guidelines addressing accessibility issues related to figures in highly cited mathematics journals. We identified a high variability in the application of recommendations related to graphical features and textual alternatives to the figures in PDF articles, as showed in Table II.

<b>Accessibility Issue</b>	<b>Rationale of the recommendation</b>	<b>Number of journals recommending it</b>	<b>Number of articles applying it</b>
Vector format recommended	To maintain resolution despite zooming and resizing	10 / 10	9/10
Do not use color alone to convey information	To allow color blindness readers and blind people to understand the image	2 / 10	8/10
Minimum Color Contrast ratio: 4.5:1	To ensure minimum contrast between letter and background	2 / 10	7/10
Avoid specific color or combination of colors	To avoid possible barriers in readability, especially for color blindness readers	2 / 10	8/10
Minimum resolution 300 dpi	To maintain readability at high magnification levels	5 / 10	Not available
Minimum dimensions (width)	To avoid readability barriers, especially in printed version	3 / 10	Not available
Font type sans-serif	To guarantee more legible fonts	2 / 10	0/10
Label Font size minimum 12 pt	To guarantee readability of labels and other textual information	4 / 10	0/10



Image alternative description (pdf version)	To provide a textual alternative to the image	0 / 10	0/10
Use of image caption	To provide a textual description of the image	5 / 10	8/10
References to images in main text	To relate textual information to images	2 / 10	7/10
Metadata for images	To provide a textual source of information about the image	0 / 10	2 / 10

Table II Recommendations concerning graphical features and textual alternatives to the figures provided by the 10 journals selected and their application in the PDF versions of the articles.

Apart from inviting scientific publishers to adhere to common, basic, accessibility guidelines, we suggest possible ways for improving image accessibility in mathematics according to the following general suggestions in the publishing workflow:

- Promote the inclusion of alternative text, by providing guidelines and examples on how to create alternative descriptions for images and implementing a checking mechanism to detect the presence of alternative text in the submission process;
- provide solutions for avoiding the loss of semantic data associated with figures during the transformation from original LaTeX documents to the final publication PDF documents. In this sense, this paper suggests research opportunities in the analysis of the whole publishing workflow, for understanding how metadata and image annotations are created and transmitted from initial creation to paper submission.

As a starting point, the International Image Processing and Interchange Standard (IPI) could be a reference for further proposals of standardization of image management in the publishing workflow. The standard includes the definition of a format for interchange of images between applications and functions for parsing and generating this format. The format, called basic Image Interchange Format (BIIF), is designed to allow 999 images and symbols to be combined in a single file. It enables the association of metadata with individual components in it, such as image, symbols and text segments.

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