Editing and reading early modern mathematical texts in the digital age

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Abstract

The advent of digital technology has brought a world of new possibilities for editors of historical texts. Though much has been written about conventions for digital editing, relatively little attention has been paid to the particular question of how best to deal with texts with heavily mathematical content. This essay outlines some ways of encoding mathematics in digital form, and then discusses three recent digital editions of collections of early modern mathematical manuscripts.[1]

Keywords: digital scholarly editions, TEI, TeX, MathML, OpenMath
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1. Introduction: digital tools and languages for historical mathematics

Over the last 30 years, the ways in which historians work have undergone a fundamental change. It is a rare historian nowadays who does not use a computer in at least some aspect of his or her work, be it for writing, looking up material in archive or library catalogues, or reading primary or secondary sources through electronic means. Modes of publishing have also changed, and whereas for hundreds of years we have been tied to the print medium and its intrinsic linearity, the digital turn is now opening up new avenues for innovative ways in which to publish scholarly work. The theory and practice of such new types of publication is part of the emergent field of digital humanities.[2]

[1]This is the accepted author manuscript. There are a few minor differences between the text of this version of the paper and that of the version of record to be published in *Historia mathematica*.

[2]Digital scholarly publishing and editing is only one of many issues being explored in depth within current digital humanities scholarship. The present paper will discuss only one aspect of this issue: namely, its implications in the specific case of the history of mathematics. I refer the interested reader to (Gold, 2012) for wider-ranging discussion of digital editions, and for an overview of the current state of the digital humanities in

In particular, any historian looking to produce a new edition of a primary source or collection of primary sources has an important choice to make: should he or she opt for a print edition, a digital edition, or some combination of the two? Each has its own advantages and disadvantages. Print editions are durable, and one knows that an edition produced in this way will still be extant and readable for as long as a copy survives. Many readers also prefer to have a physical copy of the work they are reading and referring to, finding it less straining on the eyes and easier to navigate.

On the other hand, a digital edition is more flexible for the editor and the reader: rather than choose one primary version of the text to offer to the reader, possibly augmented with alternative readings described in footnotes or marginal notes, the editor can simply present several versions of the text and allow the reader the freedom to choose which is most suitable for his or her purposes. Iliffe (2004, 33) has referred to the move towards 'unediting' scholarly manuscripts: that is, presenting the reader with something as close as possible to the original manuscript, with minimal editorial modifications so as to present all the nuances of the original document. The editor is also no longer required to choose for the reader a linear path through the material: he or she can suggest multiple different reading orders, each potentially as valid or useful as the other. For example, the reader of an edition of collected letters might choose to read only one correspondence, or read all correspondence within a particular time period, or read all correspondence on a particular subject; though this would be possible with a print edition, it would require considerably more effort on the part of the reader to select and reorder the material he or she wants. The possibilities are limited only by the imaginations of the editor and reader. However, there is some concern over how durable a digital edition is. Digital formats that were used as standard as little as twenty years ago, such as floppy disks and VHS tapes, are now becoming unusable due to the necessary hardware becoming extinct. In view of these new potential uses of edited texts and durability concerns, how can we ensure that the files produced are as useful as possible and remain readable in the future? And in particular, how can mathematics be most usefully encoded in digital format?

There is, thus far, no entirely satisfactory answer to this question. However, we can go some way towards answering it by using standardised data formats that are easy to convert automatically into new formats when needed; for example, to upgrade for compatibility with a new system. For text storage, the leading standard is TEI-XML. Extensible Markup Language (XML) is a plaintext-based metalanguage for creating markup languages to store data. Different types of XML can be used to encode different types of data; TEI-XML, the particular type of XML I will focus on in this article, was

general.

proposed by the Text Encoding Initiative (TEI) group as a set of guidelines for the encoding of texts and their metadata, and has become a widely adopted standard way to present digitally encoded texts (TEI Consortium, 2007—).

An XML document consists of a hierarchy of nested *elements* which can contain data. So, for example, one might encode a name in TEI-XML as follows:

```
<name>
  <forename>
    Leonhard
  </forename>
  <surname>
    Euler
  </surname>
</name>
```

Here, `name` is an element with two *child elements*, `forename` and `surname`; the opening tag `<name>` denotes the beginning of the `name` element, and the closing tag `</name>` denotes its end. If necessary, elements can be given *attributes* to encode extra information about the element without adding extra child elements.

The TEI P5 guidelines include consideration for the encoding of mathematics. The most important section for this is Section 14.2, on formulae, which suggests enclosing formulae in a `formula` element. However, it offers several different suggestions for how to proceed inside the `formula` element. First, it acknowledges that there already exists a widely used non-XML markup language for mathematics—TeX and its variants—and suggests embedding TeX within the formula, adding a `notation` attribute to direct the parser as to how to deal with it. For example:

```
<formula notation="TeX">
  $e^{i\pi}+1=0$
</formula>
```

will reproduce Euler's formula $e^{i\pi} + 1 = 0$. Second, it suggests using MathML, a standard developed by the World Wide Web Consortium (W3C) for representing mathematical formulae (World Wide Web Consortium, 1998—). There are two types of MathML: Presentation MathML, which describes how the formula looks on the page, and Content MathML, which describes how the formula is structured and what it means. For example, Euler's formula could be written in Presentational MathML:

```
<formula>
  <msup>
    <mi>
```

```
      &ExponentialE;
    </mi>
    <mrow>
      <mi>
        &ImaginaryI;
      </mi>
      <mi>
        &pi;
      </mi>
    </mrow>
  </msup>
  <mo>
    +
  </mo>
  <mn>
    1
  </mn>
  <mo>
    =
  </mo>
  <mn>
    0
  </mn>
</formula>
```

Here, `msup` and its two child elements are used to denote a base with a superscript; `mn` denotes a number; `mo` denotes an operator or relation. Presentational MathML is, in most cases, much more verbose and less human-readable than TEX but it is more widely supported by web browsers and therefore somewhat easier to use in a digital edition.

However, presentational markup such as TEX or Presentational MathML records only the appearance of the mathematics on the page, and does not always encode all of the semantics of a formula or statement. For example, dependent on its context, the fragment $f(x+y)$ might be interpreted as the product of a variable f with the sum $x+y$, or as the result of applying the function f to the sum $x+y$. To remove such ambiguity, one may use a type of markup which encodes the structure and meaning of the formula rather than its appearance on the page. An example of such *semantic* markup is Content MathML, in which Euler's formula may be represented as follows:

```
<formula notation="mathml">
  <apply>
    <eq/>
    <apply>
```

```
      <plus/>
      <apply>
        <power/>
        <exponentiale/>
        <apply>
          <times/>
          <imaginaryi/>
          <pi/>
        </apply>
      </apply>
      <cn>
        1
      </cn>
    </apply>
    <cn>
      0
    </cn>
  </apply>
</formula>
```

Here, the apply element denotes the application of an operator or relation, such as eq, plus, power, or times.

A third suggestion made in the TEI guidelines is the use of the OpenMath standard. Like Content MathML, OpenMath is also concerned with encoding the semantics of a mathematical expression (OpenMath Society, 2001—). Euler's formula can be captured in OpenMath as follows:

```
<OMOBJ>
  <OMA>
    <OMS cd = "relation1" name="eq"/>
    <OMA>
      <OMS cd = "arith1" name="plus"/>
      <OMA>
        <OMS cd="arith1" name="power"/>
        <OMS name="e" cd="nums1"/>
        <OMA>
          <OMS cd = "arith1" name="times"/>
          <OMS cd="nums1" name="i"/>
          <OMS cd = "nums1" name = "pi"/>
        </OMA>
      </OMA>
      <OMI>1</OMI>
    </OMA>
    <OMI>0</OMI>
```

```
  </OMA>
</OMOBJ>
```

Other than in syntax, this particular example differs little from the representation of the same formula in Content MathML: the `OMA` elements represent function applications and correspond to `apply` elements in MathML; constants and integers are given by `OMS` and `OMI` tags respectively. However, the OpenMath standard as a whole is much more comprehensive than Content MathML. While MathML deals only with a small set of mathematical objects, mostly those pertaining to school-level mathematics, OpenMath has been designed bearing in mind the need for extension of the standard without global agreement on the definitions of individual objects. This is achieved through the use of *content dictionaries*: structured documents which define a set of symbols, which can then be shared in order to allow other applications or users to understand the same symbols in the same way. In the above example of Euler's formula, the `cd` attributes for each of the `OMS` objects tell the reader in which of the official content dictionaries that object is defined.

Happily, there is a great deal of overlap between MathML and OpenMath (and between the personnel of their development teams), and it is possible to use each to extend the other in various ways. For example, MathML can be used to produce human-readable representations of OpenMath objects, and in particular, where an object does not exist in the fixed definition set of MathML, a definition can be imported from an OpenMath content dictionary. Rather than existing in competition with each other, the two standards are complementary to each other and together provide a powerful tool for representing mathematical objects through both presentation and meaning.

Of the markup languages discussed above, TeX and Presentation MathML encode the appearance of the formula on the page, whereas Content MathML and OpenMath encode its semantics, structure, and meaning. Each approach to encoding mathematics has its advantages, disadvantages, and different uses. For the encoding of historical mathematical texts, Content MathML and OpenMath are potentially very powerful for searching for related formulae across large corpuses, but they risk excessively formalising and modernising the content, and losing its nuances. The content dictionary mechanism built into OpenMath, however, could be used to refer to historical definitions of terms rather than their modern descendants. On the other hand, Presentational MathML or TeX captures as closely as possible the appearance of the original text, and leaves the question of interpretation of the mathematics open to the reader. Markup languages raise an important question for editors: can they be meaningfully used to enhance the functionality of digital editions of mathematical texts, or is the risk too great of losing fine gradations in meaning?

2. Digital editions of historical mathematics: some case studies

In this paper I illustrate the potential of various types of digital edition for enhancing scholarly work, and discuss the advantages and disadvantages of the move from print to electronic publishing for scholarly editions, especially those with significant mathematical content. There is such a wide range of digital historical-mathematical projects in existence that it is impossible to cover all of them in one article. In choosing case studies to examine in more detail, I have therefore applied several unavoidably subjective criteria. First, I have restricted myself mostly to the discussion of digital editions of texts; the inclusion of other types of digital project such as databases, data visualisation, and data mining in this discussion would fill a book, let alone an article. Second, I have restricted myself to those treating my own area of specialism: namely, early modern texts with significant mathematical content. Third, I have covered only digital publications which are available freely to all with no paywall or user registration requirement. Finally, in order to write a coherent review, I have only discussed projects whose outputs are publicly available in some usable form over the web, though not necessarily a fully complete form.

2.1. Leibniz edition

The first type of digital edition that I examine is the one most closely related to its print cousin: that in which a digital replica of the print edition is simply placed online, perhaps even before the physical copy is made available. This is usually done using Portable Document Format (PDF), which reproduces exactly the pages as they appear in the print edition. The advantage of this is that there is a stable digital edition which is consistent with the print edition and which can be easily referenced by readers, and there is no confusion over version control. However, it is less flexible than its 'born-digital' counterparts, which are usually presented as websites, rather than downloadable PDF files: errata are less easily corrected, and it is harder to add new material or features. Furthermore, since PDF files are usually larger than their HTML counterparts, the load placed on the institution's servers is usually greater.

An example of a project which has used this route is the Leibniz edition, overseen by the Gottfried-Wilhelm-Leibniz-Gesellschaft and produced by four groups of researchers, in Potsdam, Münster, Hannover, and Berlin. All volumes of the Leibniz Edition published in or after 2001 have been placed on the website of the Edition as open-access PDF files.[3] In this article, I will focus on the most recent volume of the *Mathematische Schriften*, volume VII.6 of the edition, which deals with Leibniz's work between 1673 and 1676

[3] See `http://www.leibniz-edition.de/`.

on the arithmetic quadrature of the circle (Mayer and Probst, 2012). This volume of the Leibniz edition was published (in print form) in Berlin in 2012, under the auspices of the Berlin-Brandenburgischen Akademie der Wissenschaften and the Akademie der Wissenschaften zu Göttingen, and is also available as a PDF file; my comments here refer to the electronic PDF version.

The particular focus of the present volume is on manuscripts related, in one way or another, to the treatise *De quadratura arithmetica circuli ellipseos et hyperbolae*, in which Leibniz developed the theory of infinite series and used it to give the exact quadrature of the circle and other curves. Among the results given is Leibniz's famous series

$$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \dots$$

which he had first found in 1673. Leibniz wrote several versions of *De quadratura arithmetica*, but it was not published during his lifetime; it was eventually published, following the last and most substantial of Leibniz's manuscript iterations, by Eberhard Knobloch in 1993. Volume VII.6 of the Leibniz edition contains editions of 51 manuscript texts, of which only four are dated by Leibniz himself but of which all or most of the remainder can be traced to the period 1673–1676. Two thirds of these texts appear in published form for the first time in this edition.

The editors have divided the texts into three chronological groups. The first, consisting of manuscripts written between the autumn of 1673 and the autumn of 1674, includes some longer pieces on the arithmetic quadrature of the circle, and also a draft of *De quadratura arithmetica* that Leibniz sent to Christiaan Huygens in October 1674, along with various shorter notes and calculations. The second group of texts probably dates from 1674–1676, and includes drafts for an article in the *Journal des Sçavans* on the quadrature of the circle. The final group is by far the largest, and much of it consists of drafts of, and additions and extensions to, a comprehensive treatise on circle quadrature.

The volume is well-presented, with hyperlinks to aid navigation around the PDF. There is a very useful introduction by Siegmund Probst and Uwe Mayer, which discusses the sources, context, and content of the texts presented in the volume, as well as elucidating some of the terminology and notation used by Leibniz. The editors also provide comprehensive indexes of names, of works referenced, of topics mentioned, and of manuscripts, as well as a concordance between the numbering systems used by the editors of the present volume and by Albert Rivaud in his *Catalogue critique des manuscrits de Leibniz* (1914–1924). Finally, there is a list of abbreviations and signs used in the volume. The editors have made every effort to reproduce Leibniz's written mathematics from its manuscript form (though diagrams are redrawn rather than reproduced in facsimile), and have made faithful reproductions of its layout where possible. However, there are no accompanying page images, which would have helped the reader in assessing how faithful the reproductions are.

2.2. The Newton Project and Cambridge University Digital Library

The Newton Project, launched in 1998 by Rob Iliffe and Scott Mandelbrote, aims to transcribe and make available the writings of Isaac Newton (1642–1727) for public access (Iliffe and Mandelbrote, 1998—). Newton's scientific papers were donated to Cambridge University in 1872 by the fifth Earl of Portsmouth.[4] In the early twentieth century, the 1927 bicentenary of Newton's death led to renewed interest in the papers, and several efforts were begun to edit and publish them.[5] Committees for the publication of Newton's correspondence were set up in 1938 and 1947, and the letters were subsequently published under the editorship of the mathematician H. W. Turnbull (1959–1977) for the first three volumes, J. F. Scott for volume 4, and A. R. Hall and L. Tilling for volumes 5–7. Various editions have been produced of particular subsets of the scientific papers; the mathematical papers are unusual in that a substantial and high-quality print edition does exist, namely that of D. T. Whiteside, published in eight volumes from 1967 to 1981.

The scope of the Newton Project covers all of Newton's writings.[6] The transcriptions are made in TEI-compliant XML, from which multiple versions of the text can be generated: a diplomatic transcription, showing all of Newton's later amendments and corrections to the text, and a 'clean' normalised version implementing all of Newton's later changes to the text, as a print editor would do. This allows the reader to choose the version or versions most appropriate for his or her needs. Moreover, the transcription and tagging policies adopted by the project are freely available on the Project website, allowing the reader to understand just what he or she is reading and how it might differ from the paper original.

The existing work produced by the Newton Project on the mathematical papers has been augmented through collaboration with the Cambridge Digital Library (CDL), which exists to widen access to a selection of the manuscript collections held by Cambridge University Library, and which provides high-resolution digital images of its extensive Newton collections as

[4]For a recent book-length account of the history of Newton's papers, tracing the ways in which they have been passed between various different custodians and hence become considerably disordered, see (Dry, 2014).

[5]Until the late twentieth century, something of a taboo continued to surround Newton's theological and alchemical investigations, and so these papers were not published along with the scientific manuscripts. For details, see (Iliffe, 2004).

[6]Understandably, the prior existence of Whiteside's 'definitive' print edition of the mathematical papers means that some precedence has been given to work on areas of Newton's thought that have not previously been subjected to detailed editorial work.

part of its 'Foundations of Science' project (Cambridge University Library, 2011—).[7] For a growing selection of the Newton manuscripts, the reader is now able to click through from the text on the Newton Project website to CDL, where he or she can view not only the transcribed text syndicated from the Newton Project, but also an accompanying image of the original page, and in some cases, text or video commentary.[8] This integrated view forms a very rich resource, and the well-thought-out user interface makes it easy to navigate: the browser window is split into two halves, with the left side showing the page image and the right side showing one of a selection of different views.

Where documents have mathematical content, it has been fully transcribed. Diagrams are reproduced as scanned images from the manuscripts. Substantial formulae, or those requiring mathematics-specific formatting such as superscripts, fractions, or special symbols, have been transcribed using presentational MathML. However, this is not used for all formulae, especially those containing only one character, and it is clear that the MathML has been used only for the presentational purposes of displaying formulae correctly on conversion of the XML to XHTML for display in the browser. For example, take NATP00101.xml, 'De Solutione Problematum per Motum': some instances of Newton's use of the symbol $\triangle$ are transcribed with `<choice>` tags to indicate that it should be read as 'triangulus', and others are not. Meanwhile, elsewhere in the same document, the geometrical relation $FD \perp DC = LG$ (f. 68r) is transcribed with no markup to indicate that it is mathematical. Moreover, the Project's transcription policy document, though elsewhere quite comprehensive, is somewhat coy on the transcription of mathematics, simply saying that 'Transcribers dealing with mathematical texts will be given special instruction on how to apply [presentational MathML tags].' Such inconsistency of the XML markup is perfectly understandable: the resources for transcription are finite, the project editors must prioritise which features of the text to encode, and the markup was intended solely for presentational purposes for which consistency does not matter. However, it is a pity that this inconsistency limits opportunities for computational analysis and advanced searching of the texts by readers, as one cannot differentiate consistently between mathematics and natural language text.[9] Overall, although the mathematical portions of the Newton

[7] Digital images of the Yahuda collection of Newton papers held by the National Library of Israel are also accessible via the Newton Project pages. However, as these papers relate mostly to religion, history, and alchemy, I will focus here on the images provided by CDL.

[8] Among the other scientific manuscripts digitised under the auspices of the CDL project are the Board of Longitude papers, and also the correspondence of the naturalist Charles Darwin with his close friend, the botanist Joseph Dalton Hooker. The latter manuscripts were published in collaboration with the Charles Darwin Correspondence Project.

[9] For one example of a tool that has already been developed for computational analysis of Newton's alchemical manuscripts, see the Latent Semantic Analysis component of the

Project already form a valuable and powerful scholarly resource, there is potential for even more growth.

2.3. Harriot Online

The Harriot Online Project, edited by Jacqueline Stedall, Matthias Schemmel, and Robert Goulding, and hosted by the Max Planck Institute for the History of Science in Berlin, is a collaborative effort to draw together all of the c. 8000 pages of extant manuscripts of the Englishman Thomas Harriot (1560–1621) in one digital repository (Stedall et al., 2012—). Harriot's published works are few, but study of his manuscripts reveals significant achievements in fields such as algebra, ballistics, optics, and astronomy, which have attracted numerous comparisons to Galileo Galilei (Henry, 2012; Schemmel, 2008).

In his will, Harriot appointed his friends Nathaniel Torporley, Walter Warner, and Robert Hues to order his mathematical papers, and to work to understand and publish the contents. However, they were unable to do so in full: the only publication to result was a garbled edition of Harriot's treatise on equations, *Artis analyticae praxis*, published in 1631. After the completion of their task, the will dictated that Harriot's papers should have been returned to his patron, the Earl of Northumberland. Indeed it appears that at least some of them were returned c.1632: a large collection was discovered by the astronomer Baron Franz Xaver von Zach at Petworth House in Sussex in 1784, and most of these papers are now held by the British Library. There is evidence to suggest that some of the papers were held back by Warner and Thomas Aylesbury with the intent of publishing more of them; however, it is not entirely clear what happened to these papers after the deaths of Warner and Aylesbury. What is apparent, though, is that both the papers found by von Zach at Petworth and those loose papers held back were passed around between several different guardians, and in the process they fell into disarray. It is in such a state that they are still to be found today.

Though some of Harriot's papers have been edited and published in the modern era, these have only been small subsets of the total volume of the extant papers (Stedall, 2003; Schemmel, 2008; Beery and Stedall, 2009). Moreover, the constraints of print publication have forced the editors of these editions to choose between preserving the order in which they find the papers, and presenting the papers in a comprehensible order which approaches that in which their author intended them to be read. It also forces the editor to choose one version of the text, which loses the information provided by surviving rough drafts. This problem looms particularly large

project 'The chymistry of Isaac Newton' (Newman, 2005—), and discussion thereof in (Guicciardini, 2014, 408).

with the Harriot papers: folios from the same page sequence (sometimes inferred by the reader, sometimes paginated by Harriot himself) are often to be found in different volumes or even different archives altogether.[10]

The editors of the Harriot Online project set out to overcome these difficulties by publishing digital images of all of the manuscripts, along with transcriptions of their contents which is accessible via a tabbed interface, either in a styled, human-readable version or as raw TEI-compliant XML. On its own, this digital reunion of the paper manuscripts would be a useful resource. However, the editors have also provided a valuable extra layer of navigational structure to the collection: namely, a set of 'clickable maps' through which the user can move easily around the corpus in an order marked by Harriot himself or inferred by the editors by reassembling Harriot's probable writing order. The order of the underlying image files and their transcriptions is undisturbed by this reordering based on the editors' interpretations, and so it is still possible to simply see the manuscripts in the order in which they are bound in the library volumes. Moreover, new maps and alternative interpretations could easily be added at a later date if desired, based on new studies of the manuscripts. This digital reordering of physical manuscripts, and its graphical display, is a simple but important innovation that could easily be adapted for use by similar projects.

The editors have made a decision not to transcribe the many wordless pages of equations in Harriot's notes; in lieu of a transcription, they simply give a brief description of the mathematics on each page. This is partly due to the difficult and mostly non-verbal layout of Harriot's pages: equations with very few words to explain the links between them, and rarely in a purely linear form, with rough work or other notes scattered across the pages.[11] This transcription policy is adequate for most purposes at the page level: if the reader wishes to examine the mathematics further, he or she can simply consult the page image (though not side-by-side in a single browser window). However, the lack of transcriptions reduces the scope for analysis at the whole-corpus level. For example, one might wish to search across the edition for notational features, or for particular numbers used in calculations so as to trace whether Harriot worked through a particular example calculation taken from another source: neither of these is possible

[10] See 'Harriot Online/Alchemy/Earth, Water, Air, Fire' for an example where an isolated page found in the Petworth House collections is clearly related to a page sequence now located in the British Library. Another well-known example of this phenomenon, though outside the scope of this article, is to be found in the digital publication of the Archimedes Palimpsest: the single page removed by Constantin von Tischendorf in 1840s and now held by Cambridge University Library is reunited with the rest of the palimpsest in the digital edition (Archimedes Palimpsest Program, 2004—).

[11] See the text of a lecture given by Jacqueline Stedall on 22 February 2014, quoted in (Neumann, 2015, 8-10).

at present.

The key aim of the Harriot Online project—to reunite Harriot's papers in digital form—has been realised. Nevertheless, there are still some improvements that could be made to the web interface to aid navigation and discovery of the content. First, though the transcriptions are searchable, it is only possible to search within a single manuscript volume, not across the whole collection at once. Second, it would be useful if the transcription and tagging conventions used by the editors were made explicit and freely available in the form of technical documentation in order to clarify them for the reader (as has been done by the Newton Project). However, it is to be hoped that these improvements can be made in a future update: after all, one of the advantages of digital editions over print is the ability to improve and expand them as time and technology advances. In the meantime, the project should prove to be a valuable resource for future scholarship concerning Harriot and his times.

3. Conclusion

The mass production of mathematical texts has always been more difficult than more typographically simple texts that contain only prose. The printing of mathematical symbols on presses designed mainly for prose texts is problematic, and as discussed above, even in the digital age there are a number of differing formats for the encoding and display of mathematical content.

There are, of course, many other existing digital editions of mathematical texts (and not only those of the early modern period) that, due to limitations on space and time, I have not been able to discuss in this article. For example, though not historically focused, David Joyce's edition of Euclid's *Elements* is an early but highly innovative presentation of the thirteen books of Euclid, with the diagrams made into interactive applets that the reader can move around and adjust to see how they change depending on different parameters (Joyce, 1996–1998). There are also many exciting digital edition projects still in progress, whose outputs have not yet been released to the public: for example, the Groupe d'Alembert in Paris plans to release a digital critical edition of the *Encyclopédie* of Diderot and d'Alembert, and Michalis Sialaros at Birkbeck College is preparing a new critical edition of Euclid which will have a digital component.

Digital editions are not the only type of resource for the history of mathematics on the web. There is also fruitful research being done, and to be done in future, using other forms of output, such as databases and data visualisations. For example, the French Book Trade in Enlightenment Europe database, though not specifically mathematical, is a valuable and powerful resource for beginning to understand the spread of knowledge (mathematical and otherwise) in eighteenth-century Europe, and visualisations such as those developed by the Republic of Letters group at Stanford University are helping historians to understand large datasets in ways previously unthinkable (Burrows et al., 2014).

However, we must also consider the potential pitfalls of moving wholly to digital publication of scholarly editions and neglecting the consideration of the printed and handwritten documents from which they were produced. Even a digital edition including high-resolution images of original manuscripts is no substitute for the manuscripts themselves: we must consider, among other things, the loss of fine detail that may only be visible on close inspection of the original document, and material and tactile features of the original such as the fabric from which it is made, and the size and weight of the paper. To take just one example, see the discussion by Schemmel (2008, 104) of hidden construction marks in some of Thomas Harriot's papers: these are not visible in the digital edition of the manuscripts (though they could be made visible with the addition of photographs taken under raking light, such as the ones provided by Schemmel).

If used with caution, though, the rise of the digital scholarly edition undoubtedly brings great potential for new readings of texts, and for new modes of scholarship. For example, it makes it easier to compare physically separated texts side by side; it allows for quick searching of huge collections of texts; if the editor wishes, he or she can provide multiple versions of a text and allow readers to choose between them depending upon their own aims and needs. Moreover, if readers are given access to a version of the text in a portable data format such as XML, they may enhance that data or use it in a way unenvisaged by the editors. The edition thus acquires a life of its own, and its uses are limited only by the imagination of the reader.

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