

# Semantic Markup in T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X

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## Abstract

We present a collection of T<sub>E</sub>X macro packages that allow to markup T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X documents semantically without leaving the document format, essentially turning T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X into a document format for mathematical knowledge management (MKM).

The functionality of S<sub>T</sub>E<sub>X</sub> is distributed over many packages and classes, see the original [S<sub>T</sub>E<sub>X</sub> article](#) [Koh08] for an overview and motivation.

- Content Markup of Mathematical Formulae in T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X
  - **cmath**: Content Markup for Mathematical Formulae
  - **presentation**: Flexible Notations for Semantic Macros
- Mathematical Statements
  - **omtext**: Mathematical Text
  - **statements**: Semantic Markup for Mathematical Statements
  - **sproof**: Semantic Markup for Proofs
  - **problem**: *Semantic Markup for Problems and Exercises*
- Context Markup
  - **modules**: *Object-Oriented Mathematics*
  - **smultiling**: *Support for Multilingual Mathematics*
  - **structview**: *Advanced Inheritance and Interpretation in Mathematics*
- Mathematical Document Classes
  - **omdoc**: *Open Mathematical Documents*
  - **smglom**: *Semantic Multilingual Glossary of Mathematics*
  - **mikoslides**: *Slides and Lectures for S<sub>T</sub>E<sub>X</sub>*
  - **hwexam**: *Content Markup for Homeworks and Exams*
- Metadata
  - **dcm**: Dublin Core Metadata
  - **workaddress**: *FOAF-like Metadata (persons/affiliations)*
- Auxiliary Packages
  - **metakeys**: *Extended Key/Value Management*
  - **pathsuris**: *Absolute Path Handling for S<sub>T</sub>E<sub>X</sub>*
  - **sref**: *Semantic References in S<sub>T</sub>E<sub>X</sub>*
  - **tikzinput**: *Diagrams as Standalone Images*
  - **mathhub**: *Support for S<sub>T</sub>E<sub>X</sub> on MathHub.info*

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# 1 Introduction

The last few years have seen the emergence of various content-oriented XML-based, content-oriented markup languages for mathematics on the web, e.g. OpenMath [Bus+04], content MathML [Aus+03], or our own OMDoc [Koh06]. These representation languages for mathematics, that make the structure of the mathematical knowledge in a document explicit enough that machines can operate on it. Other examples of content-oriented formats for mathematics include the various logic-based languages found in automated reasoning tools (see [RV01] for an overview), program specification languages (see e.g. [Ber89]).

The promise if these content-oriented approaches is that various tasks involved in “doing mathematics” (e.g. search, navigation, cross-referencing, quality control, user-adaptive presentation, proving, simulation) can be machine-supported, and thus the working mathematician is relieved to do what humans can still do infinitely better than machines: The creative part of mathematics — inventing interesting mathematical objects, conjecturing about their properties and coming up with creative ideas for proving these conjectures. However, before these promises can be delivered upon (there is even a conference series [] studying “Mathematical Knowledge Management (MKM)”), large bodies of mathematical knowledge have to be converted into content form.

Even though MathML is viewed by most as the coming standard for representing mathematics on the web and in scientific publications, it has not not fully taken off in practice. One of the reasons for that may be that the technical communities that need high-quality methods for publishing mathematics already have an established method which yields excellent results: the  $\text{\TeX}$ / $\text{\LaTeX}$  system: and a large part of mathematical knowledge is prepared in the form of  $\text{\TeX}$ / $\text{\LaTeX}$  documents.

$\text{\TeX}$  [Knu84] is a document presentation format that combines complex page-description primitives with a powerful macro-expansion facility, which is utilized in  $\text{\LaTeX}$  (essentially a set of  $\text{\TeX}$  macro packages, see [Lam94]) to achieve more content-oriented markup that can be adapted to particular tastes via specialized document styles. It is safe to say that  $\text{\LaTeX}$  largely restricts content markup to the document structure<sup>1</sup>, and graphics, leaving the user with the presentational  $\text{\TeX}$  primitives for mathematical formulae. Therefore, even though  $\text{\LaTeX}$  goes a great step into the direction of an MKM format, it is not, as it lacks infrastructure for marking up the functional structure of formulae and mathematical statements, and their dependence on and contribution to the mathematical context.

## 1.1 The XML vs. $\text{\TeX}$ / $\text{\LaTeX}$ Formats and Workflows

MathML is an XML-based markup format for mathematical formulae, it is standardized by the World Wide Web Consortium in [Aus+03], and is supported by the major browsers. The MathML format comes in two integrated components: presentation MathML presentation MathML and content MathML content

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<sup>1</sup>supplying macros e.g. for sections, paragraphs, theorems, definitions, etc.

MathML. The former provides a comprehensive set of layout primitives for presenting the visual appearance of mathematical formulae, and the second one the functional/logical structure of the conveyed mathematical objects. For all practical concerns, presentation MathML is equivalent to the math mode of  $\text{\TeX}$ . The text mode facilities of  $\text{\TeX}$  (and the multitude of  $\text{\LaTeX}$  classes) are relegated to other XML formats, which embed MathML.

The programming language constructs of  $\text{\TeX}$  (i.e. the macro definition facilities<sup>2</sup>) are relegated to the XML programming languages that can be used to develop language extensions. transformation language XSLT [Dea99; Kay00] or proper XML-enabled The XML-based syntax and the separation of the presentational-, functional- and programming/extensibility concerns in MathML has some distinct advantages over the integrated approach in  $\text{\TeX}/\text{\LaTeX}$  on the services side: MathML gives us better

- integration with web-based publishing,
- accessibility to disabled persons, e.g. (well-written) MathML contains enough structural information to supports screen readers.
- reusability, searchability and integration with mathematical software systems (e.g. copy-and-paste to computer algebra systems), and
- validation and plausibility checking.

On the other hand,  $\text{\TeX}/\text{\LaTeX}$ 's adaptable syntax and tightly integrated programming features within has distinct advantages on the authoring side:

- The  $\text{\TeX}/\text{\LaTeX}$  syntax is much more compact than MathML, and if needed, the community develops  $\text{\LaTeX}$  packages that supply new functionality in with a succinct and intuitive syntax.
- The user can define ad-hoc abbreviations and bind them to new control sequences to structure the source code.
- The  $\text{\TeX}/\text{\LaTeX}$  community has a vast collection of language extensions and best practice examples for every conceivable publication purpose and an established and very active developer community that supports these.
- There is a host of software systems centered around the  $\text{\TeX}/\text{\LaTeX}$  language that make authoring content easier: many editors have special modes for  $\text{\LaTeX}$ , there are spelling/style/grammar checkers, transformers to other markup formats, etc.

In other words, the technical community is heavily invested in the whole workflow, and technical know-how about the format permeates the community. Since all of this would need to be re-established for a MathML-based workflow, the technical community is slow to take up MathML over  $\text{\TeX}/\text{\LaTeX}$ , even in light of the advantages detailed above.

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<sup>2</sup>We count the parser manipulation facilities of  $\text{\TeX}$ , e.g. category code changes into the programming facilities as well, these are of course impossible for MathML, since it is bound to XML syntax.

## 1.2 A $\text{\LaTeX}$ -based Workflow for XML-based Mathematical Documents

An elegant way of sidestepping most of the problems inherent in transitioning from a  $\text{\LaTeX}$ -based to an XML-based workflow is to combine both and take advantage of the respective advantages.

The key ingredient in this approach is a system that can transform  $\text{\TeX}/\text{\LaTeX}$  documents to their corresponding XML-based counterparts. That way, XML-documents can be authored and prototyped in the  $\text{\LaTeX}$  workflow, and transformed to XML for publication and added-value services, combining the two workflows.

There are various attempts to solve the  $\text{\TeX}/\text{\LaTeX}$  to XML transformation problem (see [Sta+09] for an overview); the most mature is probably Bruce Miller’s  $\text{\LaTeX}$ XML system [LTX]. It consists of two parts: a re-implementation of the  $\text{\TeX}$  analyzer with all of its intricacies, and a extensible XML emitter (the component that assembles the output of the parser). Since the  $\text{\LaTeX}$  style files are (ultimately) programmed in  $\text{\TeX}$ , the  $\text{\TeX}$  analyzer can handle all  $\text{\TeX}$  extensions, including all of  $\text{\LaTeX}$ . Thus the  $\text{\LaTeX}$ XML parser can handle all of  $\text{\TeX}/\text{\LaTeX}$ , if the emitter is extensible, which is guaranteed by the  $\text{\LaTeX}$ XML binding language: To transform a  $\text{\TeX}/\text{\LaTeX}$  document to a given XML format, all  $\text{\TeX}$  extensions<sup>3</sup> must have “ $\text{\LaTeX}$ XML bindings” binding, i.e. a directive to the  $\text{\LaTeX}$ XML emitter that specifies the target representation in XML.

## 1.3 Generating OMDoc from $\text{\sTeX}$

The  $\text{\sTeX}$  packages (see Section 2) provide functionalities for marking up the functional structure of mathematical documents, so that the  $\text{\LaTeX}$  sources contain enough information that can be exported to the OMDoc format (Open Mathematical Documents; see [Koh06]). For the actual transformation, we use a  $\text{\LaTeX}$ XML plugin [L2O] that provides the  $\text{\LaTeX}$ XML bindings for the  $\text{\sTeX}$  packages.

## 1.4 Conclusion

The  $\text{\sTeX}$  collection provides a set of semantic macros that extends the familiar and time-tried  $\text{\LaTeX}$  workflow in academics until the last step of Internet publication of the material. For instance, an SMGloM module can be authored and maintained in  $\text{\LaTeX}$  using a simple text editor, a process most academics in technical subjects are well familiar with. Only in a last publishing step (which is fully automatic) does it get transformed into the XML world, which is unfamiliar to most academics.

Thus,  $\text{\sTeX}$  can serve as a conceptual interface between the document author and MKM systems: Technically, the semantically preloaded  $\text{\LaTeX}$  documents are transformed into the (usually XML-based) MKM representation formats, but conceptually, the ability to semantically annotate the source document is sufficient.

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<sup>3</sup>i.e. all macros, environments, and syntax extensions used in the source document

The  $\text{sTeX}$  macro packages have been validated together with a case study [Koh04], where we semantically preload the course materials for a two-semester course in Computer Science at Jacobs University Bremen and transform them to the OMDoc MKM format.

## 1.5 Licensing, Download and Setup

The  $\text{sTeX}$  packages are licensed under the  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$  Project Public License [Pro07], which basically means that they can be downloaded, used, copied, and even modified by anyone under a set of simple conditions (e.g. if you modify you have to distribute under a different name).

### 1.5.1 The $\text{sTeX}$ Distribution

The  $\text{sTeX}$  packages and classes are available from the Comprehensive  $\text{T}_{\text{E}}\text{X}$  Archive Network (CTAN [CTAN]) and are part of the primary  $\text{T}_{\text{E}}\text{X}/\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$  distributions (e.g.  $\text{TeXlive}$  [TL] and  $\text{MikTeX}$  [MiK]). The development version is on GitHub [sTeX], it can be cloned or forked from the repository URL

<https://github.com/sLaTeX/sTeX.git>

**Warning:** the  $\text{sTeX}$  is under continuous development and CTAN updates are as infrequent as they are tedious, so the GIT version is almost always preferable.

### 1.5.2 The $\text{sTeX}$ Plugin for $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{XML}$

For the OMDoc transformation of  $\text{sTeX}$  documents we use a  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{XML}$  plugin that provides the  $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{XML}$  bindings for the  $\text{sTeX}$  packages. For installation and setup follow the instructions at [L2O]

## 2 The Packages of the sTeX Collection

In the following, we will shortly preview the packages and classes in the sTeX collection. They all provide part of the solution of representing semantic structure in the T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X workflow. We will group them by the conceptual level they address. Figure 1 gives an overview.

### 2.1 The sTeX Distribution

The stex package provides stex.sty that just loads all packages below and passes around the package options accordingly and stex-logo.sty that provides the macros \sTeX and \stex that typeset the sTeX logo.

\sTeX  
\stex

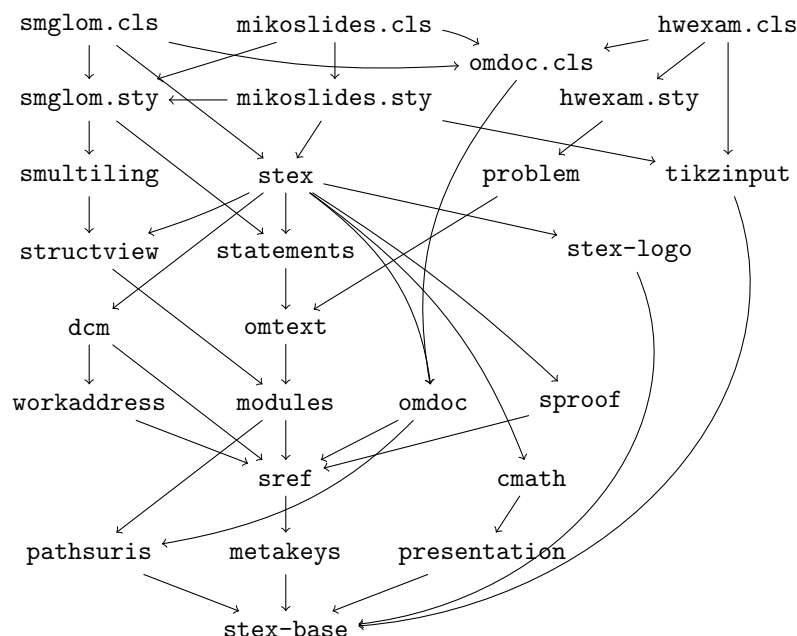


Figure 1: The sTeX packages and their dependencies.

## 2.2 Content Markup of Mathematical Formulae in T<sub>E</sub>X/L<sup>A</sup>T<sub>E</sub>X

### 2.2.1 cmath: Building Content Math Representations

The cmath package (see [Koh20a]) supplies an interface for building content math representations. It gives special macros for marking up variables, applications and bindings. It supports the transformation into both OpenMath [Bus+04] and content MathML [Aus+03].

### 2.2.2 presentation: Flexible Notations for Semantic Macros

The `presentation` package (see [KG20a]) supplies an infrastructure that allows to specify the presentation of semantic macros, including preference-based bracket elision. This allows to markup the functional structure of mathematical formulae without having to lose high-quality human-oriented presentation in  $\text{\LaTeX}$ . Moreover, the notation definitions can be used by MKM systems for added-value services, either directly from the  $\text{\LaTeX}$  sources, or after translation.

## 2.3 Mathematical Statements

### 2.3.1 omtext: Mathematical Text

The `omtext` package (see [Koh20f]) supplies an infrastructure for writing mathematical text fragments in  $\text{\LaTeX}$ . The basic `omtext` environment can be given various metadata that are relevant for content-oriented mathematics. `omtext` is specialized to various specially layouted text forms like quotes and such. Furthermore, the `omtext` package provides content-oriented index markup.

### 2.3.2 statements: Definition, Theorem, Example and the like

The `statements` package (see [Koh20j]) provides semantic markup facilities for mathematical statements like Theorems, Lemmata, Axioms, Definitions, etc. in  $\text{\LaTeX}$  files. This structure can be used by MKM systems for added-value services, either directly from the  $\text{\LaTeX}$  sources, or after translation.

### 2.3.3 sproof: sTeX Proofs

The `sproof` package (see [Koh20h]) supplies macros and environment that allow to annotate the structure of mathematical proofs in  $\text{\LaTeX}$  files. This structure can be used by MKM systems for added-value services, either directly from the  $\text{\LaTeX}$  sources, or after translation.

### 2.3.4 problem: Problems and Exercises

The `problem` package (see [Koh20g]) supplies macros and environment that allow to annotate the structure of mathematical and exercises in  $\text{\LaTeX}$  files. These structures can be used for homework assignments and exams; see section 2.5.2.

## 2.4 Context Markup for Mathematics

### 2.4.1 modules: Extending Content Macros for Mathematical Notation

The `modules` package (see [KGA20a]) supplies a definition mechanism for semantic macros and a non-standard scoping construct for them, which is oriented at the semantic dependency relation rather than the document structure. This structure can be used by MKM systems for added-value services, either directly from the



TeX sources, or after translation. A side effect of this is that we have an “object-oriented” inheritance mechanism for semantic macros: the semantic macros for the mathematical objects described in a module come with the module itself.

### 2.4.2 `smultiling`: Multilingual Mathematical Modules

In multilingual settings, i.e. where we have multiple TeX documents that are translations of each other, it is better to separate the module signature from the descriptive document. The `smultiling` package (see [KG20b]) provides the necessary infrastructure.

### 2.4.3 `structview`: Structures and Views

OMDoc/MMT structures add advanced inheritance and interpretation methods for mathematical knowledge management – see [RK13] for a motivation and the grisly details. The `structview` package (see [Koh20k]) provides the necessary infrastructure.

## 2.5 Mathematical Document Classes

The TeX distribution provides four top-level document classes for various types of mathematical documents. In all cases, the functionality of the  $\langle class \rangle$ .cls is mainly provided by  $\langle class \rangle$ .sty, allowing the L<sup>A</sup>T<sub>E</sub>Xdocument class  $\langle class \rangle$ .cls to be minimal, only setting up the required packages and calling corresponding package  $\langle class \rangle$ .sty.

### 2.5.1 `OMDoc Documents`

The `omdoc` class and package (see [Koh20e]) provides an infrastructure that allows to markup up generic mathematical documents with OMDoc structures. It provides the `omgroup` environment for reusable document fragments.

### 2.5.2 `hwexam`: Homeworks and Exams

The `hwexam` package [Koh20c] infrastructure for marking up homework assignments, and exams. The content markup strategy employed in TeX allows to specify – and profit from – administrative metadata such as time and point counts. This package relies on the `problem` package [Koh20g] which provides markup for problems, hints, and solutions.

### 2.5.3 `smglom`: Mathematical Glossary

The `smglom` package provides a document class for the Semantic Multilingual Glossary of Mathematics. This bakes in special file/module conventions that allow the concise and convenient markup of multilingual glossary modules.

#### 2.5.4 mikoslides: Slides and Course Notes

The `mikoslides` package provides a document class from which we can generate both course slides – via the `beamer` class – and course notes – via the `omdoc` class – in a transparent way.

## 2.6 Metadata

The metadata packages allow embedding linked-data-style annotations into texts. They are tied to well-known ontologies.

#### 2.6.1 dcm: Dublin Core Metadata

The `dcm` package (see [Koh20b]) provides keys and macros for annotating Dublin Core Metadata [DC].

#### 2.6.2 workaddress: Markup for FOAF Metadata

The `workaddress` package (see [Koh20m]) provides keys and macros for annotating metadata from a part of the FOAF (Friend-of-a-Friend; persons, their relations, and affiliations) ontology [FOAF14].

## 2.7 Support for MathHub

The `mathhub` package provides the supplementary packages `mikoslides-mh`, `modules-mh.sty`, `omtext-mh.sty`, `problem-mh.sty`, `smultiling-mh.sty`, `structview-mh.sty`, and `tikzinput-mh.sty` with variants of the user-visible macros that are adapted to the MathHub system – see Section 3.3 for details.

## 2.8 Auxiliary Packages

#### 2.8.1 metakeys: An extended key/value Interface for $\TeX$

`metakeys` is a purely syntactic utility package, see [Koh20d], it should eventually, probably be replaced by something more standard and maintained.

#### 2.8.2 pathsuris: Managing Relative/Absolute File Paths

Experience shows that distributing  $\TeX$  content into small  $\LaTeX$  files makes content much more reusable. The price we pay is that we have to manage many file names from which a document is composed. Practical experience shows that system-internally, we want to use absolute file URIs (as canonical file names) to get around redundant file loading which would lead to exponential blowups. The `pathsURIs` package (see [KGA20b]) provides the necessary infrastructure.

### 2.8.3 `sref`: Semantic References

`STEX` uses its own (semantic) infrastructure for internal (and cross-document!) references: the `sref` package (see [Koh20i]). It should eventually, probably be replaced by – or at least based on – something more standard and maintained.

### 2.8.4 `tikzinput`: External TIKZ Pictures as Standalone Images

`tikz` is a diagram package for  $\text{\LaTeX}$ , which can be used for mixed (i.e. with `STEX` islands) diagrams in mathematical documents. However  $\text{\LaTeX}$ ML treatment of `tikz` is still experimental, so we use the `tikzinput` package (see [Koh20i]) to externalize the `tikz` material into standalone files, which can be easily re-used and converted to e.g. SVG independently and then input as regular images.

## 3 Workflows and Best Practices

### 3.1 The “Little Modules” Approach

One of the key advantages of semantic markup with  $\text{\LaTeX}$  is that the  $\text{\LaTeX}$  sources are highly reusable by the “object-oriented” inheritance model induced by  $\text{\LaTeX}$  modules. It turned out to be useful to divide  $\text{\LaTeX}$  documents into three kinds of files:

1. **module files**: files that essentially contain a collection of  $\text{\LaTeX}$  modules [KGA20a] – usually a single one whose module name coincides the file name base.
2. **fragment files**: files that contain a group of input references to module- or fragment files – usually one group deep for flexibility, transition text, and additional remarks.
3. **driver files** that set up the document class, contain the preambles, and input reference fragment files.

These correspond to the  $\text{\LaTeX}$  documents, but can reuse and share  $\text{\LaTeX}$  fragments and modules. Figure 2 shows a situation, where we have two courses given over multiple years, which results in five course notes documents given by driver files, which share quite a few components. As drivers and fragment files are mostly content-free – they only contribute document structure, this lets all documents contribute from the development of the modules.

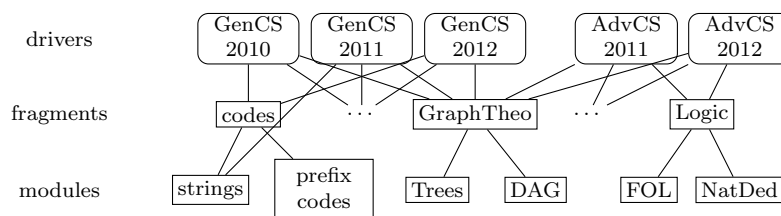


Figure 2: Reuse of Fragments and Modules in a Course Notes Setting

Another advantage of the “little modules approach” is that modules can be developed separately. Indeed all modules of a given subject share common pre- and post-ambles which can be developed in special files – usually named `pre.tex`, `post.tex`, and `preamble.tex` (the latter is included in `pre.tex`). Given such a setup, the call to `pdflatex` can be suitably adapted to handle the pre/postfixes.

### 3.2 Basic Utilities & Makefiles

The  $\text{\LaTeX}$  distribution contains three basic command line utilities to manage  $\text{\LaTeX}$  documents in the `bin` directory of the distribution.

`filedate` and `checksum` that help keeping the metadata of the self-documenting  $\LaTeX$  packages in the  $\TeX$  distribution up to date.

`installFonts.sh` that installs the fonts necessary for Chinese  $\TeX$  documents.

These are supplemented by a set of UNIX `Makefiles` in the `lib/make` directory. The way to use them is to include them into a `Makefile` in the directory and then run one of the targets `pdf` and `mpdf` to make the PDF versions of the drivers and modules and `omdoc` and `mods` to generate OMDoc.

### 3.3 MathHub: a Portal for Active Mathematical Documents

MathHub (<http://mathhub.info> see [Ian+14]) is a portal for Active Mathematical Documents – documents that are made context-aware and interactive by semantic annotations.  $\TeX$  is one of the main input formats for informal active documents. MathHub supports  $\TeX$  documents in three ways:

1. MathHub offers free/open hosting in document repositories for (mathematical)  $\TeX$  document collections.
2. the backend system supports the large-scale change- and error-management for  $\TeX$  documents in the “little modules” paradigm.
3. the front-end displays interactive (HTML5) documents generated from the  $\TeX$  sources (via OMDoc).

The MathHub system is probably the best way of developing and hosting larger  $\TeX$  document collections. It offers two authoring workflows an online authoring workflow via a direct web interface [MH] or casual users and an offline authoring workflow that we describe next.

## 4 The Implementation

### 4.1 Package Options

The first step is to declare (a few) package options that handle whether certain information is printed or not. They all come with their own conditionals that are set by the options.

```
1 <*package>
2 \DeclareOption*{\PassOptionsToPackage{\CurrentOption}{statements}}
3 \PassOptionsToPackage{\CurrentOption}{structview}
4 \PassOptionsToPackage{\CurrentOption}{sproofs}
5 \PassOptionsToPackage{\CurrentOption}{omdoc}
6 \PassOptionsToPackage{\CurrentOption}{cmath}
7 \PassOptionsToPackage{\CurrentOption}{dcm}}
8 \ProcessOptions
```

Then we make sure that the necessary packages are loaded (in the right versions).

```
9 \RequirePackage{stex-logo}
10 \RequirePackage{omdoc}
11 \RequirePackage{statements}
12 \RequirePackage{structview}
13 \RequirePackage{sproof}
14 \RequirePackage{cmath}
15 \RequirePackage{dcm}
16 </package>
```

### 4.2 The sTeX Logo

```
17 <*logo>
18 \RequirePackage{stex-base}
19 \RequirePackage{xspace}
20 \protected\def\stex{%
21 \ifundefined{texorpdfstring}%
22 {\let\texorpdfstring\@firstoftwo}%
23 {}%
24 \texorpdfstring{\raisebox{-.5ex}{S\kern-.5ex\TeX}{sTeX}\xspace%
25 }
26 \def\sTeX{\stex}
27 </logo>
```

### 4.3 The sTeX Basics

Basic setup stuff

We define a conditional `\if@latexml` to determine whether we are running L<sup>A</sup>T<sub>E</sub>X<sub>ML</sub> or pdf<sub>La</sub>TeX. We set it to `false` here, and in the L<sup>A</sup>T<sub>E</sub>X<sub>ML</sub> binding we set it to `true`.

```
28 <*base>
29 \newif\if@latexml\@latexmlfalse
30 </base>
```

## Index

Numbers written in *italic* refer to the page where the corresponding entry is described; numbers underlined refer to the code line of the definition; numbers in *roman* refer to the code lines where the entry is used.

*\**, 4, 5 LaTeXML, 5

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