

ST_EXIDE: An Integrated Development Environment for ST_EX Collections

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Abstract. Authoring documents in MKM formats like OMDoc is a very tedious task. After years of working on a semantically annotated corpus of ST_EX documents (GenCS), we identified a set of common, time-consuming subtasks, which can be supported in an integrated authoring environment.

We have adapted the modular Eclipse IDE into ST_EXIDE, an authoring solution for enhancing productivity in contributing to ST_EX based corpora. ST_EXIDE supports context-aware command completion, module management, semantic macro retrieval, and theory graph navigation.

1 Introduction

Before we can manage mathematical ‘knowledge’ — i.e. reuse and restructure it, adapt its presentation to new situations, semi-automatically prove conjectures, search it for theorems applicable to a given problem, or conjecture representation theorems, we have to convert informal knowledge into machine-oriented representations. How to exactly support this formalization process so that it becomes as effortless as possible is one of the main unsolved problems of MKM. Currently most mathematical knowledge is available in the form of L^AT_EX-encoded documents. To tap this reservoir we have developed the ST_EX [Koh08,sTe09] format, a variant of L^AT_EX that is geared towards marking up the semantic structure underlying a mathematical document.

In the last years, we have used ST_EX in two larger case studies. In the first one, the second author has accumulated a large corpus of teaching materials, comprising more than 2,000 slides, about 800 homework problems, and hundreds of pages of course notes, all written in ST_EX. The material covers a general first-year introduction to computer science, graduate lectures on logics, and research talks on mathematical knowledge management. The second case study consists of a corpus of semi-formal documents developed in the course of a verification and SIL3-certification of a software module for safety zone computations [KKL10a,KKL10b]. In both cases we took advantage of the fact that ST_EX documents can be transformed into the XML-based OMDoc [Koh06] by the L^AT_EXML system [Mil10], see [KKL10a] and [DKL⁺10] for a discussion on the MKM services afforded by this.

These case studies have confirmed that writing $\mathcal{S}\text{T}_{\text{E}}\text{X}$ is *much* less tedious than writing OMDoc directly. In particular, the possibility of using the $\mathcal{S}\text{T}_{\text{E}}\text{X}$ -generated PDF for proofreading the text part of documents. Nevertheless serious usability problems remain. They come from three sources:

P1 installation of the (relatively heavyweight) transformation system (with dependencies on `perl`, `libXML2`, $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$, the $\mathcal{S}\text{T}_{\text{E}}\text{X}$ packages),

P2 the fact that $\mathcal{S}\text{T}_{\text{E}}\text{X}$ supports an object-oriented style of writing mathematics, and

P3 the size of the collections which make it difficult to find reusable components. The documents in the first (educational) corpus were mainly authored directly in $\mathcal{S}\text{T}_{\text{E}}\text{X}$ via a text editor (`emacs` with a simple $\mathcal{S}\text{T}_{\text{E}}\text{X}$ mode [Pes07]). This was serviceable for the author, who had a good recollection names of semantic macros he had declared, but presented a very steep learning curve for other authors (e.g. teaching assistance) to join. The software engineering case study was a post-mortem formalization of existing (informal) $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ documents. Here, installation problems and refactoring existing $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ markup into more semantic $\mathcal{S}\text{T}_{\text{E}}\text{X}$ markup presented the main problems.

Similar authoring and source management problems are tackled by Integrated Development Environments (IDEs) like ECLIPSE [Ecl08], which integrate support for finding reusable functions, refactoring, documentation, build management, and version control into a convenient editing environment. In many ways, $\mathcal{S}\text{T}_{\text{E}}\text{X}$ shares more properties with programming languages like JAVA than with conventional document formats, in particular, with respect to the three problem sources mentioned above

S1 both require a build step (compiling JAVA and formatting/transforming $\mathcal{S}\text{T}_{\text{E}}\text{X}$ into PDF/OMDoc),

S2 both favor an object-oriented organization of materials, which allows to

S3 build up large collections of re-usable components

To take advantage of the solutions found for these problems by software engineering, we have developed the $\mathcal{S}\text{T}_{\text{E}}\text{XIDE}$ integrated authoring environment for $\mathcal{S}\text{T}_{\text{E}}\text{X}$ -based representations of mathematical knowledge. In the next section we recap the parts of $\mathcal{S}\text{T}_{\text{E}}\text{X}$ needed to understand the system. In Section 3 we present the user interface of the $\mathcal{S}\text{T}_{\text{E}}\text{XIDE}$ system, and in Section 4 we discuss implementation issues. Section 5 concludes the paper and discusses future work.

2 $\mathcal{S}\text{T}_{\text{E}}\text{X}$: Object-Oriented $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X}$ Markup

The main concept in $\mathcal{S}\text{T}_{\text{E}}\text{X}$ is that of a “*semantic macro*”, i.e. a $\text{T}_{\text{E}}\text{X}$ command sequence \mathcal{S} that represents a meaningful (mathematical) concept or object \mathcal{O} : the $\text{T}_{\text{E}}\text{X}$ formatter will expand \mathcal{S} to the presentation of \mathcal{O} . For instance, the command sequence `\positiveReals` is a semantic macro that represents a mathematical symbol — the set \mathbb{R}^+ of positive real numbers. While the use of semantic macros is generally considered a good markup practice for scientific documents¹,

¹e.g., because they allow to adapt notation by macro redefinition and thus increase reusability.

regular $\text{\TeX}/\text{\LaTeX}$ does not offer any infrastructural support for this. \S\TeX does just this by adopting a semantic, “object-oriented” approach to semantic macros by grouping them into “modules”, which are linked by an “imports” relation. To get a better intuition, consider the example in listing 1.1.

Listing 1.1. An \S\TeX module for Real Numbers

```

\begin{module}[id=reals]
  \importmodule{../background/sets}{sets}
  \symdef{Reals}{\mathcal{R}}
  \symdef{greater}[2]{\#1>\#2}
5  \symdef{positiveReals}{\Reals^+}
  \begin{definition}[id=posreals.def,title=Positive Real Numbers]
    The set  $\text{\positiveReals}$  is the set of  $\text{\inset{x}\Reals}$  such that  $\text{\greater{x}0}$ 
  \end{definition}
  ...
10 \end{module}

```

which would be formatted to

Definition 2.1 (Positive Real Numbers):

The set \mathbb{R}^+ is the set of $x \in \mathbb{R}$ such that $x > 0$

Note that the markup in the module `reals` has access to semantic macro `\inset` (element-hood) from the module `sets` that was imported by the document `\importmodule` directive from the `../background/sets.tex`. Furthermore, it has access to the `\defeq` (definitional equality) that was in turn imported by the module `sets`.

From this example we can already see an organizational advantage of \S\TeX over \LaTeX : we can define the (semantic) macros close to where the corresponding concepts are defined, and we can (recursively) import mathematical modules. But the main advantage of markup in \S\TeX is that it can be transformed to XML via the $\text{\LaTeX}\text{XML}$ system [Mil10]: Listing 1.2 shows the OMDoc [Koh06]. representation generated from the \S\TeX sources in listing 1.1.

Listing 1.2. An XML Version of Listing 1.1

```

<theory xml:id="reals">
  <imports from="../background/sets.omdoc#sets"/>
  <symbol xml:id="Reals"/>
  <notation>
5  <prototype><OMS cd="reals" name="Reals"/></prototype>
    <rendering><m:mo>\mathbb{R}</m:mo></rendering>
  </notation>
  <symbol xml:id="greater"/><notation>...</notation>
  <symbol xml:id="positiveReals"/><notation>...</notation>
10 <definition xml:id="posreals.def" for="positiveReals">
    <meta property="dc:title">Positive Real Numbers</meta>
    The set <OMOBJ><OMS cd="reals" name="positiveReals"/></OMOBJ> is the set ...
  </definition>
  ...
15 </theory>

```

One thing that jumps out from the XML in this listing is that it incorporates all the information from the \S\TeX markup that was invisible in the PDF produced by formatting it with \TeX .

3 User interface features of \S\TeXIDE

One of the main priorities we set for \S\TeXIDE is to have a relatively gentle learning curve. As the first experience of using a program is running the installation process, we worked hard into making this step as automated and platform independent as possible. We aim at supporting popular operating systems such as Windows and Unix based platforms (Ubuntu, SuSE). Creating a OS independent distribution of Eclipse with our plugin preinstalled was a relatively straightforward task; so was distributing the plugin through an update site. What was challenging was getting the 3rd party software (`pdflatex`, `svn`, `latexml`, `perl`) and hence OS specific ports installed correctly.

After installation we provide a new project wizard for \S\TeX projects which lets the user choose the output format (`.dvi`, `.pdf`, `.ps`, `.omdoc`, `.xhtml`) as well as one of the predefined sequences of programs to be executed for build process. This will control the ECLIPSE-like workflow, where the chosen ‘outputs’ are rebuilt after every save, and syntactic (as well as semantic) error messages are parsed, cross-referenced, and displayed to the user in a collapsible window. The wizard then creates a stub project, i.e. a file `main.tex` which has the structure of a typical \S\TeX file but also includes `stex` package and imports a sample module defined in `sample_mod.tex`.

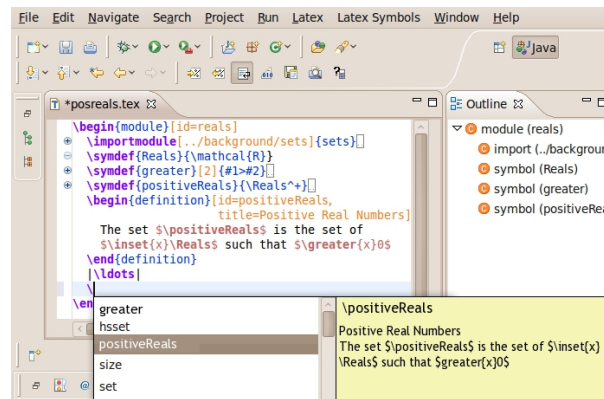


Fig. 1. Context aware autocompletion feature for semantic macros

\S\TeXIDE supports the user in creating, editing and maintaining \S\TeX documents or corpora. For novice users we provide templates for creating modules, imports and definitions. Later on, user benefits from *context-aware autocompletion*, which assists the user in writing valid \LaTeX and \S\TeX macros. Here, by valid macros, we mean macros which were previously defined or imported (both directly or indirectly) from other modules. Consider sample \S\TeX source in listing 1.1. At the end of first line, one would only be able to autocomplete \LaTeX macros, whereas at the end of second line one would already have macros like `\inset` from the imported `sets` module (see figure 1). Note that we also make use of the semantic structure of the \S\TeX document in listing 1.1 for explanations: the macro `\positiveReals` is linked to the definition via the key

`for=positiveReals`, so we can display the text of the definition as an explanation in the yellow box.

Similarly, *semantic macro retrieval* (triggered by typing `*`) will suggest all available macros from all modules of current project. In case auto-completed macro is not valid for current context, \TeX IE will insert the required import statement so that macro becomes valid.

Moreover, \TeX IE supports several typical document/collection maintenance tasks: Supporting *symbol and module names refactoring* is very important as it is extremely error-prone, especially if two different modules define a symbol with the same name and only one of them is to be renamed. The *module splitting* feature makes it easier for users to create smaller but semantically self contained modules which one can easier reuse. This feature takes care that needed imports are copied in the newly created module.

At last, *import minimization* creates warnings for unused or redundant `\importmodule` declarations and suggests to remove them. Consider for instance the situation on the right, where a modules C and B imports module A. Now, if we add a semantic macro in C that needs an import from B, then we should replace the import of A in C with one of B instead of just adding the latter (i.e. we would replace the dashed by the dotted import).

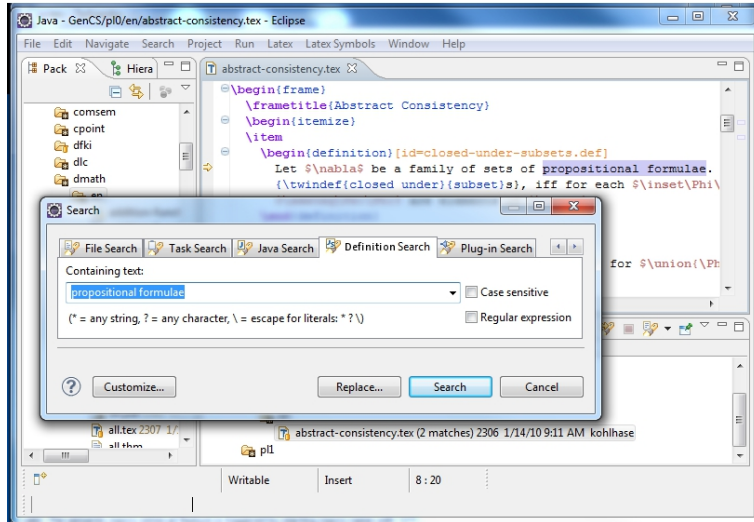
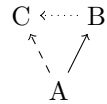


Fig. 2. Macro Retrieval via Mathematical Concepts

Three additional features make navigation and information retrieval in big corpora easier. Outline view of the document (right side of figure 1) displays main semantic document structures. One can use this layout to copy, cut and navigate to areas represented by respective structures. In case of imports one can navigate to imported modules. Theory graph navigation is another feature which creates a

graphical representation of how modules are related through imports. This gives user a chance to get a better intuition how concepts and modules are related. And the last feature is the semantic definition search feature. The aim of this feature is to search for semantic macros by their mathematical descriptions, which can be entered into search box in figure 2. This then searches definitions, assumptions, and theorems for the query terms and reports any `\symdef`-defined semantic macros ‘near’ the hits. This has turned out very convenient in situations, where the macro names are abbreviated (e.g. `\sconcjuxt` for “string concatenation by juxtaposition”) or if there are more than one name for a mathematical context (e.g. “concatenation” for `\sconcjuxt`.) and the author wants to re-use semantic macros defined by someone else.

4 Implementation

The implementation of `sTeXIDE` is based on the `TeXLIPSE` [TeX08] plugin for Eclipse. This plugin makes use of `ECLIPSE`’s modular framework (see figure 3) and provides features like syntax highlighting, code folding, outline generation, autocompletion and templating mechanisms. Unfortunately, the recognizer for a fixed set of `LATEX` macros like `\section`, `\input`, etc. is hardwired which made it quite challenging to generalize it to `sTeX` specific macros. Therefore we had to reimplement parts of `TeXLIPSE` so that `sTeX` macros like `\symdef` and `\importmodule` that extend the set of available macros can be treated specially. We have underlined all the parts of `TeXLIPSE` we had to extend or replace in Figure 3.

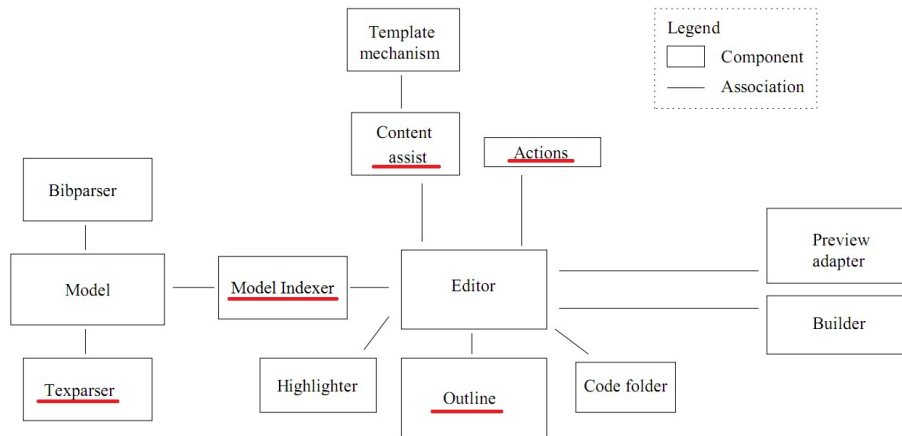


Fig. 3. Component architecture of `TeXLIPSE` (adapted from [?])

To support context sensitive autocompletion and refactoring we need to know the exact position in the source code where modules and symbols are defined. Running a full featured `LATEX` parser like `LATEXML` proved to be too slow (sometimes taking 5-10 sec) and sensitive to errors. For these reasons, we implemented

a very fast but naïve L^AT_EX parser which analyses the source code and identifies commands, their arguments and options. We call this parser naïve because it parses only one file a time (i.e. inclusions, and styles are not processed) and macros are not expanded. We realize the parse tree as an in-memory XML DOM to achieve format independence (see below). Then we run a set of semantic spotters which identify constructs like module and import declarations, inclusions as well as sections/subsections etc, resulting in an index of relevant structural parts of the S_TE_X source identified by unique URIs and line/column number ranges in the source. For example, a module definition in S_TE_X begins with `\begin{module}[id=module_id]` and ends in a `\end{module}`, so the structure identifying a module will contain these two ranges.

Note that the L^AT_EX document model (and thus that of S_TE_X) is a tree, so two spotted structure domains are either disjoint or one contains the other, so we implement a range tree we use for efficient change management: S_TE_XI_{DE} implements a class which listens to changes made in documents, checks if they intersect with the important ranges of the spotted structures or if they introduce new commands (i.e. start with `\`). If this not, the range tree is merely updated by calculating new line and column numbers. Otherwise we run the naïve L^AT_EX parser and the spotters again.

Our parser is entirely generated by a JavaCC grammar, supports error recovery (essential for autocompletion) and does not need to be changed if a new macro needs to be handled: Semantic Spotters can be implemented as XQueries, and our parser architecture provides an API for adding custom semantic spotters. This makes the parser extensible to new S_TE_X features and allows to work around the limitation of the naïve L^AT_EX parser of not expanding macros.

We implemented several indexes to support features mentioned in section 3. For theory navigation we have an index called **TheoryIndex** which manages a directed graph of modules and import relationships among them. It allows *a*) retrieving list of modules which import/are imported by module *X* *b*) checking if module *X* is directly/indirectly imported by module *Y*. **SymdefIndex** is another index which stores pairs of module URIs and symbols defined in those modules. It supports fast retrieving of (symbol,module) pairs where symbol name starts with a certain prefix using a trie data structure. As expected this index is used for both context aware autocompletion as well as semantic macro retrieval features. The difference is that context aware autocompletion feature also filters the modules not accessible from current module by using the **TheoryIndex**. Refactoring makes use of an index called **RefIndex**. This index stores (module URI, definition module URI, symbol name) triples for all symbol occurrences (not just definitions as in **SymdefIndex**).

5 Conclusion and Future Work

We have presented the S_TE_XI_{DE} system, an integrated authoring environment for S_TE_X collections realized as a plugin to the ECLIPSE IDE. Even though the implementation is still in a relatively early state, this experiment confirmed the

initial expectation that the installation, navigation, and build support features contributed by ECLIPSE can be adapted to a useful authoring environment for \LaTeX with relatively little effort. The modularity framework of ECLIPSE and the TEXLIPSE plugin for \LaTeX editing have been beneficial for our development. However, we were rather surprised to see that a large part of the support infrastructure we would have expected to be realized at the framework were indeed hard-coded into the plugins. This has resulted in un-necessary re-implementation work.

In particular, system- and collection-level features of \LaTeXIDE like automated installation, PDF/XML build support, and context-sensitive completion of command sequences, import minimization, navigation, and concept-based search have proven useful, and are not offered by document-oriented editing solutions. Indeed such features are very important for editing and maintaining any MKM representations. Therefore we plan to extend \LaTeXIDE to a general “MKM IDE”, which supports more MKM formats and their human-oriented front-end syntaxes (just like \LaTeX serves a front-end to OMDoc in \LaTeXIDE).

The modular structure of ECLIPSE also allows us to integrate MKM services (e.g. information retrieval from the background collection or integration of external proof engines for formal parts [ALWF06]; see [KRZ10] for others) into this envisioned “MKM IDE”, so that it becomes a “rich collection client” to a *universal digital mathematics library (UDML)*, which *would continuously grow and in time would contain essentially all mathematical knowledge* envisioned as the Grand Challenge for MKM in [Far05].

In the implementation effort we tried to abstract from the \LaTeX surface syntax, so that we anticipate that we will be able to directly re-use our spotters or adapt them for other surface formats that share the OMDoc data model. The next target in this direction is the modular LF format introduced in [RS09]. This can be converted to OMDoc by the TWELF system, which makes its treatment directly analogous to \LaTeX , this would provide a way of information sharing among different authoring systems and workflows.

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