MMTTeX: Connecting Content and Narration-Oriented Document Formats

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Abstract. Narrative, presentation-oriented assistant systems for mathematics on the one hand and formal, content-oriented ones on the other hand have so far been developed and used largely independently. The former excel at communicating mathematical knowledge and the latter at certifying its correctness.
MMTTeX aims at combining the advantages of the two paradigms. Concretely, we use LaTeX for the narrative and Mmt for the content-oriented representation. Formal objects may be written in MMT and imported into LaTeX documents or written in the LaTeX document directly. In the latter case, Mmt parses and checks the formal content during LaTeX compilation and substitutes it with LaTeX presentation macros.
Besides checking the formal objects, this allows generating higher-quality LaTeX than could easily be produced by hand, e.g., by inserting hyperlinks and tooltips into formulas. Moreover, it allows reusing formalizations across narrative documents as well as between formal and narrative ones. As a case study, the present document was already written with MMTTeX.

1 Introduction

A major open problem in mathematical document authoring is to elegantly combine formal and informal mathematical knowledge. Multiple proof assistants and controlled natural language systems have developed custom formats for that purpose, e.g., [Wen11,TB85,WAB07,CFK+09].

The goal of MMTTeX is not to introduce a new format but to use LaTeX documents as the primary user-written documents. That makes it most similar to sTeX [Koh08], where authors add content markup that allows converting a LaTeX to an OMDoc document. MMTTeX differs in several ways: authors write *fully formal* content in Mmt syntax [RK13] directly in the LaTeX source, either in addition to or instead of informal text; and Mmt is used to type-check the formal parts during LaTeX compilation workflow. This enables several advanced features: Formal content in LaTeX sources can use or be used by Mmt content written elsewhere; in particular, background knowledge formalized elsewhere can be used inside the LaTeX document. And formulas written in Mmt syntax are not only type-checked but result in high-quality pdf by, e.g., displaying inferred types as tooltips or adding hyperlinks to operator occurrences.

Online Resources All resources are available as a part of the MMT repository, specifically at https://github.com/UniFormal/MMT/tree/devel/src/latex-mmt for the current version. These resources include the MMT and LaTeX side of the implementation, the system documentation, and the sources of this paper, which is itself written with MMTTeX.

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2 Design and Behavior

2.1 Overview

MMTTeX consists of two components:
- an MMT plugin `latex-mmt` that converts MMT theories to LaTeX packages,
- an LaTeX package `mmttex.sty`, which allows for embedding MMT content.

The two components are tied together in bibtex-style, i.e.,
1. While running LaTeX on `doc.tex`, `mmttex.sty` produces an additional output file `doc.tex.mmt`, which is a regular MMT file. `doc.tex.mmt` contains all formal content that was embedded in the `tex` document.
2. `latex-mmt` is run on `doc.tex.mmt` and produces `doc.tex.mmt.sty`. This type-checks the embedded formal content and generates macro definitions for rendering it in the next step.
3. When running LaTeX the next time, the package `doc.tex.mmt.sty` is included at the beginning. If changes were made, this run also changes `doc.tex.mmt`.

Note that `latex-mmt` only needs to be re-run if the document changed. That is important for sharing documents with colleagues or publishers who want to run plain LaTeX: by simply supplying `doc.tex.mmt.sty` along with `doc.tex`, running plain LaTeX is sufficient to rebuild `doc.pdf`.

2.2 Formal Content in LaTeX Documents

`mmttex.sty` provides presentation-irrelevant and presentation-irrelevant macros for embedding formal content in addition to resp. instead of informal text.

Presentation-irrelevant macros only affect `doc.tex.mmt` and do not produce anything that is visible in the pdf document. These macros are usually used to embed the formalization in parallel to the informal text. At the lowest level, this is realized by a single macro that takes a string and appends it to `doc.tex.mmt`. On top, we provide a suite of syntactic sugar that mimics the structure of MMT language.

As a simple example, we will now define the theory of groups informally and embed its parallel MMT formalization. Because the formalization is invisible in the pdf, we added listings in gray that show the formalization in exactly the spot where they occur invisibly in the tex file. If this is confusing, readers should inspect the source code of this paper at the URL given above.

Our example will refer to the theory SFOLEQ, which formalizes sorted first-order logic with equality and is defined in the examples archive of MMT.[1] To refer to it conveniently, we will import its namespace under the abbreviation ex.

```
\mmtimport{ex}{http://cds.omdoc.org/examples}
\begin{mmttheory}{Group}{ex:?SFOLEQ}
```

A group consists of

- a set U,

  ```
  \mmtconstant{U}{sort}{}{}
  ```

- an operation $U \to U \to U$, written as infix $*$,

  ```
  \mmtconstant{operation}{tm U --> tm U --> tm U}{}{1 * 2 prec 50}
  ```

- an element e of U called the unit

  ```
  \mmtconstant{unit}{tm U}{}{e}
  ```

- an inverse element function $U \to U$, written as postfix $'$ and with higher precedence than $*$.

  ```
  \mmtconstant{inv}{tm U --> tm U}{}{1 ' prec 60}
  ```

We omit the axioms.

```
\end{mmttheory}
```

Here the environment mmttheory wraps around the theory. It takes two arguments: the name and the meta-theory, i.e., the logic in which the theory is written.

The macro mmtconstant introduces a constant declaration inside a theory. It takes 4 arguments: the name, type, definiens, and notation. All but the name may be empty.

We can also use the MMT module system, e.g., the following creates a theory that extends Group with a definition of division (where square brackets are the notation for λ-abstraction employed by SFOLEQ):

```
\begin{mmttheory}{Division}{ex:?SFOLEQ}
\mmtinclude{?Group}
\mmtconstant{division}
   {tm U --> tm U --> tm U}{[x,y] x*y'}{1 / 2 prec 50}
```

Note that we have not closed the theory yet.

[1] See https://gl.mathhub.info/MMT/examples/blob/master/source/logic/sfol.mmt.

Presentation-relevant macros result in changes to the pdf document. The most important such macro is one that takes a math formula in MMT syntax and parses, type-checks, and renders it. For this macro, we provide special notation using an active character: if we write "F" instead of F, then F is considered to be a math formula in MMT syntax and processed by MMT. Consider the formula " forall [x] x / x = e". MMT parses it relative to the current theory, type-checks, and substitutes it with LaTeX commands that are rendered as $\forall[x]\frac{x}{x}\doteq e$.

Type checking infers the type of tm U of the bound variable x and the sort argument of equality. These are attached to the formula as tooltips. (Tooltip display is supported by many but not all pdf viewers. Unfortunately, pdf tooltips are limited to strings so that we cannot show, e.g., MathML even though we could generate it easily.) Moreover, every operator carries a hyperlink to the point of its declaration. Currently, these links point to the MMT server, which is assumed to run locally.

This is implemented as follows:

1. An MMT formula "F" simply produces a macro like \mmt@X for a running counter X. If that macro is undefined, a placeholder is shown and the user is warned that a second compilation is needed. Additionally, a definition mmt@X = F is generated and placed into `doc.tex.mmt`.
2. When `latex-mmt` processes that definition, it additionally generates a macro definition \newcommand{\mmt@X}{$\overline{F}$} `doc.tex.mmt.sty`, where $\overline{F}$ is the intended LaTeX representation of F.
3. During the next compilation, MMT @X produces the rendering of $\overline{F}$. If F did not type-check, additional a LaTeX error is produced with the error message.

Before we continue, we close the current theory:

```
\end{mmttheory}
```

2.3 Converting MMT Content To LaTeX

We run `latex-mmt` on every theory T that is part of the background knowledge, e.g., SFOLEQ, and on those in `doc.tex.mmt`, resulting in one LaTeX package (sty file) each. This package contains one \RequirePackage macro for every dependency and one \newcommand macro for every constant declaration. `doc.tex.mmt.sty` is automatically included at the beginning of the document and thus brings all necessary generated LaTeX packages into scope.

The generated \newcommand macros use (only) the notation of the constant. For example, for the constant operator, the generated command is essentially \newcommand{\operator}[2]{#1*#2}. Technically, however, it is much more complex: Firstly, instead of #1*#2, we produce a a macro definition that generates the right tooltips, hyperreferences, etc. Secondly, we use the fully qualified MMT URI as the LaTeX macro name to avoid ambiguity when multiple theories define constants of the same local name.

This is an important technical difference between MMTTeX and sTeX [Koh08]: the latter intentionally generates short human-friendly macro names because

they are meant to be called by humans, which requires relatively complex scope management. But that is inessential in our case because our macros are called by generated LaTeX commands (namely those in the definiens of \mmt@X). But it would be easy to add macros for creating aliases with human-friendly names.

The conversion from MMT to LaTeX can be easily run in batch mode so that any content available in MMT form can be easily used as background knowledge in LaTeX documents.

3 Conclusion

We have presented a system that allows embedding formal MMT content inside LaTeX documents. The formal content is type-checked in a way that does not affect any existing LaTeX work flows and results in higher quality LaTeX than could be easily produced manually. Moreover, the formal content may use and be used by any MMT content formalized elsewhere, which allows the interlinking across document formats.

Of course, we are not able to verify the informal parts of a document this way — only those formulas that are written in MMT syntax are checked. But our design supports both gradual formalization and parallel formal-informal representations.

It is intriguing to apply the same technology to formal proofs. This is already possible for formal proof terms, but those often bear little resemblance to informal proofs. Once MMT supports a language for structured proofs, that could be used to write formal proofs in MMTTeX. Morever, future work could apply MMT as a middleware between LaTeX and other tools, e.g., MMT could run a computation through a computer algebra to verify a computation in LaTeX.

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