Semantic Markup for Mathematical Statements*

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May 11, 2016

Abstract

The `statements` package is part of the STEX collection, a version of TEX/LATEX that allows to markup TEX/LATEX documents semantically without leaving the document format, essentially turning TEX/LATEX into a document format for mathematical knowledge management (MKM).

This package provides semantic markup facilities for mathematical statements like Theorems, Lemmata, Axioms, Definitions, etc. in STEX files. This structure can be used by MKM systems for added-value services, either directly from the STEX sources, or after translation.

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*Version v1.2 (last revised 2016/04/07)

1 Introduction

The motivation for the `statements` package is very similar to that for semantic macros in the `modules` package: We want to annotate the structural semantic properties of statements in the source, but present them as usual in the formatted documents. In contrast to the case for mathematical objects, the repertoire of mathematical statements and their structure is more or less fixed.

This structure can be used by MKM systems for added-value services, either directly from the sTEX sources, or after translation. Even though it is part of the sTEX collection, it can be used independently, like it's sister package `sproofs`.

sTEX [**sTeX:online**; Koh08] is a version of TEX/LATEX that allows to markup TEX/LATEX documents semantically without leaving the document format, essentially turning TEX/LATEX into a document format for mathematical knowledge management (MKM). Currently the OMDoc format [Koh06] is directly supported.

2 The User Interface

The `statements` package supplies a semantically oriented infrastructure for marking up mathematical statements: fragments of natural language that state properties of mathematical objects, e.g. axioms, definitions, or theorems. The `statement` package provides an infrastructure for marking up the semantic relations between statements for the OMDoc transformation and uses the `ntheorem` package [MS] for formatting (i.e. transformation to PDF).

2.1 Package Options

The `statements` package provides the `defindex` option to sTEX. If this is set, then definienda are automatically passed into the index of the document. Furthermore,
`showmeta` the `statements` package passes the `showmeta` to the `metakeys` package. If this is set, then the metadata keys are shown (see [Koh15a] for details and customization options).

2.2 Statements

All the statements are marked up as environments, that take a `KeyVal` argument that allows to annotate semantic information. Generally, we distinguish two forms of statements:

block statements have explicit discourse markers that delimit their content in the surrounding text, e.g. the boldface word "**Theorem:**" as a start marker and a little line-end box as an end marker of a proof.

flow statements do not have explicit markers, they are interspersed with the surrounding text.

Since they have the same semantic status, they must both be marked up, but styled differently. We distinguish between these two presentational forms with the
display= `display` key, which is allowed on all statement environments. If it has the value `block` (the default), then the statement will be presented in a paragraph of its own, have explicit discourse markers for its begin and end, possibly numbering, etc. If it has the value `flow`, then no extra presentation will be added the semantic information is invisible to the reader. Another key that is present on all statement
id= environments in the `id` key it allows to identify the statement with a name and to reference it with the semantic referencing infrastructure provided by the `sref` package [Koh15c].

2.2.1 Axioms and Assertions

assertion The `assertion` environment is used for marking up statements that can be justified from previously existing knowledge (usually marked with the monikers "Theorem", "Lemma", "Proposition", etc. in mathematical vernacular). The environment `assertion` is used for all of them, and the particular subtype of as-
type= sertion is given in the `type` key. So instead of `\begin{Lemma}`we have to write `\begin{assertion}[type=lemma]`(see Example 1 for an example).

```
\begin{assertion}[id=sum-over-odds,type=lemma]
  $\sum_{i=1}^n{2i-1}=n^2$
\end{assertion}
```

will lead to the result
Lemma 2.1 $\sum_{i=1}^{n} 2i-1 = n^2$

Example 1: Semantic Markup for a Lemma in a `module` context

Whether we will see the keyword "Lemma" will depend on the value of the optional `display` key. In all of the `assertion` environments, the presentation expectation is that the text will be presented in italic font. The presentation (keywords, spacing, and numbering) of the `assertion` environment is delegated to a theorem styles from the `ntheorem` environment. For an assertion of type ⟨*type*⟩ the `assertion` environment calls the `ST`⟨*type*⟩`AssEnv` environment provided by the `statements` package; see Figure 2 for a list of provided assertion types. Their formatting can be customized by redefining the `ST`⟨*type*⟩`AssEnv` environment via the `\renewtheorem` command from the `ntheorem` package; see [MS] for details.

axiom The `axiom` environment is similar to `assertion`, but the content has a different ontological status: axioms are assumed without (formal) justification, whereas assertions are expected to be justified from other assertions, axioms or definitions. This environment relegates the formatting to the `STaxiomEnv` environment, which can be redefined for configuration.

2.2.2 Symbols

symboldec The `symboldec` environment can be used for declaring concepts and symbols. Note

Value	Explanation
theorem, **proposition**	an important assertion with a proof
Note that the meaning of **theorem** (in this case the existence of a proof) is not enforced by OMDoc applications. It can be appropriate to give an assertion the **theorem**, if the author knows of a proof (e.g. in the literature), but has not formalized it in OMDoc yet.	
lemma	a less important assertion with a proof
The difference of importance specified here is even softer than the other ones, since e.g. reusing a mathematical paper as a chapter in a larger monograph, may make it necessary to downgrade a theorem (e.g. the main theorem of the paper) and give it the status of a lemma in the overall work.	
corollary	a simple consequence
An assertion is sometimes marked as a corollary to some other statement, if the proof is considered simple. This is often the case for important theorems that are simple to get from technical lemmata.	
postulate, **conjecture**	an assertion without proof or counter-example
Conjectures are assertions, whose semantic value is not yet decided, but which the author considers likely to be true. In particular, there is no proof or counter-example.	
false-conjecture	an assertion with a counter-example
A conjecture that has proven to be false, i.e. it has a counter-example. Such assertions are often kept for illustration and historical purposes.	
obligation, **assumption**	an assertion on which a proof of another depends
These kinds of assertions are convenient during the exploration of a mathematical theory. They can be used and proven later (or assumed as an axiom).	
rule	a normative assertion
These kinds of assertions can be interpreted procedurally to trigger actions	
observation, **remark**	if everything else fails
This type is the catch-all if none of the others applies.	

Example 2: Types of Mathematical Assertions

the the `symdef` forms from the `modules` package will not do this automatically (but the `definition` environment and the `\inlinedef` macro will for all the definienda; see below). The `symboldec` environment takes an optional keywords argument with the keys `id`, `role`, `title` and `name`. The first is for general identification, the `role` specifies the OpenMath/OMDoc role, which is one of `object`, `type`, `sort`, `binder`, `attribution`, `application`, `constant`, `semantic-attribution`, and `error` (see the OMDoc specification for details). The `name` key specifies the OpenMath name of the symbol, it should coincide with the control sequence introduced by the corresponding `\symdef` (if one is present). The `title` key is for presenting the title of this symbol as in other statements. Usually, `axiom` and `symboldec` environments are used together as in Figure 3.

2.2.3 Types

In many cases, we can give additional information for symbols in the form of type assignments. SᴛEX does not fix a type system, but allows types to be arbitrary mathematical objects that they can be defined in (imported) modules. The `\symtype` macro can be used to assign a type to a symbol:

`\symtype[`⟨*keys*⟩`]{`⟨*sym*⟩`}{`⟨*type*⟩`}`

assigns the type ⟨*type*⟩ to a symbol with name ⟨*sym*⟩. For instance

```
\symtype[id=plus-nat.type,system=sts]{plus}{\fntype{\Nat,\Nat}\Nat}
```

assigns the type $\mathbb{N} \times \mathbb{N} \to \mathbb{N}$ (in the `sts` type system) to the symbol `plus`. This states (type assignments are statements epistemologically) that addition is a binary function on natural numbers. The `\symtype` macro supports the keys `id` (for identifiers) and `system` for the type system.

Often, type assignments occur in informal context, where the type assignment is given by a natural language sentence or phrase. For this, the `statements` package supplies the `typedec` environment and the `\inlinetypedec` macro. Both take an optional keyval argument followed by the type. The phrase/sentence is the body of the `typedec` environment and the last argument of the `\inlinetypedec` macro. The symbol name is given in via the `for` key. For convenience, the macro `\thedectype` is bound to the type. So we can use

```
\begin{typedec}[for=plus,id=plus-nat.type]{\fntype{\Nat,\Nat}\Nat}
  $+:\thedectype$ is a binary function on $\Nat$
\end{typedec}
```

instead of the `\symtype` above in an informal setting.

2.2.4 Definitions, and Definienda

The `definition` environment is used for marking up mathematical definitions. Its peculiarity is that it defines (i.e. gives a meaning to) new mathematical concepts or objects. Theseare identified by the `\definiendum` macro, which is used as

```
\symdef{zero}{0}
\begin{symboldec}[name=zero,title=The number zero,type=constant]
  The number zero, it is used as the base case of the inductive definition
  of natural numbers via the Peano Axioms.
\end{symboldec}

\symdef{succ}[1]{\prefix{s}{#1}}
\begin{symboldec}[name=succ,title=The Successor Function,type=application]
  The successor function, it is used for the step case of the inductive
  definition of natural numbers via the Peano Axioms.
\end{symboldec}

\symdef{NaturalNumbers}{\mathbb{N}}
\begin{symboldec}[name=succ,title=The Natural Numbers,type=constant]
  The natural numbers inductively defined via the Peano Axioms.
\end{symboldec}

\begin{axiom}[id=peano.P1,title=P1]
  $\zero$ is a natural number.
\end{axiom}
...
\begin{axiom}[id=peano.P5,title=P5]
  Any property $P$ such $P(\zero)$ and $P(\succ{k})$ whenever $P(k)$
  holds for all $n$ in $\NaturalNumbers$
\end{axiom}
```

will lead to the result

Symbol zero: (**The number zero**)
The number zero, it is used as the base case of the inductive definition of natural numbers via the Peano Axioms.
Symbol succ: (**The Successor Function**)
The successor function, it is used for the step case of the inductive definition of natural numbers via the Peano Axioms.
Symbol succ: (**The Natural Numbers**)
The natural numbers inductively defined via the Peano Axioms.

Axiom 2.2 (P1) 0 is a natural number.

...

Axiom 2.6 (P5) Any property P such $P(0)$ and $P(\succ k)$ whenever $P(k)$ holds for all n in $\mathbb{N}$

Example 3: Semantic Markup for the Peano Axioms

\definiendum[⟨*keys*⟩]{⟨*text*⟩}. Here, ⟨*text*⟩ is the text that is to be emphasized in the presentation. \definiendum takes the key name for the optional system name of the symbol defined (for reference via \termref, see Section 2.3). If the name key is not given, then ⟨*text*⟩ is used as a system name instead, which is usually sufficient for most situations. The set of keys is extensible to add additional metadata for the definiendum. Currently only the lemma key is supported, which allows to specify the base form of the name of the concept involved – e.g. for referencing in a glossary or index.

name

lemma

```
\symdef{one}{1}
\begin{definition}[id=one.def,for=one]
  $\notatiendum[one]{\one}$ is the successor of $\zero$
  (formally: $\one :=\succ\zero$)
\end{definition}
```

will lead to the result

Definition 2.7 1 is the successor of 0 (formally: $1 := s(0)$)

Example 4: A Definition based on Figure 3

defi

The \defi{⟨*word*⟩} macro combines the functionality of the \definiendum macro with index markup from the omdoc package [Koh15b]: For definienda where the lemma and ⟨*text*⟩ coincide use

\defi[⟨*name*⟩]{⟨*lemma*⟩}[⟨*indexkeys*⟩]

to markup a definiendum ⟨*lemma*⟩ with system name ⟨*name*⟩ that appear in the index (where ⟨*indexkeys*⟩ are passed to the \omdoc@index* macros from the omtext package) — in other words in almost all definitions of single-word concepts. We also have the variants \defii and \defiii for (adjectivized) two-word compounds. Note that if the definiendum contains semantic macros, then we need to specify the loadmodules key and also protect the semantic macro. For instance if \eset is the semantic macro for $\emptyset$, then we would use

\defii

\defiii

```
\defii[eset-comp]{$\protect\eset$}{compatible}[loadmodules]
```

for the definiendum markup.

```
A \defi{graph} consists of \adefi{vertices}{vertex}  and \defis{edge}.
```

Example 5: Definienda where Lemma and Text Form differ

For the cases where the lemma and ⟨*text*⟩ are different we can use the variants \adefi, \adefii,and \adefiii that have an additional first argument that allows

\adefi

\adefii

\adefiii

to specify an alternative ⟨*text*⟩; see Figure 6. The main use of these is to mark up inflected forms as in Figure 5.

\defis
\defiis
\defiiis

As the greatest number of these are plurals, which tends to be regular (e.g. adding a trailing "s" in English), we provide the variants `\defis`, `\defiis`, and `\defiiis` for that case: `\defiis{simple}{group}` is equivalent to much longer `\adefii{simple groups}{simple}{group}` (but also see Figure 5).

source

system name	result	index
`\defi{concept}`		
`concept`	concept	concept
`\defi[csymbol]{concept}`		
`csymbol`	concept	concept
`\adefi[csymbol]{concepts}{concept}`		
`csymbol`	concepts	concept
`\defii{concept}{group}`		
`concept-group`	concept group	concept group, group - , concept
`\adefii{small}{concept}{group}`		
`small-concept-group`	small concept group	small concept group, concept group - , small

Example 6: Some definienda with Index

Note that the `\definiendum`, `\defi`, `\defii`, and `\defiii` macros can only be used inside the definitional situation, i.e. in a `definition` or `symboldec` environment or a `\inlinedef` macro. If you find yourself in a situation where you want to use it outside, you will most likely want to wrap the appropriate text fragment in a `\begin{definition}[display=flow]` ... and `\end{definition}`. For instance, we could continue the example in Figure 3 with the `definition` environment in Figure 4.

\inlinedef

Sometimes we define mathematical concepts in passing, e.g. in a phrase like "$\ldots s(o)$ which we call **one**.". For this we cannot use the `definition` environment, which presupposes that its content gives all that is needed to understand the definition. But we do want to make use of the infrastructure introduced for the `definition` environment. In this situation, we just wrap the phrase in an `\inlinedef` macro that makes them available. The `\inlinedef` macro accepts the same `id` and `for` keys in its optional argument, and additionally the `verbalizes` key which can be used to point to a full definition of the concept somewhere else.

Note that definienda can only be referenced via a `\term` element, if they are only allowed inside a named module, i.e. a `module` environment with a name given by the `id=` key or the `theory=` key on is specified on the definitional environment.

2.2.5 Examples

`example` The `example` environment is a generic statement environment, except that the `for` key should be given to specify the identifier what this is an example for. The `example` environment also expects a `type` key to be specified, so that we know whether this is an example or a counterexample.

`\inlineex` The `\inlineex` is analogous to `\inlinedef`, only that it is used for inline examples, e.g. "...mammals, e.g. goats". Note that we have used an inline example for an inline example.

2.3 Cross-Referencing Symbols and Concepts

If we have defined a concept with the `\definiendum` macro, then we can mark up other occurrences of the term as referring to this concept. Note that this process cannot be fully automatized yet, since that would need advanced language technology to get around problems of disambiguation, inflection, and non-contiguous phrases[1]. Therefore, the `\termref` can be used to make this information explicit. It takes the keys

`\termref`

`cdbase` to specify a URI (a path actually, since LaTeX cannot load from URIs) where the module can be found.

`cd` to specify the module in which the term is defined. If the `cd` key is not given, then the current module is assumed. If no `cdbase` is specified (this is the usual case), then the CD has to be imported via a `\importmodule` from the `modules` package [KGA15].

`name` to specify the name of the definiendum (which is given in the body of the `\definiendum` or the optional argument). If the `name` key is not specified, then argument of the `\termref` macro is used.

`role` is currently unused.

`\termref[cd=`⟨*cd*⟩`,name=`⟨*name*⟩`]{`⟨*text*⟩`}` will just typeset the link text ⟨*text*⟩ with (if the `hyperref` package is loaded) a hyperlink to the definition in module ⟨*cd*⟩ that defines the concept ⟨*name*⟩, e.g. that contains `\defi[`⟨*name*⟩`]{`⟨*text*⟩`}`.

Just as the `\definiendum` macro has the convenience variants `\defi`, `\defii` and `\defiii`, the `\termref` has variants `\trefi`, `\trefii`, and `\trefiii` that take two and three arguments for the parts of the compositum. In the same module, concepts that are marked up by `\defi{`⟨*name*⟩`}` in the definition can be referenced by `\trefi{`⟨*name*⟩`}`. Here the link text is just ⟨*name*⟩. Concepts defined via `\defii{`⟨*first*⟩`}{`⟨*second*⟩`}` can be referenced by `\trefii{`⟨*first*⟩`}{`⟨*second*⟩`}` (with link text "⟨*first*⟩ ⟨*second*⟩") and analogously for `\defiii` and `\trefiii`.

`\trefi` `\trefii` `\trefiii`

`\atref*` We have variants `\atrefi`, `\atrefii`, and `\atrefiii` with alternative link text. For instance `\atrefii{`⟨*text*⟩`}{`⟨*first*⟩`}{`⟨*second*⟩`}` references a concept introduced by `\defii{`⟨*first*⟩`}{`⟨*second*⟩`}` but with link text ⟨*text*⟩. Of course, if the system identifier is given explicitly in the optional argument of the definition form, as in `\defii[`⟨*name*⟩`]{`⟨*first*⟩`}{`⟨*second*⟩`}`, then the terms are referenced by `\trefi{`⟨*name*⟩`}`.

[1] We do have a program that helps annotate larger text collections spotting the easy cases; see `http://kwarc.info/projects/stex` and look for the program `termin`.

For referencing terms outside the current module, the module name can be specified in the first optional argument of the `\*tref*` macros. To specify the `cdbase`, we have to resort to the `\termref` macro with the keyval arguments.

Note that the `\termref` treatment above is natural for "concepts" declared by the `\termdef` macro from the `modules` package [KGA15]. Concepts are natural language names for mathematical objects. For "symbols", i.e. symbolic identifiers for mathematical objects used in mathematical formulae, we use the `\symdef` macro from the `modules` package. Sometimes, symbols also have an associated natural language concept, and we want to use the symbol name to reference it (instead of specifying `cd` and `name` which is more inconvenient). For this the `statements` package supplies the `\symref` macro. Like `\termref`, and invocation of `\symref{`⟨*cseq*⟩`}{`⟨*text*⟩`}` will just typeset ⟨*text*⟩ with a hyperlink to the relevant definition (i.e. the one that has the declaration `for=`⟨*cseq*⟩ in the metadata argument.)

`\symref`

`\term`

The `\term` macro is a variant of the `\termref` macro that marks up a phrase as a (possible) term reference, which does not have a link *yet*. This macro is a convenient placeholder for authoring, where a `\termref` annotation is (currently) too tedious or the link target has not been authored yet. It facilitates lazy flexiformalization workflows, where definitions for mathematical concepts are supplied or marked up by need (e.g. after a `grep` shows that the number of `\term` annotations of a concept is above a threshold). Editors or active documents can also support the `\term` macro like a wiki-like dangling link: a click on `\term{`⟨*phrase*⟩`}` could generate a new editor buffer with a stub definition (an `definition` environment with `\definiendum` macro and appropriate metadata).[1]

EdN:1

3 Configuration of the Presentation

`\defemph`

The `\defemph` macro is a configuration hook that allows to specify the style of presentation of the definiendum. By default, it is set to `\bf` as a fallback, since we can be sure that this is always available. It can be customized by redefinition: For instance `\renewcommand{\defemph}[1]{\emph{#1}}`, changes the default behavior to italics.

`\termemph`

The `\termenph` macro does the same for the style for `\termref`, it is empty by default. Note the term might carry an implicit hyper-reference to the defining occurrence and that the presentation engine might mark this up, changing this behavior.

`\stDMemph`

The `\stDMemph` macro does the same for the style for the markup of the discourse markers like "Theorem". If it is not defined, it is set to `\bf`; that allows to preset this in the class file. [2]

EdN:2

Some authors like to lowercase the semantic references, i.e. use "axiom 2.6" instead of the default "Axiom 2.6" to refer to the last axiom in Figure 3. This can be achieved by redefining the `\STpresent` macro, which is applied to the keyword

`\STpresent`

[1] EdNote: MK: we probably need multi-part variants for `*tref*`

[2] EdNote: function declarations

EdN:3

of the `ST*Env` theorem environments.[3]

Finally, we provide configuration hooks in Figure 7 for the statement types provided by the `statement` package. These are mainly intended for package authors building on `statements`, e.g. for multi-language support. The language bindings are given in the `smultiling` [KG15] package not in `statements` itself.

Environment	configuration macro	value
`STtheoremAssEnv`	`\st@theorem@kw`	Theorem
`STlemmaAssEnv`	`\st@lemma@kw`	Lemma
`STpropositionAssEnv`	`\st@proposition@kw`	Proposition
`STcorollaryAssEnv`	`\st@corollary@kw`	Corollary
`STconjectureAssEnv`	`\st@conjecture@kw`	Conjecture
`STfalseconjectureAssEnv`	`\st@falseconjecture@kw`	Conjecture (false)
`STpostulateAssEnv`	`\st@postulate@kw`	Postulate
`STobligationAssEnv`	`\st@obligation@kw`	Obligation
`STassumptionAssEnv`	`\st@assumption@kw`	Assumption
`STobservationAssEnv`	`\st@observation@kw`	Observation
`STremarkAssEnv`	`\st@remark@kw`	Remark
`STruleAssEnv`	`\st@rule@kw`	Rule
`STexampleEnv`	`\st@example@kw`	Example
`STaxiomEnv`	`\st@axiom@kw`	Axiom
`STdefinitionEnv`	`\st@definition@kw`	Definition
`STnotationEnv`	`\st@notation@kw`	Notation

Example 7: Configuration Hooks for statement types

4 Limitations

In this section we document known limitations. If you want to help alleviate them, please feel free to contact the package author. Some of them are currently discussed in the sTeX GitHub repository [sTeX].

1. none reported yet

5 The Implementation

5.1 Package Options

We declare some switches which will modify the behavior according to the package options. Generally, an option `xxx` will just set the appropriate switches to true (otherwise they stay false). First we have the general options

[3] EdNote: this does not quite work as yet, since **STpresent** is applied when the label is written. But we would really like to have it applied when the reference is constructed. But for that we need to split the label into keyword and number in package `sref`.

```
1 ⟨*package⟩
2 \newif\ifdef@index\def@indexfalse
3 \DeclareOption{defindex}{\def@indextrue}
4 \DeclareOption*{\PassOptionsToPackage{\CurrentOption}{omtext}}
5 \ProcessOptions
```

The next measure is to ensure that some sTEX packages are loaded: `omdoc` for the statement keys, `modules` since we need module identifiers for referencing. Furthermore, we need the `ntheorem` package for presenting statements. For LaTeXML, we also initialize the package inclusions, there we do not need `ntheorem`, since the XML does not do the presentation.

```
6 \RequirePackage{omtext}
7 \RequirePackage[base]{babel}
8 \RequirePackage[hyperref]{ntheorem}
9 \theoremstyle{plain}
```

Now, we define an auxiliary function that lowercases strings

Sometimes it is necessary to fallback to symbol names in order to generate xml:id attributes. For this purpose, we define an auxiliary function which ensures the name receives a unique NCName equivalent.[4]

EdN:4

The following functions are strictly utility functions that makes our life easier later on

For the other languages, we set up triggers

```
10 \AfterBabelLanguage{ngerman}{\input{statements-ngerman.ldf}}
```

5.2 Statements

`\STpresent`

```
11 \providecommand\STpresent[1]{#1}
```

`\define@statement@env`

We define a meta-macro that allows us to define several variants of statements. Upon beginning this environment, we first set the `KeyVal` attributes, then we decide whether to print the discourse marker based on the value of the `display` key, then (given the right Options were set), we show the semantic annotations, and finally initialize the environment using the appropriate macro. Upon ending the environment, we just run the respective termination macro.

```
12 \def\define@statement@env#1{%
13 \newenvironment{#1}[1][]{\metasetkeys{omtext}{##1}\sref@target%
14 \@in@omtexttrue%
15 \ifx\omtext@display\st@flow\else%
16 \ifx\omtext@title\@empty\begin{ST#1Env}\else\begin{ST#1Env}[\omtext@title]\fi%
17 \ifx\sref@id\@empty\else\label{#1.\sref@id}\fi
18 \csname st@#1@initialize\endcsname\fi% display
19 \ifx\sref@id\@empty\sref@label@id{here}\else%
```

[4] EdNote: Hard to be unique here, e.g. the names "foo_bar" and "foo bar" would receive the same xml:id attributes... of course we can devise a more complex scheme for the symbol replacement.

```
\sref@label@id{\STpresent{\csname ST#1EnvKeyword\endcsname}~\@currentlabel}\fi%
\ignorespaces}
{\csname st@#1@terminate\endcsname\ifx\omtext@display\st@flow\else\end{ST#1Env}\fi%
\omtext@post@skip\@in@omtextfalse}}
```

assertion

```
\newenvironment{assertion}[1][]{\metasetkeys{omtext}{#1}\sref@target%
\@in@omtexttrue%
\ifx\omtext@display\st@flow\itshape\noindent\ignorespaces%
\else% display!=flow
\ifx\omtext@title\@empty\begin{ST\omtext@type AssEnv}%
\else\begin{ST\omtext@type AssEnv}[\omtext@title]\fi\fi%
\ifx\omtext@type\@empty\sref@label@id{here}\else%
\sref@label@id{\STpresent{\csname ST\omtext@type AssEnvKeyword\endcsname}~\@currentlabel}
\fi}%display=flow
{\ifx\omtext@display\st@flow\else\end{ST\omtext@type AssEnv}\@in@omtextfalse\fi}
```

\st@*@kw We configure the default keywords for the various theorem environments.

```
\def\st@theorem@kw{Theorem}
\def\st@lemma@kw{Lemma}
\def\st@proposition@kw{Proposition}
\def\st@corollary@kw{Corollary}
\def\st@conjecture@kw{Conjecture}
\def\st@falseconjecture@kw{Conjecture (false)}
\def\st@postulate@kw{Postulate}
\def\st@obligation@kw{Obligation}
\def\st@assumption@kw{Assumption}
\def\st@rule@kw{Rule}
\def\st@observation@kw{Observation}
\def\st@remark@kw{Remark}
```

Then we configure the presentation of the theorem environments

```
\theorembodyfont{\itshape}
\theoremheaderfont{\normalfont\bfseries}
```

and then we finally define the theorem environments in terms of the statement keywords defined above. They are all numbered together with the section counter.

ST*AssEnv

```
\newtheorem{STtheoremAssEnv}{\st@theorem@kw}[section]
\newtheorem{STlemmaAssEnv}[STtheoremAssEnv]{\st@lemma@kw}
\newtheorem{STpropositionAssEnv}[STtheoremAssEnv]{\st@proposition@kw}
\newtheorem{STcorollaryAssEnv}[STtheoremAssEnv]{\st@corollary@kw}
\newtheorem{STconjectureAssEnv}[STtheoremAssEnv]{\st@conjecture@kw}
\newtheorem{STfalseconjectureAssEnv}[STtheoremAssEnv]{\st@falseconjecture@kw}
\newtheorem{STpostulateAssEnv}[STtheoremAssEnv]{\st@postulate@kw}
\newtheorem{STobligationAssEnv}[STtheoremAssEnv]{\st@obligation@kw}
\newtheorem{STassumptionAssEnv}[STtheoremAssEnv]{\st@assumption@kw}
\newtheorem{STobservationAssEnv}[STtheoremAssEnv]{\st@observation@kw}
\theorembodyfont{\rm}
```

```
\newtheorem{STremarkAssEnv}[STtheoremAssEnv]{\st@remark@kw}
\newtheorem{STruleAssEnv}[STtheoremAssEnv]{\st@rule@kw}
```

EdN:5 example [5]

```
\def\st@example@initialize{}\def\st@example@terminate{}
\define@statement@env{example}
\def\st@example@kw{Example}
\theorembodyfont{\upshape}
\newtheorem{STexampleEnv}[STtheoremAssEnv]{\st@example@kw}
```

axiom

```
\def\st@axiom@initialize{}\def\st@axiom@terminate{}
\define@statement@env{axiom}
\def\st@axiom@kw{Axiom}
\theorembodyfont{\upshape}
\newtheorem{STaxiomEnv}[STtheoremAssEnv]{\st@axiom@kw}
```

symboldec We use `\symdef@type` from the `modules` package as the visual cue.

```
\srefaddidkey{symboldec}
\addmetakey{symboldec}{functions}
\addmetakey{symboldec}{role}
\addmetakey*{symboldec}{title}
\addmetakey*{symboldec}{name}
\addmetakey{symboldec}{subject}
\addmetakey*{symboldec}{display}
\newenvironment{symboldec}[1][]{\metasetkeys{symboldec}{#1}\sref@target\st@indeftrue%
\ifx\symboldec@display\st@flow\else{\noindent\stDMemph{\symdef@type} \symboldec@name:}\fi%
\ifx\symboldec@title\@empty~\else~(\stDMemph{\symboldec@title})\par\fi}{}
```

5.2.1 Types

EdN:6 \symtype [6]

```
\srefaddidkey{symtype}
\addmetakey*{symtype}{system}
\addmetakey*{symtype}{for}
\newcommand\type@type{Type}
\newcommand\symtype[3][]{\metasetkeys{symtype}{#1}\sref@target%
\noindent\type@type \ifx\symtype@\@empty\else (\symtype@system)\fi #2: $#3$}
```

\inlinetypedec

```
\newcommand\inlinetypedec[3][]{\metasetkeys{symtype}{#1}\sref@target{\def\thedectype{#2}#3}}
```

typedec We first define a theorem environment

```
\def\st@typedec@kw{Type Declaration}
\theorembodyfont{\upshape}
\newtheorem{STtypedecEnv}[STtheoremAssEnv]{\st@typedec@kw}
```

[5] EdNote: need to do something clever for the OMDoc representation of examples, in particular, the usevocab should only be defined in example

[6] EdNote: MK@DG; the type element should percolate up.

and then the environment itself.

```
\newenvironment{typedec}[2][]{\metasetkeys{omtext}{#1}\sref@target%
\def\thedectype{#2}%
\ifx\omtext@display\st@flow\else%
\ifx\omtext@title\@empty\begin{STtypedecEnv}\else\begin{STtypedecEnv}[\omtext@title]\fi%
\ifx\sref@id\@empty\else\label{typedec.\sref@id}\fi
\ifx\sref@id\@empty\sref@label@id{here}\else%
\sref@label@id{\STpresent{\csname STtypedecEnvKeyword\endcsname}~\@currentlabel}\fi%
\ignorespaces}
{\ifx\omtext@display\st@flow\else\end{STtypedecEnv}\fi\omtext@post@skip}
```

`definition` The `definition` environment itself is quite similar to the other's but we need to set the `\st@indef` switch to suppress warnings from `\st@def@target`.

```
\newif\ifst@indef\st@indeffalse
\newenvironment{definition}[1][]{\metasetkeys{omtext}{#1}\sref@target\st@indeftrue%
\ifx\omtext@display\st@flow\else%
\ifx\omtext@title\@empty\begin{STdefinitionEnv}\else\begin{STdefinitionEnv}[\omtext@title]\fi\f
\ifx\sref@id\@empty\sref@label@id{here}\else%
\sref@label@id{\STpresent{\csname STdefinitionEnvKeyword\endcsname}~\@currentlabel}\fi%
\ignorespaces}
{\ifx\omtext@display\st@flow\else\end{STdefinitionEnv}\fi}
\def\st@definition@kw{Definition}
\theorembodyfont{\upshape}
\newtheorem{STdefinitionEnv}[STtheoremAssEnv]{\st@definition@kw}
```

`notation` We initialize the `\def\st@notation@initialize{}` here, and extend it with functionality below.

```
\def\notemph#1{#1}
\def\st@notation@terminate{}
\def\st@notation@initialize{}
\define@statement@env{notation}
\def\st@notation@kw{Notation}
\theorembodyfont{\upshape}
\newtheorem{STnotationEnv}[STtheoremAssEnv]{\st@notation@kw}
```

`\st@def@target` the next macro is a variant of the `\sref@target` macro provided by the `sref` package specialized for the use in the `\definiendum`, `\defi`, `\defii`, and `\defiii` macros. `\st@def@target{`⟨*opt*⟩`}{`⟨*name*⟩`}{`⟨*text*⟩`}` makes a target with label `sref@`⟨*opt*⟩`@`⟨*modulename*⟩`@target`, if ⟨*opt*⟩ is non-empty, else with the label `sref@`⟨*name*⟩`@`⟨*modulename*⟩`@target` (the first time it encounters this symbol; i.e. if `\sref@`⟨*name*⟩`@`⟨*modulename*⟩`@defined` is undefined). And it formats the `\defemph`-emphasized ⟨*text*⟩. Also it generates the necessary warnings for a definiendum-like macro.

```
\newcommand\st@def@target[3]{\def\@symname{#1}\def\@verbname{#2}%
\ifst@indef% if we are in a definition or such
\@ifundefined{mod@id}% if we are not in a module
{\PackageWarning{statements}{definiendum in unidentified module\MessageBreak
\protect\definiendum, \protect\defi,
```

```
\protect\defii, \protect\defiii\MessageBreak
can only be referenced when called in a module with id key}}%
{% now we are in a module
\edef\@@cd{\ifx\omtext@theory\@empty\mod@id\else\omtext@theory\fi}%
\edef\@@name{\ifx\@symname\@empty\@verbname\else\@symname\fi}%
\defemph{\@ifundefined{sref@\@@name @\@@cd @defined}%
{\expandafter\sref@target@ifh{sref@\@@name @\@@cd @target}{#3}}%
{#3}}%
\expandafter\gdef\csname sref@\@@name @\@@cd @defined\endcsname{yes}%
\ifmetakeys@showmeta\metakeys@show@keys{\@@cd}{name:\@@name}\fi}%
\else% st@inde:f we are not in a definition or such
\PackageError{statements}%
{definiendum outside definition context\MessageBreak
\protect\definiendum, \protect\defi,
\protect\defii, \protect\defiii\MessageBreak
do not make sense semantically outside a definition.\MessageBreak
Consider wrapping the defining phrase in a \protect\inlinedef}%
\fi}% st@indef
```

The `\definiendum` and `\notatiendum` macros are very simple.

`\@termdef` This macro is experimental, it is supposed to be invoked in `\definiendum` to define a macro with the definiendum text, so that can be re-used later in term assignments (see the `modules` package). But in the current context, where we rely on TEX groupings for visibility, this does not work, since the invocations of `\definiendum` are in `definition` environments and thus one group level too low. Keeping this for future reference.

```
\newcommand\@termdef[2][]{\def\@test{#1}%
\@ifundefined{mod@id}{}{\ifx\@test\@empty\def\@@name{#2}\else\def\@@name{#1}\fi%
\termdef{\mod@id @\@@name}{#2}}}
```

`\definiendum`

```
\addmetakey{definiendum}{name}
\addmetakey{definiendum}{lemma}
\newcommand\definiendum[2][]{\setkeys{definiendum}{#1}%
\st@def@target{\definiendum@name}{\definiendum@name}{#2}}
```

`\notatiendum` the `notatiendum` macro also needs to be visible in the `notation` and `definition` environments

```
\newcommand\notatiendum[2][]{\notemph{#2}}
```

We expand the LaTeXML bindings for `\defi`, `\defii` and `\defiii` into two instances one will be used for the definition and the other for indexing.

`\defi` We split the `\defi` macro in two: `\defi` does the definiendum bit and `\@defi` handles the last optional argument and does the indexing. The information flow between them goes via the local `\@phrase` macro.

```
\newcommand\defi[2][]{\st@def@target{#1}{#2}{#2}\def\@phrase{#2}\@defi}
\newcommand\@defi[1][]{\ifdef@index\omdoc@indexi[#1]{\@phrase}\fi\xspace}
\newcommand\defis[2][]{\st@def@target{#1}{#2}{#2s}\def\@phrase{#2}\@defi}
```

\adefi Again we split the \adefi macro into two parts: \adef does the definiendum bit and \@adefi handles the last optional argument and does the indexing.

```
\newcommand\adefi[3][]{\def\@name{#1}\def\@verb{#3}%
\st@def@target{#1}{#3}{#2}\@adefi}
\newcommand\@adefi[1][]{%
\ifdef@index%
\ifx\@name\@empty\omdoc@indexi[#1]{\@verb}%
\else\omdoc@indexi[at=\@name,#1]{\@verb}\fi%
\fi\xspace}
```

\defii

```
\newcommand\@defii[1][]{\ifdef@index\@twin[#1]{\@pone}{\@ptwo}\fi\xspace}
\newcommand\defii[3][]{\def\@pone{#2}\def\@ptwo{#3}%
\st@def@target{#1}{#2-#3}{#2 #3}\@defii}
\newcommand\defiis[3][]{\def\@pone{#2}\def\@ptwo{#3}%
\st@def@target{#1}{#2-#3}{#2 #3s}\@defii}
```

\adefii analogous to \adefi

```
\newcommand\adefii[4][]{\def\@name{#1}\def\@pone{#3}\def\@ptwo{#4}%
\st@def@target{#1}{#3-#4}{#2}\@adefii}
\newcommand\@adefii[1][]{%
\ifdef@index%
\ifx\@name\@empty\@twin[#1]{\@pone}{\@ptwo}%
\else\@twin[at=\@name,#1]{\@pone}{\@ptwo}\fi%
\fi\xspace}
```

\defiii similar to \defii

```
\newcommand\defiii[4][]{\def\@pone{#2}\def\@ptwo{#3}\def\@pthree{#4}%
\st@def@target{#1}{#2-#3-#4}{#2 #3 #4}\@defiii}
\newcommand\@defiii[1][]{\ifdef@index\@atwin[#1]{\@pone}{\@ptwo}{\@pthree}\fi\xspace}
\newcommand\defiis[4][]{\def\@pone{#2}\def\@ptwo{#3}\def\@pthree{#4}%
\st@def@target{#1}{#2-#3-#4}{#2 #3 #4s}\@defiii}
```

\adefiii

```
\newcommand\adefiii[5][]{\def\@name{#1}\def\@pone{#3}\def\@ptwo{#4}\def\@pthree{#3}%
\st@def@target{#1}{#3-#4-#5}{#2}\@adefiii}
\newcommand\@adefiii[1][]{%
\ifdef@index%
\ifx\@name\@empty\@atwin[#1]{\@pone}{\@ptwo}{\@pthree}%
\else\@atwin[at=\@name,#1]{\@pone}{\@ptwo}{\@pthree}\fi%
\fi\xspace}
```

\inlineex

```
\newcommand\inlineex[2][]{\metasetkeys{omtext}{#1}%
\sref@target\sref@label@id{here}#2}
```

\inlineass

```
\newcommand\inlineass[2][]{\metasetkeys{omtext}{#1}%
\sref@target\sref@label@id{here}#2}
```

\inlinedef

```
\newcommand\inlinedef[2][]{\metasetkeys{omtext}{#1}%
\if@in@omtext\else% we are not in an omtext or statement
\PackageError{modules}{\protect\inlinedef\space outside a statement!}%
{Try wrapping the paragraph in a\MessageBreak
\protect\begin{omtext}, \protect\begin{assertion}, \protect\begin{axiom}, ... \MessageBreak
whatever is suitable semantically}\fi%
\sref@target\sref@label@id{here}\st@indeftrue #2}
```

5.3 Cross-Referencing Symbols and Concepts

\termref `\termref{`⟨*opt*⟩`}{`⟨*text*⟩`}` makes a hyperlink with link text ⟨*text*⟩ to the definitional occurrence of the symbol specified by the `name`, `cd`, and `cdbase` keys in ⟨*opt*⟩. We first set sensible defaults if the keys are not given. If the symbol is defined in the current document (i.e. if the macro `\sref@`⟨*name*⟩`@`⟨*cd*⟩`@defined` is defined), then we make a local hyperref, otherwise we punt to `\mod@termref`.

```
\addmetakey*{termref}{cd}
\addmetakey*{termref}{cdbase}
\addmetakey*{termref}{name}
\addmetakey*{termref}{role}
\newcommand\termref[2][]{\metasetkeys{termref}{#1}%
  \ifx\termref@cd\@empty\def\termref@cd{\mod@id}\fi%
  \ifx\termref@name\@empty\def\termref@name{#2}\fi%
  \@ifundefined{sref@\termref@name @\termref@cd @defined}
  {\ifx\termref@cdbase\@empty% external reference
    \mod@termref\termref@cd\termref@name{#2}%
    \else\sref@href@ifh\termref@cdbase{#2}%
    \fi}%
  {\sref@hlink@ifh{sref@\termref@name @\termref@cd @target}{#2}}%
}
```

\tref*

```
\newcommand\atrefi[3][]{\def\@test{#1}%
\ifx\@test\@empty\termref[name=#3]{#2}\else\termref[cd=#1,name=#3]{#2}\fi}
\newcommand\atrefii[4][]{\atrefi[#1]{#2}{#3-#4}}
\newcommand\atrefiii[5][]{\atrefi[#1]{#2}{#3-#4-#5}}
```

\tref*

```
\newcommand\trefi[2][]{\atrefi[#1]{#2}{#2}}
\newcommand\trefii[3][]{\atrefi[#1]{#2 #3}{#2-#3}}
\newcommand\trefiii[4][]{\atrefi[#1]{#2 #3 #4}{#2-#3-#4}}
\newcommand\trefis[2][]{\atrefi[#1]{#2s}{#2}}
\newcommand\trefiis[3][]{\atrefi[#1]{#2 #3s}{#2-#3}}
\newcommand\trefiiis[4][]{\atrefi[#1]{#2 #3 #4s}{#2-#3-#4}}
```

Now we care about the configuration switches, they are set to sensible values, if they are not defined already. These are just configuration parameters, which should not appear in documents, therefore we do not provide LaTeXML bindings for them.

*emph

```
\providecommand{\termemph}[1]{#1}
\providecommand{\defemph}[1]{{\textbf{#1}}}
\providecommand{\stDMemph}[1]{{\textbf{#1}}}
```

EdN:7

\term The \term macro is used for wiki-style dangling links with editor support.[7]

```
\newcommand\term[2][]{\def\@test{#1}%
\ifx\@test\@empty\else
\@ifundefined{module@defs@#1}{\PackageWarning{statements}%
{{\protect\term} specifies module #1 which is not in
  scope\MessageBreak import it via e.g. via \protect\importmhmodule}}{}
\fi%
\PackageWarning{statements}%
{Dangling link (\protect\term) for "#2" still needs to be specified}%
\textcolor{blue}{\underline{#2}}}
```

\symref The \symref macros is quite simple, since we have done all the heavy lifting in the modules package: we simply apply \mod@symref@⟨*arg1*⟩ to ⟨*arg2*⟩.

```
\newcommand\symref[2]{\@nameuse{mod@symref@#1}{#2}}
```

5.4 Deprecated Functionality

In this section we centralize old interfaces that are only partially supported any more.

def

```
\newcommand\defin[2][]{\defi[#1]{#2}%
\PackageWarning{statements}{\protect\defin\space is deprecated, use \protect\defi\space instead
\newcommand\twindef[3][]{\defii[#1]{#2}{#3}%
\PackageWarning{statements}{\protect\twindef\space is deprecated, use \protect\defii\space inst
\newcommand\atwindef[4][]{\defiii[#1]{#2}{#3}{#4}%
\PackageWarning{statements}{\protect\atwindef\space is deprecated, use \protect\defiii\space in
\newcommand\definalt[3][]{\adefi[#1]{#2}{#3}%
\PackageWarning{statements}{\protect\definalt\space is deprecated, use \protect\adefi\space ins
\newcommand\twindefalt[4][]{\adefii[#1]{#2}{#3}{#4}%
\PackageWarning{statements}{\protect\twindefalt\space is deprecated, use \protect\adefii\space
\newcommand\atwindefalt[5][]{\adefiii[#1]{#2}{#3}{#4}{#5}%
\PackageWarning{statements}{\protect\atwindefalt\space is deprecated, use \protect\adefiii\spac
```

def

```
\newcommand\twinref[3][]{\trefii[#1]{#2}{#3}%
\PackageWarning{statements}{\protect\twinref\space is deprecated, use \protect\trefii\space ins
\newcommand\atwinref[4][]{\atrefiii[#1]{#2}{#3}{#4}%
\PackageWarning{statements}{\protect\atwindef\space is deprecated, use \protect\trefiii\space i
⟨/package⟩
```

[7] EdNote: MK: document above

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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.

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