MMT is **foundation-independent**:

1. Developer defines new logic
2. MMT yields complete MKM system for it

MMT is **application-independent**:

- No single MMT application
- Instead: focus on data model, interfaces, generic services
- Logical: parsing, type-checking, module system, ...
- MKM: change management, querying, presentation, ...
- Applications developed on top

Formal editing: jEdit-MMT

navigation, hyperlinking,
auto-completion, tooltips, ...

Narrative editing: LaTeX-MMT

formulas processed by MMT –
type-checking, cross-references, ...

Browsing: MMT web server

definition lookup, type inference
theory graphs, ...

Building: MMT scripting language

easy import/export interfaces
MMT services as build tasks

The MMT API: A Generic MKM System

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CICM System Description (S&P Track), July 2013

See `https://trac.kwarc.info/MMT` for papers, source code, etc.

MMT Overview

- Universal framework for formal mathematical/logical content
- Continuous development since 2007 [5]
- Close relatives
  - logical frameworks like LF, Isabelle
    but: even more generic, knowledge management, more system integration
  - OMDoc/OpenMath
    but with formal semantics, more automation
- MMT System:
  - MMT data structures
  - logical and knowledge management services
  - $\sim$ 10 CICM papers on individual services
  - various individual applications utilizing the services
  - $\sim$ 30,000 lines of Scala code total

Central Idea: Foundation-Independence

1. We can fix and implement a logical theory — e.g., set theory
2. We can fix and implement a logic
   then define many theories in it — e.g., first-order logic
3. We can fix and implement a logical framework
   then define many logics in it — the foundation, e.g., LF
4. We can fix and implement a meta-framework
   then define many logical frameworks in it
   foundation-independence: MMT

Highly Reusable Results through Foundation-Independence

- Conceptual
  - intuitions, documentation, teaching
  - definitions, meta-theorems
  - algorithms
- Knowledge management
  - editing, parsing
  - change management [2]
  - project management, distribution [1]
  - search, querying [4]
  - interactive browsing
  - system integration, semantic interfaces
- Logical
  - module system, namespace management [5]
  - type reconstruction
  - computation [3]

MMT Design Methodology

1. Choose a typical problem

   logical: e.g., type reconstruction, module system

   MKM: e.g., change management, querying

2. Survey and analyze the existing solutions
3. Differentiate between foundation-specific and foundation-independent definitions/theorems/algorithms
4. Integrate the foundation-independent aspects into MMT

   language and system

5. Define interfaces to supply the logic-specific aspects

   formal theory and plugin interfaces

6. Repeat

MMT Language Features

few primitives . . . that unify different domain concepts

- Judgments as types, proofs as terms
  unifies expressions and derivations
- Higher-order abstract syntax unifies operators and binders
- Category of theories
  unifies logical theories, logics, foundations
  - languages as theories
  - relations as theory morphisms
- Module system (little theories)
  unifies inheritance and representation theorems
- Models as morphisms (categorical logic)
  unifies syntactical translations and semantic interpretations

A Small Formalization Example in MMT

The logical framework LF in MMT:

```
theory Types { type }
theory LF {include Types, Π, →, λ, @ }
```

First-order Logic defined in MMT/LF:

```
theory Logic meta LF {o: type, ded : o → type }
theory FOL meta LF {
  include Logic
  u: type. imp: o → o → o, ...
}
```

Algebraic theories in MMT/LF/FOL:

```
theory Magma meta FOL { ∘: u → u → u }
...
theory Ring meta FOL {
  additive: CommutativeGroup
  multiplicative: Semigroup
  ...
}
```

Key Idea: Application-independence

1. No a-priori commitment to a particular application
2. Focus on API for MMT data model
3. Abstraction from physical storage
   MMT works with file systems, databases, remote servers
4. Abstraction from user interfaces
   MMT provides API, HTTP, shell interfaces
5. Advanced functionality as independent, reusable services
   parsing, type-checking, presentation, ...
   that are customized by plugins
   typing rules, presentation styles, ...

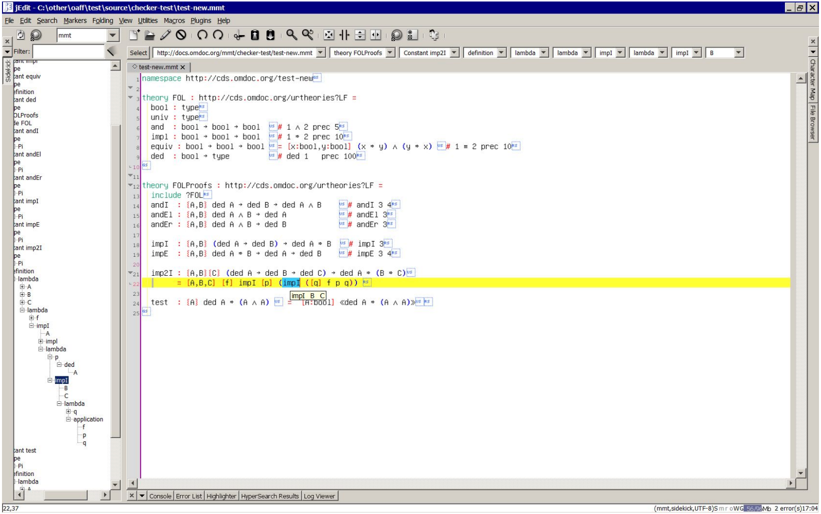
Individual applications are built flexibly on top of the API.

Application Example: Editing

- IDE-like editor for MMT projects
- MMT acting as a plugin for jEdit text editor
- MMT handles data model aspects
  - parsing (based on plugins, notations)
  - type checking (based on plugins for typing rules)
  - auto-completion suggestions
- jEdit handles GUI aspects
  - outline view
  - error highlighting
  - hyperlinks (= click on operator, jump to declaration/definition)
  - context-sensitive auto-completion: show identifiers that
    - are in scope
    - have the right type

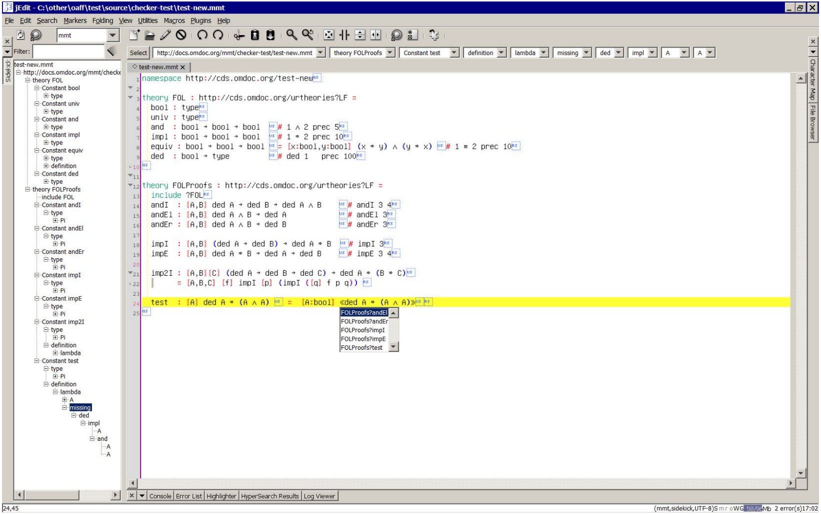
Application Example: Editing

Example feature: pop up shows reconstructed arguments



Application Example: Editing

Example feature: auto-completion shows only identifiers that are in scope and have the right type



Application Example: Mathematical Documents

- Unified document format LaTeX-MMT
- Processed by LaTeX
- MMT-relevant aspects represented in special macros
  - mmt.sty sends them to MMT via HTTP during compilation
  - MMT returns LaTeX snippet, which LaTeX processes further
- MMT processing includes
  1. parsing
  2. type reconstruction
  3. generation of high-quality LaTeX that includes
     - reconstructed information
     - cross-references
     - tooltips

Application Example: Mathematical Documents

- upper part: LaTeX-MMT source for highlighted line
- lower part: pdf after compiling with LaTeX-MMT
- enhanced LaTeX features generated by MMT
  - type argument M of equality symbol is inferred and added
  - cross-references from each symbol to its definition (works across pdfs)

```
\begin{mmtscope}
 For all \mmtvar{x}{in M},\mmtvar{y}{in M},\mmtvar{z}{in M}
 it holds that !(x * y) * z = x * (y * z)!
\end{mmtscope}
```

A *monoid* is a tuple $(M, \circ, e)$ where

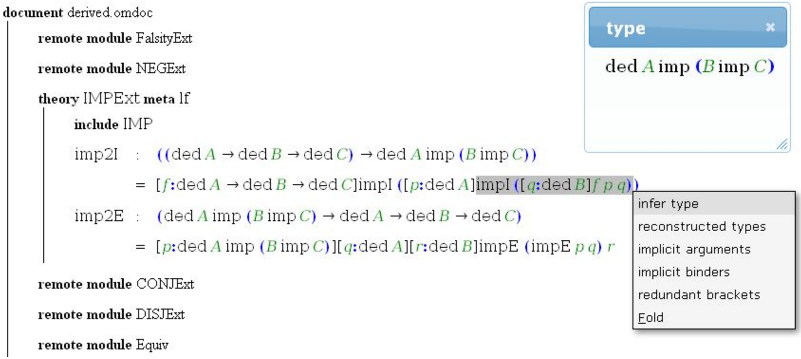
- M is a sort, called the universe.
- $\circ$ is a binary function on M.
- e is a distinguished element of M, the unit.

such that the following axioms hold:

- For all x,y,z it holds that $(x\circ y)\circ z =_M x\circ(y\circ z)$
- For all x it holds that $x\circ e =_M x$ and $e\circ x =_M x$.

Application Example: Interactive Browsing

- MMT API exposed through HTTP server
- Javascript/Ajax for interactive browsing of MMT projects
  e.g., definition lookup, dynamic type inference
- Interactive graph view based on SVG



Application Example: Build Tool

MMT chains build steps on MMT projects

- Import MMT native syntax, Twelf, Mizar, OWL, TPTP, ...
- Computation
  - validation, type reconstruction
  - flattening
- Indexing
  - theory graph
  - document hierarchy
  - substitution tree of formulas (via MathWebSearch)
  - relational index (MMT ontology)
- Export
  HTML+presentation MathML, SVG diagrams, Scala code [3], ...

Videos

- Editing (jEdit-MMT)

  outline view, error highlighting, smart auto-completion
  display of inferred information, hyperlinking

  `http://youtu.be/tdd45Uv7j_g` (left QR code)

- Interactive browsing (MMT web server)

  semantic highlighting, showing reconstructed information
  dynamic type inference, navigation, theory graph display

  `http://youtu.be/MPTzW86voI4` (right QR code)

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[4] F. Rabe.
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[5] F. Rabe and M. Kohlhase.
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Information and Computation, 2013.
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