



Integrating the Text-Editor $\text{T}_{\text{E}}\text{X}_{\text{MACS}}$ with the Proof Assistance System Ω MEGA using PLAT Ω

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Research Goals

Background: Artificial Intelligence, Formal methods, deduction (especially, Inductive Theorem Proving)

- The potential of using formal logic based techniques is clearly recognized (mathematics, reliability of software systems, . . .)
- Formal logic based tools are not routinely employed like, for instance, CAS by mathematicians, physicists or engineers.
- Two reasons:
 - ▶ the high hurdle posed by the deep formal logical knowledge that is necessary to effectively use these techniques and tools
 - ▶ that the formal techniques and tools are not integrated with standard (software) development environments.

Past and Ongoing Research



Semantics-based management of change:

- Evolutionary nature of specification and verification: MAYA
 - ▶ Development graphs to represent and exploit theory structure (now semantics for theories and locales in Isabelle)
 - ▶ Difference Analysis & Propagation of changes to preserve proof knowledge

with D. Hutter and T. Mossakowski

- Offspring: Semantics based XML difference computations
(Masters, S. Radzevich)

with D. Hutter

Past and Ongoing Research



Usability of formal reasoning tools:

- Assertion-Level (Huang'93) reasoning
 - ▶ (CoRE calculus, PhD 2003)
 - ▶ Tasklayer of the new version of the proof assistant Ω MEGA (Diploma thesis D. Dietrich)
- The next version of the Ω MEGA Proof assistant (Project in CRC "Ressource-adaptive cognitive processes (SFB-378)")
- Integrating reasoning systems as Web Services: MATHSERVE (PhD J. Zimmer)
- Automated reasoning in large structured theories: ATLAS
EPSRC Visiting Researcher (with A. Bundy and R. McCasland)

Past and Ongoing Research

Augmenting authoring and development environments by formal techniques:

- Evolution of computer-supported mathematics (and hence to all areas that employ mathematics)
- Low user-friendliness of actual proof assistants
- Interfacing scientific text-editors instead of yet another proof assistant GUI (Project VeriMathDoc (with A. Fiedler) and Diploma thesis M. Wagner)



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Brings together research developments and experience from

- Evolutionary software development (MAYA),
- Semantics-based XML-DIFF,
- Proof construction at the assertion-level (CoRE, Tasklayer)



example-dynamic.tm

File Edit Insert Text Format Document View Go Tools Help Plato

PLATΩ

E S V S NA

————— 1 - [Simple Sets] —————

This theory defines the basic concepts and properties of the Theory of Simple Sets.

Definition 1.1 [Type of Elements] :
First of all we define the type **elem**.

Definition 1.2 [Type of Sets] :
Then we define the type **set**.

Definition 1.3 [Function \in] :
The function $\in_{\text{elem} \times \text{set}} \rightarrow \text{bool}$ takes an individual and a set and tells whether that individual belongs to this set.

Notation 1.4 :
Let x be an individual and A a set, then we write
 $x \in A$, x is an element of A , x is in A or A contains x .

Definition 1.5 [Function \subset] :
The function $\subset_{\text{set} \times \text{set}} \rightarrow \text{bool}$ takes two sets and tells whether the first set is a subset of the second set.

Notation 1.6 :
Let A and B be sets, then we write $A \subset B$.

article plato menus text roman 10 pl-document pl-theory start

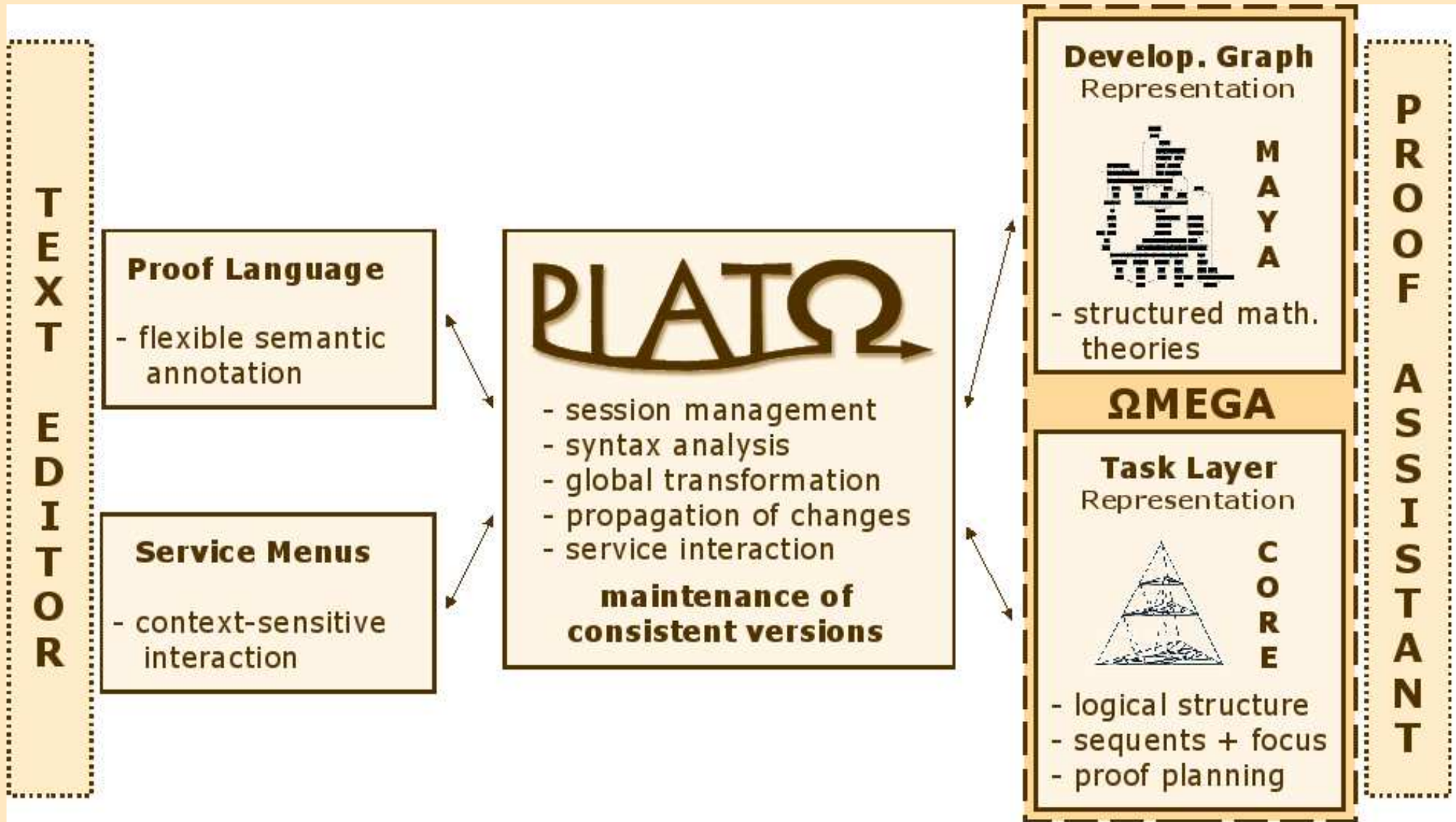
System Architecture





The Mediator PLATΩ

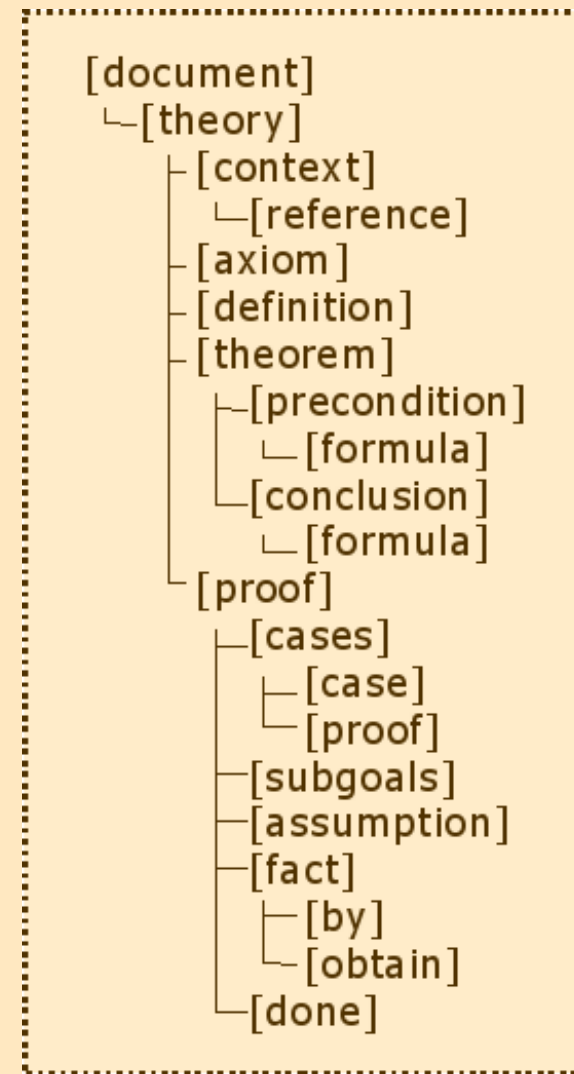
Mediation Problem



Document Language



- **Semantic Annotation of Natural Language**
 - ▶ Macros in the text-editor
 - ▶ Individual layout style
- **Designed to support**
 - ▶ Textual structure of proofs
 - ▶ Flexible and multiple positioning
 - ▶ Underspecification
 - ▶ Alternative proof attempts
- **Parameters**
 - ▶ (Sub-)Languages for formulas, definitions and references



Global Transformation



- Normalizing the flexible semantic annotations
- Separating proofs from theory knowledge
- Transforming linear proofs into the tree-like proof structure

Proof Language (PL)

- ▶ Theorems (flexible)
- ▶ Proofs (flexible, linear)
- ▶ Natural language text

Intermediate Language (IL)

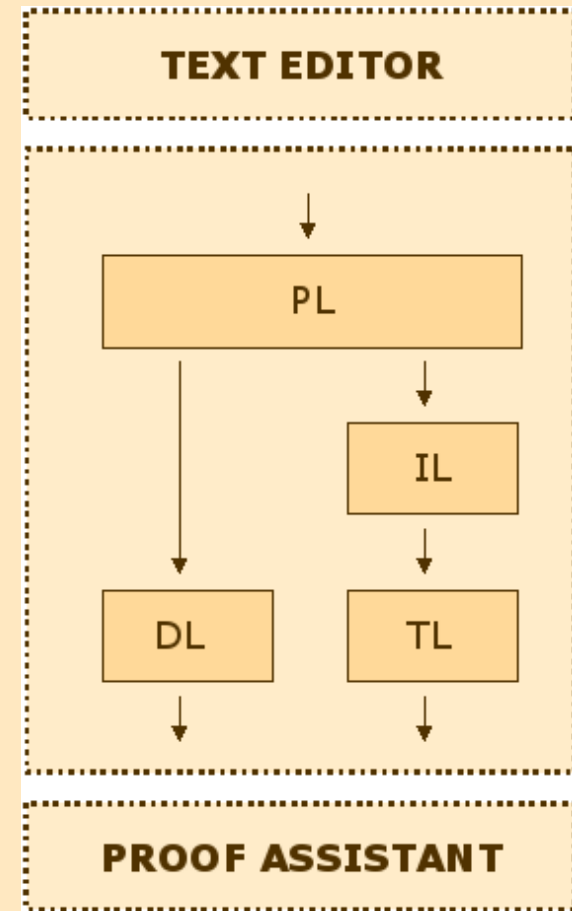
- ▶ Proofs (rigid, linear)

Development Graph Language (DL)

- ▶ Theorems (rigid)

Task Language (TL)

- ▶ Proofs (rigid, tree)



Propagation of Changes

- Semantic-based difference computation
- Efficient transformation of differences
- Preserve partial verifications in proof datastructure of PA

Proof Language (PL)

- ▶ Theorems (flexible)
- ▶ Proofs (flexible, linear)
- ▶ Natural language text

Intermediate Language (IL)

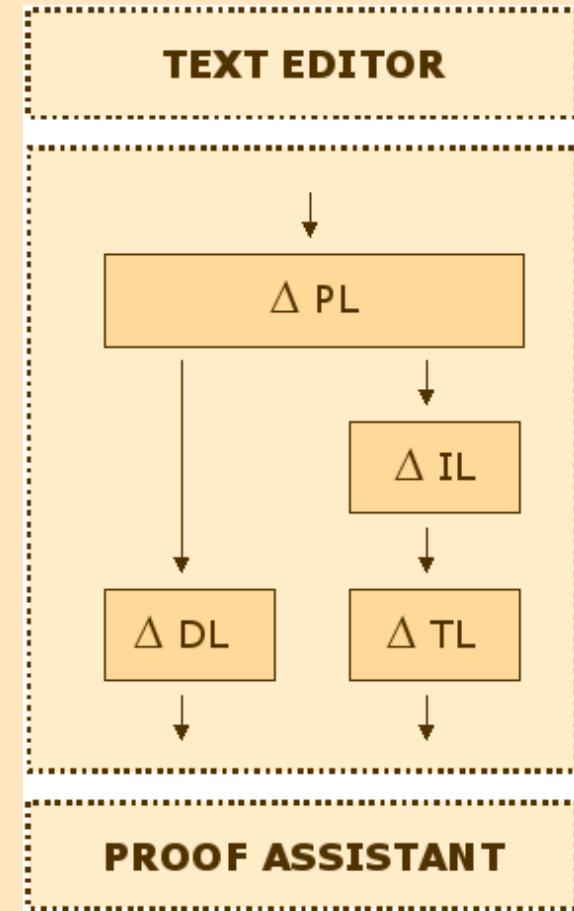
- ▶ Proofs (rigid, linear)

Development Graph Language (DL)

- ▶ Theorems (rigid)

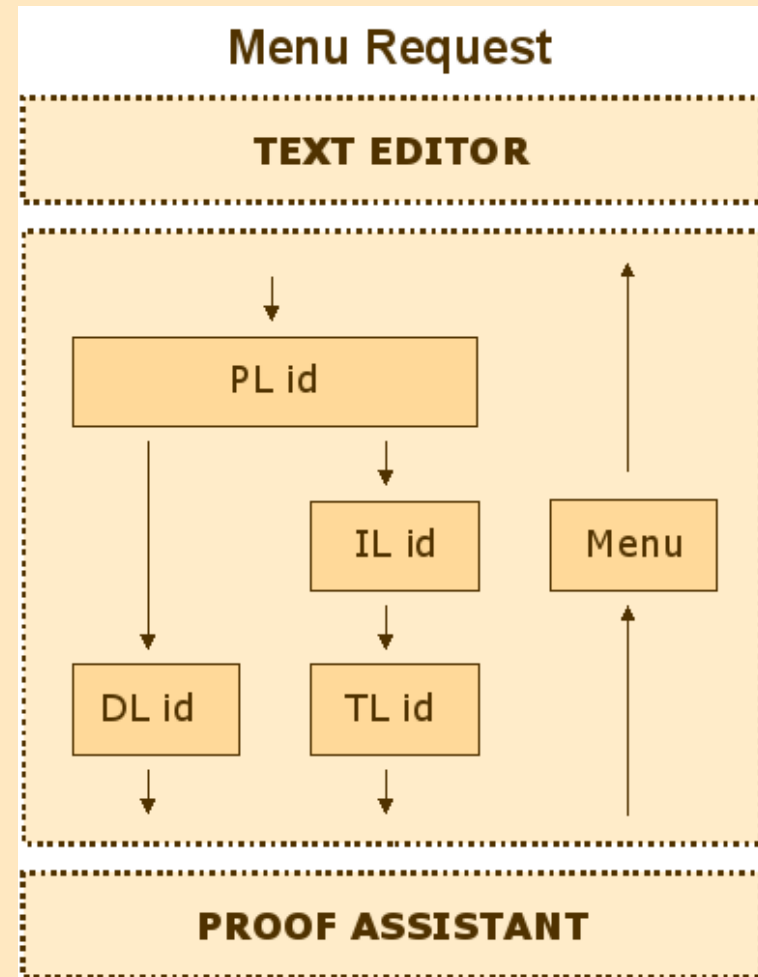
Task Language (TL)

- ▶ Proofs (rigid, tree)



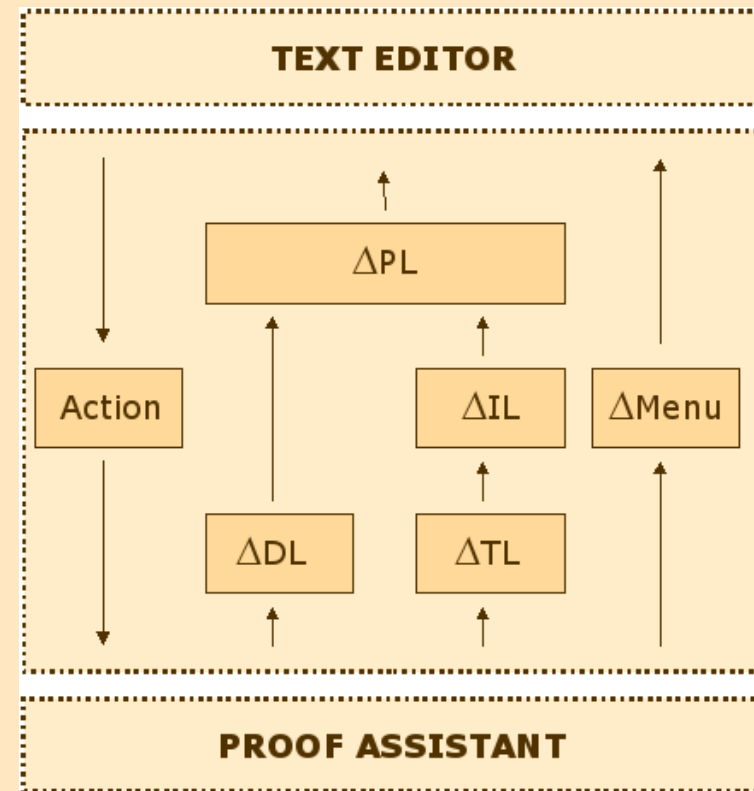
Service Interaction: Requesting a Menu

- The user selects object in the text-editor
- Lookup all related objects in the mappable of the transformation
- Request a menu from the PA for these objects
- Display the menu in the text-editor



Service Interaction: Executing Actions

- User selects an action and its arguments in the menu
- Evaluate this action in the proof assistance system
- Evaluation result:
 - ▶ Patches to the menu differences (nested evaluation)
 - ▶ Patches to the DL and TL documents (top level evaluation)
- Transformation of DL/TL patches into PL patches



The Mediator PLATΩ



- XML-RPC server as interface for the text-editor
- Connection to proof assistant in Lisp
- Operating as online webservice or local plugin

The Plugin in T_EX_{MACS}



Rôle of the Plugin

- Key and session management
- Patch applications on the $\text{T}_{\text{E}}\text{X}_{\text{MACS}}$ document
- Resolve and check references ... by [Definition of \subseteq] ...
- Communicates with $\text{PLAT}\Omega$ by fully annotated documents
- Manually writing a fully annotated document is tedious
 - ▶ Have a context sensitive menu to write the annotations
 - ▶ May be acceptable for the user to write large structures (begin definition, theorem, proof, etc.)
 - ▶ But certainly not for formulas ...
 - To obtain: $x \in U \Rightarrow x \in V$
 - Write:

$\backslash\text{imp}\{\backslash\text{in}\{\backslash\text{V}\{\mathbf{x}\}\}\{\backslash\text{V}\{\text{U}\}\}\}\{\backslash\text{in}\{\backslash\text{V}\{\mathbf{x}\}\}\{\backslash\text{V}\{\text{V}\}\}\}$

Writing Formulas

- Use a parser for formulas
- Allow the user to define its own syntax for any concepts

```
\notation{for=in}{  
Let \declare{x} be an element and \declare{A} be a set.  
Then we write \denote{x \in A}, \denote{x is in A},  
\denote{x is element of A}, or \denote{A contains x}.
```

Notation. Let x be an element and A be a set. Then we write $x \in A$, x is in A , x is element of A , or A contains x .

- Procedure:
 - ▶ Scan all notation definitions, convert automatically into parser grammar rules
 - ▶ Using parser generator create (document) specific parser
 - ▶ Use that parser to parse formulas

The Parser Generator

- Standard LALR(1) parser generator implemented in Scheme
- Creates parser that generates all possible readings
- Allows specification of external call-backs to use to single-out invalid readings.
Example: Could be used to integrate a “refiner”
- Sophisticated specification mechanism for precedences of operators

The Interface of the Proof Assistant



Features of the Proof Assistant

- Create inference rules from axioms/lemmas

Example: $\forall A, B : set. (A \subseteq B \wedge B \subseteq A) \Rightarrow A = B$

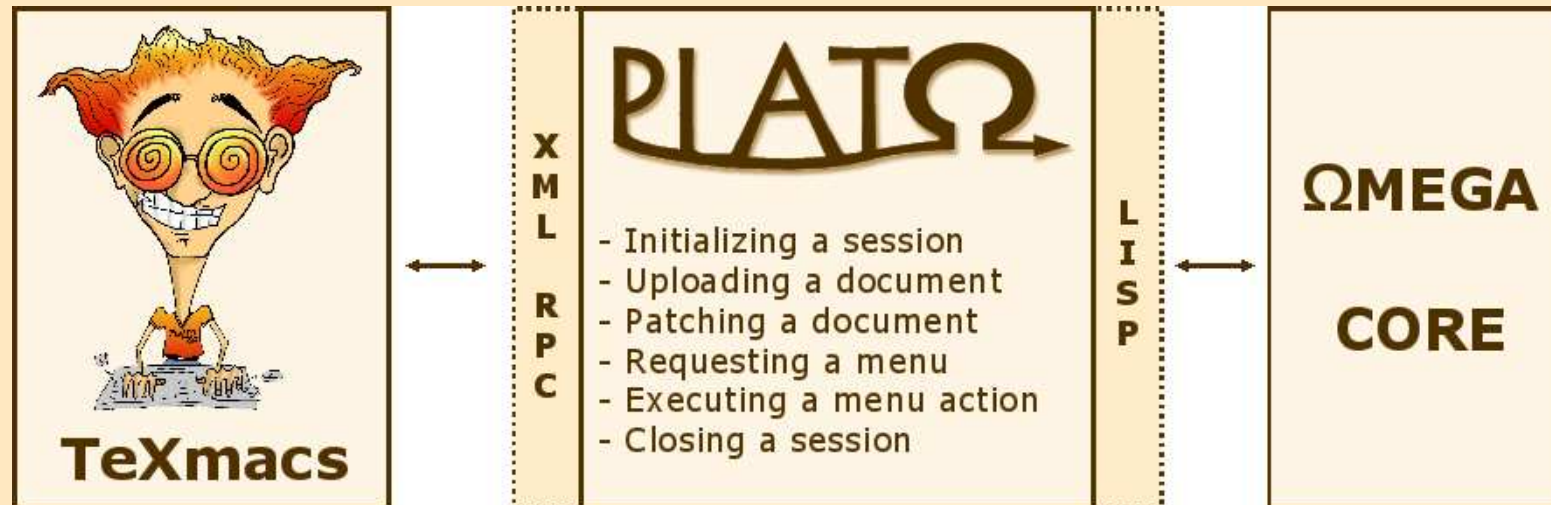
$$\frac{A \subseteq B \quad B \subseteq A}{A = B}$$

Mixture of CoRE ideas and B. Wacks' super natural deduction

- Proof construction on that level (assertion level)
- Requires proof representation that allows encoding of proof continuations
- Every (additional) feature of the PA is immediately available on the corresponding text part.

Example: Automatic Theory Exploration System MATHSAID

System Demo



- Definition of concepts and their notations
- Writing Axioms, Conjectures using pre-defined and user-defined notations
- Proof support: interactive and automatic

Related Work

- **Automath, Mizar, Isar:**
 - ▶ Balanced compromise between machine processable and human readable
- **Grammatical Framework:**
 - ▶ Framework to define grammar for an abstract and a concrete syntax
- **PCOQ:**
 - ▶ Schematic quasi-natural language output
- **Nuprl, Clam, Omega/P.Rex:**
 - ▶ Natural language processing technique to generate proof descriptions

Related Work

- **Theorema:**

- ▶ Strictly separated formal and informal parts

- **Mathlang:**

- ▶ Top-down from natural language
- ▶ Use annotations for structure, no parser as well
- ▶ Still even more far away from PAs

- **ProofGeneral:**

- ▶ Top-down processing of documents
- ▶ Documents are input format of PA rather than of some typesetting program.

Conclusion



- **Have a stable connection between $\text{T}_{\text{EX}}_{\text{MACS}}$ and ΩMEGA**
 - ▶ PLAT Ω deals with all mediating (translation, consistency, patching, relationship between parts of text and formal parts in PA, menus)
 - ▶ Clean interface to text-editor
 - ▶ Parameterized over language for formulas, definitions and references
- **Either side can be enhanced without affecting the mediator**
 - ▶ PLAT Ω plugin:
 - User-definable notation used when parsing formulas
 - Add more NL analysis to automatically annotate text(parts)
 - Add NL generation (incremental)
 - ▶ ΩMEGA :
 - Added theory exploration, classical ATPs are available
 - Increase proof search automation

Future Work



■ Technicalities:

- ▶ XML-RPC Interface for PAs (OMDOC based)
- ▶ Asynchronous communications

■ Editing:

- ▶ Library mechanism
- ▶ Dependent types (Scunak, ΩMEGA'07, others are welcome)
- ▶ Support overloading
- ▶ More natural language analysis and NL generation
- ▶ Semantics-based versioning, collaborative editing

■ Proof support

- ▶ Automation of proof search at the assertion-level
- ▶ Exploit structure of and in theories to enhance automatic proof search

Future Work

