
SPASS-XDB

Automated Reasoning with World Knowledge

by

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With help from a bunch of people, particularly ...

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Abstract

SPASS-XDB

Automated Reasoning with World Knowledge

Introduction 🍩

- Automated Theorem Proving - [What is it?](#), [What is it Good For?](#)
- [Motivation - Commonsense Reasoning](#)
- [Problem - Large Theories](#) with **(too) many axioms**
- [Solution - External Axioms](#)

Design and Implementation 🏗️

- [System Design and Architecture](#)
- [SPASS-XDB Implementation](#)
- [External Sources](#)

Testing and Application 🖥️

- [Testing](#)
- [SporcleAI](#)
- [New External Sources](#)

Conclusion 🎉

The End - Any Questions?

And now, [A Word from My Sponsor](#)



Commonsense Reasoning

"Reasoning methods that exhibit the features of human thinking"

Application Domains

- Reasoning over ontologies
- Question answering
- Planning
- Education
- Personalization

The Nature of the Reasoning

- Large theories (many symbols, many axioms, many theorems)
- Human expectations (fast reasoning, friendly interfaces, world knowledge)
- Inconsistent, uncertain, imprecise, temporal, incomplete ... (aaaargh)
- Unnecessary axioms (how to choose the right few)
- Short and simple arguments (easy once you have the axioms)



Reasoning with World Knowledge

- Commonsense reasoning with the plethora of facts
 - Example systems
 - SPASS-XDB, CYC, SigmaKEE, LogAnswer, NAGA, Open Mind, TrueKnowledge, Watson, HALO, ...
 - NOT Google, Wikipedia, Bing, WolframAlpha, ...
 - Example deployments
 - [TrueKnowledge](#), [START](#), [askHERMES](#), [LogAnswer](#) [SporcleAI](#)
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Large Theories and World Knowledge

Large Theories

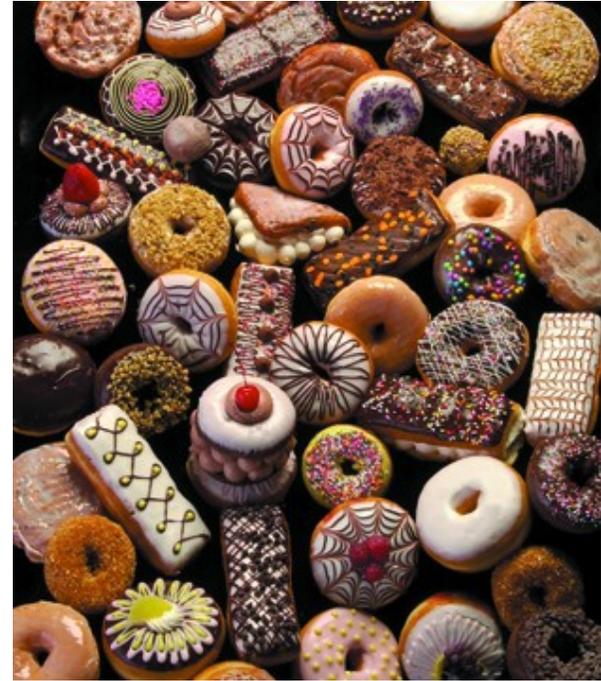
- Many functors and predicates, many (common) axioms, many theorems 📄
- SUMO, Cyc, Mizar, YAGO, Wikipedia, WordNet, MeSH, DBPedia, CIA Factbook, GenBank ...
- Different challenges for ATP
 - Parsing and building data structures
 - Loading and preprocessing the common axioms only once
 - Selecting axioms that are likely to be useful
 - Extracting heuristics and lemmas from proofs

Infinite Theories

- Dynamic and computational sources of axioms
- Mathematica, HR, XchangeRates, Weather, AGInT, ...
- Infinite number of "axioms" 📄

The State-of-the-Art in ATP

- Large theories only a recent focus
- Few systems can load and reason with millions of axioms 📄
- No system can load an infinite number of axioms 📄



External Axioms

This Work

- Accessing *external sources of axioms* from ATP 
- Axioms not loaded/stored in the ATP system
- Axioms retrieved on demand from external sources
- Further challenges
 - Specifying availability of external axioms
 - Retrieving and integrating external axioms
 - Adapting ATP to axioms arriving during reasoning

Previous work

SPASS-XDB

- On-demand, asynchronous, retrieval of external axioms for a common ATP system design
- Unifying syntax and protocols, based on de facto standards (TPTP)
- Implemented in a state-of-the-art ATP system
- Implemented external sources - SQL, SPARQL, Prolog, WWW, Computation
- Testing and deployment to demonstrate capability 



System Design and Architecture

The Nature of External Axioms

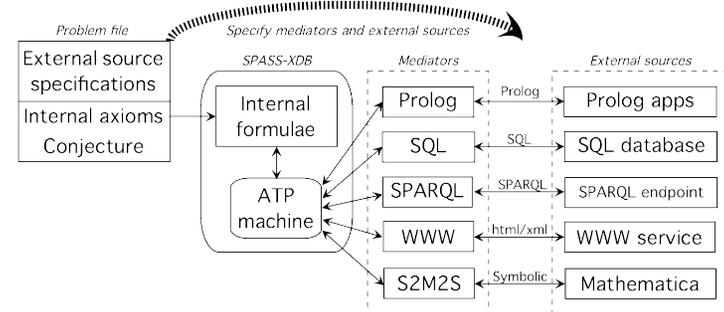
- External axioms are positive ground facts
- External axioms are consistent, certain, precise, non-temporal
- External axioms can be repeated
- Retrieval from external sources can be incomplete
- External sources are comparatively slow

ATP's Use of External Axioms

- External axioms requested on demand
- External axioms delivered in batches
- External axioms requested and delivered asynchronously
- No constraints on external source technology

System Architecture

- Based on SPASS' classic given-clause architecture
- Problem specification includes external specifications
- External axioms requested based on chosen clause literals
- Requests and deliveries are mediated
- External axioms integrated into the "Usable" list
- External requests are never duplicated
- [TPTP-based syntax and protocols](#)



SPASS-XDB Implementation

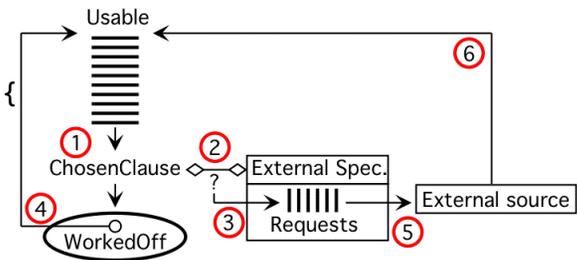
Algorithm

```
while (!Solved && (Usable || DeliveryPending || RequestQueue)) {  
  repeat {  
    Accept deliveries, add to Usable;  
    Dequeue requests and send  
    if (!Usable && DeliveryPending) sleep(1);  
  until (Usable || !DeliveryPending);  
  if (!Usable) break;  
  Move ChosenClause from Usable to WorkedOff;  
  Enqueue requests for negative literals of ChosenClause  
  Do relaxed-extended inferencing with ChosenClause  
}
```

- Points to note

Controls on Retrieval

- Universal quantification in external specifications
- `xdb(limit,*)` terms
- `xdb(group,*)` terms



External Sources

- **Amazon:** Facts about products, especially books.
- **DBpedia:** Curated data from Wikipedia, from a SPARQL endpoint. Requires translation server for URLs.
- **Linked Movie Database:** Information about movies, from SPARQL + translation.
- **City information:** Latitude, longitude, etc., for a city, from Yahoo and GeoNames.
- **Mondial:** CIA Factbook geographic information, from an XML fact file.
- **YAGOSUMO:** About 14.5 million facts, compatible with SUMO. Stored in an SQL database.
- **Weather:** Weather for location, and city with weather, from Yahoo.
- **Xchange:** Converts one currency to another, from Time Genie
- **Arithmetic:** SOLUTIONS to conjunctive requests, by Mathematica.
- **Babelfish:** Natural language translation, provided by Yahoo.
- **LookDifferent:** Checks for syntactic difference. Controlled implementation of UNA.
- **RegExp:** Matching regular expressions, in Perl.
- **PrintTTY:** Axioms with output as a side effect. No axioms with output for continued search.
- **Twitter:** Axioms with tweets as a side effect.
- **XDB Translator:** Aimed at internal translation of terms, but can be used explicitly.
- [Online Access](#)



Testing

Abraham Lincoln is a Mammal

- *Prove that Abraham Lincoln is a mammal*
- YAGOSUMO facts and SUMO ontology (internal)
- 188 requests queued, 175 sent, 266 axioms delivered, 1 axiom used
- 15s CPU, 18s WC. 5863 clauses derived.

An Early 18th Century Composer

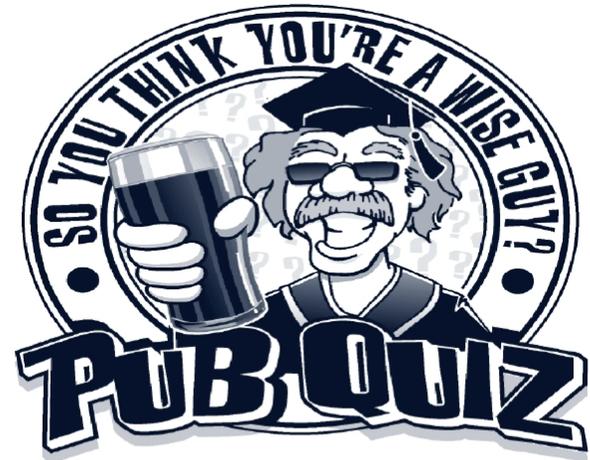
- *Name a composer born in the first half of the 18th century*
- YAGOSUMO facts, Arithmetic
- 515 requests queued, 427 sent, 456 axioms delivered, 2 axioms used
- 18s CPU, 26s WC. 7600 clauses derived.

Prize Winning Curies

- *Name all Nobel prizes won by members of the Curie family*
- YAGOSUMO facts
- 32 requests queued, 32 sent, 31 axioms delivered, 11 axioms used
- 2s CPU, 14s WC. 10 clauses derived.

An OECD Capital at the Same Latitude as Moscow that could get Flooded

- *Name an OECD country's capital that is at the same latitude as Moscow (to the nearest degree), that could get flooded*
- Needs preemptive requests for axioms ($-IAN_0=0$)
- YAGOSUMO facts, Yahoo map services, Arithmetic, Syntactic difference SUMO ontology (internal)
- 230 requests queued, 227 sent, 321 axioms delivered, 11 axioms used
- 3s CPU, 19s WC. 1047 clauses derived.



SporcleAI

Mentally Stimulating Diversions

- Questions by the people, for the people
- Automated player
- SPASS-XDB used a backend knowledge provider
- [Online access](#)

Architecture

- GreaseMonkey scripts
- SporcleAI server
- NLP by string hacking and ACE translation
- Two backend knowledge providers

Illustrative Results

Quiz topic	Solutions	Time
US state capitals	50/50	7:33/10:00
Countries of the world	149/195	7:45/15:00
Floodable world capitals	36/36	3:34/10:00
Words ending with 'ACE'	15/16	0:21/4:00
Greek gods and goddesses	11/12	0:15/5:00
Actor by movie	6/30	6:00/6:00



New External Sources

Mathematica

- Built-in arithmetic does ground evaluation
- Mathematica as a source of arithmetic axioms
- Accepts conjoined requests, of all relevant literals
- Returns axiom for first literal
- Allows SPASS-XDB to enter TFA division of CASC

Web Search

- The obvious thing to do
- Query search engine, match results with template, build axiom
- Currently limited to unary and binary predicates
- Leverage search engines, and still provide answers



Conclusion, Current and Future Work

Contributions

- Analysis of issues of accessing external axioms from ATP
- Design, implementation, and testing of working system
- New capability for ATP

Current and Future Work

- Natural language (ACE) input and output (*Partly done!*)
 - Ontology axiom selection using SInE (*Student failed!*)
 - Automatic alignment of terminology between external sources (*Some parts done!*)
 - Automatic configuration of control features (*Not done*)
 - Theoretical properties for ATP system (*Not done*)
 - Question answering using TPTP standards (*Externally done!*)
 - Make it play [Trivial Pursuit!](#)
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