Event-B & Cloud Provers

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Outline

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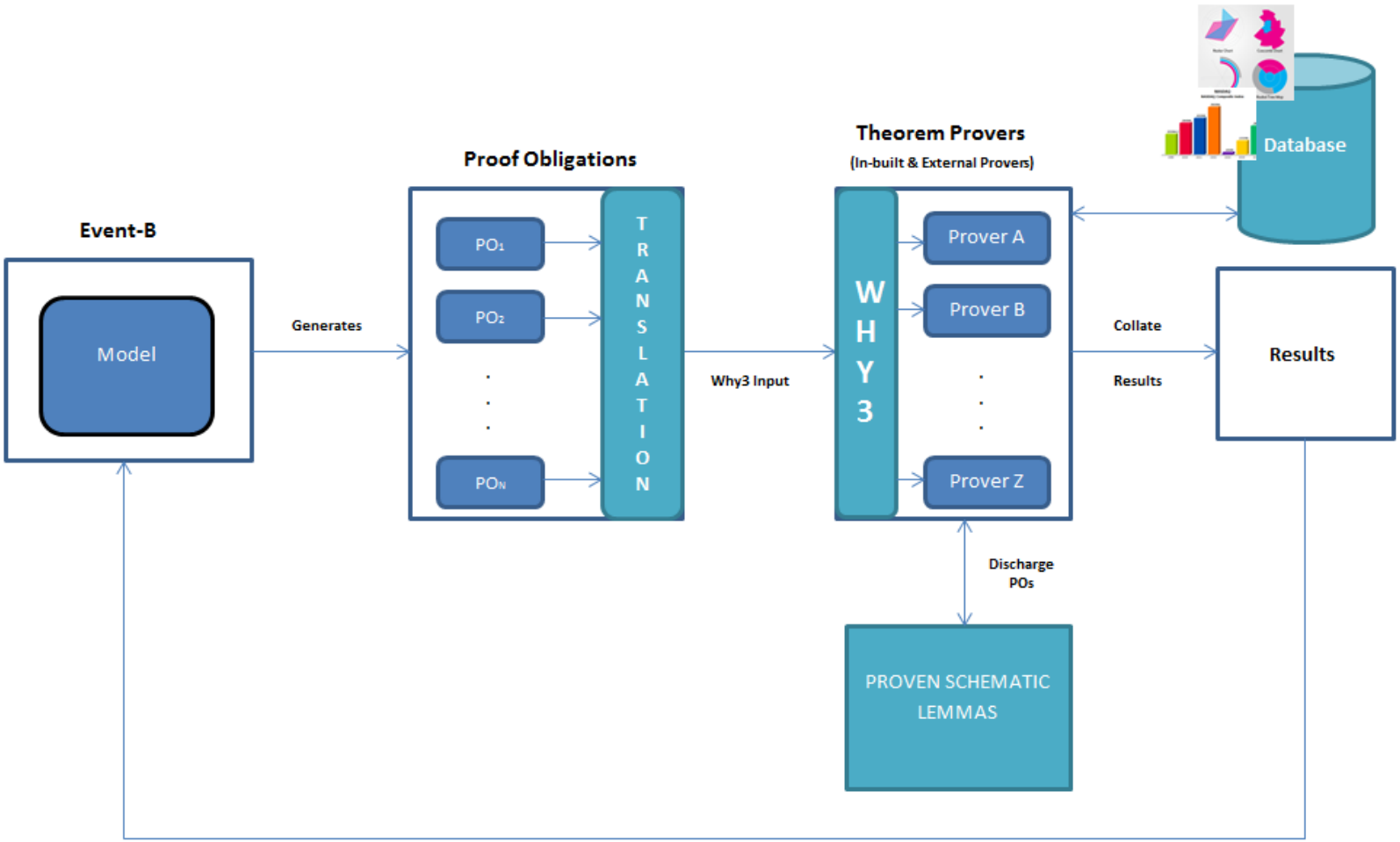
Visual Concept



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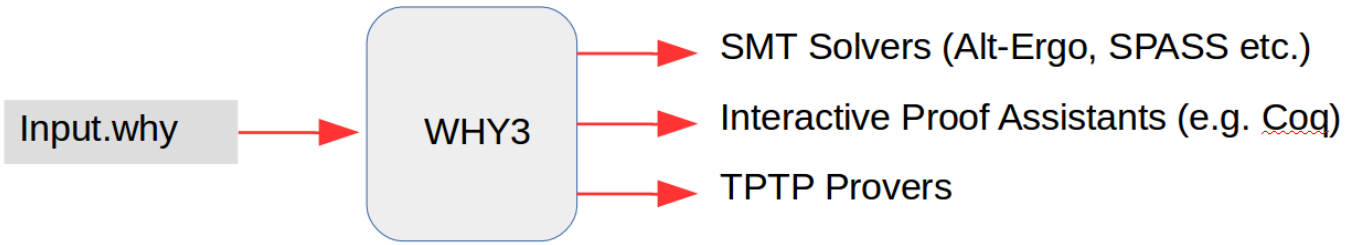
Why3 Tool

Provides interface to theorem provers like SMT solvers (e.g Z3, Spass), TPTP provers, interactive proof assistants (e.g Coq)



Why3 Tool

Input is a collection of small units - theories, where as theory may contain functions, type declarations, predicates, axioms, lemmas and goals.

WHY3 Tool: Atelier B vs WHY3

Machine	# of PO	Unproved by Atelier B	Unproved by Why3
Automaton	4	0	0
Automaton_context_i	10	**8**	9
Automaton_i	229	71	**0**
Automaton_transitions	189	7	**0**
Automaton_transitions_i	1678	25	**0**
Boom_detectors_i	16	0	0
Configuration_i	7	4	**0**
Indicators_i	12	0	0
Lamps_bells_i	4	0	0
Timer	3	1	**0**
Timer_i	10	0	0
Track_circuit	2	0	0
Track_circuit_i	1	0	0
Train_detector_i	4	0	0
Warning_section	2	0	0
Warning_section_i	59	11	**10**
Warning_section_r	17	2	**0**
Total	2247	129	**19**

Number of proof obligation not discharged by the tools. [1]

[1] David Mentr, Claude March, Jean-Christophe Fillitre, Masashi Asuka (2012) Discharging Proof Obligations from Atelier B Using Multiple Automated Provers

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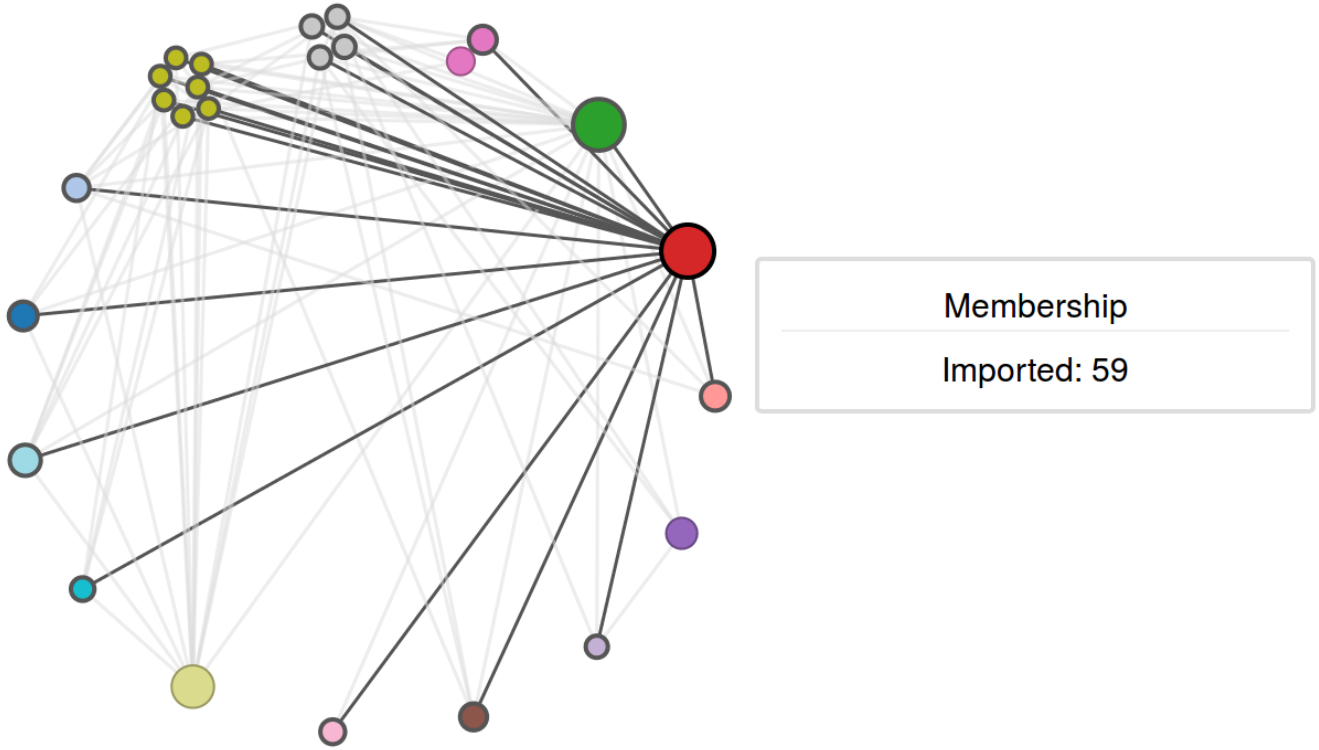
Translation and Axiomatization

- Event-B to Why3 *theory* input notation

In total 67 functions, 8 predicates, 3 constant relations were translated and defined by 78 axioms and 115 lemmas.

Translation and Axiomatization

In order to implement filtering mechanism operators were separated.



Example of Set Size:

```
function card (set 'a) : int

axiom card_def0:
forall s: set 'a. finite s -> card s >= 0

axiom card_def1:
forall x : 'a.
card (singleton x) = 1

axiom card_def2:
forall s: set 'a.
  ((finite s) /\ is_empty s) -> (card s) = 0

lemma card_def3:
forall s, t: set 'a.
(finite t /\ (subsetprop s t)) -> (card s) < (card t)
```

```
lemma card_def4:
forall s : set 'a, t : set 'b, f : rel 'a 'b.
(finite t /\ (mem f (s >->> t))) -> (card s = card t)

lemma lemma_def5: (*eProver 12s*)
forall s : set 'a, t : set 'b, f : rel 'a 'b.
((card s = card t) /\ mem f (s >-> t)) ->
mem f (s -->> t)

lemma lemma_card6: (*eProver 19s*)
forall s, t: set 'a.
finite t /\ (forall x : 'a. mem x s -> mem x t) ->
(card s) <= (card t)
```

Translation & Axiomatization

Simple mistake in translation file could result in inconsistent theory and thus allow to prove anything. Possible mistakes: missing finite statement, bi-implication used instead of implication.

Quick check: use dummy lemma e.g. $1 = 2$

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Results

Model	Total POs	Open, built-in	Open, built-in + FA	Open, Open, built-in + z3($c \cdot \star$)
prime15r3	625	281/62[2]	18	201
paxos3a3	348	121	4	27
fishers	82	14	0	14

[2] The second figure includes POs discharged by SMT plug-in.

Outline

Server-side scenario language

- A client generates *n* verification conditions;
- These are sent, individually, to a cloud-based service;
- Each verification condition is treated by a *verification scenario* that may involve several provers;
- Scenario results are collated and, if necessary, some prover instances are terminated before they complete;
- An adjudicated response is communicated back to the client.

Server request API

The service accepts as inputs *sequents* $s \in \mathcal{S}$ of the form: $(\tau, l, \mathbf{T}, \mathbf{I}, \mathbf{H}, G)$ where

- τ defines the mathematical notation used for defining types, hypothesis and the goal. It can be, for instance, Classical B, Event-B, why3, SMT-LIB, and so on;
- l defines the client time-out in milliseconds;
- $\mathbf{T}$ is a set of types used in the sequent;
- $\mathbf{I}$ is a set of typed free identifiers occurring in the sequent;
- $\mathbf{H}$ is a set of sequent hypothesis;
- G is the sequent goal.

Scenario examples

$$\mathrm{pr}_1(c \cdot \star)$$

Apply some prover pr_1 to an input sequent

Scenario examples

$$FA \equiv \mathrm{pr}_1(c \cdot \star) \vee \mathrm{pr}_2(c \cdot \star) \vee \mathrm{pr}_1(c \cdot \star) \vee \ldots$$

Make use of multiple verification tools, trying them concurrently and report any (first) result.

Scenario examples

$$SA \equiv \mathrm{pr}_1(c \cdot \star) \wedge \mathrm{pr}_2(c \cdot \star) \wedge \mathrm{pr}_3(c \cdot \star) \wedge \ldots$$

Increase the confidence by adjudicating prover results.

Plans

- Machine learning to match a theorem with a most suitable prover and scenario;
- Server API with more input notations: Event-B, Classical B
- Non-real time operation mode: upload conditions on the cloud and they are processed in some spare and results are communicated back automatically.
- User-definable axiomatization extensions: must be proven and will be automatically integrated.
- Support for other input notations (of an interest to anybody?)

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Demonstration