Towards a Tool for Featherweight OCL: A Case Study On Semantic Reflection

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Abstract

We show how modern proof environments comprising code generators and reflection facilities can be used for the effective construction of a tool for OCL. For this end, we de ne a UML/OCL meta-model in HOL, a meta-model for Isabelle/HOL in HOL, and a compiling function between them over the vocabulary of the libraries provided by Featherweight OCL. We use the code generator of Isabelle to generate executable code for the compiler, which is bound to a USE tool-like syntax integrated in Isabelle/Featherweight OCL. It generates for an arbitrary class model an object-oriented datatype theory and proves the relevant properties for casts, type-tests, constructors and selectors automatically.

Isabelle:
The "Eclipse" of Formal Methods Tools
(not just a theorem prover)

The Isabelle System Framework

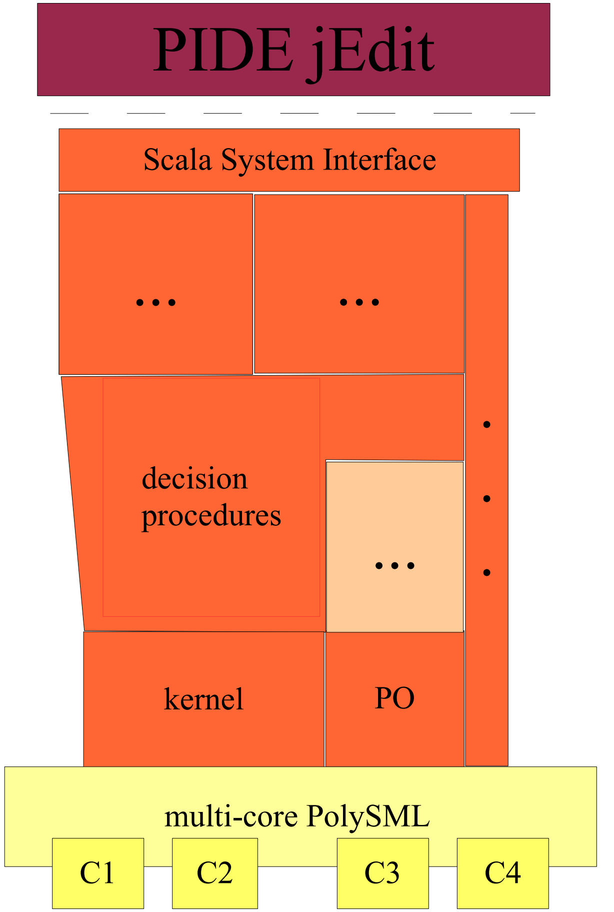
Isabelle Architecture

- Modern Isabelle Architecture consists of 5 identifyable layers
  - SML layer
  - Kernel & Proof Object Layer
  - Tactic Layer and decision procedures
  - Isar Engine
  - PIDE Framework and Interface Layer

Isabelle Architecture

Observation:

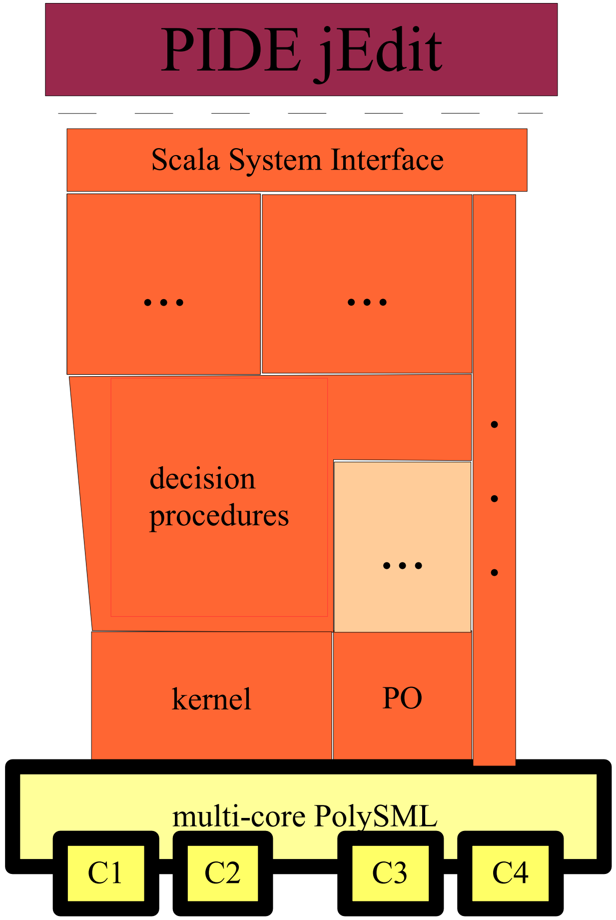
Effective parallelization is a PERVASIVE PROBLEM, that must be addressed



Isabelle Architecture

- In detail:

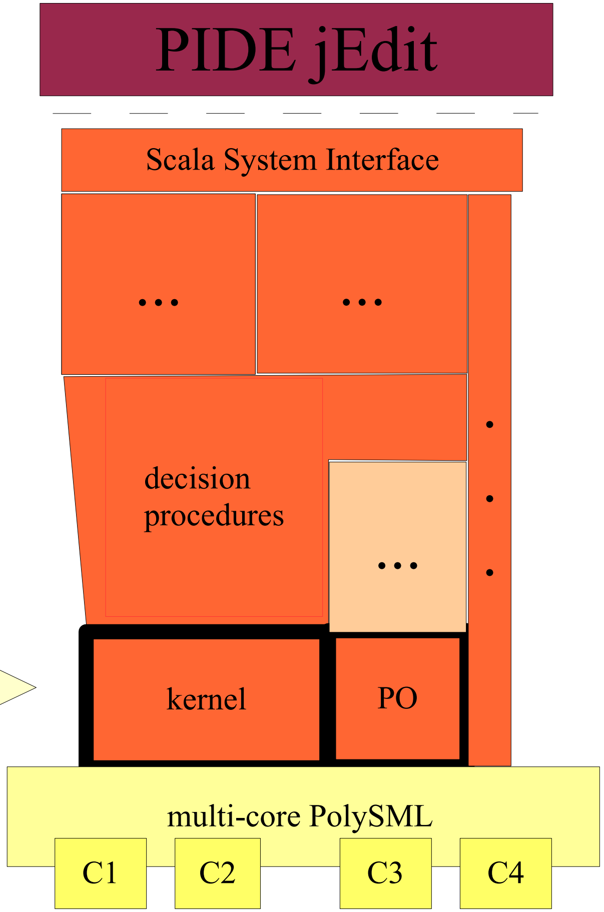
on the execution platform layer



Isabelle Architecture

- In detail:

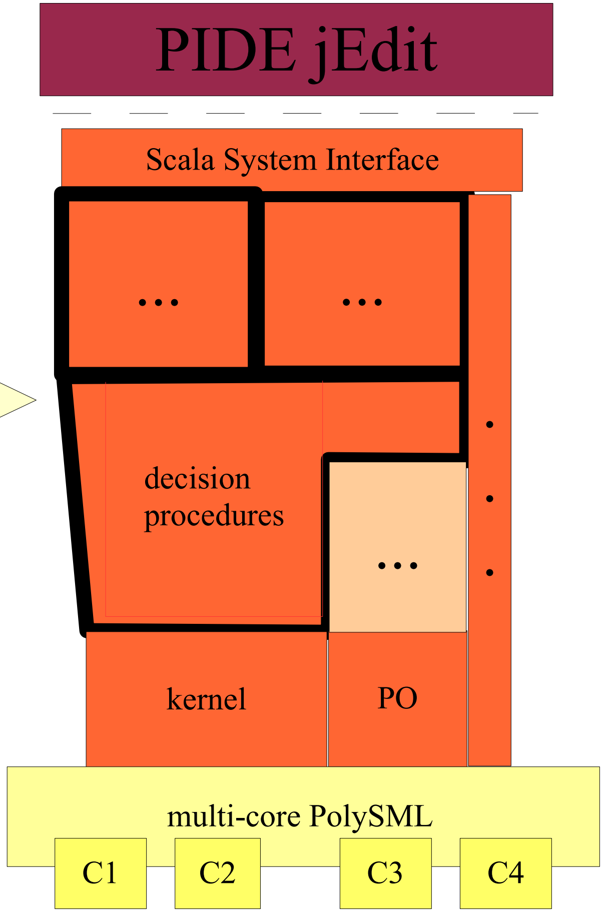
on the kernel layer



Isabelle Architecture

- In detail:

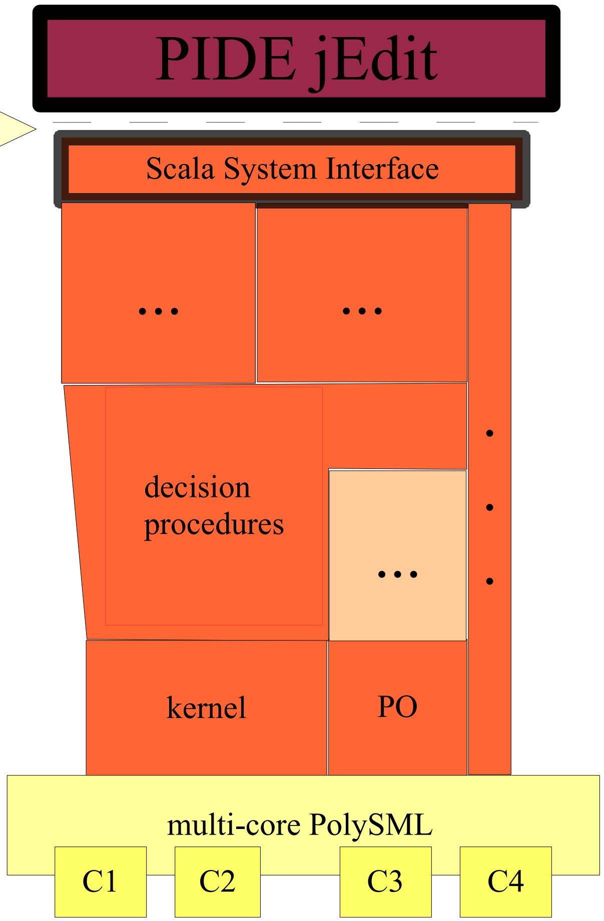
on layer of procedures and packages



Isabelle Architecture

- In detail:

on the interface layer
PIDE framework + Editor



Idea:

Let's reuse this rich
system Framework
(not only the logical
meta-language HOL)
to construct an OCL Tool !

Why is this necessary:

- A concrete class-models semantics consist of
  - an denotational object universe
  - definitions / proofs for accessors
  - definitions / proofs for tests
  - definitions / proofs for casts
  - definitions / proofs for type-tests

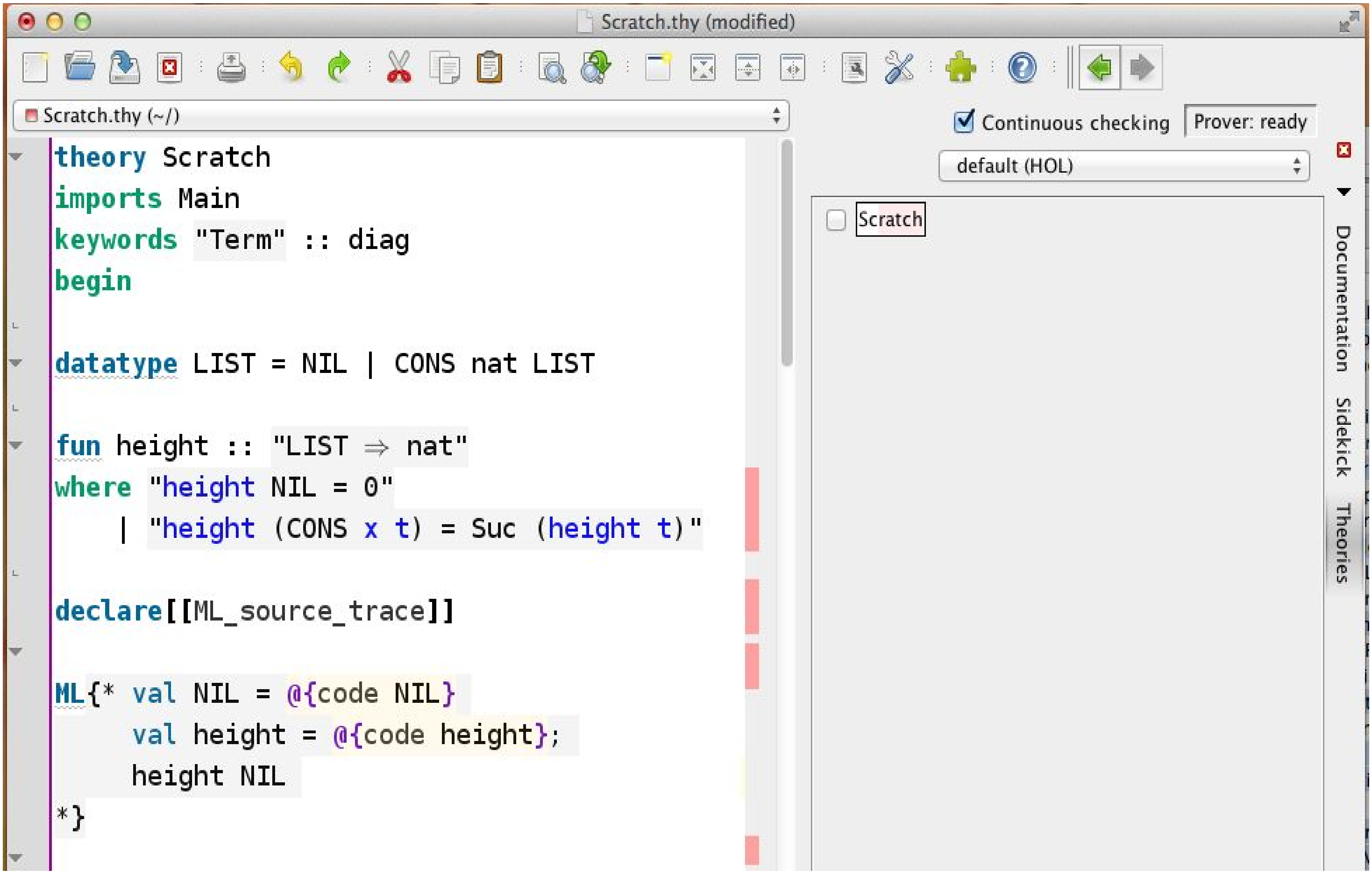
… in Featherweight OCL, this induces hundreds of definitions and proofs.

Lets automate that.

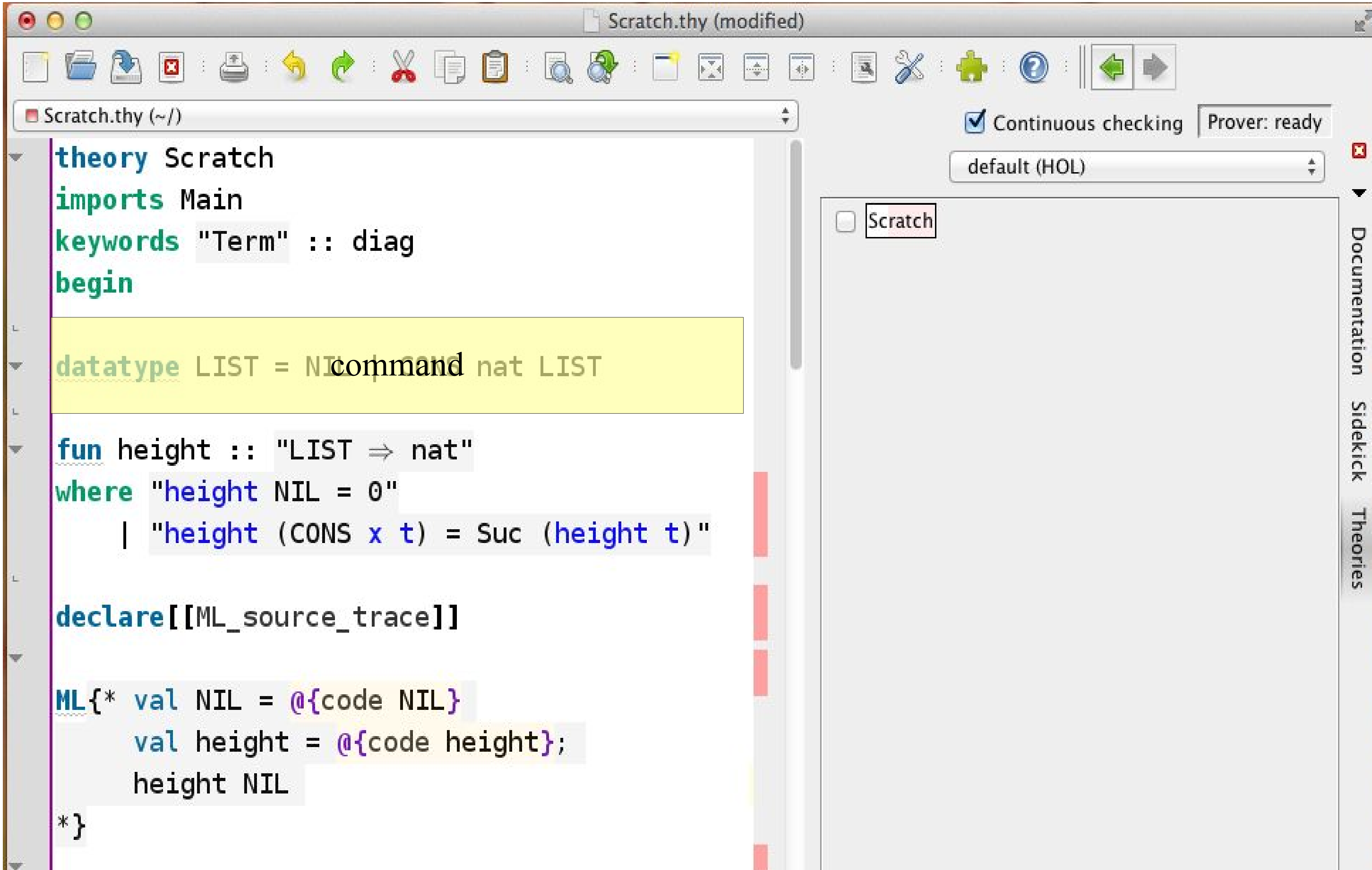
What is the “Output”?

- Well, as in Eclipse, this is not so easy to point out ...
  - a derived theory (thousands of lemmas and their proofs)
  - a set-up for provers
  - a set-up for code-generators
  - a set-up for document generation
  - well, and user-interaction, a GUI, a code-generator that can be reused.

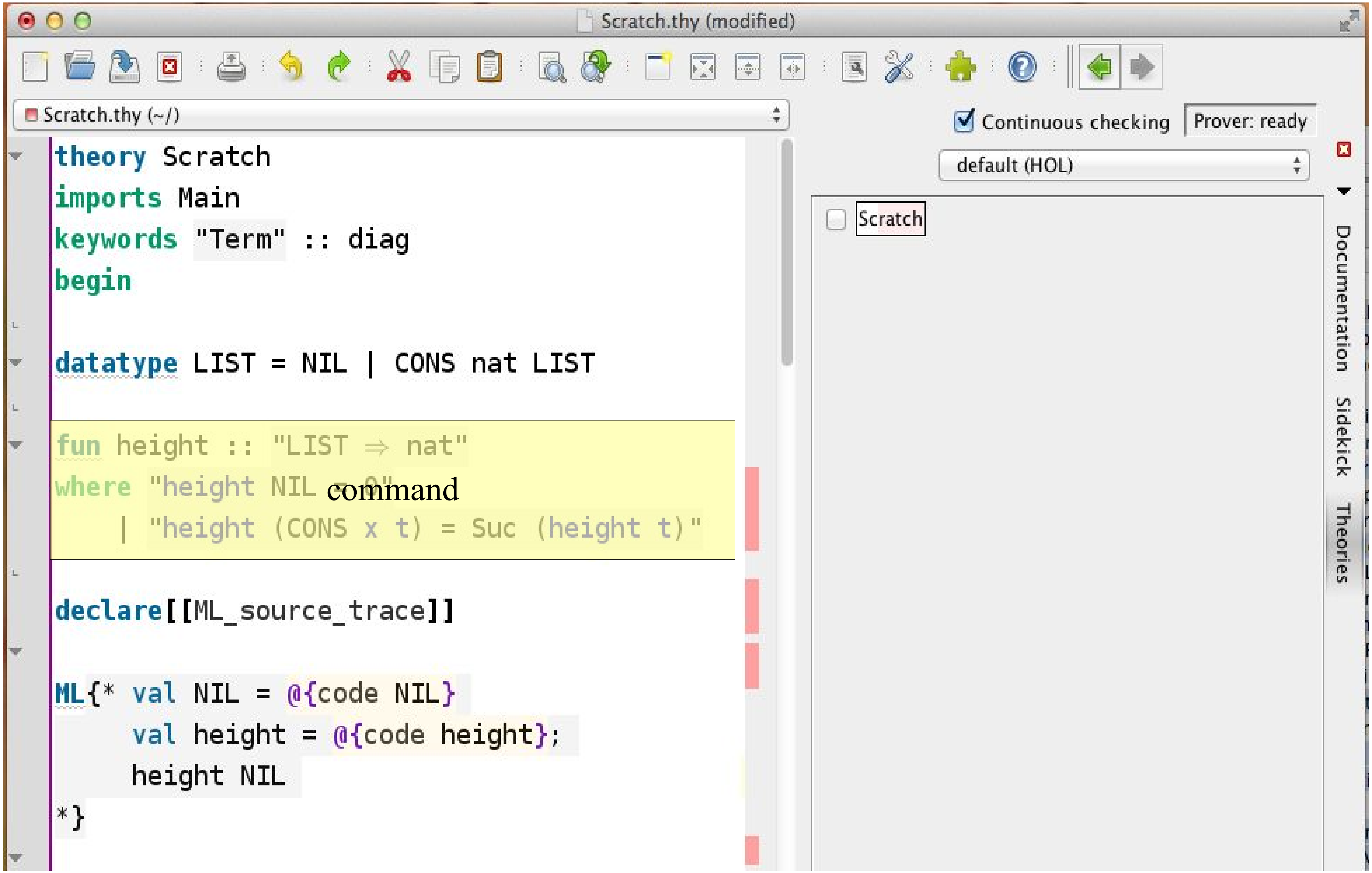
An Isabelle Isar Document



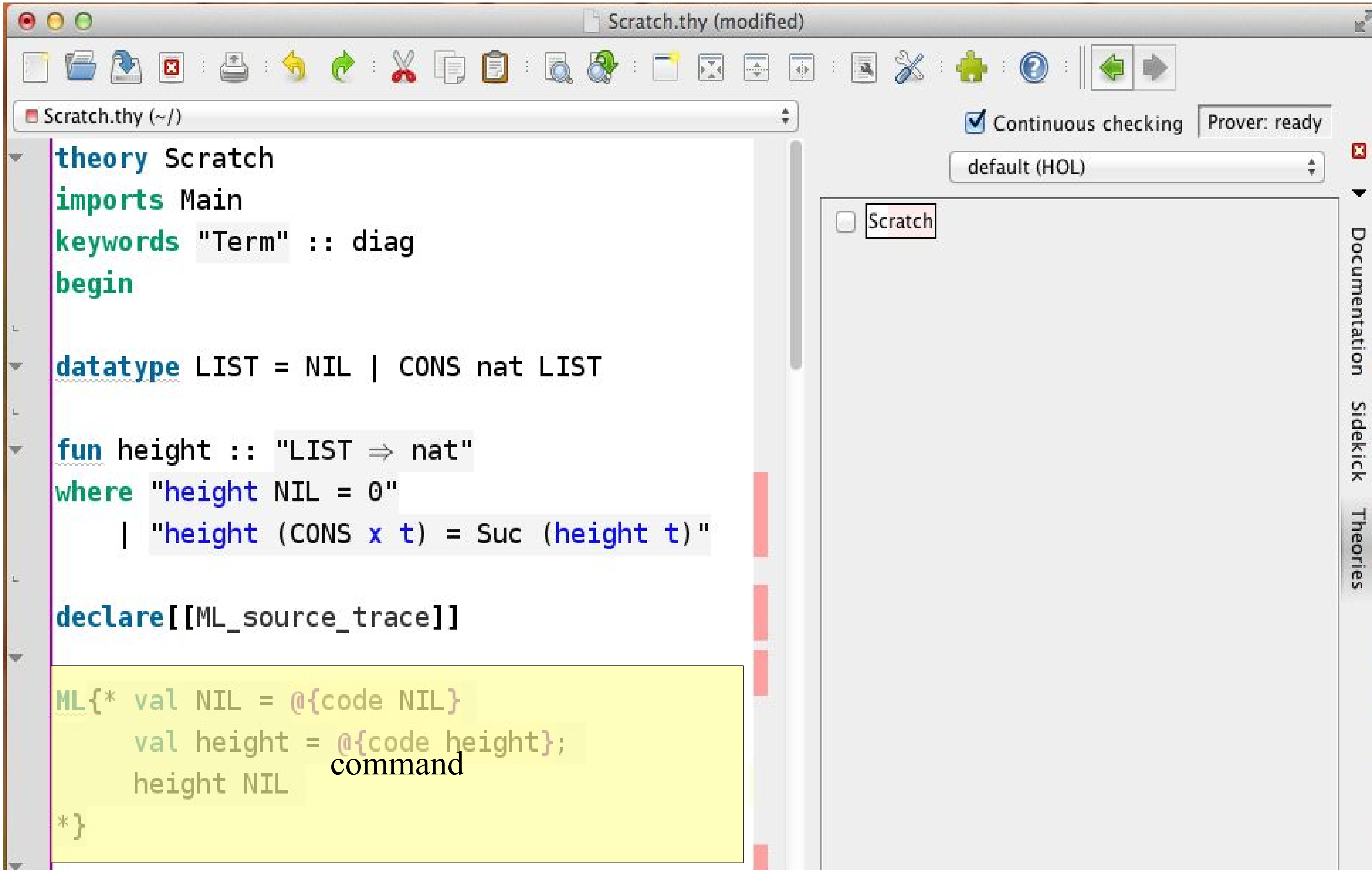
An Isabelle Isar Document



An Isabelle Isar Document



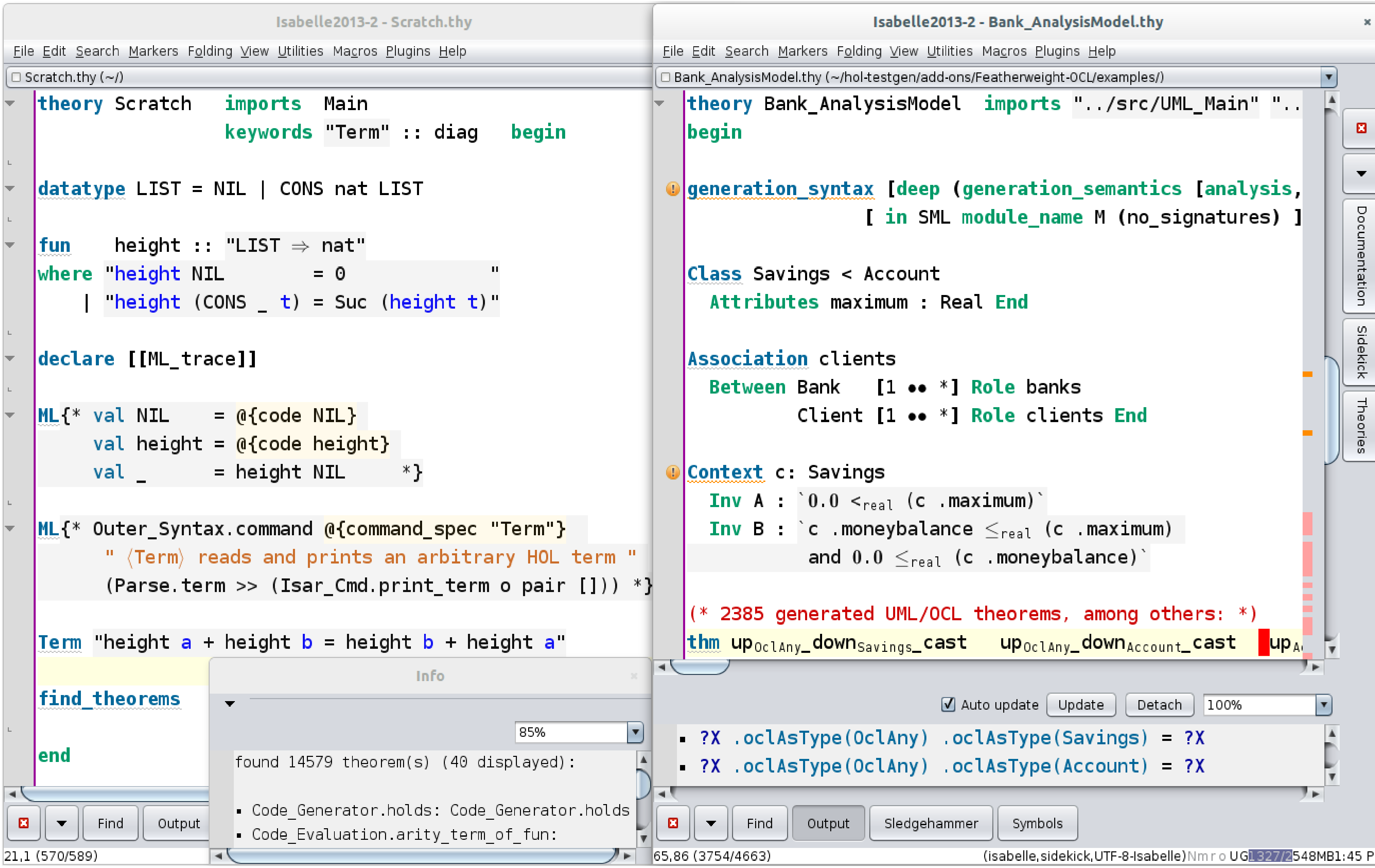
An Isabelle Isar Document



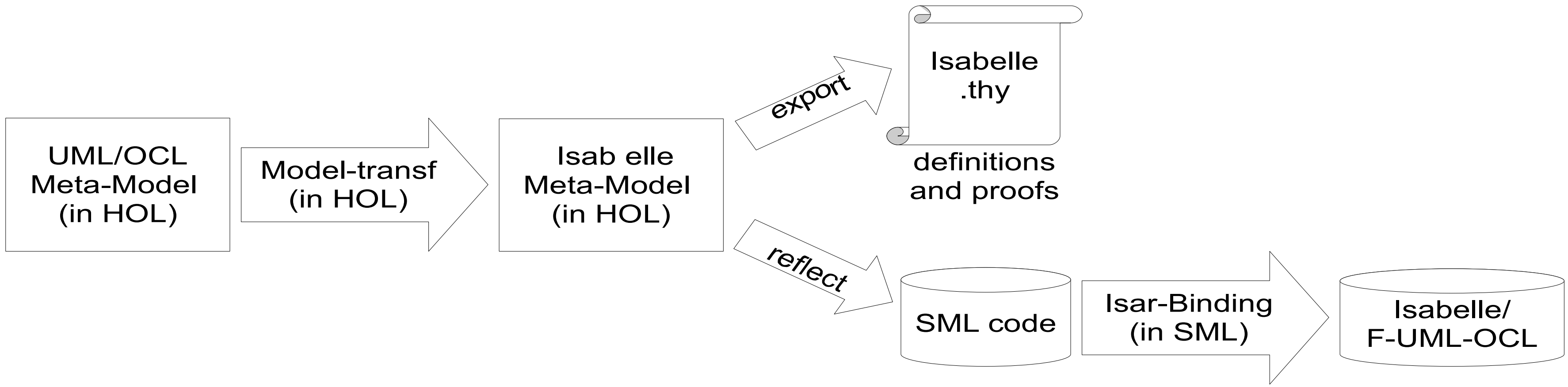
Instead of Standard Commands …

- … we redefine our own commands inside the Isabelle Framework
  - for classes
  - … with attributes and operations
  - … and types
  - associations
  - invariant declarations
  - operation contracts

The result at a glimpse



The technique at a glimpse



- Note that this “model-transformation” also generates the family of
  - declarations for constructors, accessors casts and tests
  - the proofs for the lemmas (concerning strictness, null, up-cast-down-cast, down-cast-upcast, constructors-destructors, tests, ...

Experimental Results at a glimpse

- The compiler is about 10000 lines of code
- Some generation info:

c	depth c	depth 5	depth 4	depth 3	depth 2	depth 1
12	$(1, c)$ 14K				$(3, 2)$ 12K	$(c, 1)$ 11K
14	$(1, c)$ 20K			$(2, 3)$ 17K		$(c, 1)$ 16K
20	$(1, c)$ *52K*				$(4, 2)$ *39K*	$(c, 1)$ *39K*
30	$(1, c)$ *155K*		$(2, 4)$ *121K*		$(5, 2)$ *115K*	$(c, 1)$ *115K*
39	$(1, c)$ *330K*			$(3, 3)$ *240K*		$(c, 1)$ *240K*
42	$(1, c)$ *409K*				$(6, 2)$ *288K*	$(c, 1)$ *294K*
56	$(1, c)$ *964K*				$(7, 2)$ *649K*	$(c, 1)$ *661K*
62	$(1, c)$ *1.3M*	$(2, 5)$ *907K*				$(c, 1)$ *882K*
72	$(1, c)$ *2M*				$(8, 2)$ *1.3M*	$(c, 1)$ *1.3M*
84	$(1, c)$ *3.3M*			$(4, 3)$ *2.1M*		$(c, 1)$ *2.1M*
90	$(1, c)$ *4.2M*				$(9, 2)$ *2.5M*	$(c, 1)$ *2.5M*

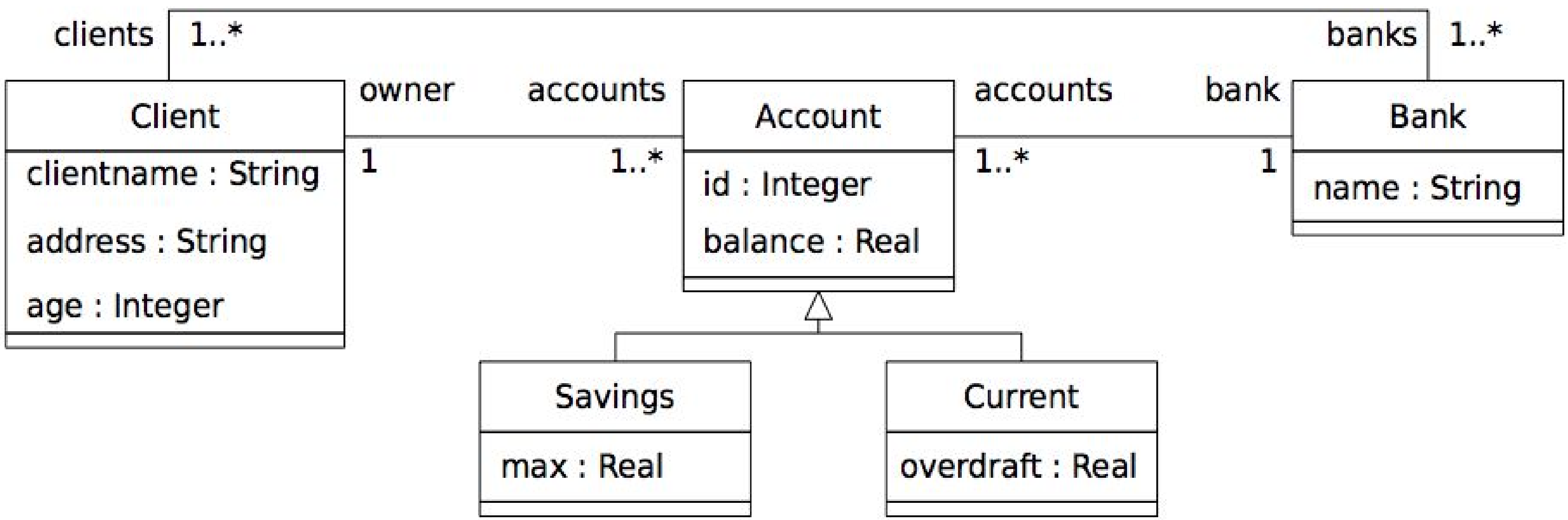
Fig. 5. Number of theorems generated

A Summary

- Formal semantic-centric view of tool construction (based on Higher-order Logic in Isabelle/HOL)
- A technique to Embed OCL deeply on the System Framework of OCL.
- Technique amenable to a wide range of (text-based) domain specific languages (DSL)'s and semantic-based model-transformations.

Demo V

Running Example



Running Example

```
Class Bank
      Attributes
        name        : String
End

Class Client
      Attributes
        clientname  : String
        address     : String
        age         : Integer
End

Class Account
      Attributes
        id          : Integer
        balance     : Real
End

Class Savings < Account
      Attributes
        max         : Real
End
```

```
Class Current < Account
      Attributes
        overdraft   : Real
End

Association clients
  Between Bank     [1 .. *]
            Role banks
          Client   [1 .. *]
            Role clients    End

Association accounts
  Between Account [1 .. *]
            Role accounts
          Client   [1]
            Role owner      End

Association bankaccounts
  Between Account [1 .. *]
            Role accounts
          Bank     [1]
            Role bank       End
```

Running Example

```
Context c: Savings
  Inv A : ‘0 < (c .max)‘
  Inv B : ‘c .balance <= (c .max) and 0 <= (c .balance)‘

Context c: Current
  Inv A : ‘25 < (c .owner .age) implies (c .overdraft = 0)‘
  Inv B : ‘c .owner .age <= 25 implies (c .overdraft = -250)‘

Context c: Client
  Inv A : ‘c .accounts ->collect(banks) = c .banks‘
```