Natural Semantics Based Tools for Semantic Web with Application to Product Models

CUGS thesis proposal

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Outline

- Introduction
- Research Track
- Thesis goals
  - short term goal
  - long term goal
- Thesis Plan
- Conclusions

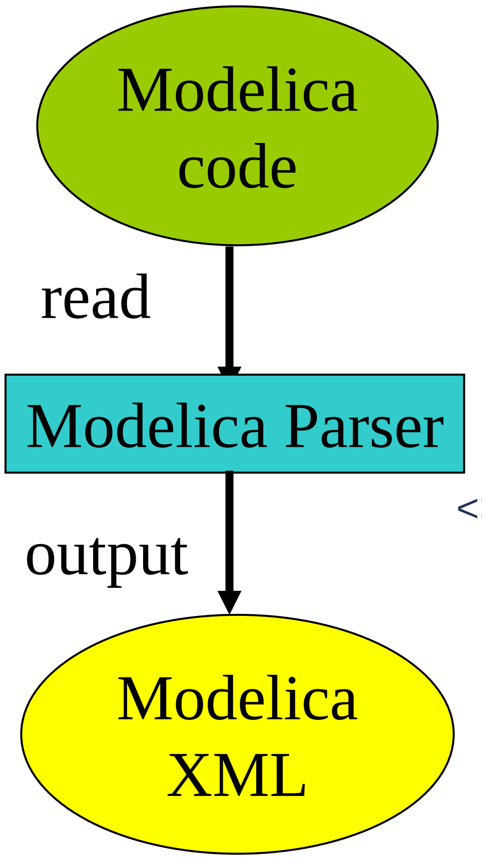
- The research combines several computer science areas
  - Compilers, Debuggers, Compiler generation for high level declarative programming languages (Natural Semantics)
  - Semantic Web (Description Logics)
  - Integrated product design using Modeling and Simulation with Modelica
- Involvement in Research Projects
  - SWEBPROD (Semantic Web for Products)
  - REWERSE (Reasoning on the web with rules and semantics)
  - SECD (Systems Engineering & Computational System Design)

- short term goal
  - practical tool implementation for Semantic Web languages using Natural Semantics
- long term goal
  - adapt and integrate Semantic Web technologies into a framework for model-driven product design and development

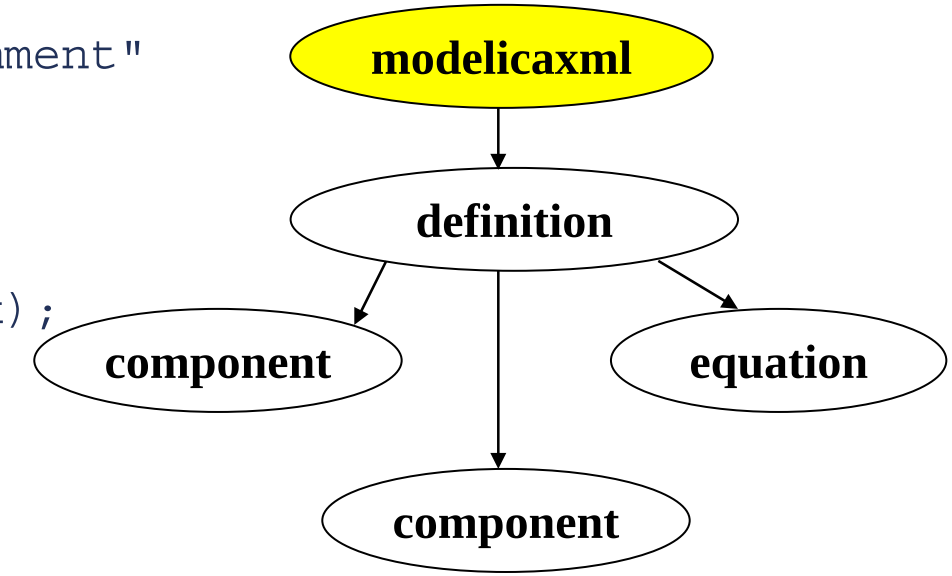
- Preliminary results
  - Adrian Pop, Peter Fritzson, *ModelicaXML: A ModelicaXML representation with Applications*, International Modelica Conference, 2003
  - Adrian Pop, Ilie Savga, Uwe Assmann, Peter Fritzson, *Composition and XML dialects: A ModelicaXML case study*, Software Composition Workshop, 2004
  - Adrian Pop, Olof Johansson, Peter Fritzson, *An Integrated Framework for Model-Driven Product Design and Development using Modelica*, Conference on Simulation and Modeling, 2004
- Systems
  - a Relational Meta-Language (RML) debugger
  - ModelicaXML toolbox

- *Declarative language*
  - Equations and mathematical functions allow acausal modeling, high level specification, increased correctness
- *Multi-domain modeling*
  - Combine electrical, mechanical, thermodynamic, hydraulic, biological, control, event, real-time, etc...
- *Everything is a class*
  - Strongly typed object-oriented language with a general class concept, Java & Matlab like syntax
- *Visual component programming*
  - Hierarchical system architecture capabilities
- *Efficient, non-proprietary*
  - Efficiency comparable to C; advanced equation compilation, e.g. 300 000 equations

ModelicaXML




```
class Test "comment"
   Real x;
   Real xdot;
 equation
   xdot = der(x);
end Test;
```




```
<modelicaxml>
  <definition ident= "Test"
              comment="comment">
    <component ident="x" type="Real"
               visibility="public" />
    <component ident="xdot" type="Real"
               visibility="public" />
    <equation>...</equation>
  </definition>
</modelicaxml>
```

ModelicaXML

- Advantages
  - Declarative query languages for XML can be used to query the XML representation
  - The XML representation can be accessed via standard interfaces like Document Object Model (DOM) from practically any programming language
  - Analysis of Modelica models (model checkers and validators)
  - Pretty printing (un-parsing)
  - Translation between Modelica and other modeling languages (interchange)
  - Query and transformation of Modelica models
  - Certain models could be translated to and from the Unified Modeling Language (UML)
- Shortcommings
  - XML can represent only structure, no semantics
- Initial ideas on using Semantic Web
  - to represent some of the Modelica semantics

ModelicaXML composition and transformation

- **Why the need for Modelica composition and transformation?**
  - Interoperability between existing modeling languages or CAD tools and Modelica
  - Automatic generation of different version of models from product specifications. Choosing best design based on automatic simulation.
  - Automatic configuration of models using external sources (XML, databases, files)
  - Protection of intellectual property through obfuscation
  - Fine grain support for library developers

- The information in the current web:
  - has meaning for human only
  - is not machine processable
- Semantic Web brings:
  - semi-structured information
  - means to add more than structure (semantics/constrains) on data
  - languages: XML, XMLSchema, RDF, RDFS, OWL
  - reasoning and inferences services (Description Logics): subsumption, classification, coherence checking, etc
  - integration and reuse of knowledge by using shared ontologies

ModelicaXML and Semantic Web

- The benefit of using Semantic Web languages for Modelica
  - Models could be automaticaly translated between modeling tools
  - Software information systems (SIS) could more easily be constructed for Modelica, facilitating model understanding and information finding
  - Model consistency could be checked

- Based on
  - Gordon Plotkin's Structural Operational Semantics (SOS)
  - Gentzen's Sequent Calculus for Natural Deduction.
- "Natural Semantics" (NS)
  - term by Gilles Kahn
  - formalism widely used for specifications of:
    - type systems
    - programming languages

Natural Semantics - Syntax

$$\frac{H_1 \vdash T_1 : R_1 \quad \ldots \quad H_n \vdash T_n : R_n}{H \vdash T : R} \quad \text{if } \langle\text{cond}\rangle$$

- Hi are hypotheses (environments)
- Ti are terms (pieces of abstract syntax)
- Ri are results (types, run-time values, changed environments)
- Hj |- Tj : Rj are sequents
- Premises or preconditions are above the line
- Conclusion is below the line
- Condition on the side if exists must be satisfied

Natural Semantics vs Relational Meta-Language (RML)

RML has the same visual syntax as NS

```
rule    <cond>
        RelName1(H1,T1) => R1 & ...
        RelNameN(Hn,Tn) => Rn &
        ------------------------------
        RelName(H, T) => R
```

RML language properties

- Separation of input and output arguments/results
- Statically strongly typed
- Polymorphic type inference
- Efficient compilation of pattern-matching

RML debugger

- based on source code instrumentation
- some support from the runtime system

Short term goal

- reasoning tools for Semantic Web languages (OWL Lite/DL)
  - implementation in RML of Natural Semantics specifications for Description Logics reasoning tasks
  - use the RML debugger to output explanation of such tasks
- possible problems:
  - scalability
  - RML has some limitations (formal arguments to relations, number of constructors in datatypes)
- why?
  - to have our own reasoning toolbox and to be able to experiment with alternative semantics and means to express the dynamic semantics implemented in RML

Long term goal

- integrating Semantic Web technologies with Product Design and Modeling and Simulation tools
  - model interchange
  - use of already defined vocabularies (taxonomies) and ontologies in the product design process
  - facilitating several tasks in the product development management
    - consistency checking (documents, components, forms, etc)
    - searching and information retrieval (large distributed libraries)
    - composition and interoperability
    - traceability (from requirements to design to product)
    - comparison (version management etc)

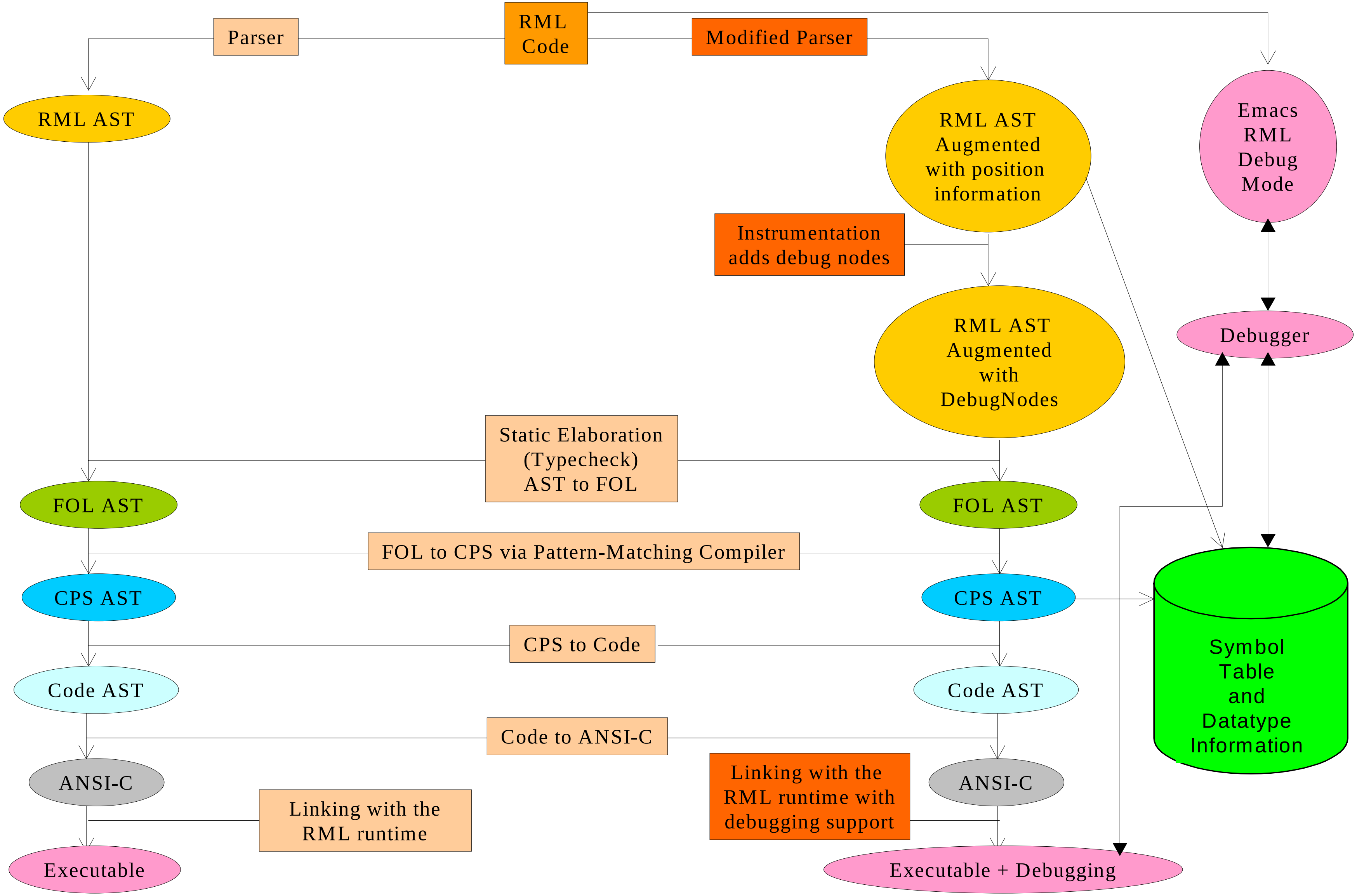
Thesis Plan

Date	Task
2002-01	The beginning of PhD studies
2003-08	The ModelicaXML meta-model for Modelica (paper accepted)
2004-03	Composition and transformation of XML dialects: A ModelicaXML case study (paper accepted)
2004-05	Release of the first version of RML debugger (work in progress)
2004-05	An integrated framework for model-driven product design and development using Modelica (paper submitted)
2004-06	RML prototype of basic reasoning tasks in OWL Lite
2004-08	Evaluation of the RML prototype and improvements (also improvements of RML debugger based on feedback from the OpenModelica project)
2004-10	Article on using RML to perform reasoning
2004-12	Lic. thesis
2005-03	Integration of our toolbox with the work of the partners involved in current research projects.
2005-06	Research on novel methodologies to improve product design.
2006-05	Experimenting with these new methodologies in our framework for product design.
2007-01	Thesis

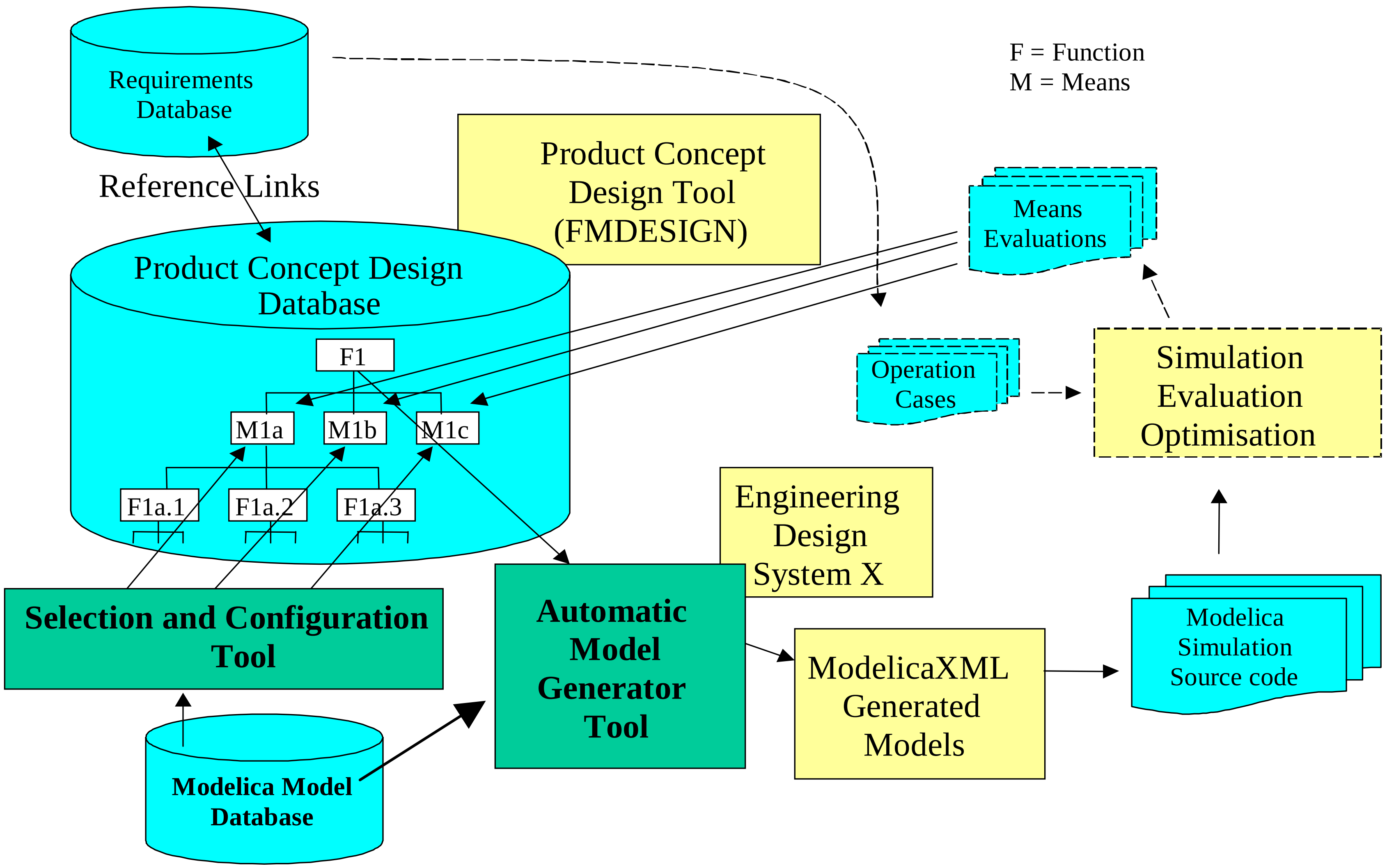
Thank you!

Questions?

Relational Meta-Language debugger



Integrated Product Development

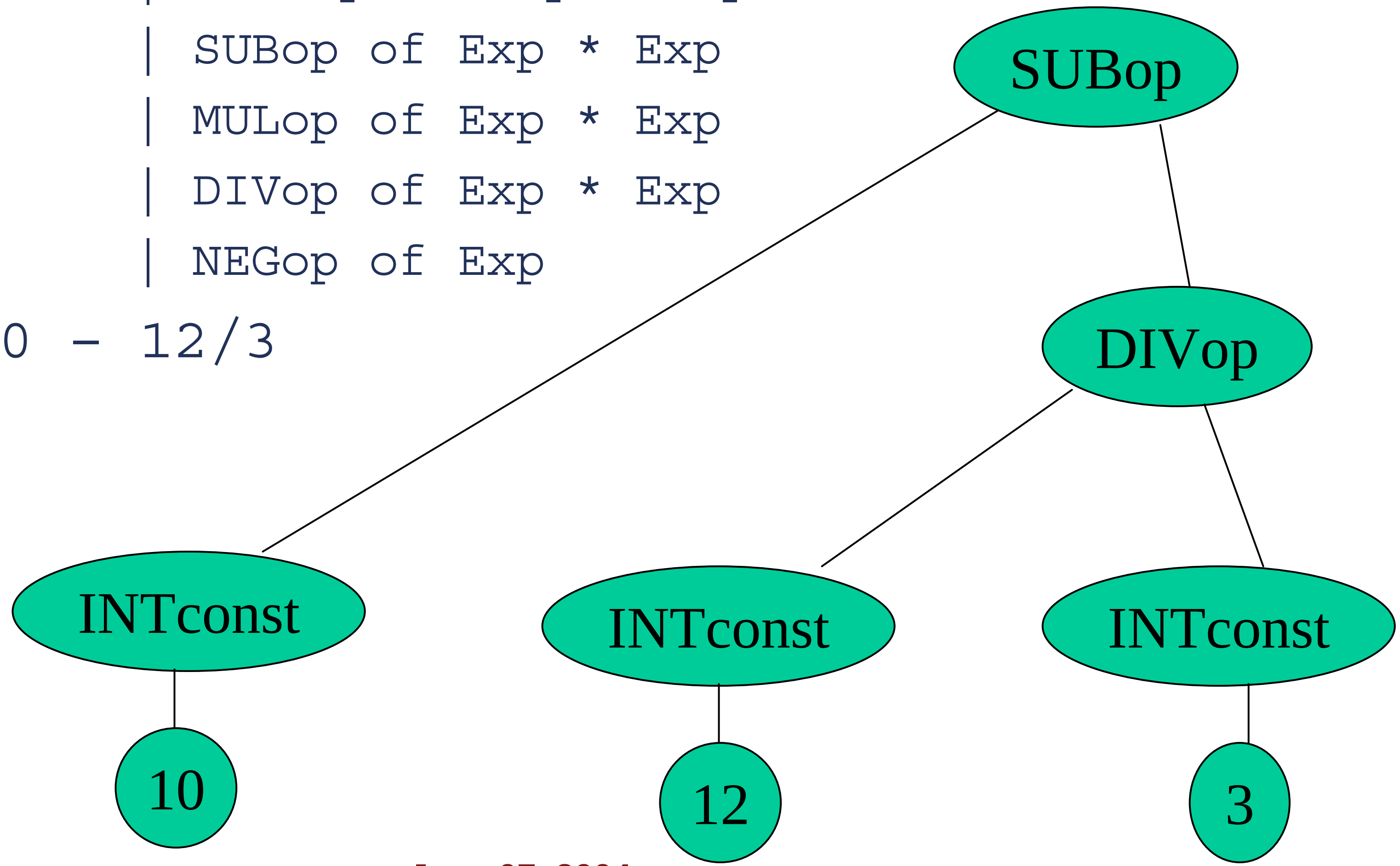


RML example: the Exp language

- Abstract syntax

```
datatype Exp = INTconst of int
             | PLUSop of Exp * Exp
             | SUBop of Exp * Exp
             | MULop of Exp * Exp
             | DIVop of Exp * Exp
             | NEGop of Exp
```

```
Exp: 10 - 12/3
```



RML example: the Exp language

- Relation eval

```
relation eval: Exp => int =
 axiom eval(INTconst(ival)) => ival
 rule eval(e1) => v1 & eval(e2) => v2 & int_add(v1,v2) => v3
      ------------------------------------------------------
      eval (PLUSop(e1,e2)) => v3
 rule eval(e1) => v1 & eval(e2) => v2 & int_sub(v1,v2) => v3
      -----------------------------------------------------
      eval (SUBop(e1,e2)) => v3
 rule eval(e1) => v1 & eval(e2) => v2 & int_mul(v1,v2) => v3
      -----------------------------------------------------
      eval (MULop(e1,e2)) => v3
 rule eval(e1) => v1 & eval(e2) => v2 & int_div(v1,v2) => v3
      -----------------------------------------------------
      eval (DIVop(e1,e2)) => v3
 rule eval(e) => v1 & int_neg(v1) => v2
      -----------------------------------------------------
      eval (NEGop(e)) => v2
end
```