Model-Based Design

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CHESS Review
May 10, 2004
Berkeley, CA

UC Berkeley: Chess
Vanderbilt University: ISIS
University of Memphis: MSI

Objectives

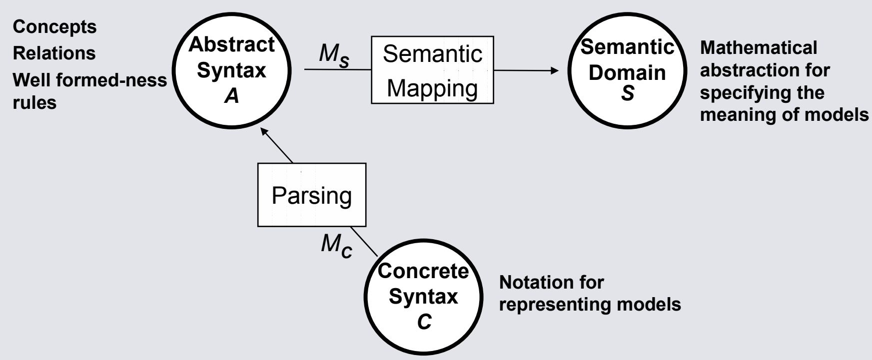
Model-based design focuses on the *formal representation, composition, and manipulation of models* during the design process.

Specific research areas:

1. Composition of Domain Specific Modeling Languages
2. Model Transformation
3. Model Synthesis

1. Composition of Domain Specific Modeling Languages

$$L = < C, A, S, M_S, M_C >$$



Research Agenda

Baseline:

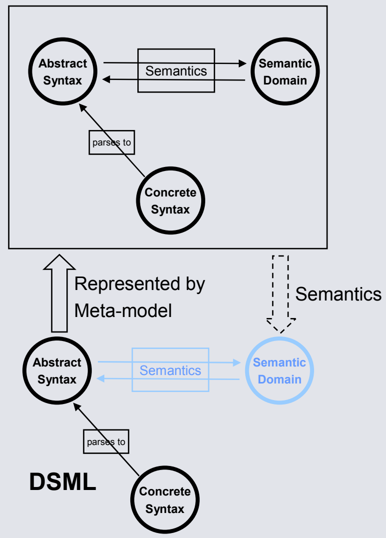
- Modeling of Abstract Syntax using UML class diagrams and OCL as meta language;
- Meta-programmable Graphical Model Editor (GME)

Research Agenda:

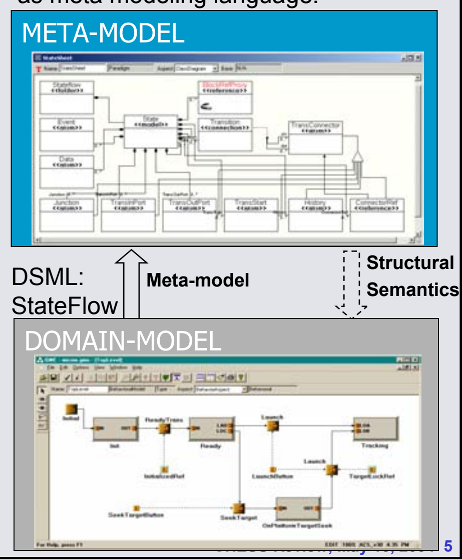
1. Using the Meta-Object Facility (OMG) as the meta-metamodel
2. Specification of DSML semantics via meta-modeling
3. Foundation for composing DSML-s
4. New Semantic Domains
5. Extension of meta-programmable tools

Semantics via Meta-Modeling: Baseline

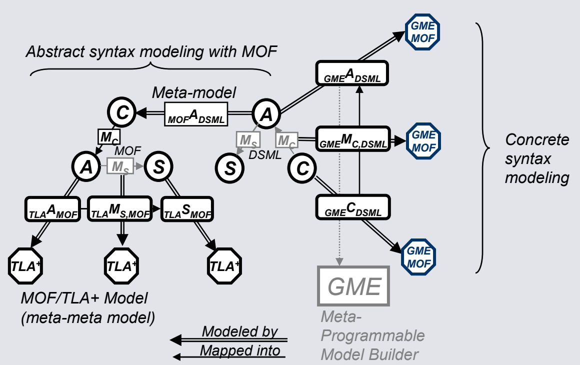
Meta-modeling language with well-defined semantics

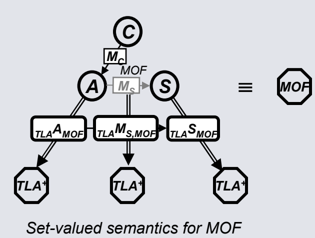


Meta-Model of StateFlow using uml/OCL as meta modeling language.



New Direction: Precise Meta-Modeling



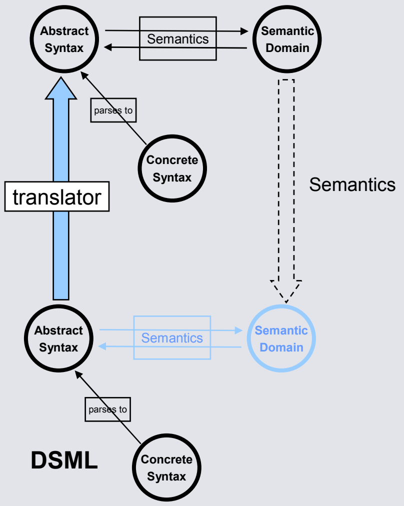


Ongoing Work: (Poster: *Compositional Metamodeling for DSMLs***)**

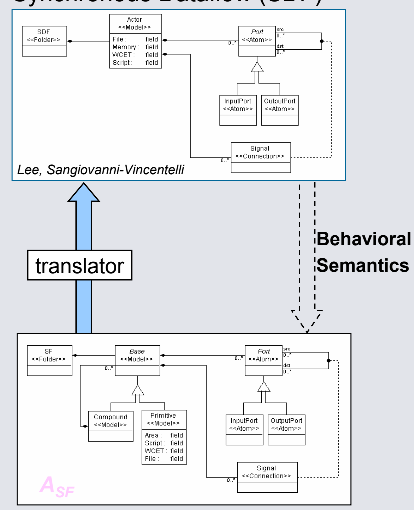
- Changing from UML-CD/OCL to MOF in abstract syntax modeling
- Developing set-valued semantics for MOF using TLA+ as meta-language
- Developing ${}_{MOF}A_{DSML} \rightarrow {}_{TLA}A_{DSML}$ translator

Semantics via Translation: Baseline

Modeling language with well-defined semantics

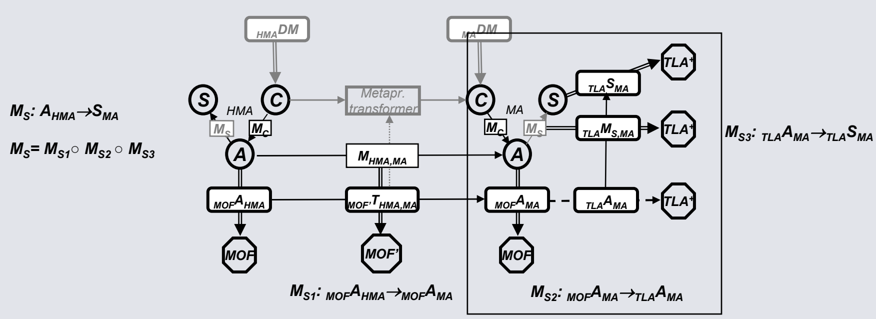


Synchronous Dataflow (SDF)



Hierarchical Signal Flow (HSF)

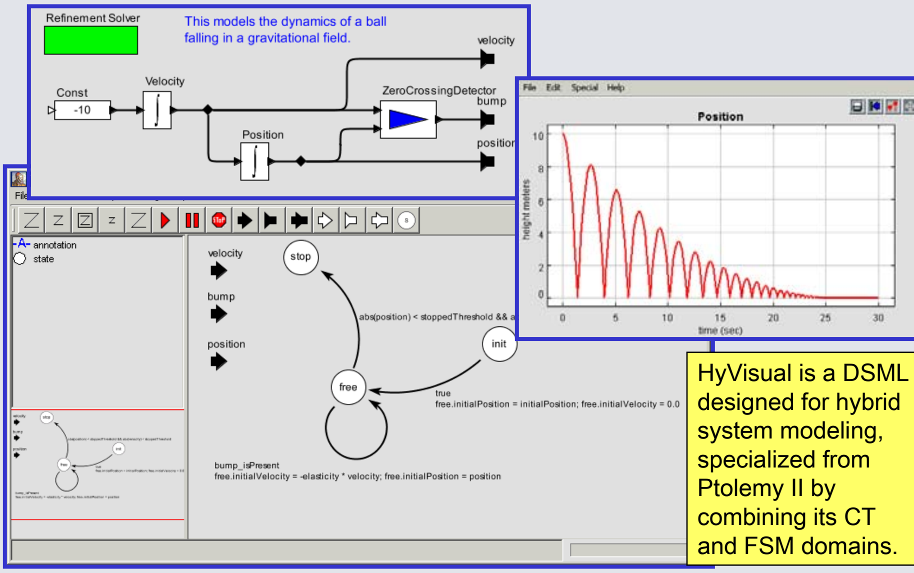
New Direction: Translational Specification of DSML Semantics



Ongoing Work: (Poster: *Compositional Metamodeling for DSMLs***)**

- TLA+ specification of the semantics of selected models of computations (reference models)
- Specifying DSML semantics via specifying mapping between the abstract syntax of DSML and the reference models
- Developing modeling and translation tools

New Semantic Domains: HyVisual – Hybrid System Modeling Tool Based on Ptolemy II



HyVisual is a DSML designed for hybrid system modeling, specialized from Ptolemy II by combining its CT and FSM domains.

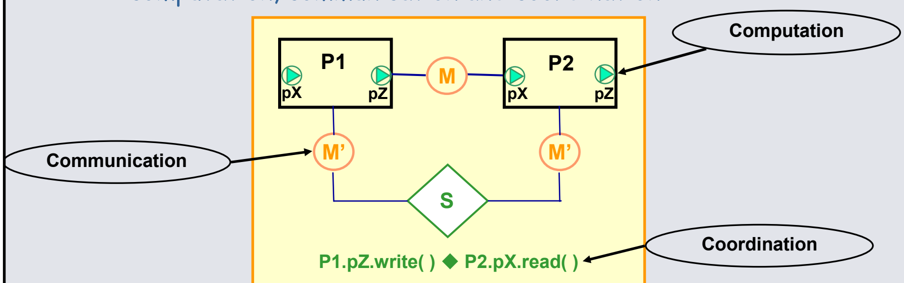
Major Applications of Meta Modeling: Metropolis Meta Model (Formal Model)

- How are designs represented in Metropolis?

  Metropolis "meta-model": a language + modeling mechanisms
  - represents all key ingredients: function, architecture, refinement, platforms
  - parser and API to browse designs, interact with tools

Metropolis Meta-Model

- Must describe objects at different levels of abstraction
  - Do not commit to the semantics of any particular model of computation
- Define a set of "building blocks"
  - specifications with many useful Models of Computations can be described using the building blocks
  - Processes, communication media and schedulers separate computation, communication and coordination

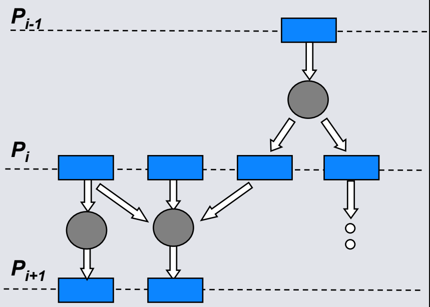


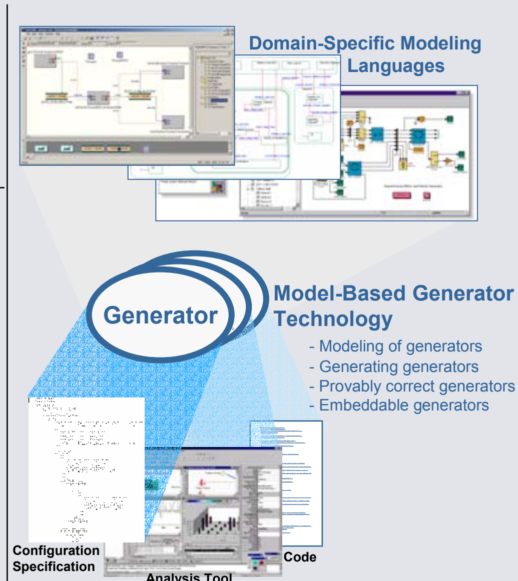
Core Metropolis "Meta Model"

- Processes
  - Concurrent Computation, sequential execution within each process
  - Execution within a process can be suspended with the AWAIT statement
- Interfaces
  - The types of Ports, bundle function declarations
- Media
  - Model Communication by providing definitions of Interface Functions
  - Passive, cannot run in their own threads
- Netlists
  - STRUCTURE and CONCURRENCY
- Quantity Managers
  - Performance modeling
- Constraints
  - Specification & Synchronization
- Formal Semantics
  - Operational Semantics based on Action Automata

2. Model Transformations

Platform-Based Design of Embedded Systems



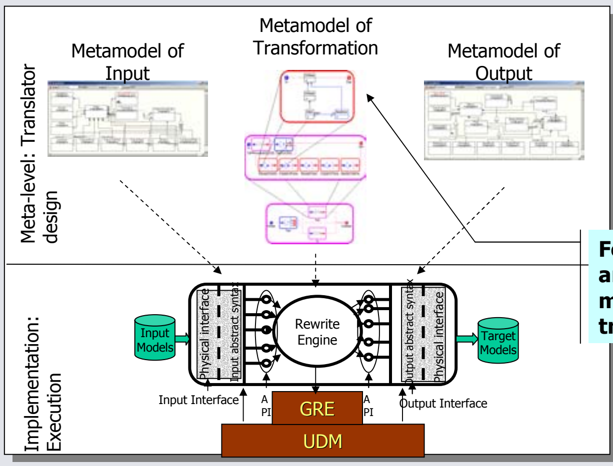


Research Agenda

Baseline:
- Meta-models of the Abstract Syntax of the source and target DSML-s;
- Tools helping the procedural implementation of translators

Research Agenda:
1. Meta Generators: Specification and generation of model transformations using graph rewriting technology
2. Embeddable generators
3. Generative extensions to modeling languages

Model Transformation Using Meta-Models and Graph Rewriting

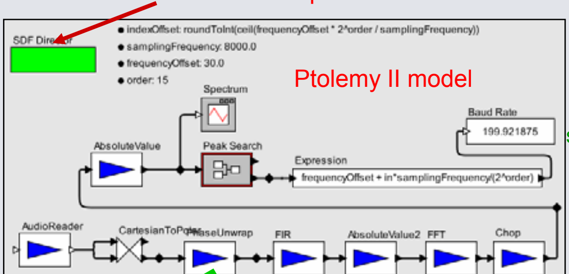


Formal, explicit, and precise model of the transformations

Karsai/Agrawal, ISIS

Component Specialization

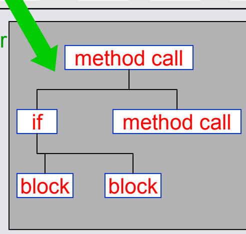
Model of Computation semantics defines communication, flow of control



scheduler

Schedule:
- fire Gaussian0
- fire Ramp1
- fire Sine2
- fire AddSubtract5
- fire SequenceScope10

parser



abstract syntax tree

Java actor definitions are parsed and then specialized for their context.

specializer

Specialize for
- data types
- parameter values
- scheduling

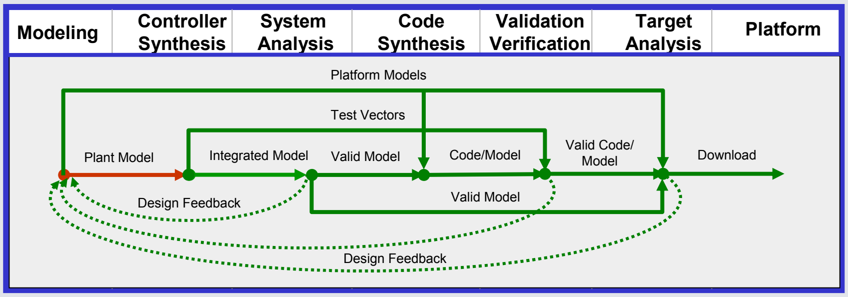
By
- token unboxing
- inlining
- partial evaluation
- dead code elimination

```
…
for (int i = 0; i < plus.getWidth(); i++) {
  if (plus.hasToken(i)) {
    if (sum == null) {
      sum = plus.get(i);
    } else {
      sum = sum.add(plus.get(i));
    }
  }
}
…
```

target code

3. Model Synthesis

Example design flow:



Challenge:
Compose plant and controller models using library components with alternatives so as to satisfy design constraints

Research Agenda

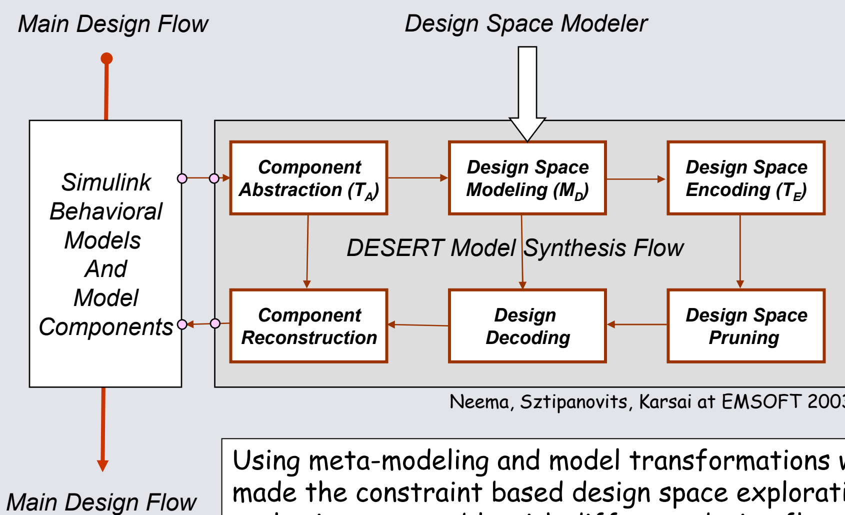
Baseline:

– Constraint-based design space exploration coupled to a dataflow language

Research Agenda:

1. Pattern-based model synthesis
2. Models of Computations as design patterns
3. Design constraints and design patterns for multiple Models of Computations

Pattern-based Model Synthesis



Neema, Sztipanovits, Karsai at EMSOFT 2003

Using meta-modeling and model transformations we made the constraint based design space exploration tool suite composable with different design flows.

Example: Use of Model Translation in the DESERT Tool Chain