Transformations to Automate Model Change Evolution

Yuehua Lin *(liny@cis.uab.edu)* Jeff Gray *(gray@cis.uab.edu)*

Department of Computer and Information Sciences, University of Alabama at Birmingham, Birmingham, AL 35294

http://www.cis.uab.edu/liny

1. Background

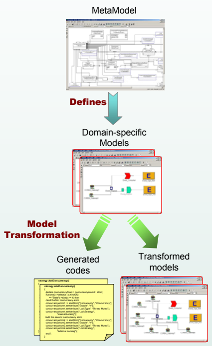
❖**Domain-Specific Modeling (DSM)** addresses the complexity of software development by raising the specification of software to visual models at a higher-level of abstraction

❖**MetaModel** describes the entities and their relationships in an application domain

❖**Models** are instances of a metamodel to visually represent software using idioms familiar to domain experts

❖**Model Transformation** is a process that converts source models to the target software artifacts (e.g. models, codes)

❖**Generic Modeling Environment (GME)** is a modeling tool that allows one to define a domain-specific visual modeling language http://www.isis.vanderbilt.edu/Projects/gme/



2. Motivation

❖**MODEL COMPLEXITY IN SIZE & STRUCTURE:** Distinguished from traditional class-level UML models, many Domain-Specific models are instance models that usually have repetitive and nested structures, and may contain large quantities of components.

❖**EXPLORATION OF DESIGN ALTERNATIVES:** A powerful justification of the use of Domain-Specific models concerns the flexibility of system analysis that requires an ability to change models rapidly and correctly. However, manually evolving such models can be labor intensive, time consuming and prone to errors.

Research Goal:

Alleviating the accidental complexity of modeling large-scale, complex applications by providing a model transformation approach to automate model change evolution

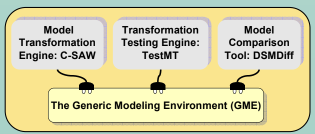
- Improve the productivity and reduce the potential errors in model evolution

The repetitive and nested structures of large-scale system models

3. Research Overview

Areas of Contribution:

- Explore new roles for model transformation in addressing model change evolution issues such as model scalability.
- Provide an easy-to-use model transformation language to specify and execute model change evolutions; a core model transformation engine has been developed to automate such tasks.
- Provide support for testing model transformation specifications. Model differencing techniques are applied to model transformation testing for comparing the actual output and the expected output.



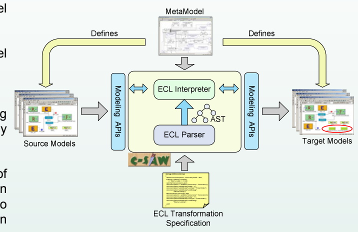
The tool chain consists of 3 GME plug-ins:

- **C-SAW** is for executing transformation specifications
- **TestMT** is for detecting errors in the transformation specification
- **DSMDiff** is for identifying mappings and differences between two models

4. Model Transformation Engine: C-SAW

The Embedded Constraint Language (ECL)

- ECL is an imperative transformation language supporting model-to-model transformation.
- It provides operations for model navigation, selection and transformation.
- It has two kinds of modular units:
  - **Aspect** specifies a crosscutting concern across a model hierarchy (e.g., multiple locations in a model).
  - **Strategy** specifies elements of computation (e.g., transformation behaviors) which will be bound to specific model elements defined by an aspect.

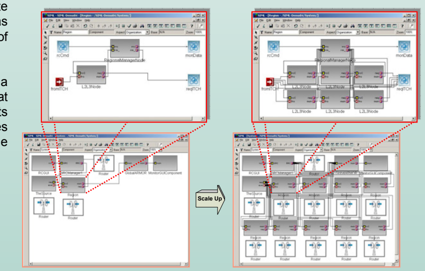


C-SAW: The Transformation Engine

- It is implemented as a GME plug-in component, with a parser and an interpreter for ECL.
- C-SAW takes source models and the ECL transformation specifications as input, and generates target models as output by weaving changes into source models.

5. Case Study: Transformation to Address Model Scalability

- It is often desirable to evaluate different design alternatives as they relate to scalability issues of the modeled system.
- Model scale-up is automated by a transformation process that expands the number of elements from the base model and makes the correct connections among the generated modeling elements.



Source Model **Target Model**

Model Scalability

This example shows the capability of C-SAW to scale up a system configuration model by increasing its region and associated router from 1 to 9 and building the necessary connections.

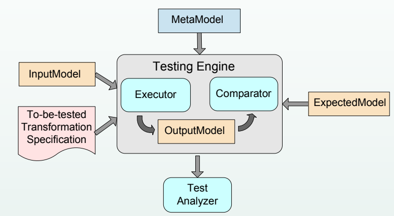
```
strategy scaleUpRegion(reg_name : string; max : integer)
{
    rootFolder().findFolder("System").findModel("System").addRegion(reg_name,max,1);
}

strategy addRegion(region_name, max, idx : integer)    //recursively add regions
{
    declare region, new_region, out_port, region_in_port, router, new_router : object;

    if (idx<=max) then
        region := rootFolder().findFolder("System").findModel(region_name);
        new_region := addInstance("Component", region_name, region);

        //add connections to the new region;
        out_port := findModel("TheSource").findAtom("eventData");
        region_in_port := new_region.findAtom("fromITCH");
        addConnection("Interaction", out_port, region_in_port);

        //add a new router and connect it to the new region
        router := findAtom("Router");
        new_router := copyAtom(router, "Router");
        addConnection("Router2Component", new_router, new_region);
        addRegion(region_name, max, idx+1);
    endif;
}
```

ECL transformation specification to scale up a model

6. Model Transformation Testing

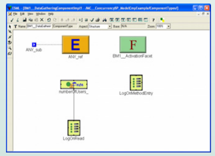
A **testing engine** performs all the tests for testing a specification, which has three components:

- **Executor** executes the to-be-tested specification on the input model to generate the output model.
- **Comparator** compares the output model (i.e., the actual result) to the expected model (i.e., the expected result) and collects the results of comparison. ***A test passes if there are no differences between the output and the expected models; otherwise, the test fails.***
- **Test analyzer** visualizes the model differences to assist in comprehending the testing results.

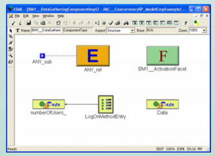


Critical Issues of Model Comparison

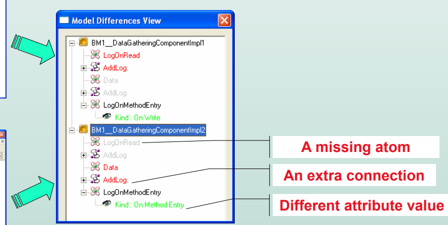
- **Model Comparison Algorithms:** detect the mappings and differences between the two models; start from the root models and then walk down to the child sub-models to compare all the contained elements.
- **Visualization of model differences:** use graphical symbols and colors to indicate all possible kinds of model differences in a structural way.



The Expected Model



The Output Model



Model Differences in a Tree View

7. Evaluation and Contribution

Evaluation

- C-SAW has helped to address model scalability issues for different applications such as **embedded avionics**, **computational physics** and **performance analysis.** Example languages that were used in the evaluation include:
  - The System Integration Modeling Language (SIML) can be used to specify configuration of large-scale data processing systems used by physicists.
  - The Stochastic Reward Net Modeling Language (SRNML) assists in modeling system performance of middleware.
  - Other modeling artifacts from the Escher repository (http://repository.escherinstitute.org/)
- The experimental results have shown using C-SAW to perform model change evolution is significantly **faster** and **more accurate** than manual processes.
- Future evaluation will be conducted on determining the effectiveness of the testing engine in detecting errors in the transformed results.

Contributions

- Automating model transformations for evolving models rapidly and correctly.
- Applying software engineering processes such as testing to model transformations.
- Developing algorithms for comparing models in the context of Domain-Specific Modeling.

Acknowledgement:
This project was previously funded by the DARPA Program Composition for Embedded Systems (PCES) program, and currently supported by the National Science Foundation under CSR-SMA-0509342.