Date: 22 July 2008

TIMELINE:

The goal of the thesis is to provide a solution for the model co-evolution problem (in the context of Concurrent Engineering). The focus is on the synchronization of geometric and dynamic models. In particular, the following tools are used:

1. a CAD (Computer Assisted Design) mechanical modeling tool (Solid Edge by UGS) , and
2. a simulation tool (Dymola by Dynasim) based on the declarative, multi-disciplinary Modelica language

The integration should achieve the following:

1. Model both mechanical and behavioral aspects of a given system
2. Allow both models to evolve in parallel and independently while providing a formal process for consistency propagation and enforcement at regular intervals during the development process.

To achieve the above, the following **have already been completed:**

1. Research topic and define the optimal level at which to model a bi-directional mapping between elements of the CAD and the Modelica models and how changes from one model can be propagated to the other.
   - Published: Chahé Adourian and Hans Vangheluwe. Consistency between geometric and dynamic views of a mechanical system. In *Summer Computer Simulation Conference (SCSC).* Society for Computer Simulation International (SCS), July 2007. pp. 1268 -- 1273. San Diego, CA.

2. Research topic and define the mechanisms by which inconsistencies between the two models can be detected and acted upon automatically and semi-automatically depending on the situation.
   - Various consistency detection mechanisms in the literature have been researched and triple graph-grammars chosen as the best match for our needs.
   - Relevant papers have been gathered and a summary report was written.

3. Research topic and determine the programming tools needed to implement the mapping from CAD to Modelica, and vice-versa.
   - the Solid Edge Programming API has been used to develop partial extraction of CAD model information
   - Dymola's and OpenModelica's Modelica language parsing capabilities have been explored.

4. Develop Modelica CAD library to simplify the mapping requirements from CAD to Modelica; This library was used to:
   a. Demonstrate an almost one-to-one mapping between elements of CAD and the Modelica CAD Library elements
   b. demonstrate that all geometric features of a CAD Part can be modeled in Modelica correctly.
   c. Demonstrate Modelica assembly relationship equivalent to their CAD counterparts
   d. Demonstrate how Modelica assembly relationships together with Modelica geometric features are used to replicate assembly relationships in the CAD model. Do this for all possible combinations of geometric features and assembly relationships.
   e. demonstrate that Parts with relevant properties can be modeled with Modelica using the CAD library

In my **remaining work**, I intend to formalize those concepts, as well as produce a partial code implementation demonstrating the concepts. Estimated time required is indicated for each task.

1) Discuss the thesis topic and the proposed solution approach briefly: (2 weeks)
   a. Elements of the problem:
      i. CAD model
      ii. Modelica model
      iii. Consistency and mapping problems/solutions
   b. Proposed solutions and results for
      i. Mapping CAD to Modelica

        ii. Mapping Modelica to CAD
        iii. Maintaining bi-directional consistency using triple graph grammars

2) Describe the CAD model (4 weeks)
    a. Document the building blocks of a CAD model: parts, assemblies and assembly relationships
    b. Document the information contained in a Part model: mass properties, shape and list of geometric features that are used by assembly relationships.
    c. Document the various assembly relationships, both elemental and composite, and how individual geometric features are used to define the relationships.

3) Describe the Modelica model: (4 weeks)
    a. Object oriented and acausal modeling
    b. Multidisciplinary modeling capability including mechanical modeling with the Modelica Mechanics library
    c. Similarities between CAD assemblies and Mechanical models in Modelica

4) Describe the consistency and mapping problems/solutions: (4 weeks)
    a. Co-evolution of two models describing the same system and resulting manual consistency management difficulties
    b. Partial solution using unidirectional mappings from one tool to the other
    c. Improving over unidirectional mapping by using bi-directional mappings and automated consistency management solutions
    d. Research results into current consistency management solutions
    e. Our selection of triple-graph grammars as an adequate solution for our problem

5) Develop/Describe the CAD to Modelica mapping solution: (4 weeks)
    a. Develop the Modelica CAD library (80% complete)
    b. Describe the Modelica CAD library used to simplify the mapping of CAD models to Modelica (0% complete)
        i. Describe the existing Modelica Mechanics library used as the starting point for the Modelica CAD library
        ii. Describe the Modelica CAD library developed to simplify the mapping between CAD and Modelica:
            1. Building blocks such as Geometric types, Geometric features, Assembly relationships
            2. Justifications for the adopted architecture in creating the building blocks
            3. Example models demonstrating correct behavior
    c. Use API to extract CAD model information, including (80% complete):
        i. List of Parts, mass properties and relevant geometric features
        ii. List of assemblies and their composition out of other assemblies, parts and assembly relationships
        iii. List of Assembly relationships and the parts/geometric features they connect to.
    d. Use CAD information to generate Modelica models based on the Modelica CAD library (30% complete):
        i. Create the appropriate Modelica models automatically
        ii. Prepare examples demonstrating the functionalities of the CAD to Modelica mapping process.
    e. Describe the CAD to Modelica conversion

6) Describe the Modelica to CAD mapping solution: (4 weeks)
    a. Modelica used to supplement behavioral information to the mechanical information derived from the CAD model
    b. Filtering done on Modelica model to extract only Mechanical information and map them to the CAD model
    c. Extent of modifications allowed in Modelica on CAD information
        i. Addition and deletion of parts and assemblies.
        ii. Addition of assembly relationships and the appropriateness of doing so in a geometry poor tool/language (Dymola/Modelica) as opposed to doing the addition in a geometry rich tool (CAD/Solid Edge)

   iii. The extent to which assembly relationships can be added in Modelica, and which assembly relationships are better suited for that.
   iv. The extent to which mechanical joints from the Modelica Mechanics library can be used to create CAD assembly relationships, and implications of having two sets of models in Modelica that represent the same behavior on the CAD side.
   v. Deletion of assembly relationships.
   vi. Visibility of Part Geometry parameters in Modelica, and implications.

7) Maintaining bi-directional consistency (6 weeks)
   a. Describe the triple graph-grammars
      i. how it is initialized the first time the two models are synchronized;
      ii. the user intervention required for initialization (to map equivalent elements to each other)
      iii. how it maintains a memory of past state from last synchronization;
      iv. how it detects changes
      v. when it can propagate changes automatically
      vi. When it requires user intervention to select changes needed to reach consistency
   b. Formalize the description of triple graph-grammars in relation to particularities of the CAD and Modelica models
      i. List operations allowed on both CAD and Modelica sides
      ii. their effects
   c. Prepare multiple examples as to how the triple graph-grammars behave in reaction to various changes on the CAD model, the Modelica model, or both models at the same time. Support this by graphical snapshots of the evolution of CAD and Modelica models

8) Conclusions, Summary and Future work (1 week)