WRT-1011: Architecting Digital Twins For Model-Centric Engineering: Combined Semantic Modeling and Machine Learning Approach

Mark Austin (PI), Maria Coelho, Mark Blackburn

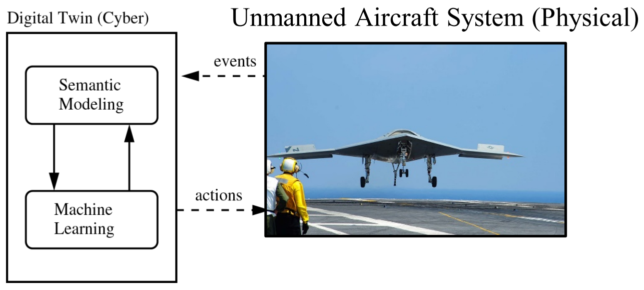
SYSTEMS ENGINEERING RESEARCH CENTER

UNIVERSITY OF MARYLAND 18 56

Research Opportunity

- **Digital Twin:** A digital representation of system that mirrors its implementation in physical world through real-time monitoring and synchronization of data associated with events

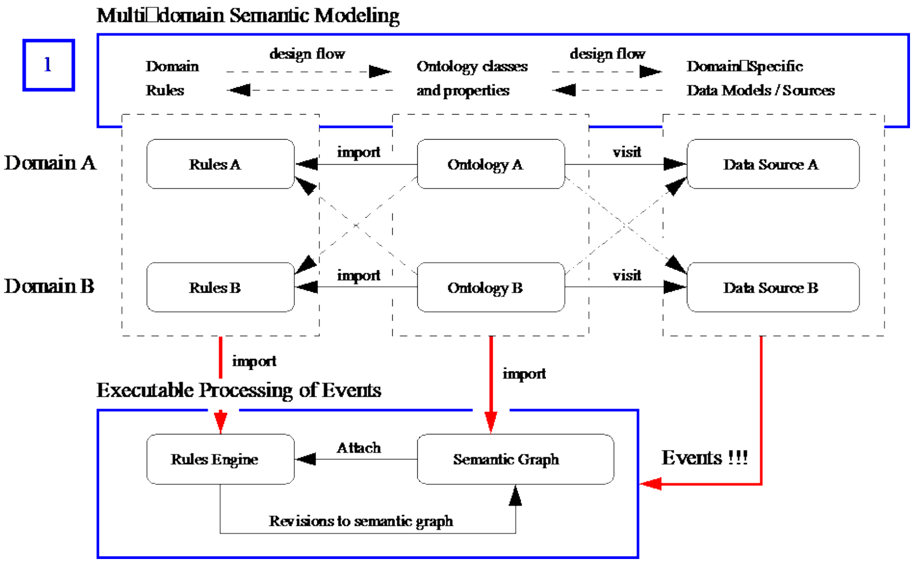
- **Expectation:** AI and machine learning (ML) technologies will be deeply embedded in digital twin operating system environments for observation, reasoning and physical systems control.



- **Incubator Idea.** Support model-based engineering activities with operating systems where semantic modeling and machine learning work together as a team.

Preliminary Work

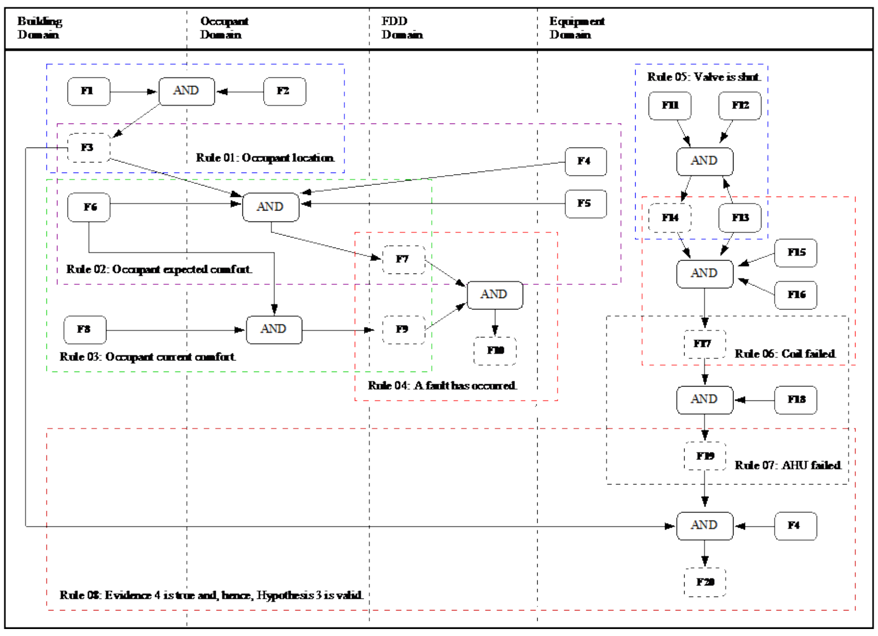
Architectural Template for Multi-Domain Semantic Modeling and Reasoning (Research at UMD/SERC, 2016-2017).



Key Points for Layer 1:

- Concurrent development of data, ontologies and rules.
- Executable processing of events.

Example from Building Domain: Detection and diagnostic analysis of faults in building equipment:



Points to note:

- Semantic model and reasoning procedures span 4 domains: building domain, occupant domain, fault detection and diagnostics (FDD) domain, equipment domain.
- Systems Integration is in the rules. Rules 1-4 detect existence of a fault; rules 5-8 examine the evidence to diagnose the cause.

Conclusion: Event-driven multi-domain reasoning works great! Let's add data mining / machine learning and see if they can work together?

Project Goals & Objectives

Project Goal: Understand opportunities for supporting model-based engineering activities through semantic-modeling / machine learning cooperation.

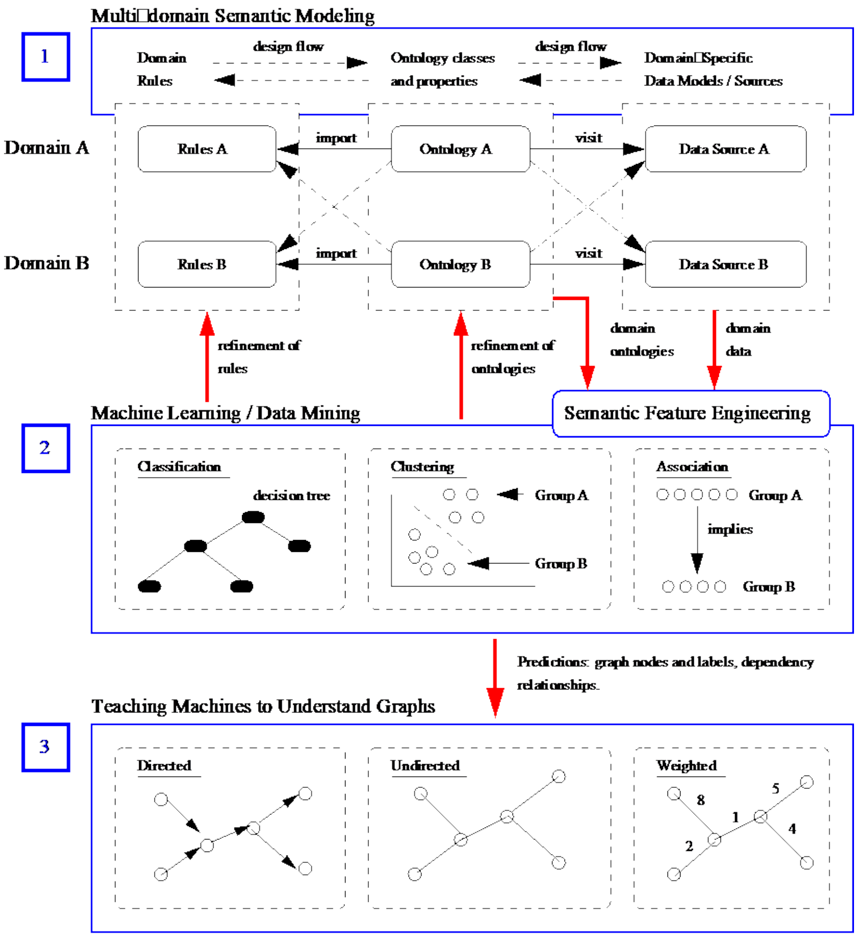
The addition of machine learning to semantic modeling leads to the simple question:

What will the machine learning do?

Basic Observation: Model-based engineering activities involve development and reasoning with models of system structure and system behavior, and system processes. The common modeling abstraction is graphs.

Methodology

Proposed Methodology: Extend architectural template for multi-domain semantic modeling to cover: (a) data mining, and (2) machine learning of graphs.



Layer 2: Algorithms for data mining can suggest organization of ontologies and structuring of rules.
Layer 3: Neural net representations for graphs found in model-based engineering.

Future Research

Our investigation aims to answer the following questions:

(1) What types of graphs (e.g., undirected, directed, weighted) are easy for the ML to learn?
(2) How well do these techniques work with topology and attributes that are dynamic?
(3) What can ML techniques do that is outside the capability of semantic modeling? And vice-versa?
(4) How can the ML improve the semantic modeling?
(5) How can the semantic modeling improve the ML?
(6) How to design the red arrows connecting architectural layers 1, 2 and 3?
(7) How does the difficulty of these challenges vary as a function of graph size?

Contacts

- Mark Austin (PI), austin@isr.umd.edu
- Maria Coelho, mecoelho@terpmail.umd.edu
- Mark Blackburn, mblackbu@stevens.edu