Ontological Controls In Smart Buildings

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THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

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Smart Buildings as a Pixel in "Smart City" Picture

Motivation:

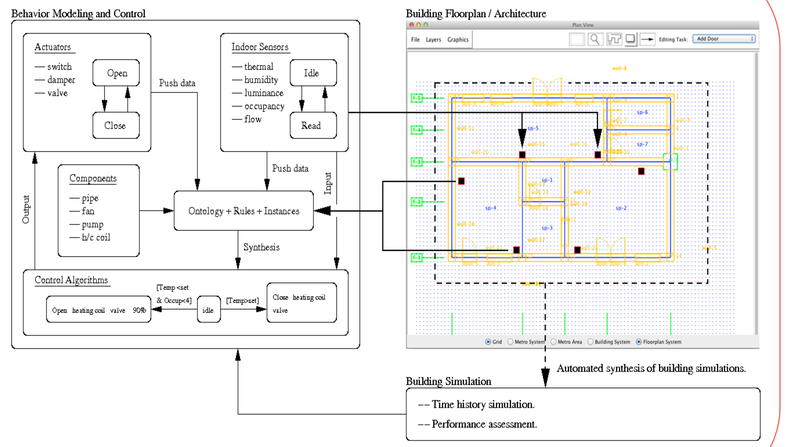
- Modern HVAC systems in buildings consist of thousands of devices from local dampers, heaters to boilers, air handling units, chillers and cooling towers.
- Over time, efficiency of HVAC systems tends to degrade from the optimum.
- Intelligent agents distributed throughout a HVAC system would orchestrate the operation of all components so as to maintain peak performance.

Long History with little real-world progress:

- Individuals spend 80% of their life indoors.
- Commercial buildings account for about 19 percent of the total and a third of electric power consumption.*
- Energy management in the buildings are least optimized (PI, PID Controllers with one or two levels of heuristic).**
- Energy-eating operations can be accomplished far more efficiently by more intelligently control strategies.

Towards Intelligent Building Agents

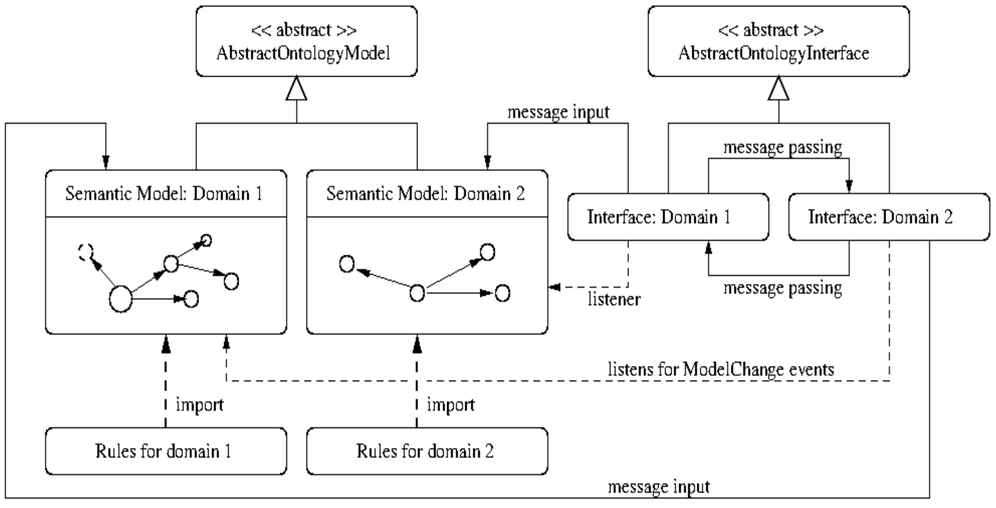
- Collect extensive data from sensors in the buildings.
- Identify the current status of all equipment/systems.
- Store data in semantic graphs of ontologies.
- Exploit message passing mechanisms for agent communications.
- Utilize inference engines to perform automated rule-based decision making techniques on data.
- Solve for of local (individual) vs. global (system-wide) optimums.



Current Framework for Ontological Controls in HVAC Systems in Smart Buildings

Goal: Develop a software infrastructure for distributed intelligent control strategies in smart buildings:

- Define semantics of domains in domain-specific ontologies (RDF, Jena API).
- Loosely couple each semantic model to a semantic interface.
- Capture domain constraints as governing rules and import them into ontologies.
- Perform formal reasoning which results in model and graph transformations.
- Provide message-passing mechanisms among all semantic model interfaces.



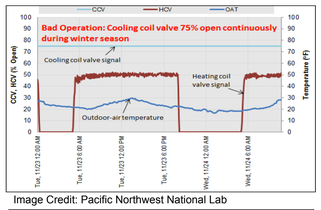
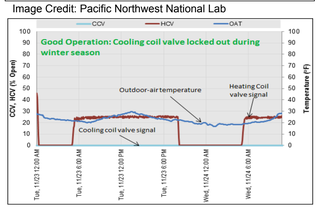


Image Credit: Pacific Northwest National Lab

Rule to support lockout Cooling Coil (winter operation)

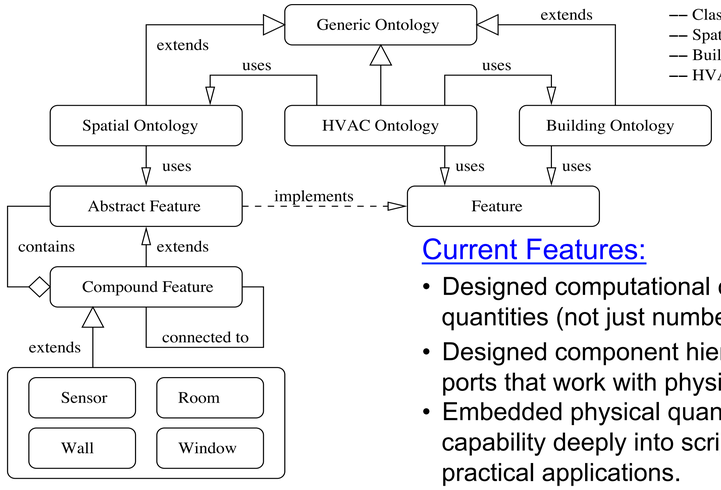
(?cc RDF:type Cooling) (?cc ont:isLocked? ?l) (?out_temp ont:hasValue ?v) lessThan(?v,55) -> (?l, true)



Rule to check for coil leakage

(?c rdf:type Coil) (?c ont:leakage ?leak) (?c ont:coil_temp ?t) (?c, ont:locked ,true) lessThan (?t, ?room_temp) -> (?leak, true)

Building System Structure Ontologies and Models



Jena Rules

— Class relationship rules
— Spatial rules
— Building rules
— HVAC rules.

Current Features:

- Designed computational cores that can reason with physical quantities (not just numbers), time and space.
- Designed component hierarchies and networks, and component ports that work with physical quantities.
- Embedded physical quantities, ontologies, and reasoning capability deeply into scripting languages. Script and solve practical applications.

References:
* U.S. Department of Energy, *Buildings Energy Data Book,* http://buildingsdatabook.eren.doe.gov/ChapterIntro1.aspx.
** Kelly G. E., Bushby S T. (2012) *"Are intelligent agents the key to optimizing building HVAC system performance?"* The Journal of HVAC&R Research,18(4),1938-5587.

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