Preliminary Results in Virtual Testing for Smart Buildings

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Goal

Providing a framework for effective virtual testing of smart building applications

Contributions

An execution platform
for coupling continuous and discrete models
in the domain of smart buildings

Physical Environment Modeling

Goal

To describe physical environment properties

Contribution

Acumen: A domain-specific description language for continuous systems

Heat transfer in a thermodynamics book

$$\frac{dT_i}{dt} = \frac{1}{C_i}\left(\sum_{k \in Neighbors(i)} \frac{T_k - T_i}{R_{ik}} + (B_{h(i)} \cdot P_i - B_{c(i)} \cdot Q_i)\right) + \frac{1}{C_i} \cdot \sum_{j \in Occupants(i)} H_j$$

Heat transfer in Acumen

```
(* Building topology *)
building=((0),(0,2),(0,1,3),(0,2));
(* Temperature in each building room *)
T=(T0,T1,T2,T3);
[ ... ]
continuous
  foreach room in building begin
    T'[room] = 1/C[room] *
      ((sum n < length(building[room]) in
          ((T[building[room][n]]-T[room]) / R_th[room][n]))
        + Bh[room] * P[room] - Bc[room] * Q[room]
        + (sum p < length(occupants[room])
              in H[occupants[room][p]]));
  end

 boundary conditions
   T0 with T0(0) = 10;
   [ ... ]
```

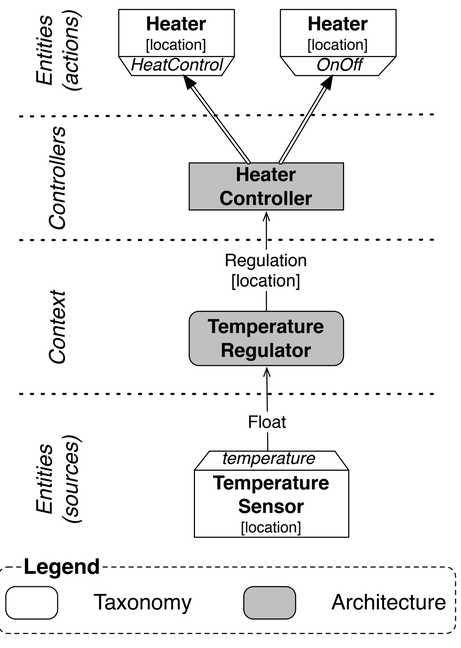
Smart Building Application Modeling

Goal

To describe smart building applications

Contribution

DiaSpec: A domain-specific design language for Sense/Compute/Control systems




```
device Heater {
  attribute location as Location;
  action HeatControl { heat(); cool(); };
  action OnOff { on(); off(); };
}

controller HeaterController {
  context TemperatureRegulator;
  action OnOff,HeatControl on Heater;
}

context TemperatureRegulator as Regulation
    indexed by location as Location {
  source temperature from TemperatureSensor;
}

device TemperatureSensor {
  attribute location as Location;
  source temperature as Float;
}
```

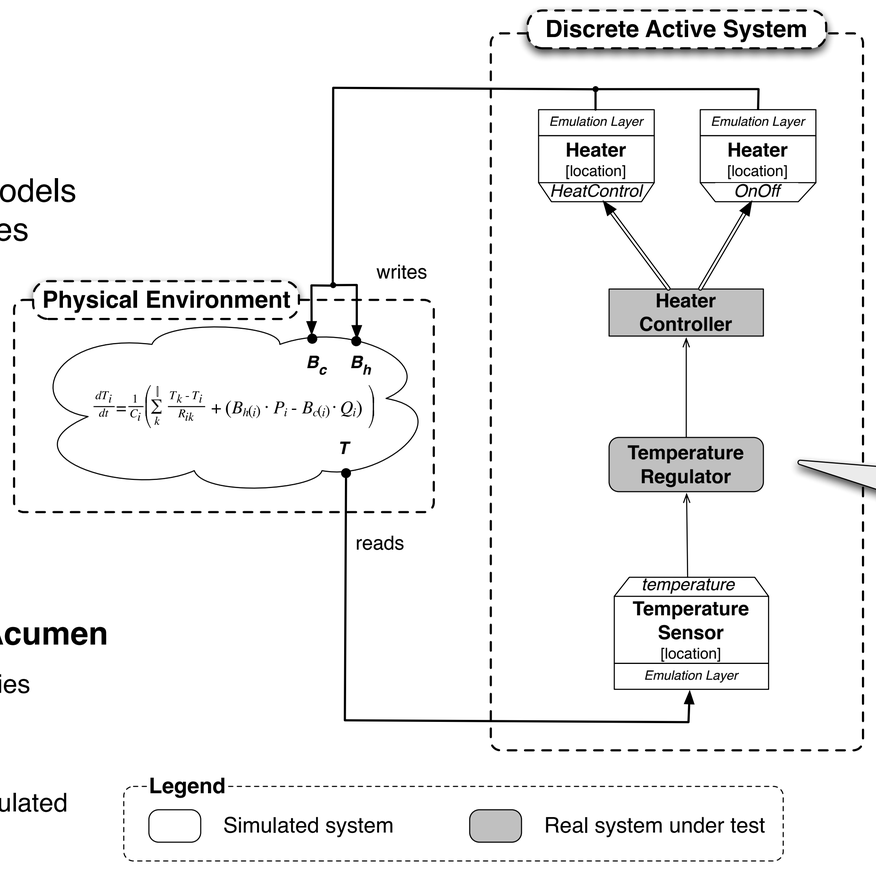
Simulation Execution

Goal

To execute complete models

Contribution

Physical environment and active system models mapped into executable simulation codes



Smart building simulation

Active device simulation with DiaSim

- Graphical configuration of the active devices
- Graphical rendering of the tested active system
- Logging of the active system execution

Physical environment simulation with Acumen

- Discretizes in time the continuous physical properties
- Provides physical property values to simulated active devices
- Updates its state with respect to the actions of simulated active devices

Implementation and virtual testing of a smart building application

- Generated programming support from the smart building application description
- Conformance between description and implementation
- Virtual testing without any modification in the smart building application implementation

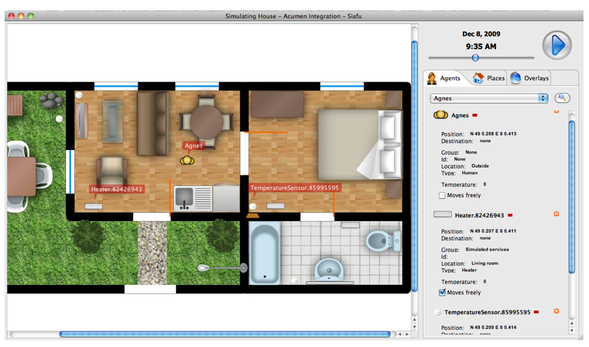
```
public class TemperatureRegulator
          extends AbstractTemperatureRegulator {
    ...
    @Override
    public void onNewTemperature(Float value,
                                 Location location) {
        if (value < COMFORT_ZONE_MIN) {
          Regulation regulation = Regulation.HEAT;
          publish(regulation);
        } else if (value > COMFORT_ZONE_MAX) {
          Regulation regulation = Regulation.COOL;
          publish(regulation);
        }
    }
}
```

HVAC Virtual Testing

Evaluation of smart building systems

- **Algorithmic variations**
  Variations in the active controller algorithm
- **Structural variations**
  Variations in the sensor and actuator configuration

Evaluation of an HVAC system in a 3-room house

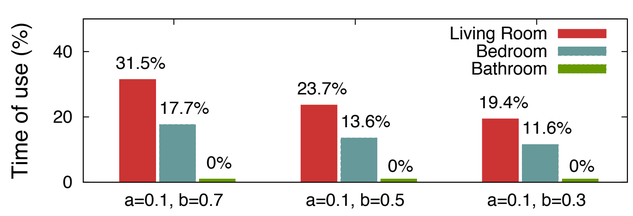


Algorithmic Variations

Temperature regulation algorithm

$$T_{min} = T_{c-min} + a * (T_{c-max} - T_{c-min})$$
$$T_{max} = T_{c-min} + b * (T_{c-max} - T_{c-min})$$
$$a, b \in [0, 1] \text{ and } a < b$$

Testing with different T_{min} and T_{max} values



Structural Variations

Comparison of two temperature regulation configurations

- **Global regulation:** 1 thermostat per house
- **Local regulation:** 1 thermostat per room