



Methods for Network Enabled Embedded Monitoring and Control for High-Performance Buildings

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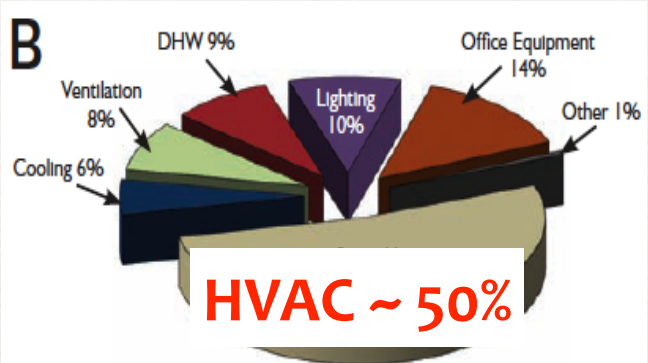


- ◆ Occupancy modeling and prediction, control of evacuation
- ◆ Platform-based design space exploration for cyber systems relevant to building monitoring and control
- ◆ Energy efficiency improvement through estimation and control
- ◆ Learning and adaptation of models and networks across buildings and time-scales

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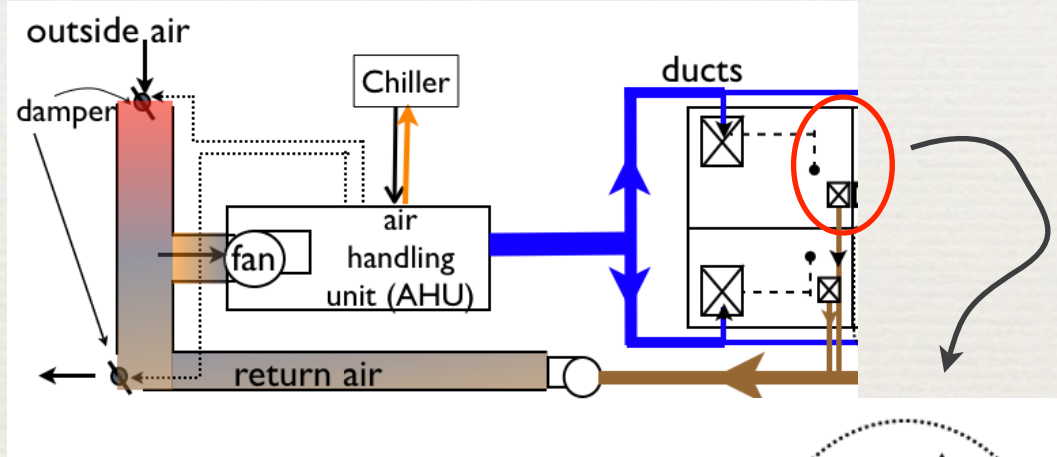
Buildings and Energy (U.S.A.)

> 70% of electricity*, 40% of total energy, ...
 > commercial vs. residential : close to 1

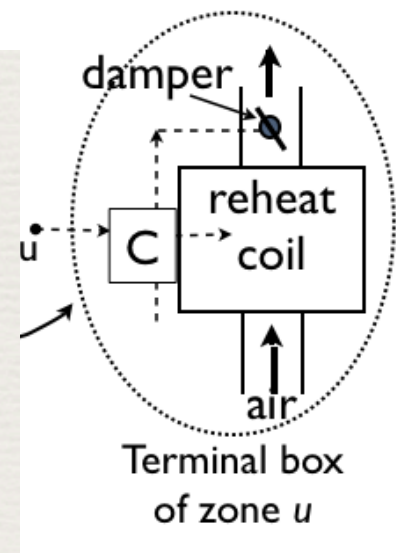
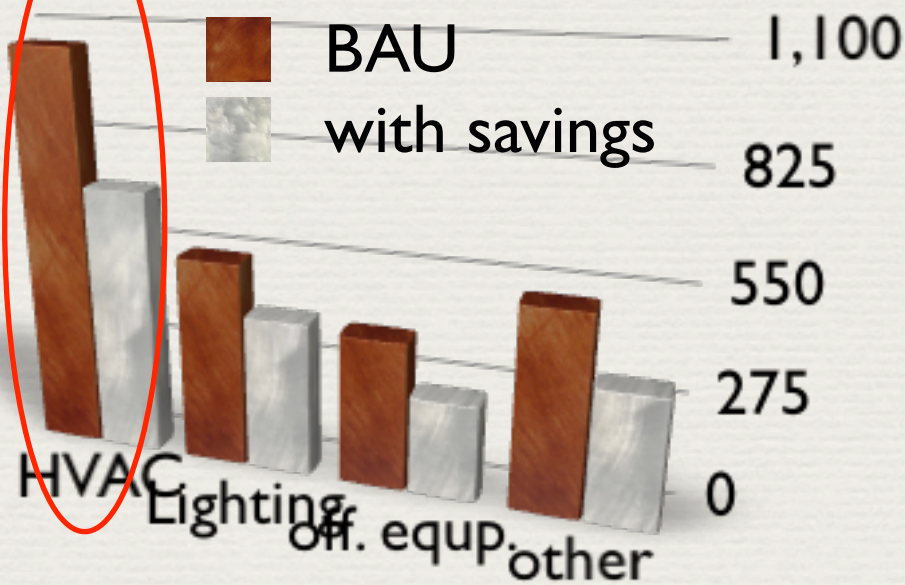


heating, ventilation, air conditioning

Sources of Inefficiency:
 (1) over-design, (2) poor operation

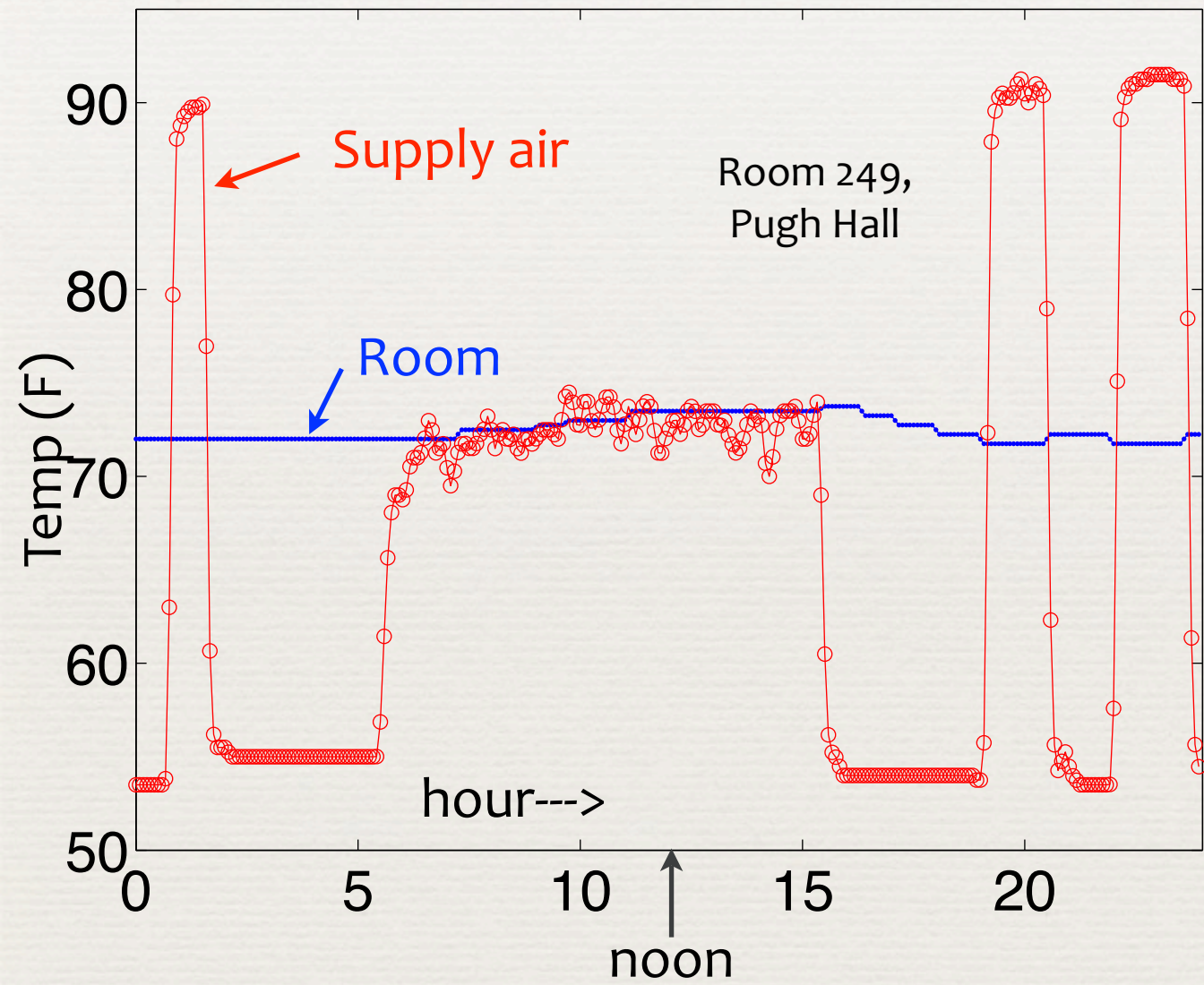


2050 U.S. building energy use

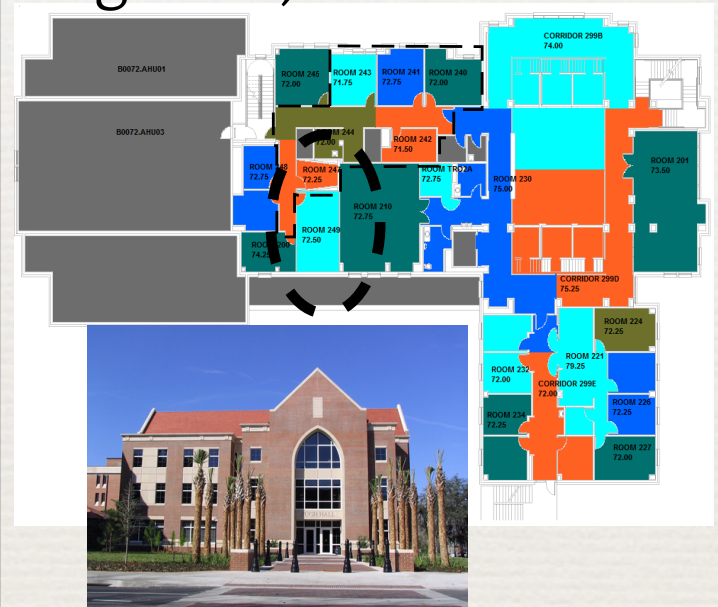


State of the art?

inefficiency: (1) over-design (2) **poor operation**



Pugh Hall, Univ of Florida



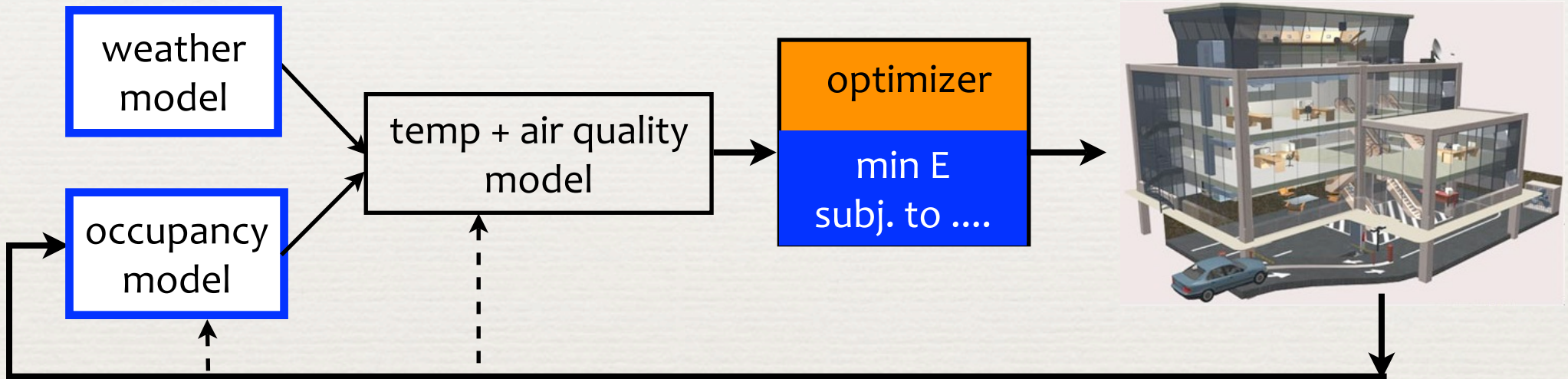
serve the occupants,
not empty space!

Air quality!!!
(ASHRAE standards)

High performance buildings

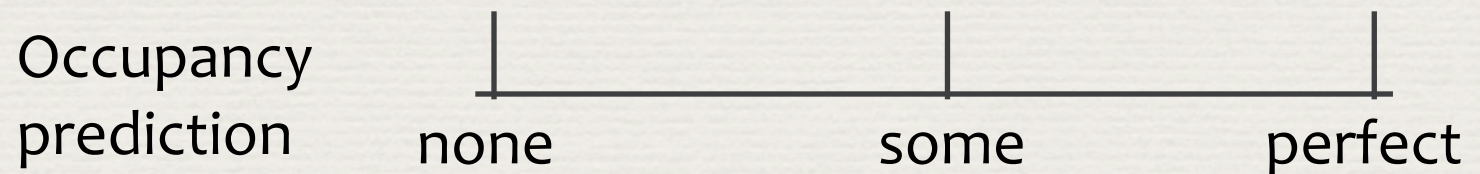
efficiency: (1) ... (2) **better operation**

“minimize energy use while maintaining comfort and IAQ”



complexity and uncertainty makes modeling/prediction/design challenging

- *) Delay between action and its effect
- *) Air quality and temp vs. energy



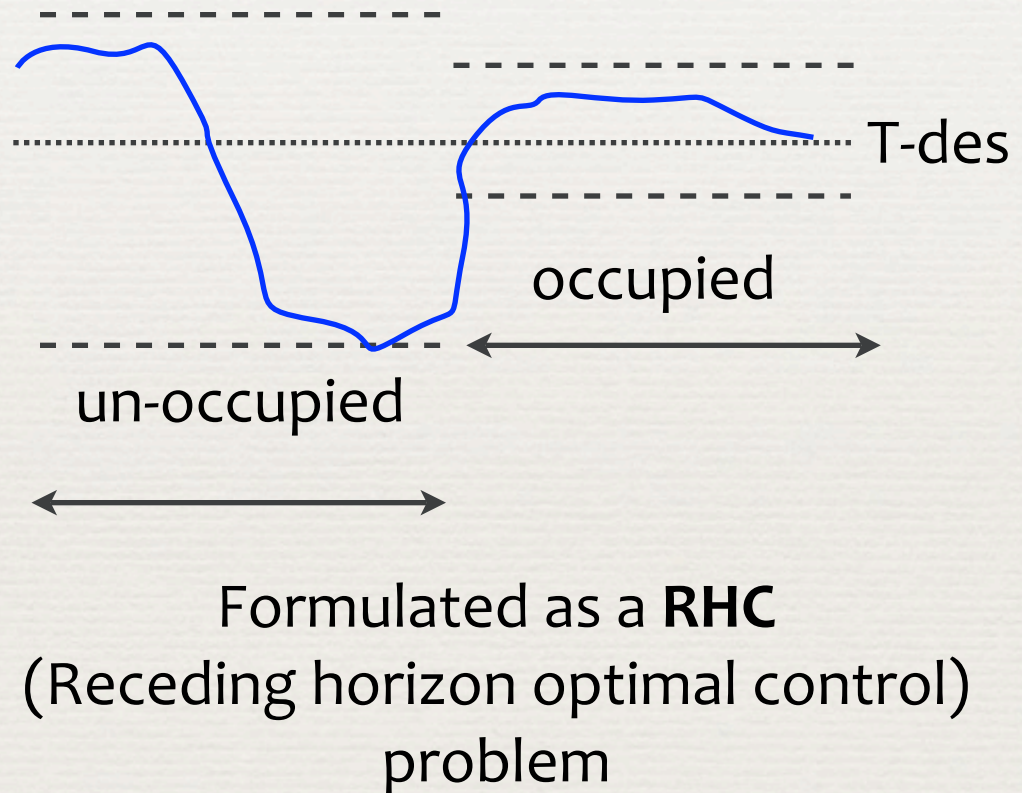
Predictive control w/o occp. prediction

Set-point based control
(PID+logic)

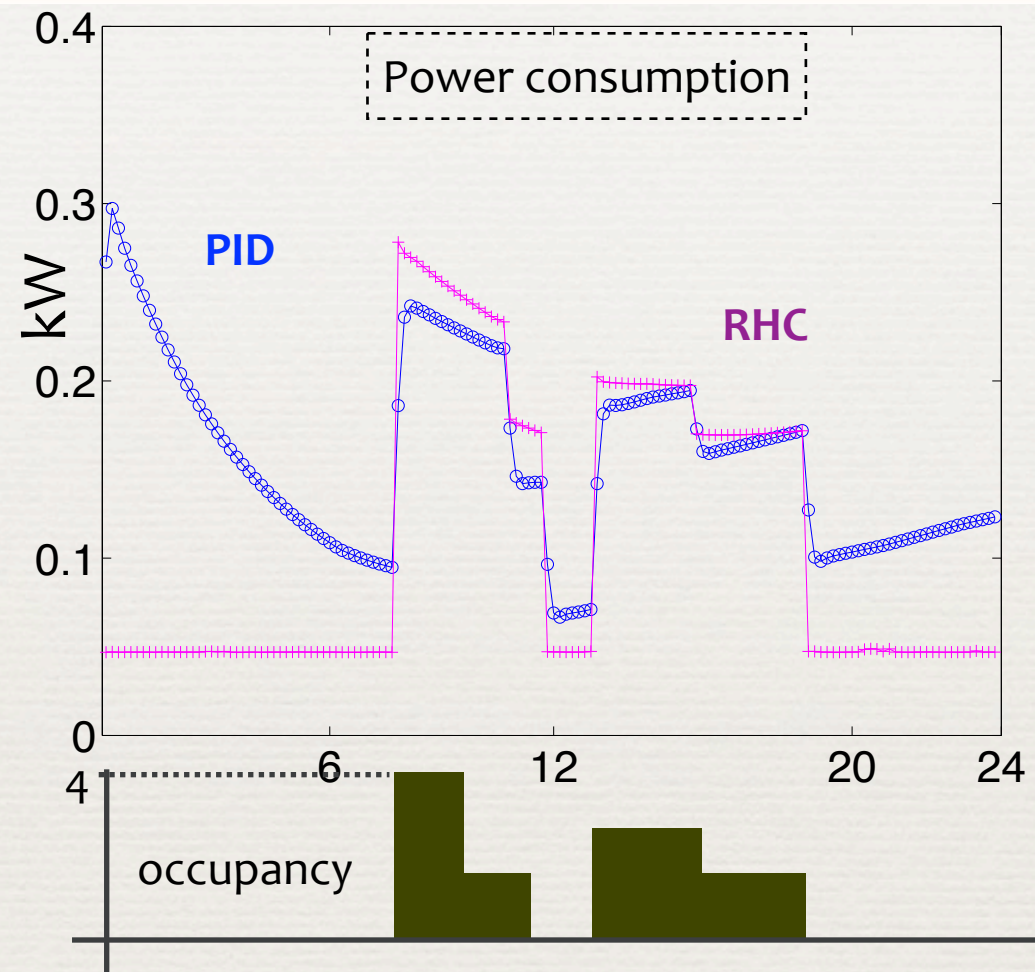
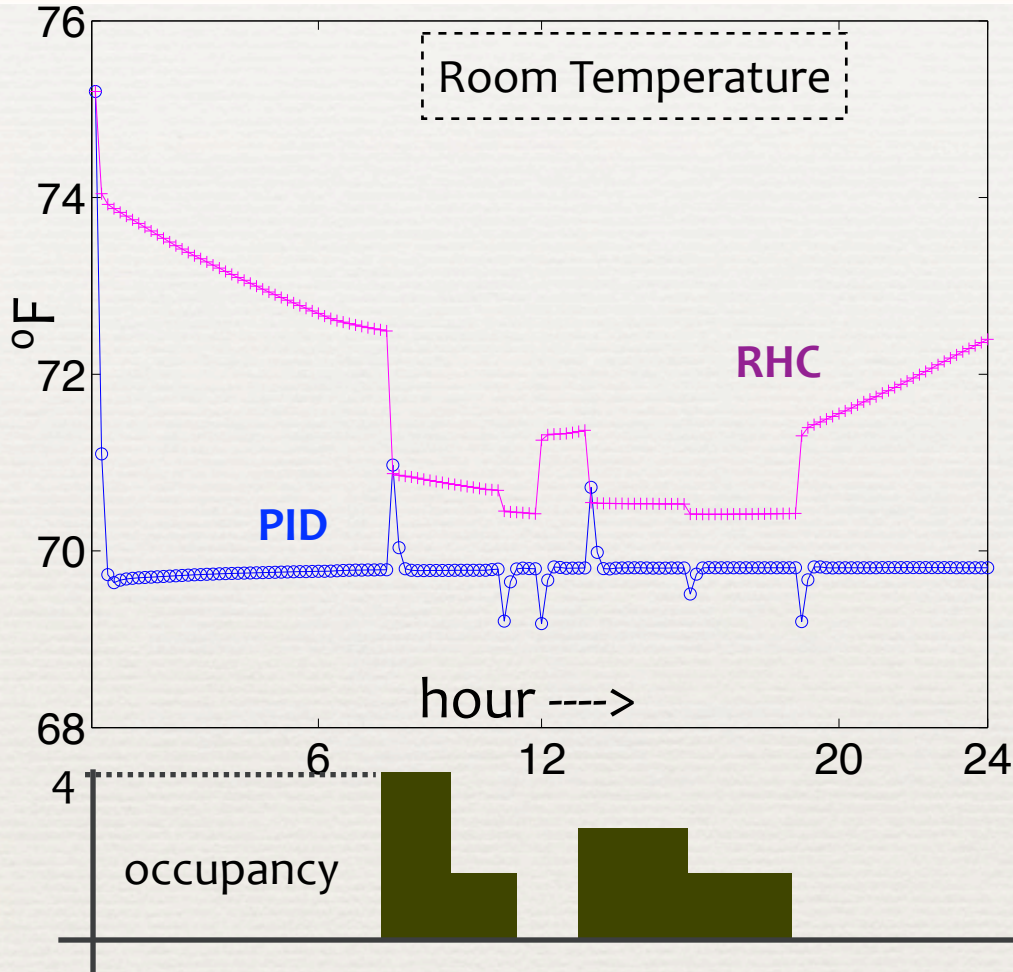


Floating-point control:

- *) allow temp within a band
- *) wider band when unoccupied
- *) maintain minimum airflow to remove VOC and CO₂
- *) if occupied now, assume will be occupied for the next T minutes
- *) control changes only every T minutes
- *) minimize energy over the next NT minutes

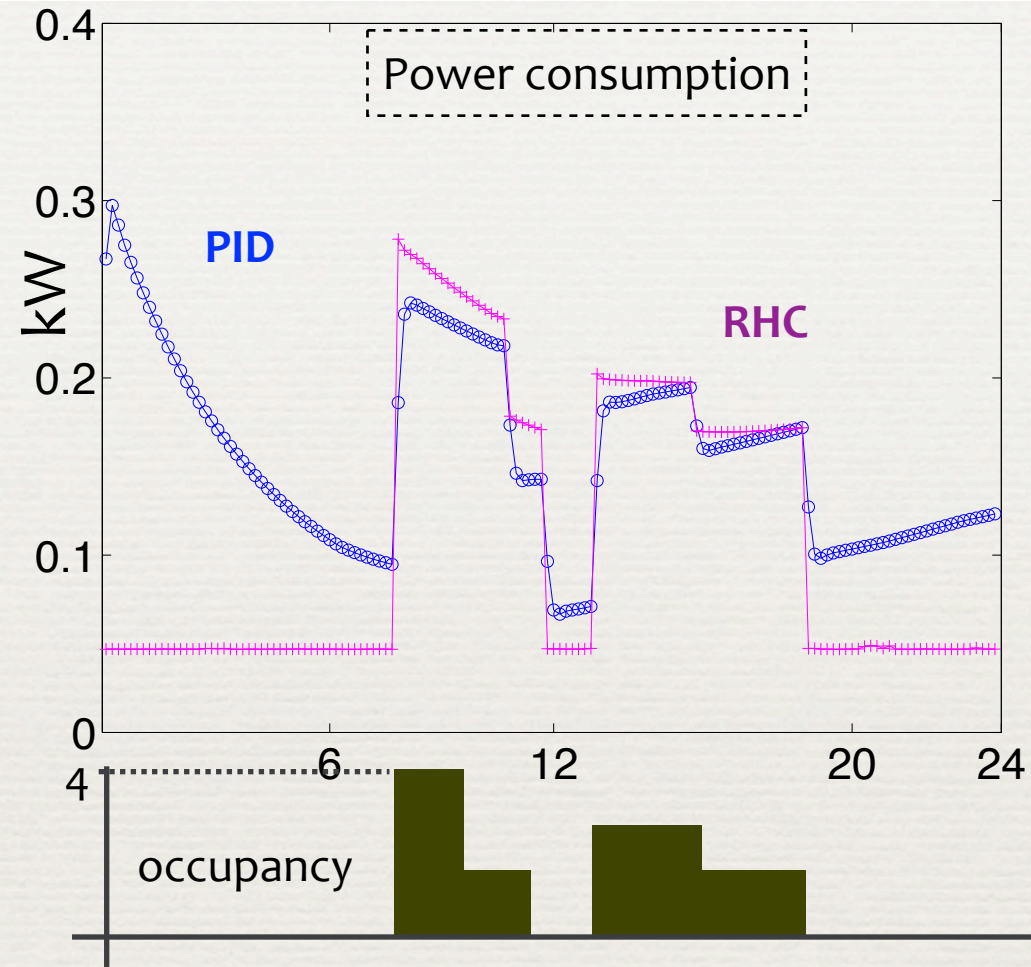
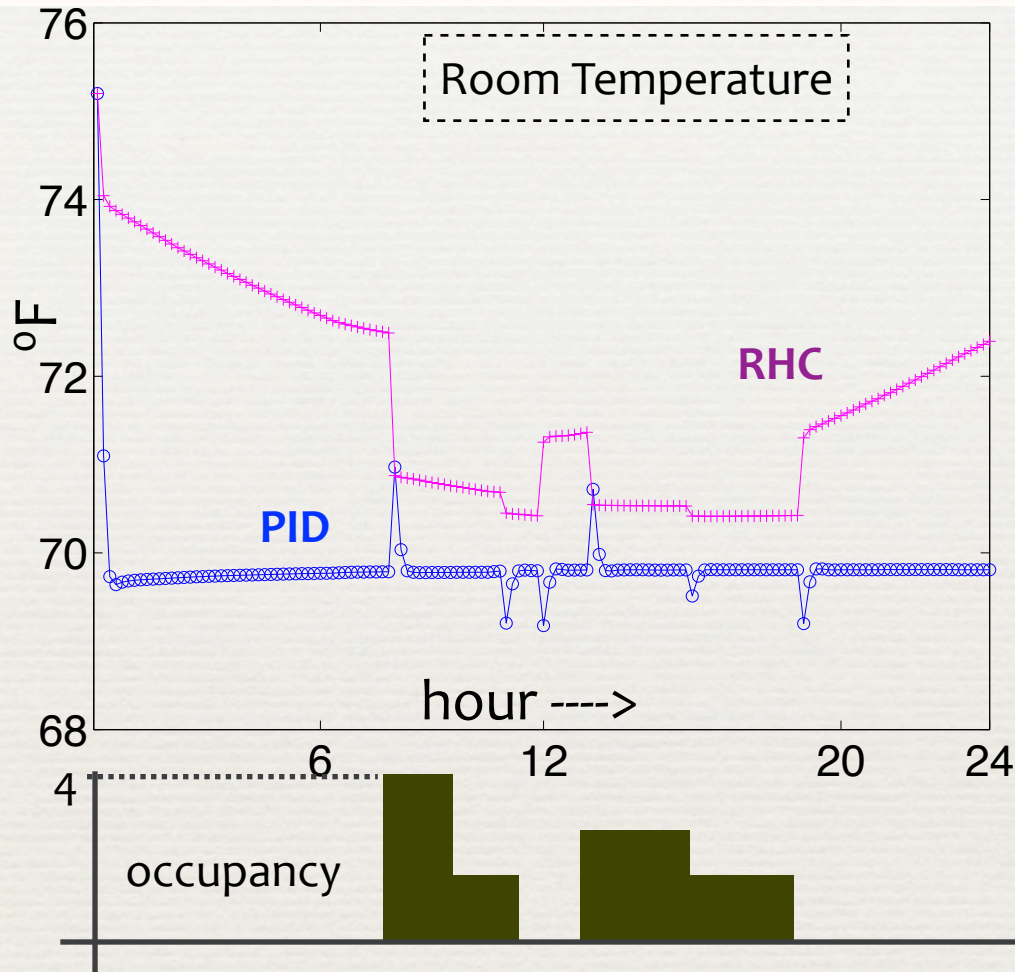


Example



30% savings over PID (ex 2: occupied 18 of 24 hours: 10%)

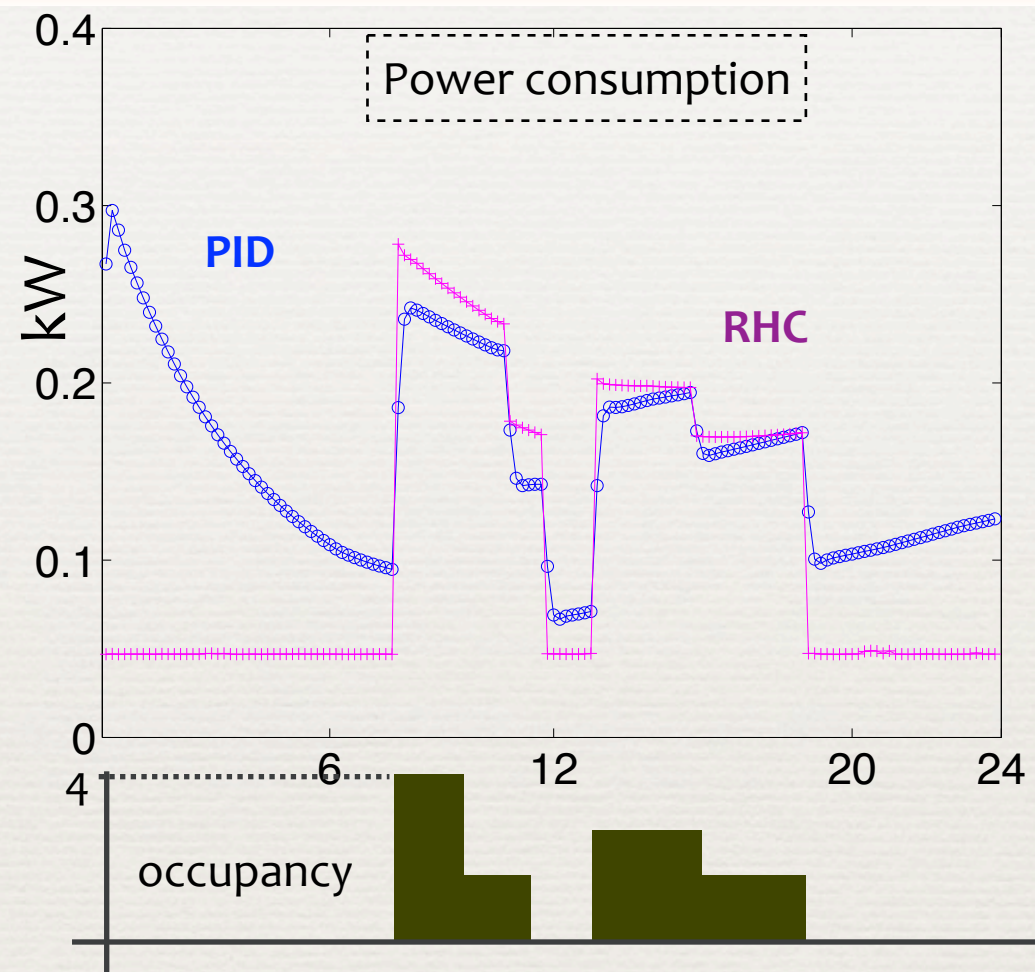
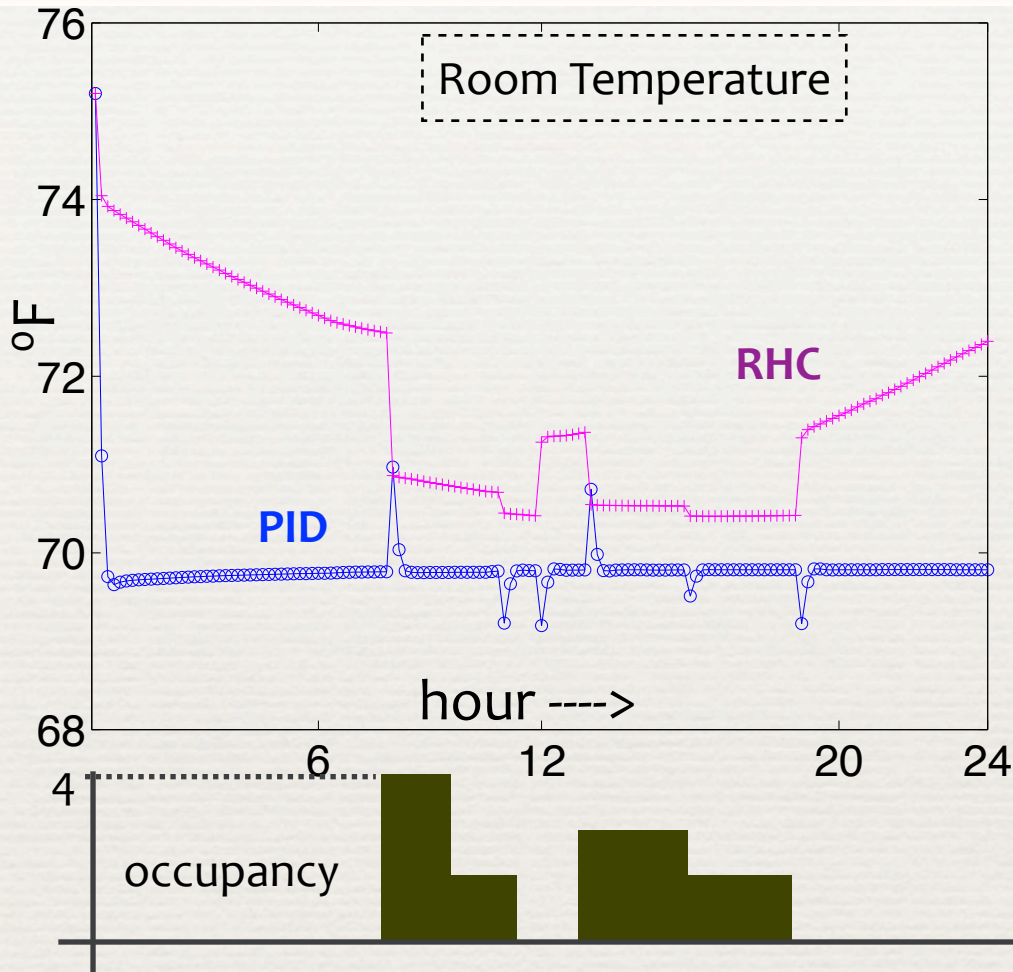
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- ◆ Large savings are possible with only occupancy measurement, w/o prediction
- ◆ bottleneck is not temperature control but air quality/ventilation (health problems, lawsuits, ..)

Example



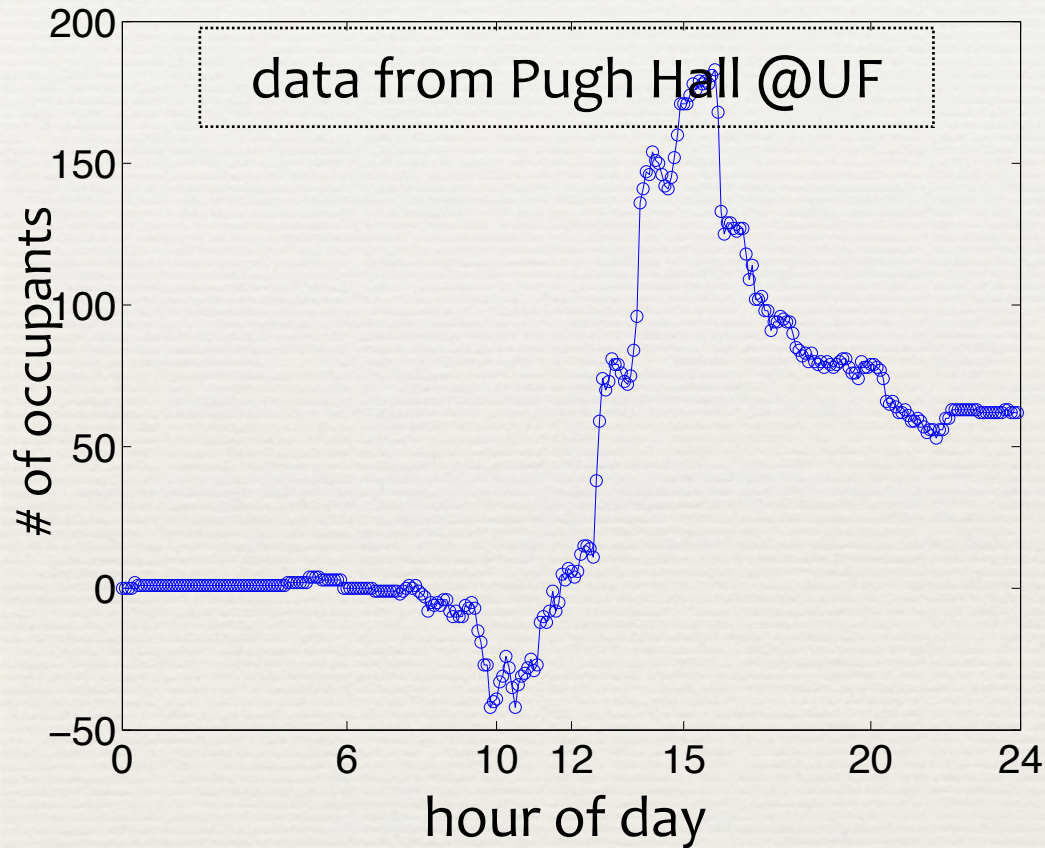
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Measuring occupancy

Most sensors are “flow” sensors => large drift!

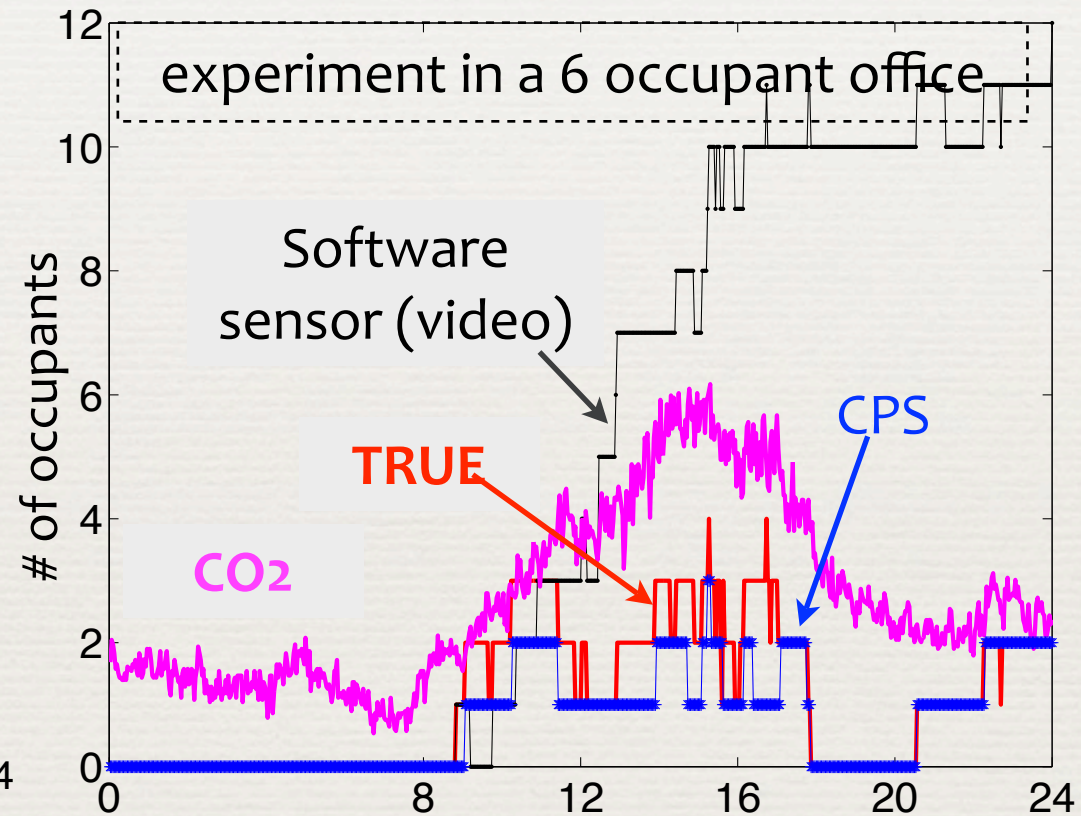
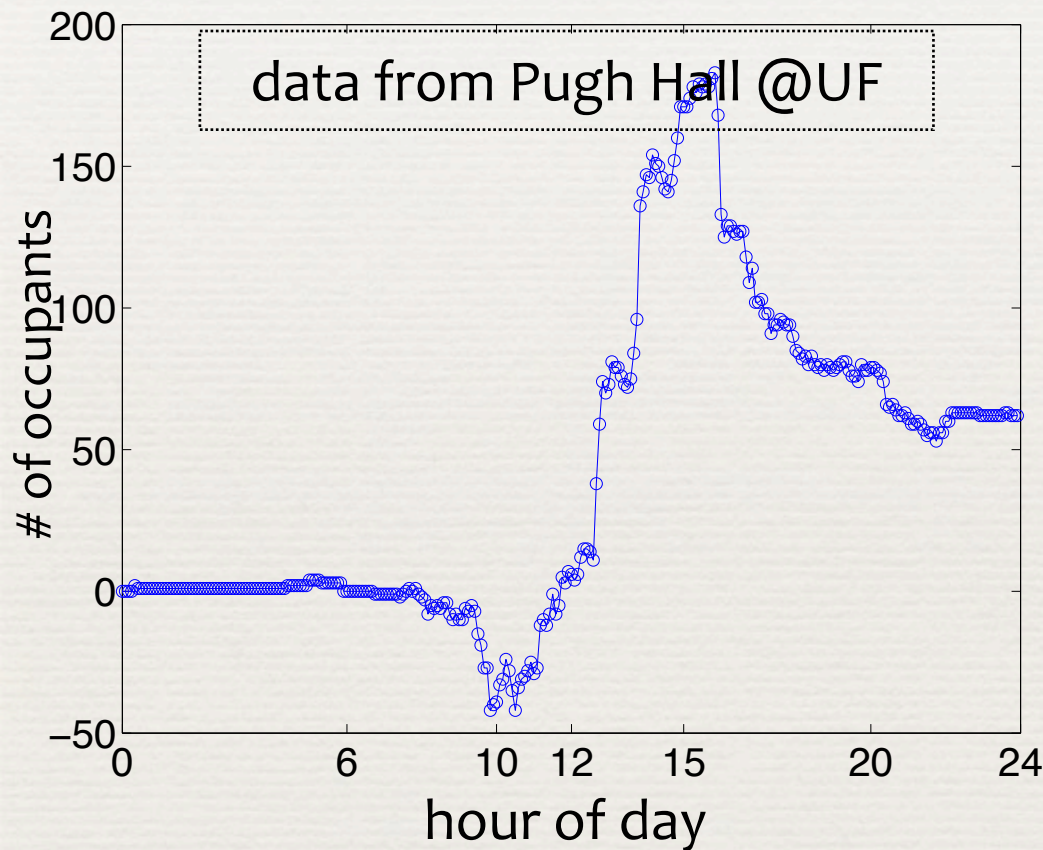
$$\text{Occp}(k) = \text{flow in}(1) + \text{flow in}(2) + \dots + \text{flow in}(k)$$



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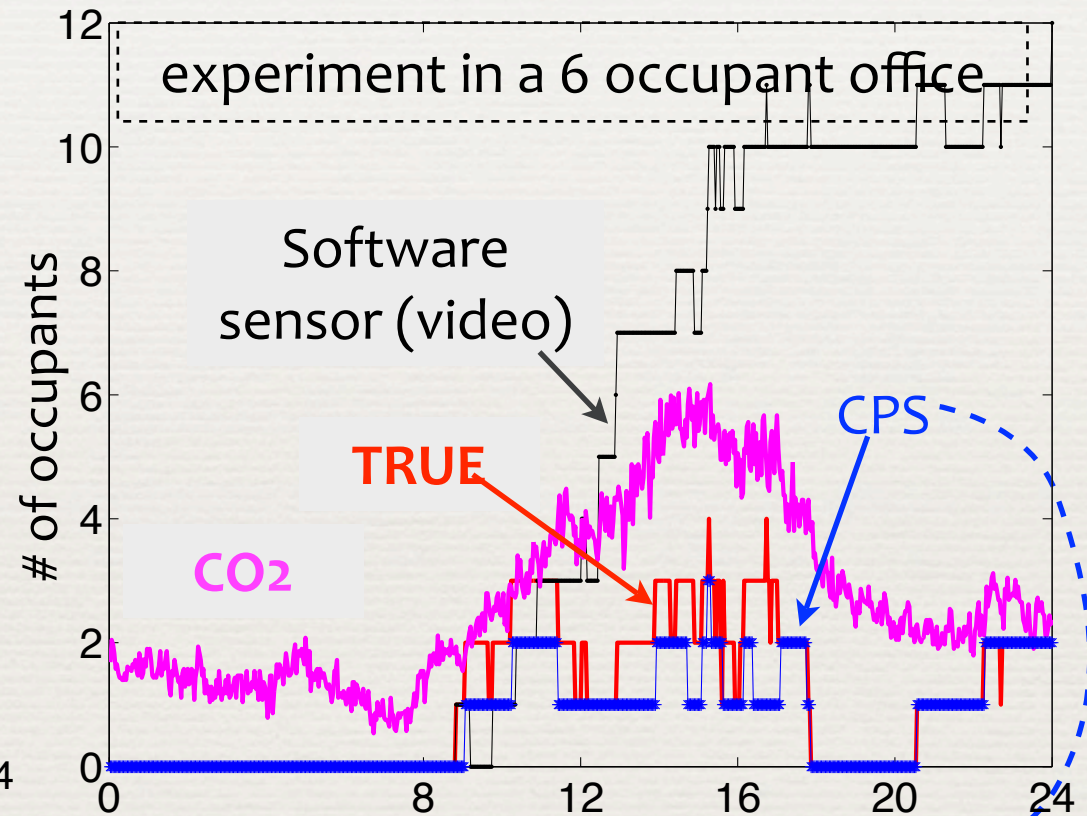
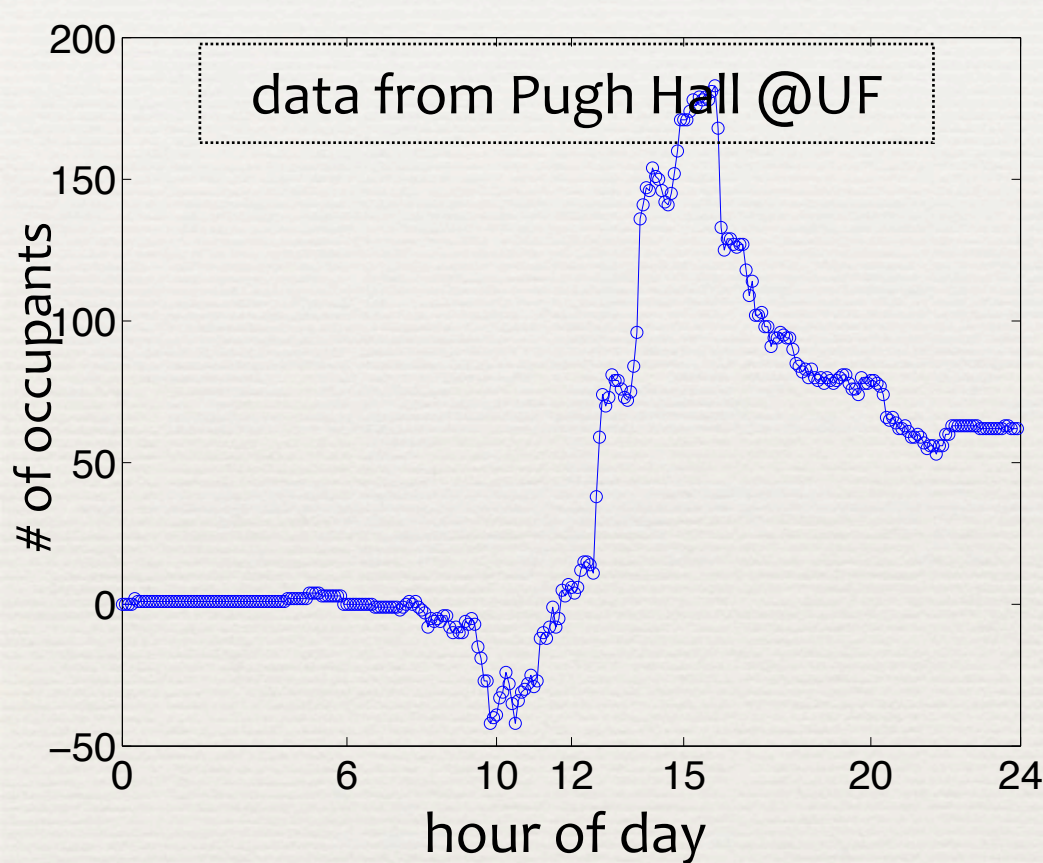
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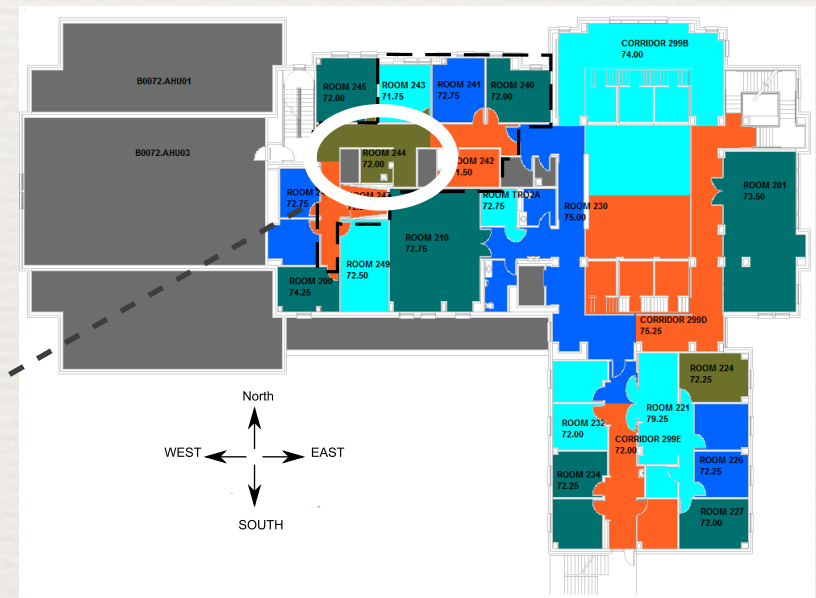
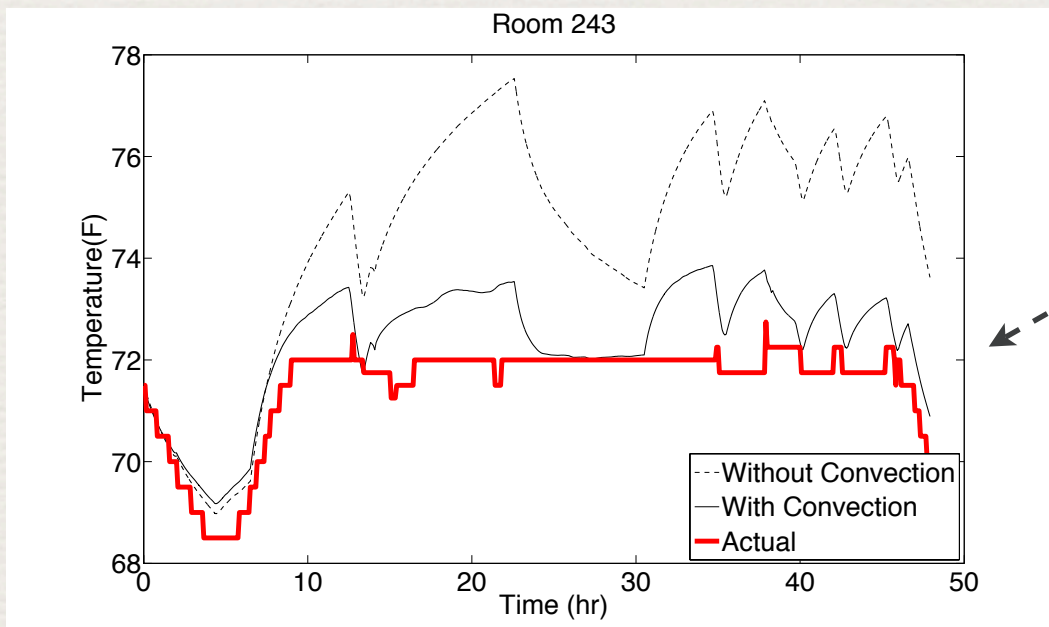


Cyber Physical Sensor:
software to detect mouse/keyboard idle

Exploit inter-zone convection

Which rooms have convection interaction (airflow thermal exchange)?

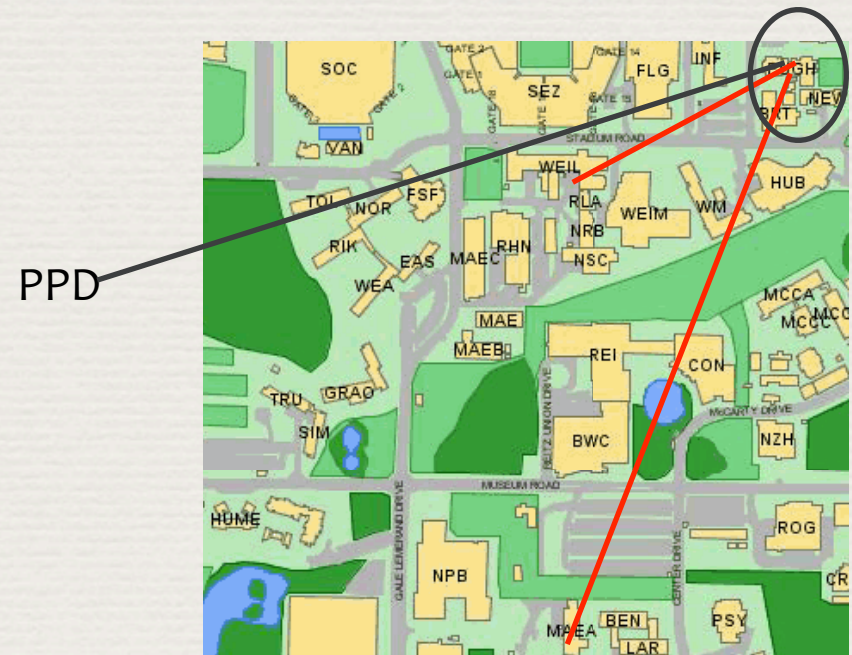
A network structure identification problem
proposed solution based on estimating conditional probabilities



Test-bed Development

- ◆ BACnet stack server
 - ◆ runs on a PC residing @Pugh
 - ◆ communication through VLAN
- ◆ Capable of high frequency control of all actuators (not just “set point” change)
- ◆ Control software being stress-tested

Pugh Hall @UF campus
LEED Silver, 66 zones



Team

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(Pugh hall DAC server)

