Quantification of HVAC Energy Savings for Occupancy Based Control

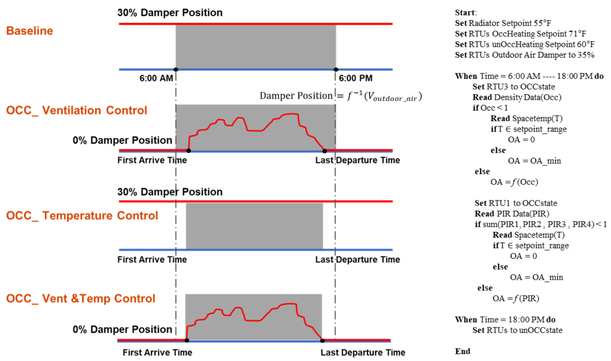
Zixin Jiang, Prof. Bing Dong
Department of Mechanical and Aerospace Engineering

- **Abstract:**

Occupant behavior was becoming one of the most important factors influencing building energy consumption. The present and absence information can be used to operate the HVAC system more flexible. The occupancy numbering information can be used to drive better ventilation control. In this study, a set of state of art occupancy sensors were installed in an office building and two residential buildings. For office building, three different control algorithms(Occ_based temperature control, Occ_based ventilation control and Occ_based temperature & ventilation control) were implemented in our testing bed via BACnet system. For residential building, Occ_based temperature control was implemented in two well calibrated Energyplus models. Up to 60% outdoor air load can be reduced in heating season for office building and up to 30% energy can be saved by Occ_based temperature control for residential building compared with a fix schedule baseline model.

- **Methodology**

For office building, the space is divided into occupied mode(6:00AM to 18:00PM), unoccupied mode(18:00PM to 6:00AM), and occupied-standby mode(occupied time but no occupants in the zone). System would turn off during unoccupied time, the temperature would have a 3F setback during standby mode and ventilation would be controlled by ASHRAE standard 62.1:



Start:
Set Radiator Setpoint 55°F
Set RTUs OccHeating Setpoint 71°F
Set RTUs unOccHeating Setpoint 60°F
Set RTUs Outdoor Air Damper to 35%

When Time = 6:00 AM ---- 18:00 PM **do**
  Set RTU3 to OCCstate
  Read Density Data(Occ)
  if Occ < 1
    Read Spacetemp(T)
    if T ∈ setpoint_range
      OA = 0
    else
      OA = OA_min
  else
    OA = f(Occ)

  Set RTU1 to OCCstate
  Read PIR Data(PIR)
  if sum(PIR1, PIR2 , PIR3 , PIR4) < 1
    Read Spacetemp(T)
    if T ∈ setpoint_range
      OA = 0
    else
      OA = OA_min
  else
    OA = f(PIR)

When Time = 18:00 PM **do**
  Set RTUs to unOCCstate

End

Figure 1. Three control algorithms and pseudo code

For residential building, space would enter into unoccupied mode if the motion sensor didn't detect people motion for 15 minutes

- **Case Study**

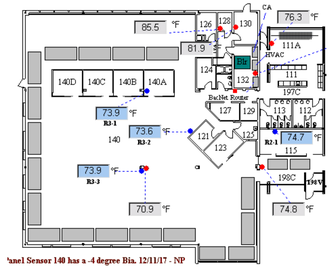


Figure 2. Floor Plan of Office Building_CPDC

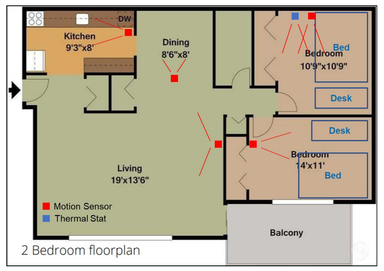


Figure 3. Floor Plan of Residential Building_Student Apartment

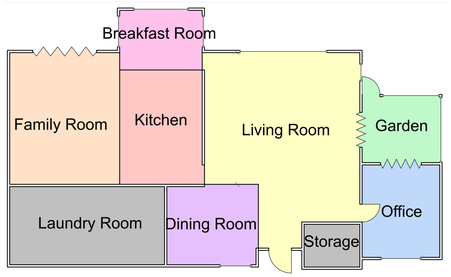


Figure 4. Floor Plan of Residential Building_Single Family House

Figure 5. Office Building Testing Plan

-- Figure 1 is the floor plan of the office building. One RTU is serving the big open space and another RTU is serving the four small cubic.
-- Figure 2&3 are the floor plan of the residential building. A smart thermostat with couples of smart motion sensors were installed in different rooms.

- **Occupancy Testing Results**

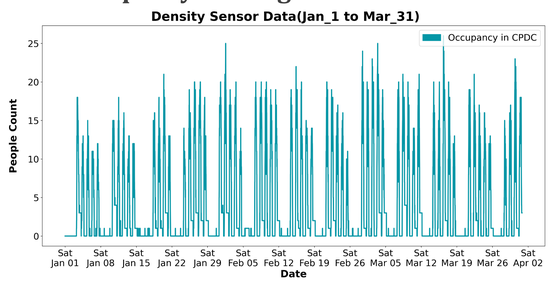


Figure 6. Occupancy Level of Office Building_CPDC

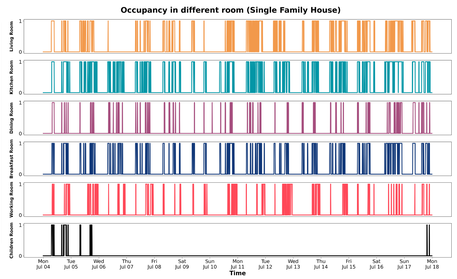


Figure 7. Motion Status of Residential Building_Single Family House

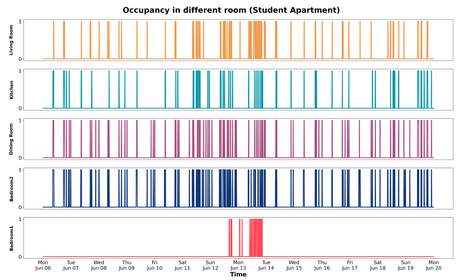


Figure 8. Motion Status of Residential Building_Student Apartment

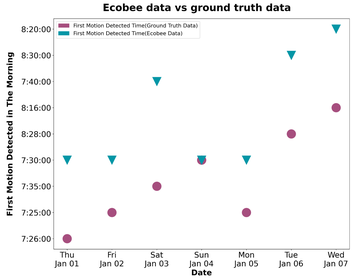


Figure 9. Testing Data vs. Ground Truth Data

-- Figure 6 is the occupancy level of office building, these data were collected every 15 minutes and stored into a database by Python API.
-- Figure 7&8 are the motion status of two residential buildings, HVAC would enter in unoccupied mode if no motion signal for 15 minutes.
-- Figure 9 is the sensor performance testing, the mismatch time for Ecobee sensor is always lower than 5 minutes.

- **Occupancy Based Control Results**

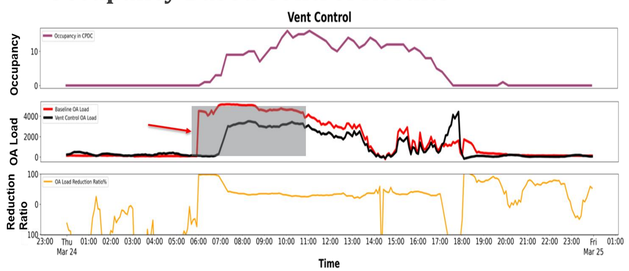


Figure 10. Occ based Ventilation Control of Office Building_CPDC

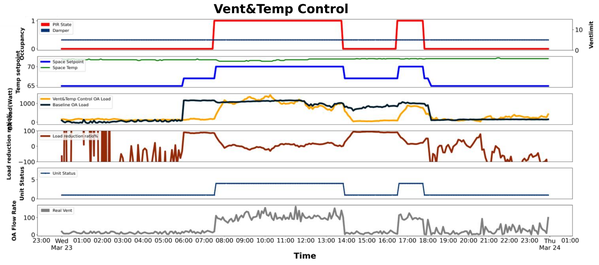


Figure 11. Occ based Ventilation&Temperature Control of Office Building_CPDC

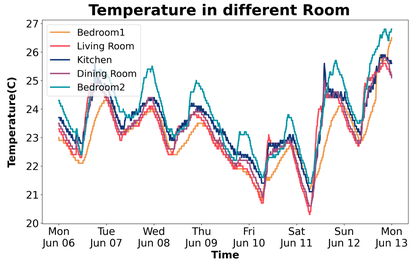


Figure 12. Temperature in different room of apartment

-- Figure 10&11 shows the results for occ-based control, up to 60% of OA load can be reduced during stand mode by decreasing OA intake.
-- Figure 12 is the temperature of different rooms in an apartment, genetic algorithm was used to calibrate the Energy plus model. An occupancy-based schedule was used, which can save about 30% energy compared with the fix schedule.

Acknowledgments: The research reported in this paper was supported by the Advanced Research Projects Agency–Energy (ARPA-E)