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Sensor Selection and Placement for CO^2 and Temperature Fields

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Motivation

The number of sensors in buildings tends to be large. Besides the increased capital cost, this introduces significant maintenance cost and vulnerability in the sensing and control system. Reducing the number of sensors in future smart buildings is the main purpose of this project. Here we propose a methodology to use sparse sensors, occupancy information and models to infer CO^2 and temperature fields in a networked collection of rooms.

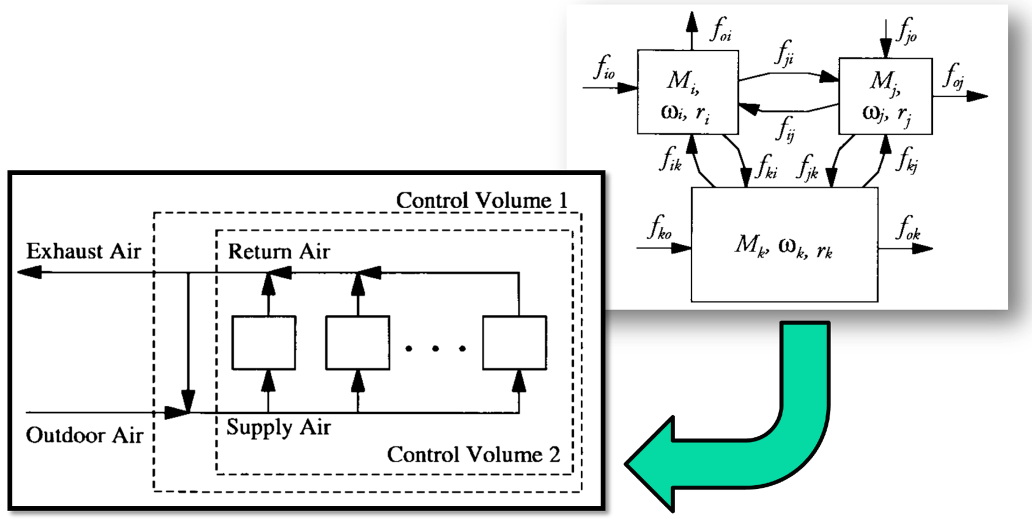
Information about the strength of gas sources (e.g. CO^2) and the air temperature in buildings has a number of applications in the area of building automation and control, including temperature and ventilation control, fire detection, and security systems. The estimation problem can be formulated as a Kalman filtering problem, where the states estimated by the Kalman filter are the unknown process parameters, the source strength and the air temperature.

2012 Main Objectives

- Step A: Site selection, instrumentation, developing the infrastructure for gathering CO^2, occupancy, temperature data.
- Step B: Develop field model, use complete data set for parameter estimation, disturbance estimation
- Step C: Write estimation/inference code
- Step D: Verification and testing. Use data from selected sensor locations to estimate filed values at other locations under various operating conditions.
- Step E: Decide on placement strategy in general based on results from Step D. Understand parameters that guide placement strategy, error bounds etc.

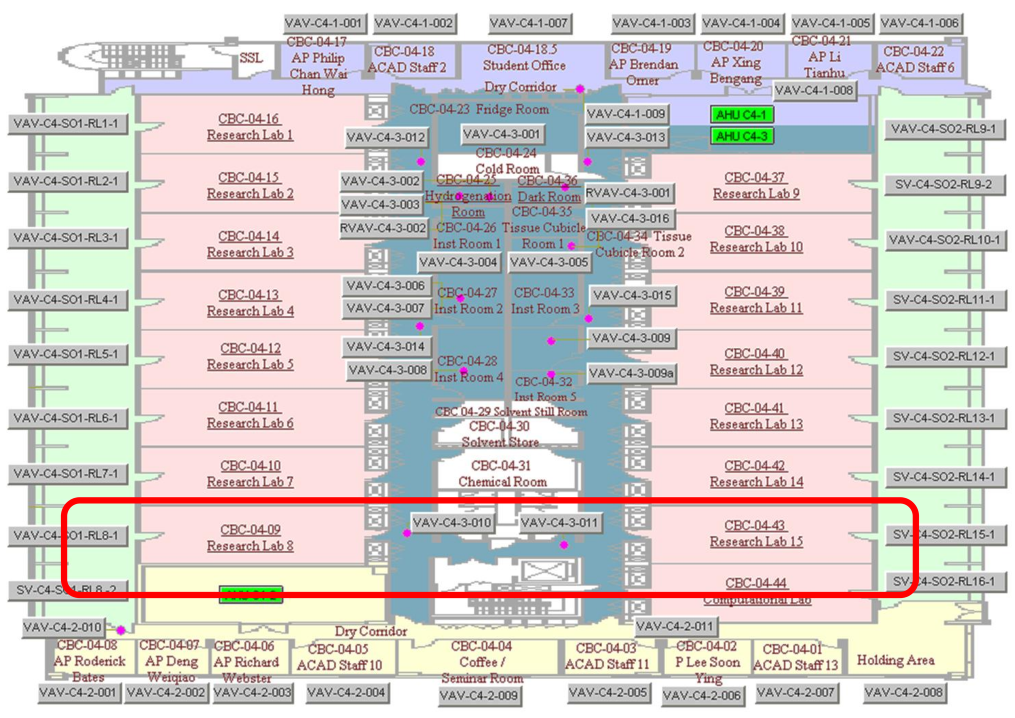
The Problem

Idea: Use sparse sensor placement, occupancy information, models, to infer CO^2 and Temp fields in a networked collection of rooms.



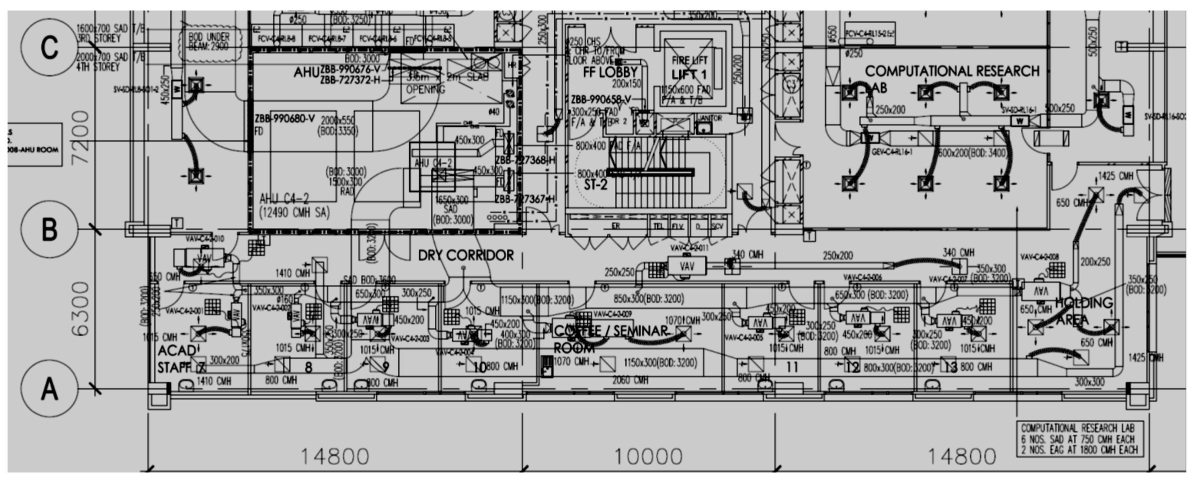
Site Selection: SMPS Building, Level 4

Alternative 1: SMPS Building, Level 4



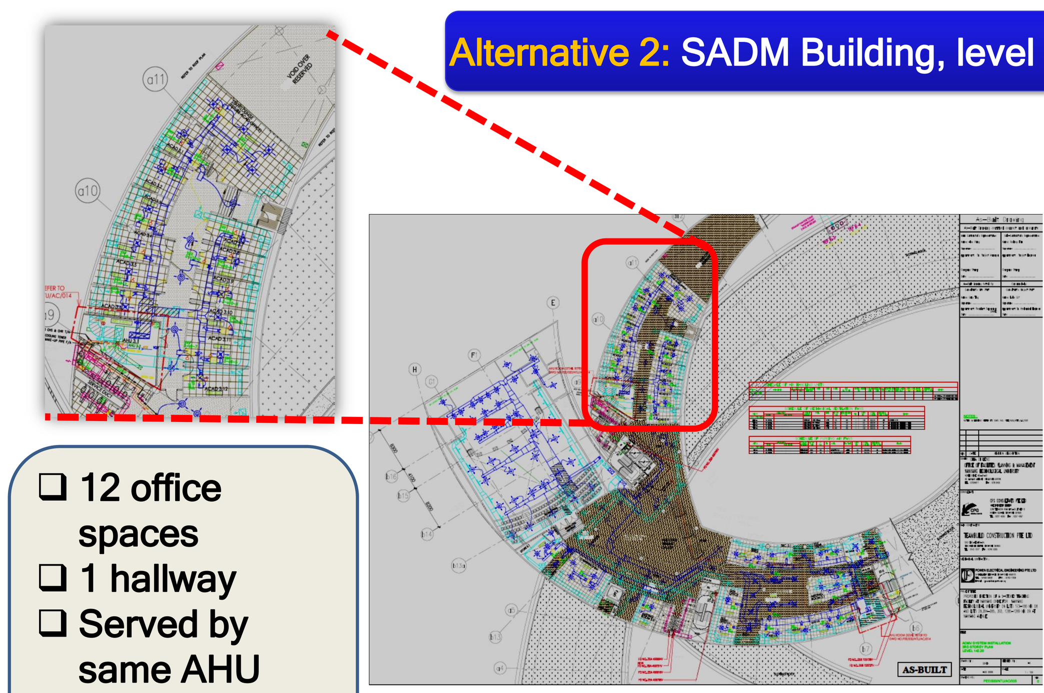
Site Selection: SMPS Building, Level 4

- ❑ 7 office spaces
- ❑ 1 discussion room
- ❑ 1 holding are a + hallway
- ❑ Served by same AHU



Site Selection: SADM Building, level 4

Alternative 2: SADM Building, level 4



- ❑ 12 office spaces
- ❑ 1 hallway
- ❑ Served by same AHU (AHU 3.1)

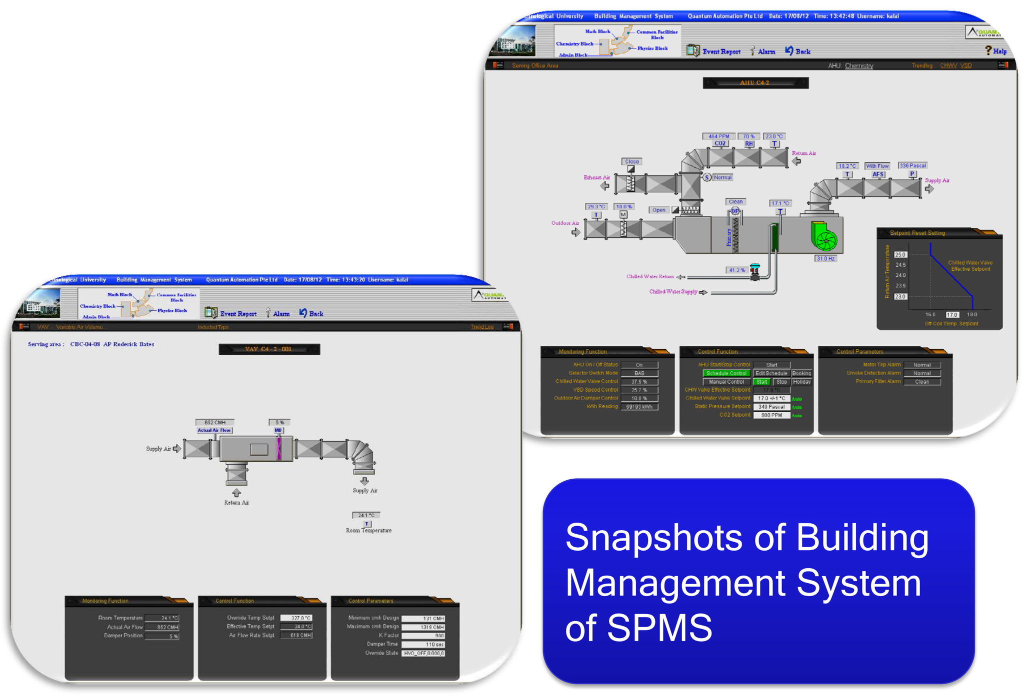
Site Selection: Decision

Decision: SMPS building

Due to the following reasons:

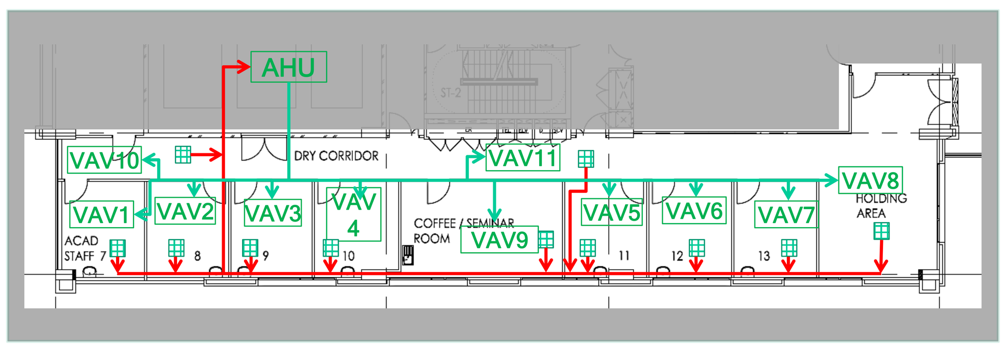
- ✓ The area is totally enclosed and the amount of infiltration and exfiltration are minimal (as opposed to SADM where there is a staircase to the below and above floors.)
- ✓ Manageable number of rooms in terms of sensor deployment, data collection, and initial analyses.
- ✓ Danielle is already working on this building. She will help us in this project.
- ✓ The residents of the rooms in our study are very eager to conduct energy reduction related projects on the SPMS building.

Building Management System (BMS)



Snapshots of Building Management System of SPMS

Analysis of the Space Under Study



Supply Air Duct	→
Return Air Duct	→
Return Air Grille	▦

Optimal Sensor Placement

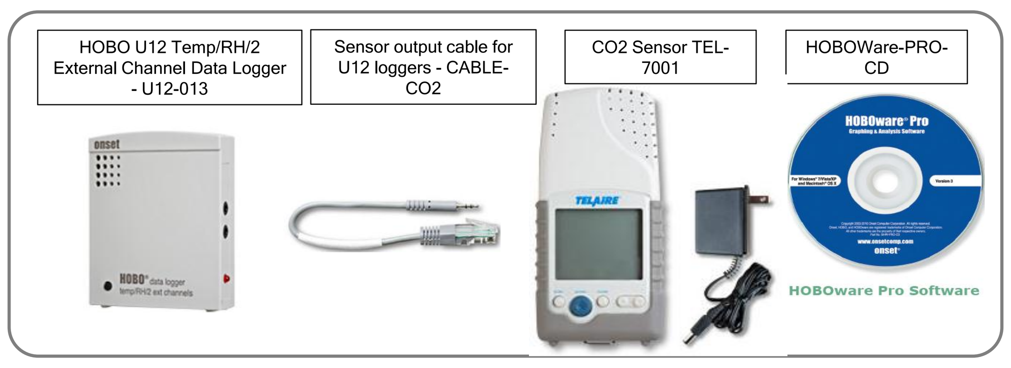
Schematic of the airflow in the HVAC duct network

Equipment Selection

The data required for the study includes temperature, RH, CO^2 concentration, occupancy and supply airflow rate in the defined spaces. The airflow rate and temperature are available from the existing BMS. The lab users and facility operation and maintenance have noted that the temperature sensors may not be accurate, therefore additional temperature and RH sensors are recommended for the study.

Additionally, the CO^2 sensors were selected with a measurement range of 0-2500 ppm. Additional equipment selection criteria are listed below, while the image includes the equipment which meets the study requirements:

- Temporary data acquisition
- Connectivity is not required (no control strategies will be tested in this study)
- CO^2 sensors, Temp/RH sensors at each VAV box (11 in total, reference Analysis of the Space Under Study)



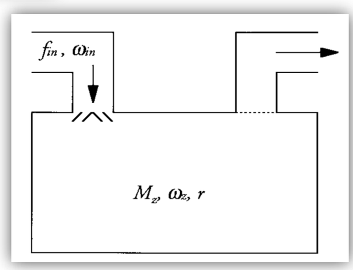
Future work

- ❖ *Sensors are going to be purchased and installed in the SPMS building within the next month.*
- ❖ *Data will be collected by the Singapore colleagues.*
- ❖ *In Berkeley the team will work on the theory and developing the estimation code to be used on the data.*

$$\frac{d}{dt}(M_z(t)\omega_z(t)) = f_{\text{in}}(t)\omega_{\text{in}}(t) - f_{\text{out}}(t)\omega_{\text{out}}(t) + r(t)$$

$$\dot{M}_z(t) = f_{\text{in}}(t) - f_{\text{out}}(t)$$

$$\dot{m}_z(t) = w_{\text{in}}(t) - w_{\text{out}}(t) + r(t)$$



References

[1] CC Federspiel "Conditions for the input-output relation of perfect-mixing processes to be first order with application to building ventilation systems" Journal of dynamic systems, measurement, and control, 199

[2] CC Federspiel "Estimating the inputs of gas transport processes in buildings" Systems Technology, IEEE Transactions on, 1997

[3] S Wang "CO^2-based occupancy detection for on-line outdoor air flow control" Indoor and Built Environment, 1998