IEQ Bot

Ming Jin, Yulun Tian, Mingjian Lu, Costas Spanos
EECS Department, UC Berkeley
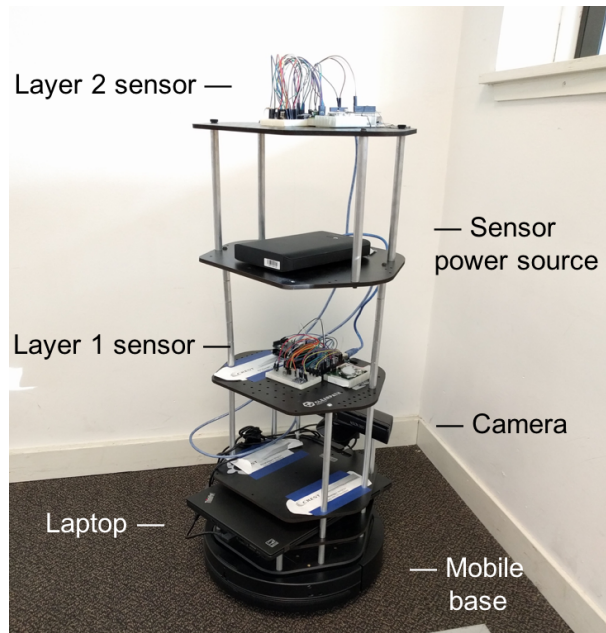
Shichao Liu, Stefano Schiavon
CBE, UC Berkeley
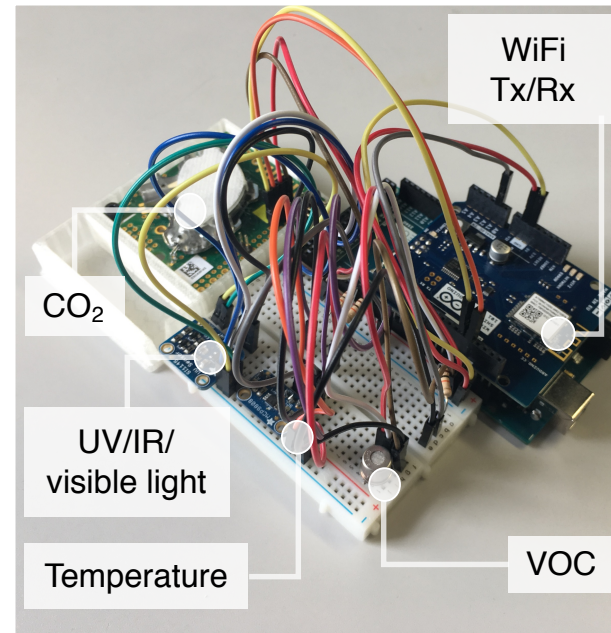
Robots are slowly entering the home and office space

Vaccuum
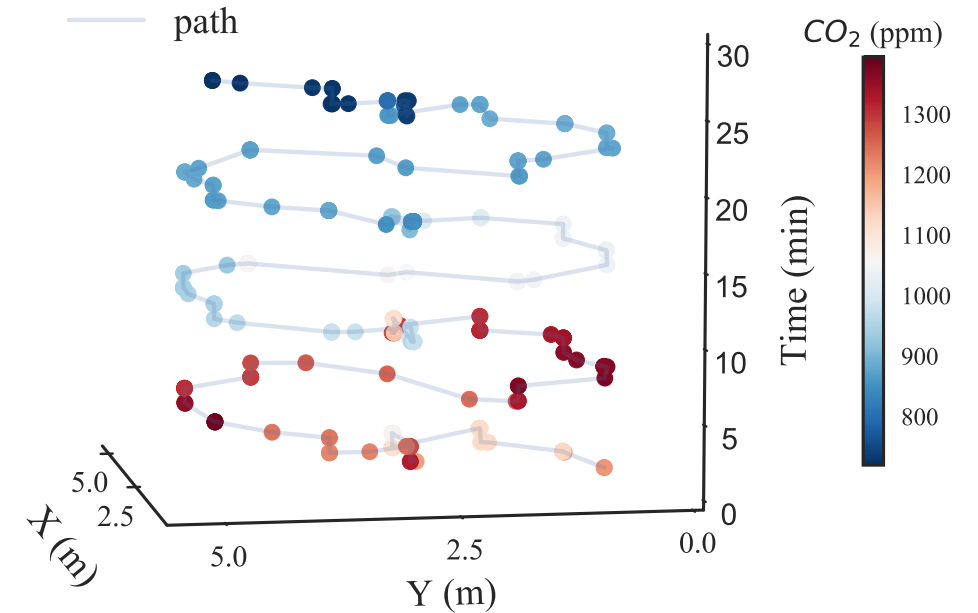
Brett

Delivery robot

Humanoid robot

Enabling technology: mobile robot, sensor, and data analytics

Robot with indoor positioning, navigation capability

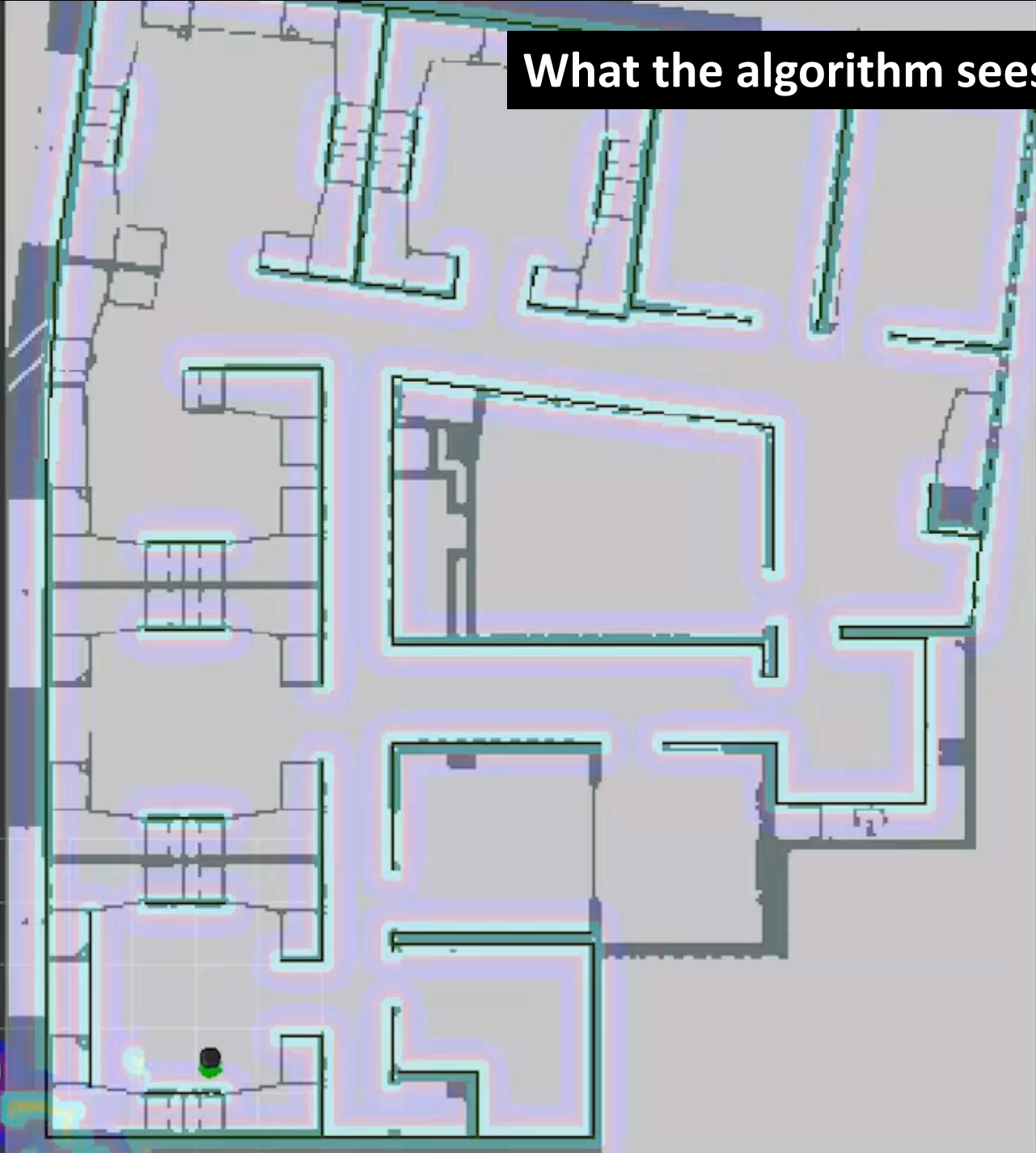Internet-connected **sensor platform** with IEQ sensing modules

Data analytics to derive valuable insights from samples that are sparse in time and spatial domains
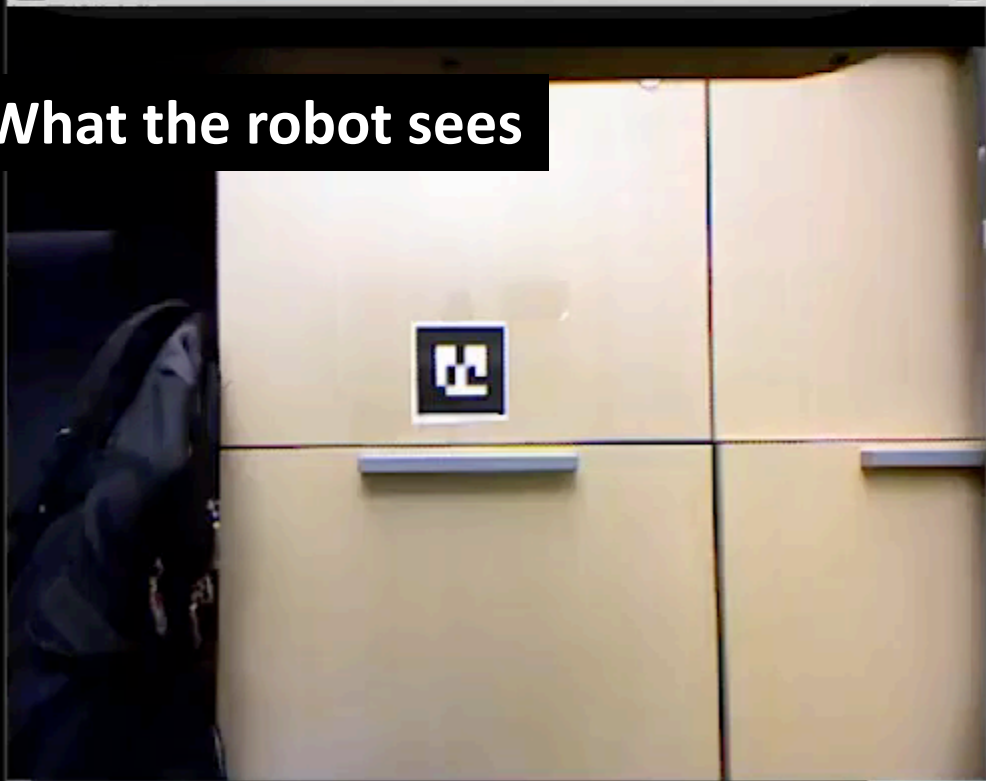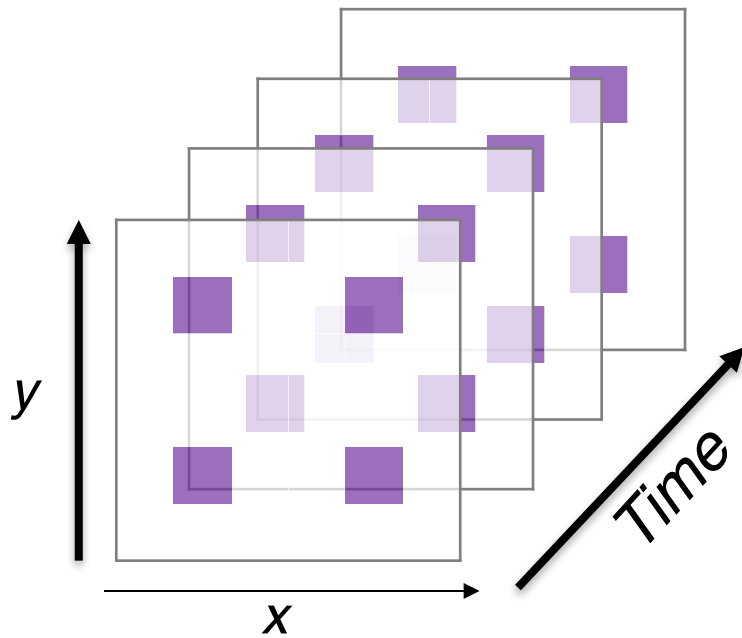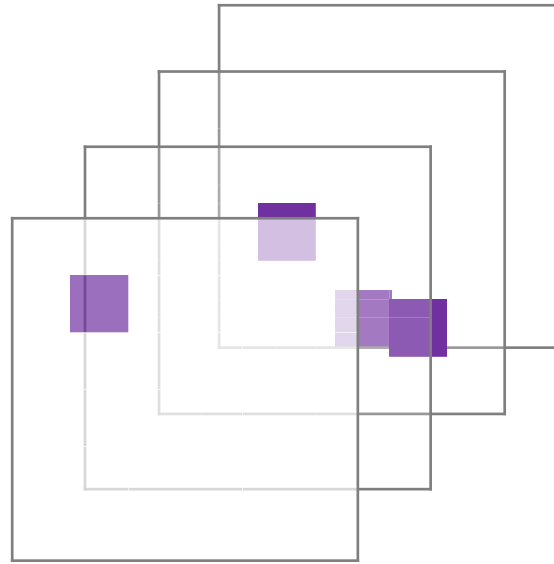
What the person sees

Camera

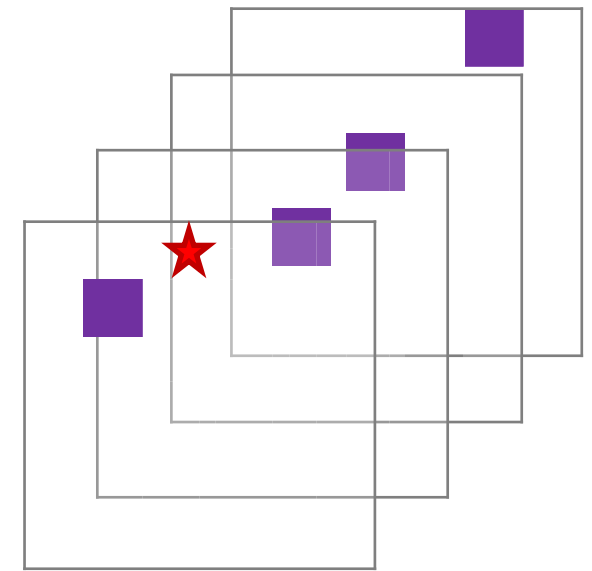What the robot sees

What the algorithm sees

How does "mobility" augment indoor sensing capability?

y

x

Time

Static sensors measure IEQ at fixed locations continuously

$$\underset{\text{sensor}}{\$} \times N > \underset{\text{robot}}{\$} + \underset{\text{sensor}}{\$}$$

Mobile sensor can survey IEQ at high spatial granularity, but samples are discontinuous in time

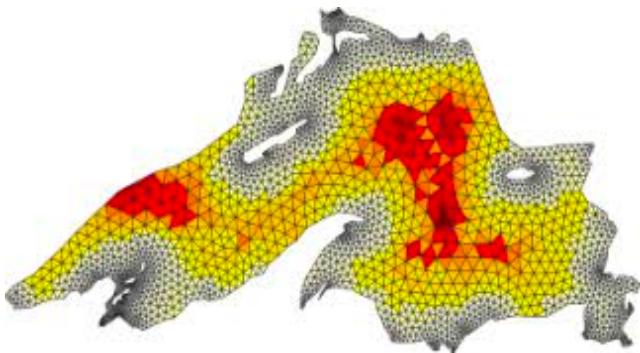Samples are taken as-needed, where-needed, and event-driven

Response to emergency

Indoor pollution identification

Prior arts on spatio-temporal data interpolation

Shape Function (Li and Revesz, 2004)

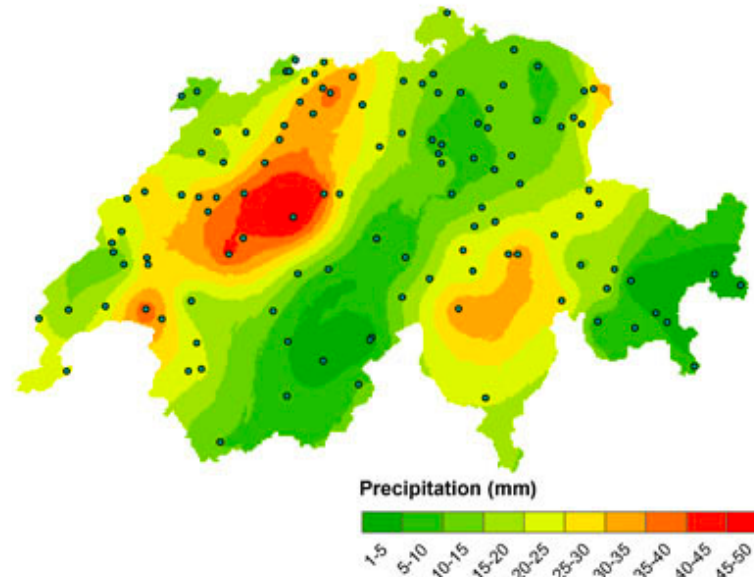[+] finite element mesh generation, easy to implement

[-] cannot extrapolate well at unknown regions

Kriging (Mardia et al., 1998; Cressie and Wikle, 2015)

[+] smoothing based on sample distances

[-] assumes static sensors with data continuous in time

Precipitation (mm)

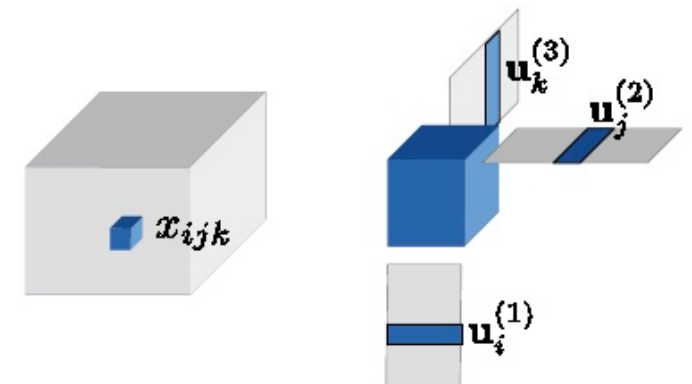1-5 5-10 10-15 15-20 20-25 25-30 30-35 35-40 40-45 45-50

Factor analysis (Luttinen and Ilin, 2009)

[+] sample-efficient

[-] unstable with non-stationary data

[-] assumes static sensors with data continuous in time

Data-efficient spatio-temporal interpolation

Insight 1: environmental parameters varies slowly over time
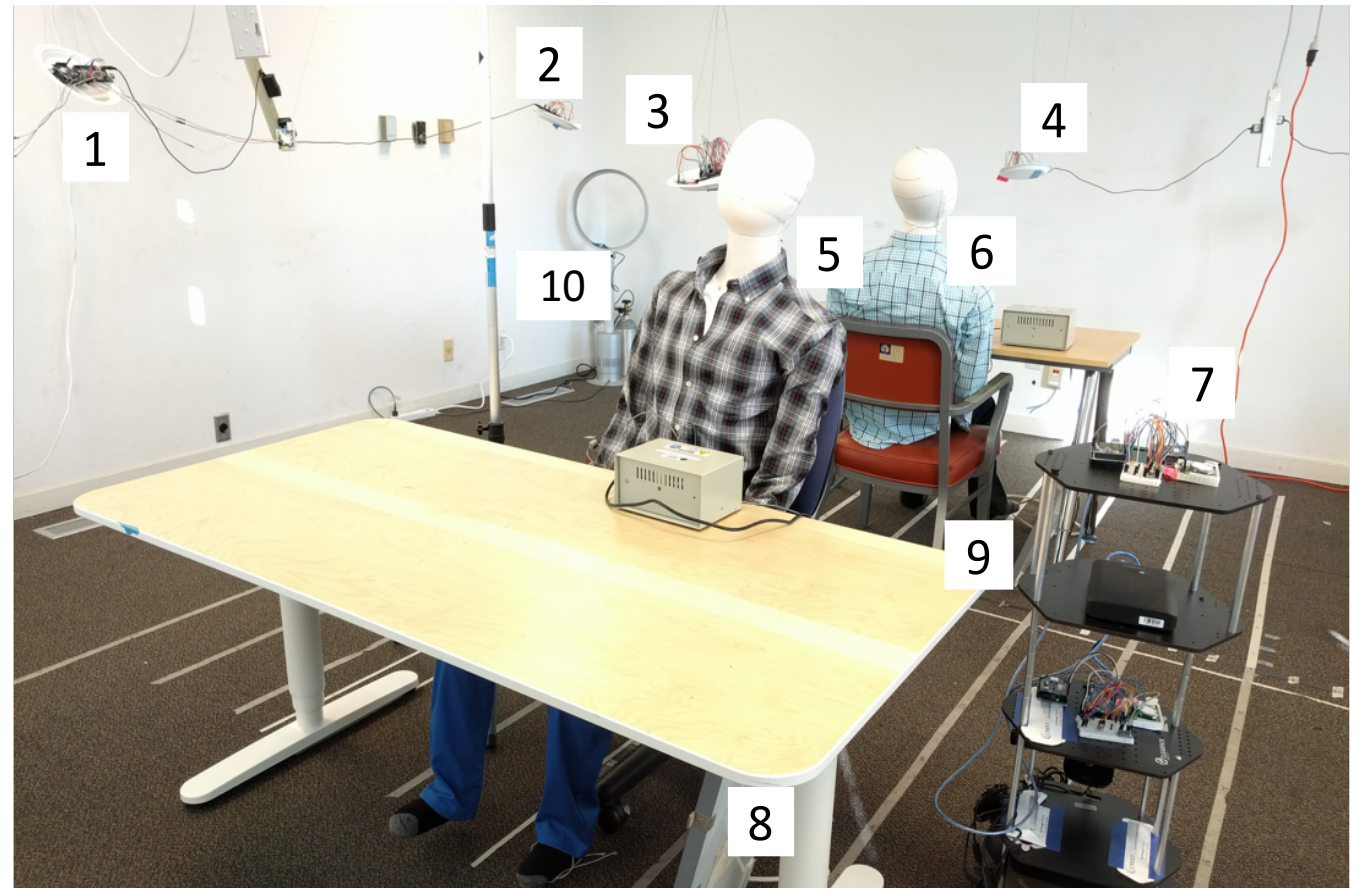
Insight 2: spatial variation carries actionable information

Objective

- Demonstrate the mobile sensing platform by comparing with static sensor network
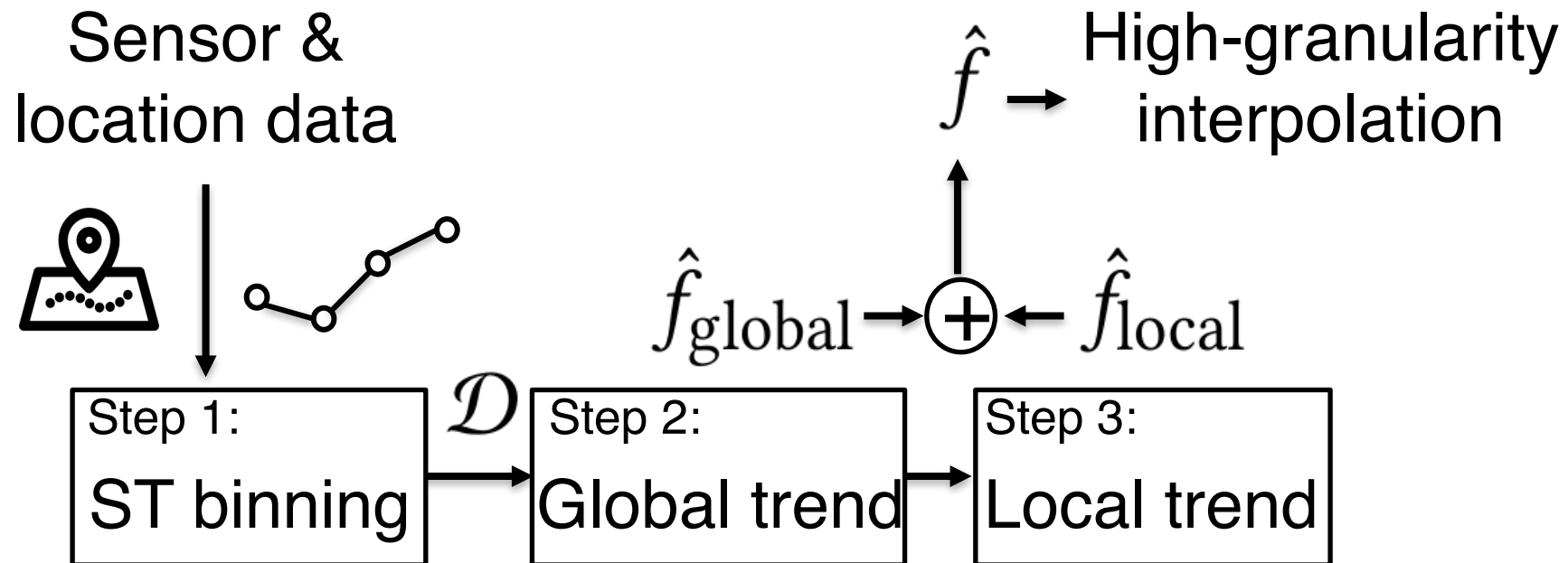
- Air-change effectiveness (ACE) is "a measure of ventilation efficiency"
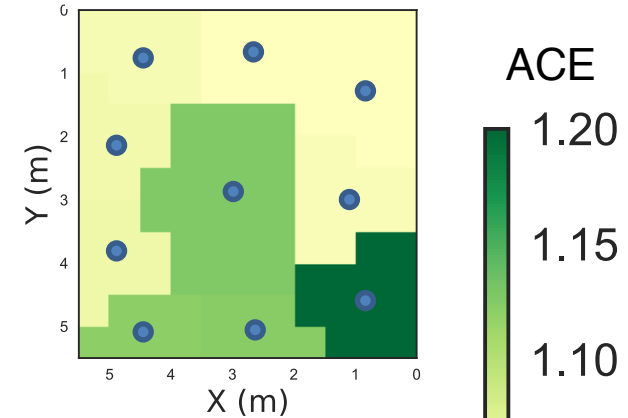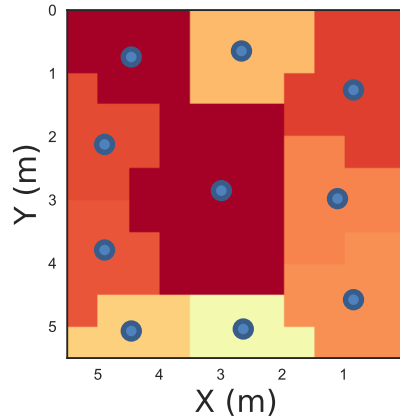
Approach

- Standard tracer-gas decay procedure by ASHRAE 129

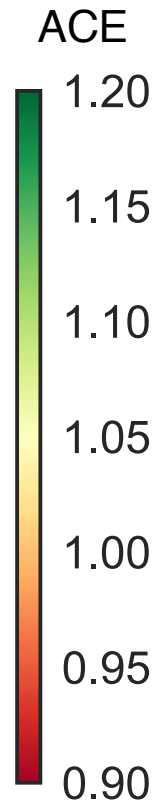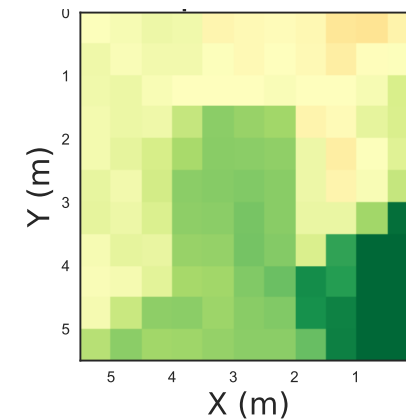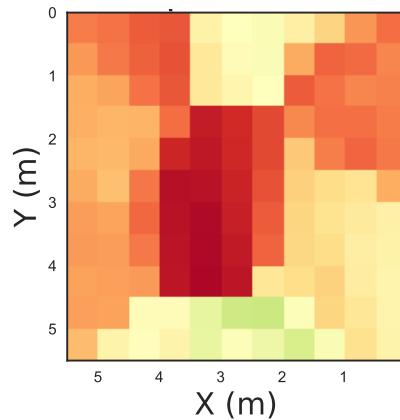- Side-by-side measurements by static sensors and mobile robot

Testbed snapshot, showing the static sensor stations (1--4), thermal manikins to model realistic heat sources (5,6), robot (7), floor heaters (8,9), and CO_2 source (10).
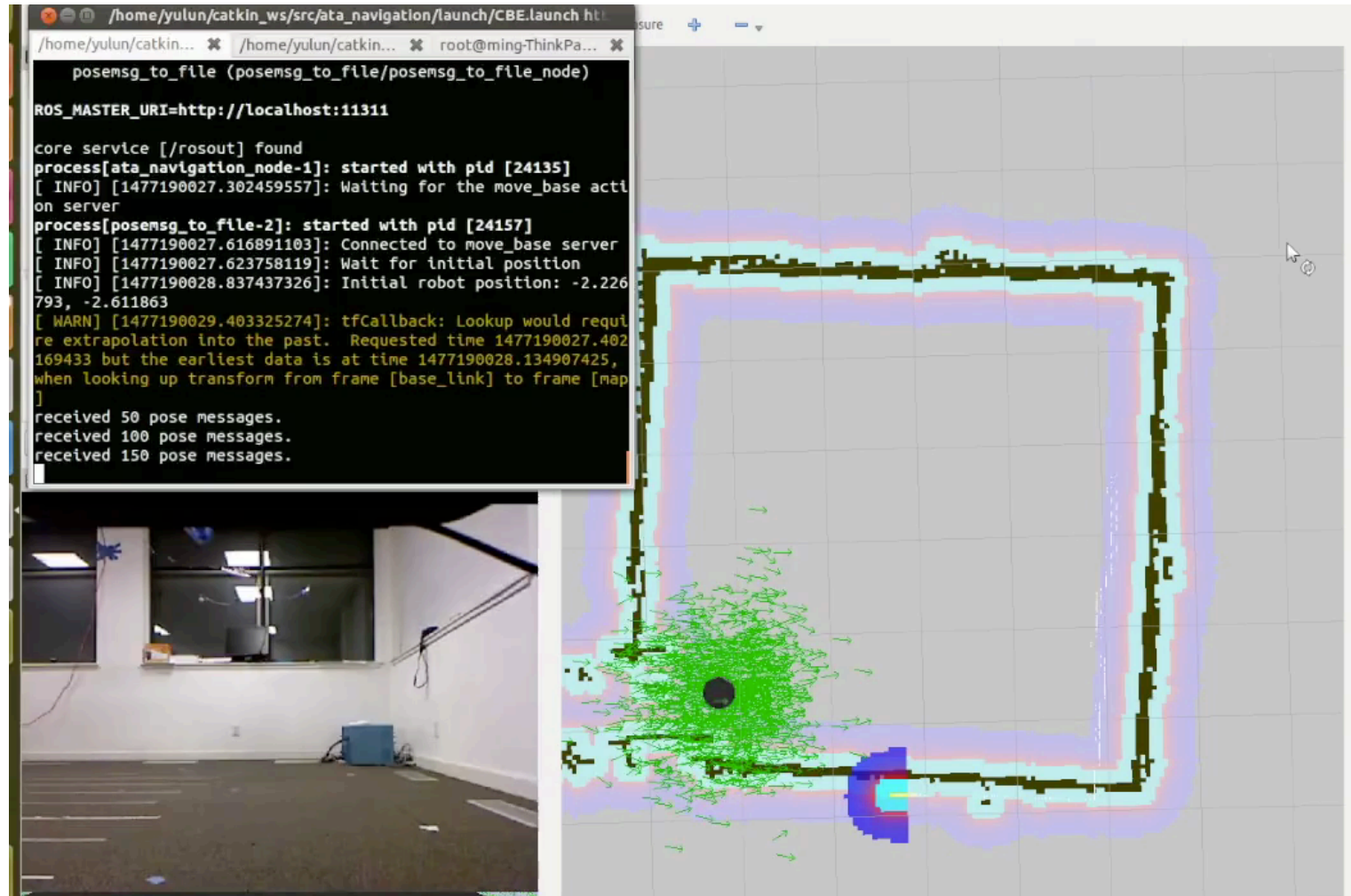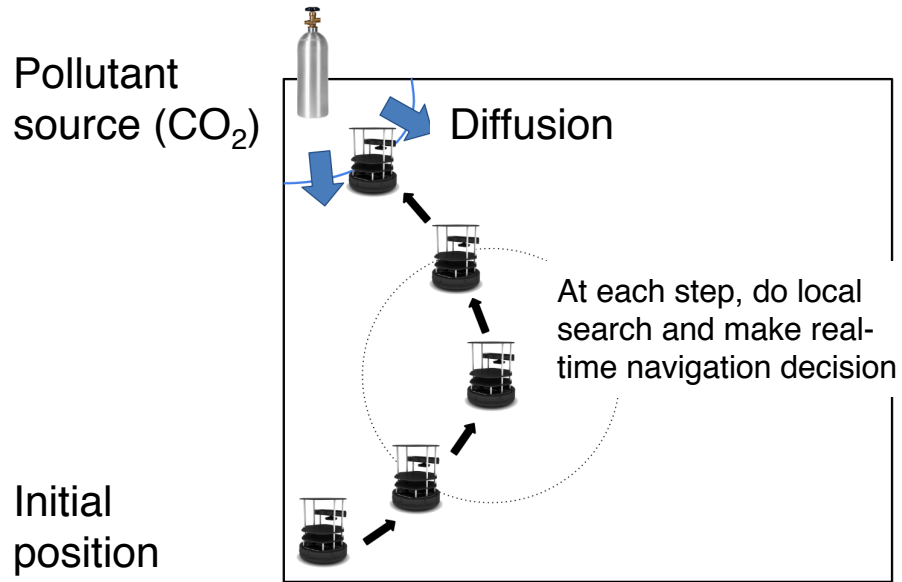
Estimation by **10 static stations**

Estimation by **1 mobile robot**

Poor ventilation   Good ventilation

Automated mobile sensing enables numerous applications

Pollutant source (CO_2)

Diffusion

At each step, do local search and make real-time navigation decision

Initial position

Automated mobile sensing enables numerous applications
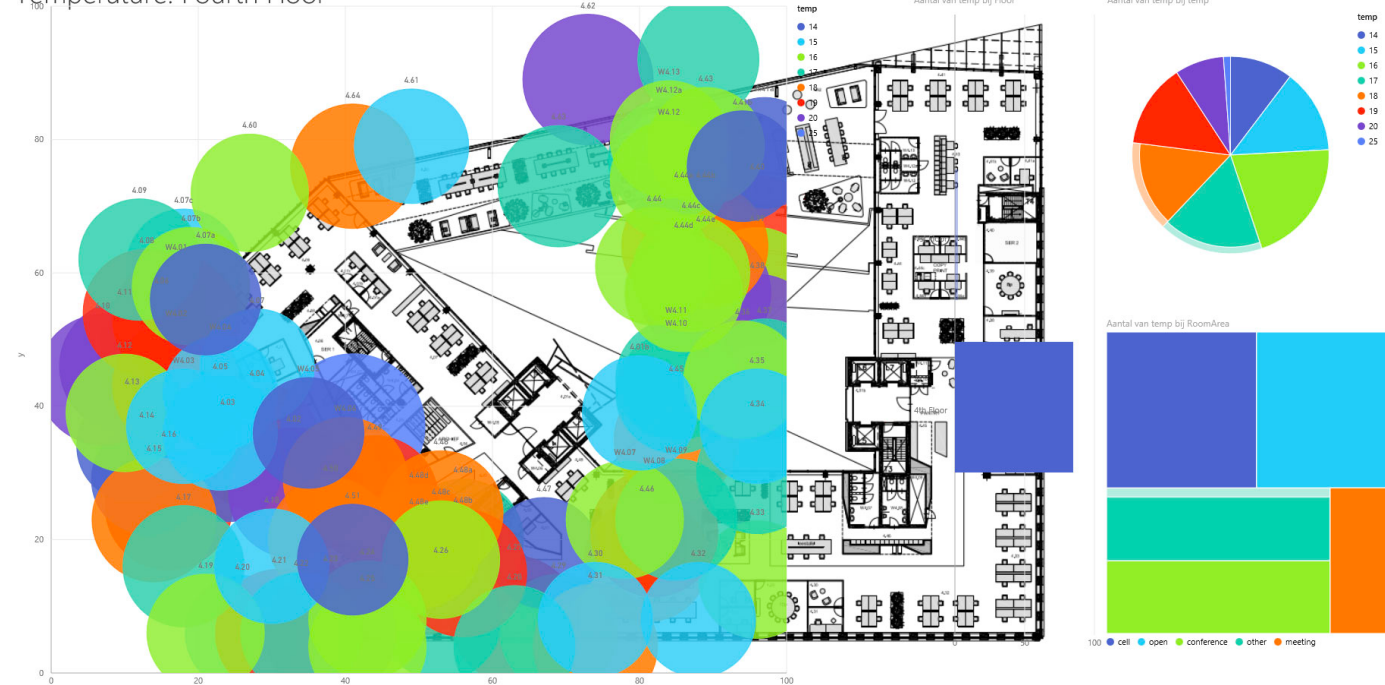
Full space temperature/humidity sensing

Automatic building commissioning

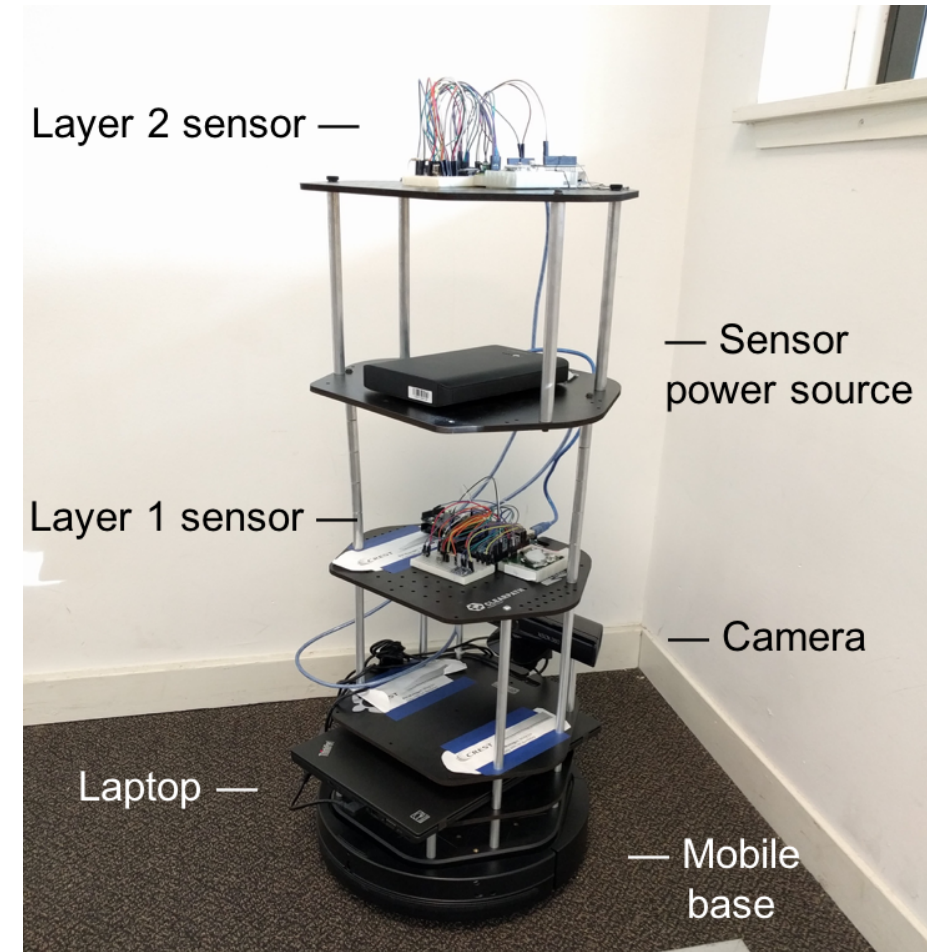https://github.com/jinming99/IEQbot

Thank you

Ming Jin
jinming@berkeley.edu

Stefano Schiavon
schiavon@berkeley.edu

Please take a moment to fill out the feedback form.

IEQ Bot