IEQ Bot

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Robots are slowly entering the home and office space
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

What the robot sees

What the algorithm sees
How does “mobility” augment indoor sensing capability?

**Static sensors** measure IEQ at fixed locations continuously.

**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.

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

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

**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
Validation of air-change effectiveness (ACE) by static and mobile sensors

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 CO₂ source (10).
Static and mobile sensors have good agreement on ACE evaluation

Estimation by 10 static stations

Estimation by 1 mobile robot

Poor ventilation  Good ventilation
Automated mobile sensing enables numerous applications

Pollutant source (CO₂)  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

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Please take a moment to fill out the feedback form.