MetaSense: Calibration of Personal Air Quality Sensors in the Field

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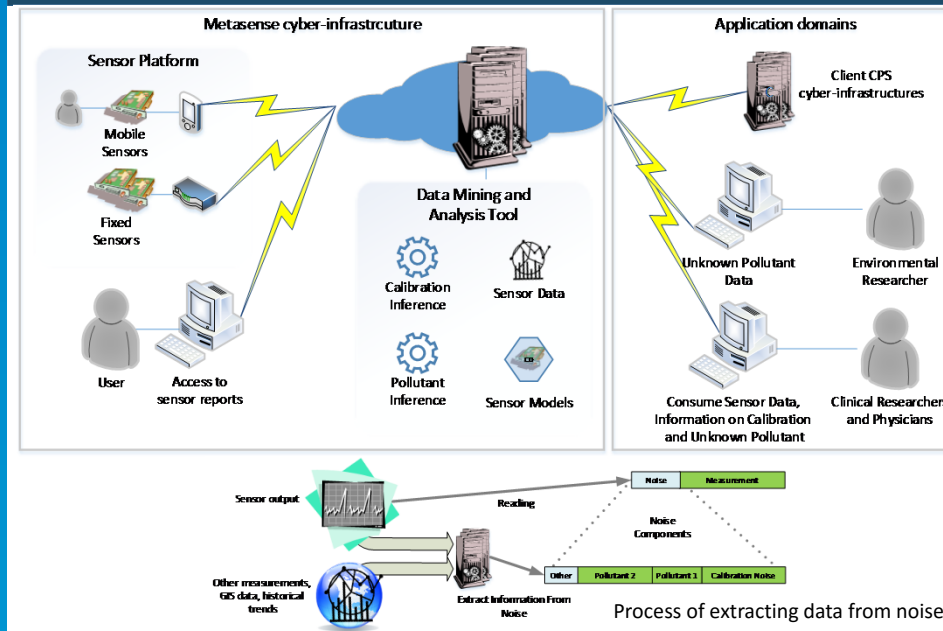
Motivation

Cyber-Physical Systems (CPS) promise to change how we study and interact with the physical world. CPSs depend upon the correct calibration of their sensors. Commodity sensor precision degrades over time. Consequently, sensors must be periodically recalibrated. The current state of the art is to calibrate sensors in labs, often manually. Moreover, sensors can lose calibration without users noticing, impacting the dependability of the data collected.

For mobile commodity sensors, we propose leveraging large networks of sensors connected to the "cloud" to support self-calibration. The cloud enables using large data repositories and machine learning to cross-reference data from different sensors to detect loss of calibration.

MetaSense must be able to discern signal from noise. Humidity, temperature, barometric pressure, and cross-contaminants can alter sensor readings. Also necessary is knowing that two sensors are in the same context, e.g. both outdoors. Both require a significant application of context-aware computing.

MetaSense System Concept

Process of extracting data from noise

Wearable air-quality sensor and phone app

Modular, heterogeneous sensor platform
- Distributed, mobile and stationary deployment
- Drives two context aware applications:
  - Environmental air quality monitoring
  - Online dynamic sensor recalibration
- Sensitive to both device and environmental context
  - Power circuitry, ambient temperature, humidity, gas cross-dependencies

Dual-purpose phone app
- Wireless bridge between sensor and server
- Real-time air quality for user

Machine Learning

Our strategy for calibration exploits spatial and temporal locality of sensor readings. With a series of readings from several sensors over time, we wish to model the interactions between the readings. Accurate prediction of future sensor readings enables us to detect if a sensor is miscalibrated.

To start, we obtained San Diego air quality readings over the last three years from the Air Quality Control District. With 5 stations, we trained several models to predict the next hourly ozone sensor reading of a selected station, given all station readings from the previous hour.

Early results suggest that a sparse Lasso regressor achieves error comparable to a standard linear regression, implying the problem is inherently sparse.

This plot shows prediction over a 3 day period at the Del Mar station. A Gaussian Process can provide both a prediction and a confidence interval.

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