HazeWatch: A Participatory Sensor System for Monitoring Air Pollution in Sydney

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Air Pollution: Effects

- 1.4 billion urban residents live in areas with air pollution above guidelines [WHO]
  - 2 million deaths worldwide
  - 2.3% of deaths in Australia
  - NSW: $4.7 billion in health costs

- Chronic exposure
  - cardiovascular and respiratory mortality and morbidity

- Acute short-term inhalation
  - exacerbates existing conditions asthma, COPD, heart disease
Air Pollution: Causes

- Regional Air Quality Index (RAQI) system recommends monitoring 5 main air pollutants:
  - Ozone $\text{O}_3$
  - Carbon monoxide CO
  - Sulfur Dioxide $\text{SO}_2$
  - Nitrogen Dioxide $\text{NO}_2$
  - Particulate Matter PM

- Major sources of air pollution:
  - Industrial processes
  - Motor vehicles: cars, trucks, buses
Air Pollution Monitoring in Sydney

- NSW Office of Environment and Heritage runs 15 stations across greater Sydney
- Data published and updated on hourly basis
- AQI reported; Health warnings posted

### Pollutants

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<th>Pollutants</th>
<th>Ozone (ppb)</th>
<th>Ozone (ppb)</th>
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<th>Visibility (km)</th>
<th>Carbon Monoxide (ppb)</th>
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<th>Particulate Matter PM2.5 (μg/m³)</th>
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Limitations of Current System

- Poor spatial resolution
  - Sites separated by tens of kilometers
  - Need interpolation models:
    - Complex: land topography, chemical compositions
    - Inaccurate: meteorological conditions

- Do not reflect actual exposures of individuals
  - Spatial heterogeneity
    - Concentrations can change over short distances
  - Mobility patterns of users
    - Time spent and activity level at home, work, travel
Idea Behind “HazeWatch” System

- “Crowd source” data from users (drivers)
  - Users upload pollution measurement as they drive
  - Measurements stored in “cloud”
  - Displayed as pollution map in real-time
  - Can build cloud-based tools and services around it

Advantages:
- Cost-effective: mobile sensors cover more ground
  - E.g. sensor on one bus can cover tens of kilometers
- Better spatial resolution for same sensors
  - 30-50 mobile sensors can cover a city well?
- Personalized tools
  - Personal exposure meter, route-planning, …
Existing Designs

- **Commercial pollution monitors:**
  - Gases: Honeywell GasAlertmicro5
  - Particulate Matter: Met One Aerocet 531

- **Research prototypes:**
  - MESSAGE project (UK)
  - iSniff (Columbia Uni)
  - MAQUMON (Vanderbilt Uni)
  - City Senspod (Sensaris)
  - Common sense (UC Berkeley)
  - OpenSense (Switzerland)
System Architecture

1. Sensor measures pollution and transmits to mobile phone
2. Mobile phone uploads measurements to server using 3G network
3. Server sanitizes and stores data, and generates GIS maps and profiles
4. Users can use their devices to view maps and query data, and run applications e.g. for personal exposure estimation
Pollution Measuring Hardware

- Portability: fixed vs personal vs vehicle
- Complexity: on-board GPS, 3G?
  - Sensors, micro, bluetooth, battery
- Gas sensors: CO, NO₂, O₃
  - Metal oxide vs electrochemical
Calibration and Mounting

- Calibration: challenging!
  - Custom-built air-tight container
  - CO from car exhaust, NO₂ from nitric acid + Copper
  - Comparison to commercial monitor

- Casing and mounting:
  - Custom casing vs off-the-shelf
  - Mounting: front/rear, low/high, into/across wind, …
Data Upload

- No GPS/3G in device
- Bluetooth to mobile phone
- Platform: Android
- User visualization:
  - Unit id, location/address
  - Pollution readings
  - Battery level
- 3G upload to server:
  - Time and location stamped
  - Update intervals configurable
“Cloud” Server Software

- Located in UNSW data center
  - Database: MySQL
    - User contributed data and dept. environment data
  - Model: interpolation methods
  - Web-server: XML based import and export
Modelling and Mapping

- Choices: interpolation, regression, dispersion
- Two interpolation models implemented:
  - Inverse distance weighting vs ordinary kriging
- Map: Google maps, gridded colour contour

Live at: http://www.pollution.ee.unsw.edu.au
Personal Exposure App

- Records location periodically
- Fetches pollution estimate from model on server
  - User need not carry hardware
- Displays:
  - Route
  - Plot of concentration
  - Mean exposure
- Can aid medical studies correlating exposure to health outcomes
Field Trial 1: Single Driver

- High spatial variation: tunnels and intersections
- Our unit corroborates well with commercial unit
- Data from nearest govt. site is very low
Field Trial 2: Multiple Drivers

- Subject has no hardware, uses estimation app
- Estimate reasonable but not great:
  - Still better than govt. estimate
  - Need higher deployment density
Challenges

- Highly inter-disciplinary, need expertise in:
  - Sensors, calibration (Chemistry)
  - Circuits, comms (Electrical Eng.)
  - Packaging, mounting (???)
  - Cloud software & db, mobile apps (Computer Sc.)
  - Pollution modeling (Atmospheric Sc.)
  - Health outcomes (Medical)

- Mass production and deployment strategy ?
- How to ensure data is of good quality ?
- Uptake of personal tools ?
- Validity for clinical studies ?
Conclusions

Current systems for air pollution monitoring
- Are spatially coarse
- Do not provide personalized services

Participatory sensing (cheap hardware + mobile apps) can:
- Yield fine-grained spatial measurements e.g. within tunnels
- Enable personalized tools for reactive exposure estimation and proactive route mapping
- Inform clinical studies of impact of air pollution on health
- Offer viable alternative to waiting for govt. action

Future work:
- Emerging off-the-shelf pollution measuring hardware (e.g. NODE)
- Combine pollution exposure with human activity levels (e.g. Fitbit)

Project web-page: [http://www.pollution.ee.unsw.edu.au](http://www.pollution.ee.unsw.edu.au)