Personalising Air Pollution Exposure Estimates Using Wearable Activity Sensors

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Air Pollution: Effects

- Air pollution killed **seven** million people in 2012
  - More than Aids, diabetes and road accidents combined
- Air pollution causes 1 in 8 deaths worldwide
- Air pollution becomes the world’s **largest** environmental health risk

Images From: [http://environment.nationalgeographic.com](http://environment.nationalgeographic.com)
Motivation:

- Control the air pollution
  - Monitoring air pollution
    - Pollutants? Concentrations?
    - Increase spatial resolution of air pollution data
  - Include other information to personalize the air pollution influence
    - People concern about
      - What’s “My” real-time inhalation dosage?
      - How does “My” different activity levels effect air pollution dosage?
      - how does air pollution impact “My” health
Our proposal:

- A “Crowd source” sensing system to estimate real-time personal air pollution inhalation dosage
  - Data from users (Obtained from participatory sensing system)
  - Both air pollution data and activity data is collected
  - Display inhalation dose in real-time

Advantages:

- Personalized tools, not in city or suburb level
- Indicate real air pollution exposure, not air pollution concentrations around people
System Architecture

1. Wireless sensor network
2. Data Centre
3. User interface
Sensor selection

- Air pollution sensors
  - **Node**: Plug-in modules mode; Measures various pollutants; Only CO is measured in this study;
  - **Sensordrone**: Measures CO, Ozone;

- Activity sensors
  - **Wahoo heart rate monitor**: Heart rate readings;
  - **Fitbit activity wristband**: Calories burned;

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Air pollution sensor (Carbon Monoxide)  Activity sensors
Application: Data upload interface

- No GPS/3G in sensors
- Bluetooth to mobile phone
- Platform: iOS

User visualization:
- Location
- Pollution readings (optional)
- Heart rate readings (optional)

Mobile network upload data to server
Application: Personalized tool interface

- Fetches pollution estimate from model on server
  - User need **not** carry air pollution sensors

- Displays:
  - Plot of inhaled dose
  - Plot of concentration
  - Average heart rate
  - Total inhaled dosage

![Monitor System]

- Total Inhaled Dosage: 15.10 mg
- Heart Rate: 146
- Average Heart Rate: 128
Inhalation dose measurements

- **Respiratory minute volume (RMV):**
  - The inhaled volume of air into a person’s lung per minute.

- **Calculate RMV:**
  - Ratio heart-rate (beats per minute) : RMV (L/min) in [jogging, bicycling, driving] = [3.3 : 1, 4 : 1, 6 : 1].
  - When activity levels are not available, we use a typical RMV of 12 (L/min).

- The inhaled dose of pollutant is then calculated as follows:
  \[
  \text{Inhaled\ dose} = \frac{\text{Respiratory\ minute\ volume}}{\text{CO\ concentration} \times \text{time} \times \text{conversion\ factor}},
  \]

  The CO concentration unit is ppm and conversion factor for carbon monoxide is 1.145g/L.
Server

- Database: MySQL
- Will not share heart rate information with other users
- Model: interpolation methods
  - Inverse distance weighting (IDW)
  - Ordinary kriging
Trail Setup

- Time: Aug 2013
- Location: Sydney
- Participants: 3
  - Carry heat rate monitor and air pollution monitor
  - Take 3 different activity modes (Jogging, Bicycling and Driving)

Route
- Distance: 7.6Km
- Contains bike lane
- Encounters varying traffic conditions

Air pollution data: Two sources
- Fixed site data from government
- Data from participatory sensing system
Result: Experiment attributes

- **CO concentrations**
  - Data from fixed-sites is very low
  - Data from participatory system shows significant variation

- **RMV**
  - Jogger gain highest RMV compared with bicyclist and driver

<table>
<thead>
<tr>
<th>Activity</th>
<th>Heart rate(bpm)</th>
<th>Real - time RMV (L/min⁻¹)</th>
<th>Constant RMV (L/min⁻¹)</th>
<th>CO concentration(ppm)</th>
<th>Duration(min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Government fixed-site (FS)</td>
<td>Participatory system (PS)</td>
</tr>
<tr>
<td>Jogging</td>
<td>153.2(75-172)</td>
<td>46.4(22.7-52.1)</td>
<td>12</td>
<td>0.19</td>
<td>64</td>
</tr>
<tr>
<td>Bicycling</td>
<td>123(76-146)</td>
<td>30.7(19-36.5)</td>
<td>12</td>
<td>0.19</td>
<td>41</td>
</tr>
<tr>
<td>Driving</td>
<td>84.9(77-93)</td>
<td>14.1(12.8-15.5)</td>
<td>12</td>
<td>0.19</td>
<td>28</td>
</tr>
</tbody>
</table>
Result: Inhaled dose

- With fixed-site (FS) CO concentrations and constant RMV
  - Inhaled dose is very low \((2.6 \mu g \, min^{-1})\)

- With fixed-site (FS) CO concentrations and real-time RMV
  - Inhaled dose increases a little bit

- With participatory system (PS) CO concentrations and constant RMV
  - Inhaled dose per minute significantly increases, and driving incurs highest inhaled dose \((94.3 \mu g \, min^{-1})\)

- With participatory system (PS) CO concentrations and real-time RMV
  - The situation reverses, the jogger’s inhaled dose per minute increases to \((215.5 \mu g \, min^{-1})\), while driving is lower at \((114 \mu g \, min^{-1})\).

<table>
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<th>Activity</th>
<th>Inhaled dose (\mu g , min^{-1})</th>
</tr>
</thead>
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<tr>
<td></td>
<td>FS CO data + constant RMV</td>
</tr>
<tr>
<td>Jogging</td>
<td>2.6(2.5-2.6)</td>
</tr>
<tr>
<td>Bicycling</td>
<td>2.6(2.5-2.6)</td>
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<td>Driving</td>
<td>2.6(2.5-2.6)</td>
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</tbody>
</table>
Result: Inhaled dose
Result: Inhaled dose
Result: Inhaled dose
Result: Total inhaled dose

- Jogging entails the highest inhaled dose (15037.8 μg), followed by bicycling (9031.5 μg), and driving the least (3767.1 μg).
- Bicyclists and joggers get exposed for longer duration while traversing the same distance, compared to drivers.
Conclusion

- We presented a novel system for estimating personal air pollution inhalation dosage.
  - First research group that integrate air pollution and human activity data collected by sensor network
  - Can aid medical studies correlating inhaled dosage to health outcomes

- Our initial field trial in Sydney indicate that our system can more accurately estimate individual air pollution inhalation dosage.

- Future work
  - Individuals wearing activity sensors who will benefit from the fine-gained air pollution data collected by other participants.