Personalising Air Pollution Exposure Estimates Using Wearable Activity Sensors

Ke Hu, Yan Wang, Vijay Sivaraman
(School of Electrical Eng. & Telecommunications, UNSW)
& Ashfaqur Rahman
(Intelligent Sensing and Systems Laboratory, CSIRO)

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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

Motivation:

- Control the air pollution

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- 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

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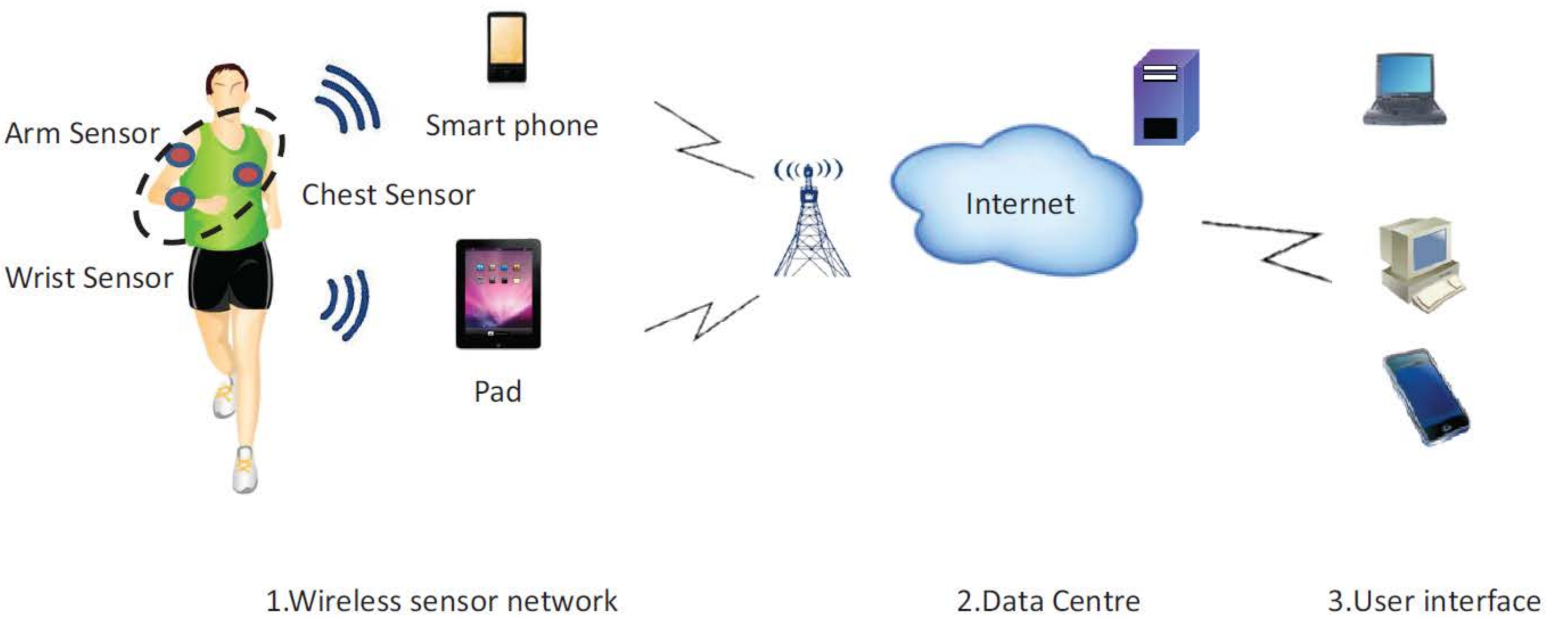
Our proposal :

- 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



Sensor selection

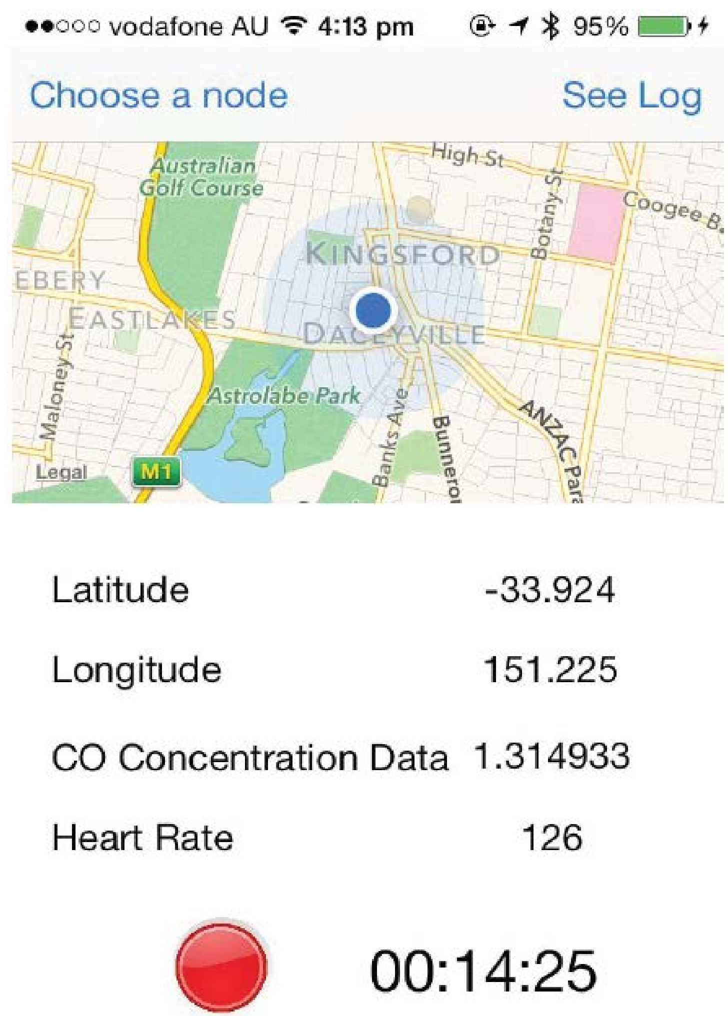
- Air pollution sensors
  - **Node**: Plug-in modules mode; Measures various pollutants; Only CO is measured in this study;
  - Sensordrone: Measures CO, Ozone;
- Activity sensors
  - **Wahoo heart rate monitor**: Heart rate readings;
  - Fitbit activity wristband: Calories burned;

Air pollution sensor (Carbon Monoxide)

Activity sensors

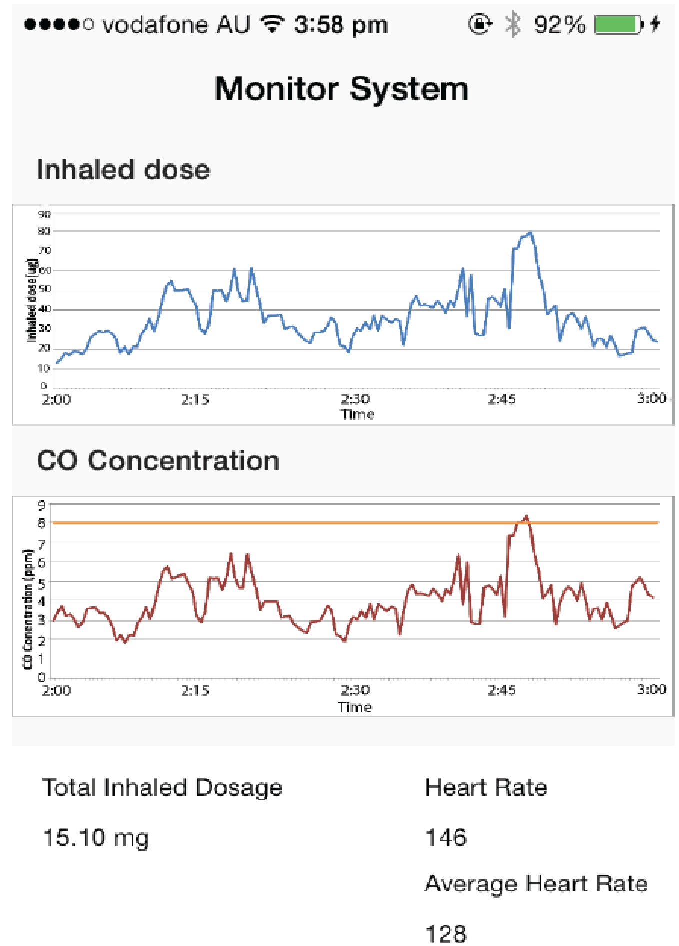
Application: Data upload interface

- 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



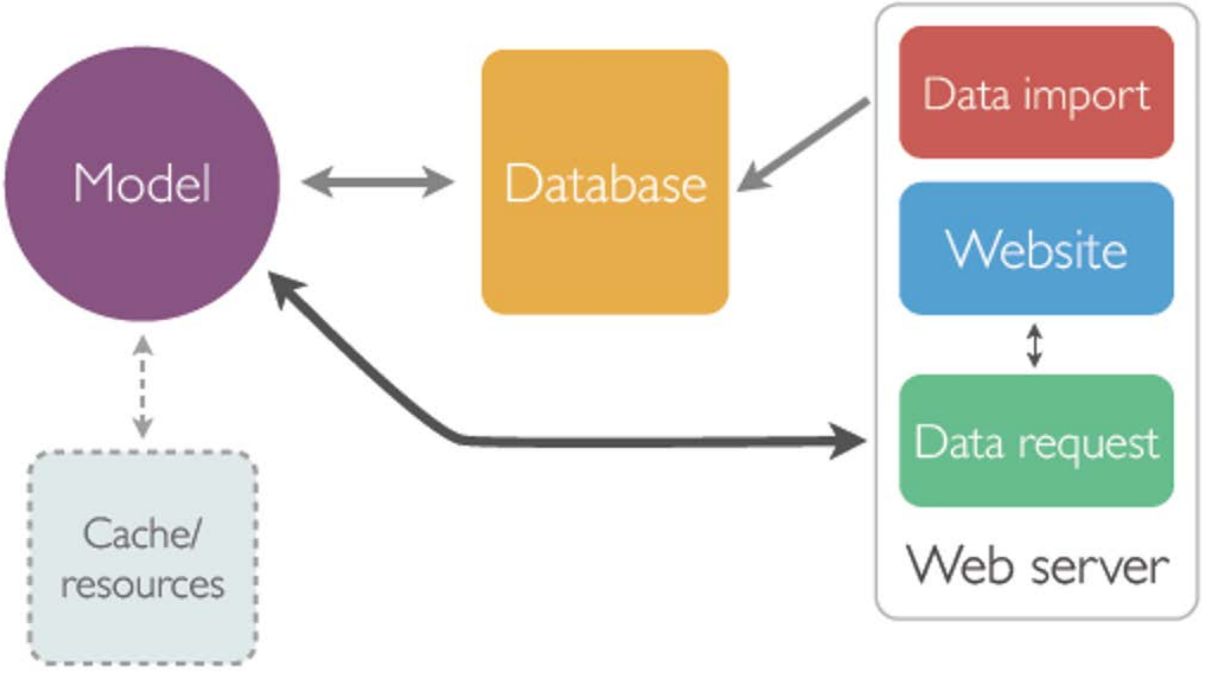
Inhalation dose measurements

- 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:

$$\begin{aligned} Inhaled\_dose = {} & Respiratory\_minute\_volume \\ & \times CO\_concentration \times time \\ & \times conversion\_factor, \end{aligned}$$

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

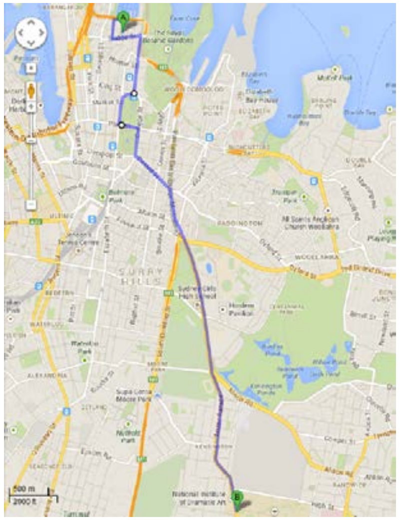
Server



- 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

	Heart rate(bpm)	Real - time RMV ($Lmin^{-1}$)	Constant RMV ($Lmin^{-1}$)	CO concentration(ppm)		Duration(min)
				Government fixed-site (FS)	Participatory system (PS)	
Jogging	153.2(75-172)	46.4(22.7-52.1)	12	0.19	4.0(1.1-8.4)	64
Bicycling	123(76-146)	30.7(19-36.5)	12	0.19	6.1(1.3-18)	41
Driving	84.9(77-93)	14.1(12.8-15.5)	12	0.19	6.9(1.7-34.7)	28

Result: Inhaled dose

- With fixed-site (FS) CO concentrations and constant RMV
  - Inhaled dose is very low (2.6μg 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 (94.3μg min^{-1})
- With participatory system (PS) CO concentrations and real-time RMV
  - The situation reverses, the jogger's inhaled dose per minute increases to (215.5μg min-1) , while driving is lower at (114 μg min-1) .

	Inhaled dose(μg min^{-1})			
	FS CO data + constant RMV	FS CO data + real-time RMV	PS CO data + constant RMV	PS CO data + real-time RMV
Jogging	2.6(2.5-2.6)	10.0(4.9-11.4)	55.3(25.3-115.1)	215.5(77.3-479.5)
Bicycling	2.6(2.5-2.6)	6.6(4.1-8.0)	84.4(17.3-247.2)	220.3(36.8-690.1)
Driving	2.6(2.5-2.6)	3.1(2.7-3.4)	94.3 (22.9-477.2)	114(25.1-563.3)

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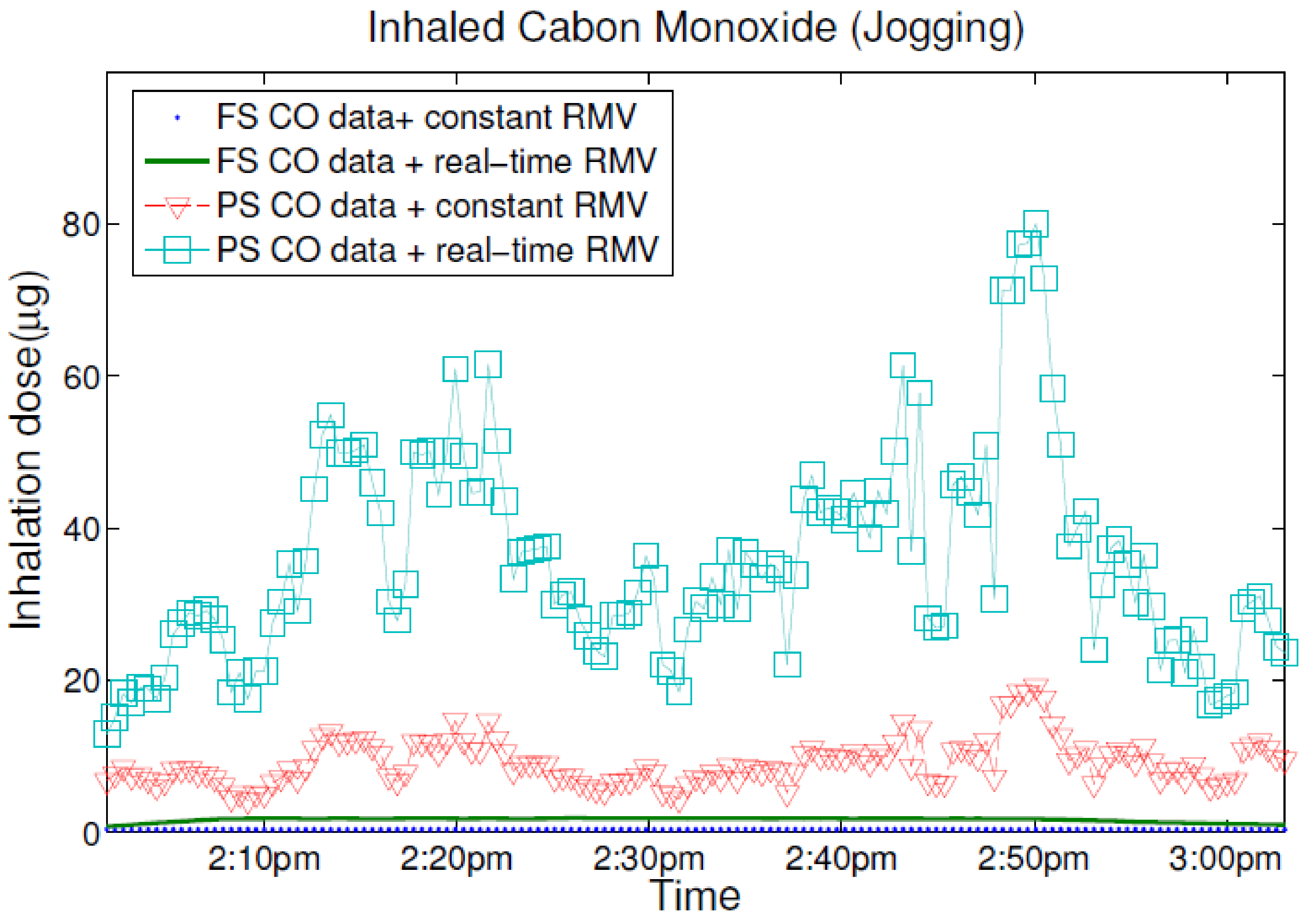
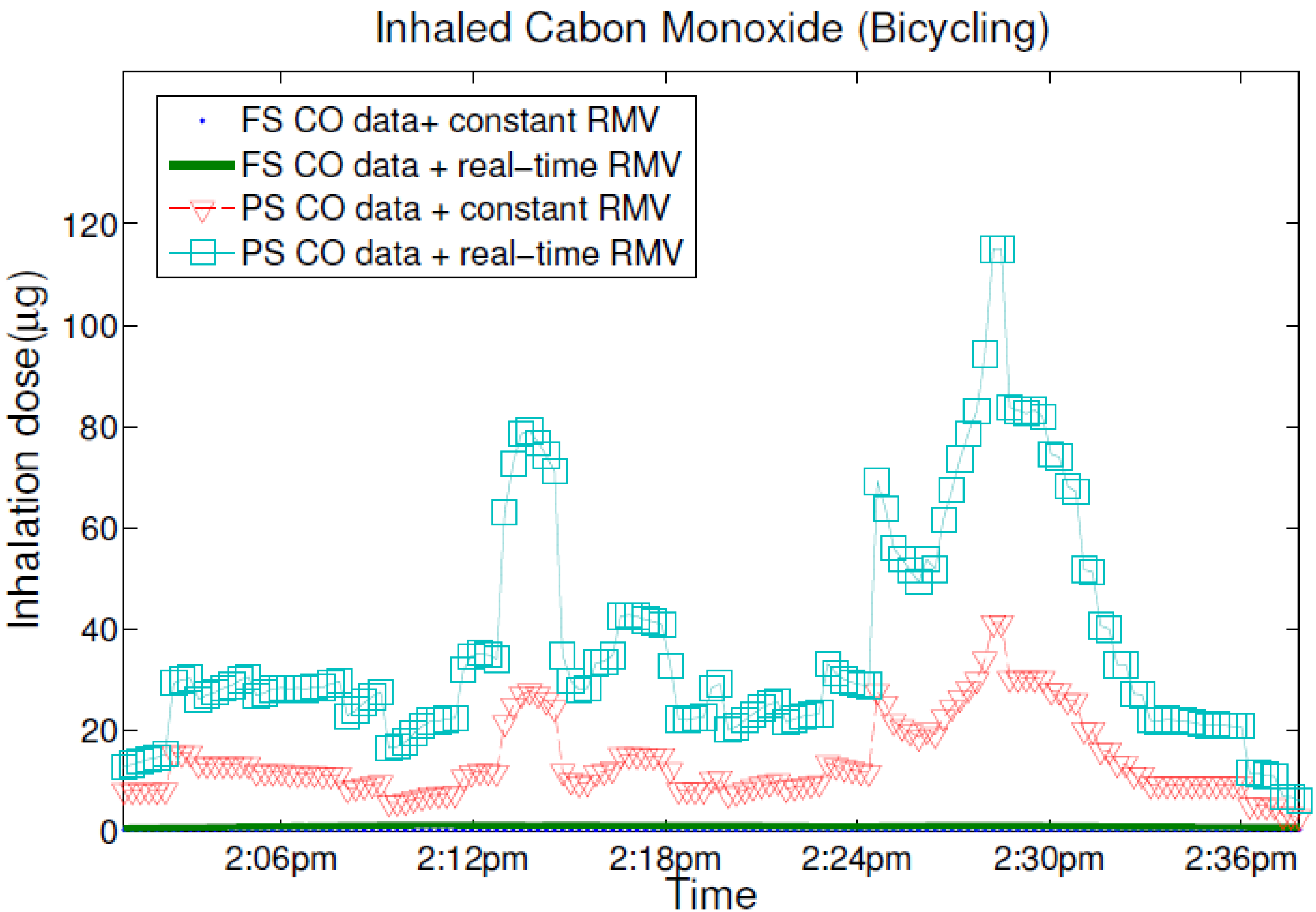
Result: Inhaled dose



Result: Inhaled dose



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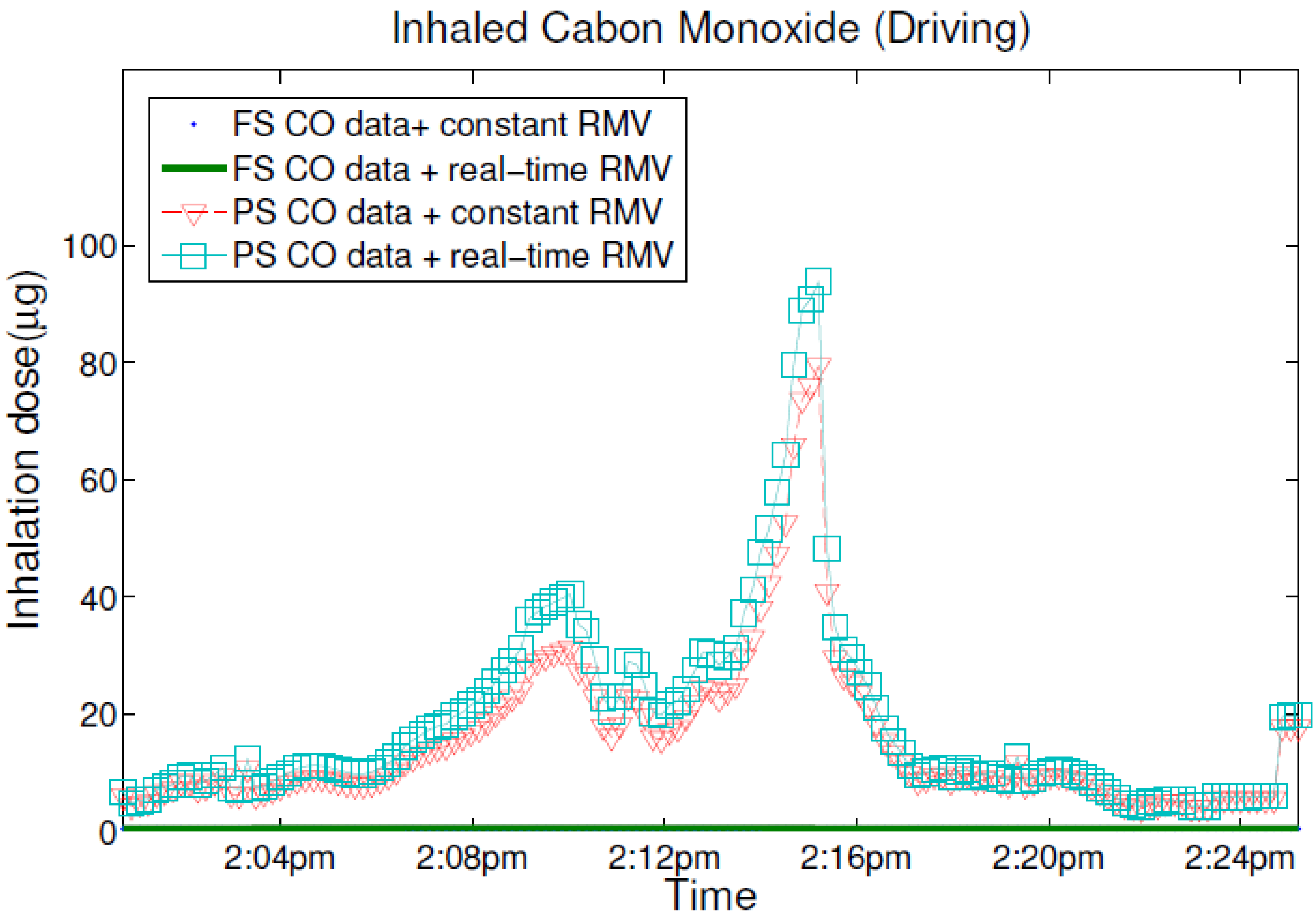
Result: Inhaled dose



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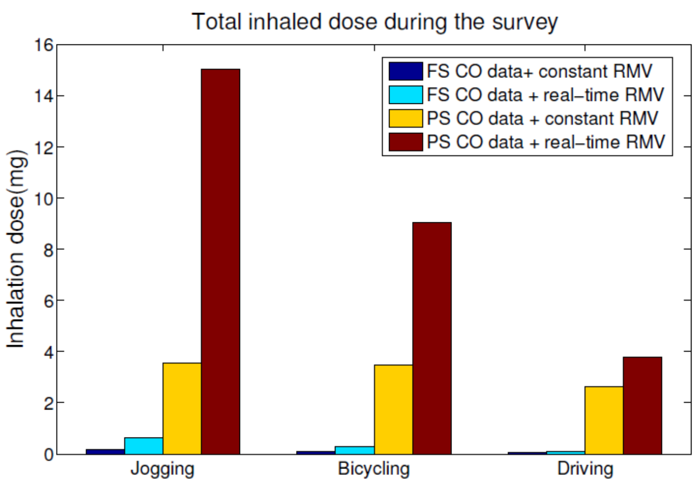
Result: Total inhaled dose

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



	Total inhaled dose(μg)			
	FS CO data + constant RMV	FS CO data + real-time RMV	PS CO data + constant RMV	PS CO data + real-time RMV
Jogging	165.7	642.2	3540.2	15037.8
Bicycling	106.2	272.2	3459.2	9031.5
Driving	72.5	85.5	2640.7	3767.1

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.