MobiSense: Lifespace Tracking and Activity Monitoring on Mobile Phones

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Motivation

- Lifespace
  - Measure of the frequency, geographic extent and independence of an individual's travels
  - Useful metric relating to cardiovascular health, community engagement and nutrition
- Data is good
  - Feedback based on true behavior provides incentive, measurement and reward for change
  - Examples: Quantified self movement, m-Health initiative
- Smartphones
  - Packed with sensors
  - Worn throughout the day
  - Open programming interface
  - Geeky fun to play with

The CanWheel Project

- Founded under six year emerging team grant from CIHR
  - 15+ researchers from 6+ universities across Canada
- Guiding Questions:
  - How are power wheelchairs used now?
  - How can power wheelchairs be used better?
  - How can power wheelchairs be better?
- Five core projects:
  - Evaluating needs & experiences
  - Measurement of mobility outcomes
  - Wheelchair innovation
  - Data logging
  - Wheelchair skills program for powered mobility

www.canwheel.ca

CANWHEEL

MobiSense: Goals & Approach

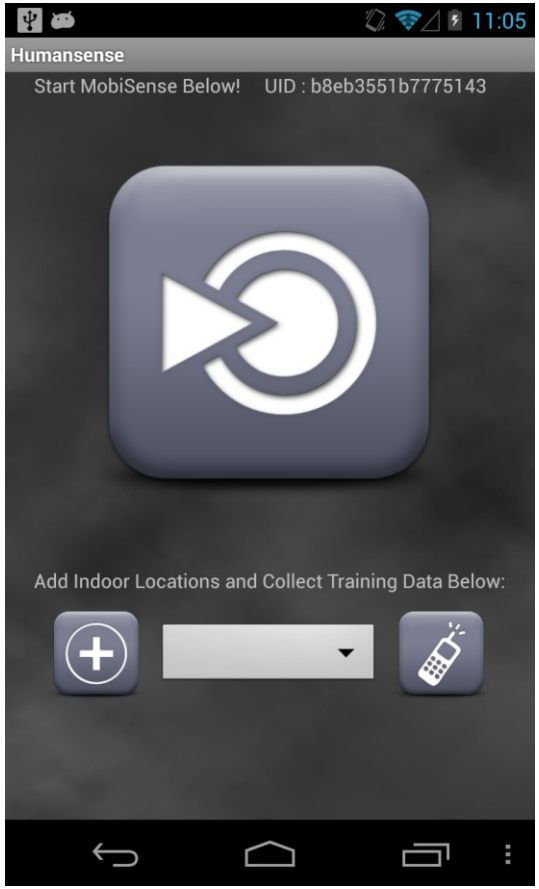
- Three desirable and feasible measurements:
  - Outdoor mobility tracking
  - Indoor mobility tracking
  - Mobility activity classification
- Two challenges:
  - Providers and consumers of data are not engineers
  - Underlying technology and algorithms are rapidly changing
- Three approaches:
  - Simple user interfaces for data collection and visualization
  - Partition code into production, analysis and visualization components with simple data exchange formats
  - Minimize code on the mobile platform
  - Open source the code

Related Work

- UbiFIT [Consolvo et al, ICUC 2008]
  - Track pedometer activity, displayed on phone
- Ohmage [Hicks et al, 2011]
  - Example Open mHealth application
  - Has been used to track activity levels and other studies
- FUNF: Open Sensing Framework [Pentland et al, 2013]
  - Extensible framework for getting sensor data to a web site
- HumanSense [Frank, 2013]
  - Open source data collection platform + classification
- Lifespace measurement [Schenk et al, *J. Am. Geriatric Society*, 2011]
  - Track indoor location using bluetooth beacons in rooms
- Commercial products
  - Exercise products: FitBit, Jawbone, Nike FuelBand
  - Phone providers: Google Now and Maps

Indoor Localization: Training

- Data collection
  - User creates a room name and walks around the room
  - App samples WiFi SSIDs and signal strengths for a few minutes
  - Data uploaded to cloud server in compressed text file
- Construct a room classifier
  - Which room is most likely?
  - Random forest of decision trees [Breiman, *Machine Learning* 2001; Balaguer et al, IROS 2012]
- Construct a novelty classifier
  - Has this room been seen before?
  - Nearest centroid threshold with Euclidean distance

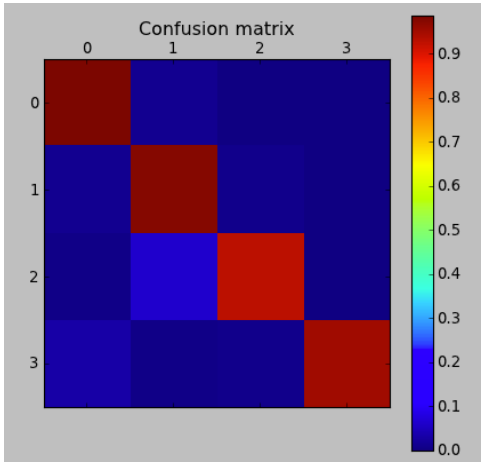


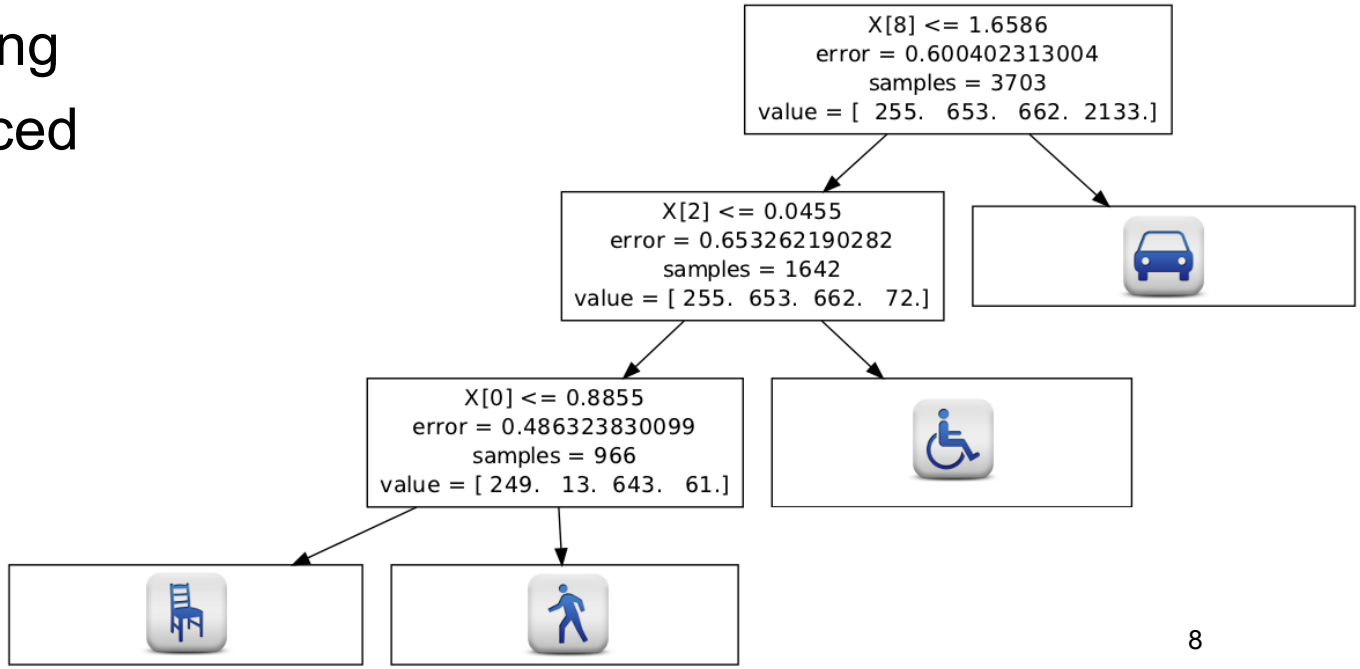
Indoor Localization: Operation & Testing

- Data collection
  - Phone collects WiFi SSID and signal strengths at 10s interval
  - Data uploaded to cloud server
- Testing
  - Six buildings, 4–6 rooms each, 7–189 WiFi access points, 1140–3138 readings for training purposes
  - Secondary app built to collect images during testing and label ground truth
  - Six more test sets created by randomly removing 20% of access points from original test sets
  - Random forest achieves 91% accuracy average (range 76%–98%) over twelve test sets

Activity Classification

- Based on [Frank et al 2012; Hicks et al, 2011]
- Accelerometer readings (total magnitude) at 20 Hz
- Features pulled from 3 second moving window
- Nine features considered: Mean and variance of accelerometry (2), frequency and amplitude of top three Fourier coefficiens (6), GPS speed estimate (1)
- Build single decision tree
- Limited testing
- Easily replaced





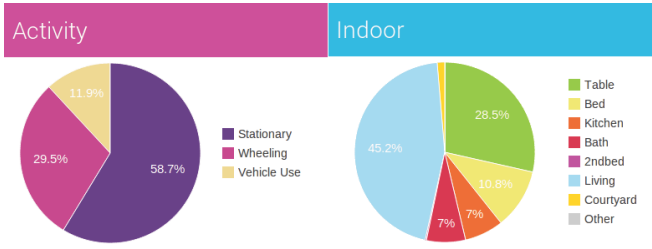
Other Implementation Details

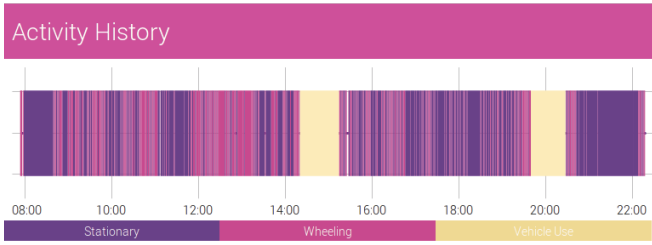
- Outdoor localization
  - GPS latitude and longitude measured once per minute
- Lots of data uploaded
  - Raw data is 15 MB compressed (50 MB uncompressed) in 18 hours
  - Summarized data is 100 KB per day
- Significant power requirement
  - Runs for 22 hours without recharge (but no other phone use)
- Phone held in backpack or pants pocket (except during room training)

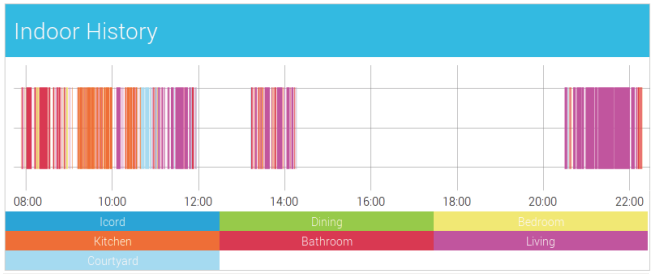


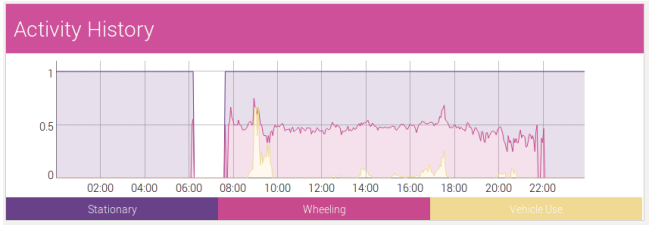

Visualization

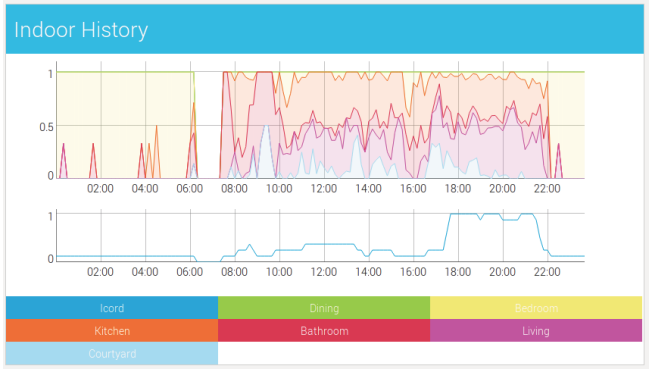
- Daily or multi-day summaries available
- Five visualizations
  - Summary pie charts of indoor location and activity
  - Time series of indoor location and activity
  - Google map heat chart of outdoor location and traces
- Visit http://mobisense.ca and use Android id 71b82dc2885abaca

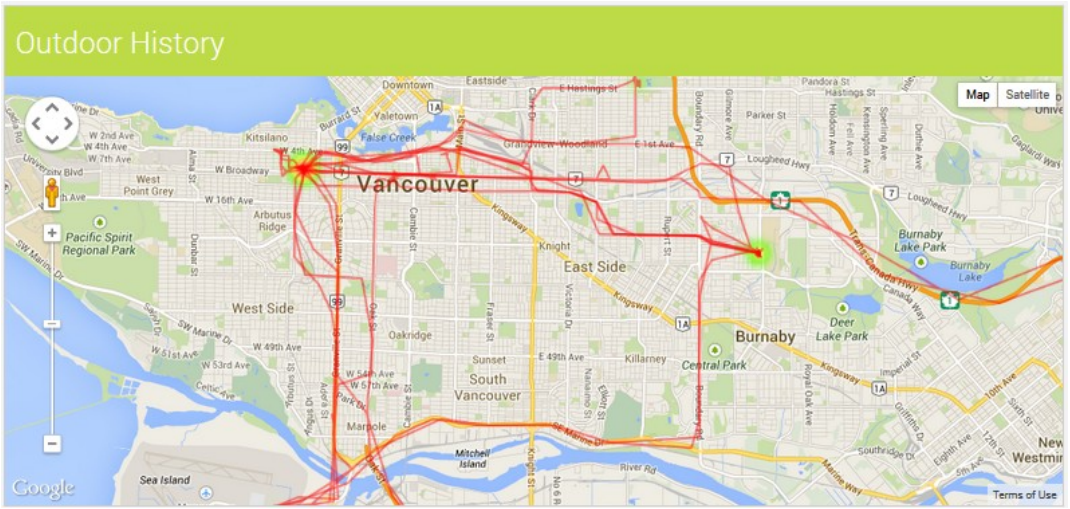












Conclusions

- MobiSense system
  - Provides indoor and outdoor localization plus four category activity classification
  - Android phone app to collect wifi signal strength, GPS and accelerometry
  - Cloud server to construct and evaluate decision trees
  - Could server to visualize results
  - Based on Open mHealth separation of concerns
  - Easily modified
- Squashed by commercial products?
  - But they provide little or no access to raw data
- Open source the code
  - Contact me if you are interested

Acknowledgements

- Thanks
  - Jordan Frank for his open source HumanSense app
  - CanWheel team for valuable feedback
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