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
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
  - 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?

• 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 coefficients (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
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