Urban Sensing Applications

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History

Initial Drivers: Smartphones and Connected Vehicles


- Andrew T. Campbell, Shane B. Eisenman, Nicholas D. Lane, Emiliano Miluzzo, and Ronald A. Peterson, “People-centric Urban Sensing,” In Proc. 2nd annual international workshop on Wireless Internet (WICON), August 2006. (Cited by 463)

Global Device Penetration Per Capita

Source: Bii estimates, Gartner, IDC, Strategy Analytics, company filings, World Bank 2013

Internet Usage (Engagement) Growth Solid
+11% Y/Y = Mobile @ 3 Hours / Day per User vs. < 1 Five Years Ago, USA

Time Spent per Adult User per Day with Digital Media, USA, 2008 – 2015YTD

Source: eMarketer 01/11, eMarketer 01/12, eMarketer 02/13, eMarketer 01/14, eMarketer 01/15, eMarketer 01/16

Note: Other connected devices include OTT and game consoles. Mobile includes smartphone and tablet. Usage includes both work and social media. Usage includes both work and social media. Usage includes both work and social media.
Smart phones

Global Device Penetration Per Capita

Percent of Households that Own Camera Phones

Installed Base of Devices as a % of Global Population

Source: Blt estimates, Gartner, IDC, Strategy Analytics, company filings, World Bank 2013

Internet Usage (Engagement) Growth Solid
+11% YOY = Mobile @ 3 Hours / Day per User vs. <1 Five Years Ago, USA

Time Spent per Adult User per Day with Digital Media, USA, 2008 – 2015YTD

Source: @KPCB (2008-2010), @KPCB (2011-2013). Note: Other connected devices include OTT and game consoles, mobile excludes smartphone and tablet. Usage includes both hours and week. Ages 10+. Time spent with each medium includes all time spent with that medium, regardless of multitasking.
Sensing Gadgets

- Google Glass
Sensing Gadgets
SmartGlasses in 2017

Vuzix Blade 3000 (Augmented Reality) $1000

Snap Spectacles (upload 10sec video to snapchat/Twitter)

Solos (fitness stats display for cyclists), $500

ODG R7 (Augmented Reality) PokemonGo included, $1K-3K
Personal Sensing Gadgets

Sleep and activity tracking

Activity tracking earbuds
Personal Sensing Gadgets

- Withings (smart scale, etc)
Sensing Gadgets for Cars

- OBD II
Sensing Gadgets for Things

- RFIDs and tracking (e.g., luggage)
Universal Sensing Gadgets

- Smart Phones
A Note on Projects

- You can propose a device budget of up to $500
  - Make a case for why you need the devices and what you want to do with them
  - We shall order them (if the case is convincing)
Structure of the (Human-centric) Sensing Landscape

- How is sensing done?
- Who uses the data?
  - Me?
  - My friends?
  - An interest group/the world?
- What is the sensing purpose?
  - Application types
- What does the person do?
Who Uses the Data?

- MetroSense: Where people are the focal point of sensing
Fitness Tracking

Sleep and activity tracking

Activity tracking earbuds
CenceMe (2007)

- A Facebook app
- Sensors compute user context (or “sensing presence”).
- Context is shared with social circle (e.g., Facebook friends) according to specified privacy policies.
CenceMe

- A Facebook app
- Sensors compute user context
  - Activities (sitting, walking, or meeting friends),
  - Disposition (happy, sad, or okay)
  - Locations (at the gym, coffee shop, or at work) and
  - Surroundings (noisy, hot, or bright).

- Context is shared with social circle (e.g., Facebook friends) according to specified privacy policies.
Sharing in Virtual Worlds

- Integrate second life with sensors in the real world (e.g., on a phone) for various "cyber-physical" games
Sharing in Virtual Worlds

- Integrate Second Life with sensors in the real world (e.g., on a phone) for various "cyber-physical" games
Exploit mobile devices and dissemination options in the possession of individuals to perform acts of sensing for common interest

Two competing flavors

- Participatory sensing
- Opportunistic sensing
Two Competing Flavors

- **Participatory sensing**: “the custodian consciously opts to meet an application request out of personal or financial interest”.
  - Places demand on the user
  - Offers control

- **Opportunistic sensing**: “custodians configure their devices to let [sensing] applications run (subject to privacy and resource usage restrictions), but they might not be aware which applications are active at any given time”
Three Application Types

- Geotagging
- Statistics
- Modeling
Application Types

1. Geo-tagging (participatory)

- Phone-based geo-tagging of events of interest (UCLA)
  - Crowds/pollution on beach
  - Invasive species (weeds)
  - Trucks in residential neighborhoods
  - Drinking fountains

Reprinted from UCLA/CENS
Application Types:
2. Statistics/Mapping (opportunistic)

- Example: BikeNet
Applications:
3. Data Modeling

Subscribers

- OBDII-WiFi Adaptor ($50)
- GPS Phone

Green GPS
The fuel efficient option

Saves 6% over shortest path and 13% over fastest path

Fuel Data + Physical Models

\[
F_{\text{engine}} = \frac{\Gamma(\omega)Gg_k}{r}
\]

\[
F_{\text{air}} = \frac{1}{2}c_dApv^2
\]

\[
F_{\text{friction}} = c_r rmgsin(\theta)
\]

\[
F_{\text{car}} = F_{\text{engine}} - F_{\text{friction}} - F_{\text{air}} - F_g
\]
Sensing Challenges

- Humans as Sensing Targets?
Sensing Challenges

- Humans as Sensing Targets
  - Energy and resource consumption challenges
  - Context inference
    - Who is wearing me?
    - What are they doing?
  - Privacy and data sharing policies
    - What can the application know when?
- Personal sensor networks
  - My fitbit does not measure my steps when I am pushing a shopping cart. Detect and transfer sensing function to my Nike shoe.
Sensing Challenges

- Humans as Sensor Operators?
Sensing Challenges

- Humans as Sensor Operators
  - Data collection campaigns: Recruitment and incentive challenges
  - Task assignment challenges (who measures what)
    - Who is where? What’s their context?
    - How does the context impact data quality?
    - Who wants what?
    - Patterns of life, mobility prediction, and marginal cost?
    - Assignment for best coverage?
  - Sparse sampling and generalization
  - Privacy and spatio-temporal obfuscation
    - Anonymity is not enough (think GPS traces)
    - Trade-off between privacy and pattern obfuscation effort
Sensing Challenges

- Humans as Sensors?
Sensing Challenges

- Humans as Sensors
  - What is the noise/perturbation model?
  - How is perturbation correlated? Why is that bad?
  - How to fix it?
- Inferring trust/influence patterns
- Inferring correlated bias
- Data cleaning challenges:
  - Accounting for correlations
  - Accounting for source reliability
  - Accounting for confidence in data
  - Accounting for opportunity to observe
  - Accounting for “chattiness” and silence
  - Accounting for time lapse
Conclusion

- A very rich space is emerging where even the simplest applications (geotagging) lead to interesting research problems. More on that in the rest of the semester...