Place-based Indoor Positioning Using Crowdsensing Signatures

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The Smartphone Era

- There are many sources of data available to a modern developer, and many unexplored, indirect methods to filter or evaluate that data in order to provide more context to their application or service

- We see an ever-growing adoption of sensor components by smart devices - but are we really using these devices to their full potential?

Issues with Modern Location Technology

- Standard location technologies have posed tremendous limitations to the ever-expanding domain of modern location services / smartphone applications
- GPS requires line-of-sight between receiver and multiple satellites, making it inadequate for indoor positioning
- WiFi and Bluetooth depend on large-scale infrastructure (and an ideal spatial configuration) to cover a service area and are still susceptible to marginal positioning errors
- Both approaches have serious power requirements for applications that depend on high-frequency location updates

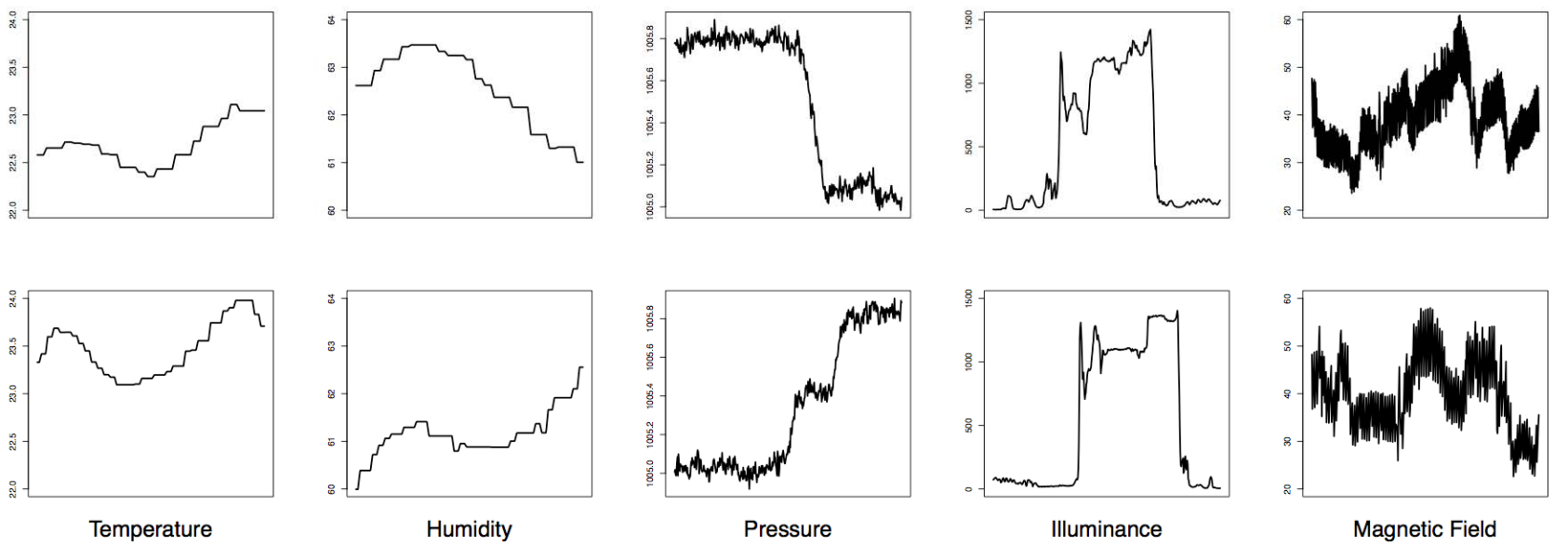
Ambient Sensor Hardware

- Accessible hardware on a typical smartphone may include the ability to make observations of the following environmental fields (including spectra ranges):
  - Temperature
  - Relative Humidity
  - Air Pressure
  - Visible Light (e.g., Luminosity, Color Temp)
  - Magnetic
  - Audio (i.e., Pressure Waves)

Ambient Information

- Ambient sensors offer low-power, high-frequency measurements of the surrounding environment
- Most importantly, these ambient sensors are measuring values exhibited by naturally-ocurring fields, which exist everywhere and hence require no infrastructure to set up
- Treating each of these fields conceptually as "bands" of a spectrum, we correlate the sensor signatures of various places to their categorical types and the activities that those environments typically afford

Sensor Signatures



- **Ambient sensor signatures from two different elevator rides including entering and exiting the elevator**

Augmenting Location Technology

- Ambient sensors are excellent at indicating environmental changes at crisp borders, which can be used to supplement location provider algorithms
  - For example, detecting that a person has entered a building is an indication that GPS should be turned off
- Location services are entirely spatial, so marginal positioning errors can lead to significant loss in accuracy when deriving *place*. Ambient sensor data can provides the additional context to correct for these "border conditions"
  - For example, locating a user at the grungy dive bar next door rather than the tranquil pedicure spa they are actually relaxing in

Place-Type Identification

- Collecting lots of training data, use machine learning to correlate signatures to types of places
- This approach enables smartphone apps to estimate the type of place (such as library, cafe, gymnasium) by sampling just a few seconds of the environment, even for spaces that may not have been observed prior

Activity Detection

- Take a similar approach to detecting the type of activity taking place in the surrounding environment
- Spaces vary over time, especially the types of activities they afford

Smart Places

- This leads us towards developing Volunteered Geographic Services, wherein users contribute sensor observations to a centralized system, which in turn informs remote users about place status' in real-time or as predictions
  - e.g.: "Will the basketball courts busy tonight?"
  - e.g.: "Where is the warmest room to study on campus right now?"
- Scaling this up, we can cover large areas and simulate models of an environment; effectively creating a distributed, crowd-sourced sensor network
- Naturally, popular areas will have the most accurate and frequently updated information

Questions