# Ubiquitous and Mobile Computing
## CS 403x: A Survey of Mobile Phone Sensing

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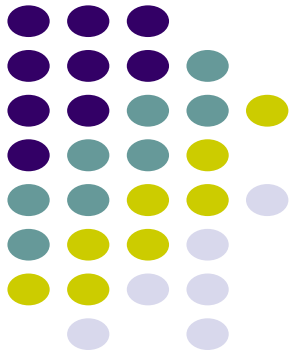


# Sensors

- Gyroscope
- Compass
- Accelerometer
- Proximity Sensor
- Ambient Light Sensor
- Front and Back facing cameras
- Dual microphones
- GPS
- WiFi
- Bluetooth

# Sensor Applications

- Sensors added to support the user interface
- Accelerometers determine phone orientation to reorient display
- Proximity and light sensor used to disable touch screen when phone is held to the face to speak
- Light sensors used to adjust screen brightness
- GPS for location-based apps such as local search or navigation
- Compass/Gyroscope provides additional location information such as direction and orientation

# Sensor Applications

- Activity Recognition
  - Determine activities such as walking, running, or standing
- Hands free voice control
- Eye tracking

# Predicted Sensors

- Barometer
- Thermometer
- Humidity
- Blood Pressure
- Heart Rate
- EEG
- Gas Sensors

# Modern Sensors

- Barometer
- Hall Sensor
- Thermometer
- Humidity
- Pedometer
- Heart rate monitor
- Fingerprint Sensor
- Radiation Sensor

# Sensor Applications

- Transportation
  - Fine grained traffic information
  - Accurate travel time estimation
- Social Networking
  - Determine events in people's lives
- Environmental Monitoring
  - Personalized environmental impact reports
- Health and Well Being
  - Track physical activity and personal health goals

# App Store and Large Scale Research

- Easy app distribution
  - Facilitates reaching a large user base quickly
- Perform experiments and studies with participants all over instead in small laboratory controlled conditions

## Sensing Scale

- Personal Sensing
  - Single individual, data collection and analysis
  - Usually private data
- Group Sensing
  - Sensing applications with a common goal or concern
  - Aggregate data protects individual
- Community Sensing
  - Large number of participators
  - Track spread of disease, traffic congestions patterns

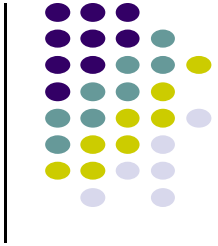
## Sensing Types

- Participatory Sensing
  - Active participation in the sensing process
- Opportunistic Sensing
  - Passively sense such as while in your pocket

# Sensing Paradigms

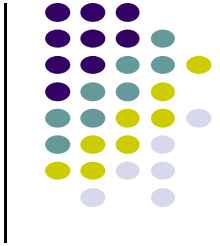
- Opportunistic Sensing
  - Lowers burden placed on user
  - Relies on context sensing
  - Easier to have lots of users but hard to develop
- Participatory Sensing
  - Higher burden placed on user
  - Manual data collection
  - Solves context problem

# Sensing Architecture



- Sense
  - Collect raw sensor data
- Learn
  - Information is extracted using machine learning and data mining techniques
  - On the phone or on the cloud
  - Need to consider privacy, real-time feedback
- Inform, Share, and Persuasion

# Sensing Architecture (Cont.)

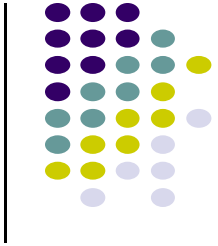


- Inform, Share, and Persuasion
  - Personal application only informs user
  - Group/Community sensing shares aggregate information obfuscating individual data
  - Main benefit is big data analysis from large user base

# Mobile Phones as Sensors: Programmability

- Difficult to access sensors on most traditional phones
  - Phones which included sensors often didn't have APIs to access them
- Smartphones offer SDKs, APIs, etc. for third-party programming
  - Smartphones tend have unreliable sensor output
  - Nokia Symbian returns accelerometer samples at a rate of 25-38 Hz depending on CPU load
- Different vendors have different APIs
  - Cross-platform support difficult
- Today, Android features function calls to directly access sensors (IOS does as well).

# Mobile Phones as Sensors: Continuous Sensing

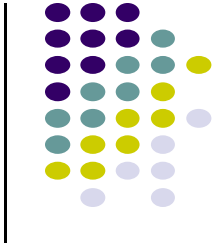


- Constant data collection, useful for healthcare
- Requires ability to run in the background
  - High resource consumption
    - Paper claims it detracts significantly from phone experience
    - Paper is hopeful hardware will improve enough to make continuous sensing viable
    - Jigsaw Continuous Sensing Engine, developed and tested on IPhone and Nokia N95, considered energy efficient and usable

# Mobile Phones as Sensors: Phone Context

- Context of phone use changes rapidly
  - In hand? In pocket? Walking? Driving? Etc.
- Context matters
  - Example: an application which requires voice input might work differently in a quiet space than in a loud one.
- Training data and machine learning
- Supervised machine learning used to model human behaviour.
  - Output data is compared to an expected output when training
- Data for sensing behaviour can come from any combination sensors on the phone
  - Microphone, accelerometer, GPS, etc.

# Interpreting Sensor Data: Scaling Models



- No two human beings behave the same, and some human behaviours can overlap.
- Context models must be able to adapt to different users.
  - Active learning: phone periodically queries user and asks what they are doing
  - Community Guided Learning: data from multiple phones in a given group is combined.
    - Used for modeling community behaviour

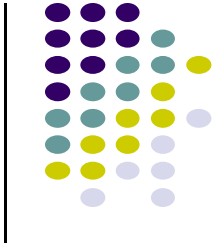
# Closing the sensing loop

- Once behaviours and data are inferred from sensors, what do you do with them?
- Sharing via social media and other media outlets
  - Build community awareness
- Personalization: adapt applications to user's behaviour and environment
  - Ads, voice recognition, etc.
- Persuasion: convince user to change behaviour
  - Example: "You have spent 4 hours sitting down, you should get some exercise."

# Privacy

- The ability to sense user behaviour has obvious privacy implications.
- Doing computations on sensor data 100% locally improves privacy
- Sending sensor data to a remote server for computations might be more powerful
- *Second Hand Smoke* problem when apps are designed to collect data from nearby phones
  - How can the privacy of third parties be effectively protected when other people wearing sensors are nearby?
  - How can mismatched privacy policies be managed when two different people are close enough to each other for their sensors to collect information from the other party?

# Conclusion



- Lots of Sensors!
- Sensor access has come a long way
- Ability to do big data research
- Continuous sensing is possible, but consumes battery
- Context modeling is possible through machine learning and statistical models.

# References


Android sensor access: *http://developer.android.com/guide/topics/sensors/sensors_overview.html*
Apple sensor access: http://www.slideshare.net/thomasfankhauser/ios-sensors-15579340
Continuous sensing on smarphones: http://www.cs.dartmouth.edu/~campbell/papers/jigsaw.pdf

Face and Eye-tracking: http://www.computerworld.com/article/2495384/smartphones/inside-samsung-galaxy-s4-s-face-and-eye-tracking-technology.html
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