Mobile Sensing: Evolution of Mobile Sensing

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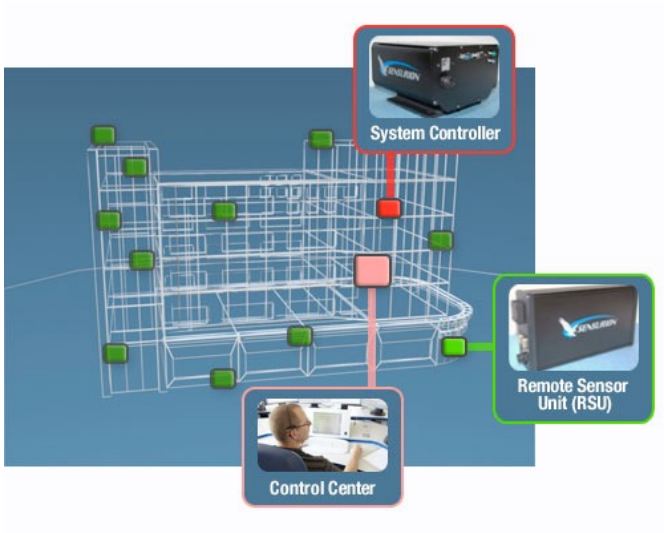
History of Mobile Sensing

- Environment sensing
  - Took off around 1990
  - Fixed sensors in mostly indoor locations
  - Applications:
    - Infrastructure sensing
    - Safety monitoring (temperature, gases, etc.)
    - Security monitoring (fixed cameras)
  - Challenges:
    - Data gathering – wireless is power hungry and unreliable
    - Power management – difficult to recharge batteries



History of Mobile Sensing

- Wearable sensing
  - Early 2000s
  - Strapping a person with specialised equipment
  - Applications:
    - Gait recognition
    - Fall monitoring
    - Social encounters (Socimeter)
  - Challenges:
    - Scalability – difficult to do an experiment with 1000 people
    - Power management

History of Mobile Sensing

- Mobile phone sensing
  - Personal commodity devices
  - Array of sensors
  - Applications on a grander scale
  - Phone manufacturers never intended their devices to act as general-purpose sensing devices
    - Accelerometer to trigger screen rotation
    - Gyroscope for playing games
    - Microphone for making calls
    - Camera for taking conventional photos

Mobile Phone Sensing Challenges

- Phone sensing requires a significant engineering effort:
  - Frequent sampling with what was supposed to be an occasionally used feature
    - Accuracy problems
    - Battery lifetime
    - Processing overhead
- Android is trying to lower the sensing overhead:
  - E.g. Google Play Services for location updates
- Manufacturers start viewing sensors as a central component of their platforms

Smartphone – Under the Hood

Accelerometer
Magnetometer
GPS
Light
Camera
Barometer
Gyroscope
Proximity
Microphone

WiFi
GSM
NFC
Bluetooth (BT)
Touch screen
Thermometer
Humidity sensor
Wireless gesture radar

Smartphone – Under the Hood

Octa-core CPU
256 GB Flash
8 GB RAM
GPUs
NPUs
OLED
Touchscreen

Mobile OS: Android, iOS

Access to:

- Processing
- Networking
- UI
- Sensors
- High-level inferences

Android – OS of Choice for this Class

- Google's OS for mobile devices
  - Based on Linux
  - Runs on a range of different mobile devices
  - Largest market share (~85%)
- Development supported through Android SDK and Android Studio
  - Programming in Java or Kotlin
  - Follow Android design guidelines
- TODO: Complete "Preparatory Lab"

Pros and Cons of Smartphone Sensing

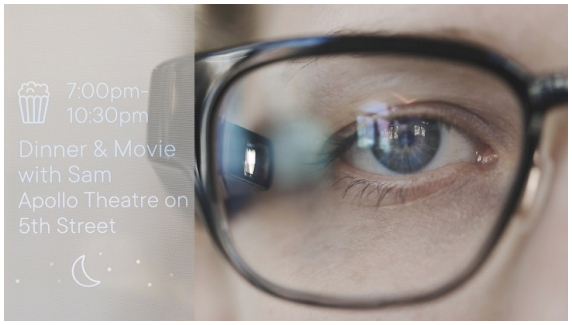
- Pros
  - Personalised –suited for sensing human activities
  - Low cost of deployment and maintenance (millions of users where each user charges their own phone)
- Cons
  - General purpose hardware, often inappropriate sensor placement lead to inaccurate sensing of the target phenomena
  - Multi-tasking OS. Main purpose of the device is to support other applications, yours can get killed
  - Apps could get uninstalled

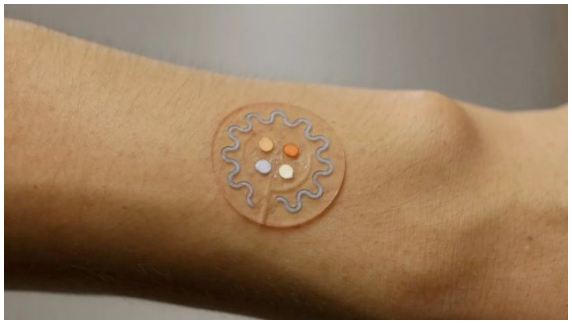
Wearable Sensing Devices

- Activity trackers and smart watches
  - Pedometers – count steps
    - Built in accelerometers also allow more sophisticated activity recognition
  - Heart rate sensors
  - Electrodermal activity - EDA (Galvanic skin response - GSR)
  - GPS
  - Bluetooth connectivity

Wearable Sensing Devices

- Smart glasses
  - Google glass failed, but other products are filling the void
- Chest straps
  - Breathing and heart rate sensors
- Patches
  - Sweat analysis, glucose level
- Electro encephalogram (EEG)
  - Emotion detection
- Earables
  - A sensor that fits in your ear!





Pros and Cons of Wearable Sensing

- Pros
  - In a close contact with users
  - (Usually) cheap and widely available
- Cons
  - (Usually) low sensor accuracy, placement issues
  - A wide range of devices – no uniform API
  - Devices quickly become obsolete, unsupported
  - Not so widely available, researchers often have to supply devices to study participants

Mobile Sensing Applications

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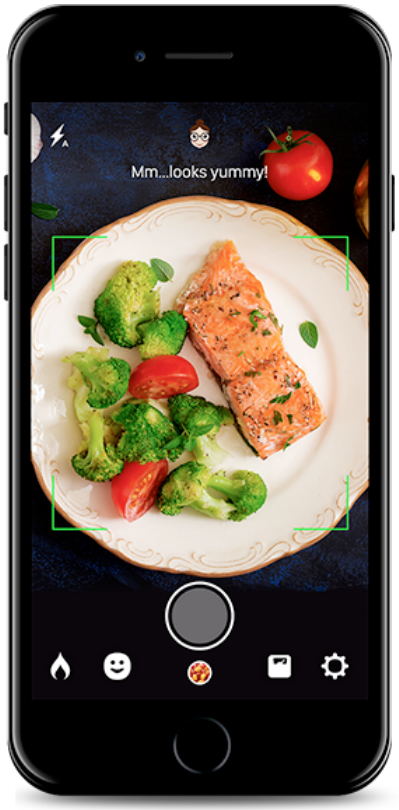
Mobile Sensing App Scales

- Individual sensing:
  - Fitness applications
  - Behaviour intervention applications
- Group sensing:
  - Sense common group activities and help achieving group goals, environmental sensing
- Community/urban-scale sensing:
  - Large scale sensing - a large number of people have the same application installed; e.g. tracking speed of disease across the country

Nicholas D. Lane, Emiliano Miluzzo, Hong Lu, Daniel Peebles,Tanzeem Choudhury, Andrew T. Campbell.A Survey of Mobile Phone Sensing. IEEE Communications Magazine. September 2010.

Example Apps – Behaviour Change Intereventions

- Goals:
  - Lose weight, quit smoking, reduce stress
- Activity recognition:
  - Sensors: accelerometer, gyroscope
  - Infer: walk, run, climb stairs
- Exercise monitoring:
  - Sensors: HR, GSR, skin temperature
  - Count calorie expenditure
- Food recognition:
  - Sensor: camera
  - Machine learning models for image classification



Source: caloriemama.ai

Example Apps – Profiling Social Interactions

- Goals:
  - Understand social interactions, conversations, roles
- Interaction recognition
  - Custom wearables sensing infra red, BT, acceleration
- Speech processing
  - Sensors: microphone
  - Recognise: turn taking, stress, emotion

Source: “Measuring Interaction Proxemics with Wearable Light Tags“, Montanari et al., 2018

Example Apps – Air Quality Monitoring

- Goals:
  - Crowdsource pollution monitoring
- Sensors
  - Custom sensors
  - Data from multiple sources
- Processing challenges:
  - Outliers
  - Heterogeneous data
  - Different data granularities
  - Blind spots

Source: "Smart London – Air Quality Monitoring with IoT Big Data"

From hardware to knowledge

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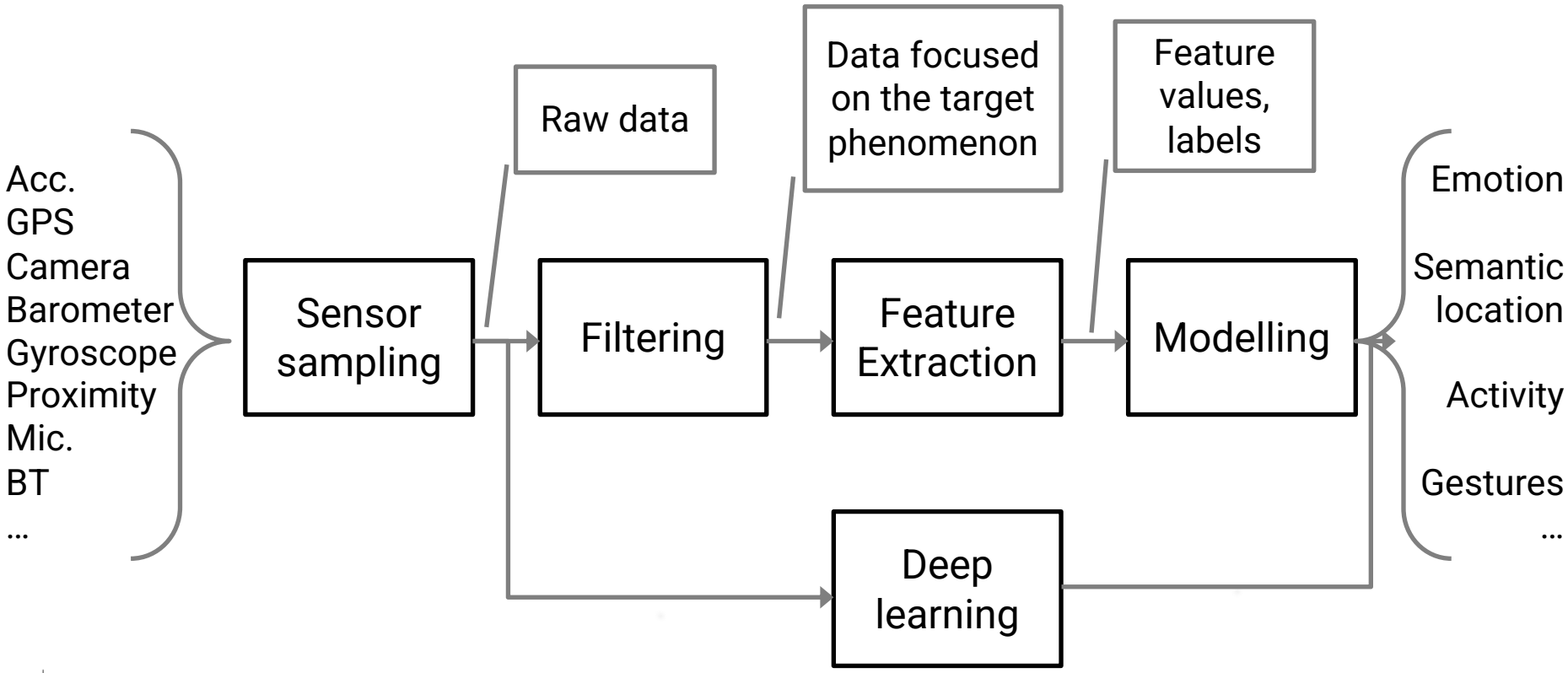
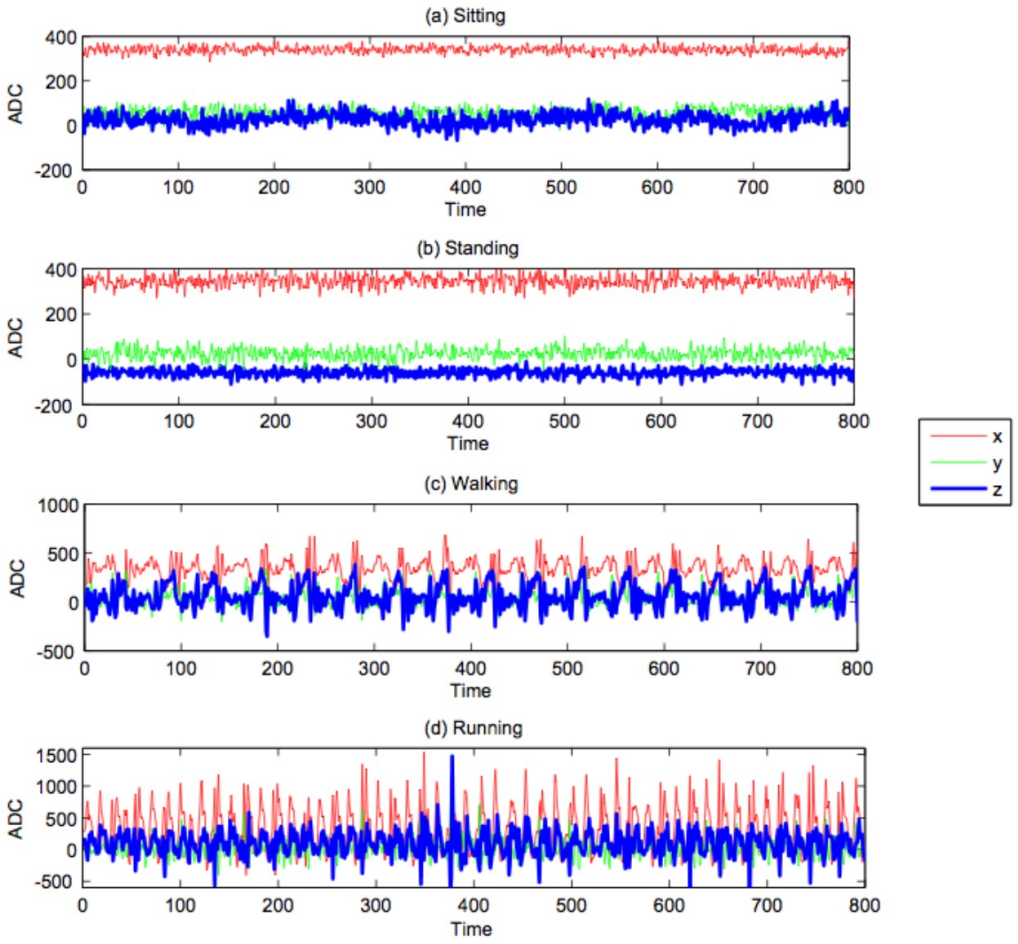
Sensing and Learning Pipeline



From Raw Data to High-Level Inferences

- Example: activity recognition -



Source: "Sensing Meets Mobile Social Networks: The Design, Implementation and Evaluation of the CenceMe Application"
Miluzzo et al., 2008

Understanding Mobile Sensing

- Understand the target domain
  - What do I want to infer/detect?
  - How does it manifest in the physical world?

Talk to domain experts!

- Understand the sensors
  - What do they measure?
  - Range, accuracy, sampling rate, etc.
- Understand machine learning
  - Which features are likely to be informative?
  - Do I have enough data?
  - Evaluate the explanatory power of the models

Focus of this class

TODO

- Brush up your Android skills:
  - Labs from Platform Based Development course posted on Ucilnica
  - Udemy courses
  - Android developers Training page
- Next week's lab:
  - Complete the preparatory lab to make sure your Android Studio environment is set

TODO

- Project Proposal – v1 due on Wed 23rd
  - Describe what you plan to do and how
    - Be specific!
  - Describe your evaluation plan
  - If your project is risky, think about Plan B
  - Timeline
    - Take into account the midsemester and the final presentation
  - List any resources you might need
  - 1-2 pages long

TODO

- Meetings with Octavian (sign up sheet soon)
- Read
  - *A Survey of Mobile Phone Sensing* by Lane et al.
  - *Deep Learning in Mobile and Wireless Networking: A Survey* by Zhang et al.