Mobile Health: Introduction

Cecilia Mascolo
Assessment and Practical Classes Team:
Kayla-Jade Butkow, Jing Han, George Rizos, Jake Stuchbury-Wass, Sotirios Vavaroutas, Yvonne Wu
About Me

• Professor of Mobile Systems

• Work on mobile and sensing systems and wearable devices
  • Devising new ways to use sensors to measure behaviour
  • Making these systems efficient given resource constraints
  • Wearable data analysis and machine learning
  • Applications related to health and diagnostics
What is Mobile Health

Mobile Health tries to make use of digital wearable devices and sensors to proxy information about human behaviour and health, including diagnostics and progression.

We will see example of use of these techniques in a variety of health settings and making use of a variety of sensing methods.
Why

• Affordable
• Scalable
• Continuous
• Non invasive
• Sustainable
Challenges

• Type of Sensors
• Resource constraints
• Frequency of data harvesting (sampling)
• Location of (pre)processing of data
• Data labelling
• Data sparsity
• Signal Processing/Machine learning for this data
• Data Privacy
• Linking data to clinical outcomes
Mobile and Wearable Sensing
Mobile Data
Breakdown for some states of type of connectivity

Fraction of browsing sessions on each network technology

Source: Chrome logs
Phone Sensors and Radios

- Inertial Measurement Unit
- Global Positioning System
- Cameras
- Proximity Sensors
- Microphones
- Radios: WiFi, BLE, Cellular...

Processors: CPU, GPU, coprocessors
“Basic” Mobile Health

- Mobile questionnaires
- Feedback carefully tailored through messages or apps
Growth in the number of medical apps downloaded during the COVID-19 pandemic by country in 2020*

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Korea</td>
<td>135%</td>
</tr>
<tr>
<td>India</td>
<td>90%</td>
</tr>
<tr>
<td>Worldwide</td>
<td>65%</td>
</tr>
<tr>
<td>Spain</td>
<td>65%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>60%</td>
</tr>
<tr>
<td>Japan</td>
<td>55%</td>
</tr>
<tr>
<td>Italy</td>
<td>40%</td>
</tr>
<tr>
<td>France</td>
<td>35%</td>
</tr>
<tr>
<td>United States</td>
<td>30%</td>
</tr>
<tr>
<td>Germany</td>
<td>30%</td>
</tr>
<tr>
<td>China</td>
<td>25%</td>
</tr>
</tbody>
</table>

* Based on downloads from the iOS and Google Play App stores. Data compare the number of medical app downloads in each country using its respective ‘peak’ month for the COVID-19 health crisis to the number of medical app downloads during January 2020.
Wearables!

Watch

- Heart rate monitor
- Sleep monitor
- Activity monitor
- Blood Oxygen
- Electrocardiogram

- More coming...(Blood Pressure..)
Future/Other Devices

• Many exist. Some more mobile than others.
• Scales that measure body composition and pulse wave velocity

• Earables have been defined as the “next computing platform after smartphone” [1]
• Sensors in these devices could bring novel ways to monitor health [2]

[1] Romit Roy Choudury https://www.youtube.com/watch?v=1Qvu1G59JC0

COMMUNICATIONS
ACM

eBP: An Ear-Worn Device for Frequent and Comfortable Blood Pressure Monitoring
Sensors woven into a shirt can monitor vital signs
Comfortable, form-fitting garments could be used to remotely track patients’ health.

Anne Trafton | MIT News Office
April 23, 2020

“We can have electronic pets that we wear as garments,” said Electronics Professor of Computer Science and Artificial Intelligence Timдон. Image: Courtesy of MIT News Office.
How do we measure performance of these systems?
Machine Learning Metrics

• Classification tasks (trying to understand if a point is of a certain class)

• You are familiar with precision and recall and F1 score (which is a combination of precision and recall)

\[
\text{Precision} = \frac{\text{true positives}}{\text{true positives} + \text{false positives}}
\]

\[
\text{Recall} = \frac{\text{true positives}}{\text{true positives} + \text{false negatives}}
\]
Metrics meaningful to Health Applications

- **Precision** = \( \frac{\text{true positives}}{\text{true positives} + \text{false positives}} \)
- **Recall** = \( \frac{\text{true positives}}{\text{true positives} + \text{false negatives}} \)
- **Sensitivity** = \( \frac{\text{true positives}}{\text{true positives} + \text{false negatives}} \)
- **Specificity** = \( \frac{\text{true negatives}}{\text{true negatives} + \text{false positives}} \)
Example of why sensitivity matters

• Let us assume that a COVID-19 test has a **sensitivity** of 70%.

• Let us assume that we test 10 people that we know have COVID-19. How many would the test correctly identify (in average)?
  • 7 would be identified. 3 would be false negatives.

• If the sensitivity was 80% we would identify 8.

• A **specificity** of 70% indicates that if we test 10 individuals who do not have COVID-19, the test would correctly identify 7 as healthy and 3 as affected by COVID-19 (wrongly).
Disease Prevalence

• When trying to find if someone has a specific disease in a population often the distribution of the disease in the population is not “50-50” for this binary task...

• Prevalence indicates the amount of “diseased” people in the population in the “test set”.
Confounding

- Confounding factors:
  - A confounding variable (factor) which produces spurious associations which are not the underlying causal link of from your data to your result.

- Example: trying to find link between lack of exercise and weight gain.
  - You find that lack of exercise leads to weight gain.
    - But if you do not check how much people eat it might be that in your set, you have that all the people who exercise eat less and those who don’t eat more.
  - Eating should be a "control variable"
Data Bias

• Bias in the data collection can lead to wrong conclusions/predictions.

• If data on which you train your model contains data from a predominant group which means other groups are not able to be predicted well.
  • “models for cardiovascular disease that claim to predict heart attacks 5 years before they happen are trained in predominantly male datasets”.
  • Prediction in women may not be accurate as the disease has different expression in women!
Prediction for COVID-19 with Audio

COVID-19 Sounds App

Upload short recordings of cough and breathing and report symptoms to help researchers from the University of Cambridge detect if a person is suffering from COVID-19. Healthy and non-healthy participants welcome.

Press the red button below and breathe in and out as deeply as you can five times. Please do so in a quiet environment.

Press the red button below and cough three times.

Press the red button below and read the following sentence three times.

"I hope my data can help manage the virus pandemic!"

or use the online form
Example of Confounding and Bias

• At some point our classifier was “too good”

• Bias:
  • Our training data was biased: Italians had COVID and English did not
  • Our model was learning if the people were speaking English or Italian 😊
  • The model was biased by language: solution was to control for language
Ethics!

• Sensitive data: continuous nature, very personal, very revealing, easily collected, easily aggregated...

• What can be done?
  • On device approaches
  • Differential privacy
  • Federated learning

• Model development vs model deployment
Outline

• 1 Introduction
• 2 Signal Processing Primer
• 3-4 PPG: Physiological and Sleep monitoring
• 5-6 Audio for Health Diagnostics and Physiology
• 7-8 Inertial Measurement Units and Human Activity
• 9-10 Bluetooth and GPS: Population Health and Contact/Location Tracing
• 11 Radios and Contactless Health Monitoring
• 12 Apps, Behaviour Intervention (and Applied Reinforcement Learning)
• 2 Practical Classes (8\textsuperscript{th} February, 22\textsuperscript{nd} February)
• 2 Guest Lectures
Guest Lectures

• 29th February 2pm: Tong Xia, University of Cambridge

• 5th March 2pm: Dr Alessandro Montanari, Nokia Bell Labs
Seminars on Mobile and Wearable Health

• Generally at 4pm on Tuesdays in FW26 (some online)

Mobile and Wearable Health Seminar Series

Talks about applications of mobile and wearable systems to health

Tell a friend about this list: your friend’s e-mail Send e-mail

If you have a question about this list, please contact: Cecilia Mascolo; tx229. If you have a question about a specific talk, click on that talk to find the organiser.

11 upcoming talks and 17 talks in the archive.

Dealing with uncertainty in physiological sensing in the wild

Christian Holz, ETHZ.
Computer Lab, FW26 and Online.
Tuesday 23 January 2024, 16:00-17:00

Title to be confirmed

Silvia Santini, Università della Svizzera Italiana.
Computer Lab, FW26 and Online.
Tuesday 30 January 2024, 16:00-17:00

Title to be confirmed

Alex Casson, University of Manchester.
Computer Lab, FW26 and Online.
Tuesday 06 February 2024, 16:00-17:00

AI for Health with Wearables

Chenyang Lu, Washington University in St Louis.
Online.
Tuesday 13 February 2024, 16:00-17:00
Course Assessment

• **Two assignments** based on datasets:
  
  • **First** assignment (worth 40% of the final mark): preprocessing and basic data analysis steps in a “colab” style report. (1000 words)
    • Deadline: 19th February 2024
  
  • **Second** assignment (worth 60% of the final mark) will be a fuller analysis where the students are asked to compare and contrast ML algorithms/solutions and discuss findings and interpretation in terms of health context.
    • **Part II**: This will be in the form of a colab and a reflection report of 1200 words.
    • **Part III/MPhil**: This will be in the form of a colab and a reflection report of 1800 words.
    • Deadline: 15th March 2024
Where to find information

- [https://www.cl.cam.ac.uk/teaching/2324/MH/](https://www.cl.cam.ac.uk/teaching/2324/MH/)
- [https://www.cl.cam.ac.uk/teaching/2324/L349/](https://www.cl.cam.ac.uk/teaching/2324/L349/)
Student Support: Office Hours

Assignment Support

Office Hours for Assignment 1:

- 13/02/2024: 3:00 - 4:00 PM in room FW26 (after lecture)
- 15/02/2024: 3:00 - 4:00 PM in room FW26 (after lecture)

Office Hours for Assignment 2:

- 05/03/2024: 3:00 - 4:00 PM in room FW26 (after lecture)
- 12/03/2024: 3:00 - 4:00 PM in room FW26 (no lecture, only office hour)
Student Support: On Moodle

Assignment 1 Open Help Forum

Please feel free to post here any questions you may have with regards to Assignment 1.

Assignment 2 Open Help Forum

Please feel free to post here any questions you may have with regards to Assignment 2.
Teaching Assistants

Kayla Butkow

Jing Han

George Rizos

Jake Stuchbury-Wass

Sotiris Vavaroutas

Yvonne Wu
Questions?