Birkbeck
UNIVERSITY OF LONDON

# Unobtrusive Tracking and Context Awareness: Challenges and Trade-offs

George Roussos
Birkbeck College, University of London
g.roussos@bbk.ac.uk

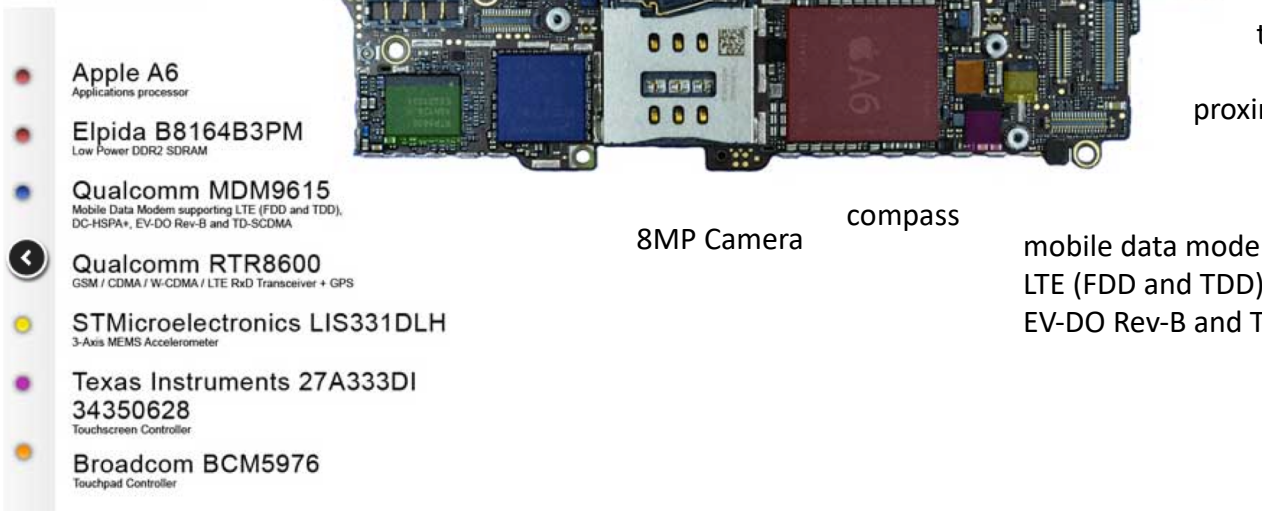
LONDON'S EVENING UNIVERSITY

Birkbeck
UNIVERSITY OF LONDON

# What's inside a mobile phone?

Image credit: IHS/zdnet.com

# Smartphone Sensors




single-chip dual-band combo device supporting 802.11n, Bluetooth 4.0+HS and FM receiver

3-axis digital MEMS gyroscope module

3-axis MEMS accelerometer

microphone audio codec

touchpad controller

proximity sensor

ambient light sensor

compass

8MP Camera

mobile data modem supporting LTE (FDD and TDD), DC-HSPA+, EV-DO Rev-B and TD-SCDMA

Image credit: techinsights.com

Birkbeck
UNIVERSITY OF LONDON

# Recording data

| Sensor | Data |
| --- | --- |
| accelerometer | x- y- z-coordinate of acceleration ($m^2/s$)<br>4.999093, 10.620679, 0.45010993 |
| GPS | latitude, longitude, speed, heading<br>46.81006, -92.08174, 18, SW |
| proximity | distance from object (cm)<br>32 |
| compass | x- y- z-axis geomagnetic field strength (µT)<br>31.869, 45.739, 23,195 |

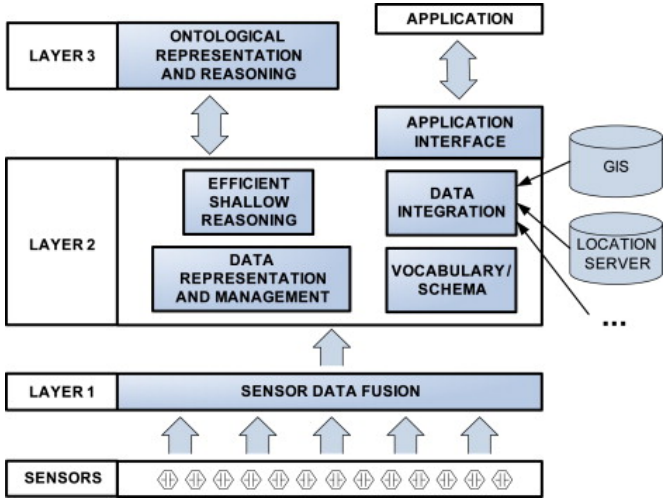
Birkbeck
UNIVERSITY OF LONDON

# From observations to events

| observation | event | context |
|---|---|---|
| longitude, latitude | at work | Geo-located map of significant places / points of interest |
| acceleration | cooking | Statistical model of activity profiles |
| phone call to specific number | chatting with friend | Contact list, social media profile |
| proximity 30cm<br>BLE profile observed | hanging out with friend | Fingerprint map of BLE, statistical model of collocation |

# Context awareness is critical

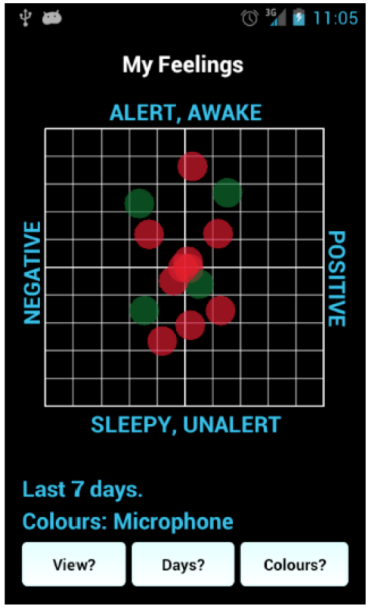
- Data recording provide low-level information which in itself is not enough to identify significant events for the person using the phone
- Context of use is critical for the interpretation of data
- Without context, data observations are meaningless
- Understanding context has been the objective of 20+ years of pervasive computing research




Bettini et. al "A survey of context modelling and reasoning techniques" Pervasive and Mobile Computing, Volume 6, Issue 2, April 2010, pp. 161-180

# Emotion Sense app

- Un-obstructive/passive background sensor recording **and** self-reporting
- Toolkit for comprehensive monitoring of all sensors on the phone
- Approach: use ML to learn how to infer context from data observations
- Discover routines
- Relate routines to mental-wellbeing
- Predict mood from passively monitored data



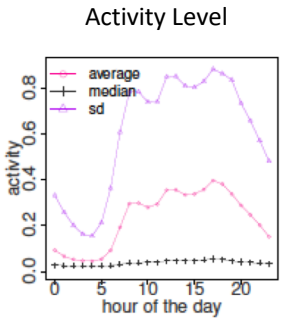

Servia-Rodríguez et. al "Mobile sensing at the service of mental well-being: a large-scale longitudinal study" Proc. WWW17, Computational Health Track, Perth, Australia. April 2017

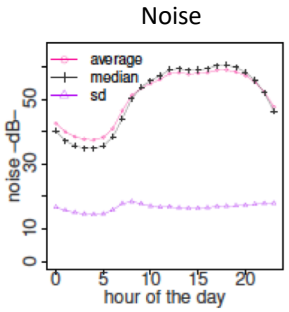
Open Source Library https://github.com/emotionsense

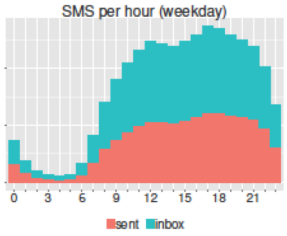
Birkbeck
UNIVERSITY OF LONDON

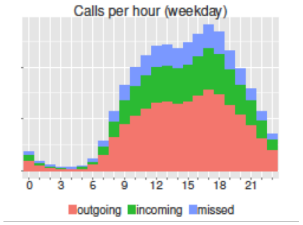
# Findings

- Feb 2013 to Jan 2016
- 40k downloads, 11k provided data
- Effective way to measure activity level, environmental noise, messaging and phone calls
- Associate self-reported mood and sensor data i.e. environment (microphone), activity (accelerometer), and sociability (messages and phone calls)
- Varied performance by sensor but typically possible for less than 40%

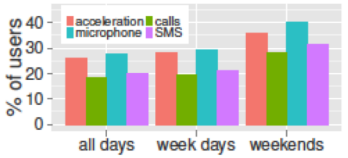


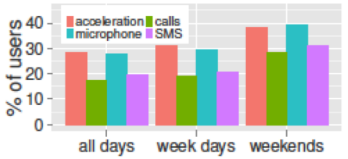




Predicting valence

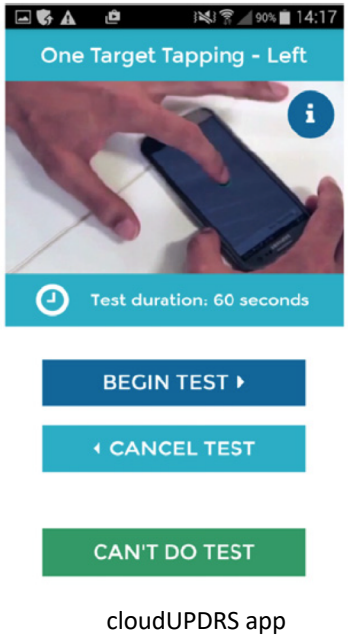



Predicting arousal



# Constraining context

- Clinical assessment of motor symptoms of Parkinson's Disease
- Part III of the UPDRS
- Certified as Class I Medical Device
- Clinical evidence so needs to be objective, comprehensive, consistent **and** acceptable
- Unsupervised assessment at home
- Unable to assess performance consistently using continuous passive monitoring

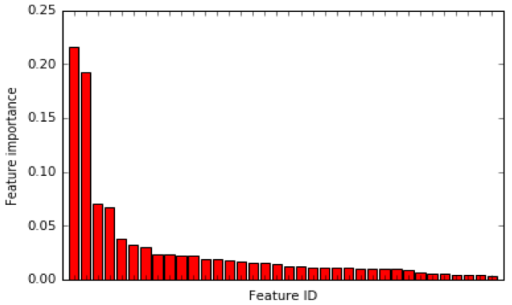




cloudUPDRS app

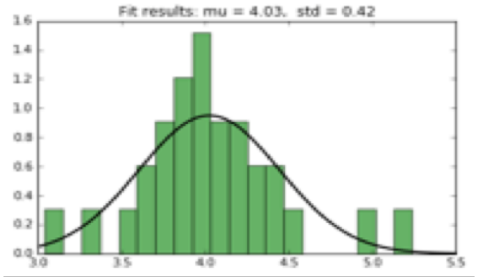
Birkbeck
UNIVERSITY OF LONDON

# Findings

- Solution: constrain context i.e. measure during specific prescribed movements, 17 tests from UPDRS
- Support unsupervised operation:
- Use ML to ensure movements were carried out according to the guidance
- Full test duration for PwP ~25 minutes
- Reduce duration of test to less than 4 minutes
  - Learn which test are significant for the individual
- UPDRS too coarse-grain to capture motor performance variations




Learn which tests provide data features that are most predictive of overall performance for a specific patient




Aggregating many measurements over a week and using descriptive statistics of the distribution is a better way to characterise PD progression.

Birkbeck
UNIVERSITY OF LONDON

# Summary

- Smartphones and wearables offer unique opportunities for frequent observation of populations at scale
- Passive observation gives good results for simple events such as activity levels, significant places and similar
- Passive observation is promising but currently significantly limited when more complex events are relevant e.g. emotional state
- Typically these limitations are due to the lack of context to interpret the data
- Especially for clinical use, constraining the context is necessary and this typically means moving away from passive approaches