Fogarty International Center

Global mHealth Research Training Institute

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Center for Global Health Studies

Fogarty International Center

NIH Fogarty International Center
Advancing Science for Global Health

Global mHealth Research Training Institute

What Technology Do You Need?

Gari Clifford and Omer Inan

Intro to ‘technology’

Technology: “*equipment* developed from the application of scientific knowledge”

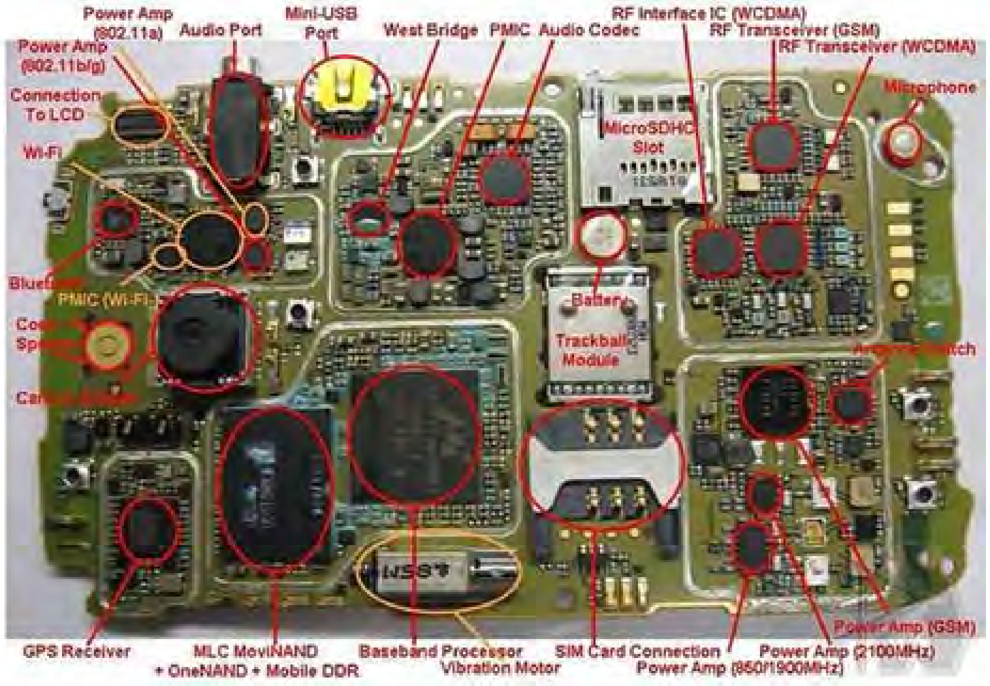
mHealth technology: devices, user interfaces, communications infrastructure, sensors …

The phone itself

UI, sensors, ...

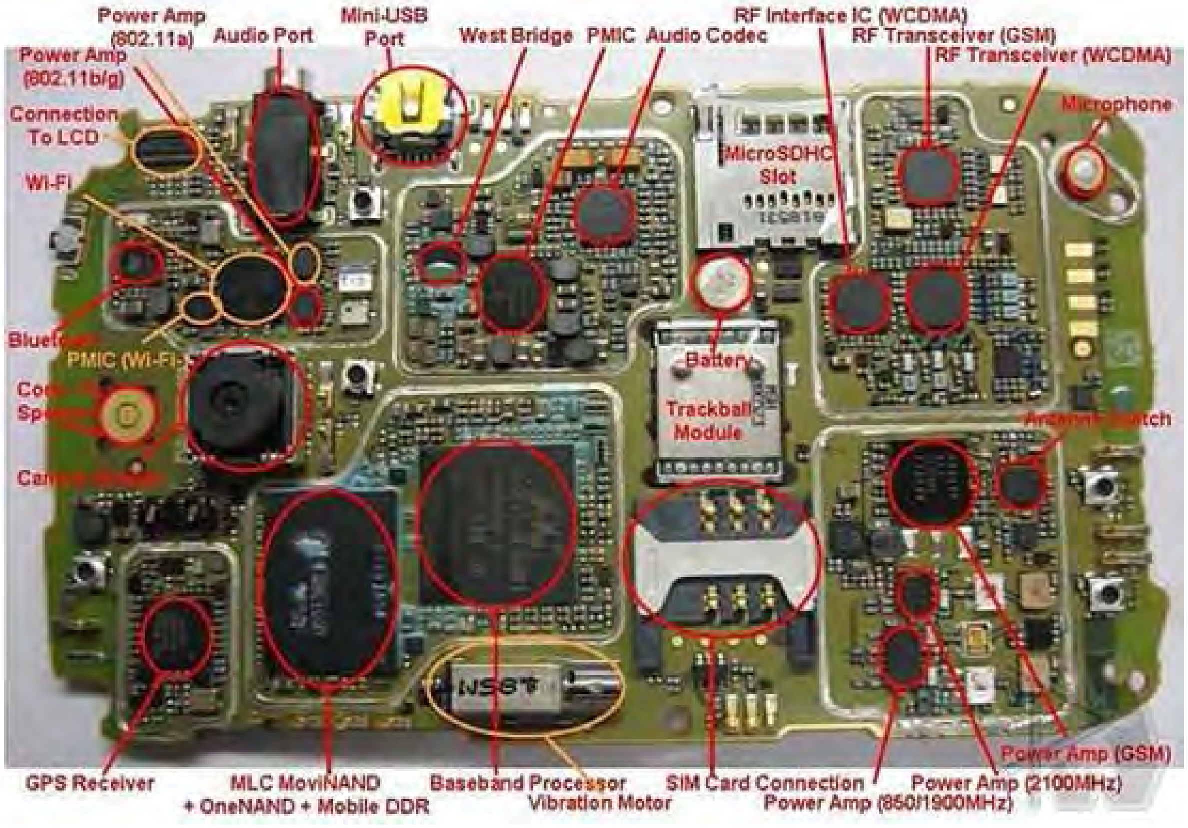
Connected sensors and systems

The network to which it is connected



Communications

1. Audio (phono)
2. Radio
3. Bluetooth
4. NFC
5. USB
6. GSM (Voice)
7. SMS (text)
8. USSD



Still using SMS?

Reaches the largest audience - 6/7 Bn

(just above global literacy: 5.9Bn)

Works in very low bandwidth scenarios (140 Bytes ~ 1 kbit)

Good open source stacks out there

e.g. FrontlineSMS, MedicMobile, CommCare ...

Not an encrypted system - don't send HIV status etc!

Doesn't guarantee delivery (3-7% loss) - no handshake

Delays can be from minutes to days!

Order of messages not guaranteed

Limited content

Very expensive (~10x more than data)

USSD vs SMS

Advantages of Unstructured Supplementary Service Data (USSD) over Short Message Service (SMS):

1. provides cost effective messaging worldwide.
2. allows messages to take place during a call.
3. does not incur charges for roaming.
4. works with interactive menus as well as notifications.
5. much faster than other messaging options, as it is session based – always has an active connection.
6. not mobile software or SIM based. i.e. it can run without both - just requires a connection to the the GSM network.

There are two types of options:

Push - Network pushed USSD service in which the network sends the USSD message to the mobile subscriber.

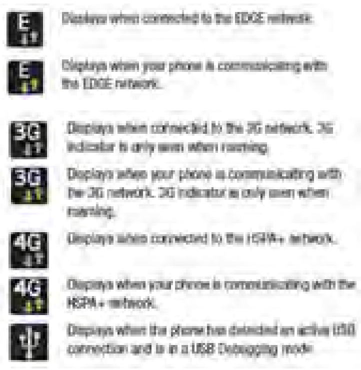
Pull - Mobile Subscriber requested USSD with user sending a USSD message towards the Gateway. i.e. using USSD Short Codes. e.g. *100

IVRS - Interactive Voice Response Systems

Good for low literacy, but ask potential vendor:

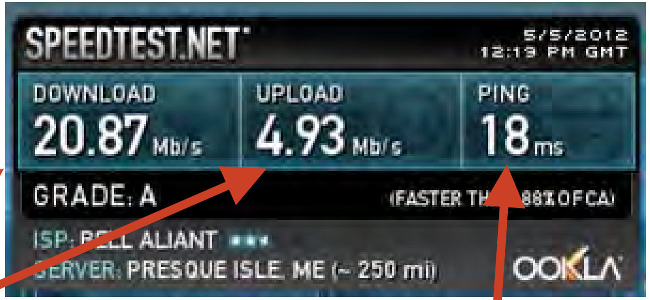
1. What customer inquiries can the IVR handle on its own?
2. Can I connect the system to other service features?
3. What speech recognition technology does the system use?
4. Does it work for my purposes?
5. **Is the system ‘context’ aware?**
6. Can the system keep track of callers?
7. What is the authentication process like?
8. How do callers navigate the system?
9. How do I design the system menus/layers?
10. Can I try it out?

Network speeds & connectivity



- 2G: **35–171** Kilobits per second (**Kbps**). [recall: sms ~ 1Kb]
- EDGE (Enhanced Data rates for GSM Evolution): **120 - 384 Kbps.**
- 3G: **384 Kbps to 2 Megabits/s** (Mbps).
- HPSA ('3.5G'): 600 Kbps - 10 Mbps … average is **1-3 Mbps**.
- 4G (based on the WiMAX or LTE (Long Term Evolution) systems) …**3-10 Mbps** av
- WiFi: **1 Mbps - 1 Gbps** (depends on service, WiFi card, router, downstream cabling)

Check the bandwidth on any device+network: **speedtest.net** (Apps or website)



Note that most providers:

- Throttle when you exceed a quota
- Have **asymmetric** upload/download speeds in ratio ⅕

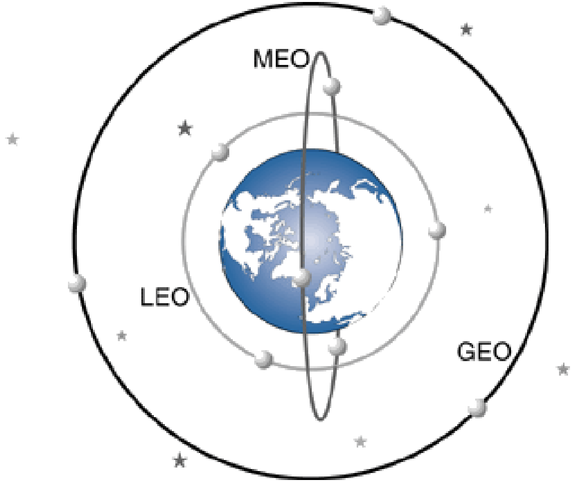
latency

How to use faster/alternative networks

- Store and forward – serendipitous uploads … think out of the box

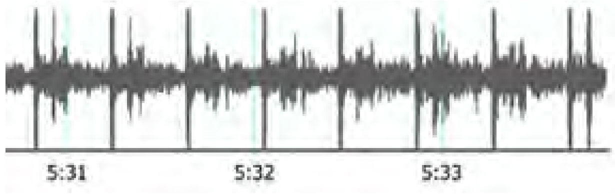
- E.g.: Daknet, Project Loon (Google), Satellite (Elon Must)

- FM radio?

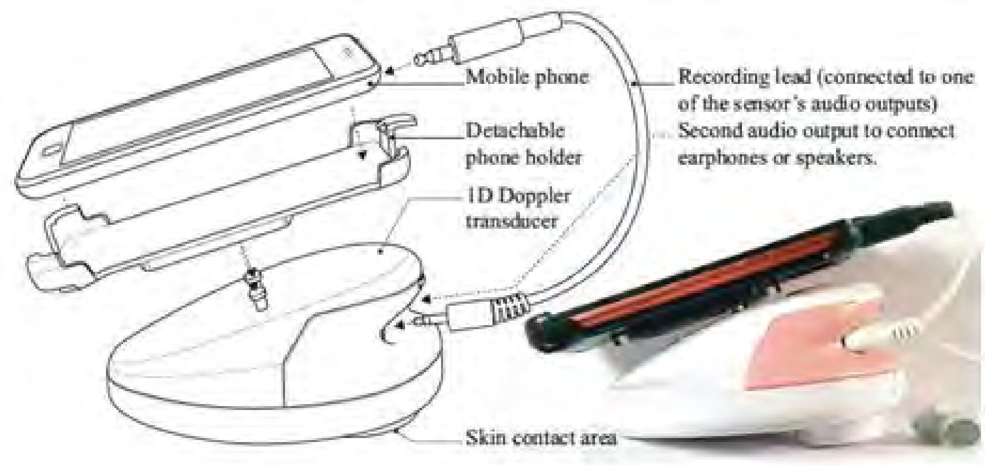


Case Study - monitoring ultrasound for fetal distress

- Pictograms and audio cues on phone guide a traditional birth attendant through screening (preeclampsia, hemorrhage, fever, etc.)



- Ultrasound sensor provides an audio signal, recorded to phone for quality checks
- Data analysed locally and remotely
- SMS/voice for emergency
- GPRS upload for EMR integration
- Bulky study data: WiFi upload



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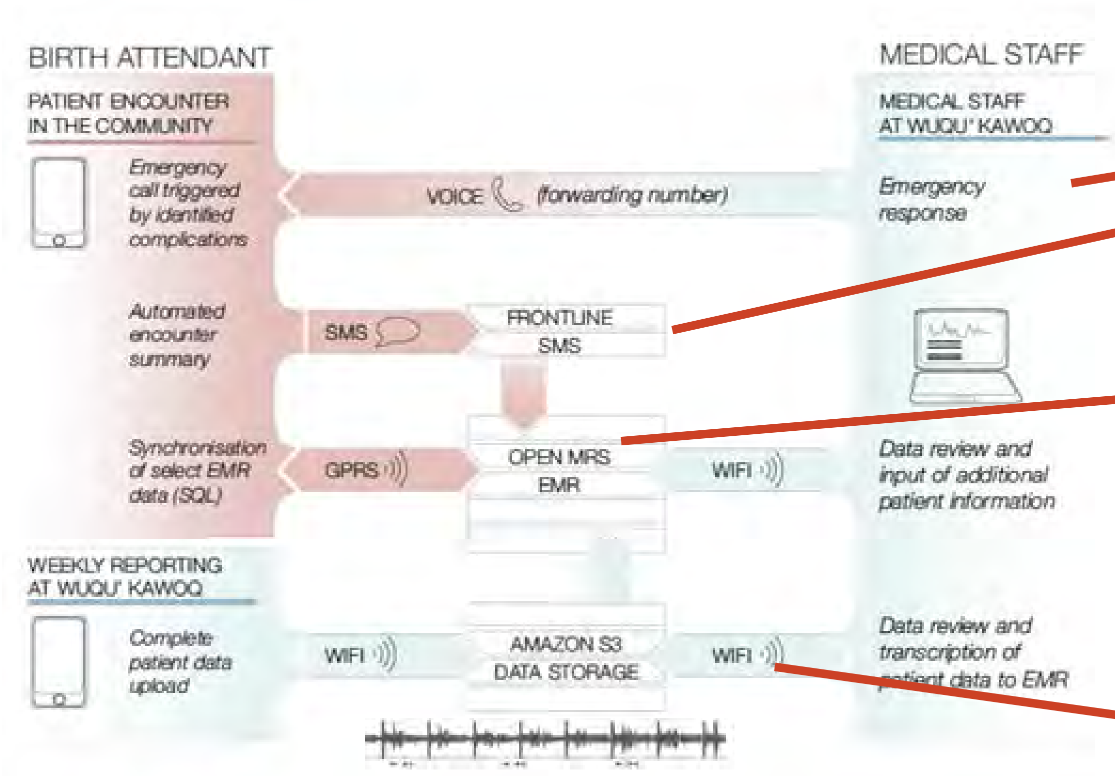
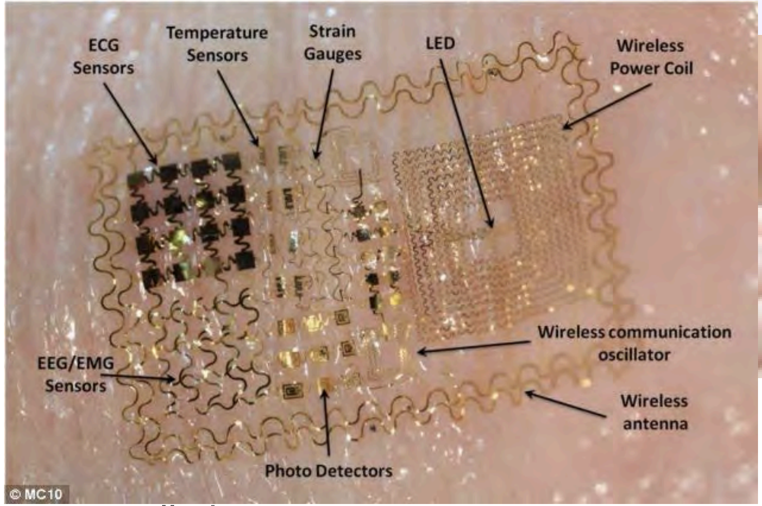


Examples of sensors - overview

Movement:

- on body: accelerometer
- off body: PIR, video

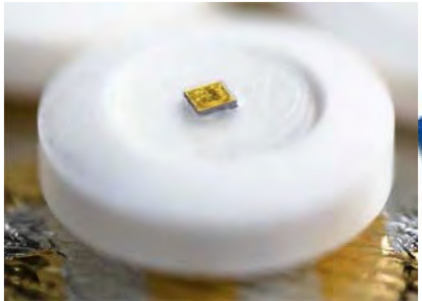


Physiological:

- ECG, BCG, PPG, Temp

Environment:

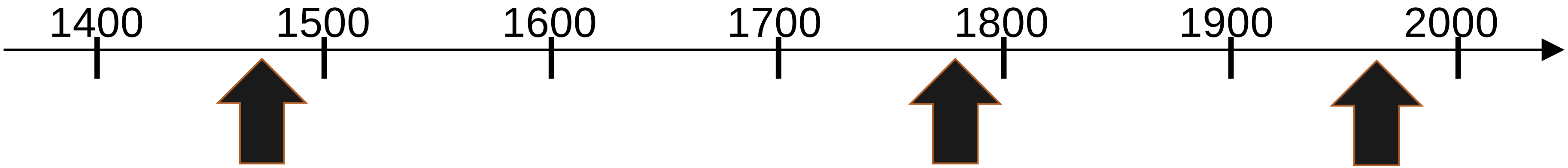
- Light, air pollution, noise pollution, water pollution, heat, weather, location (context)



Social:

- Text message, calls, emails, Tweets

History of Activity Monitoring



Da Vinci sketch of mechanical pedometer

Perrelet invents first pedometer;
Jefferson modifies (?) or brings technology to US

Yamasa Corporation (Japan) begins to market the "manpo-kei" (10,000 steps meter)

TODAY:

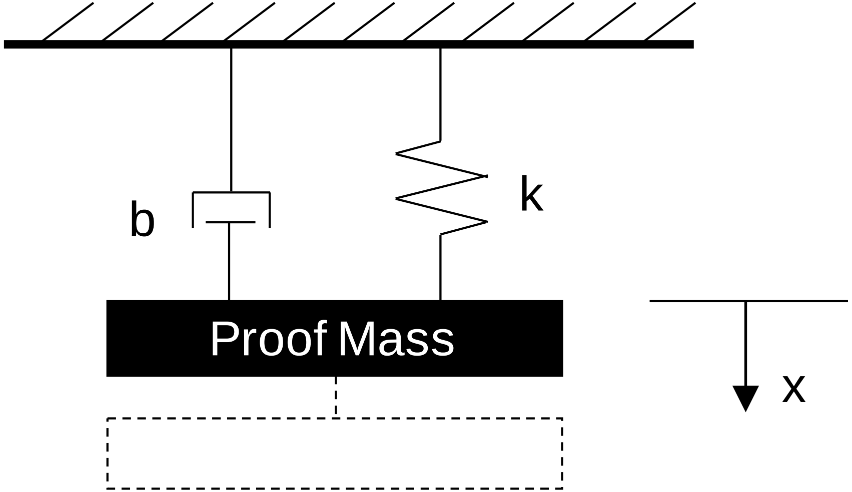
Fitbit One

Nike Fuelband

Nike + iPod Sports Kit

Ozeri 4x3runner

Brief Accelerometer Overview



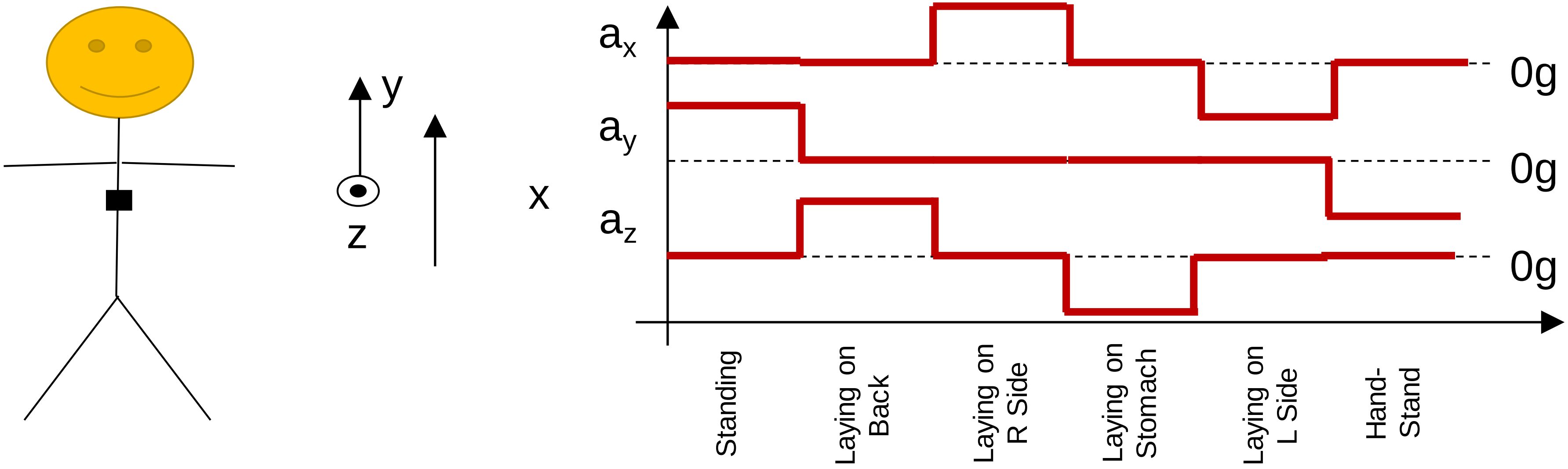
Forces applied on proof mass translate to displacement, from which acceleration is calculated.

Micromachined accelerometers are now very popular, using silicon as the mechanical material, and etching, photolithography, etc. as the process for fabrication.

These "MEMS" accelerometers are tiny, inexpensive, and have solid performance characteristics.

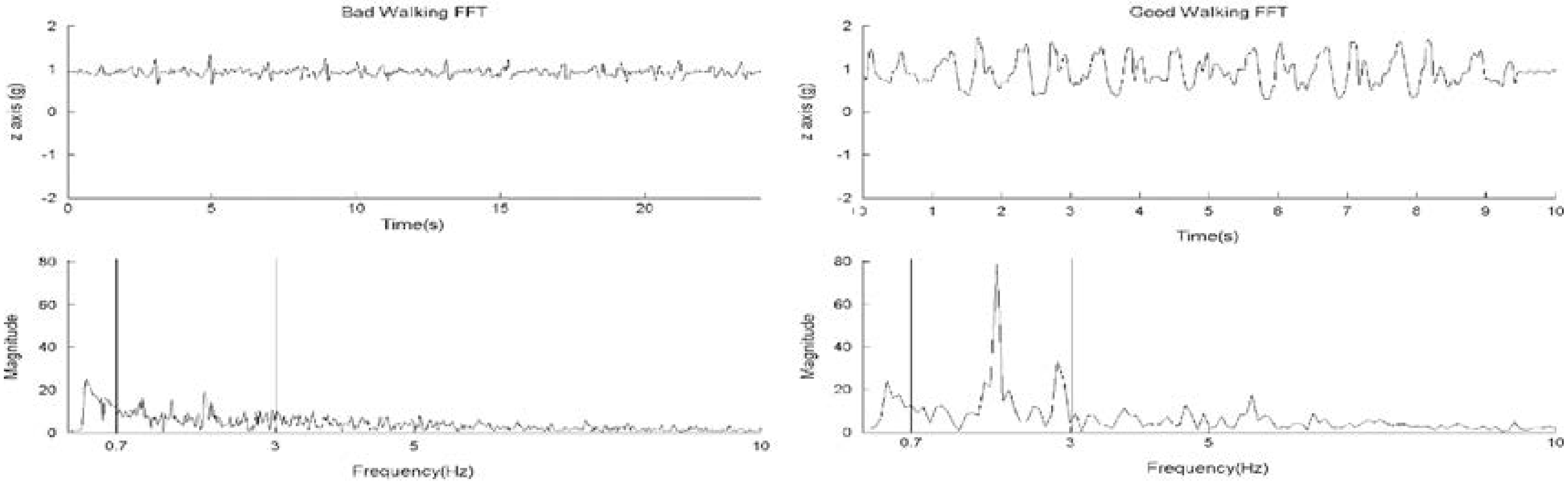
Larger piezoelectric models also available with better performance, but more expensive and larger.

Posture Detection



- Important thing is knowing the orientation of the accelerometer with respect to the body (wear it?)
- In practice, it is important to find ways to determine this automatically, or allow the person to always orient the accelerometer appropriately

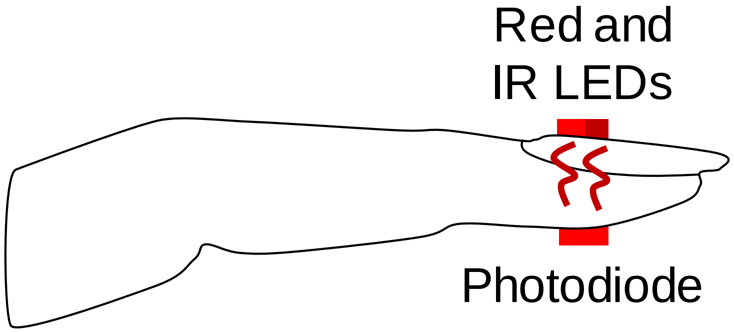
Walking (Vertical Axis Only)



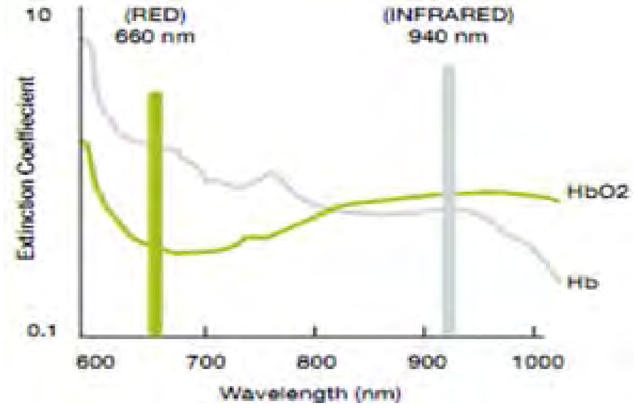
“Good” versus “Bad” walking – with good corresponding to slow-paced, and bad to normal-paced walking. The z-axis peaks are much smaller in the “bad” walking signal, as seen by the lack of obvious peaks in the FFT tracing.

Source: D. M. Karantonis, et al. IEEE TITB 2006.

Pulse Oximetry (SpO2) and Photoplethysmography (PPG)



Hemoglobin Light Absorption



Source: Freescale semiconductor.

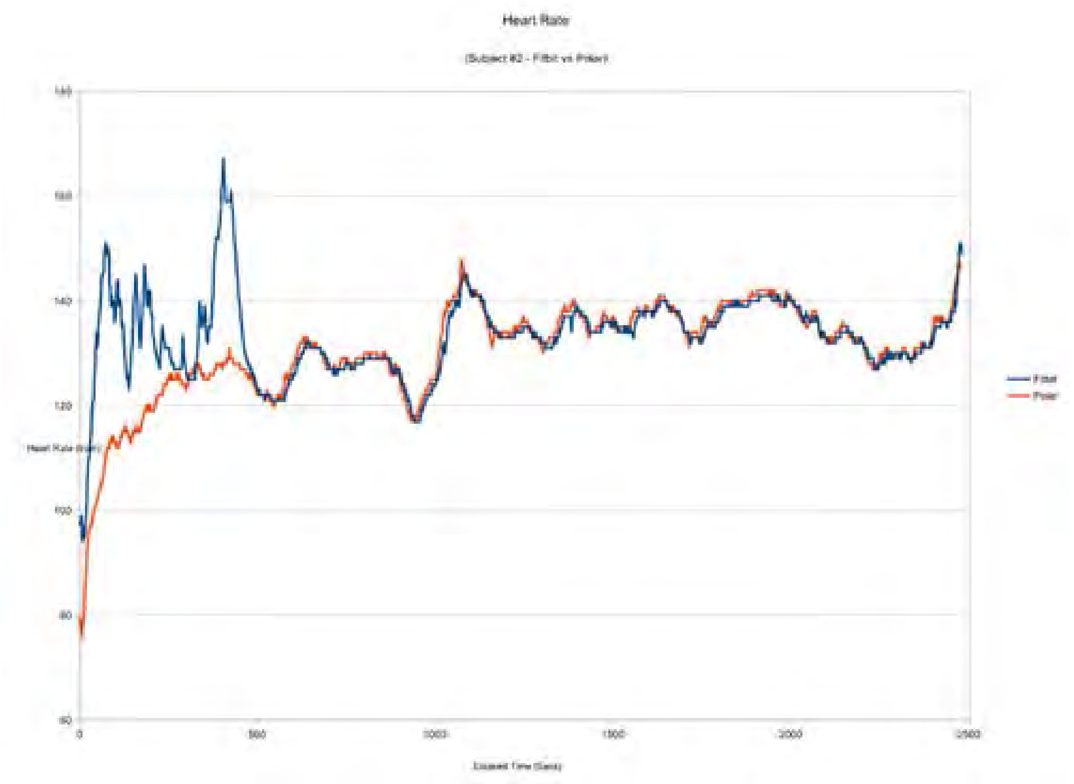
Hemoglobin is the oxygen carrying protein in red blood cells.

Oxygen saturation is the fraction of actual O2 concentration to O2 carrying capacity in blood (HbO2 / Hb).

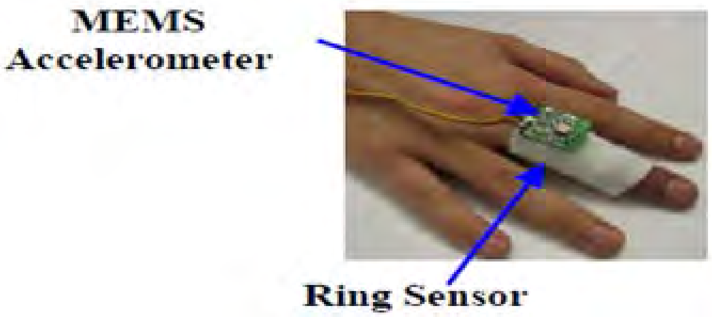
SpO2 should be approximately 97% for the healthy population.

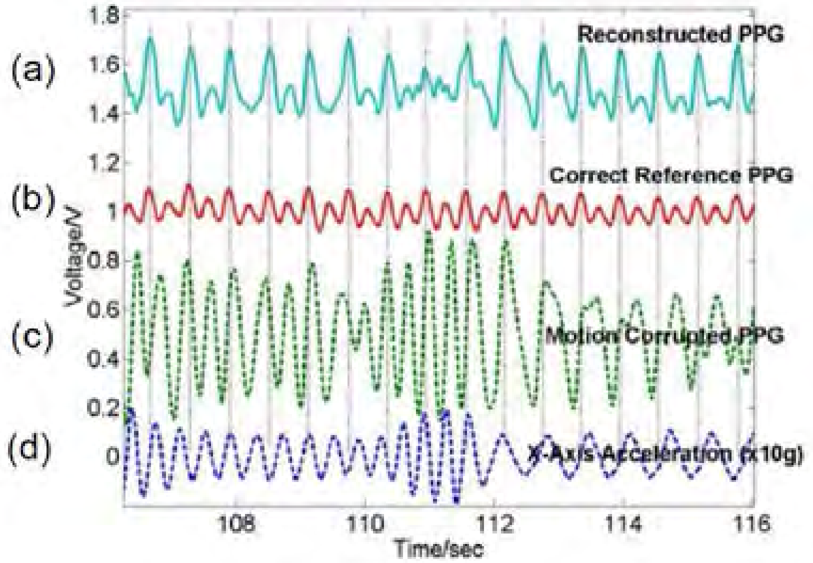
How do I remove poor sensor data?

- Noise and signal are correlated
- Noise usually happens when you are moving
- Recording signals at source will help .. can’t improve garbage data downstream!



Motion Artifact Reduction in PPG

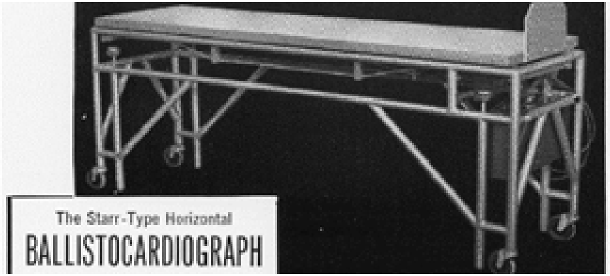




Motion detected by an accelerometer is filtered and cancelled from the PPG signal. Such approaches are employed by commercially available sensors to provide improved accuracy in the presence of movement.

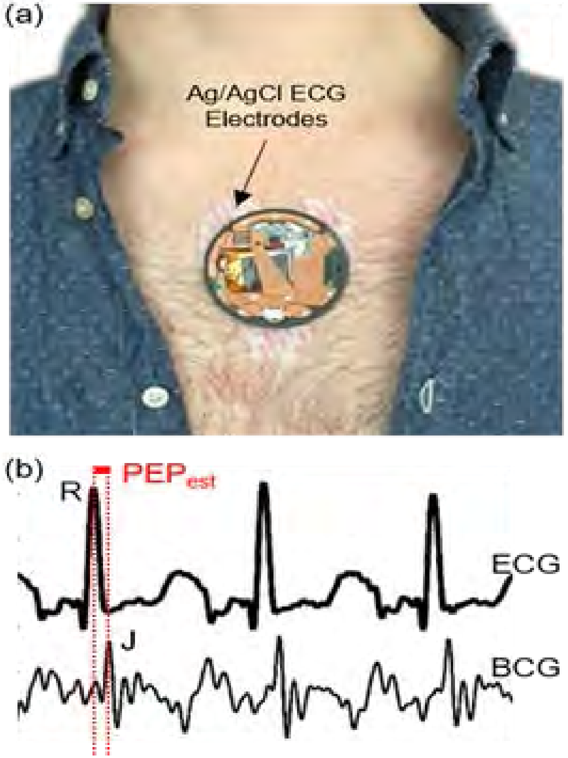
Source: Wood and Asada, IEEE EMBC 2006; Asada, et al. IEEE EMBC 2004

Ballistocardiography (BCG)



“Table” BCG: 1940 & 50s

Scale BCG: 2009

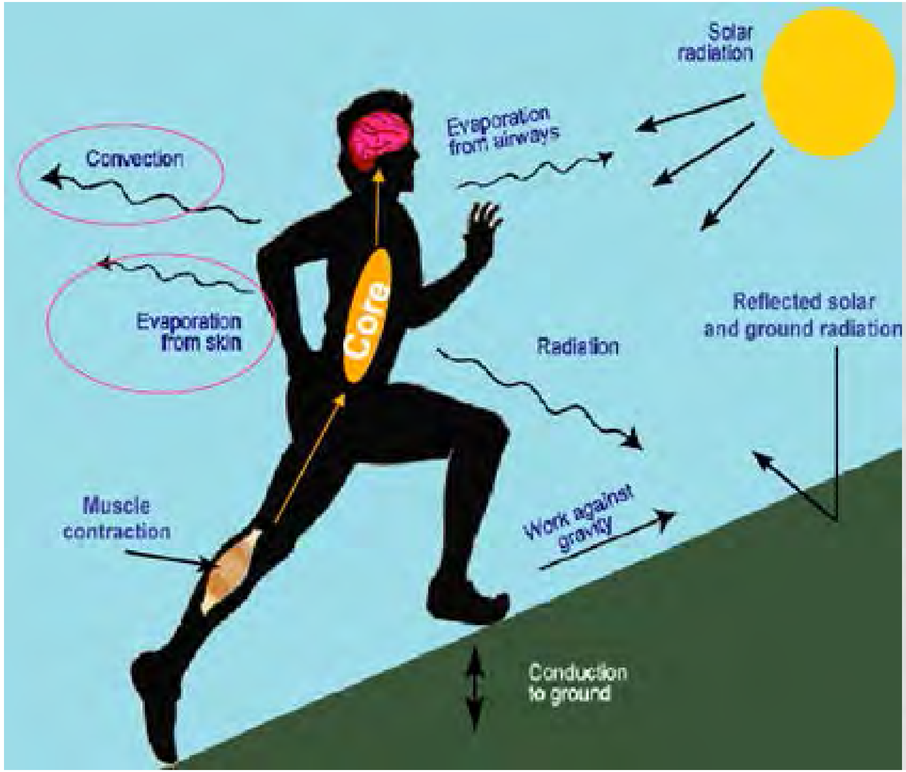


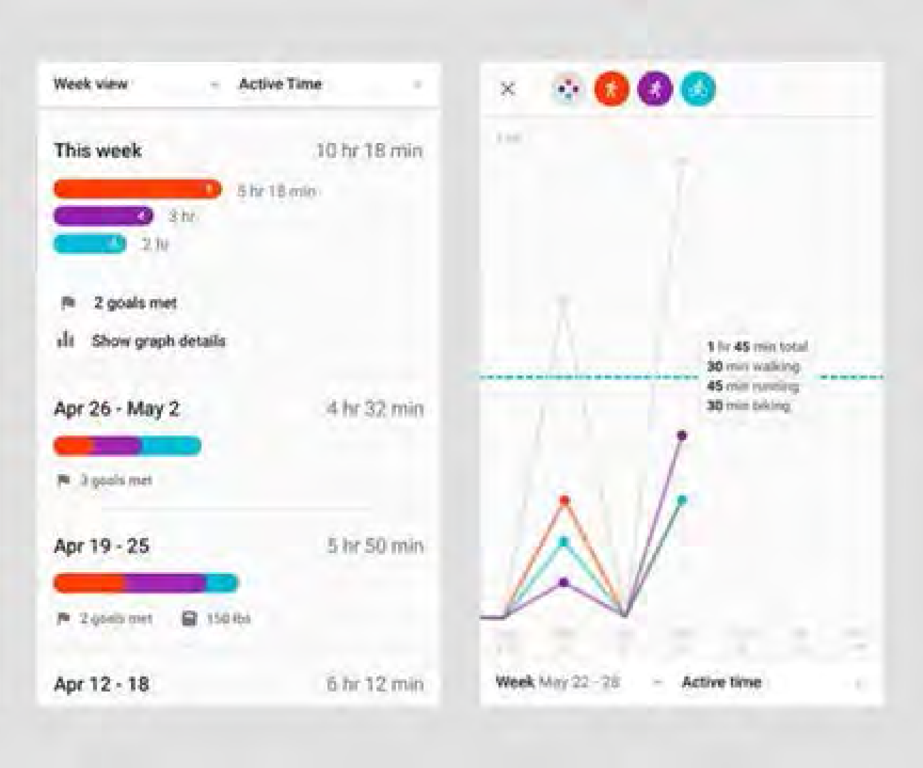
Wearable BCG and ECG: 2016

BCG signals can also be measured using on-body accelerometers.

A wearable patch form factor can provide simultaneous ECG and BCG measurements which can then be used to derive systolic time interval measures such as PEP.

Context: Activities and Environment

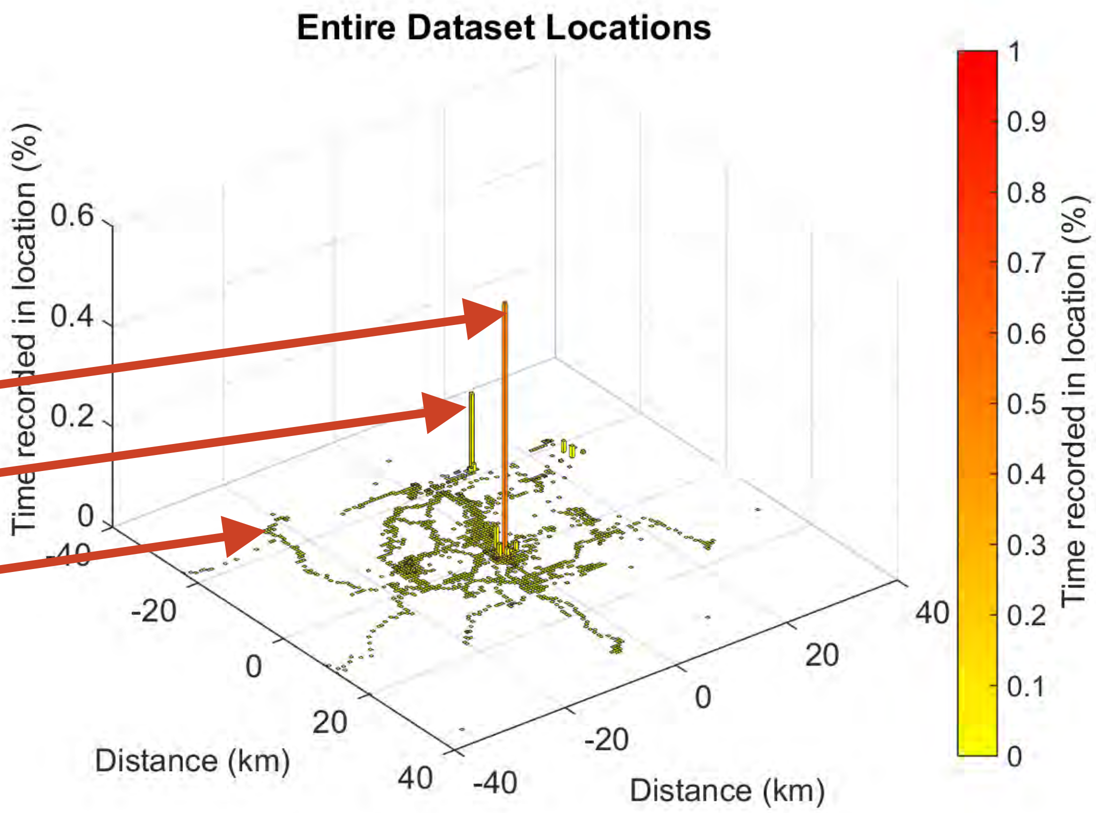




Sawka and Young, ACSM Exercise, 2006

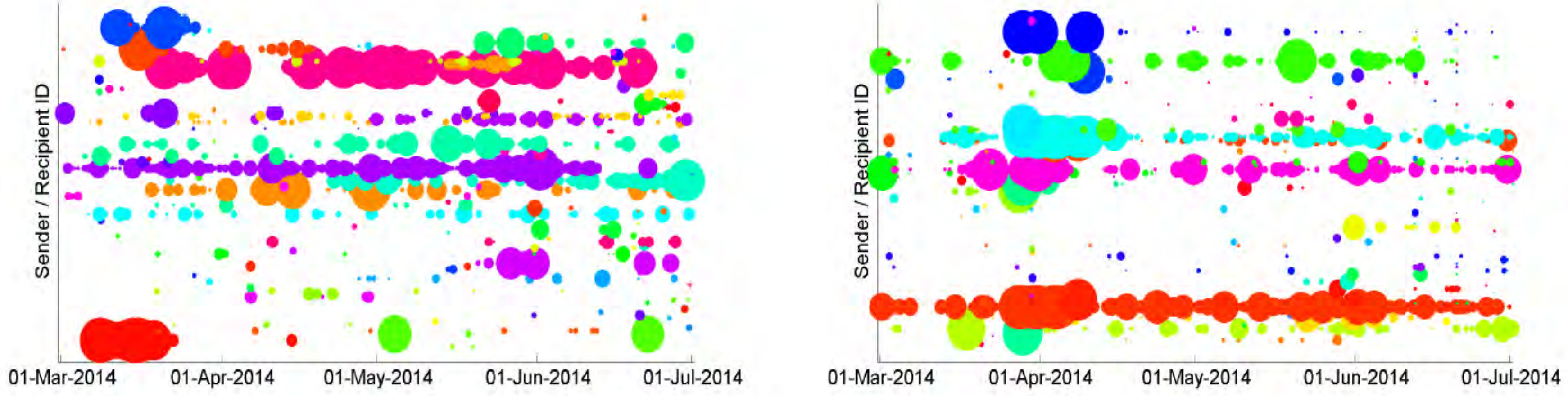
Context: Location

- Phone allows you identify:
  - home
  - work
  - 'other'



Social network activity

- identify mood & illness through mobile phone logged interactions:



(c) Social network activity levels by contact (healthy control).

(d) Social network activity levels by contact (bipolar).

- ↑social network & ↓activity = physical illness
- ↓social network & ↓activity = mental illness

Trade off axes

Cost

Battery life

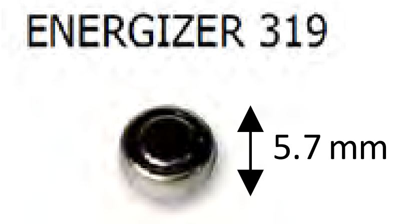
Data accessibility

Intrusiveness versus silent data harvesting

Security

Trade-Off Examples

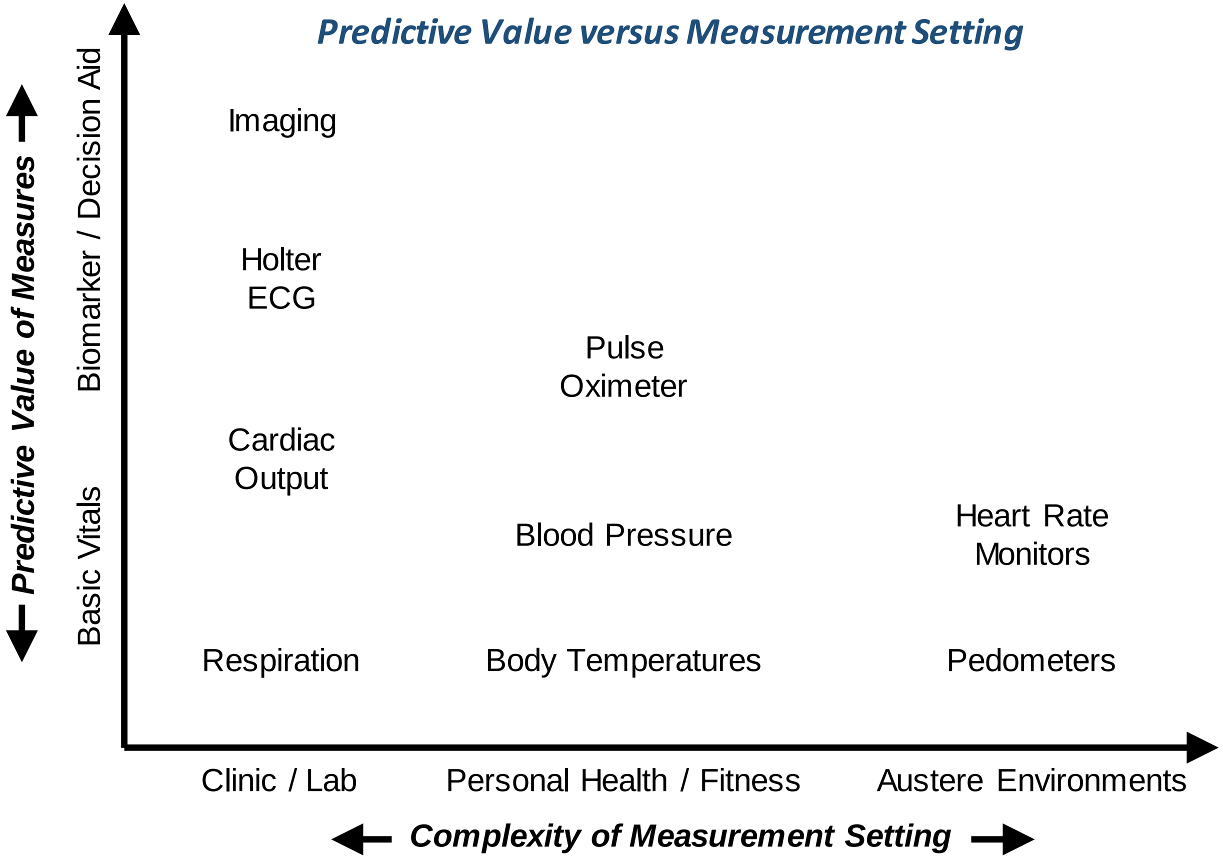
Size versus Battery Life



Energy Capacity: 0.0345 Whr

Energy Capacity: 1.86 Whr

Predictive Value versus Measurement Setting



Case Study: Cardiac Fitness Monitoring

Approach	Example Sensing Modalities	Advantages	Disadvantages
Heterogeneous OS and Hardware	Smartphone	User pays, totally scalable, dynamically updatable	Heterogenous hardware, UI-driven (non-real time OS / packet loss / clock drift), random updates
Consumer Grade Electronics	FitBit / Jawbone	Low cost, consumer may pay	Proprietary data, undersampled data
Industry-Standard FDA Approved	Holter ECG / Patch	Known standard signal, easy to obtain hardware / disposables	Moderate cost / lack of grand scalability, less convenient, disposables required
Custom, In-House Hardware	BCG / ECG Patch	Full control, known hardware response, adaptability / easy to upgrade	Requires hardware guru, cost, time, scalability

Reaching Out to Experts

What are the benefits of working with someone in this field?

- You need to understand the data pipeline from sensor to back end. You can't rely on 3rd parties to magically fill in the missing bits for you - you need an expert who understands where the errors will appear.

How might engaging someone in your discipline enhance/strengthen a mHealth application or data?

- Improve data quality, identify important co-factors to be collected, understand limitations and feasibility

- Avoid buying the *wrong* off-the-shelf solution - not all technology is the same – innovate if you need

When should someone reach out to you?

- At the start of the project to discuss options about what can and cannot be collected.

Questions for you to think about:

1. Which data will you collect, and how long do you want to collect it for?
    a. Think about battery life and how you will download it (over a bale, from a webserver)
2. What temporal or spatial resolution do you need?
    a. E.g. location down to 100m, once a day?
    b. Think about battery life (phone and peripheral)
3. How often do you want to analyse the data, and will that be at source or remotely?
4. What level of data corruption is acceptable?
5. How do you deal with humans gaming the system and inter-device variability?