6.808: Mobile and Sensor Computing aka IoT Systems

http://6808.github.io

Lecture 12: Mobile Health

Course Staff

Lecturers: Fadel Adib (fadel@mit.edu)

Hari Balakrishnan (hari@csail.mit.edu)

Maya Nielan (mnielan@mit.edu)

Sayed Saad Afzal (afzals@mit.edu)

Announcements

1- PSet 2 out

2- Lab 3 due today

3- Lab 4 will be out Friday

Today in IoT

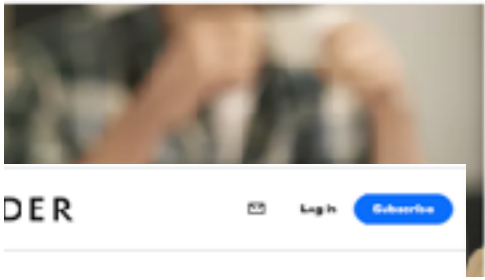
ars TECHNICA SUBSCRIBE

Apple Pay and Google Pay cut off some Russian customers

UN Refugee Agency Successfully Implements Water-Monitoring Pilot Program Using Kerlink LoRaWAN® Gateways

Posted by IoT Business News | Date: February 24, 2020 | in: General IoT News

unable to use mobile payment services

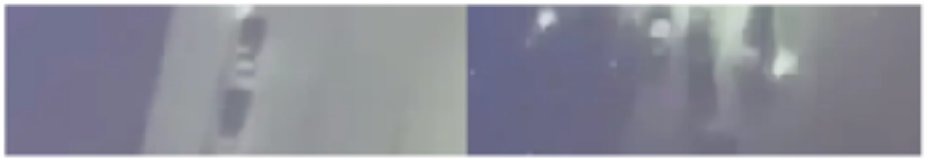


SCIENCE

How to send messages in Ukraine if the internet shuts down

The Russian army is targeting Ukraine's communication and internet infrastructure. Here's how you can communicate if your internet connection has been destroyed.

Hackers Can Cut the Lights With Rogue Code, Researchers Show (Argus Mordant/

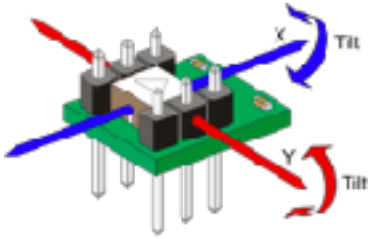


Where are we in the class?

4 Quadrants of IoT

Sensing Tasks & Modalities

- Localization
- Inertial
- Camera-based



Computation

Sensor Proc. & Fusion (localization, inertial, split proc., fusion)

Power/Energy

Energy management & harvesting

Connectivity

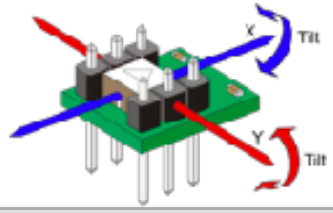
- Connectivity tech
- Mesh architectures
- Battery-free IoT

Remainder of the Class

4 Quadrants of IoT

Sensing Tasks & Modalities

- Localization
- Inertial
- Camera-based



Computation

Sensor Proc. & Fusion (localization, inertial, split proc., fusion)

Power/Energy

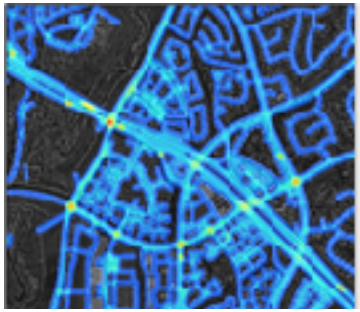
Energy management & harvesting

Connectivity

- Connectivity tech
- Mesh architectures
- Battery-free IoT

Emerging Application Domains & Cross-Cutting Topics

1. Transportation

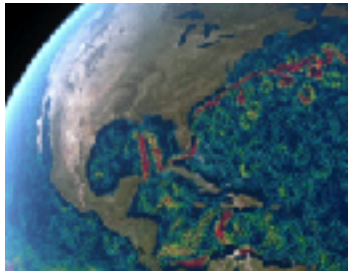


2. Health

This lecture

3. Agriculture

4. Oceans/ Climate



5. Security/ Privacy

Mobile Health

Monitoring health and well-being using mobile devices, wearable sensors, and smart environments

Applications: What do we want to measure? And why?

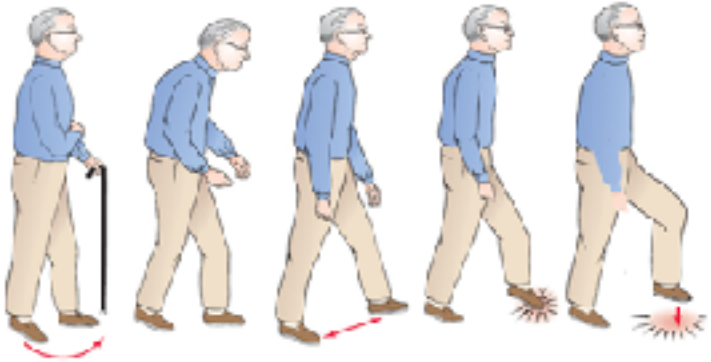
Calories

Sleep

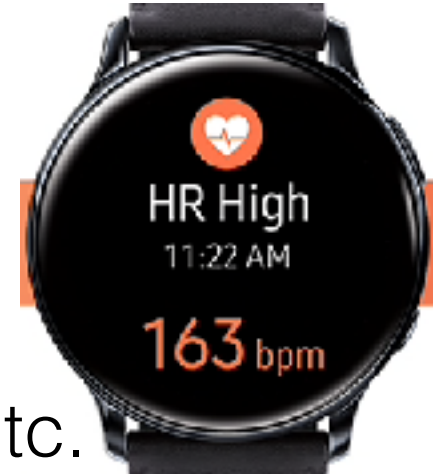
Steps

Mental & emotional well-being

Gait & activity



Vitals (HR, breathing)

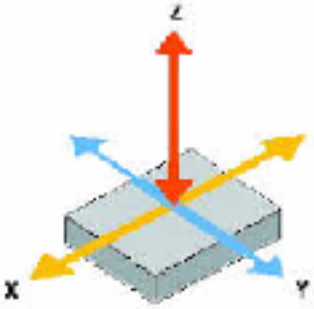


Many others: Hb, skin, etc.

How do we measure?

Voice

Accelerometer

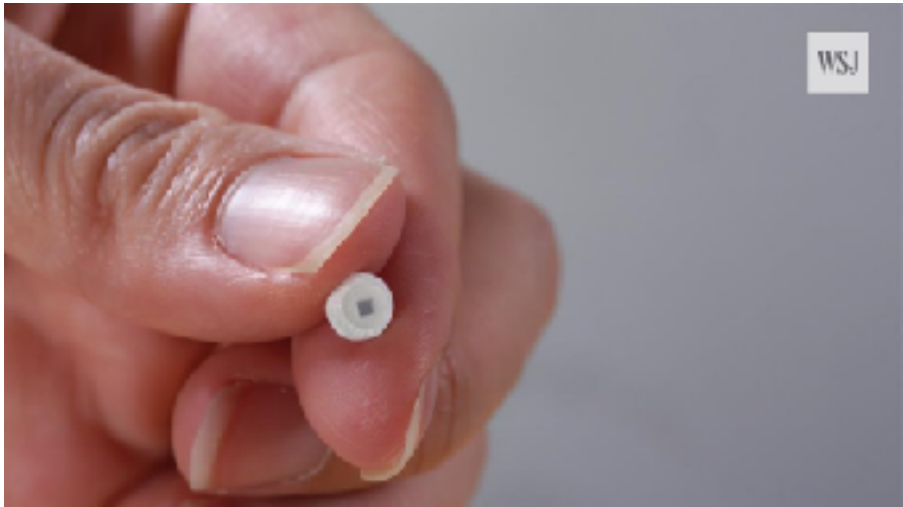


Cameras (food, diseases)

Log it

Wireless reflections

Digital pill: beyond measurement



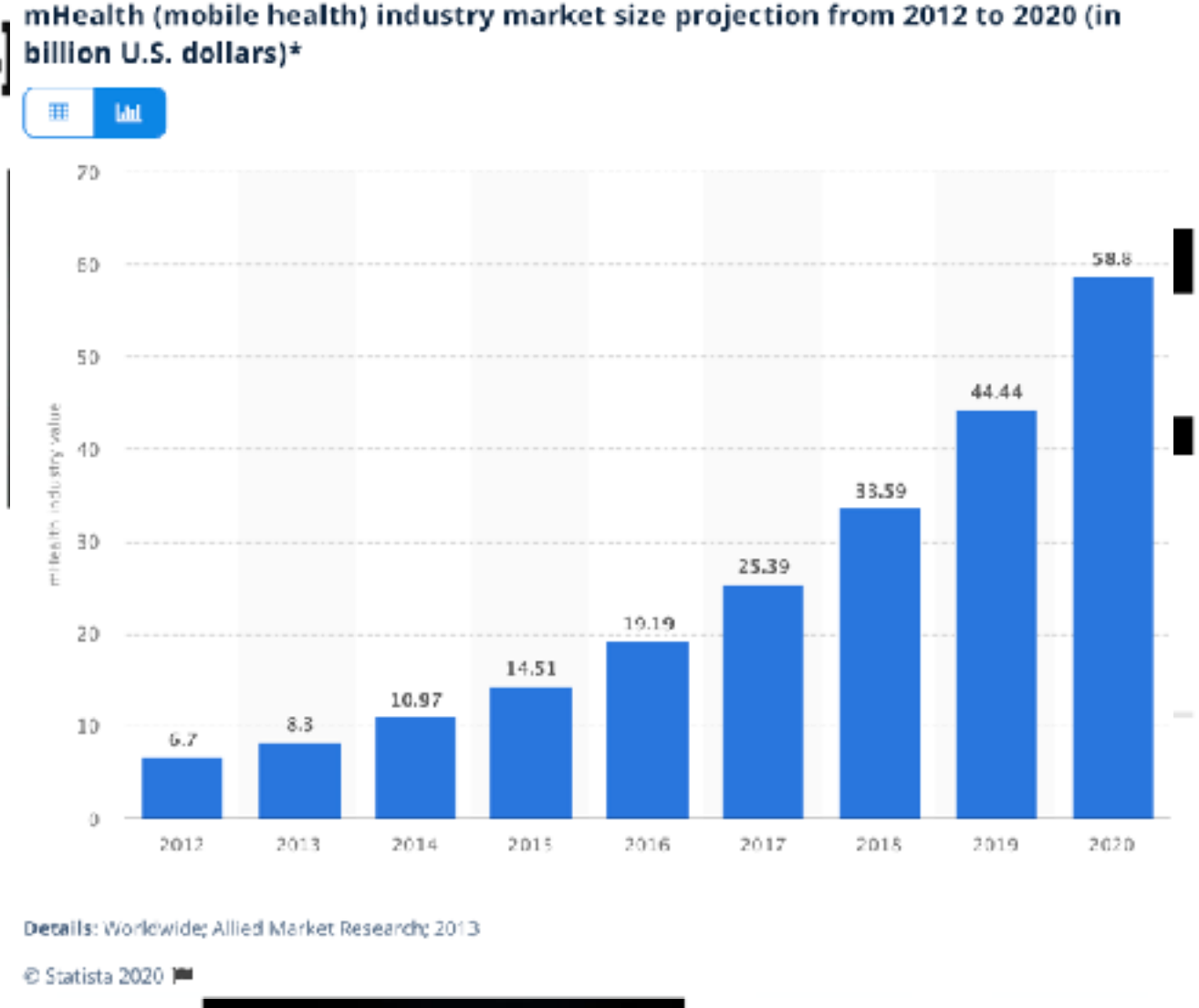
Background

The New York Times Magazine

The Data-

By Gary Wolf

April 28, 2010

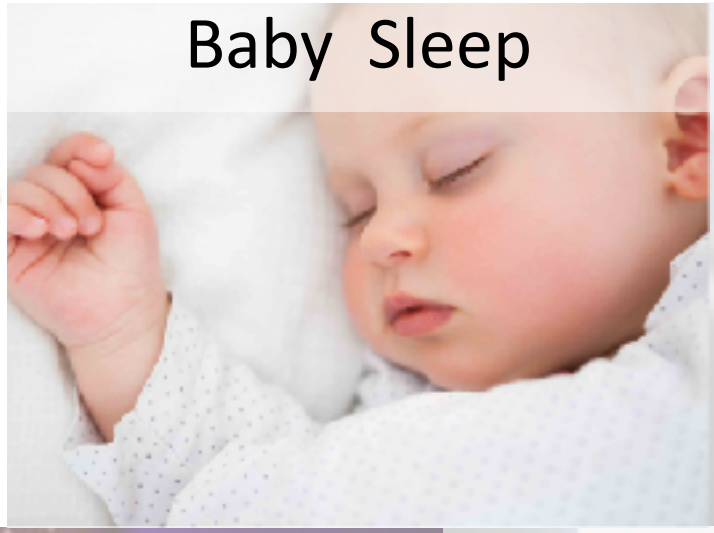


What is the purpose of the assigned paper?

Can smart homes monitor and adapt to our breathing and heart rates?

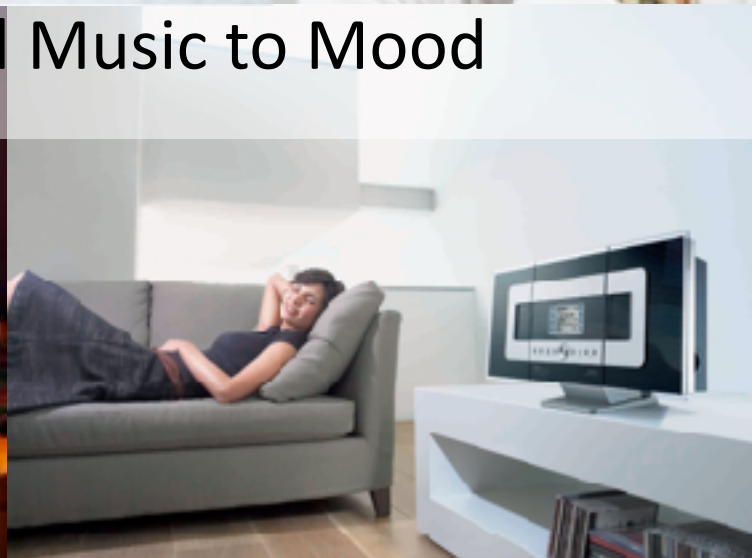
Personal Health

Baby Sleep



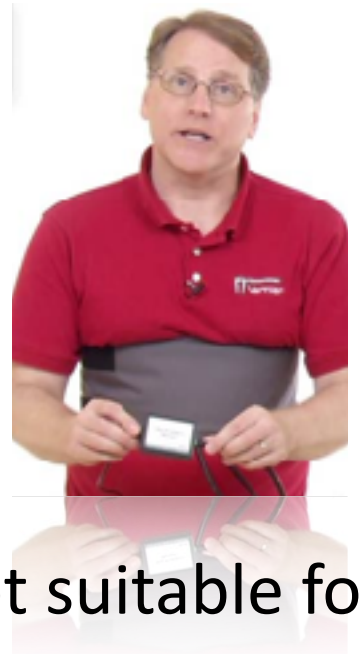
Elderly Health

Adapt Lighting and Music to Mood



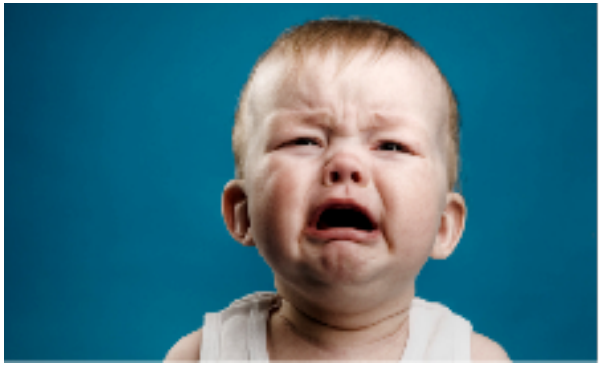
But: today's technologies for monitoring vital signs are cumbersome

Breath Monitoring



Heart Rate Monitoring

Not suitable for elderly & babies



Can we monitor breathing and heart rate from a distance?

Vital-Radio

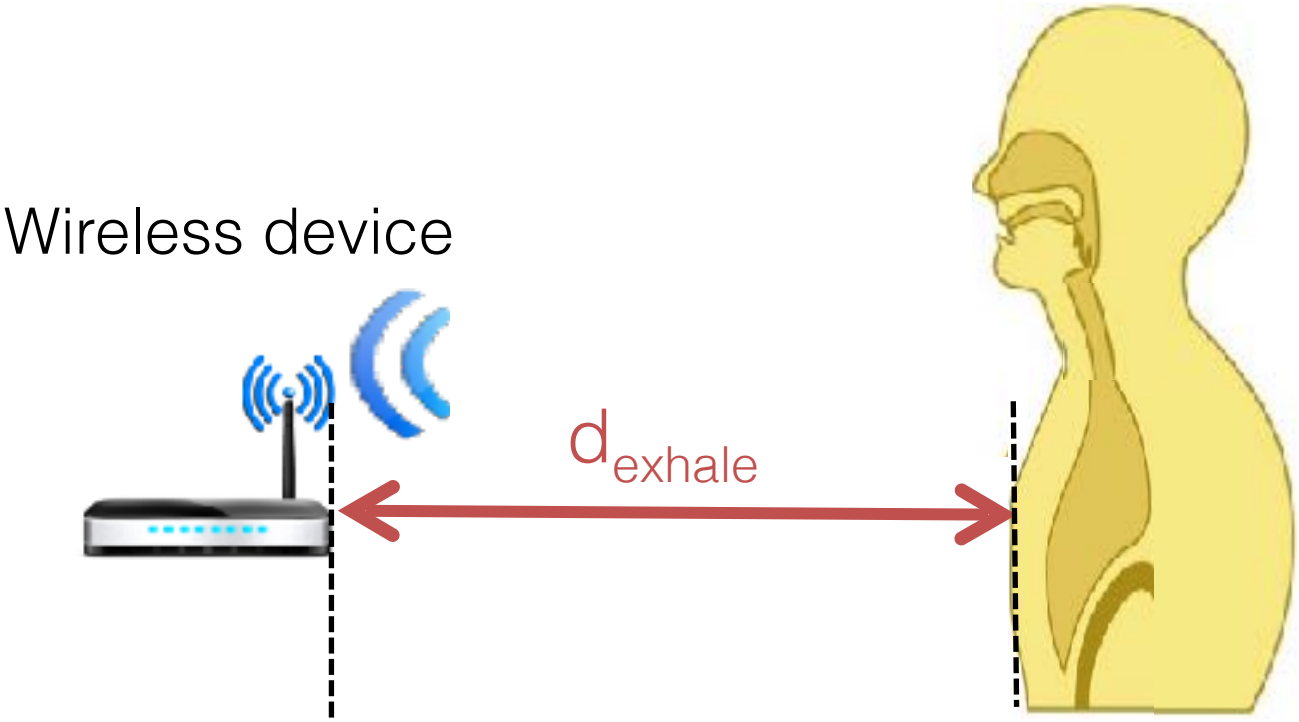
- Technology that monitors breathing and heart rate remotely with 97% accuracy
- Can monitor multiple users simultaneously
- Operates through walls and can cover multiple rooms

Idea: Use wireless reflections off the human body

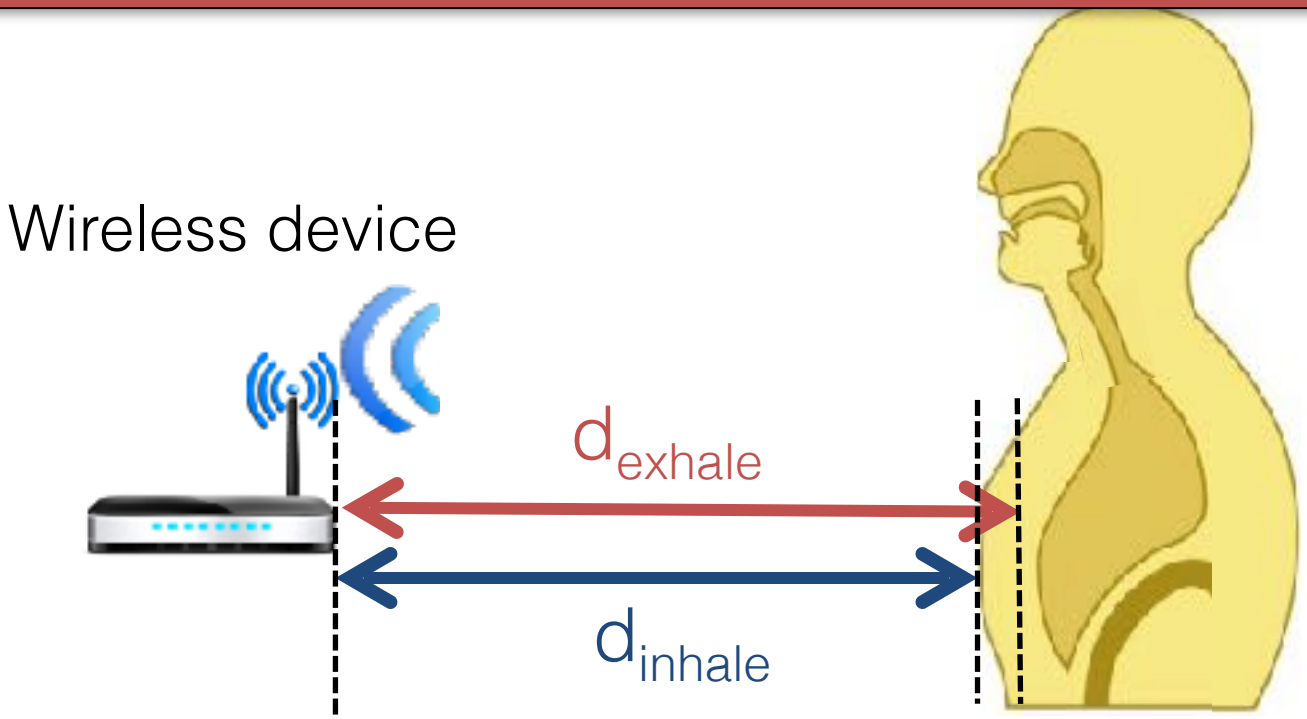
Idea: Use wireless reflections off the human body

Wireless device

Device analyzes the wireless reflections to compute distance to the body

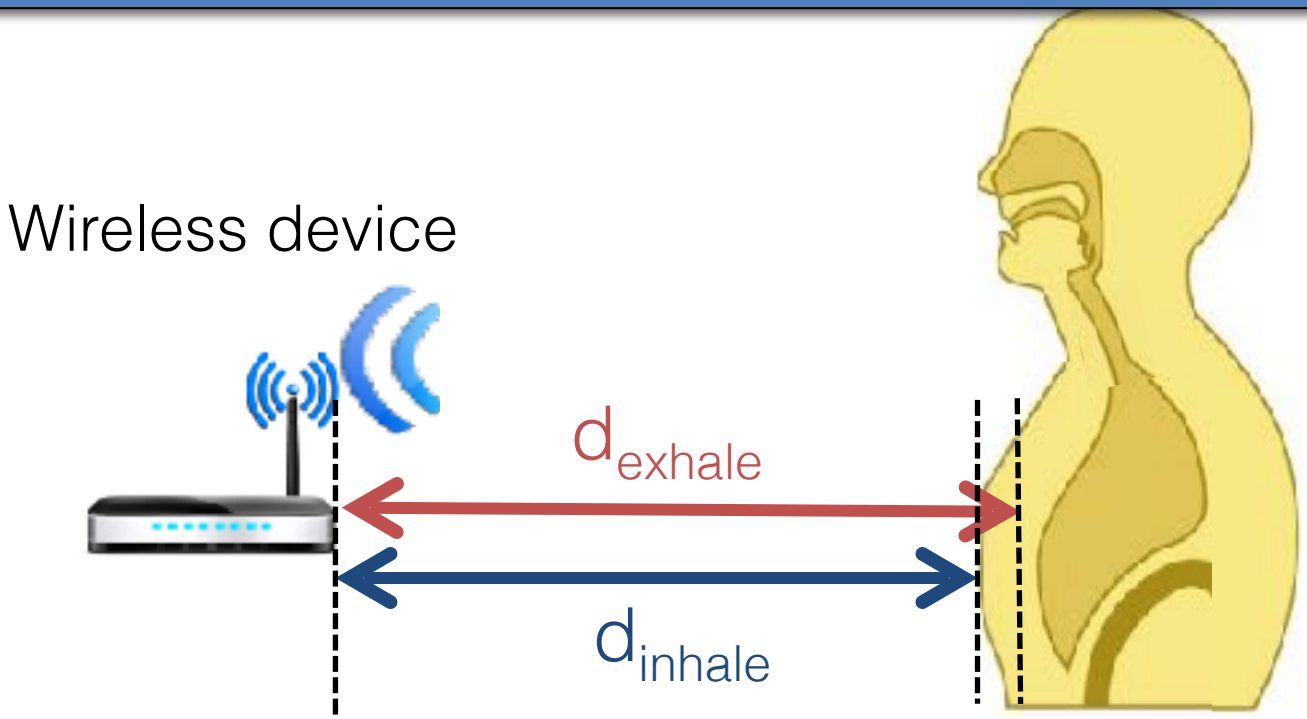


Problem: Localization accuracy is only 12cm and cannot capture vital signs



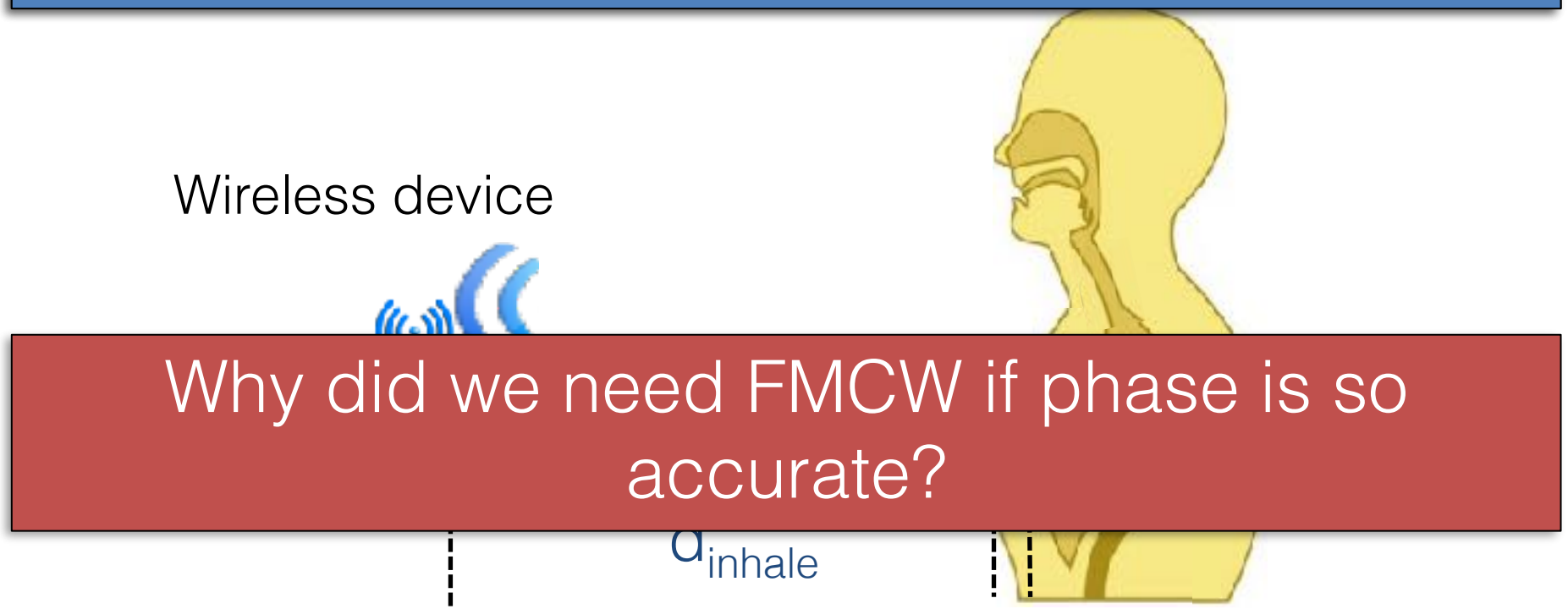
Why? How did we compute the resolution?

Solution: Use the phase of the wireless reflection



Why does phase allow us to get the distance at higher granularity?

Solution: Use the phase of the wireless reflection



Why did we need FMCW if phase is so accurate?

Wireless wave has a phase: $\phi = 2\pi \frac{\text{distance}}{\text{wavelength}}$

- Chest Motion changes distance
- Heartbeats also change distance

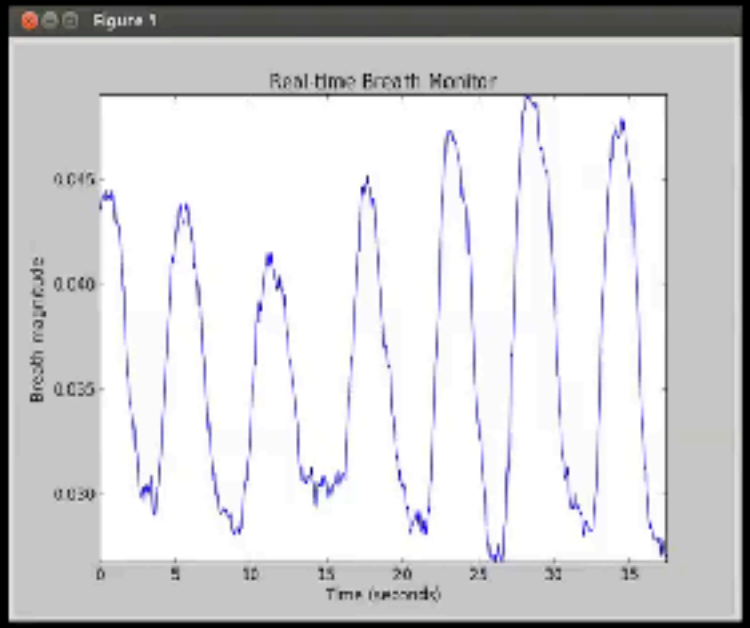
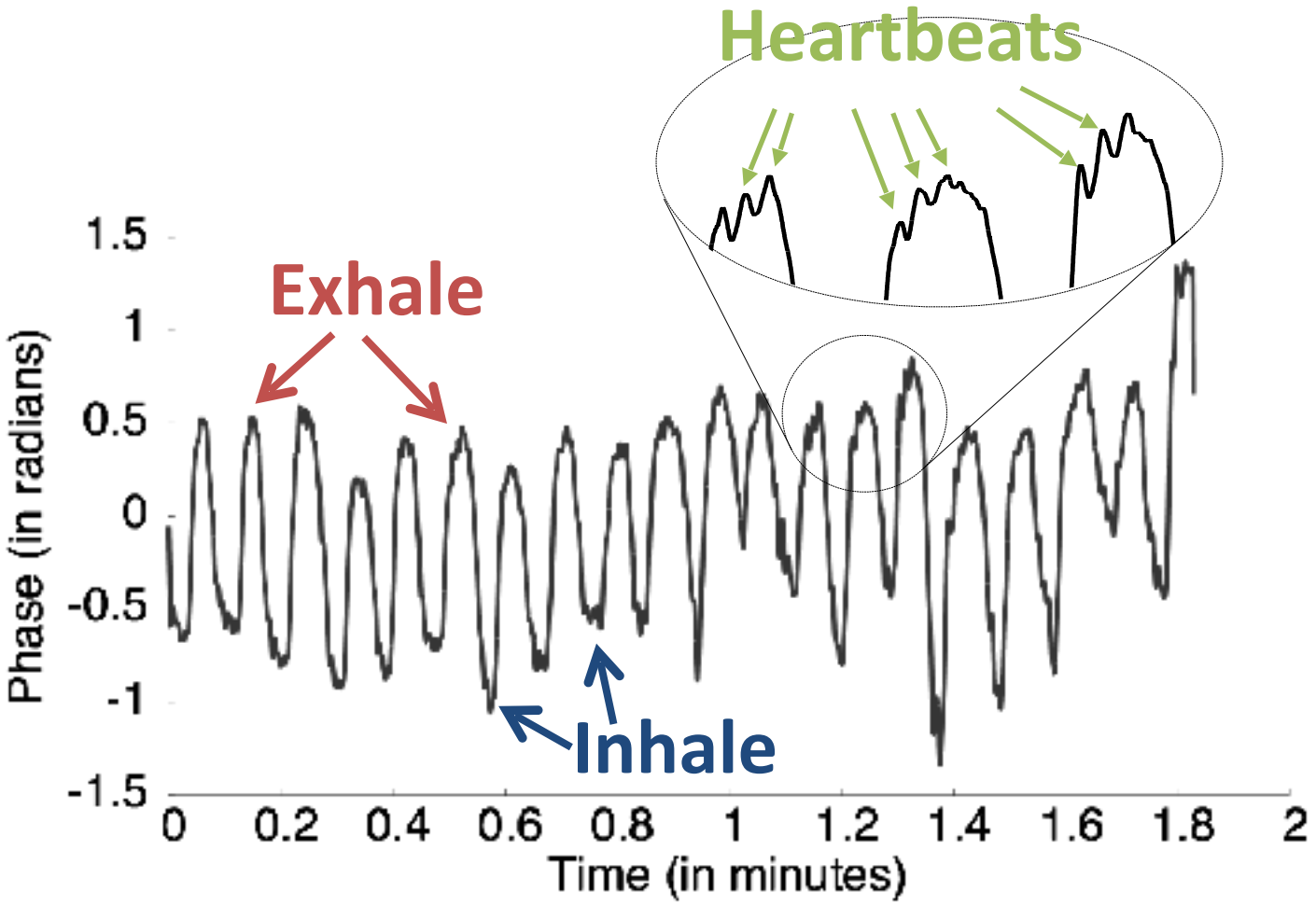


Figure 1
Real-time Breath Monitor
Breath magnitude
0.045
0.040
0.035
0.030
0
5
10
15
20
25
30
35
Time (seconds)

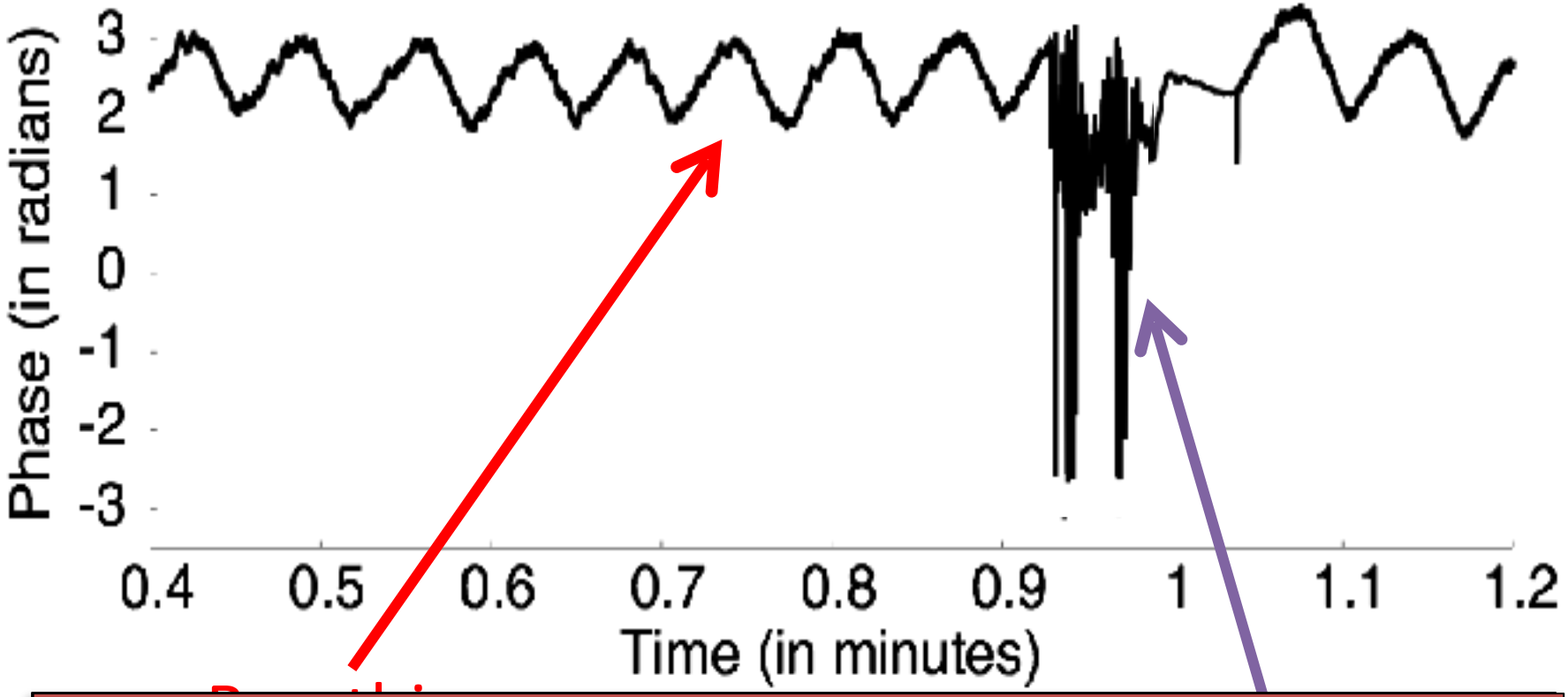
Let’s zoom in on these signals



How do we get from here to extracting breathing rate and heart rate?

What happens when a person moves his limb?

What happens when a person moves his limb?

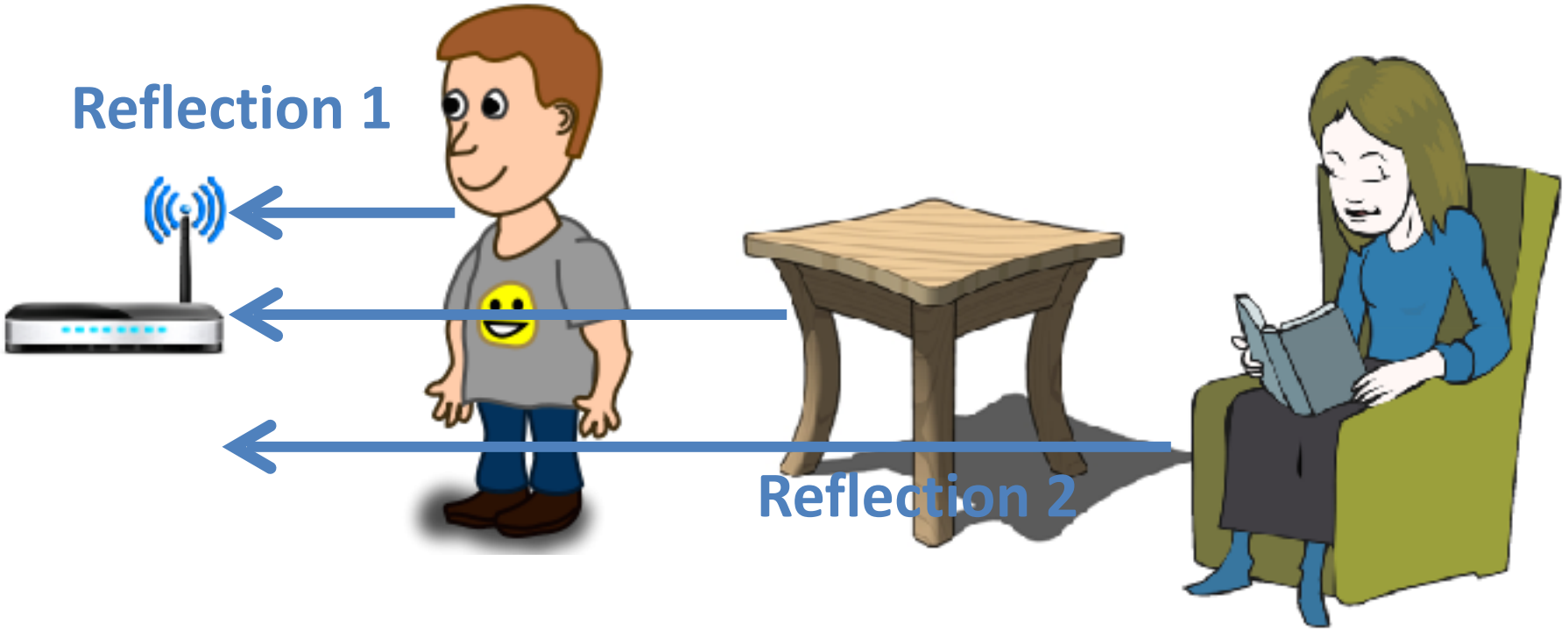


Band-pass filter the cleaned signals to extract breathing and heart rate

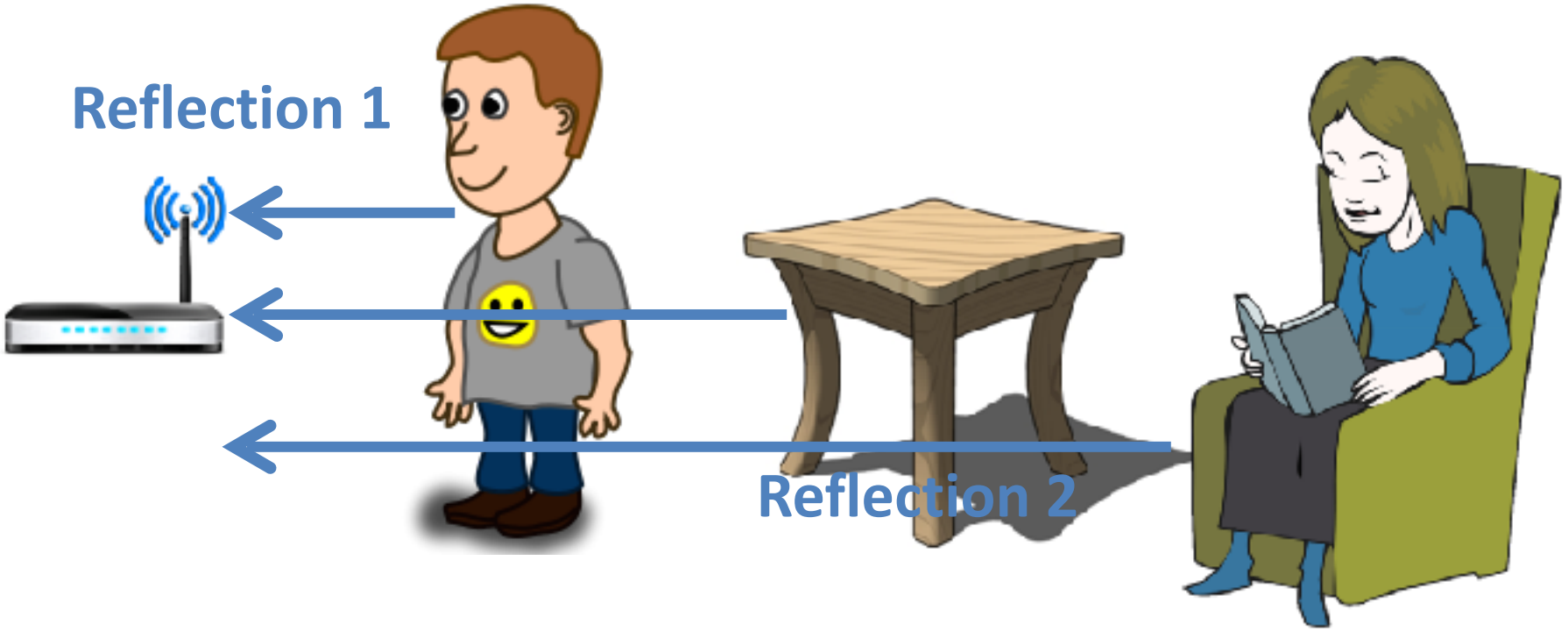
What happens with multiple users in the environment?

Reflections from different objects collide

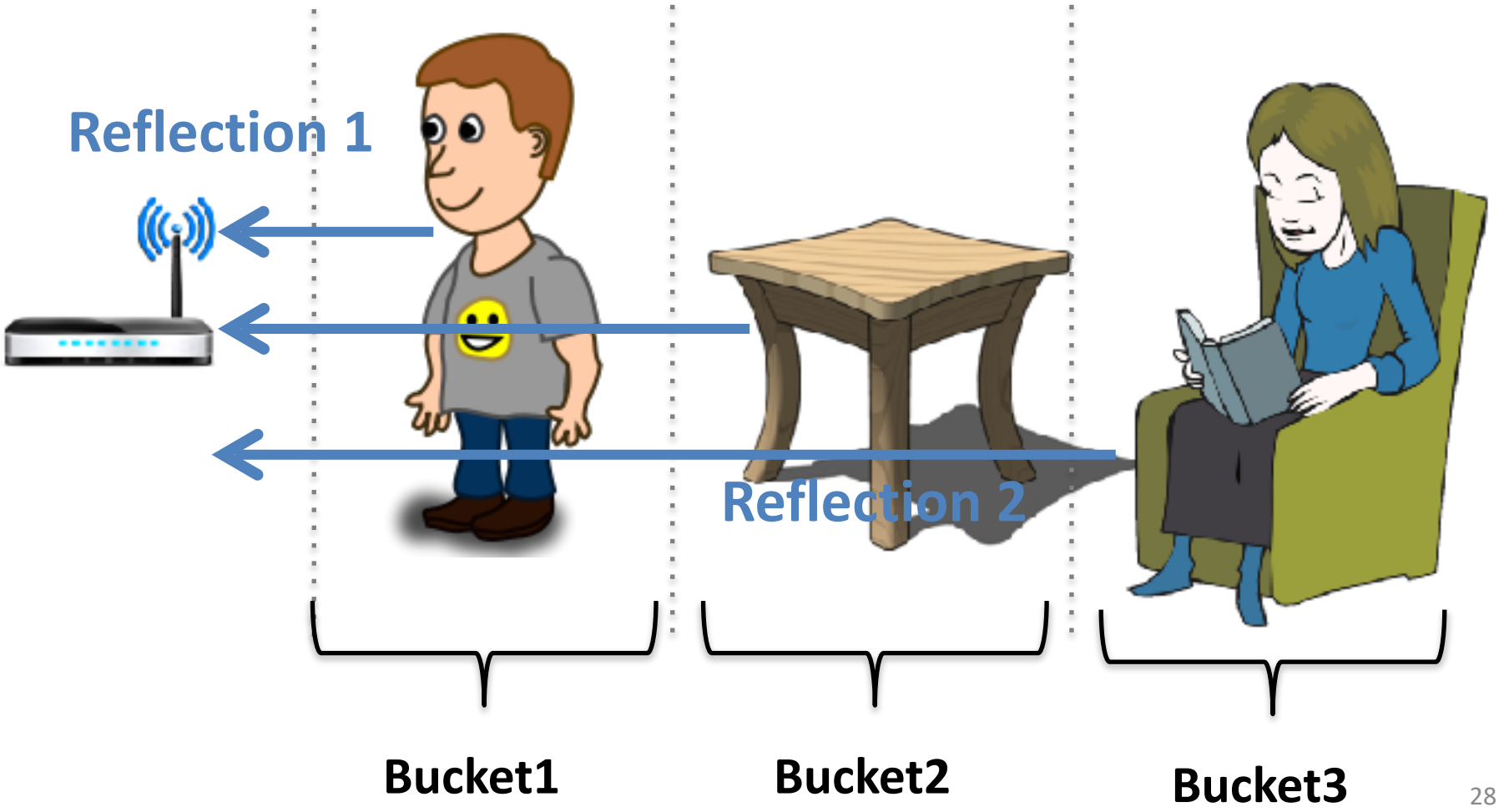
<u>Problem:</u> Phase becomes meaningless!



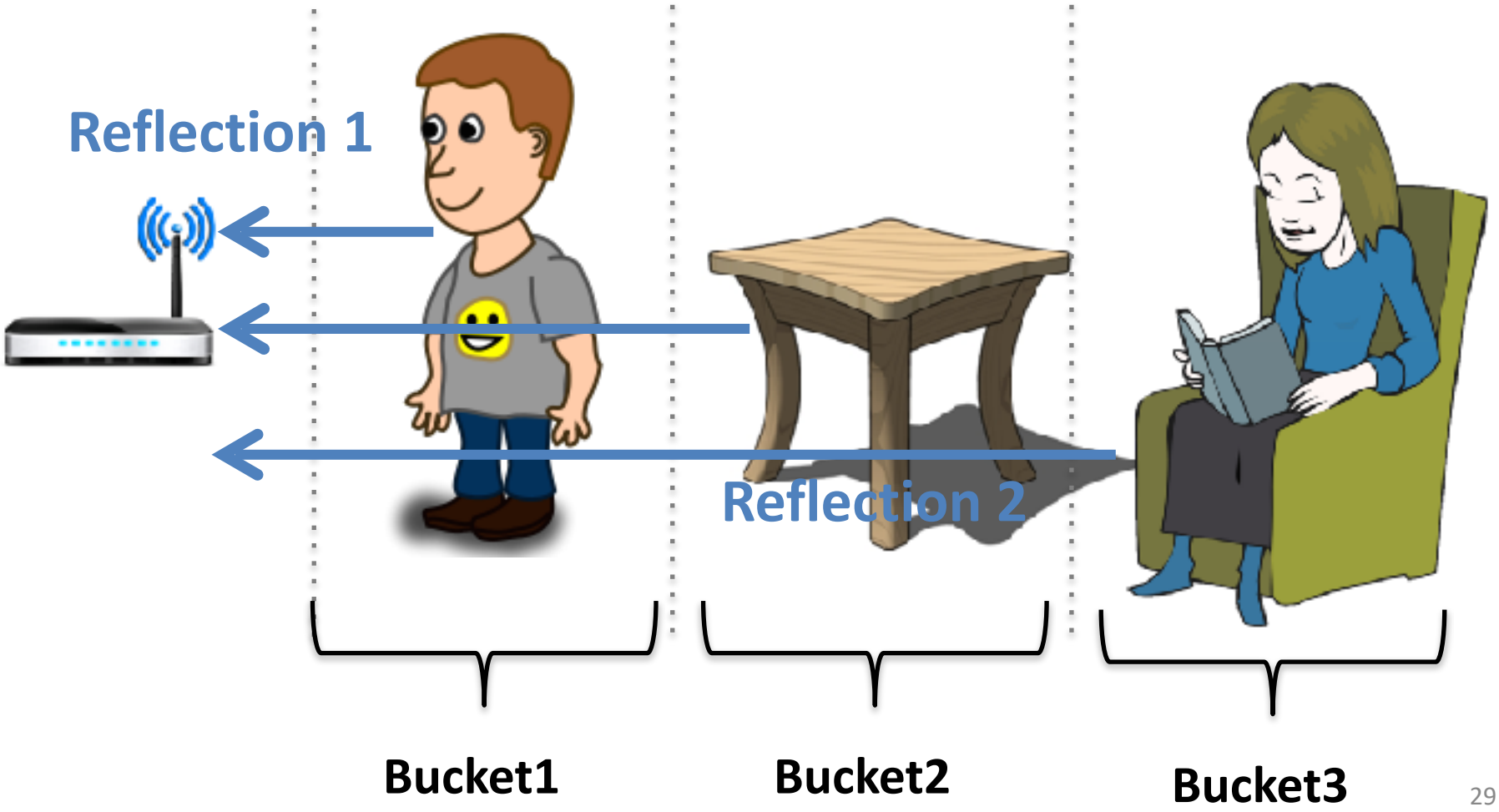
Solution: Use WiTrack as a filter to isolate reflections from different positions



Solution: Use WiTrack as a filter to isolate reflections from different positions



Solution: Use WiTrack as a filter to isolate reflections from different positions



Recall Formulation with FMCW

Recall Formulation with FMCW

- Output of FFT with reflectors
- Looked at the amplitude only
- Now will also look at phase

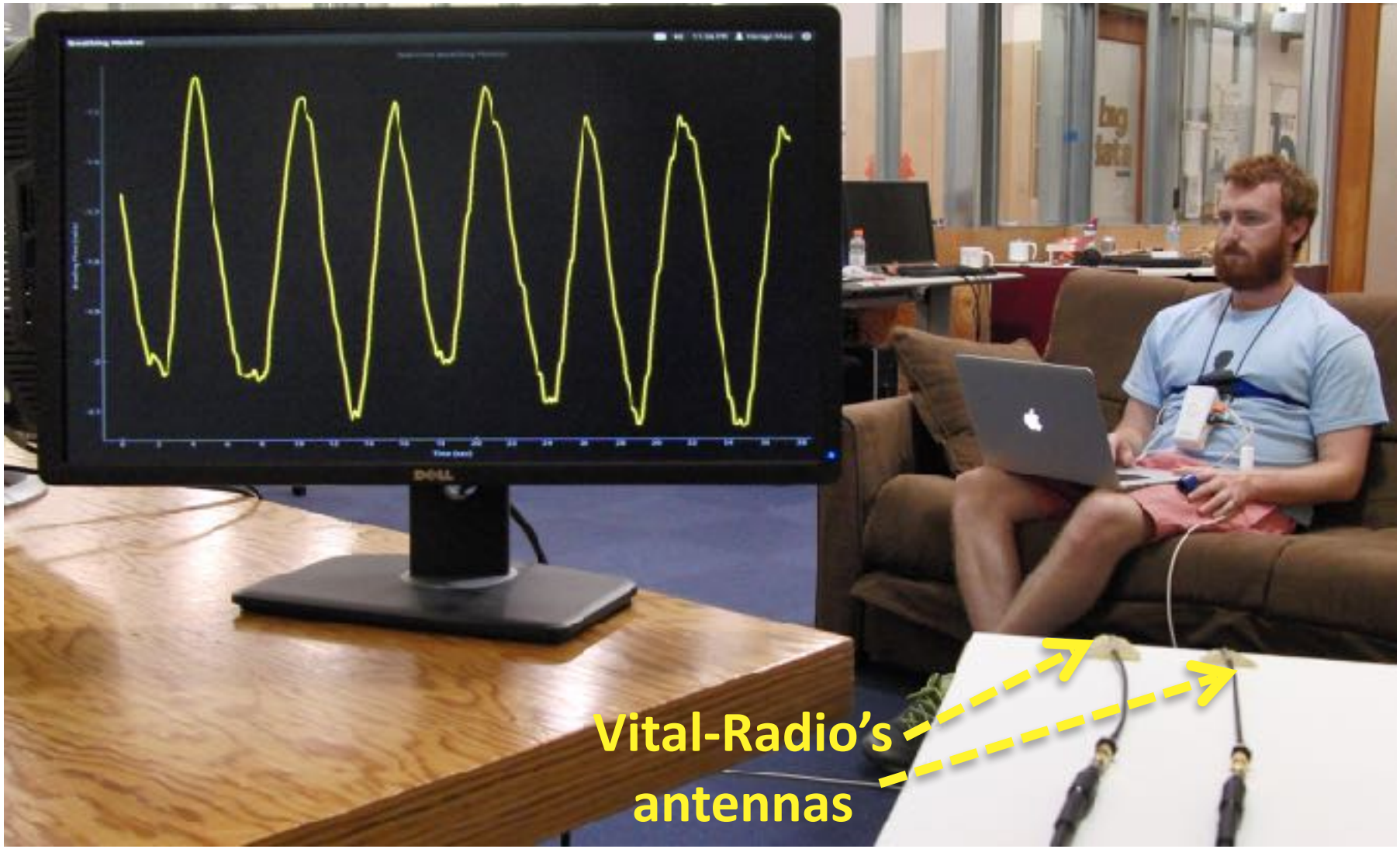
Putting It Together

Step 1: Transmit a wireless signal and capture its reflections

Step 2: Isolate reflections from different objects based on their positions

Step 3: Zoom in on each object's reflection to obtain phase variations due to vital signs

Vital-Radio Evaluation



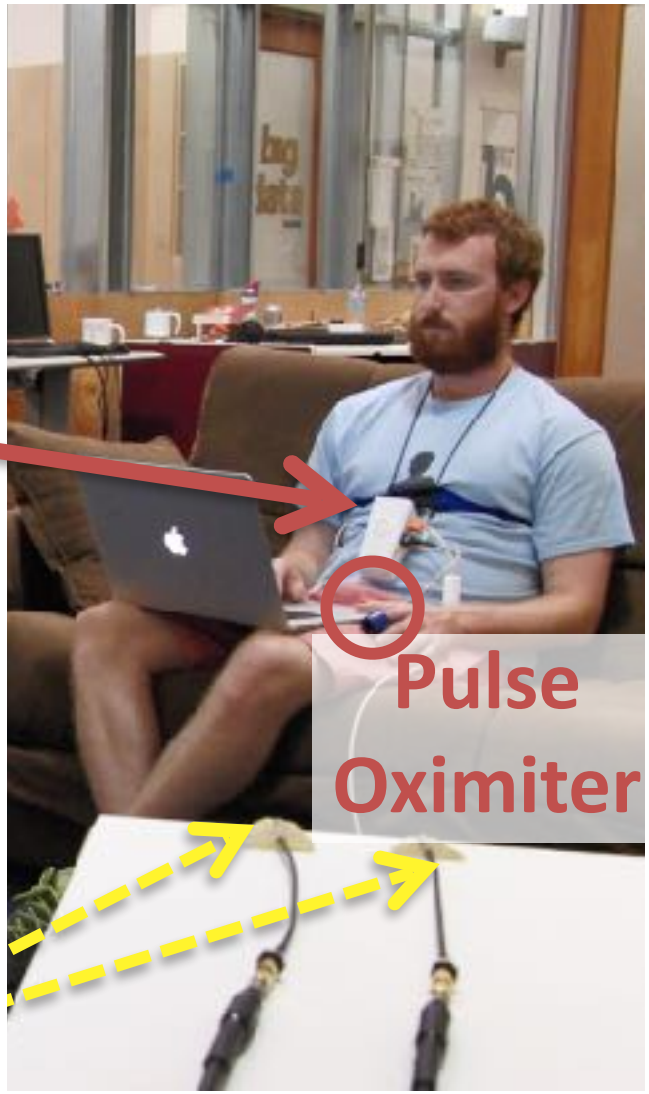
Vital-Radio Evaluation

Baseline:

- FDA-approved breathing and heart rate monitor

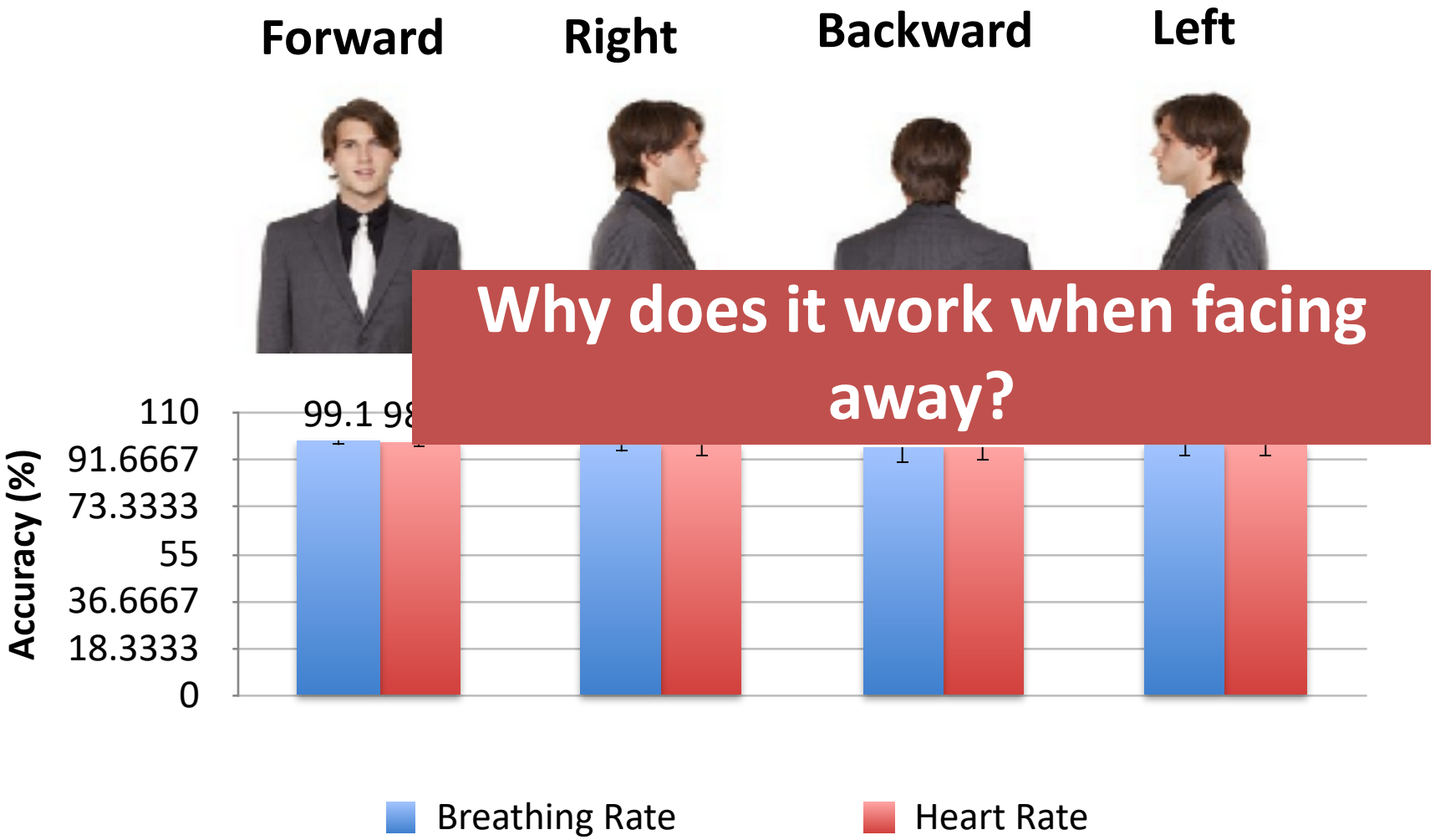
Experiments:

- 200 experiments
- 14 participants
- 1 million measurements



Accuracy vs. Orientation

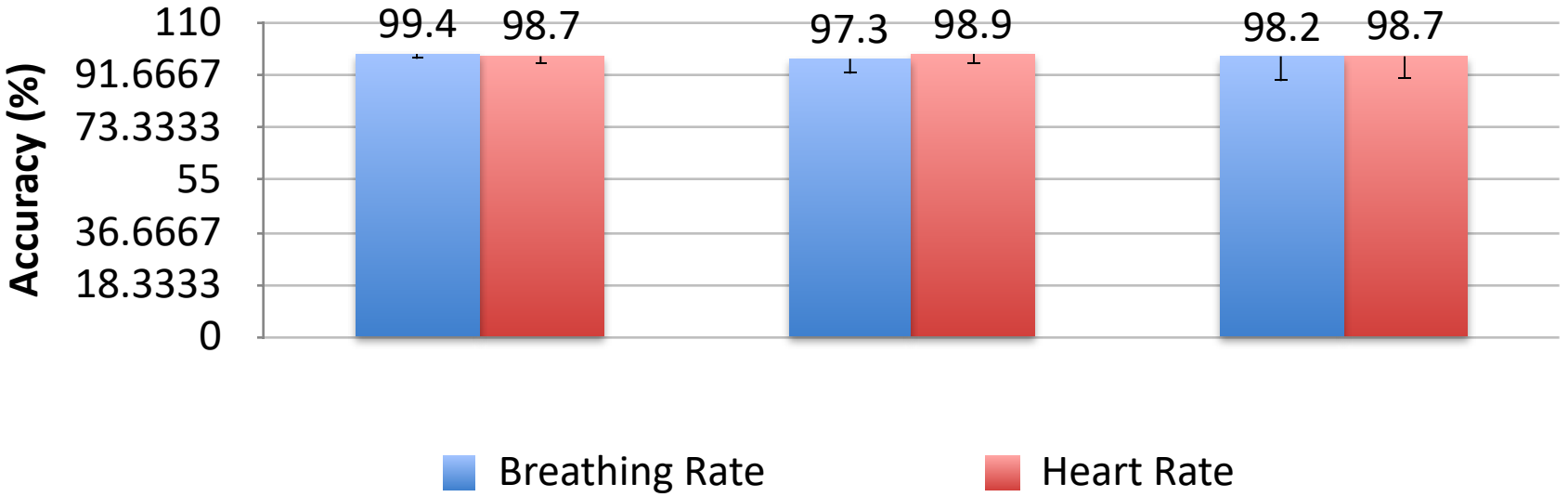
User is 4m from device, with different orientations



Accuracy for Multi-User Scenario

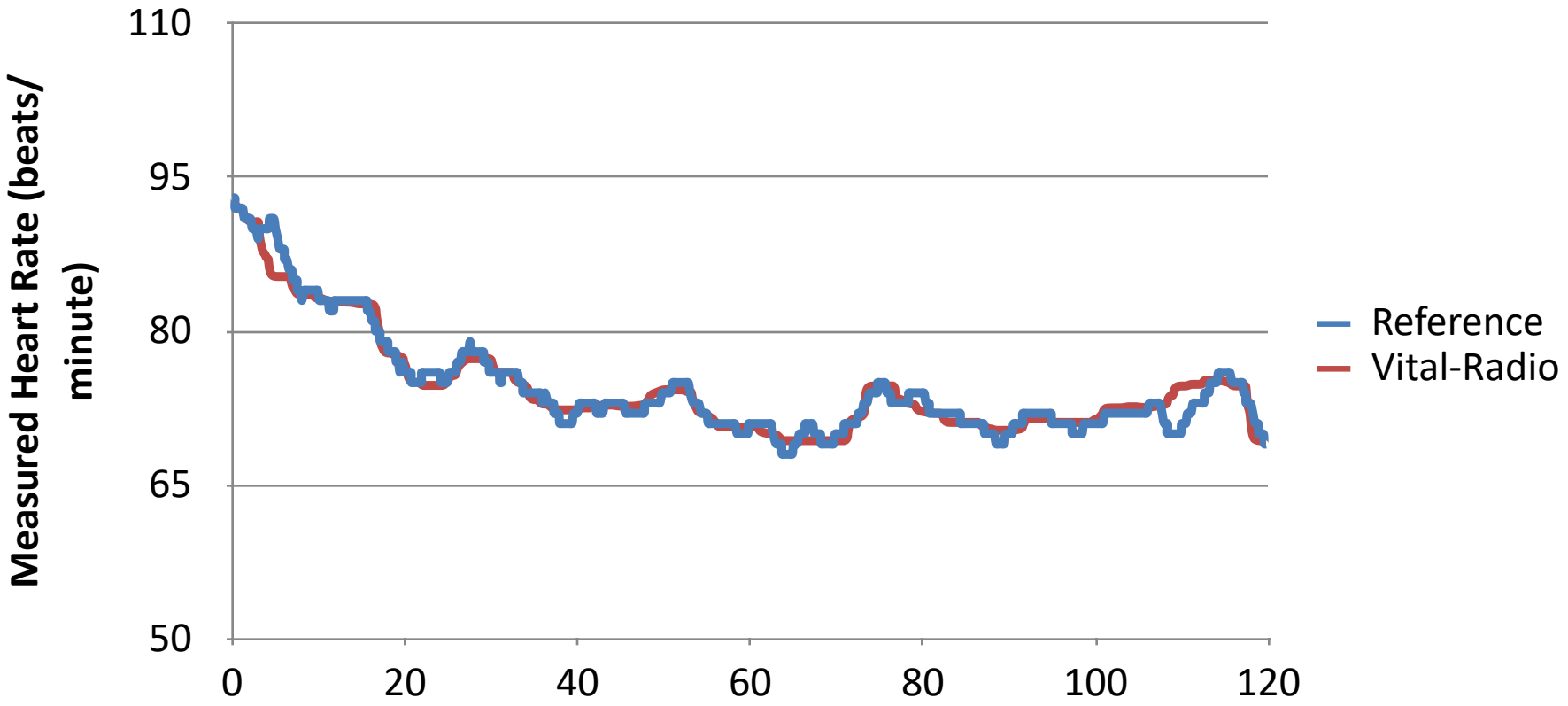
Multiple users sit at different distances

Nearest (at 2m) Middle (at 4m) Furthest (at 6m)



Accuracy for Tracking Heart Rate

Measure user's heart rate after exercising



Vital-Radio accurately tracks changes in vital signs

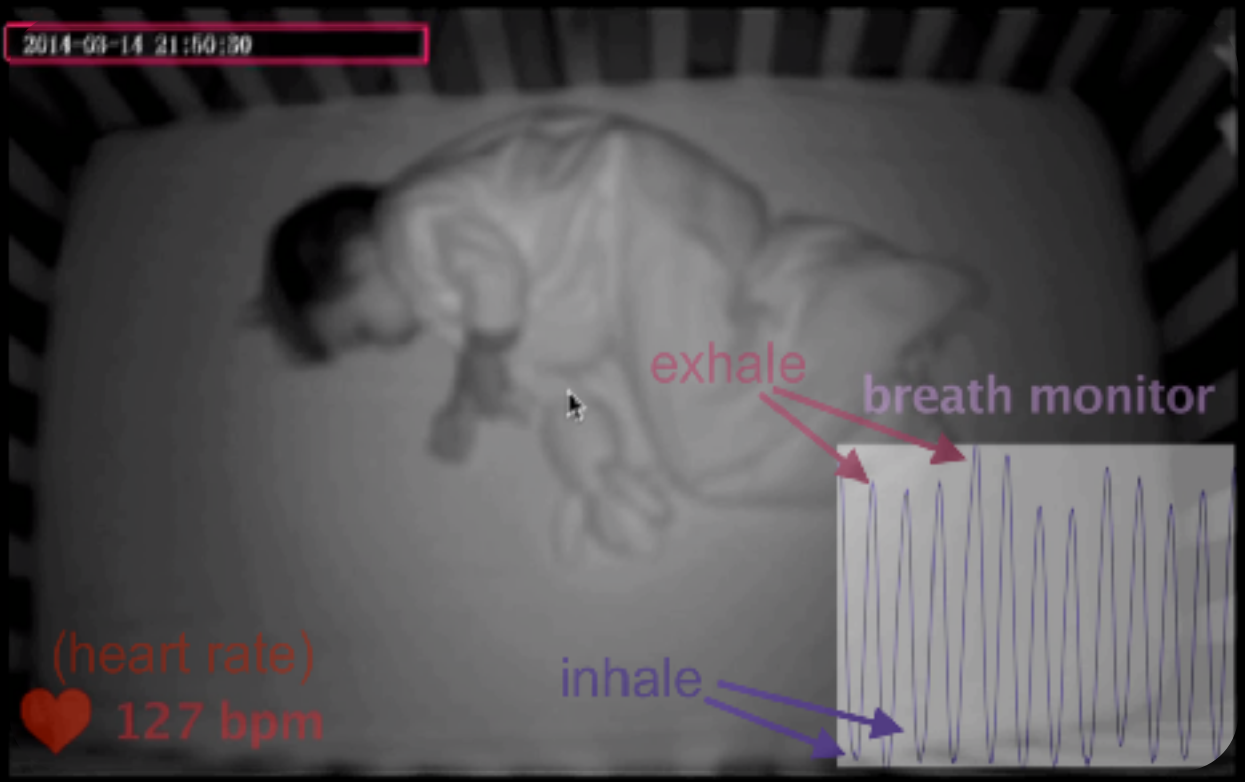
Vital-Radio Limitations/Extensions

- Stretching Break!

Vital-Radio Limitations

- Minimum separation between users: 1-2m
- Monitoring range: 8m
- Collects measurements when users are quasi-static

Baby Monitoring



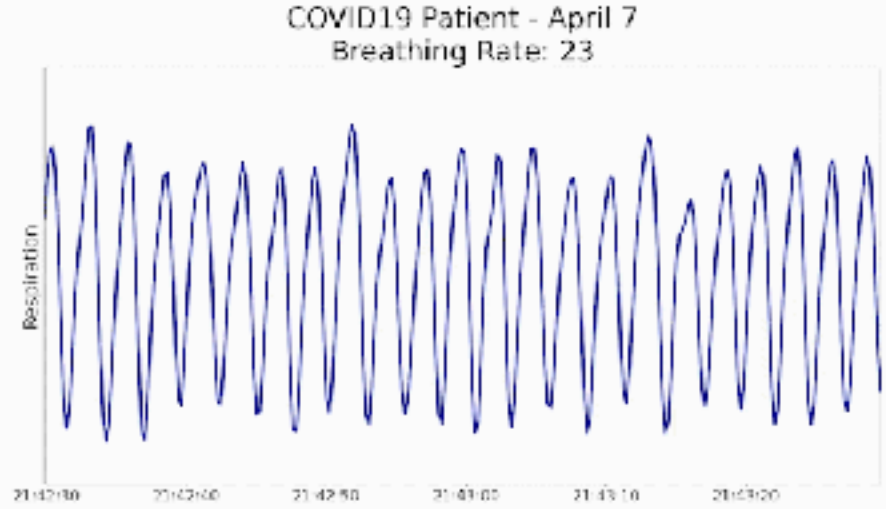
Non-contact Respiration Monitoring

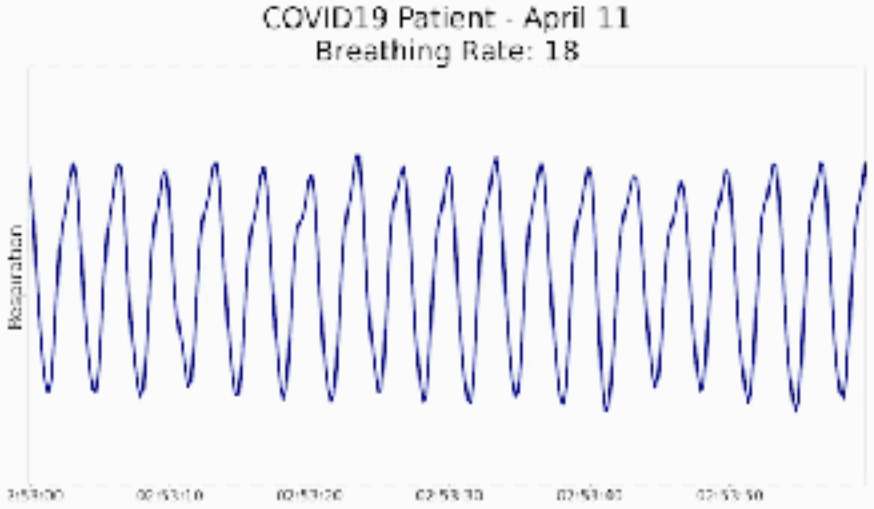
- Technology has been used in monitoring a COVID-19 Patient

- Deployed in ***Heritage Assisted Living*** in Boston suburb

- Medical doctors from Harvard Medical School analyzed remotely

Monitoring COVID-19 Patient





The patient's breathing decreased as it went back to normal

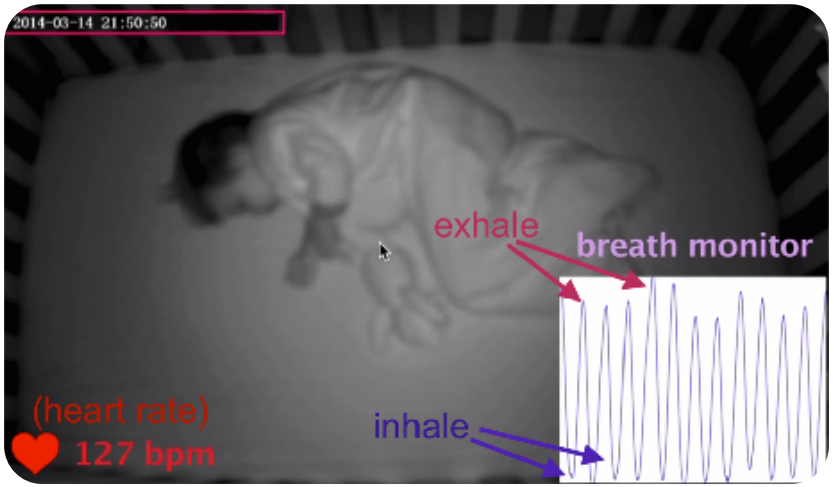
The patient's movements also demonstrate a marked improvement.

How can we capture heart recordings?

98-99% accuracy in timing micro-cardiac events

[ACM MobiCom'20]

Breathing & Heart Rate



Want Emotions

Why and how would you be able to get from BR/HR -> emotions?

Man receives under-skin chip implant live at mobile show

REUTERS

BARCELONA (Reuters) - A man volunteered t
stage at a trade fair in Barcelona on Monday, and another man who had already undergone

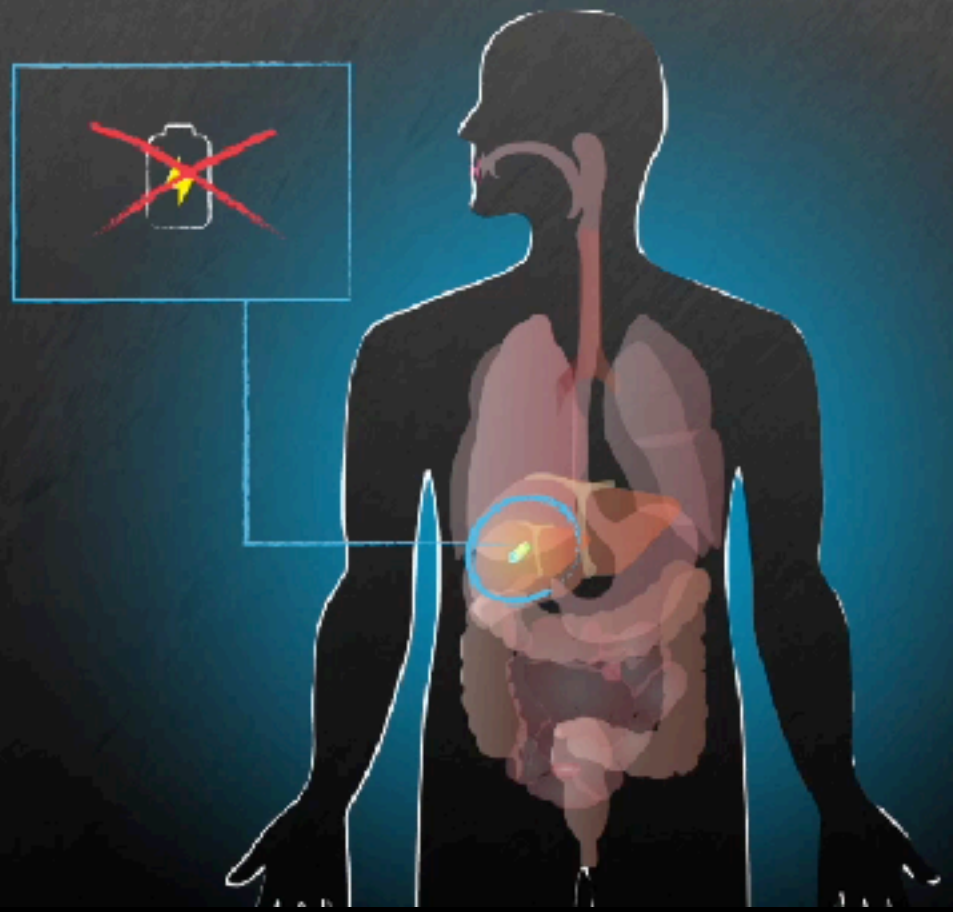
POPULAR SCIENCE

TECHNOLOGY

Why Did I Implant A Chip In My Hand?

My so-called cyborg life

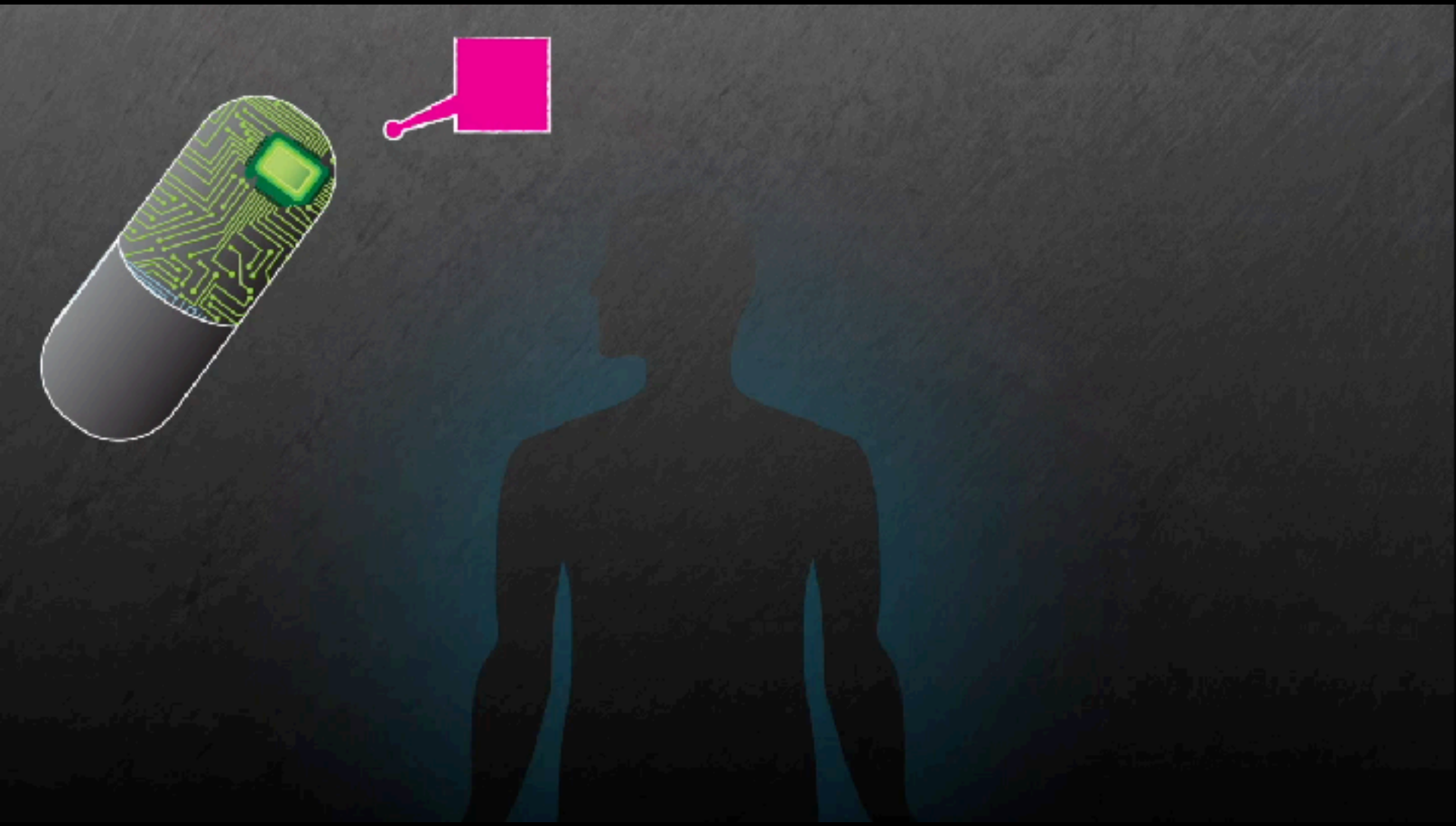
My implant is both less scary and less useful than you might think.



Wirelessly
Power &
Communicate

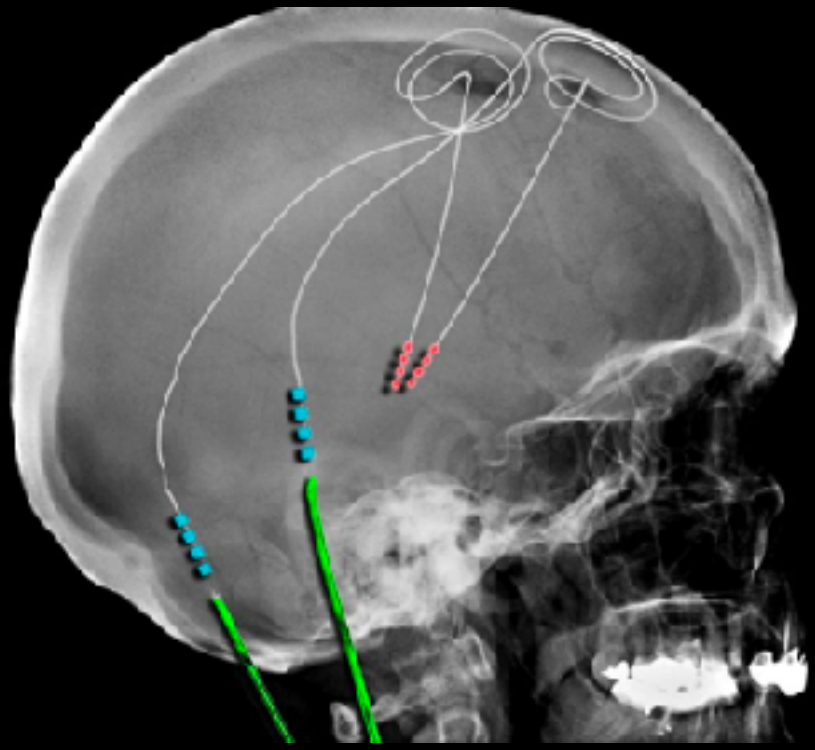
Continuous Sensing of Biomarkers & Tumors

Ultra Long-Lasting Drug Delivery



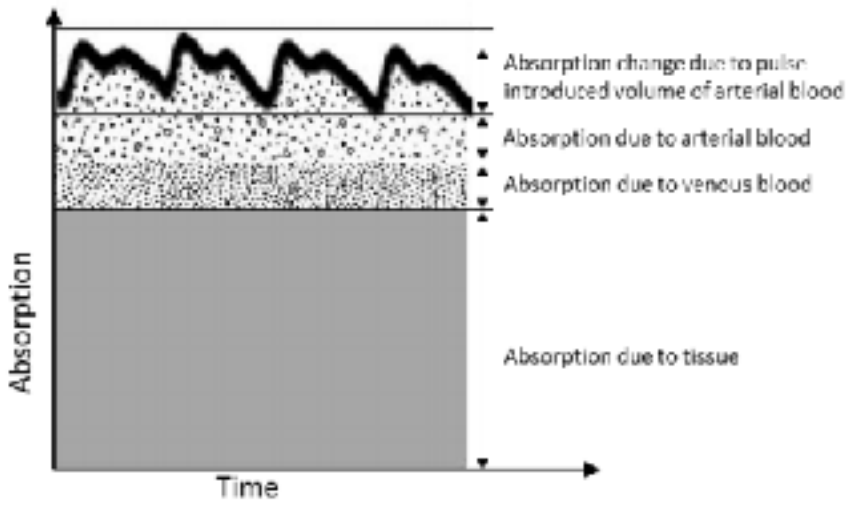
Wireless & Batteryless

Artificial Pancreas



Deep Brain Stimulators

HemaApp: Noninvasive Blood Screening of Hemoglobin Using Smartphone Cameras



Upcoming Lab & Project Ideas

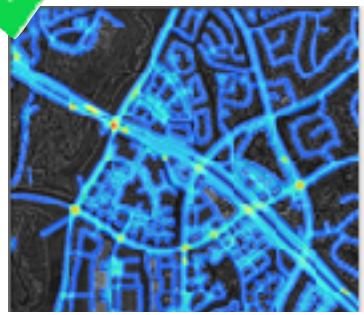
- Idea 1: RF requires specialized hardware (and can work through walls). An alternative approach is to achieve a similar sensing using active sonar (using iPad/iPhone/ Alexa), since sound is slower. Can you design a contactless sensing system for vital signs using sound?
  - Lab 4: location tracking from acoustics

- Idea 2: Given measurements from a state-of-the-art millimeter-wave device on cardiovascular sensing, can you collect a large dataset and develop algorithms to deal with motion artifacts?

Remainder of the Class

Emerging Application Domains & Cross-Cutting Topics

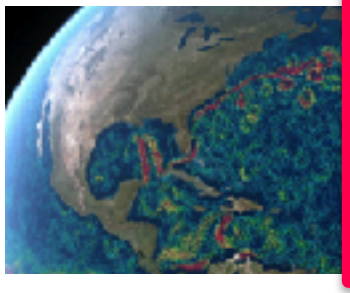
1. Transportation



2. Health

3. Agriculture

4. Oceans/ Climate



Next lecture

5. Security/ Privacy

TODO:

1- PSet 2 out

2- Lab 3 due today

3- Lab 4 will be out Friday