Mobile Health

Lecture 11
Contactless Radio and Health

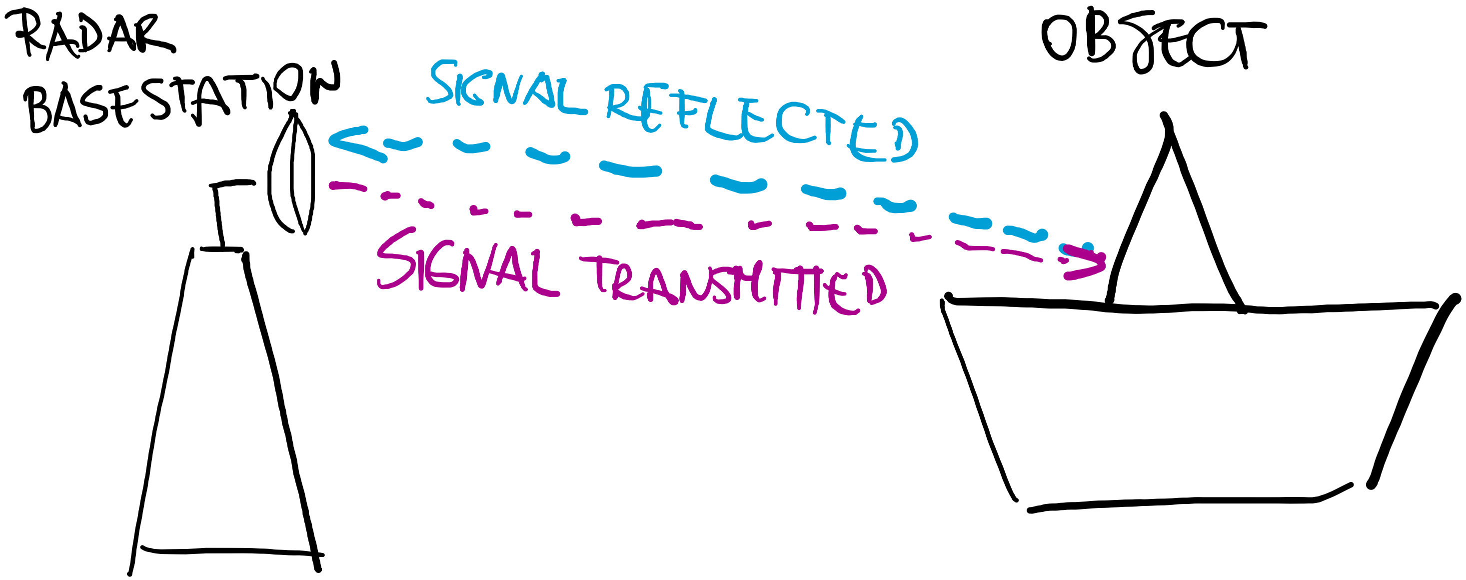
Cecilia Mascolo

UNIVERSITY OF CAMBRIDGE

Radar and Sonar Properties

- The ability of radio signal to bounce off objects with different speed and intensity can be exploited to understand:
  - Position of objects and individuals
  - Physiological markers

Radio Reflection: not a new concept!

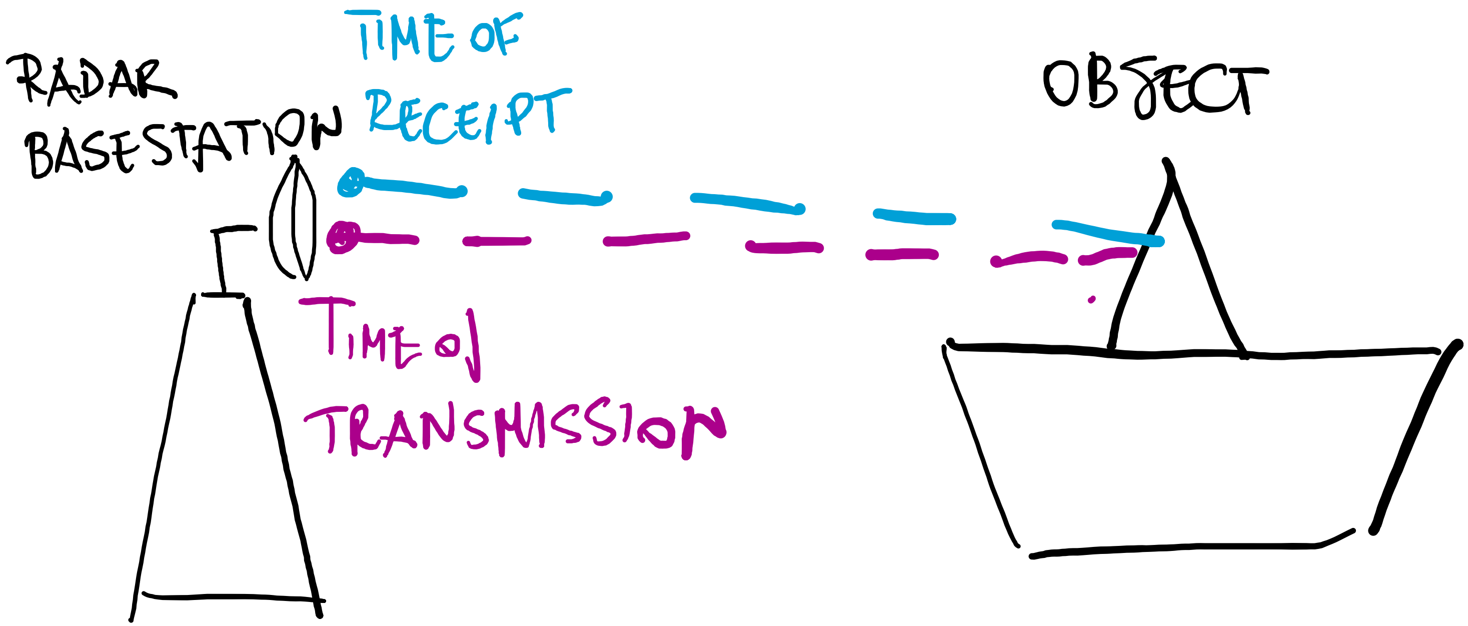


How do we use it for health

- Commodity (or small) devices (possibly low power)
- Acceptable radio frequencies
- Can it detect meaningful aspects of our health?

- See through walls? (infrared/imaging cannot)
- Multiple users?

How can we detect an object and its distance



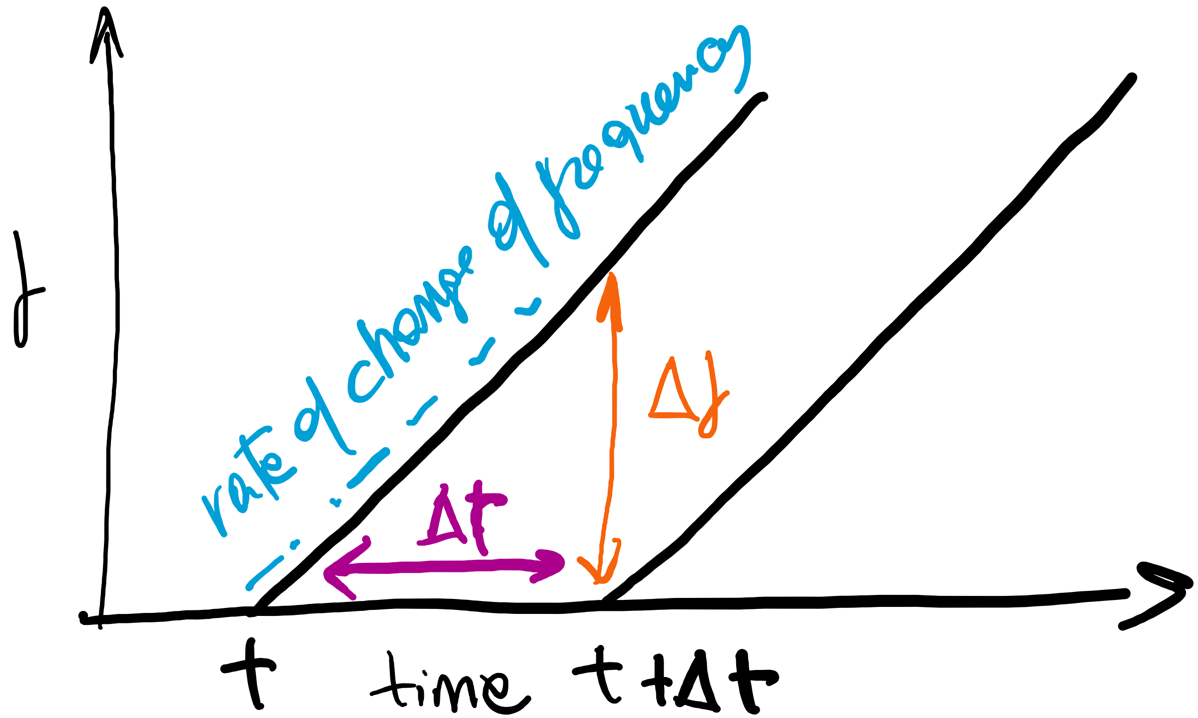
Distance= reflection time * speed of light

UNIVERSITY OF
CAMBRIDGE

The idea measuring reflection time using frequency changes!

Delta t= Delta f/slope

Delta f calculated by multiplying the wave with a simple function and looking at the DFT (this computation can happen on device)



UNIVERSITY OF CAMBRIDGE

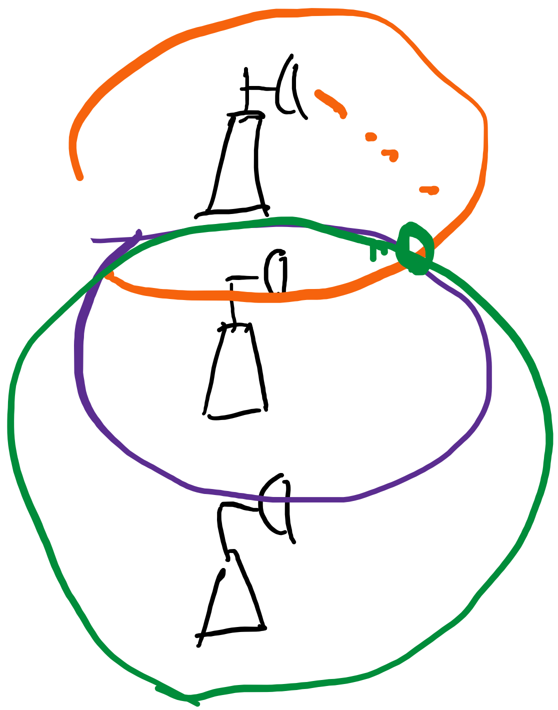
The signal changes frequency linearly…

https://www.mit.edu/~fadel/papers/Fadel_PhD.pdf

Distance vs Position

- With one antenna I can find out the object distance but not position.

- How do I find position?
  - Triangulation using multiple basestations

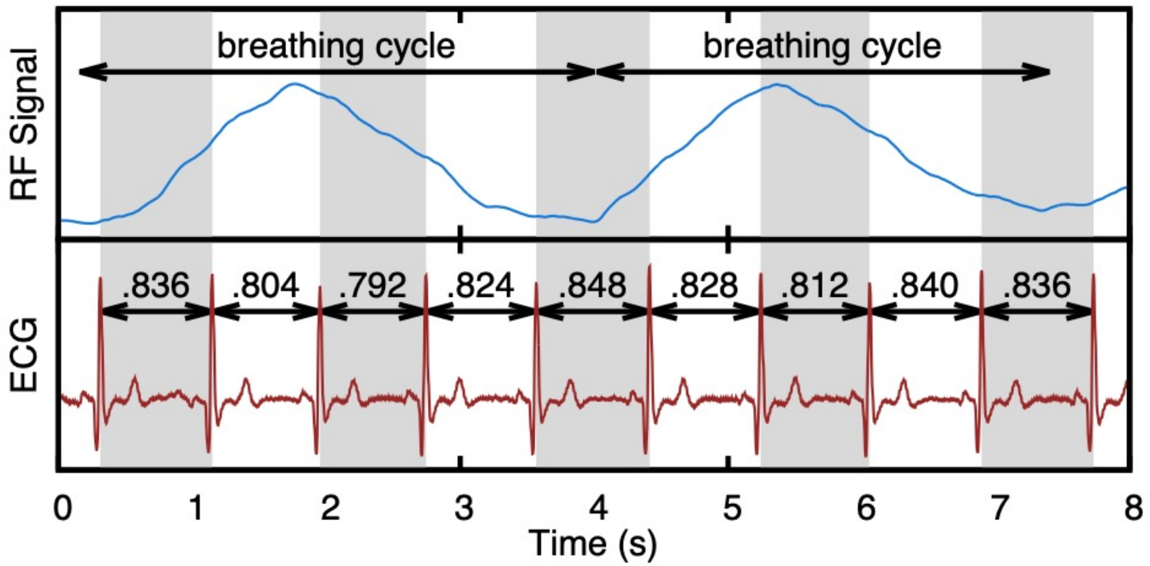


Problems that needed solving

- Static multipath from objects (exclude)
- Dynamic multipath from movement of people
- Multiple people

Big Bang Theory S10E14

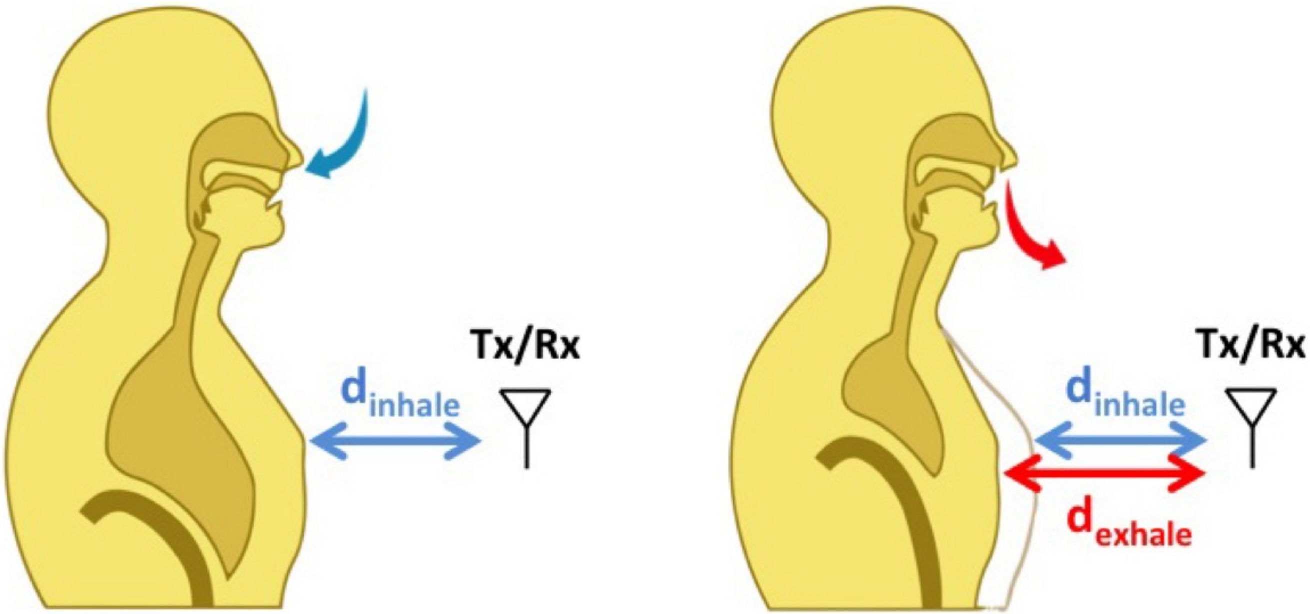
How to go from Radio Signal to Emotions?



UNIVERSITY OF CAMBRIDGE

Figure from Emotion Recognition using Wireless Signals, Mingmin Zhao, Fadel Adib, Dina Katabi. International Conference on Mobile Computing and Networking (Mobicom'16).

Monitoring Respiration



(a) Inhale Motion (b) Exhale Motion

UNIVERSITY OF CAMBRIDGE

From Emotion Recognition using Wireless Signals, Mingmin Zhao, Fadel Adib, Dina Katabi. International Conference on Mobile Computing and Networking (Mobicom'16).

Detecting Respiration and Inter Beat Intervals

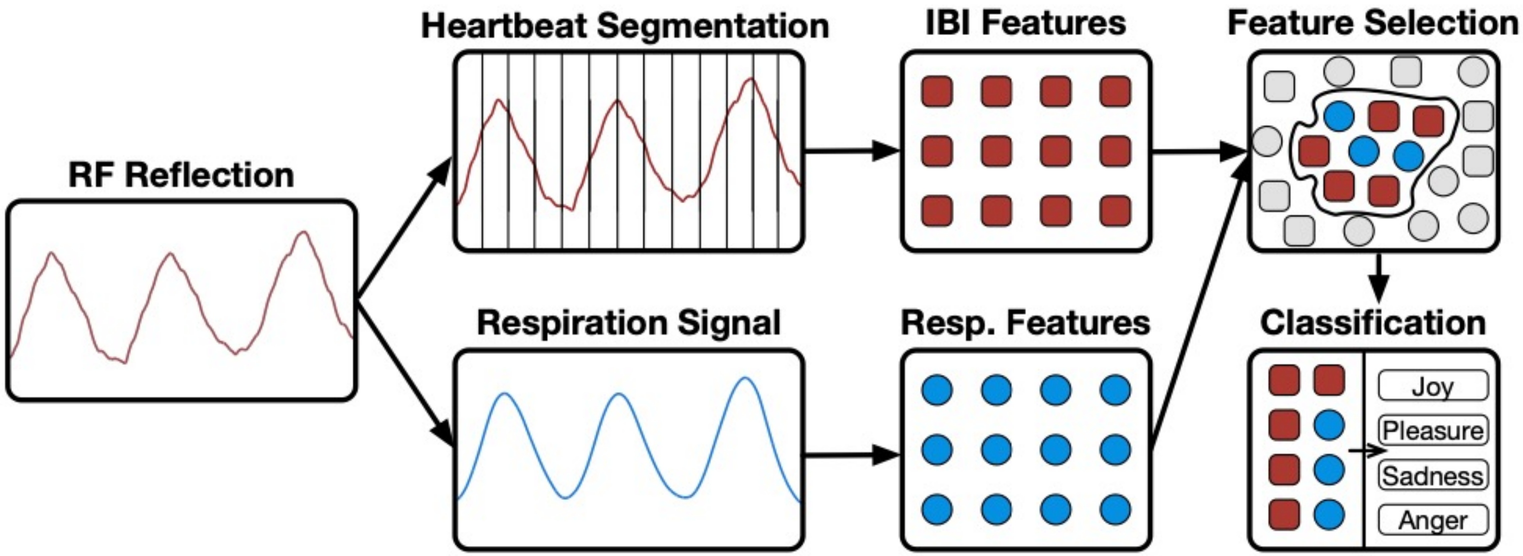
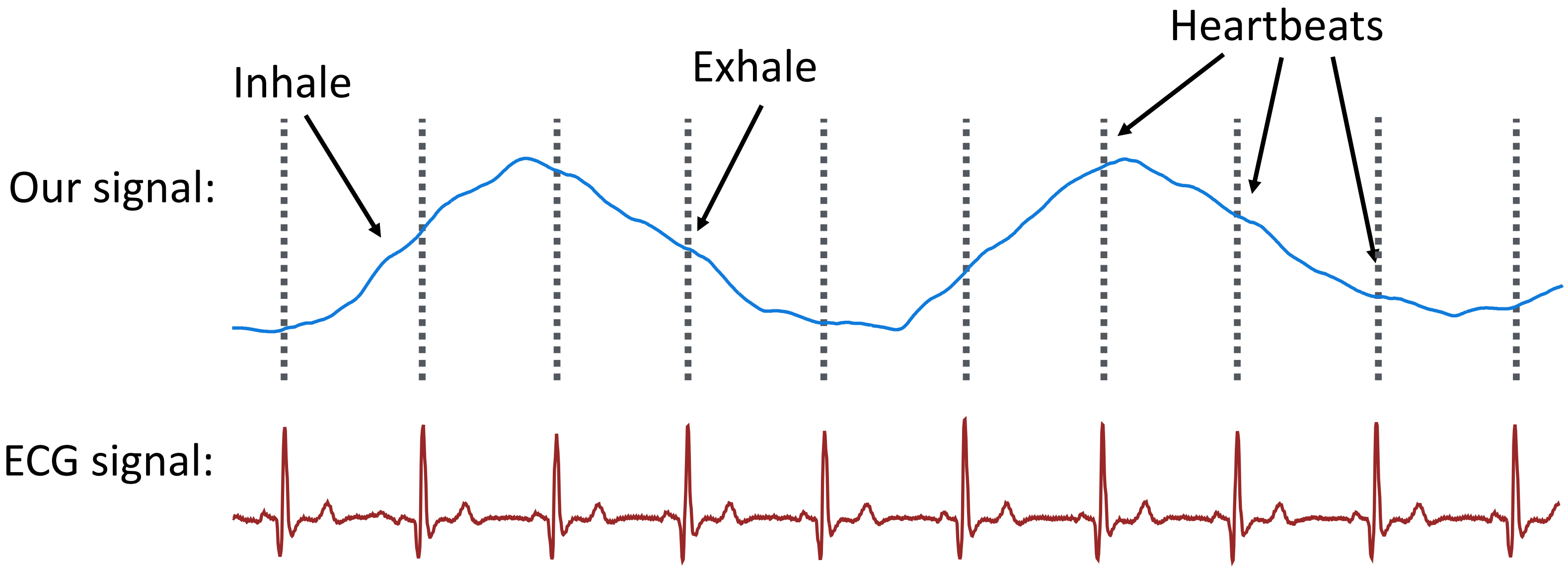


Figure from Emotion Recognition using Wireless Signals, Mingmin Zhao, Fadel Adib, Dina Katabi. International Conference on Mobile Computing and Networking (Mobicom'16).

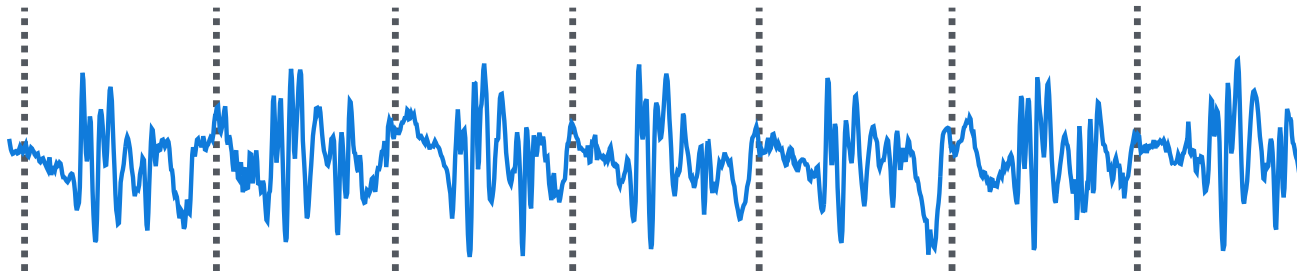
UNIVERSITY OF CAMBRIDGE

Input signal

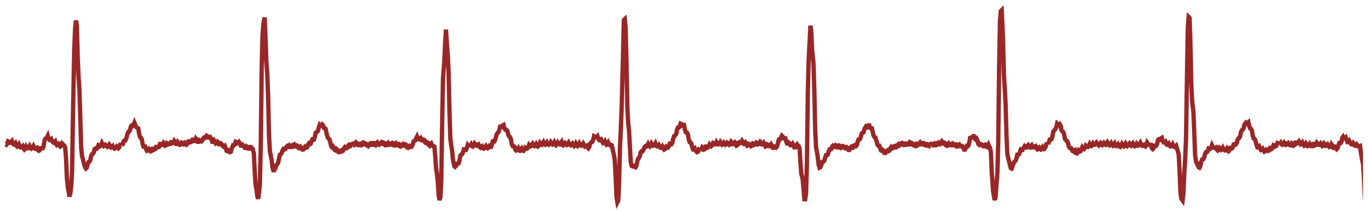


Spotlight on heart beat

- Signal second derivative



- ECG signal



Physiological Features for Emotion Recognition

- 37 Features similar to PPG methods
  - Variability of IBI
  - Irregularity of breathing

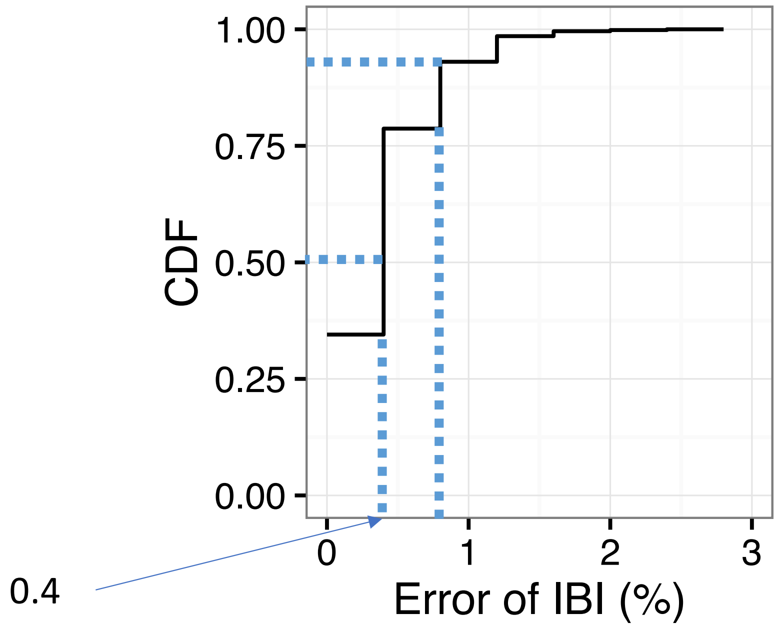
Domain	Name
Time	Mean, Median, SDNN,**pNN50**, RMSSD, SDNNi, meanRate, *sdRate*, HRVTi, *TINN*.
Frequency	Welch PSD: **LF/HF**, peakLF, peakHF. Burg PSD: **LF/HF**, peakLF, peakHF. Lomb-Scargle PSD: **LF/HF**, peakLF, peakHF.
Poincaré	SD_1, $\mathbf{SD_2}$, $\mathbf{SD_2/SD_1}$.
Nonlinear	$\mathbf{SampEn_1}$, $\mathbf{SampEn_2}$, $\mathbf{DFA}_{all}$, DFA_1, DFA_2.

selected IBI features in **bold**;
selected respiration features in *italic*.

UNIVERSITY OF CAMBRIDGE

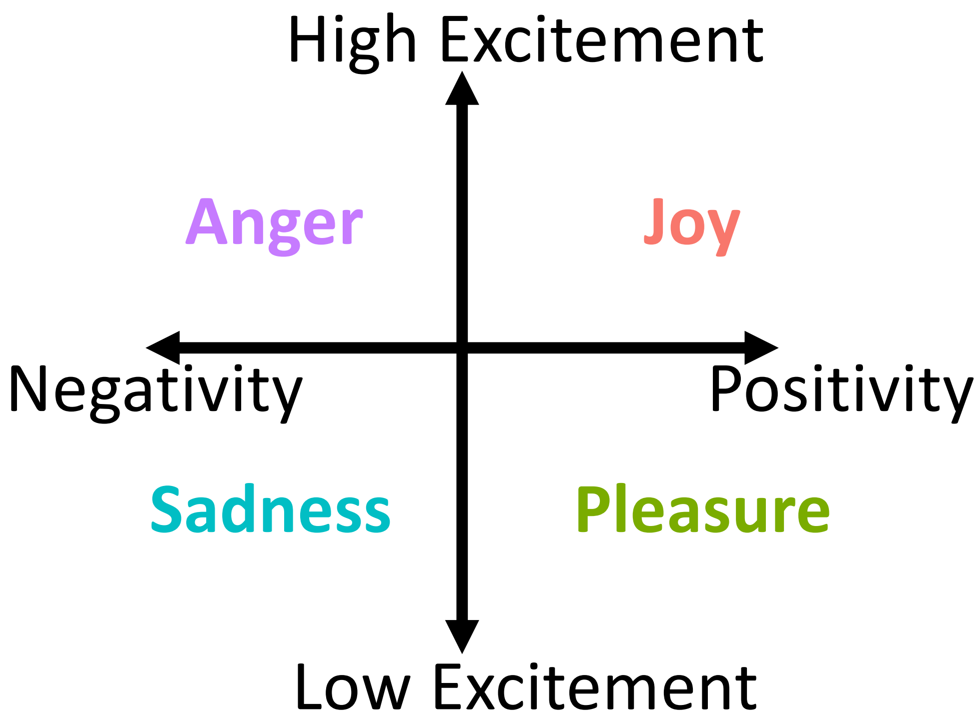
Is IBI Detection Accurate?

- Ground truth: ECG
- 30 subjects, over 130,000 heartbeats



Emotion Model

- Standard 2D emotion model
- Classify into **anger**, **sadness**, **pleasure** and **joy**



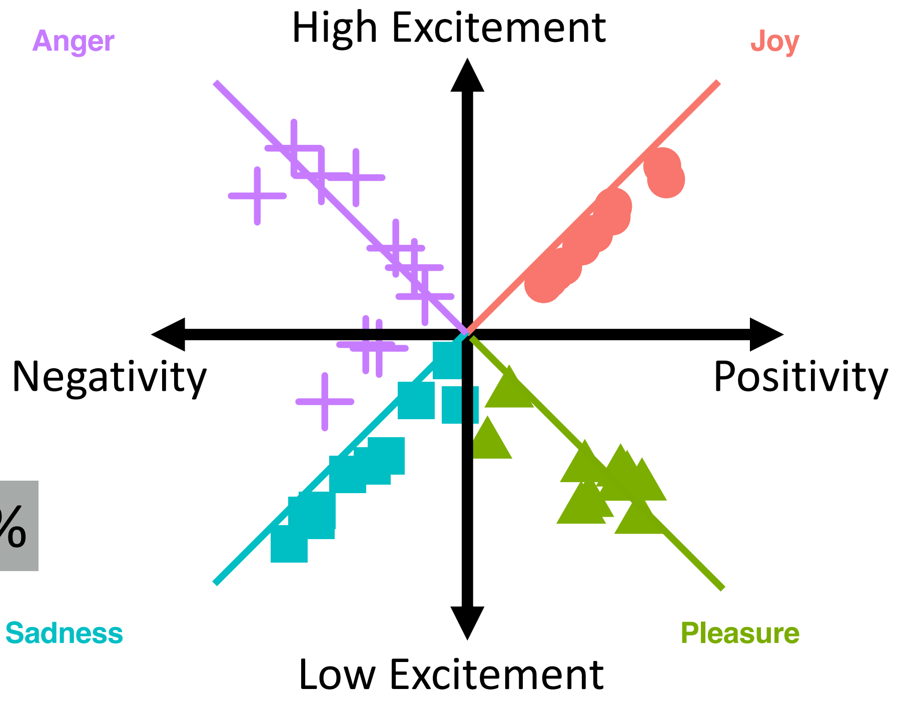
Does EQ-Radio detect emotion accurately?

- Experiment:
  - 12 subjects (6 female and 6 male)
  - Prepare personal memories for each emotion
  - Elicit certain emotion with prepared memories
  - classify every 2 minutes to an emotional state
- Ground truth: self-reported for each 2-min period.

Person-dependent Classification

- Train and test on the same person

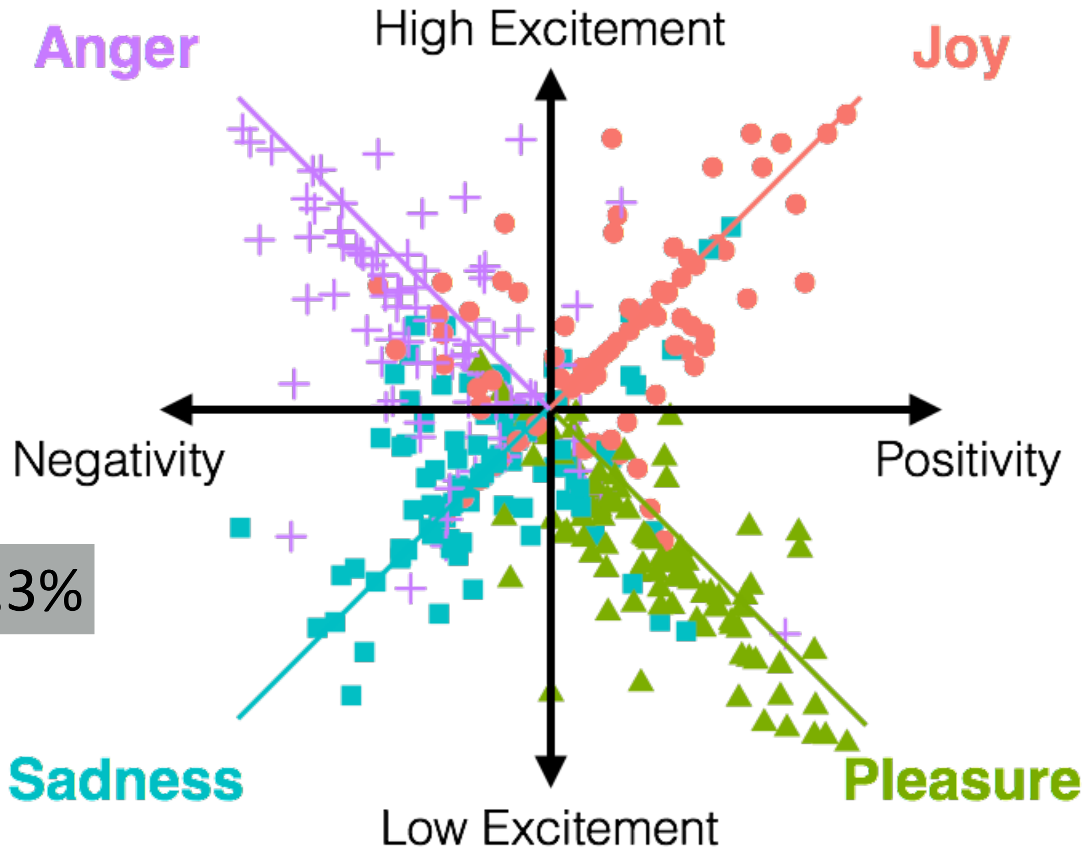
Accuracy: 92.5%



UNIVERSITY OF CAMBRIDGE

Person-independent Classification

- Train and test on the different person

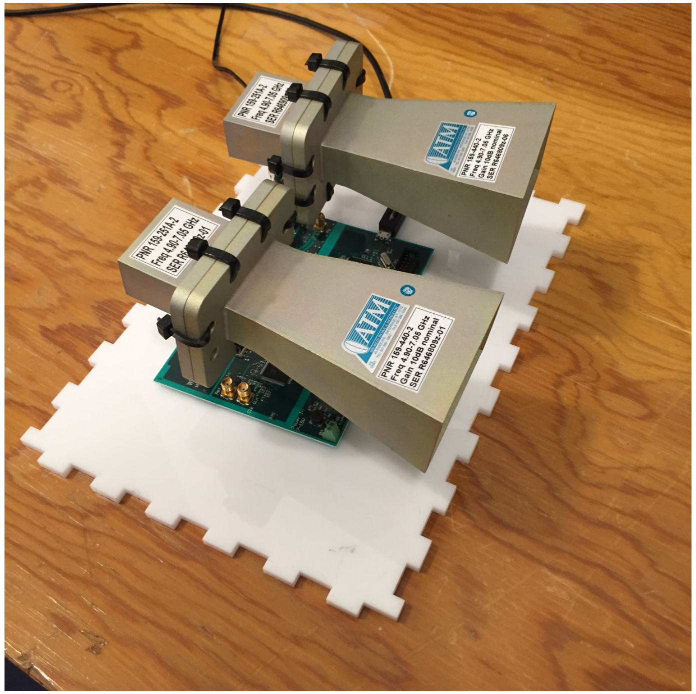


Accuracy: 72.3%

UNIVERSITY OF CAMBRIDGE

Hardware

- 5.5 GHz to 7.2 GHz
- sub-mW power



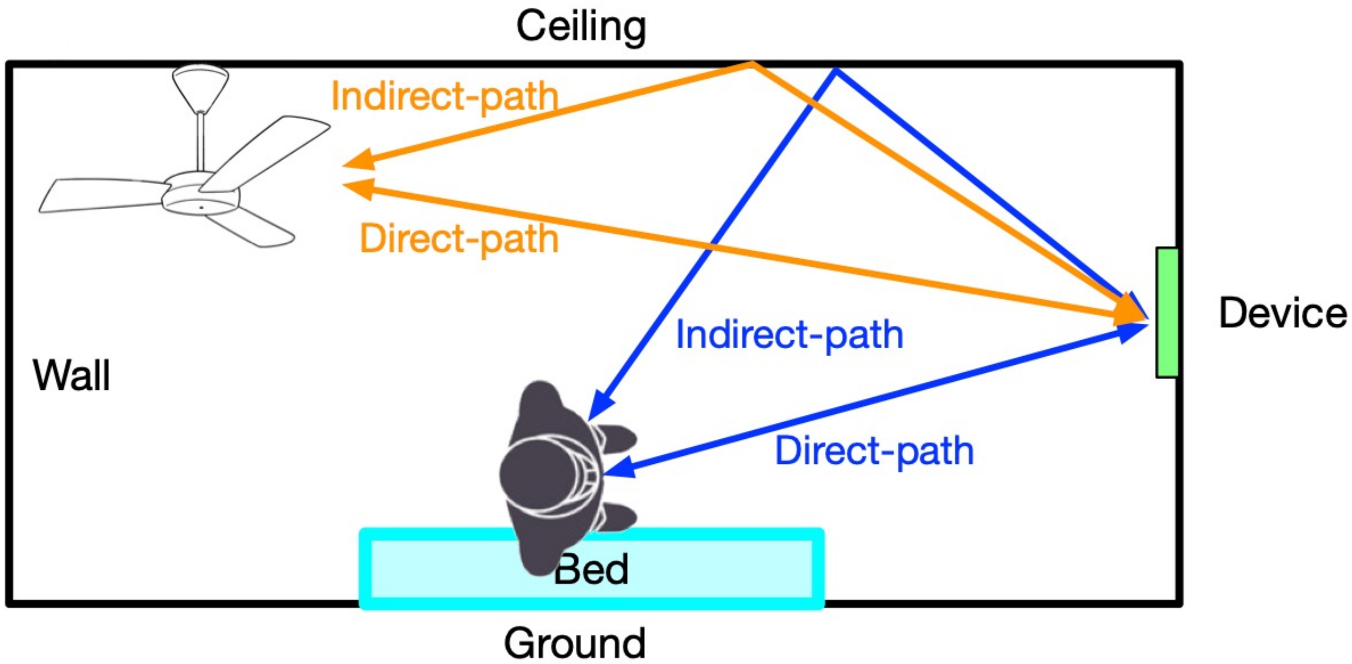
Sleep Posture Monitoring: Why

- Avoiding bedsores after surgery,
- Reducing sleep apnoea events,
- Progression of Parkinson's disease,
- Alerting epilepsy patients to potentially fatal sleep postures.

BodyCompass: Monitoring Sleep Posture with Wireless Signals. S. Yue, Y. Yang, H. Wang, H. Rahul, D. Katabi ACM (Ubicomp 2020)

The idea

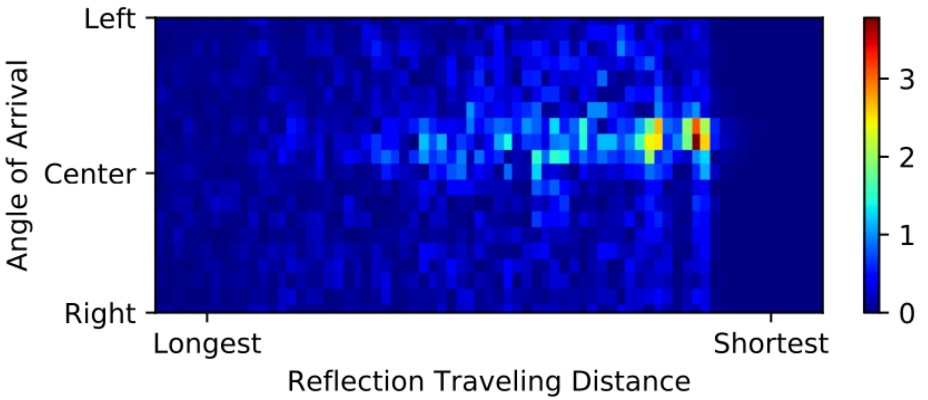
- Reflection from a body is modulated by breathing
- Reflection from other objects are not



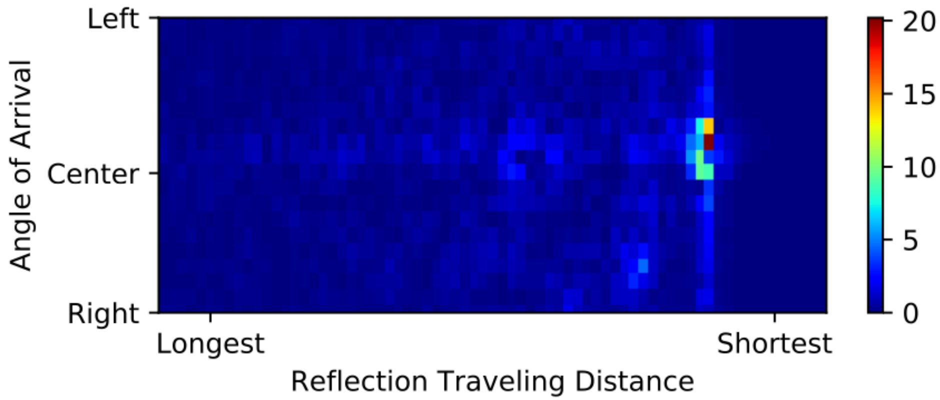
BodyCompass: Monitoring Sleep Posture with Wireless Signals. S. Yue, Y. Yang, H. Wang, H. Rahul, D. Katabi. ACM (Ubicomp 2020)

UNIVERSITY OF CAMBRIDGE

Heatmaps of different postures



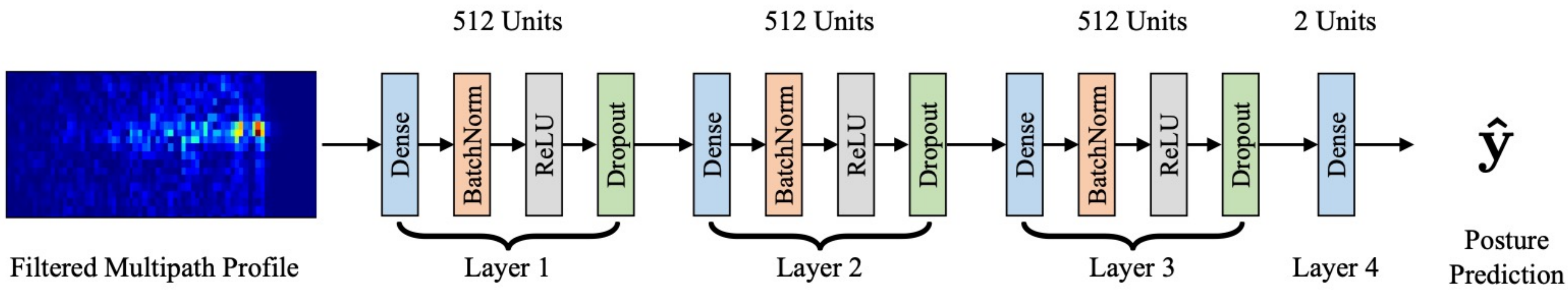
User facing up: lots of indirect reflections



User facing towards the device

UNIVERSITY OF CAMBRIDGE

Deep Learning over multipath profiles



UNIVERSITY OF CAMBRIDGE

Transfer Learning

- Assume limited labelled data for a target user
- Data from different (source) users (labelled) exist

- Data from source users most similar to target user data used to *augment the target user data*
- Adapt the model trained on all source users to the target data and choose the best with majority voting (using the real user data)

UNIVERSITY OF CAMBRIDGE

Performance

	BodyCompass	k-NN (A)	k-NN (T)	RF (A)	RF (T)	XGB (A)	XGB (T)
Angle Error (1-week)	15.3° ± 4.4°	NA	31.3° ± 9.7°	NA	33.8° ± 13.0°	NA	33.8° ± 13.3°
Accuracy (1-week)	94.1% ± 4.3%	NA	77.7% ± 9.8%	NA	75.4% ± 12.0%	NA	75.5% ± 12.9%
Angle Error (1-night)	25.6° ± 6.7°	43.1° ± 11.0°	40.6° ± 11.0°	52.5° ± 17.0°	45.4° ± 15.1°	53.9° ± 16.2°	49.2° ± 13.1°
Accuracy (1-night)	86.7% ± 6.7%	65.2% ± 10.5%	67.8% ± 10.2%	54.8% ± 14.5%	62.2% ± 13.8%	53.5% ± 14.2%	59.9% ± 10.5%
Angle Error (16-min)	28.3° ± 8.7°	59.1° ± 19.0°	60.6° ± 19.0°	58.4° ± 20.2°	55.0° ± 18.9°	60.7° ± 20.1°	65.1° ± 13.1°
Accuracy (16-min)	83.7% ± 6.8%	50.3% ± 14.6%	46.4% ± 17.0%	51.0% ± 14.9%	52.2% ± 15.0%	48.7% ± 15.8%	42.8% ± 11.4%

Other things that can be monitored

- Stress
- Sleep stages
- Movement

Other signals (e.g. audio) can be used!

communications
biology

ARTICLE

Check for updates

https://doi.org/10.1038/s42003-021-01824-9 OPEN

Using smart speakers to contactlessly monitor heart rhythms

Anran Wang [1✉], Dan Nguyen[2], Arun R. Sridhar [2✉] & Shyamnath Gollakota [1✉]

Questions