Lecture 06

SmartPhone Sensing

Some information

- Labs are optional, I would suggest you come to show your progress and to discuss the challenges you face.
- If the rooms in the 5th floor are closed, come to my office or the TA's (we are usually there). If you can't find us, post the message in FF, we will find a slot for you.
- Regarding the reports
  - Do not explain what Bayesian, Particle Filters are (we already know).
  - Do not write the equations unless you need them to highlight something that is novel.
  - Focus on writing what is new/different: filtering of APs, motion model, new methods, tools, etc.

Let's look at FF

WRITING GUIDELINES FOR SECOND REPORT

Assignment description

- You need to develop an App for indoor localization using RSS signals from WiFi.
- NO motion sensors (IMU) need to be used for this assignment.
- You will need to gather training data from the 5th floor in EWI, according to the map provided in FF. Then, you will need to evaluate the accuracy of your method and provide a confusion matrix for at least half of the cells. Choose some office cells and some cells in the aisle.
- People are working in the offices so please be quite while you are in our floor and, in particular, when you enter a room to gather data.

Guidelines for Report: Bayesian (max 1 page, except for confusion matrix)

- Name file with the same instructions as for the first assignment.
- Top part same as for report 1
  - group name, student names phone, android version, code used from somewhere else.
- Data collection (1 paragraph)
  - Sampling rate, sampling time per cell, etc
- Data Processing (1 paragraph)
  - Filters used for APs and RSS (if any)
- Radio Map (1 paragraph, ** 2 figures)
  - pmf examples for 2 cells that are similar and 2 cells that are different.
- Evaluation
  - Snapshot of App
  - Confusion Matrix (for **at least half of the cells**, you must test the cells in the 5th floor of our building, don't wait until the last minute to do this)
- Discussion (bulletpoints)
  - What is **hard**? What is **novel**? i.e. new methods, etc

FINAL EVALUATION GUIDELINES

Localization (6 points)

- Evaluation will be done on the 5th floor of EWI.
- No training will be done on the spot for Bayesian.
  - The Localization App should be already trained.
- For localization, you can assume that the phone will always be on our hand facing our face.
- We will test all cells for each method.

- There will be a Q&A component to see if you really understand the methods and to check load balancing.
- If the Q&A goes wrong, points will be deducted.
- If things don't work, explain clearly and concisely why they don't.

Localization grading (6 points)

- You can get a maximum of 20 points.
  - Precise cell: 1 point
  - Adjacent cell: 0.75
  - Two cells away: 0.25
  - Further than two cells away: 0.0
- The maximum grade you can get for this is 6
- We will do grading curve. The best team will determine this curve.
- Remember that you are free to come up with other tricks to improve your accuracy (novelty).
- For Particle filters, you can use as input the starting floor.
- For Bayesian filters, you don't need to assume anything.

Birds-eye view

App option 1: localization

KNN

Bayes and Particle Filters

problem: shadowing and fading

Activity & Loc.

Bayesian filters

α-trimmer filters

Log normal shadowing

Particle filters

Paper:

"An Industrial Strength Audio Search Algotihm"

http://www.ee.columbia.edu/~dpwe/papers/Wang03-shazam.pdf

Blog posts:

http://laplacian.wordpress.com/2009/01/10/how-shazam-works/

http://www.slate.com/articles/technology/technology/2009/10/that_tune_named.html

HOW SHAZAM WORKS

How Shazam works

Shazam is revolutionary work

My encounter with Shazam:
- drinks, noise, short sampling, magic

Not a trivial solution:
- that's why we focus on technical depth

Author:
- Avery Wang, PhD, Stanford 1994
- Topics: Signal Processing, Audio

He was told: not possible (circa 2000),

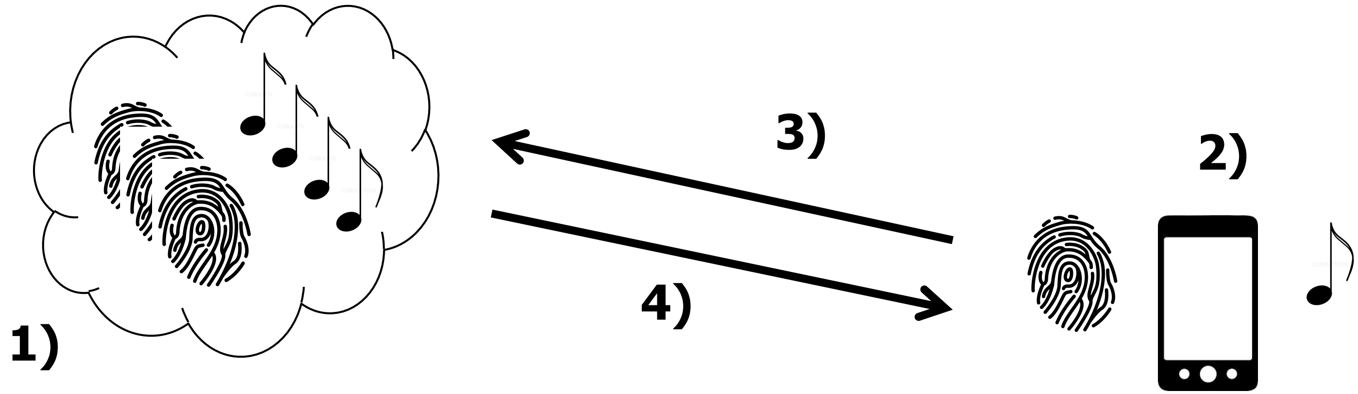
but one Prof. said maybe it is possible.

Challenges

- Too much information in a song to compile in a single signature
- Too big of a search space: millions of songs
- Too little time process information: people are not patient
- Very likely too much noise: corrupted/missing data

- Main goal:
  - Create a 'fingerprint' of each performance
- Magic touch:
  - Music pattern matching from several hours/days to seconds/milliseconds

Basic steps



1) Beforehand, Shazam fingerprints a comprehensive catalog of music, and stores the fingerprints in a database.

2) A user "tags" a song they hear, which fingerprints a 10 second sample of audio.

3) The Shazam app uploads the fingerprint to Shazam's service, which runs a search for a matching fingerprint in their database.

4) If a match is found, the song info is returned to the user, otherwise an error is returned.

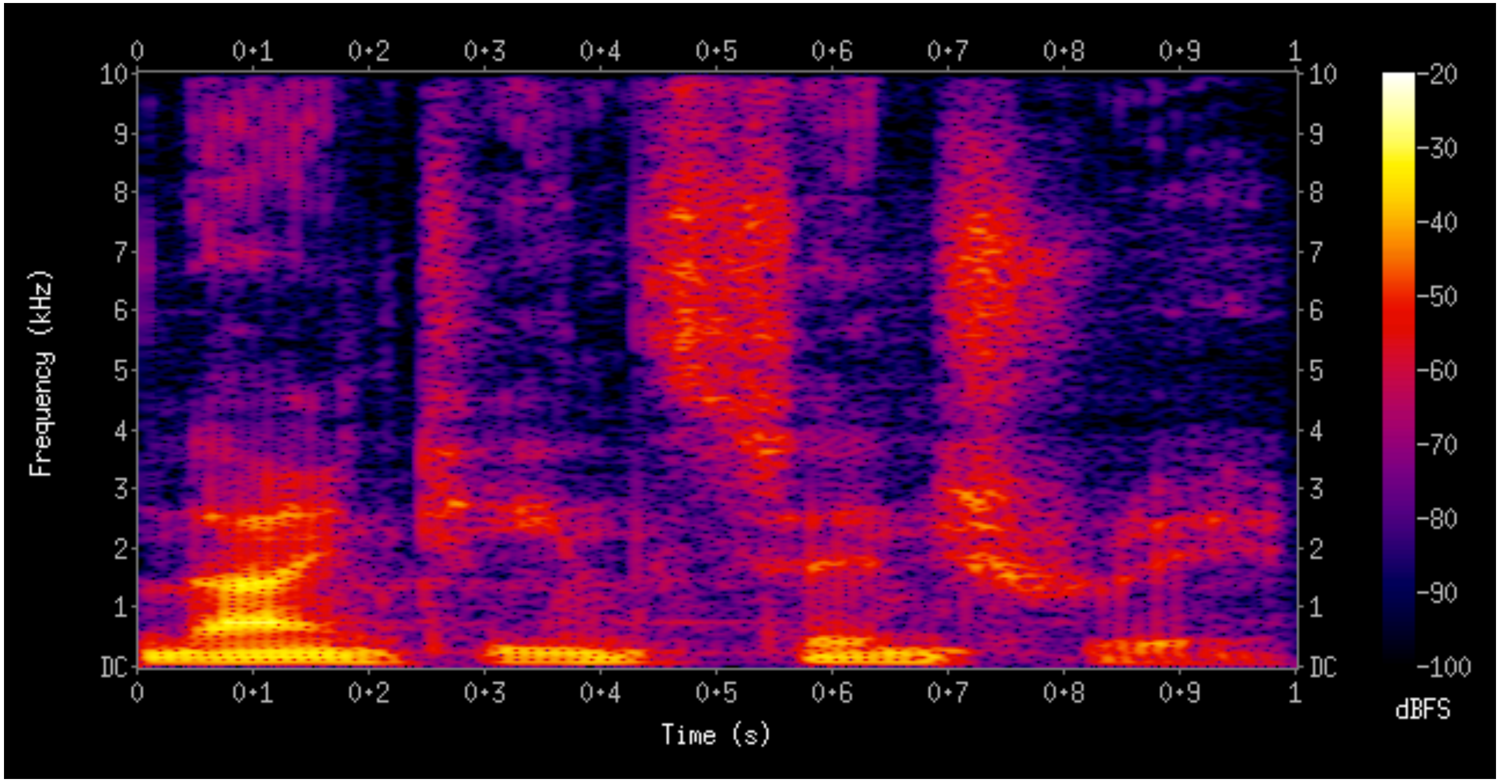
Text taken from: http://laplacian.wordpress.com/2009/01/10/how-shazam-works/

A bit of history to appreciate progress

- In the first version of Shazam (early 2000), you had to:
  - call a service number …
  - and then get an sms with information

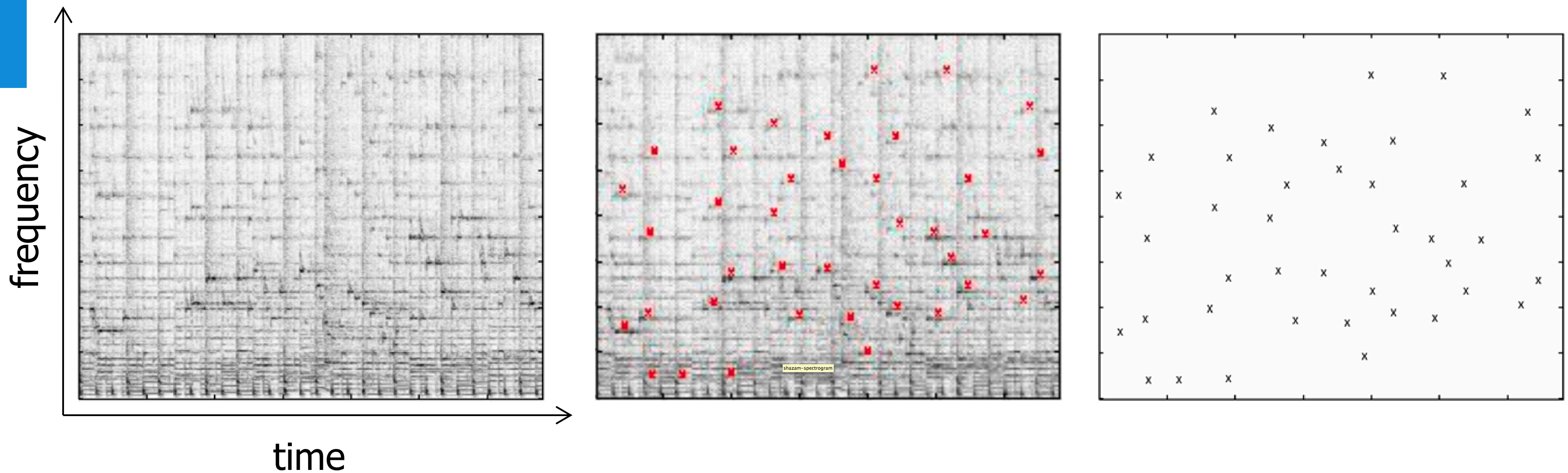
We have moved a long way from those (pre-historic) times

Spectrogram: think of mountains



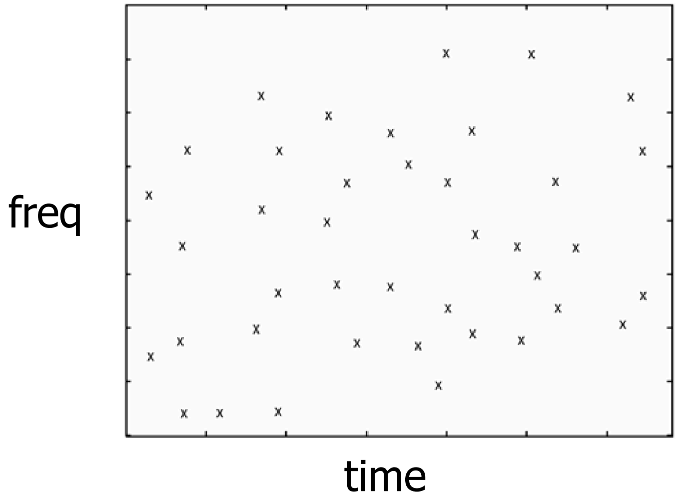
A horizontal line is a single tone. A vertical line is white noise
Z-axis is intensity
Problem of spectrogram: too much data

Fingerprints: constellation maps



Fingerprint: picks out just those points that represent the peaks of the graph—notes that contain "higher energy content". This reduces the amount of data dramatically.

Mapping: hash functions

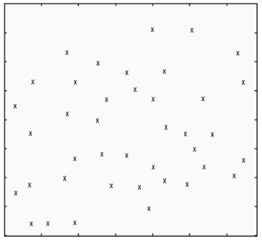


Frequency in Hz	Time in seconds
823.44	1.054
1892.31	1.321
712.84	1.703
…	…
819.71	9.943

The song information is encoded and transmitted in hash functions

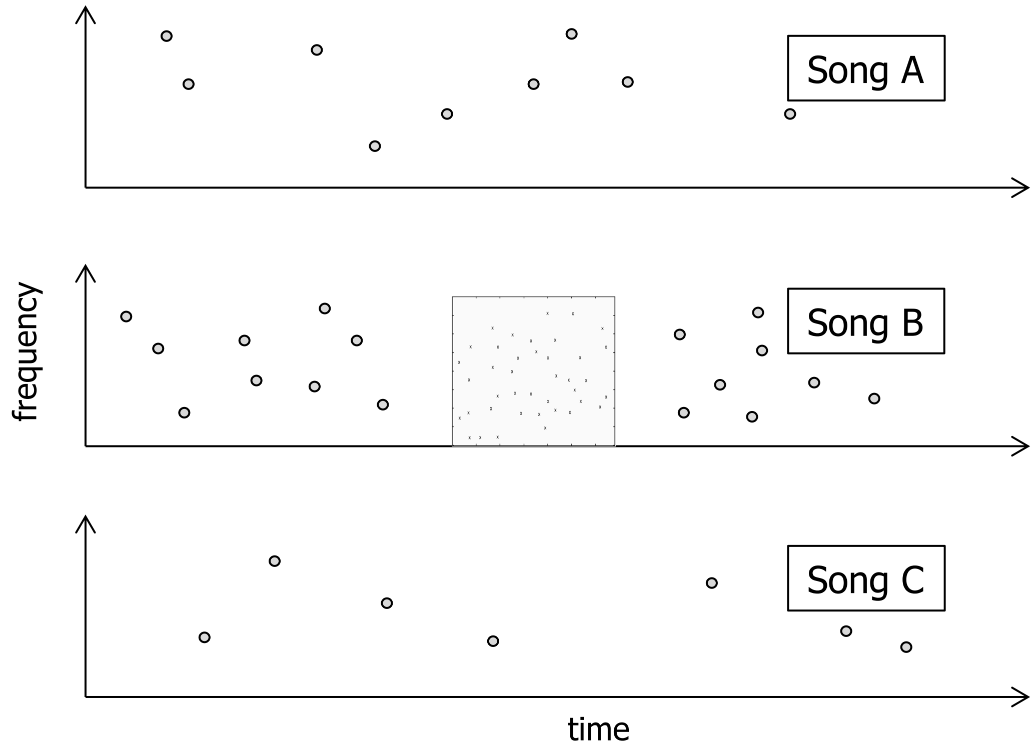
Mapping: hash functions

Frequency in Hz	Time in seconds
823.44	1.054
1892.31	1.321
712.84	1.703
…	…
819.71	9.943

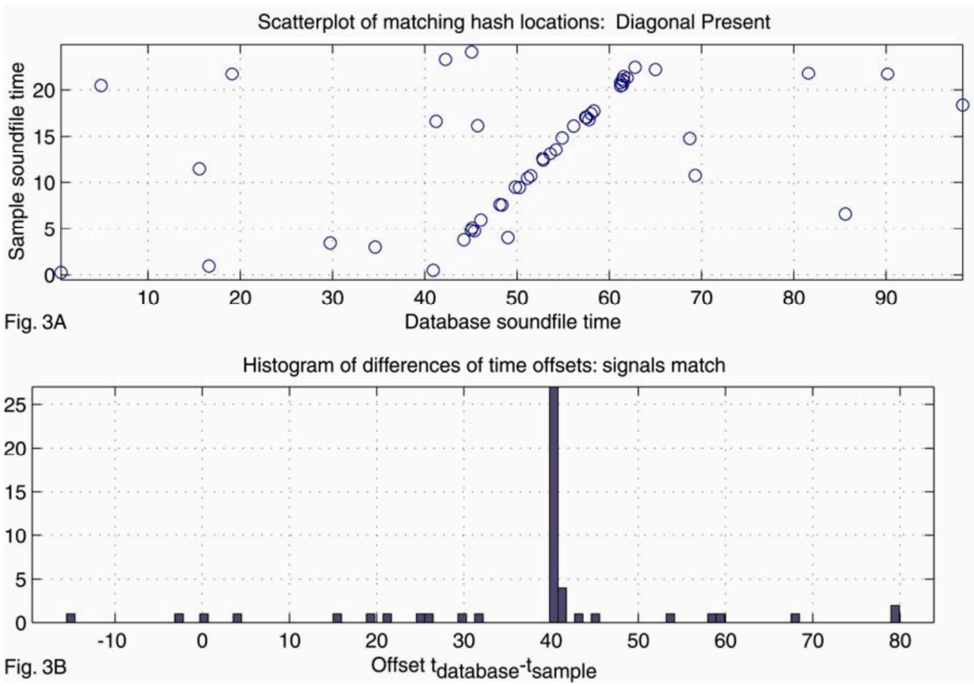


Hash functions' computation complexity is O(1)

Frequency in Hz	Time in seconds, song information
823.43	53.352, "Song A"
823.44	34.678, "Song B"
823.45	108.65, "Song C"
…	…
1892.31	34.945, "Song B"



A good match



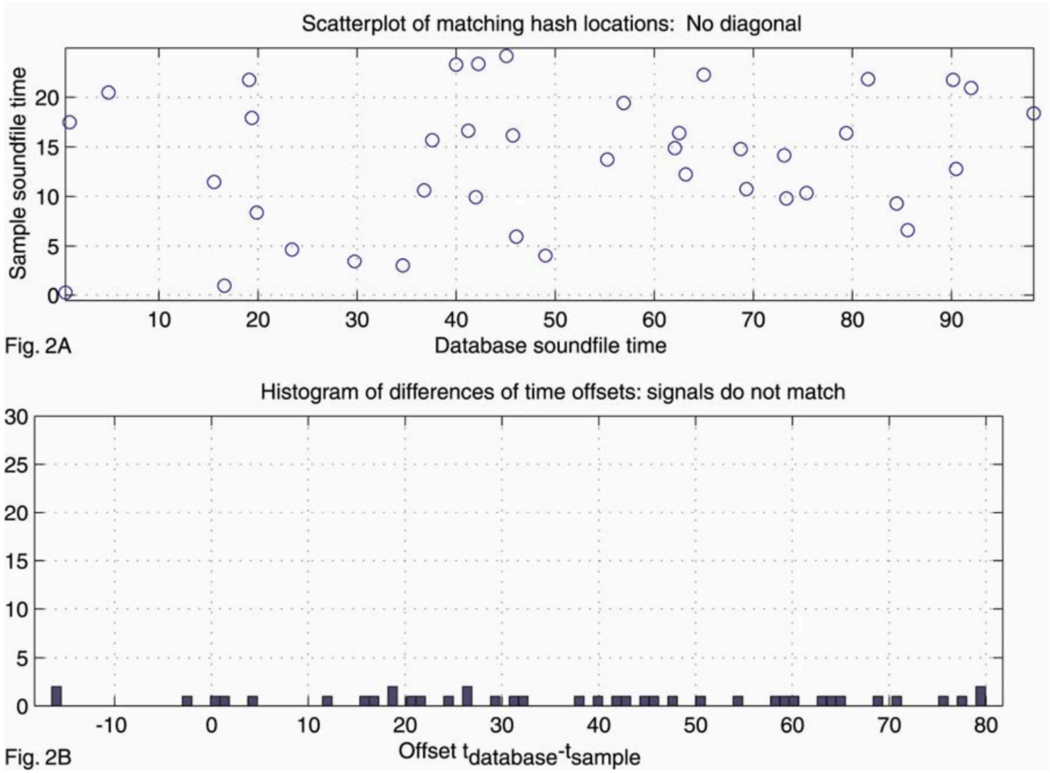
Freq.	Time (sample song)	Time (cloud)	tuples
f_1	t_1	Song A $\{t_1^i, t_1^j\}$	$\langle t_1, t_1^i \rangle$ $\langle t_1, t_1^j \rangle$
f_2	t_2	Song A $\{t_2^i\}$	$\langle t_2, t_2^i \rangle$
f_3	t_3	Song A $\{t_3^i\}$	$\langle t_3, t_3^i \rangle$
…	…	…	
f_n	t_n	Song A $\{t_n^i, t_n^j\}$	$\langle t_n, t_n^i \rangle \langle t_n, t_n^i \rangle$

$$t_{song} = t_{sample} + \text{offset}$$

$$d_{tk} = t_{song} - t_{sample}$$

d_{tk} should have a high frequency of appearance in a matching song

A poor match



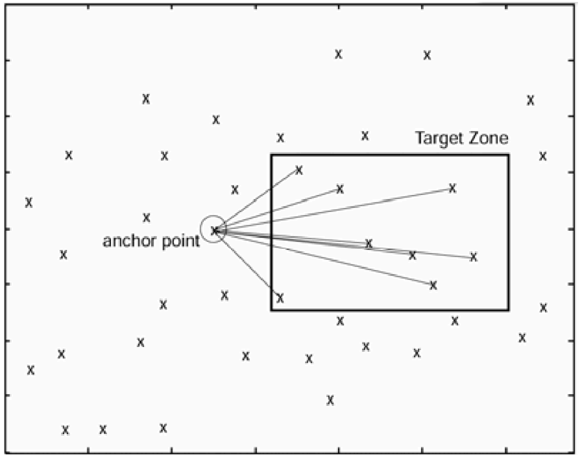
Shazam's fingerprint is actually quite unique

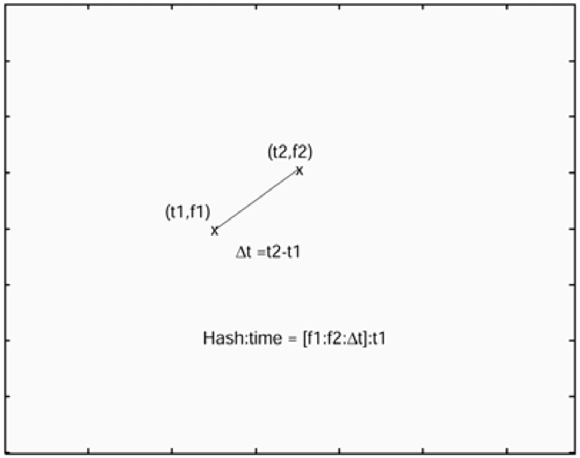
This is good but we still need more speed.

What we just explained wouldn’t make the cut.

Increasing Hash Specificity

- Hashing single points
  - $H(f_1) = t_1$
- Hashing pairs
  - $H(f_1{:}f_2{:}\Delta t) = t_1$

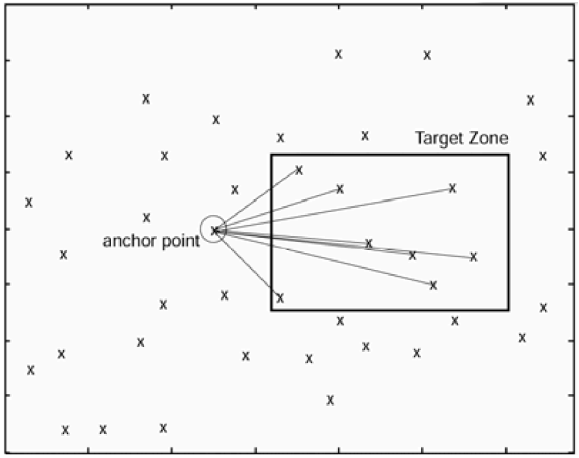


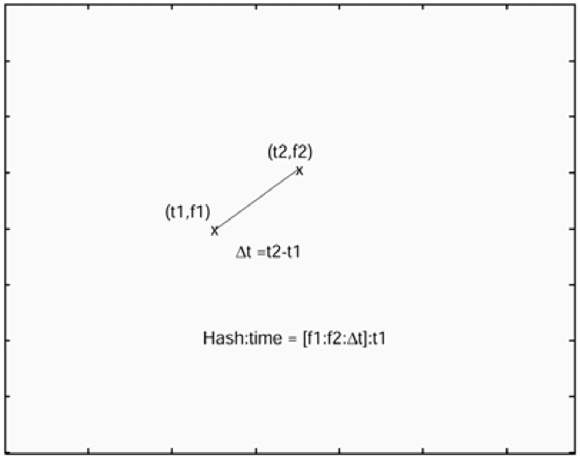


pairs have more entropy
(more information)

Reducing computation delay

- Hashing **pairs** increases specificity, which in turn increases speed.
  - Single point, 10 bits. Pairs, 30 bits.
  - Speed up 1 million, 2^{20}
- But there are F times as many tokens in the database.
- This implies that actual speed up is $1000000/F^2$. For F=10, this implies a speed up of 10000.





Overall gain

- Letting p = prob that one point survives

- Then prob of at least one hash surviving per anchor point is:

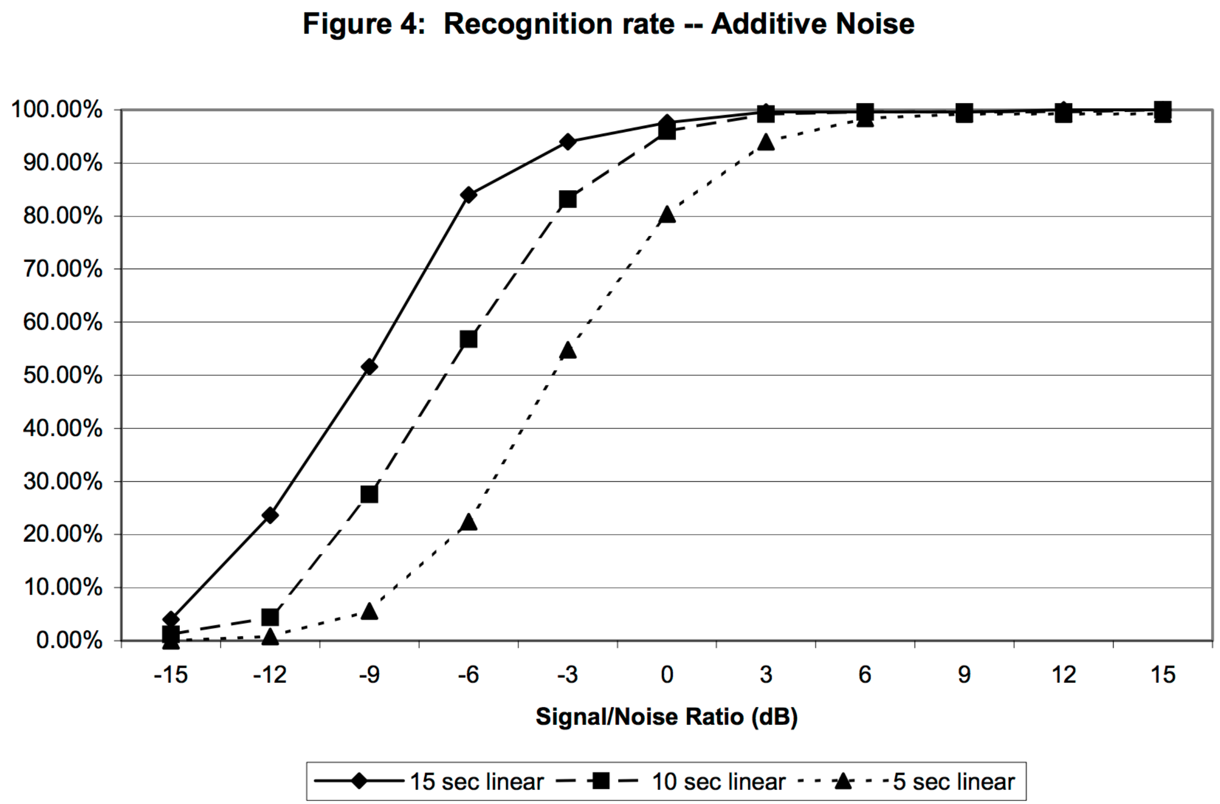
$$p*[1-(1-p)^{F}]$$

- But for large values of F and reasonable values of p, e.g $p>0.1$:

$$p \approx p*[1-(1-p)^{F}]$$

- So at the end we have:
  - 10 times more storage space (F)
  - 10000 times more speed (3 hours vs 1 sec)
  - small loss prob. in detection

Results



In practice, this seems to work out to about three data points per second per song.

Extremely Resilient

- To noise, compression
- To missing data!
- To multiple songs playing at the same time!
- Not only fans looking for songs, but songs looking for fans
- Now for TV
- If you are a bad live singer, Shazam can't help. (well maybe now)

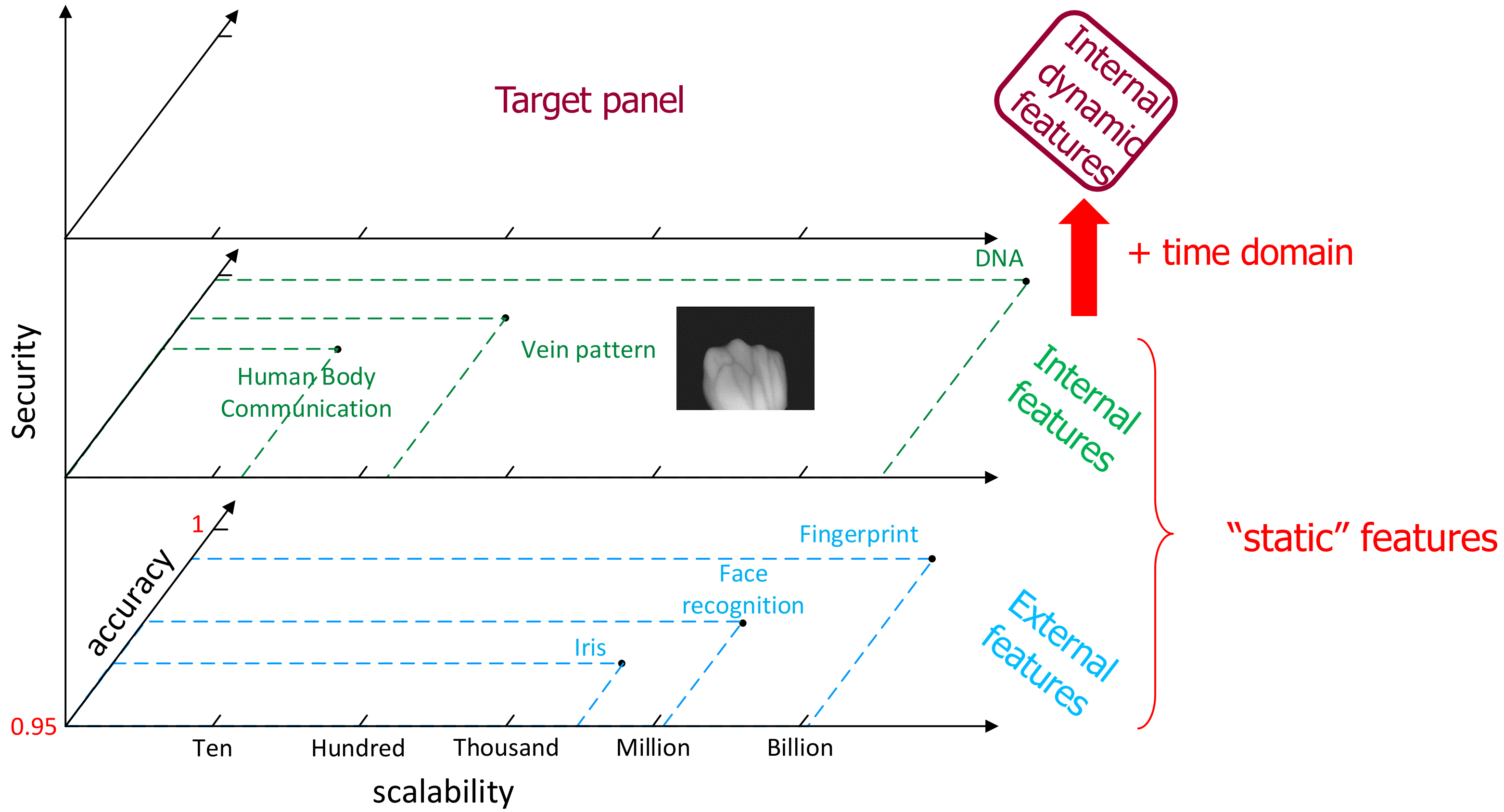
MSC Thesis options

OTHER TOPICS

HemaApp

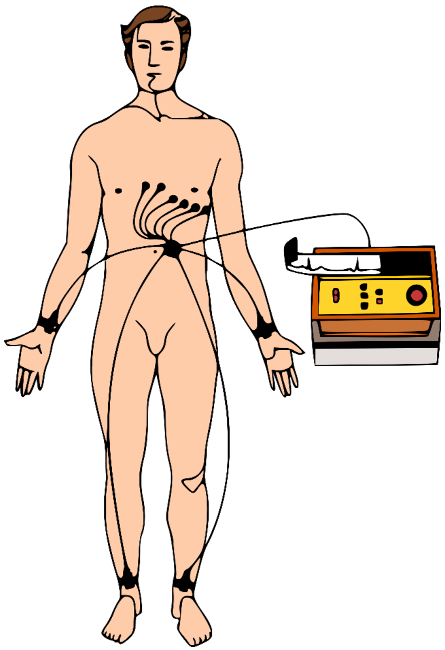
- Website:
  - https://ubicomplab.cs.washington.edu/publications/hemaapp/
- Video:
  - https://www.youtube.com/watch?time_continue=89&v=9Gb-uer1cEI
- Paper:
  - https://ubicomplab.cs.washington.edu/pdfs/hemaapp.pdf

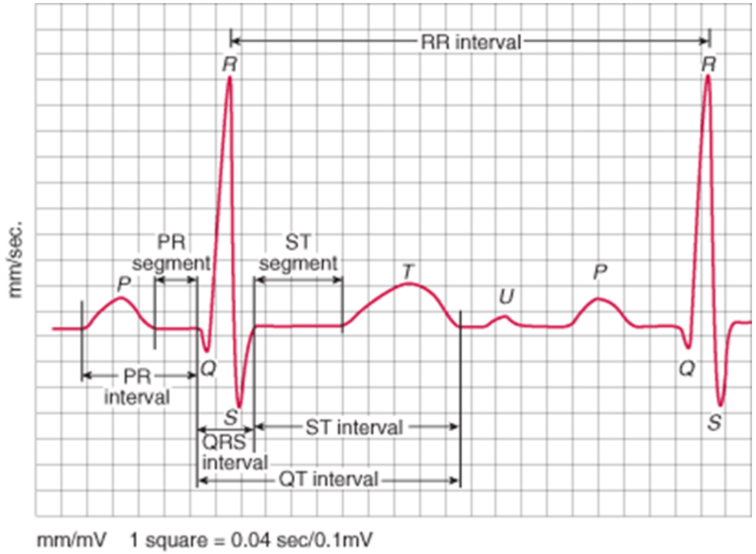
(1) BloodID



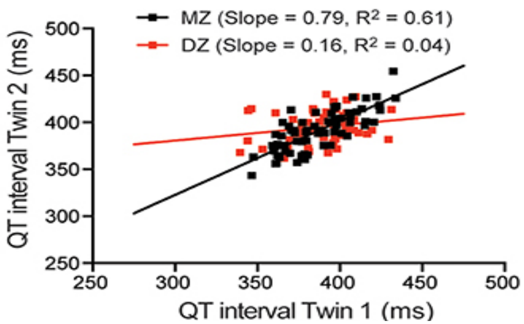
Target panel
Internal dynamic features
+ time domain
DNA
Vein pattern
Human Body Communication
Internal features
Fingerprint
Face recognition
Iris
External features
"static" features
Security
accuracy
1
0.95
Ten
Hundred
Thousand
Million
Billion
scalability

Potential of the cardiac authentication





1. Blood vessels
2. Heart structure
3. Heartbeat strength



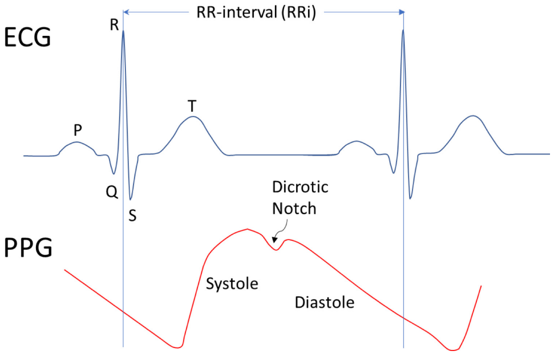
Distinguish twins

Drawbacks for ECG authentication:
1. Highly invasive
2. bulky

30

Photoplethysmogram(PPG)

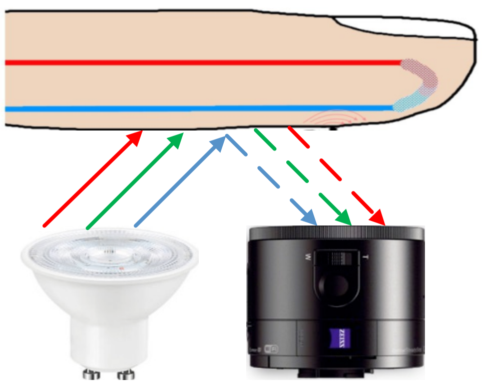
A photoplethysmogram (PPG) is an optically obtained plethysmogram, a volumetric measurement of an organ.



Authentication advantages:

1. Similar properties to ECG signal
2. Non-invasive
3. Low cost and portable

Phone camera PPG authentication



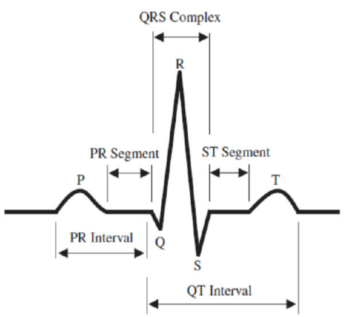
Flash light Camera

Advantages:

1. Integrated with phone (pervasive and no additional cost)

2. Non-invasive

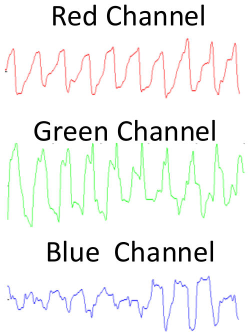
3. Exploit more spectrums than the PPG sensor (more potential features



ECG signal

Entropy

≈



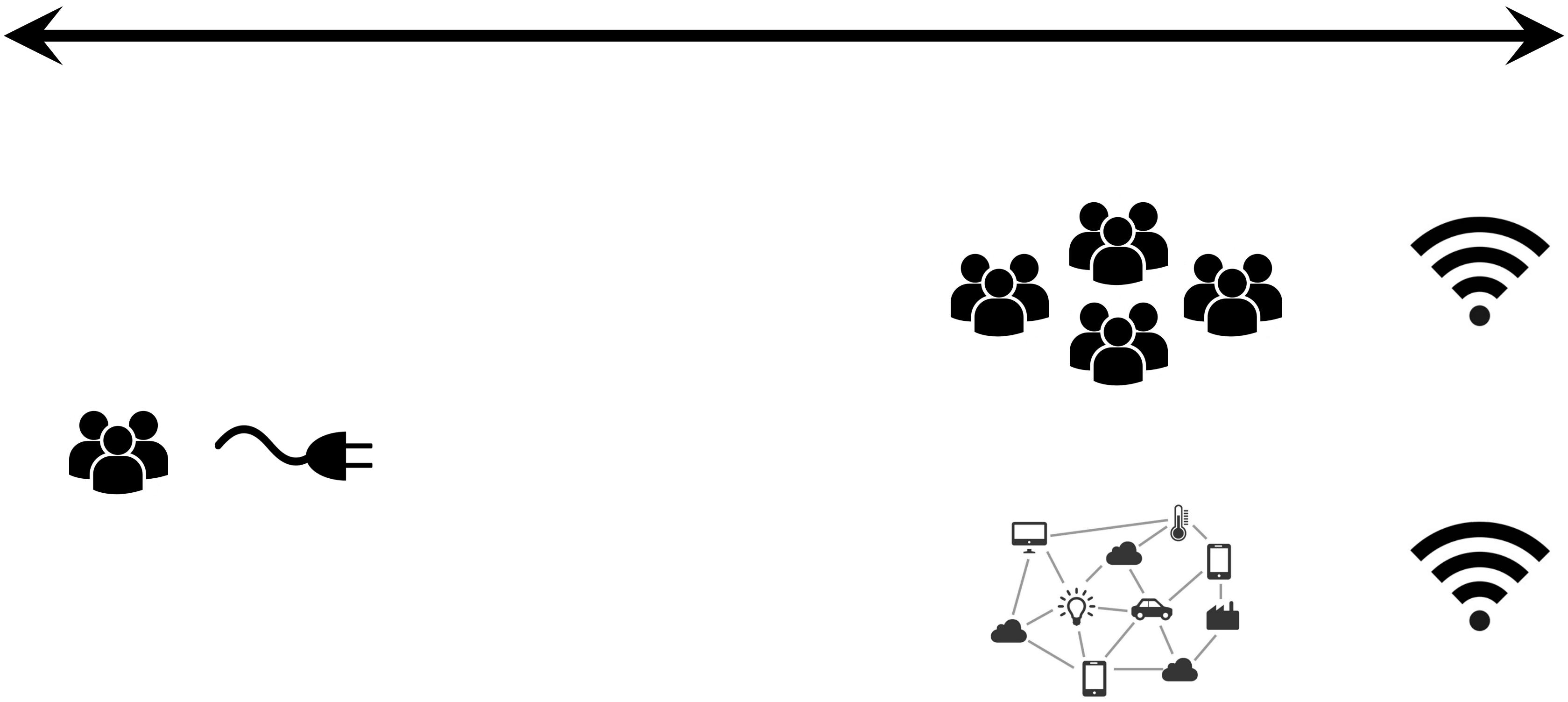
RGB PPG

(2) Indoor Localization

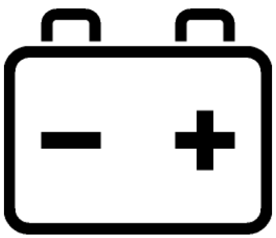
- New methods
- Chronos:
  - Video: https://www.youtube.com/watch?v=cJx7ewEyuzo
  - Paper: https://www.usenix.org/system/files/conference/nsdi16/nsdi16-paper-vasisht.pdf
- SpotFi
  - Paper: https://web.stanford.edu/~skatti/pubs/sigcomm15-spotfi.pdf
  - Presentation at conference:
  - https://www.youtube.com/watch?v=TTJbKMVx3PQ

Sunlight for Wireless Communication

In less than 20 years, wireless has exploded



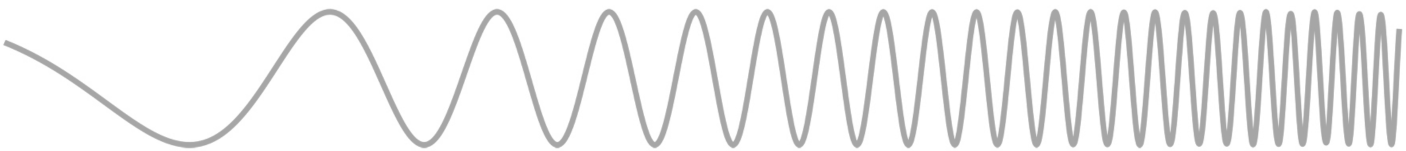
Wireless needs two fundamental resources



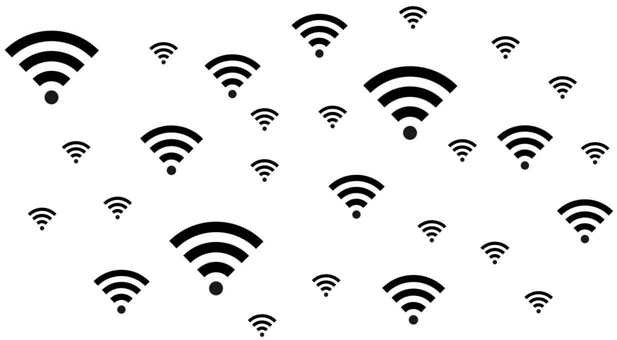
energy

bandwidth

More bandwidth: from radio to light

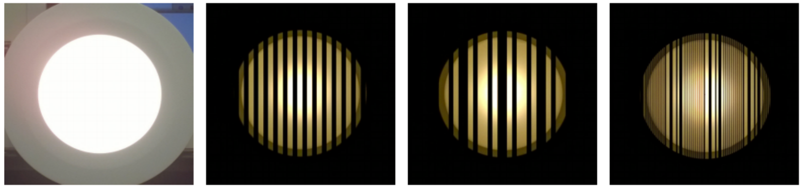


Radio

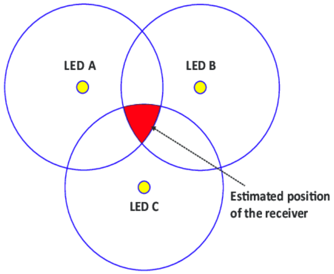


Light

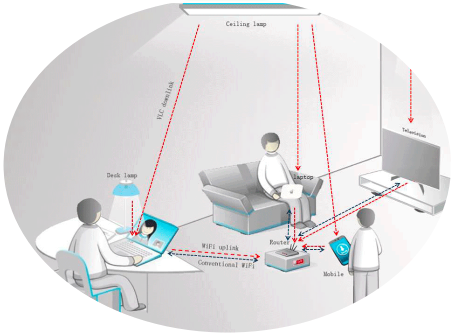
Active light communication: applications



smart lighting systems

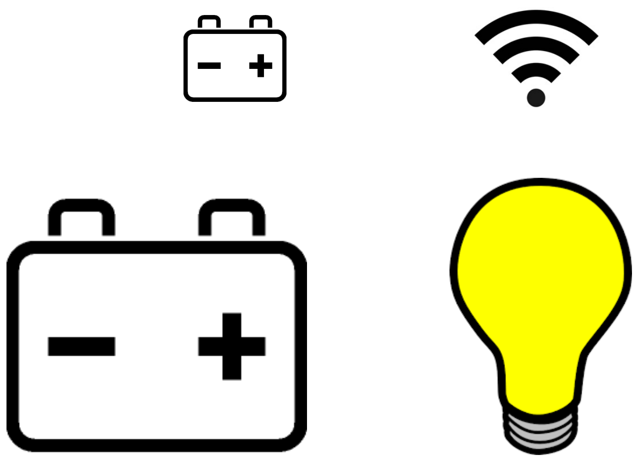


indoor localization



low-cost platforms

Active light communication: limitations

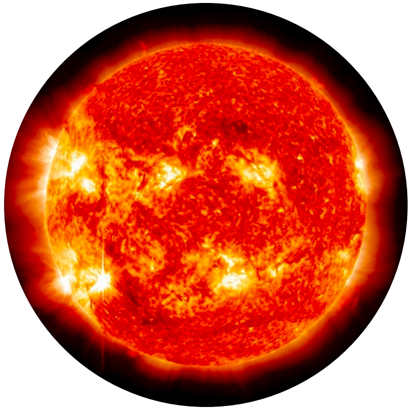


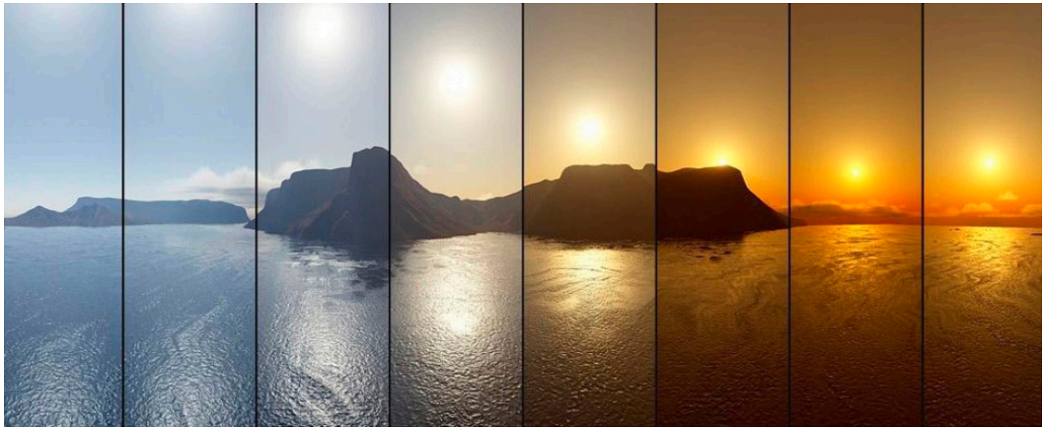
Communication
(10 %)

Illumination
(90 %)

Bandwidth ✓ Energy ✗

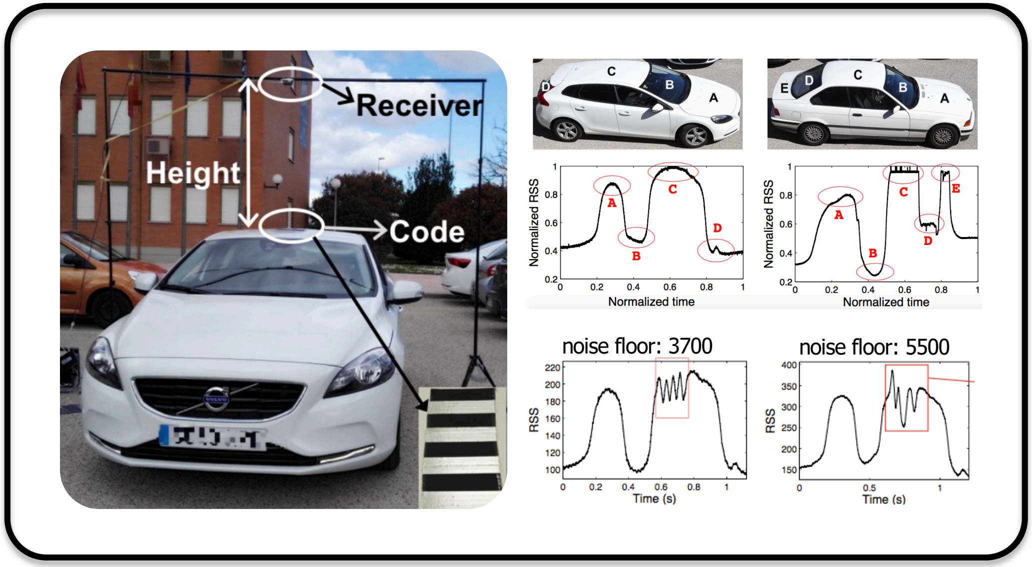
Energy: Passive light



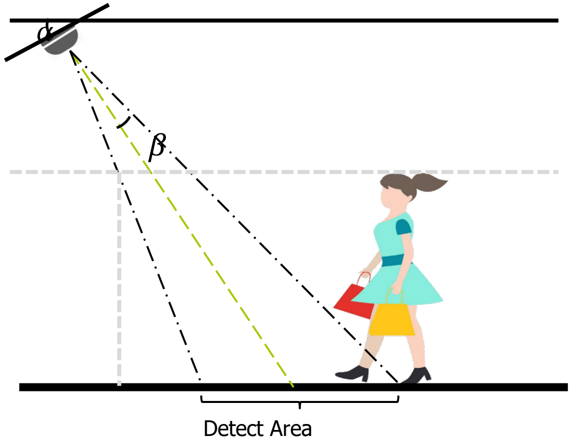


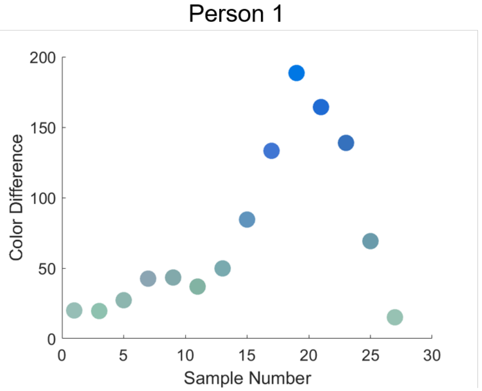
more pervasive
more energy

Passive light: mobile objects



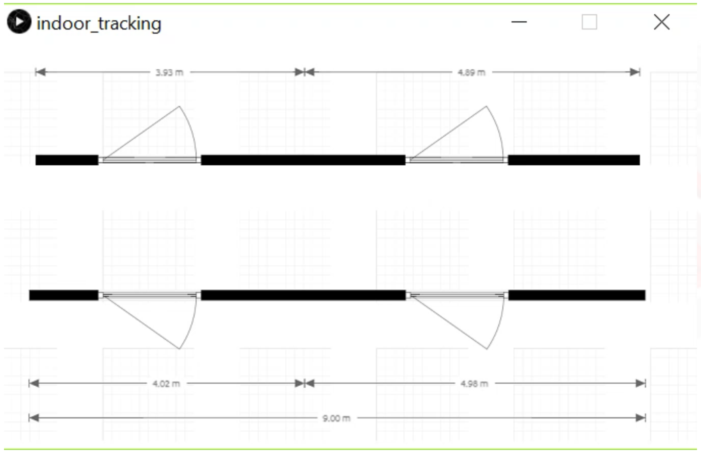
Passive light: mobile people



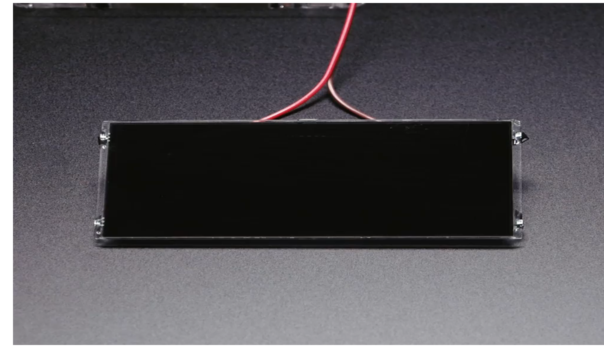


ZUMTOBEL

PATENT PENDING

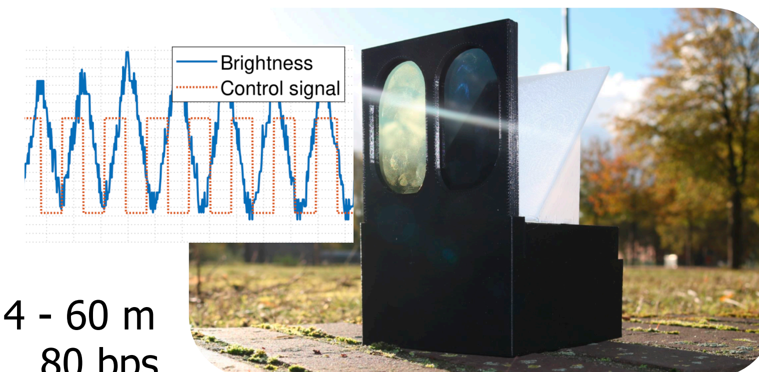


Passive light: static objects



Receiver

Range: 4 - 60 m
Data rate: 80 bps
No flickering



Transmitter

Passive light *vision*: theory, platforms & protocols

sunlight link

enlighted tram stop

reflective car