Welcome!

CIS 7000-008: Special Topics on Wireless and Mobile Sensing

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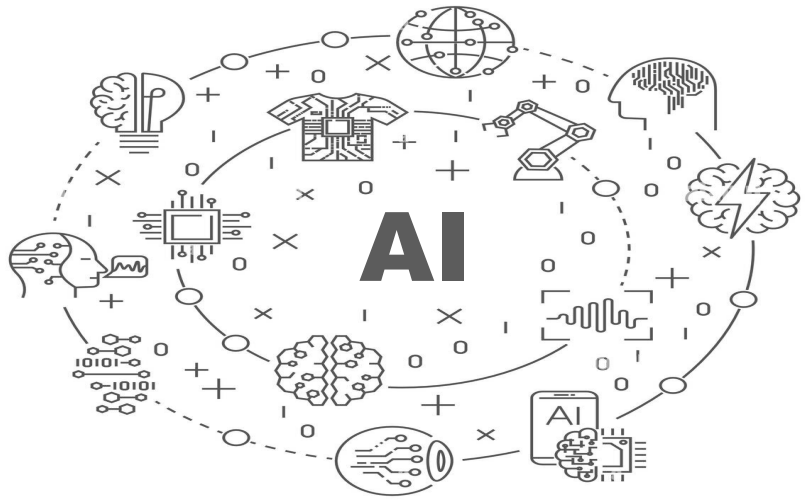
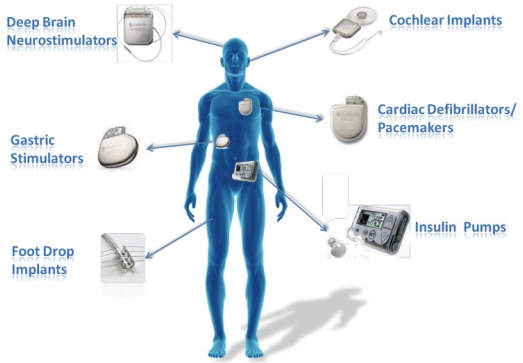
Lecture 1



Penn
University of Pennsylvania

Wireless Homes

Wireless Biomedical Implants



Wireless Wearables

Cellular Networks

Wireless Sensors

UAVs

Wireless Data Centers

Wireless VR

Wireless Vehicles

Wireless Signals Are Every Where

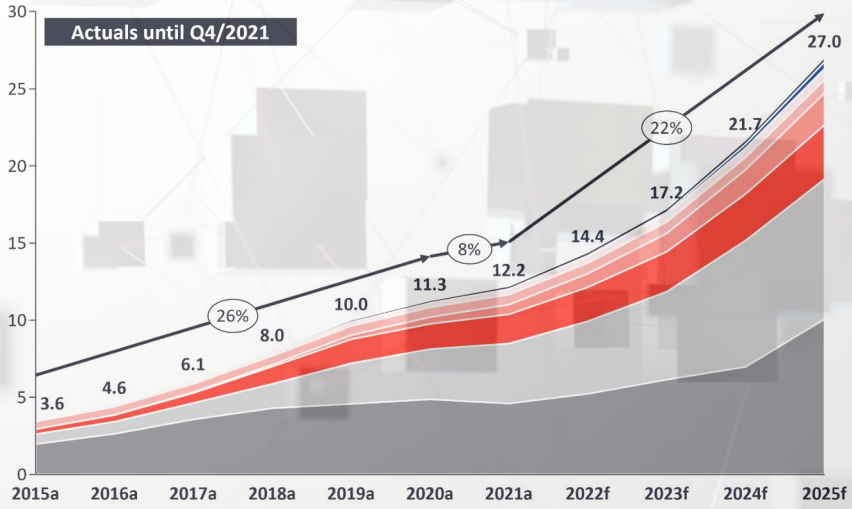
IOT ANALYTICS

May 2022

Your Global IoT Market Research Partner

Global IoT Market Forecast [in billion connected IoT devices]

Number of global active IoT Connections (installed base) in Bn

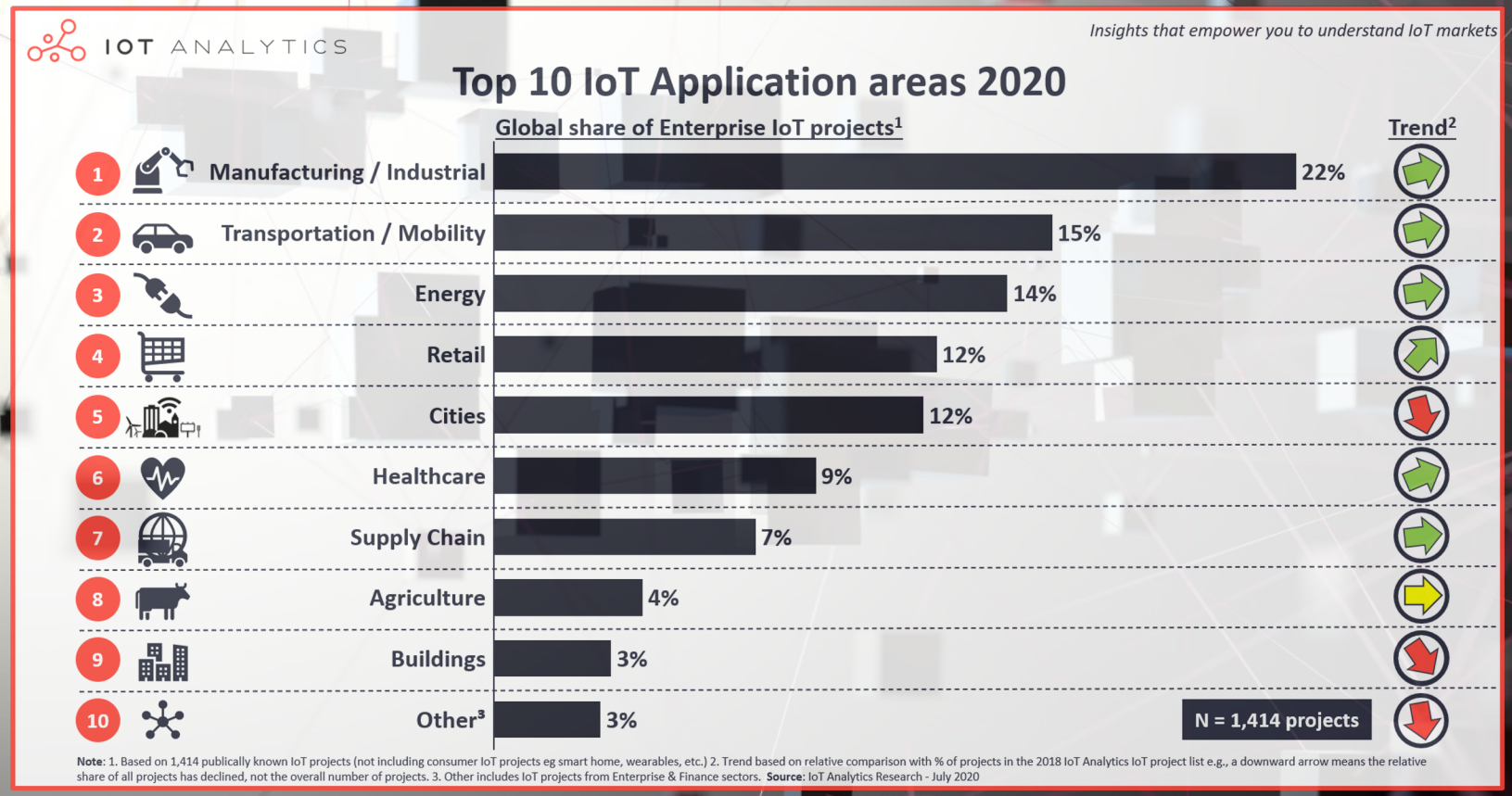


CONNECTIVITY TYPE	CAGR 20-21	CAGR 21-25
Wireless Neighborhood Area Networks (WNAN)	17%	11%
5G IoT	-	159%
Other	22%	20%
Wired IoT	4%	7%
LPWA	42%	34%
Legacy Cellular (2G/3G/4G)	16%	17%
Wireless Local Area Networks (WLAN)	19%	24%
Wireless Personal Area Networks (WPAN)	-6%	22%

XX% = CAGR

Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes Ethernet and Fieldbuses (e.g., connected industrial PLCs or I/O modules); Cellular includes 2G, 3G, 4G; LPWAN includes unlicensed and licensed low-power networks; WPAN includes Bluetooth, Zigbee, Z-Wave or similar; WLAN includes Wi-fi and related protocols; WNAN includes non-short range mesh, such as Wi-SUN; Other includes satellite and unclassified proprietary networks with any range.

The Explosion of Connected Devices



The Explosion of Connected Devices

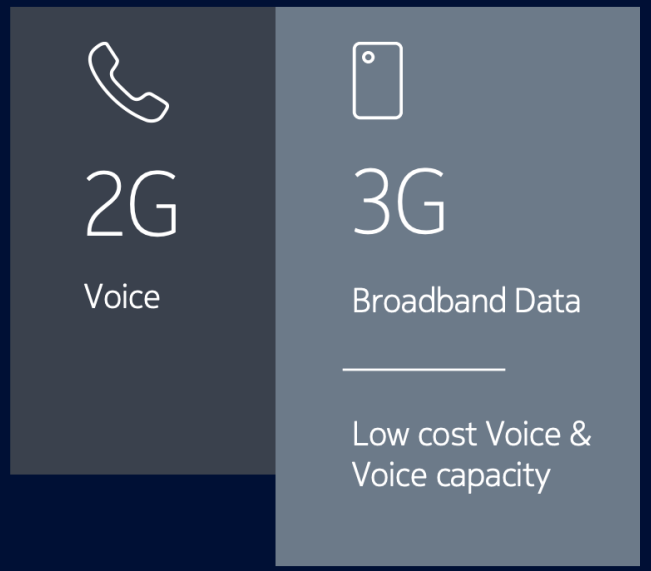
The past, present, and future

2G

Voice

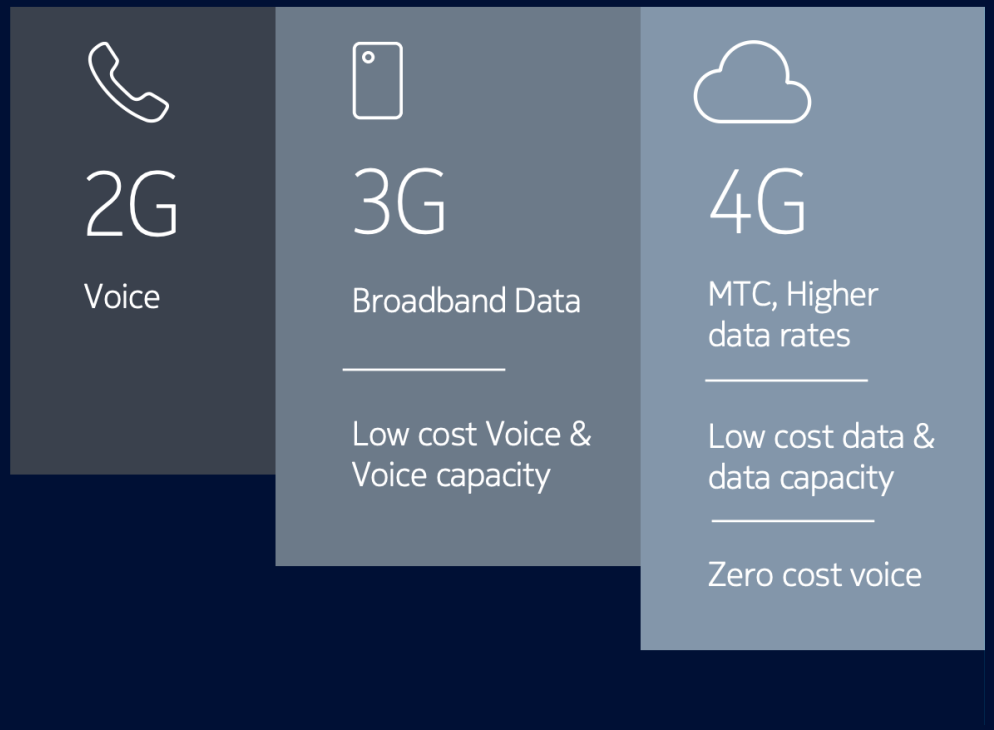
NOKIA Bell Labs

The past, present, and future

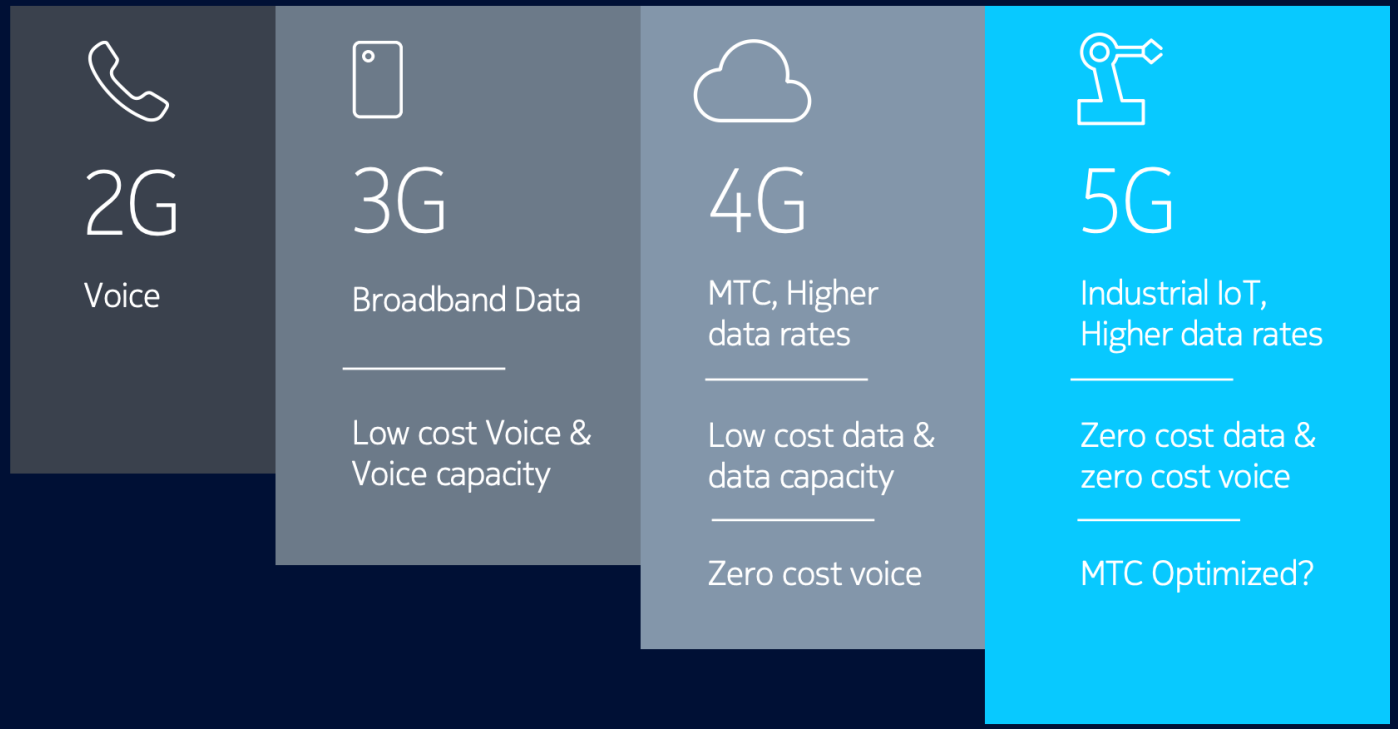


NOKIA Bell Labs

The past, present, and future



The past, present, and future



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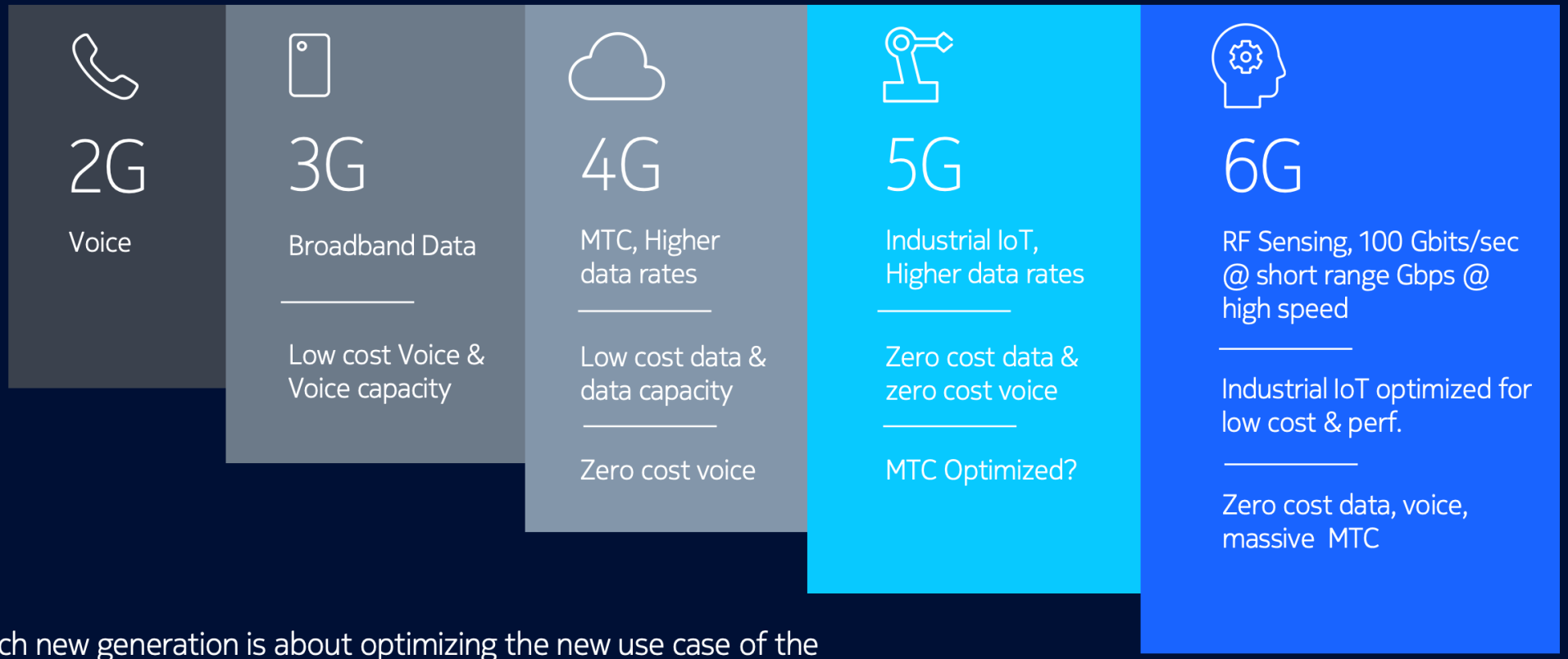
The past, present, and future

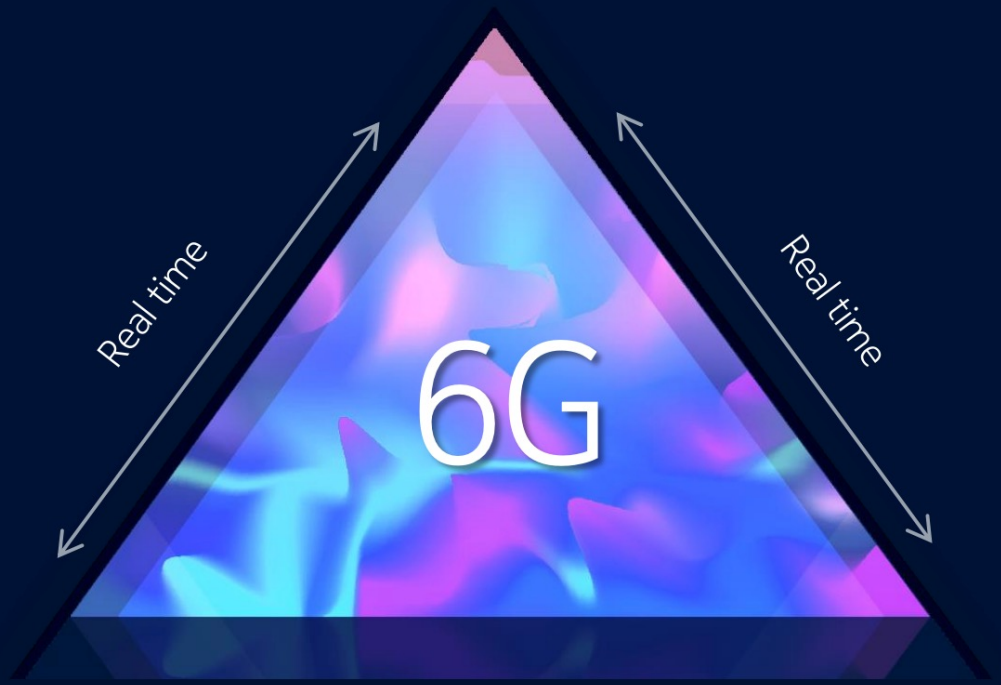


Each new generation is about optimizing the new use case of the previous generation to reduce cost and introduction of new use cases

NOKIA Bell Labs

2030

Digital World



Physical World

Biological World

Real time

6G to unify the experience across physical, digital and biological worlds

NOKIA Bell Labs

Mixed reality co-design

- Remote collaboration
- High resolution, precision
- Low latency interaction
- Experience before prototyping

Emerging Sensing Technologies

New Services: Wireless Localization

GPS does not work indoor→ Use WiFi to localize.

Indoor Navigation

Business Analytics

WiFi Geofencing

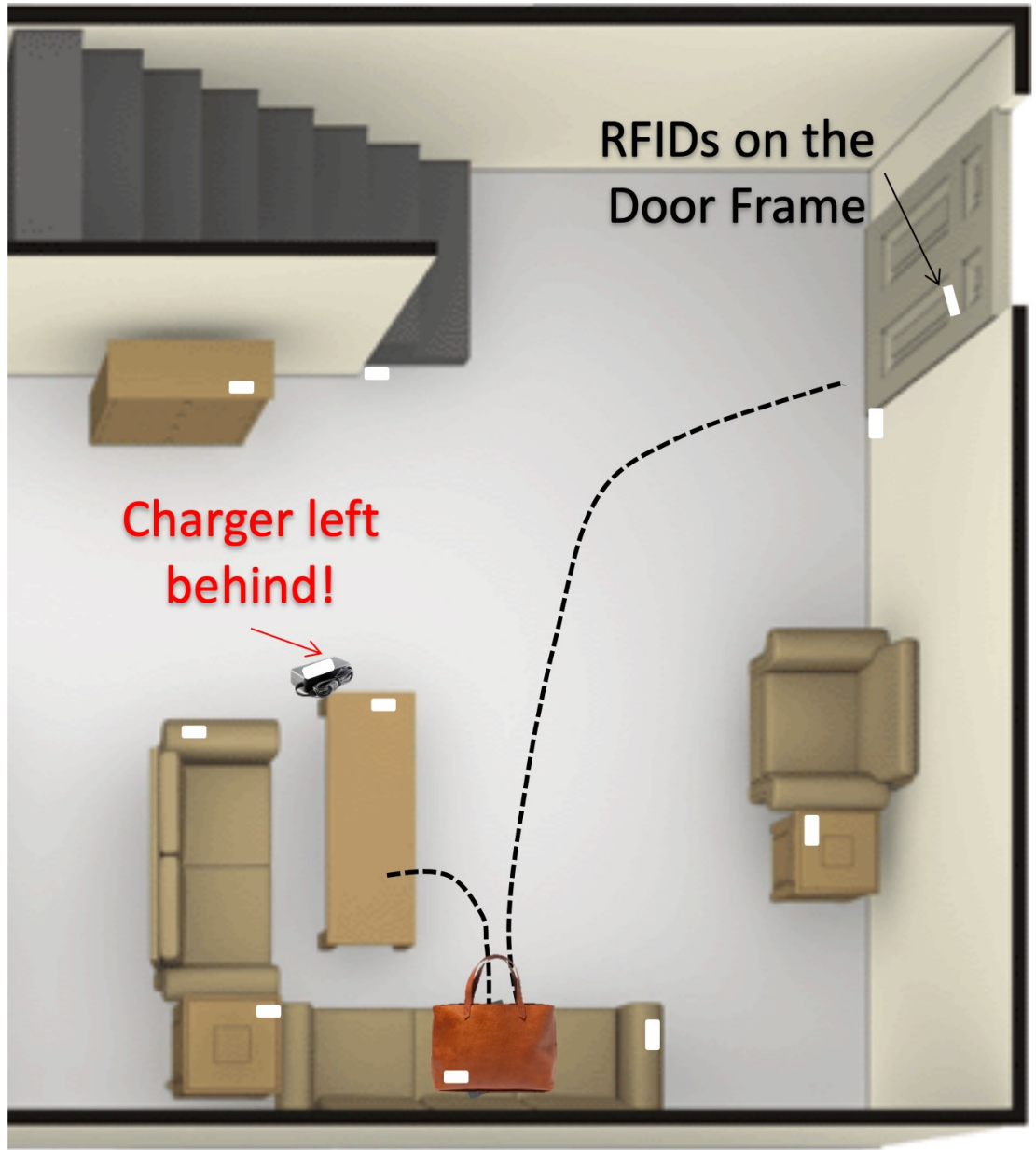
Indoor Robotic Navigation

New Services: Wireless Localization

Localize Everything and Anything!

Battery-free stickers to tag any and every object

Smart Homes



How Do We Get Virtual Touch Screens?

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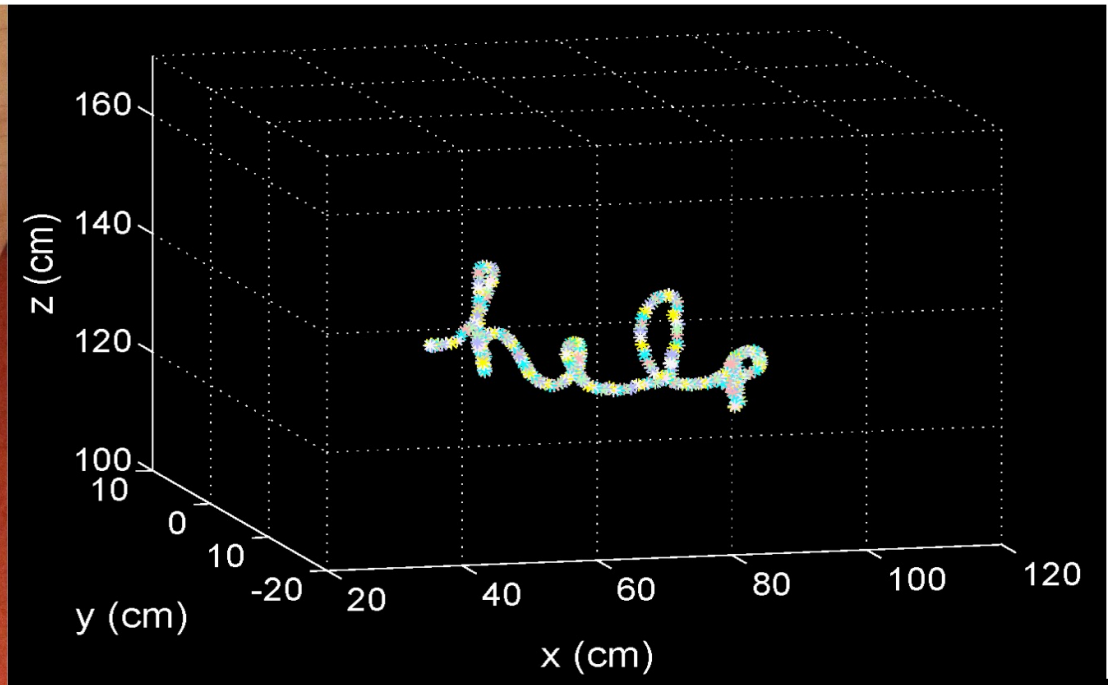
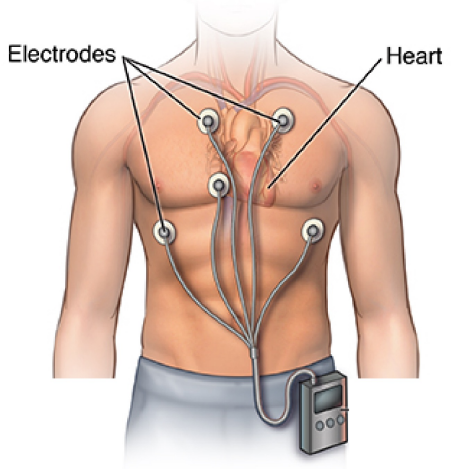


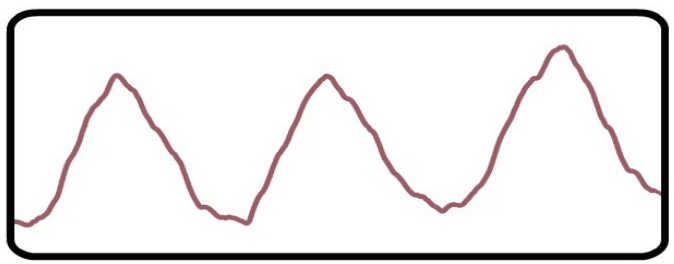
Existing approaches measure vital signs

Use ECG to get very accurate heartbeats [Picard 2001; Kim 2008]

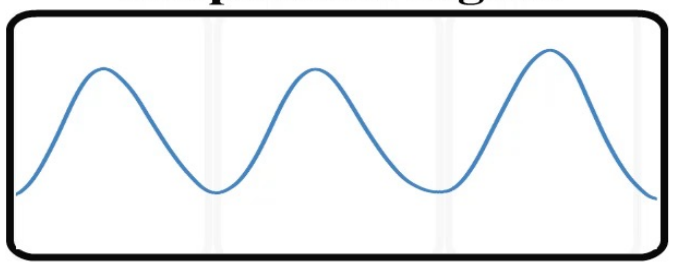


But ECG is too intrusive

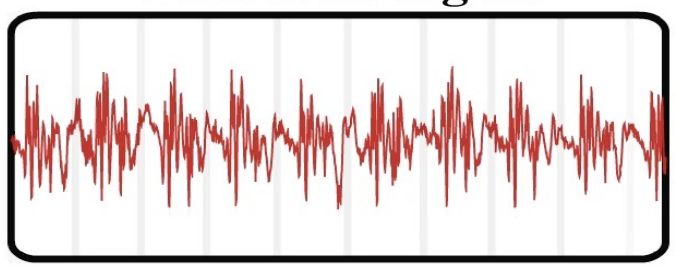
Reflection

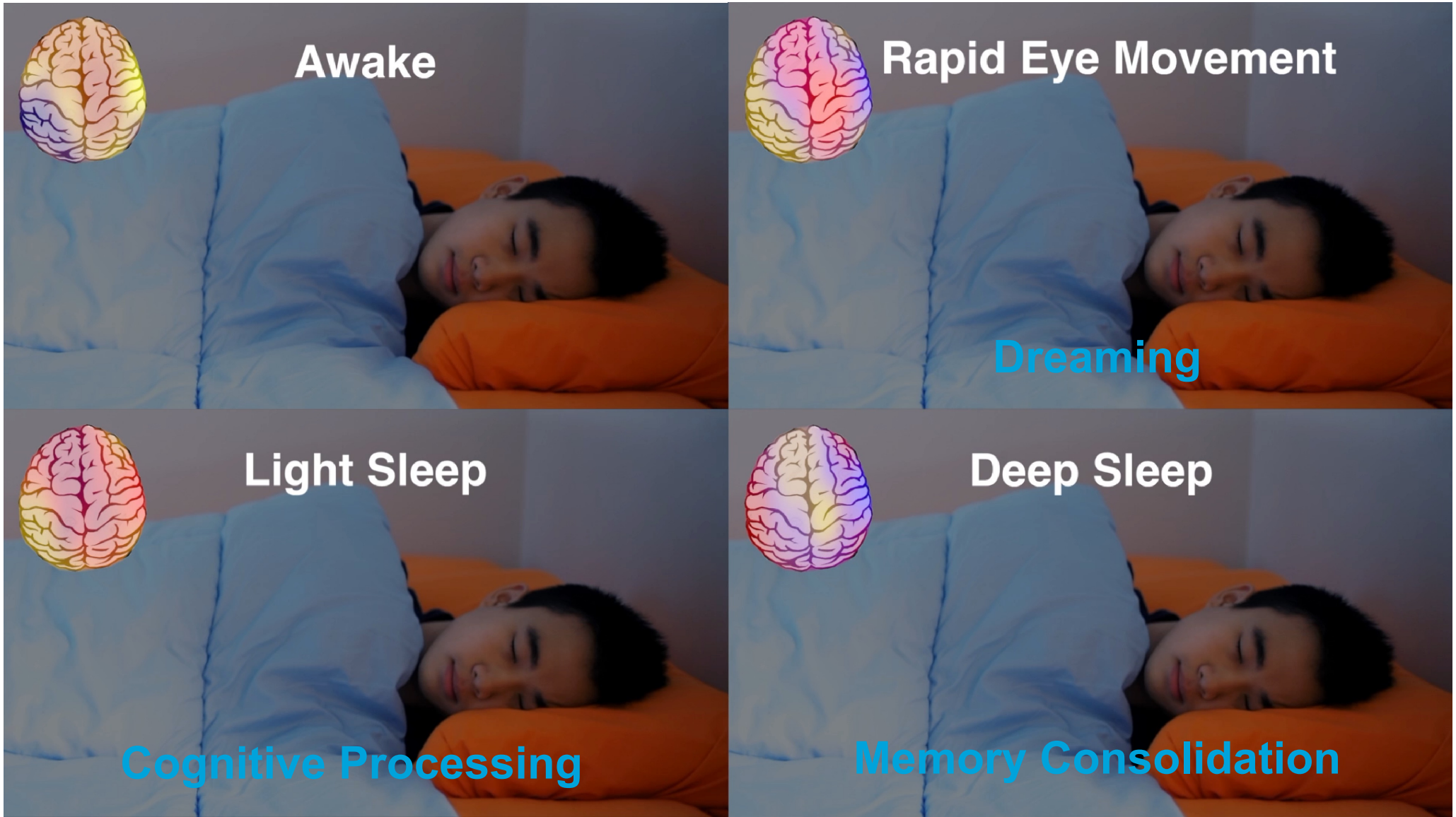


Respiration Signal

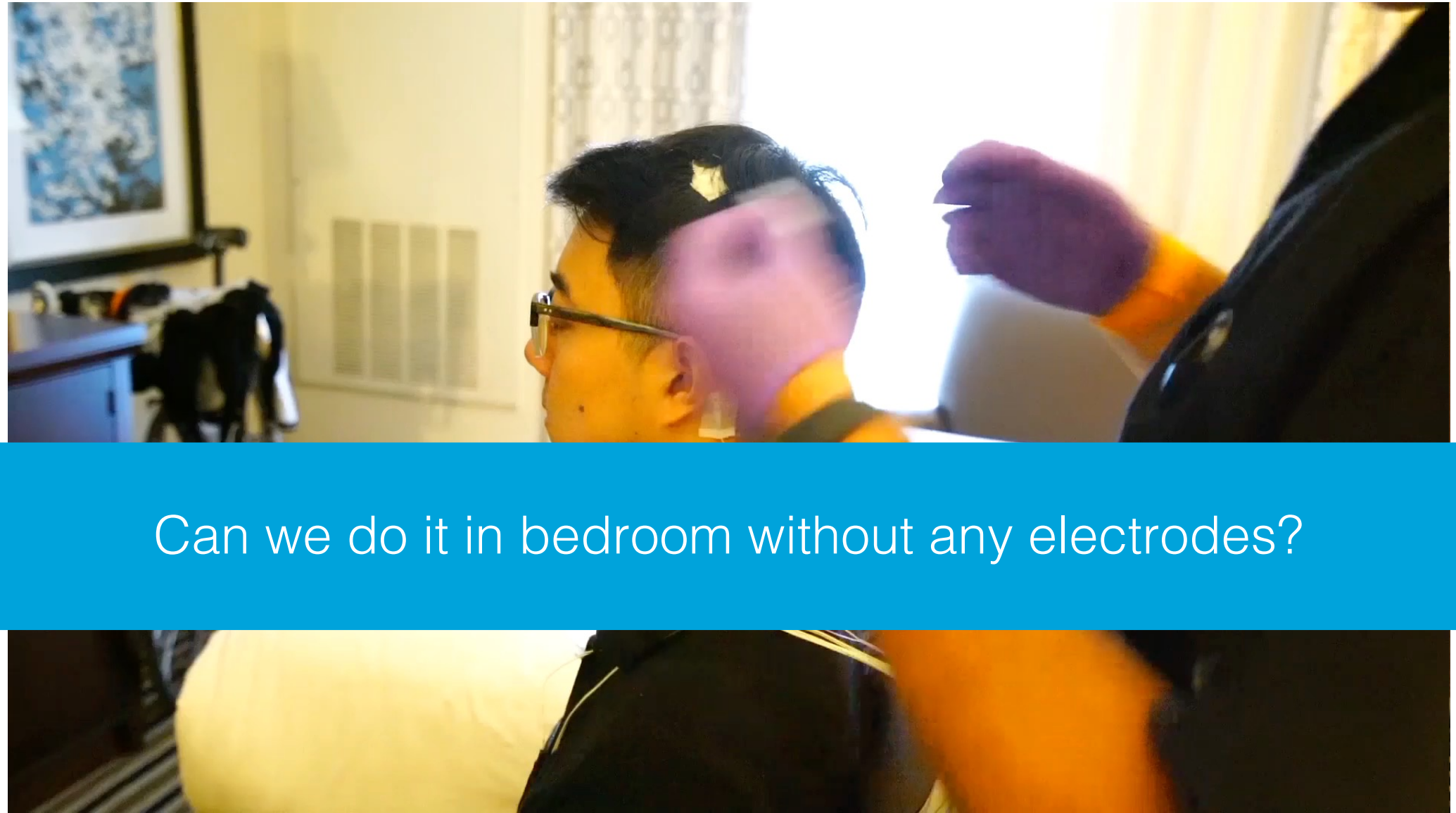


Heartbeat Signal



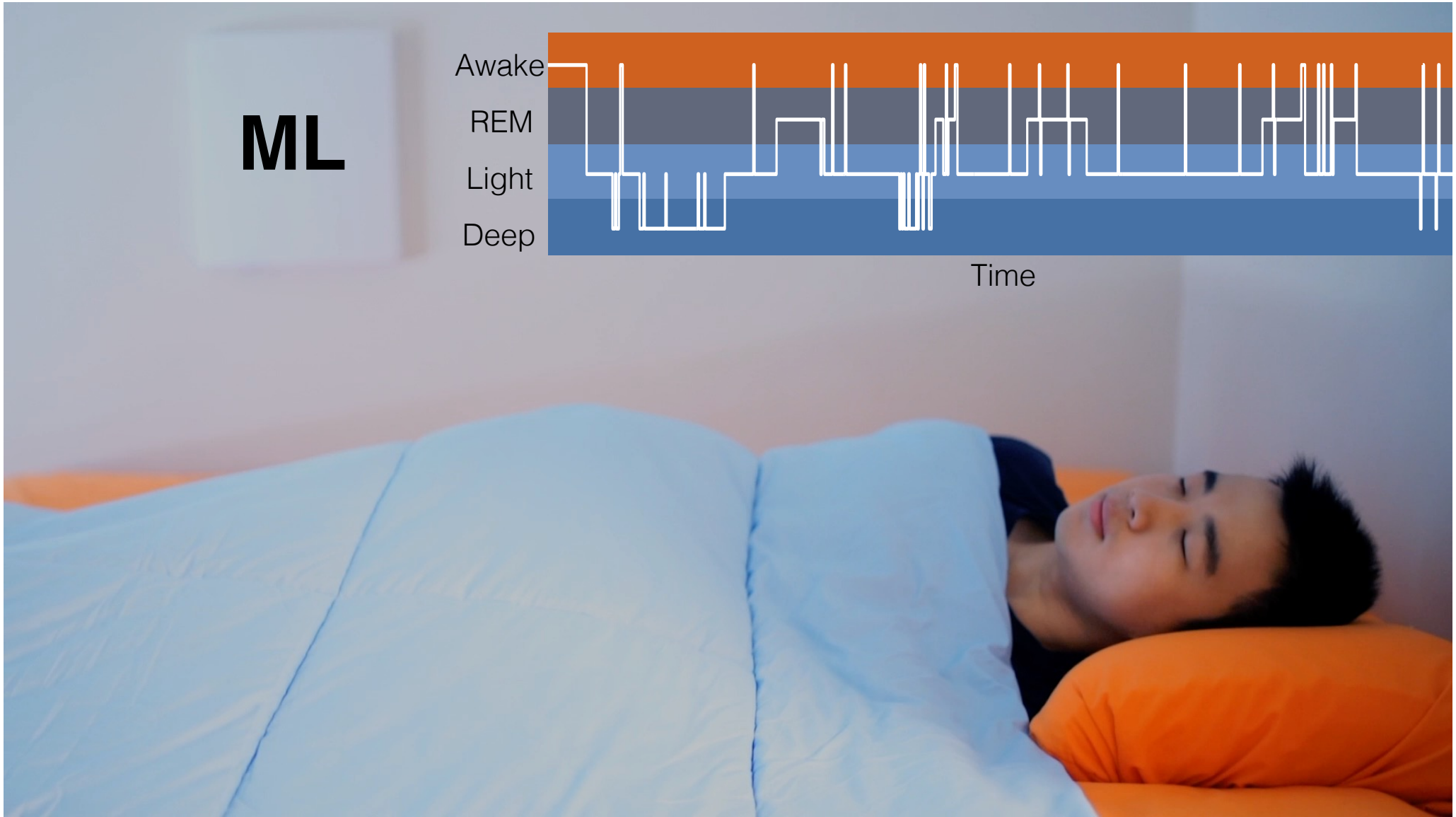

Awake
Rapid Eye Movement
Dreaming
Light Sleep
Cognitive Processing
Deep Sleep
Memory Consolidation

Monitoring Sleep Stages Is Difficult Today



Can we do it in bedroom without any electrodes?

Contactless Sleep Monitoring



Multi-Source Domain Adaptation

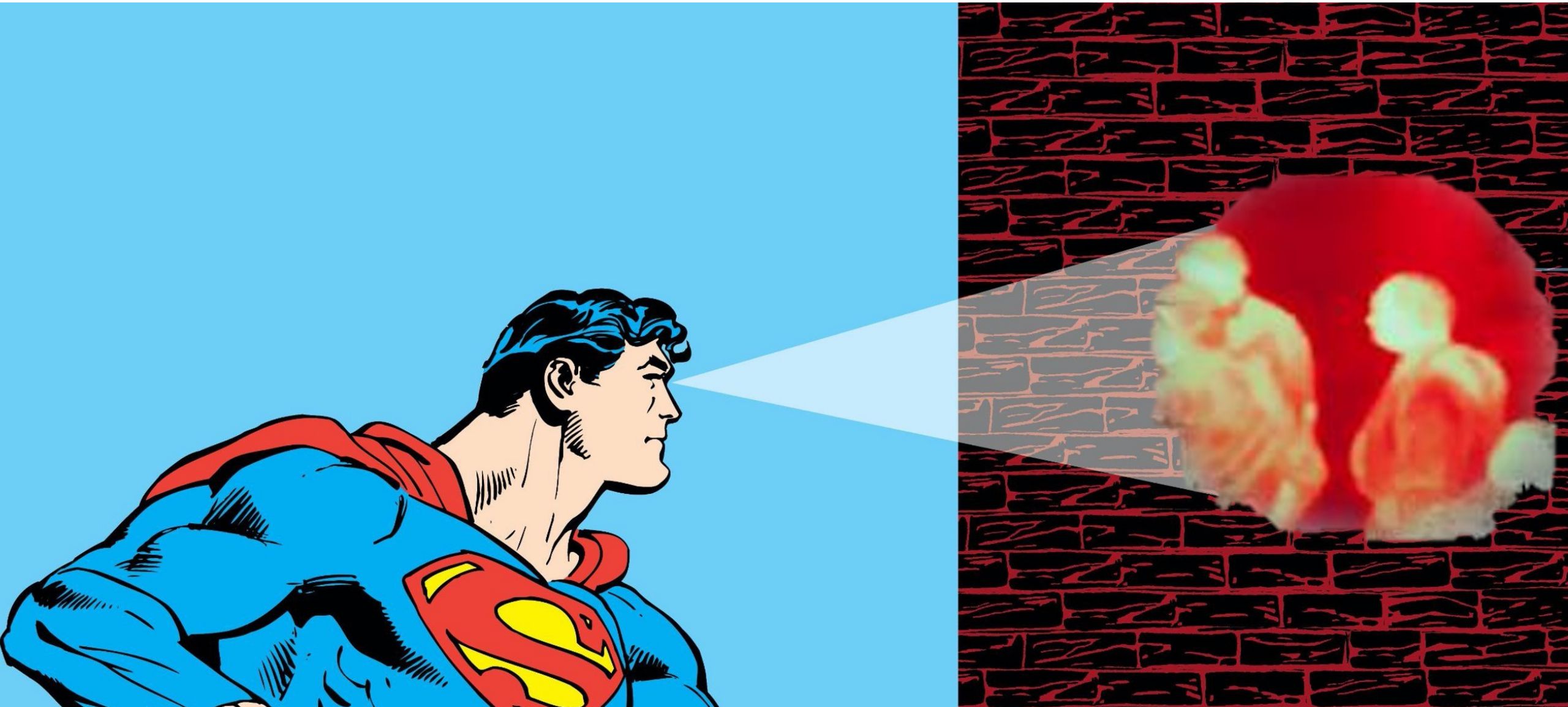
domain = measurement condition + individual

Source domain A

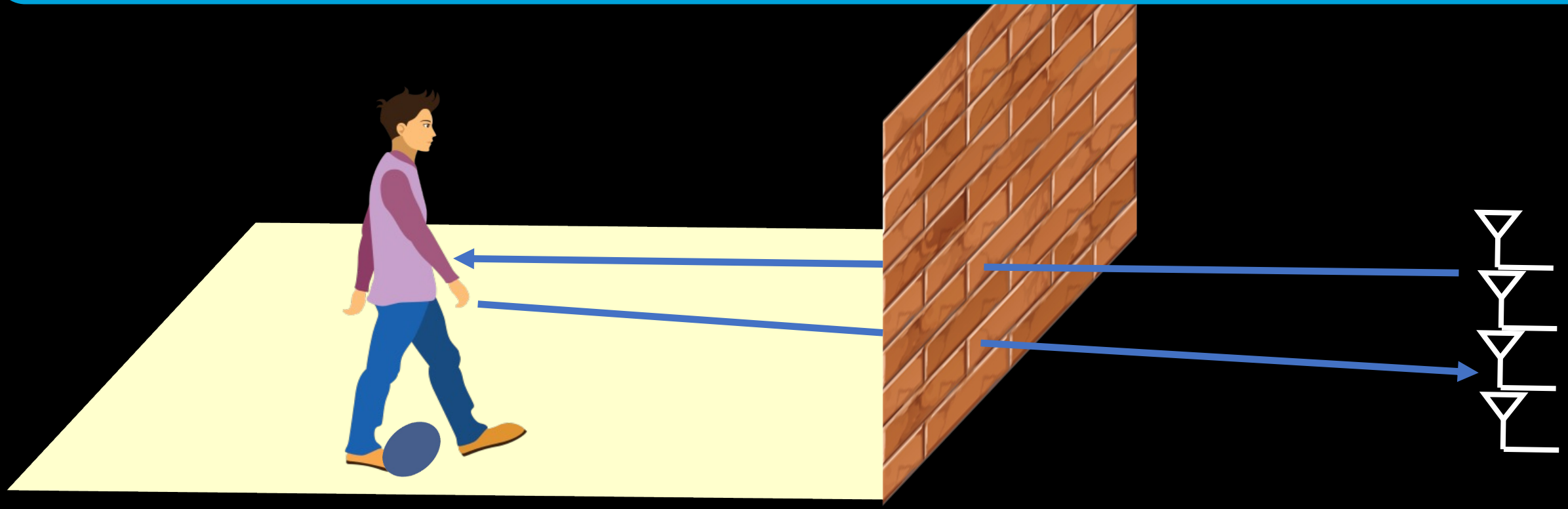
Source domain B

Target domain C

X-Ray Vision



Can we get an x-ray image of a person’s skeleton through the wall?



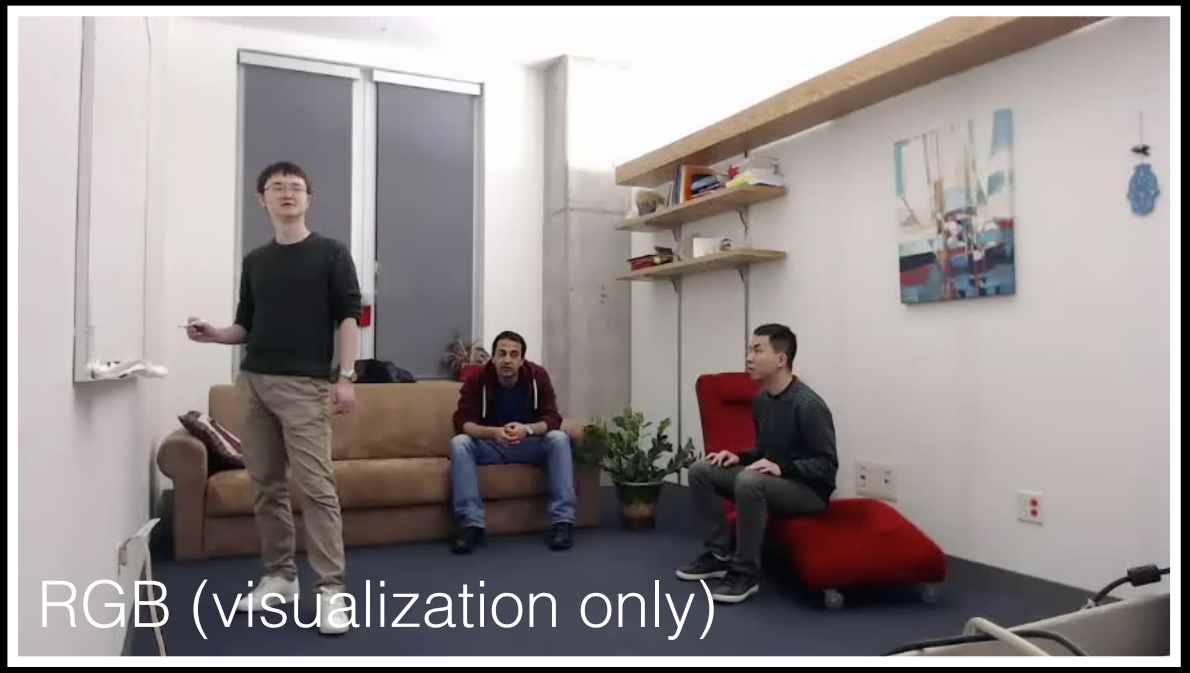
RF-Pose: Through-wall poses using **only** RF

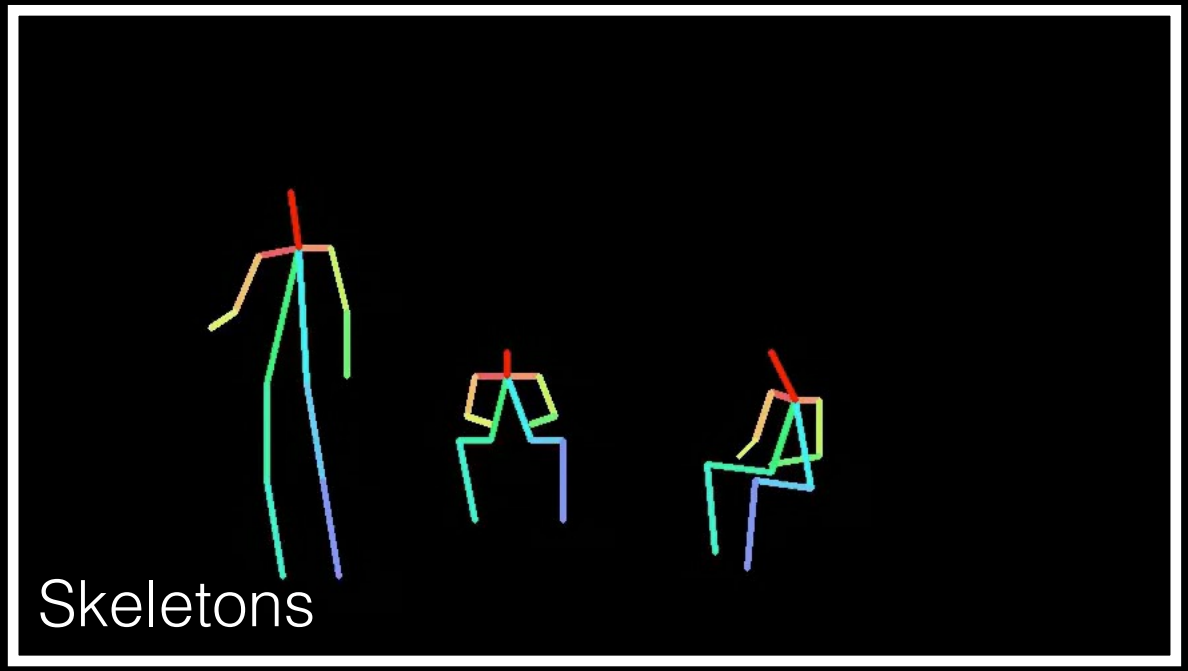
[Zhao et al. CVPR'18]

Skeletons

Confidence Maps

It works with different environments and daily activities





RF-Pose3D

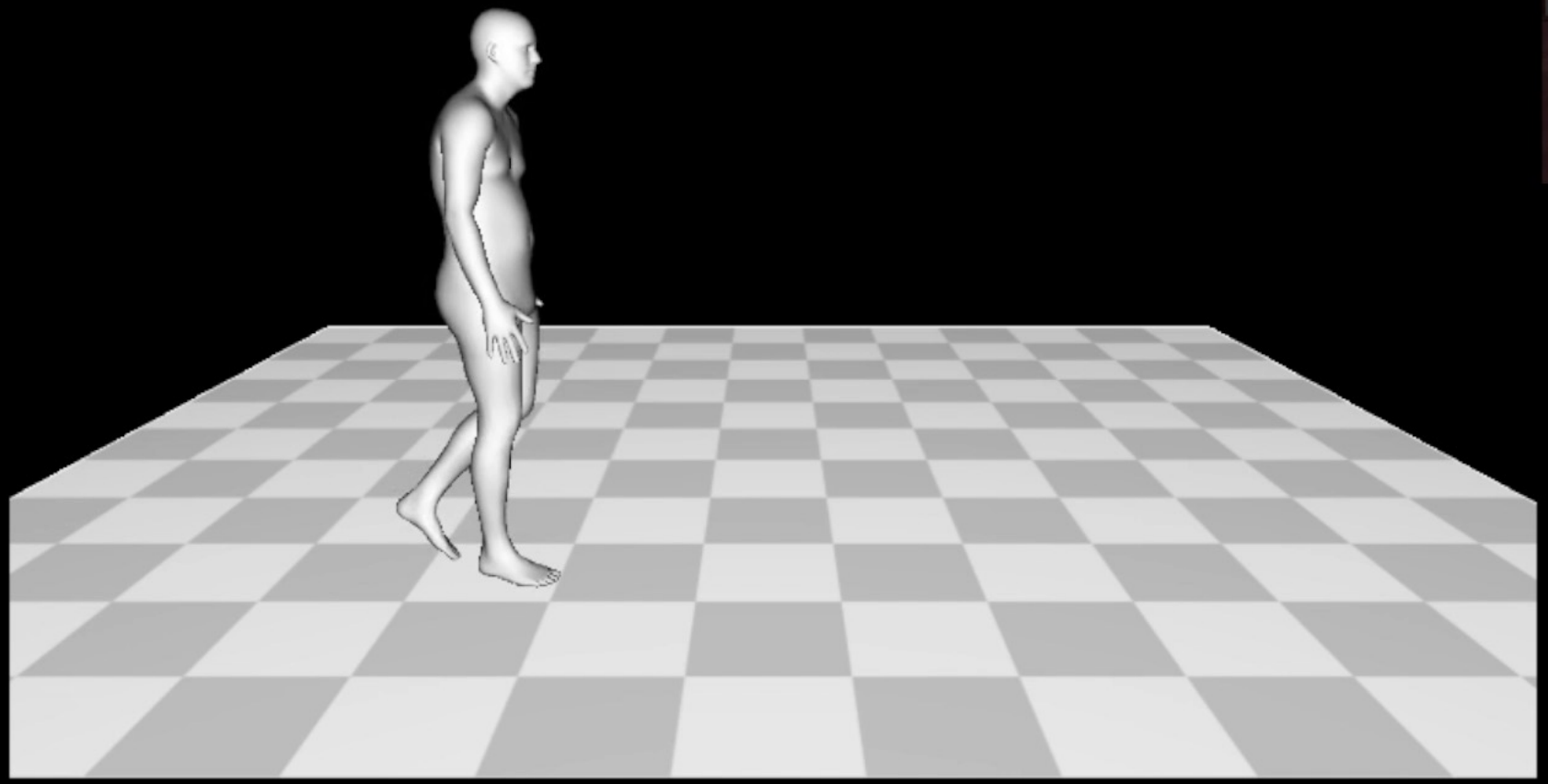
RGB video
(for visualization only)

Zhao et al. (SIGCOMM'18)

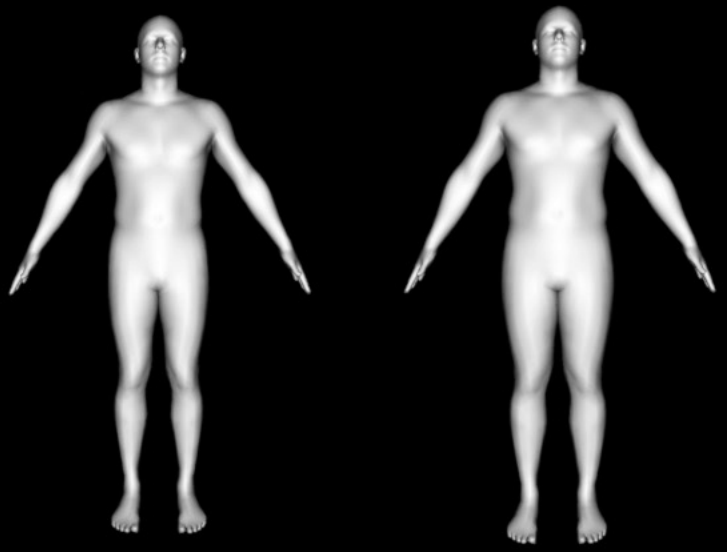
RF-Pose3D

RGB video
(for visualization only)

RGB view

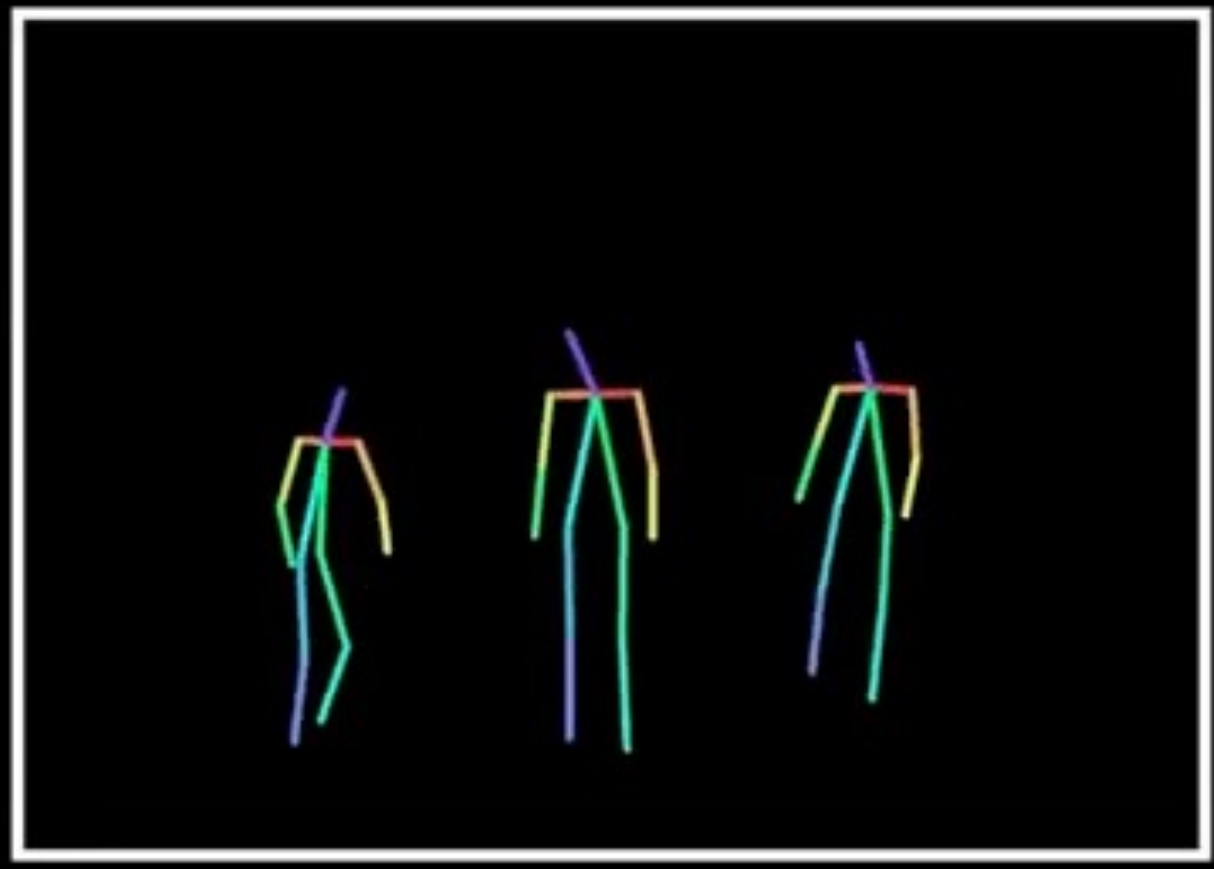


Dynamic human meshes from RF

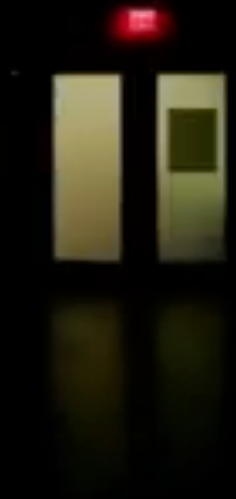


Body shapes from RF

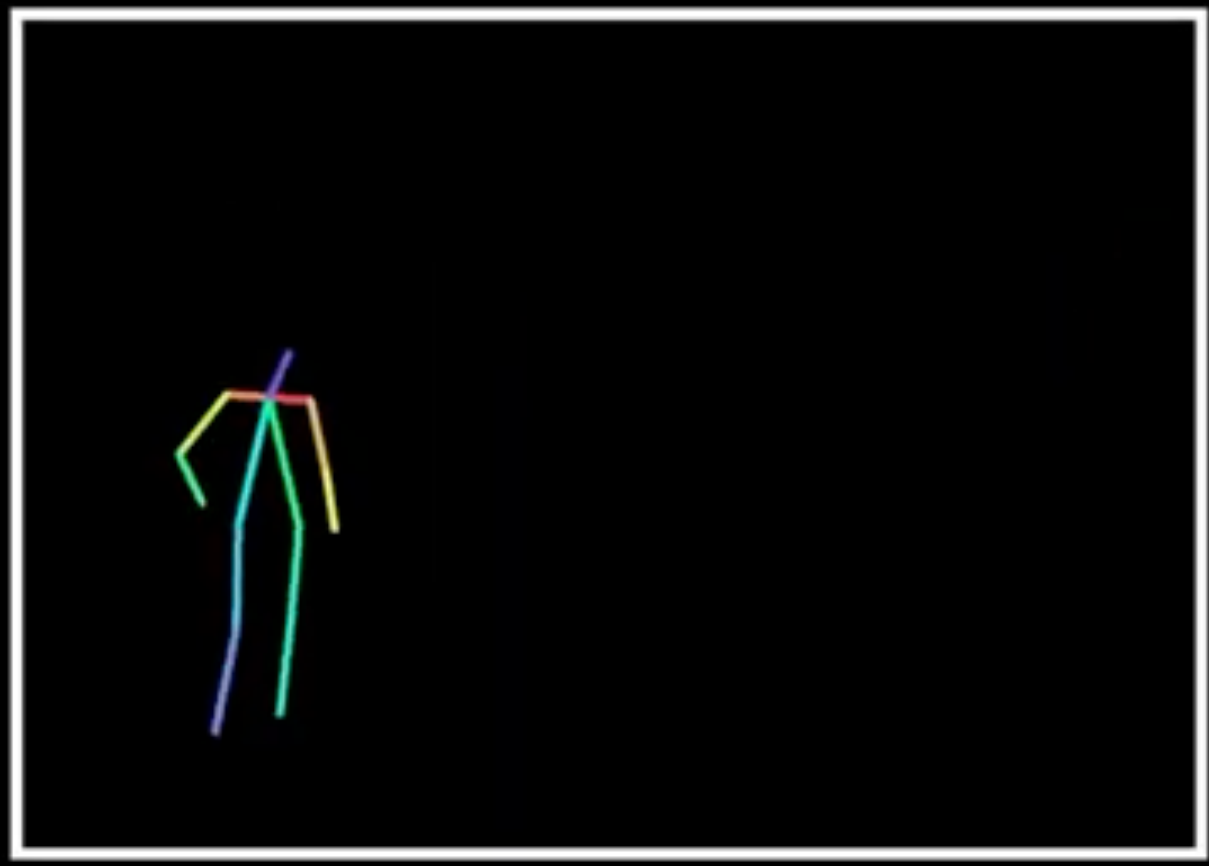
RGB video
(for visualization only)



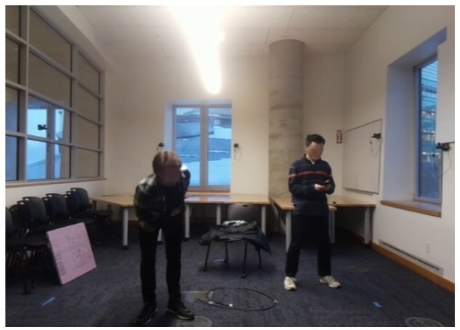
Our predictions

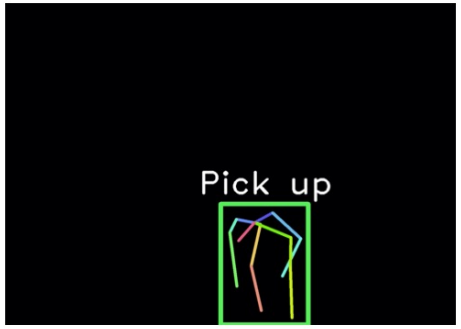


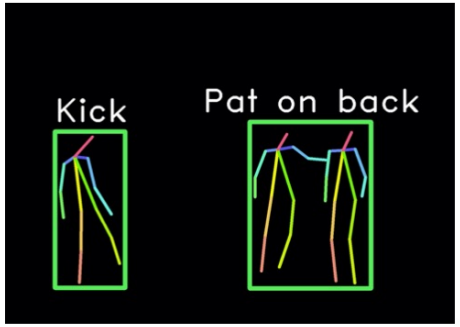
RGB video
(for visualization only)

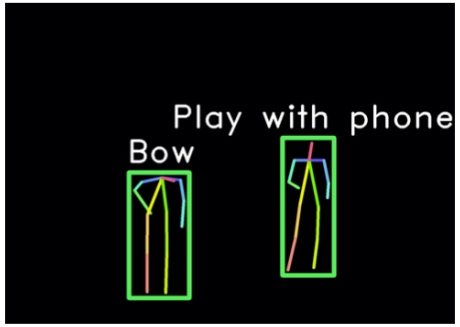


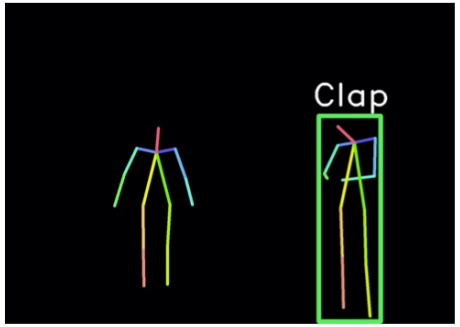
Our predictions

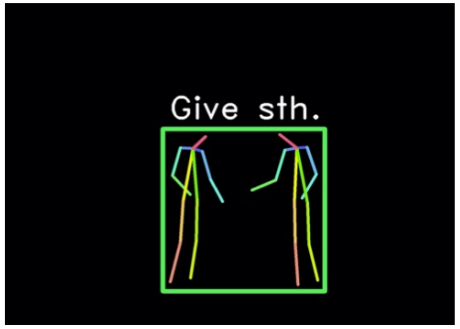


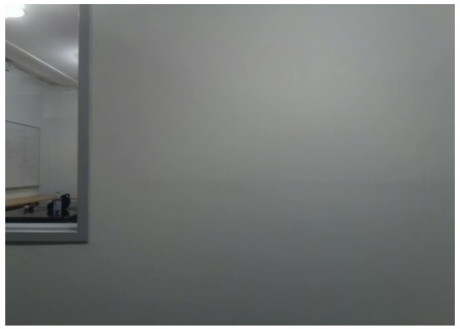

Pick up

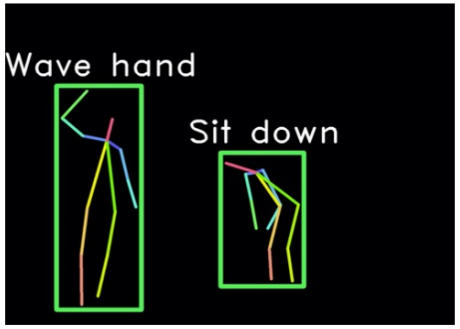

Kick
Pat on back

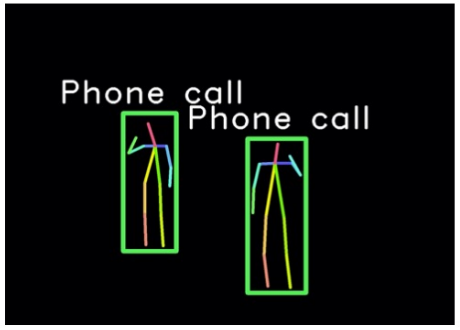

Play with phone
Bow

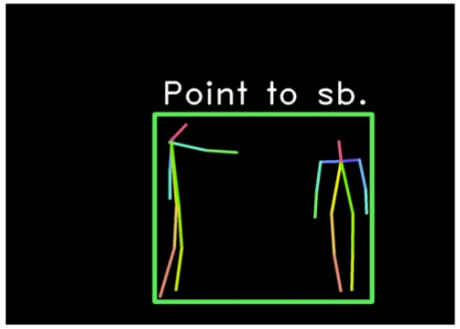

Clap

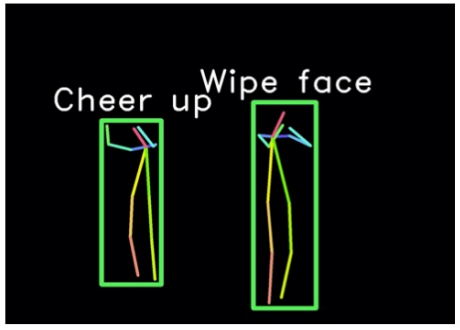

Give sth.

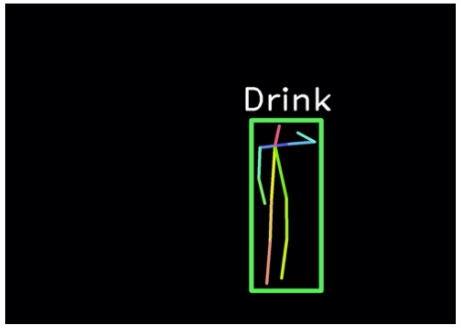



Wave hand
Sit down

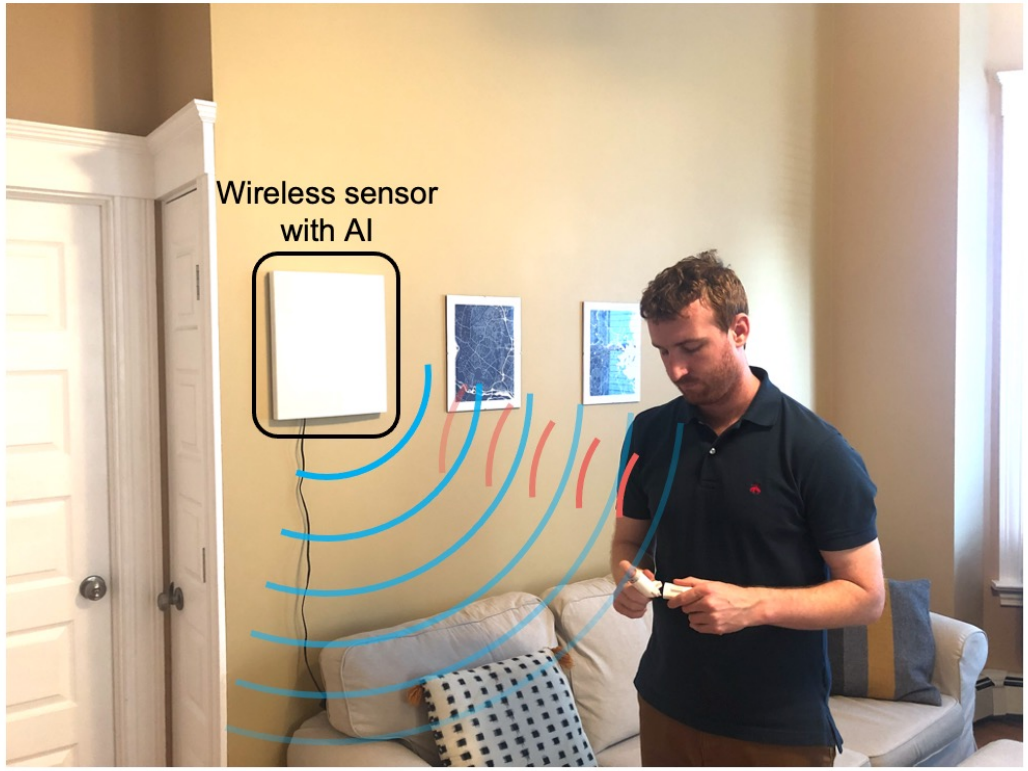

Phone call
Phone call


Point to sb.


Cheer up
Wipe face


Drink

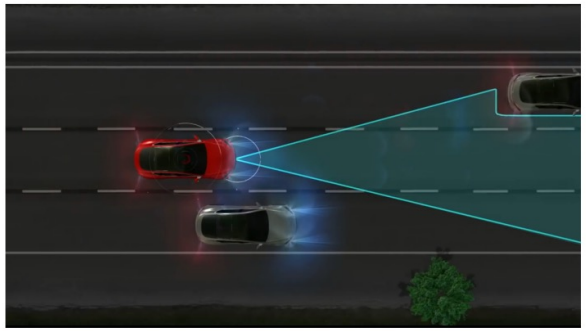
Medication Self-Administration Assessment

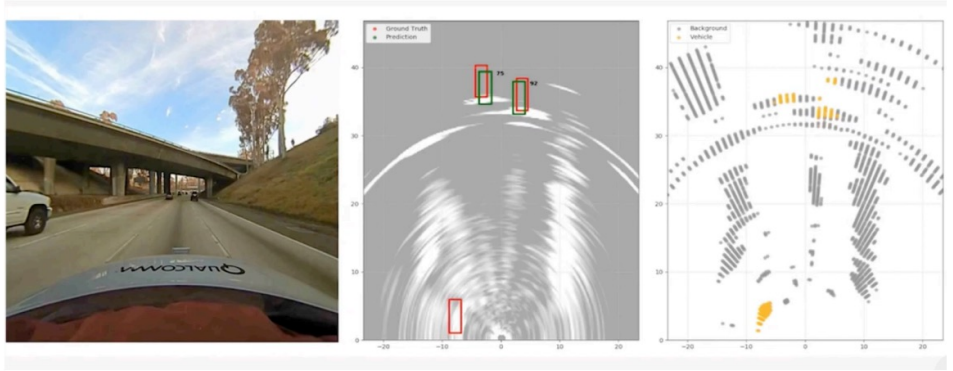


Self-Driving Cars in Fog: LiDAR & Camera Fail

Millimeter Wave radar can function in adverse conditions

State of the Art: Automotive Radars only used for 1D/2D Ranging

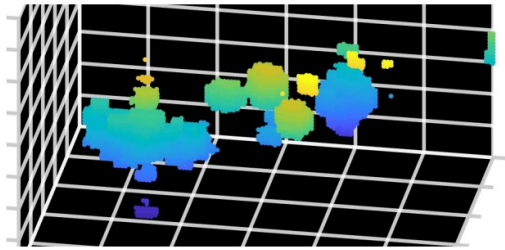




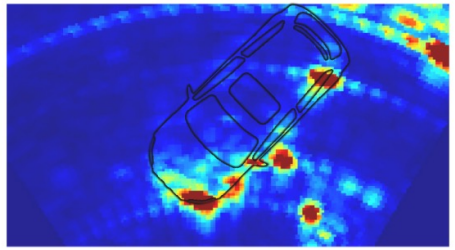
Qualcomm snapdragon ride platform

Radar Imaging is Low Resolution & Suffers from Specularity & Artifacts

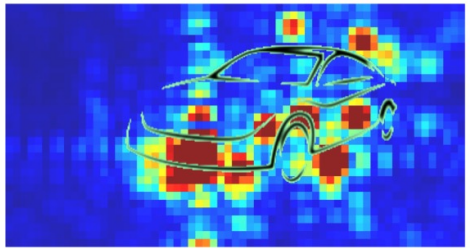
(a) Camera Image



(b) Radar Point Cloud

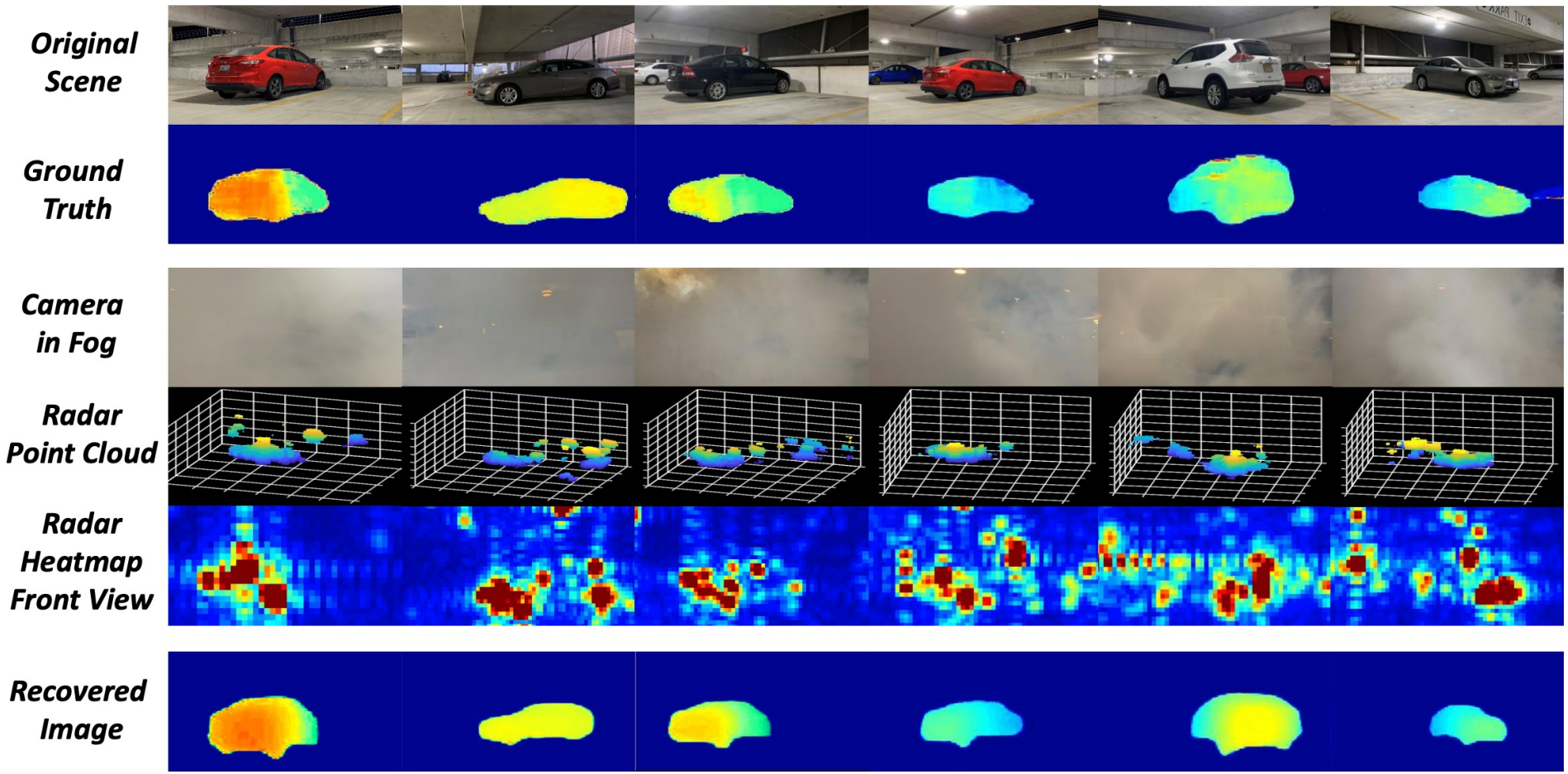


(c) Top-View Heatmap

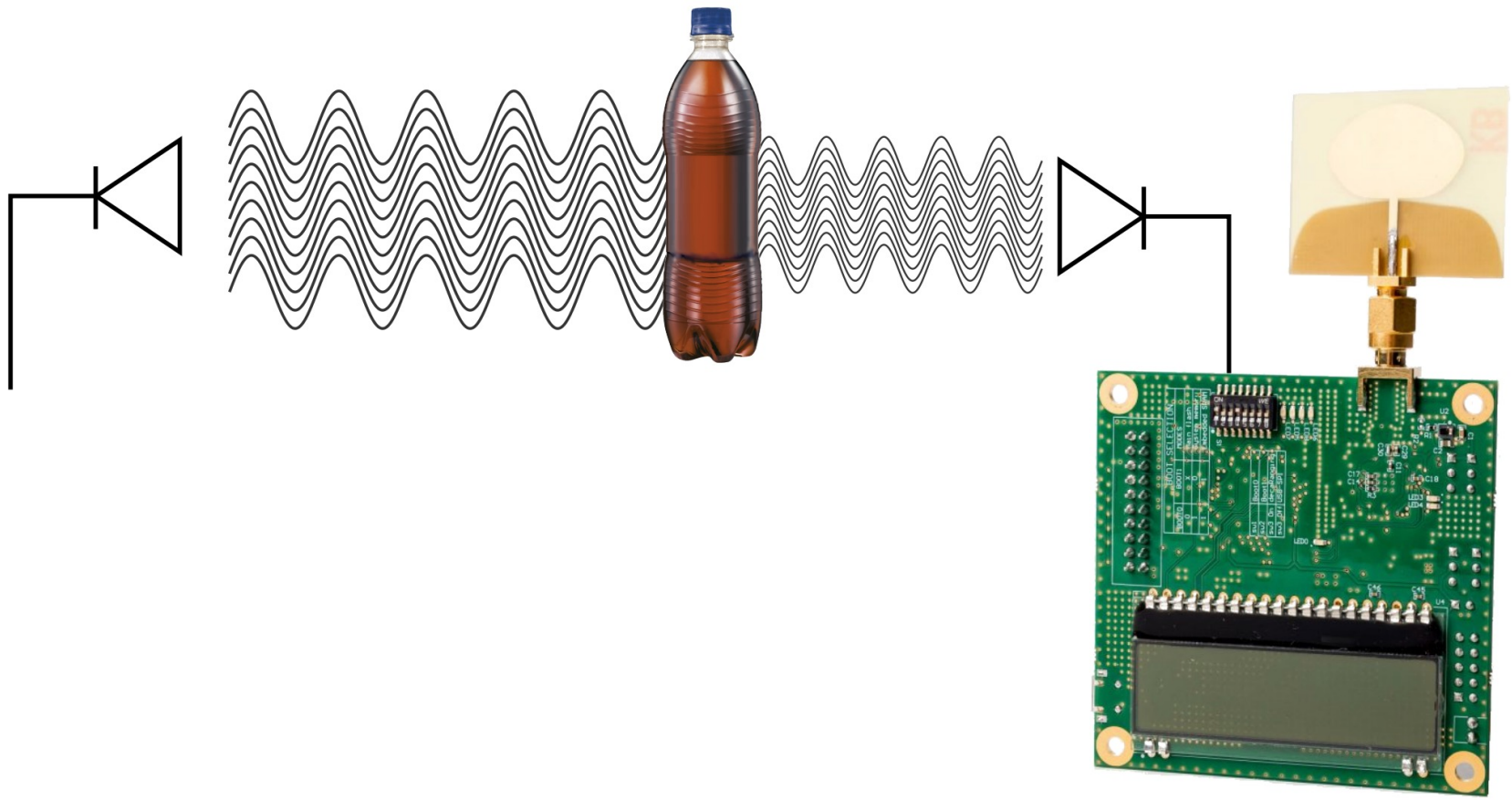


(d) Front-View Heatmap

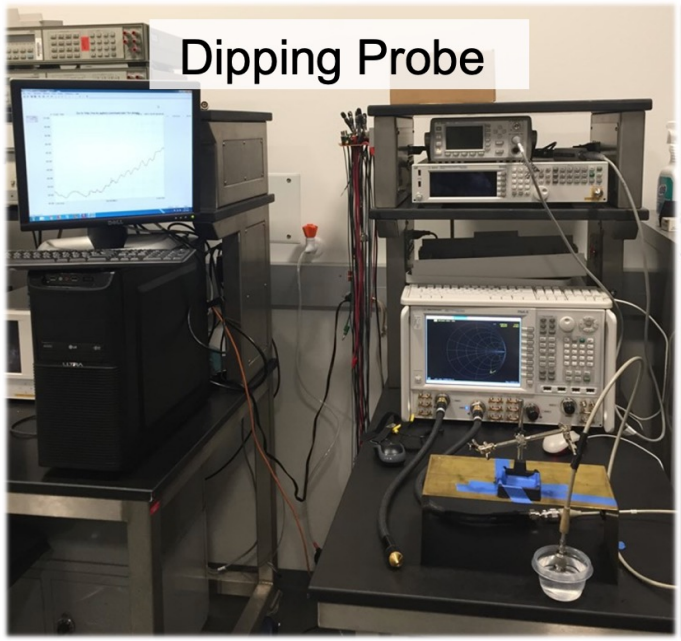
Leverage Deep Generative Adversarial Networks to Enhance Imaging Resolution.

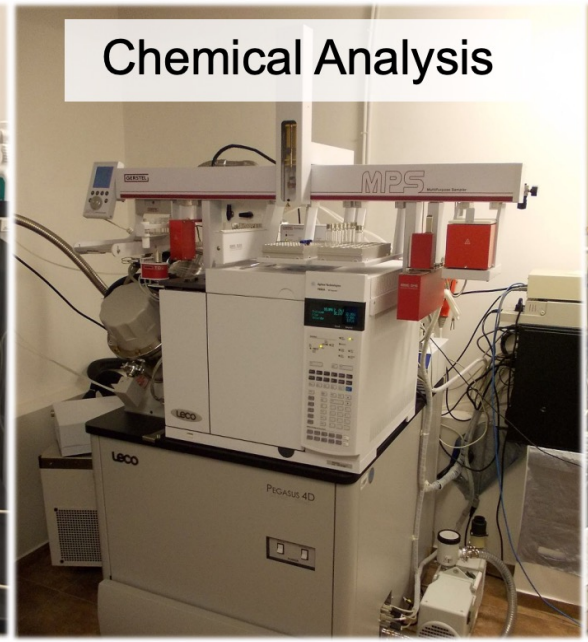


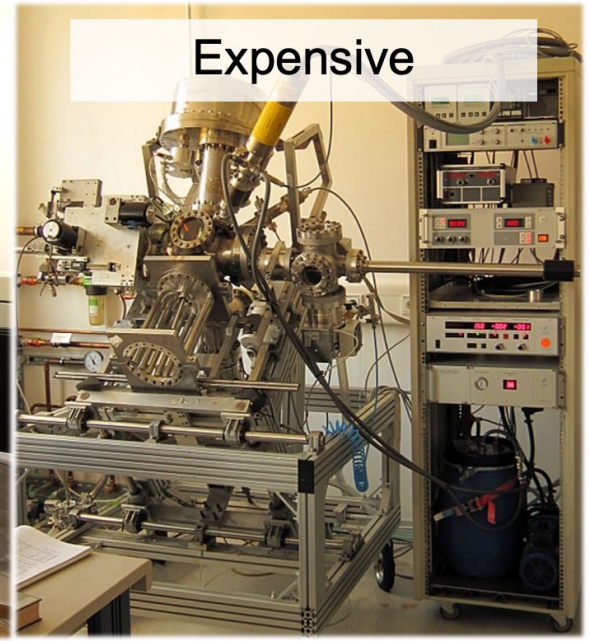
Food and Liquid Sensing



Existing Solutions







Food Quality Monitoring

Water Contamination

This course

Wireless Networks

5G & Next Generation

- Millimeter Wave Networks
- Massive MIMO
- Full Duplex Radios
- Dynamic Spectrum Access
- Programmable Surfaces

Internet of Things

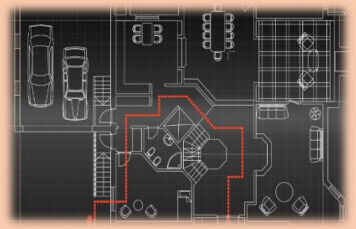
- LoRa Networks
- Backscatter Networks
- Smart Cities & Homes
- Acoustic IoT
- IoT security

Cross Layer Wireless

- Rateless Code & Soft PHY
- Interference Alignment
- Virtual MIMO
- Opportunistic Routing
- Network Coding

Wireless Sensing

Wireless Localization



- WiFi Localization
- Battery Free Localization
- Antenna Arrays
- Time of Flight
- Tracking

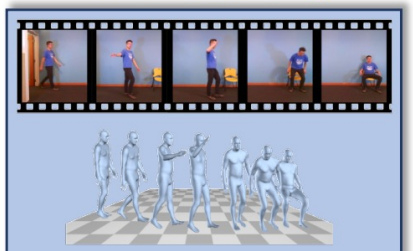
Wireless Imaging

- Radar Imaging
- Self Driving Cars
- Through wall Imaging
- Human Imaging
- 3D Mesh Recovery

Emerging Areas

- Self-driving Cars
- Medical Micro-Implants
- Robotics & Drones
- Underwater Networks
- Noise Cancellation

Wireless Sensing



- Gesture Sensing
- Vital Sign Monitoring
- Behavioral Sensing
- Human Sensing
- Food Sensing

Course Organization & Logistics

Reading Questions: 20%

Class Discussions: 20%

Course Project: 60%

Each lecture = Fundamentals + State-of-the-art system(s)

Office hours, Canvas will be sent out soon

Reading Questions:

We will review and discuss 1 – 2 papers per class:

- Everyone is expected to read the papers before the class
- Submit a short **review** of the assigned reading by the midnight before the class
- More on this later

Course Project

- Research-oriented (can be very related to your own research; talk to me)
- Will suggest project ideas; you can come up with your own as well.
- Work in groups of two
- The projects involve system implementation.
- What is expected?

Timeline:

- Proposal (1-2 pages): Mar 12
- Project proposal discussion: Mar 13
- Weekly discussion: Mar 20 – Apr 17
- Final presentation: Apr 24
- Final report: May 7

How to Read a Paper

First pass:

- Title, abstract
- Figures
- Skim intro & conclusions

Second pass:

- Intro in details
- Overview, related work, and/or background
- Figures in details

Third pass:

- Read in detail
- Virtual reimplementation

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation
Is this an important problem?

- New problem? → Worthwhile or artificial?
- Existing problem? (i.e., have others worked on it) → Does it improve over prior work?

2) Related Work

- Does it really outperform prior work?
- Does it accurately represent prior work?
- Do you know past work? If not, search Google Scholar to get a sense of past work

3) Techniques

- Are they novel? intellectually interesting?
- Are they technically sound? Is there a key technical flaw?

How to Review a System Paper

How to think when reviewing a paper?

4) Implementation

- Significant effort?
- Matches the motivation?
- Simulation or real-world prototype?

5) Evaluation

- Comprehensive? Convincing?
- Does the system deliver what it promises?

How to Review a System Paper

How to think when reviewing a paper?

1) Motivation

2) Related Work

3) Techniques

4) Implementation

5) Evaluation

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstract"

Rough structure:

This paper presents XXX, a system that does YYY. **The goal is to** XXX. The **main challenge** the authors try to address is YYY.

The key idea is to do XXX. The authors do this by introducing/proposing ZZZ

The authors implement (or simulate) their system and **demonstrated** (results) that it outperforms the baseline?

How to Review a System Paper

How to write a review?

1) Summary

- 5-10 sentences
- If someone hasn't read the paper at all, they should understand what it's about
- Should sound like a "brutally honest and straightforward abstracT"

2) Strengths & Weaknesses

- Use your answers to the questions of "How to think when reviewing"
- List 2-4 pros/cons
- Each should be a direct statement about the paper

<u>Rough structure:</u>

Pros:
+ Statement 1
+ Statement 2

Cons:
-
-
-

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comments to authors

- Detailed comments to authors
- Elaborate on your pros/cons, areas for improvement, key concerns
- Ask questions about techniques, figures, results, etc.
- Based on the 5 points from how to think as well as technical details

Examples:

- If you listed a weaknesses small delta over prior work, specify in details why with references
- If experimental details are missing, state exactly what is missing and why it is problematic
- Include typos/grammar mistakes, potential suggestions to correct

How to Review a System Paper

How to write a review?

1) Summary

2) Strengths & Weaknesses

3) Comm… to authors

- Detailed c… …c…
- Elabor… …r pro…
- …s about t…
- …the 5 points…

Examples:

- If you liste… …all delta o…
- If exper… …ng, state…
- Inclu… …amma… …, potent…

For the sake of this class, we will drop "comments to authors".

Instead, you should add a paragraph on "suggestions for improvement".

- If you could improve this paper, how would you do it?
- How do you envision your proposed technique will improve the work

How to Review a System Paper

How to write a review? (for this class)

1) Summary

2) Strengths & Weaknesses

3) Suggestions for Improvement

Next class

- Wed Jan 18th (no class on Monday 16th)
- Wireless Localization: WiFi
  - Required: ArrayTrack
  - Optional: Cricket, RADAR