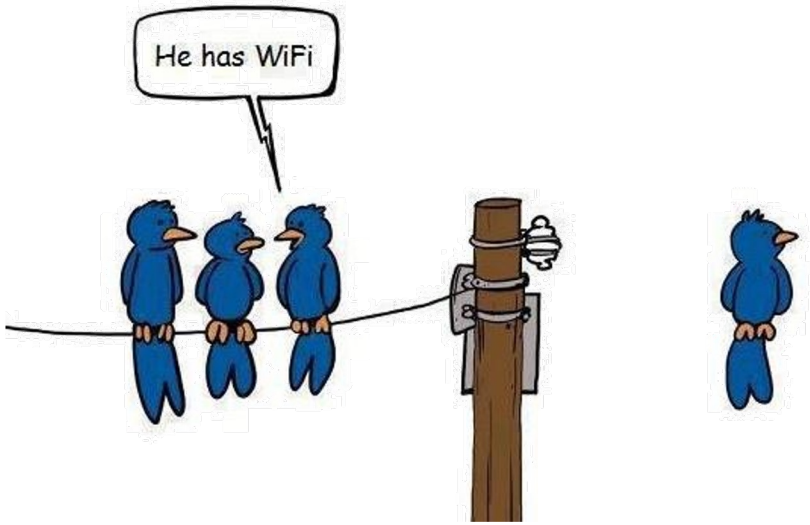
COM-405: Mobile Networks

Lecture 11.1: Wireless Imaging

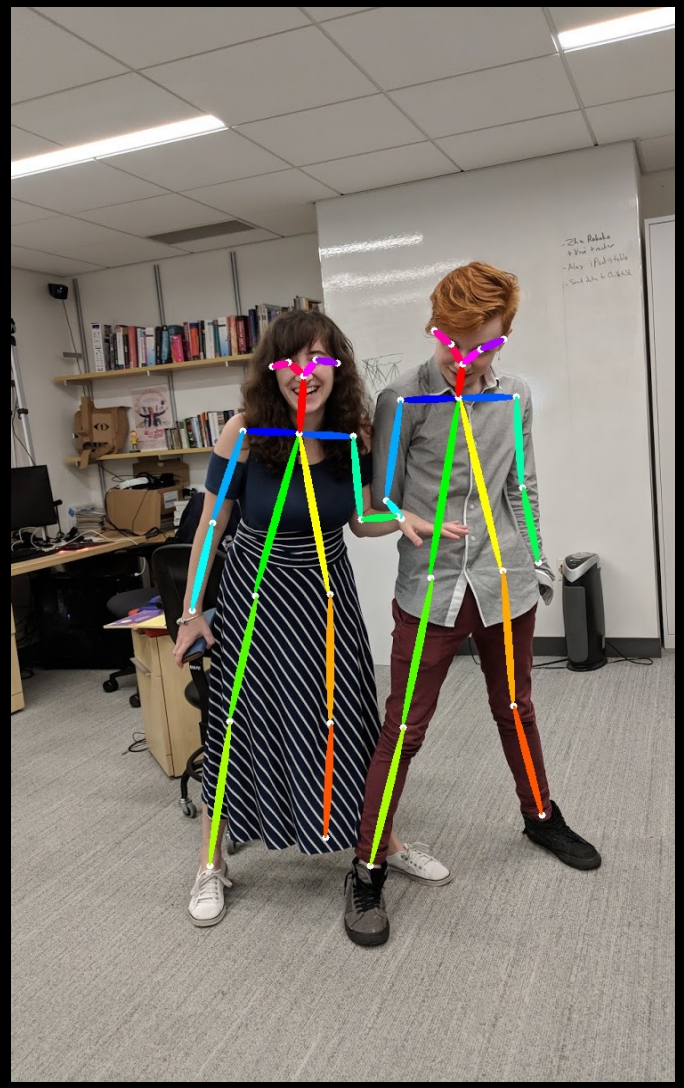
Haitham Hassanieh

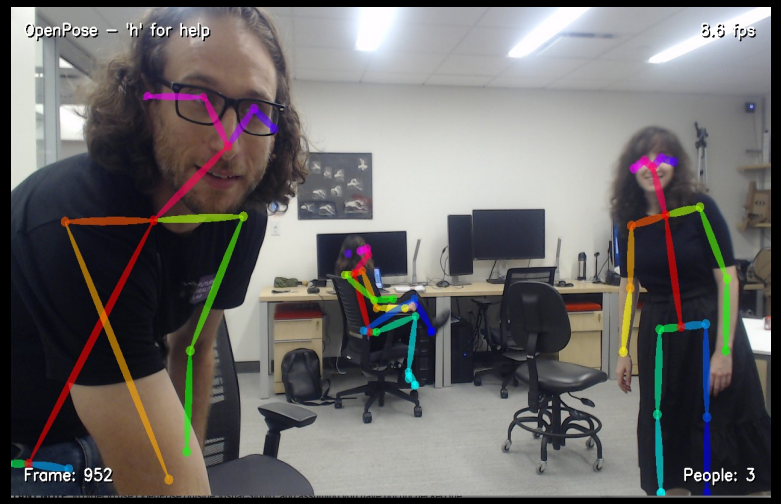


EPFL

SENS
Laboratory of SEnsing
& Networking Systems

Sensing Humans in the Environment

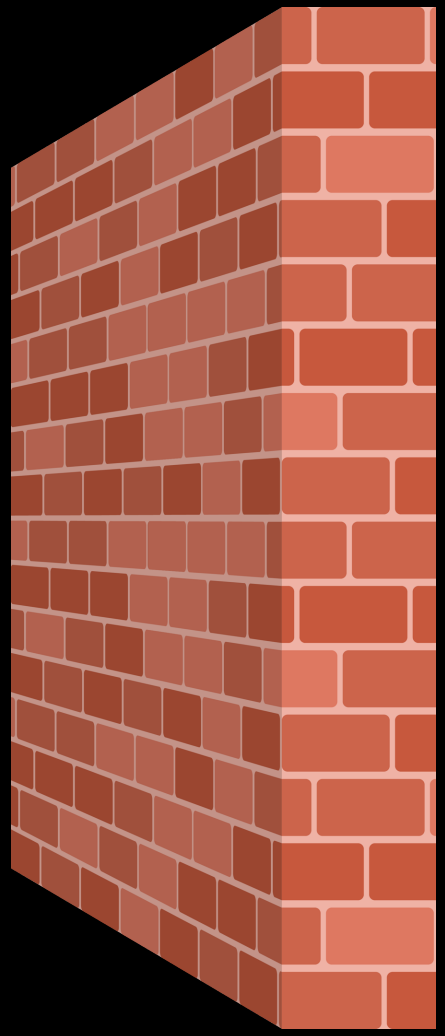




Occlusion is a fundamental challenge for vision

Vision also fails in bad lighting conditions

Want to see the human through walls & in the dark



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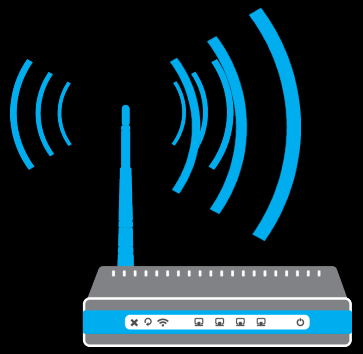
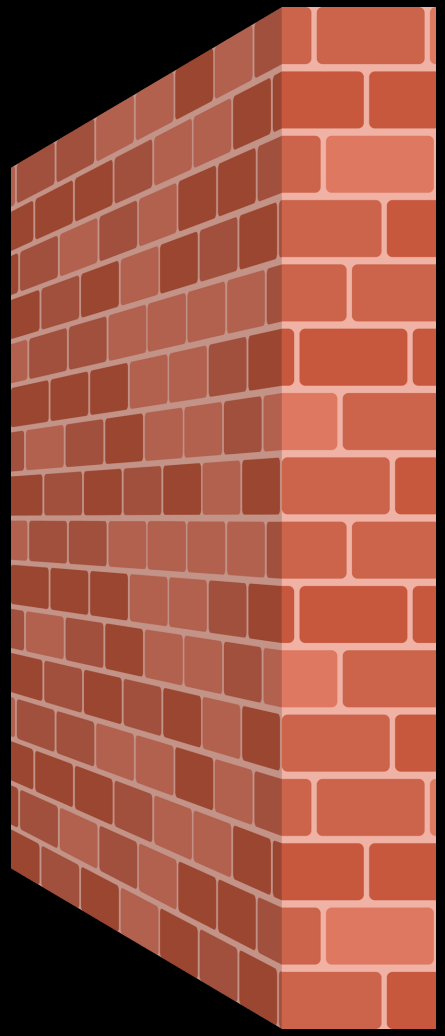
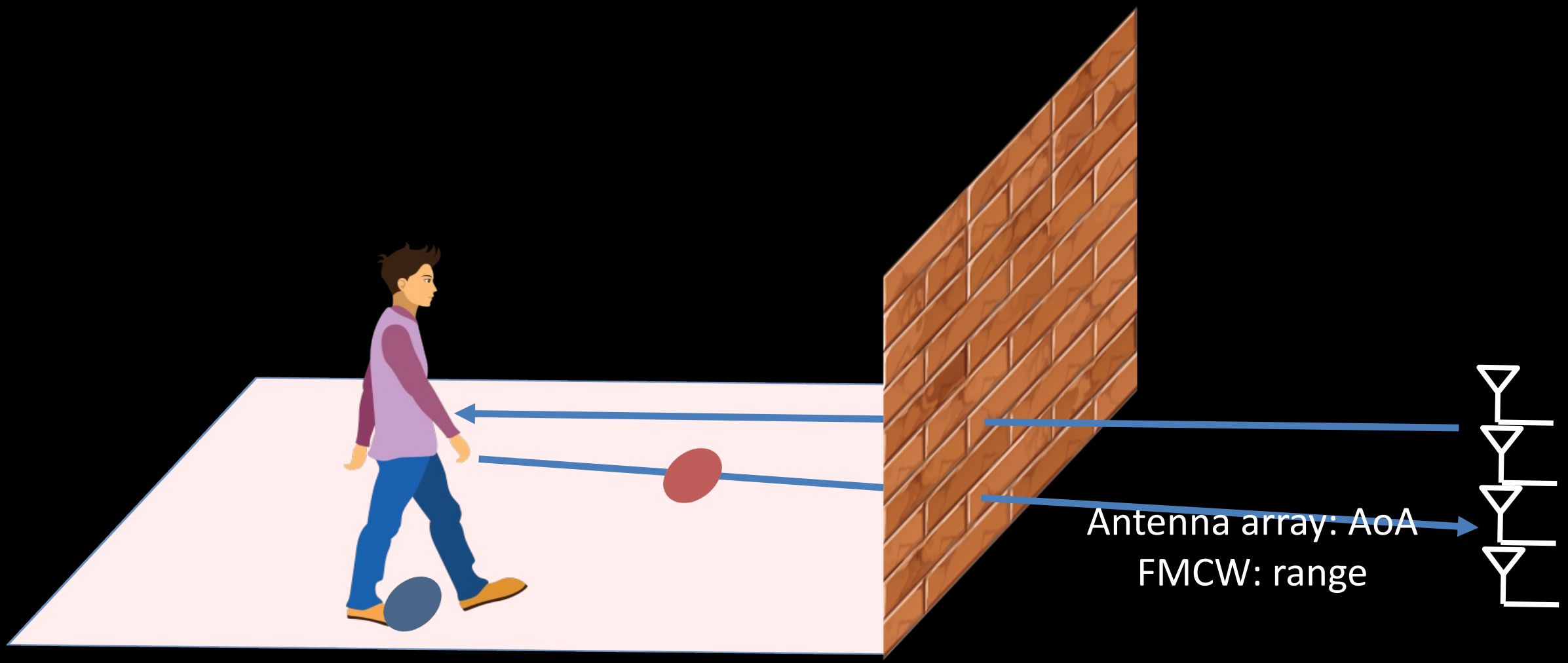
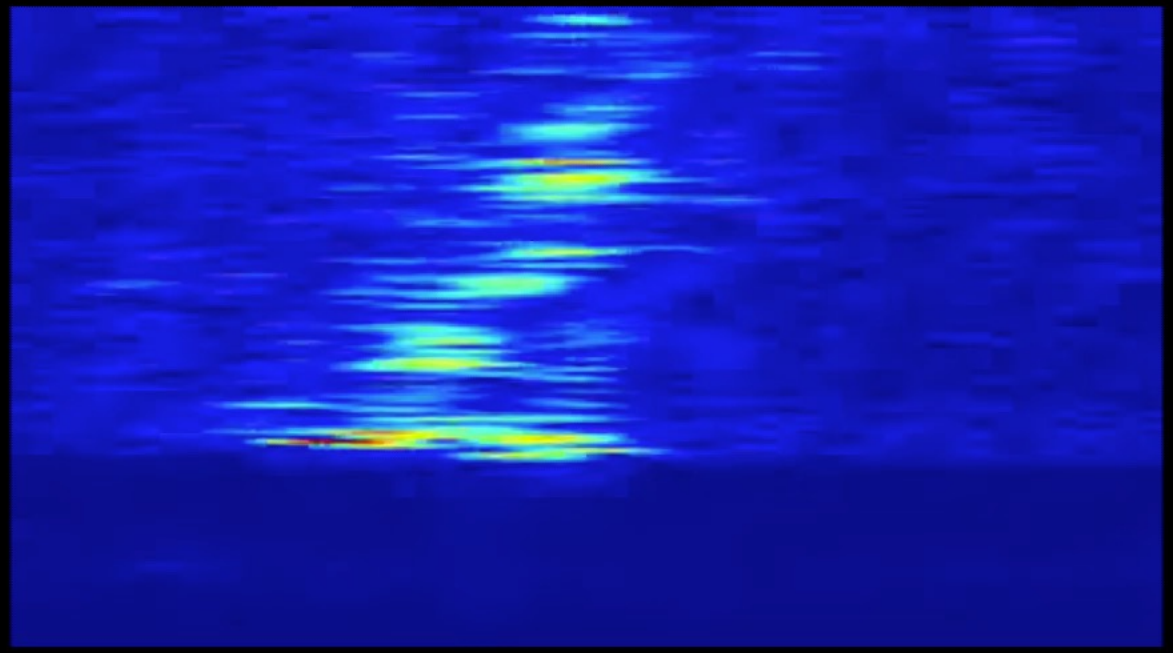




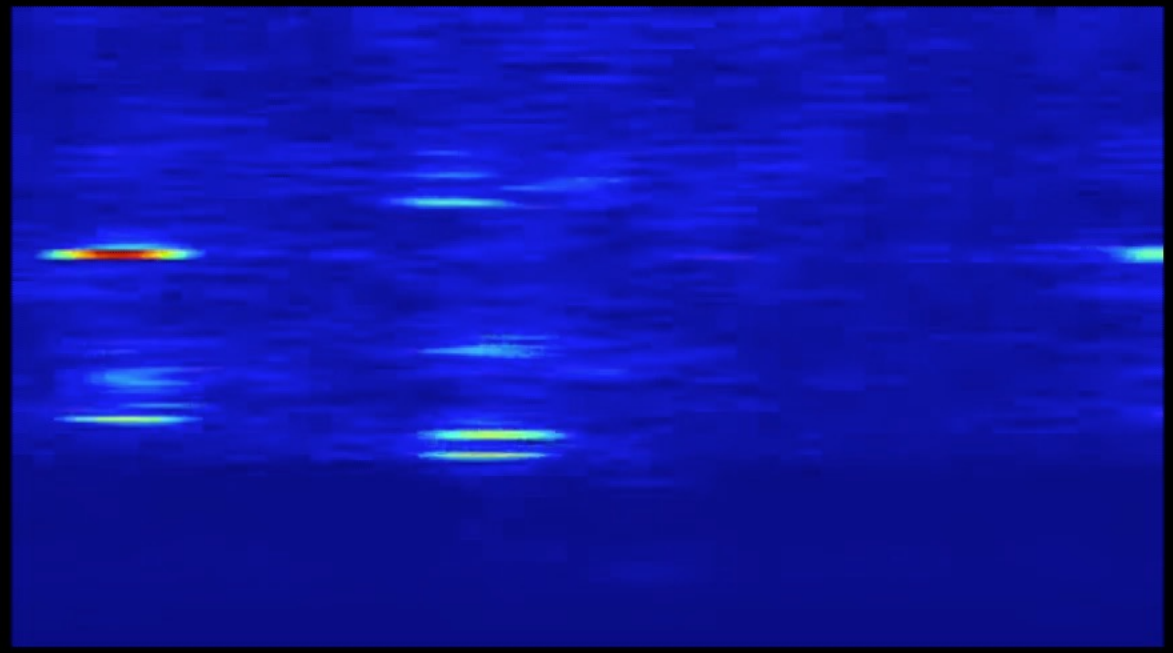
RF-based Approach



How to train a model to estimate pose from RF?

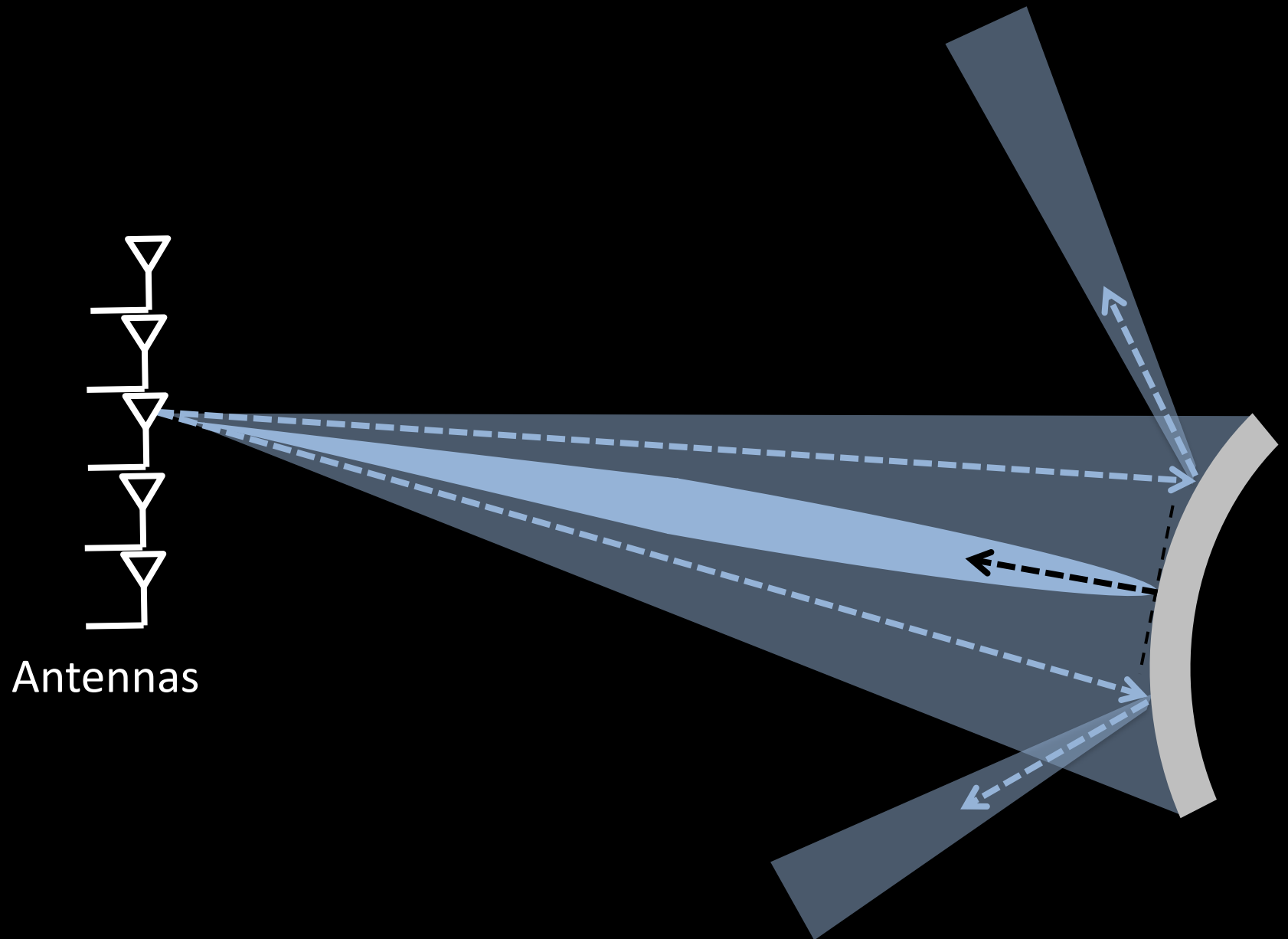


Vertical RF heatmaps

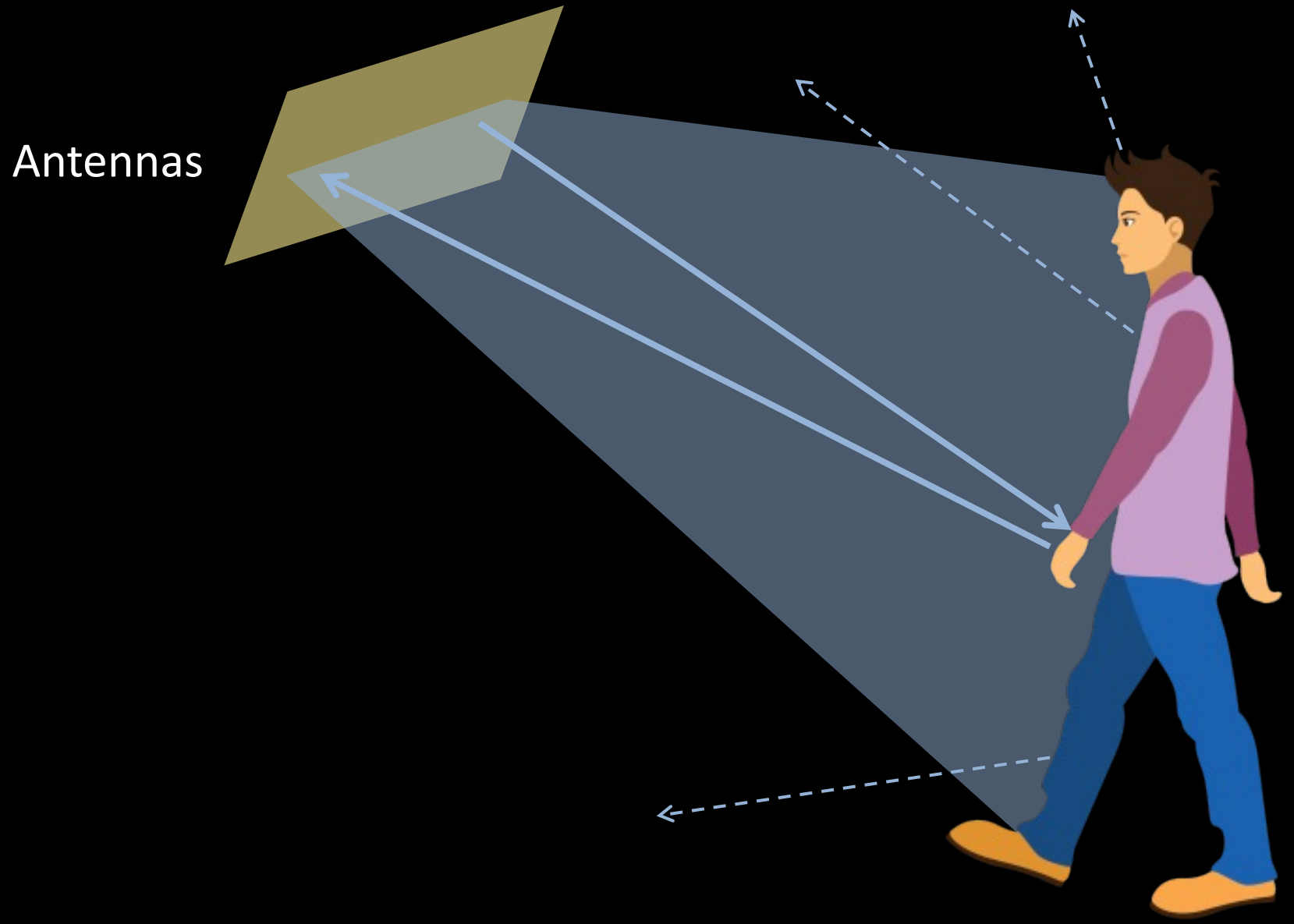


Horizontal RF heatmaps

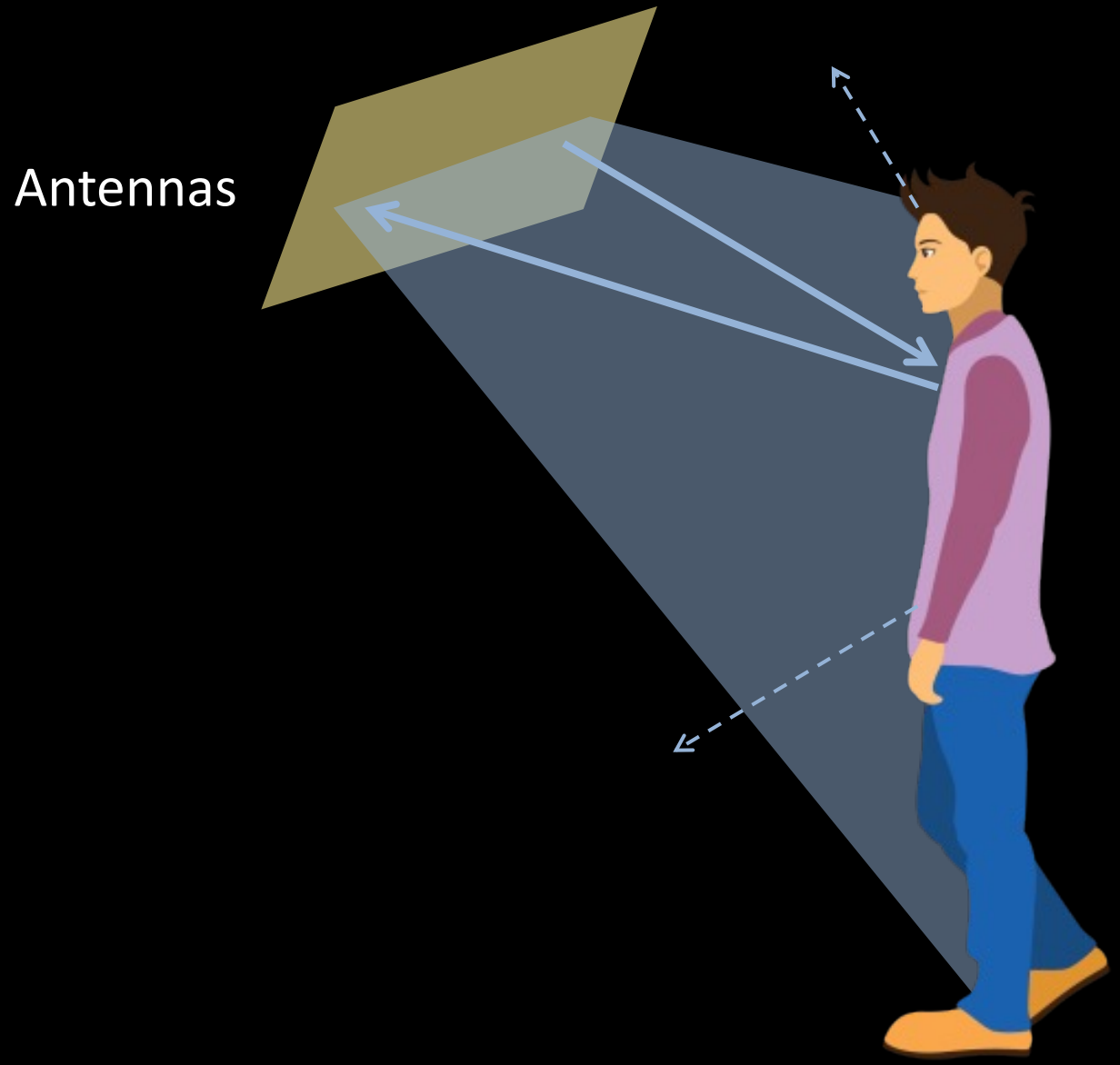
Challenge: Specularity of Human Body



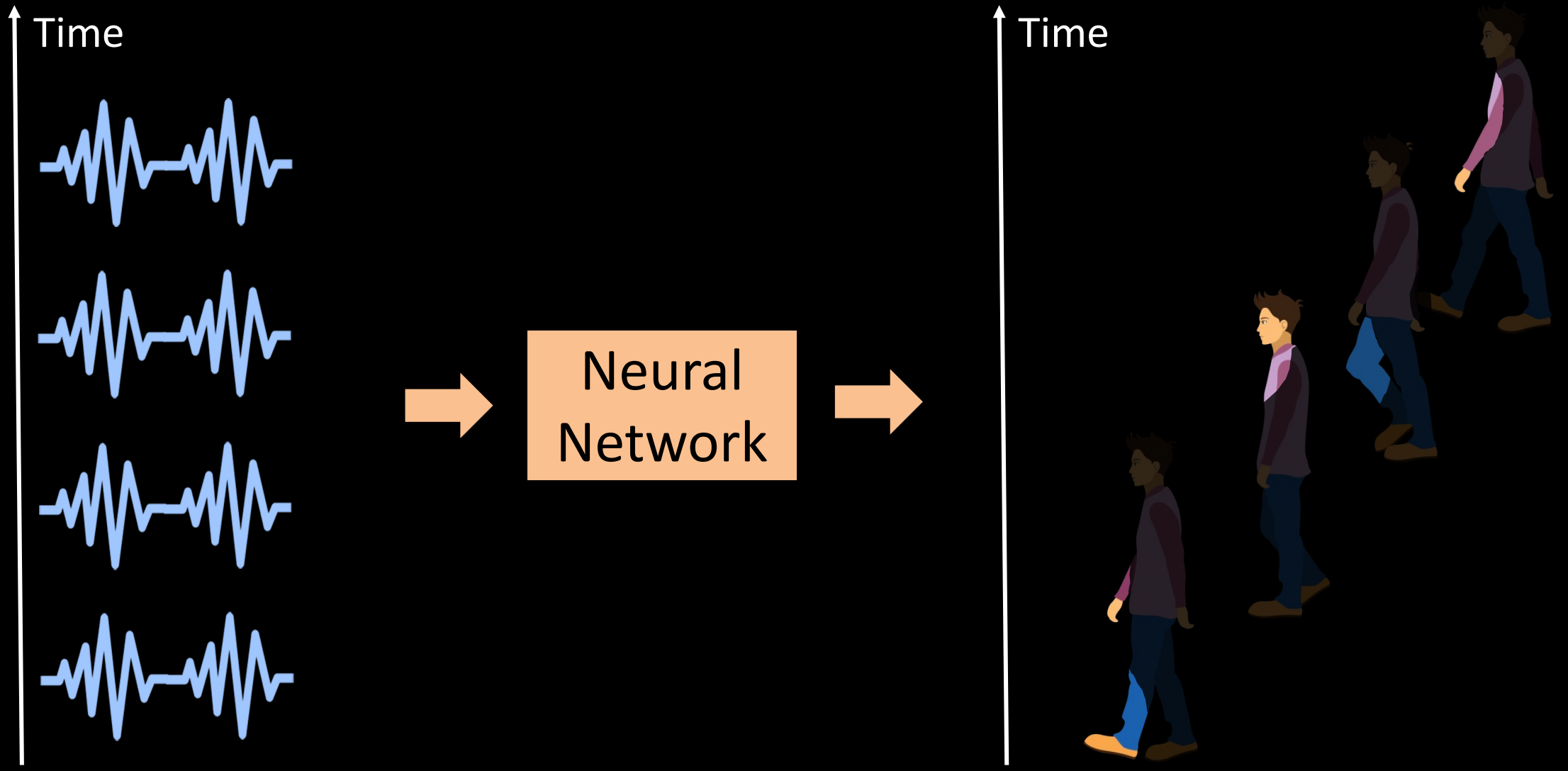
A Snapshot Doesn’t Have Skeleton



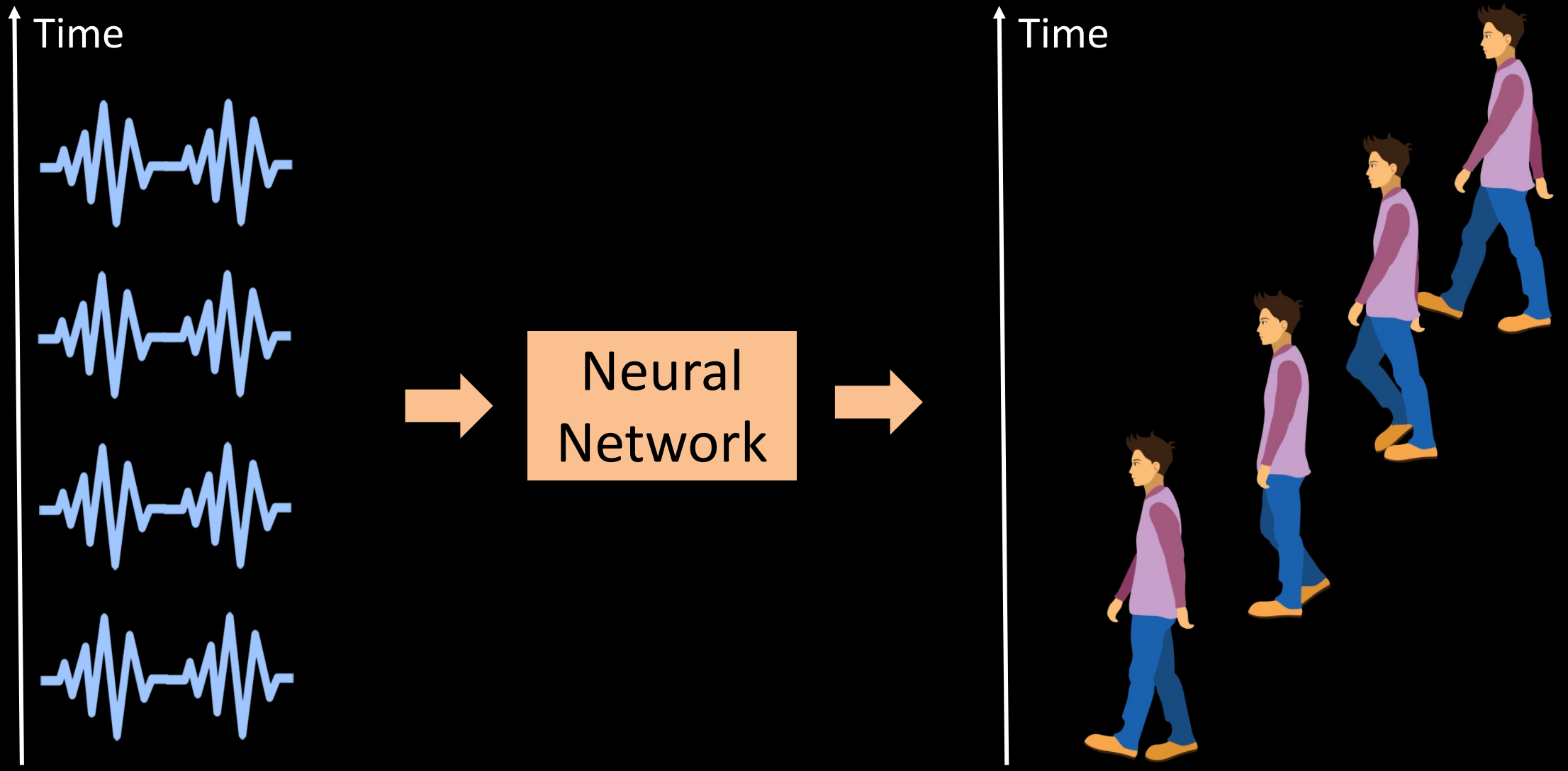
Solution: Use Human Motion Across Time



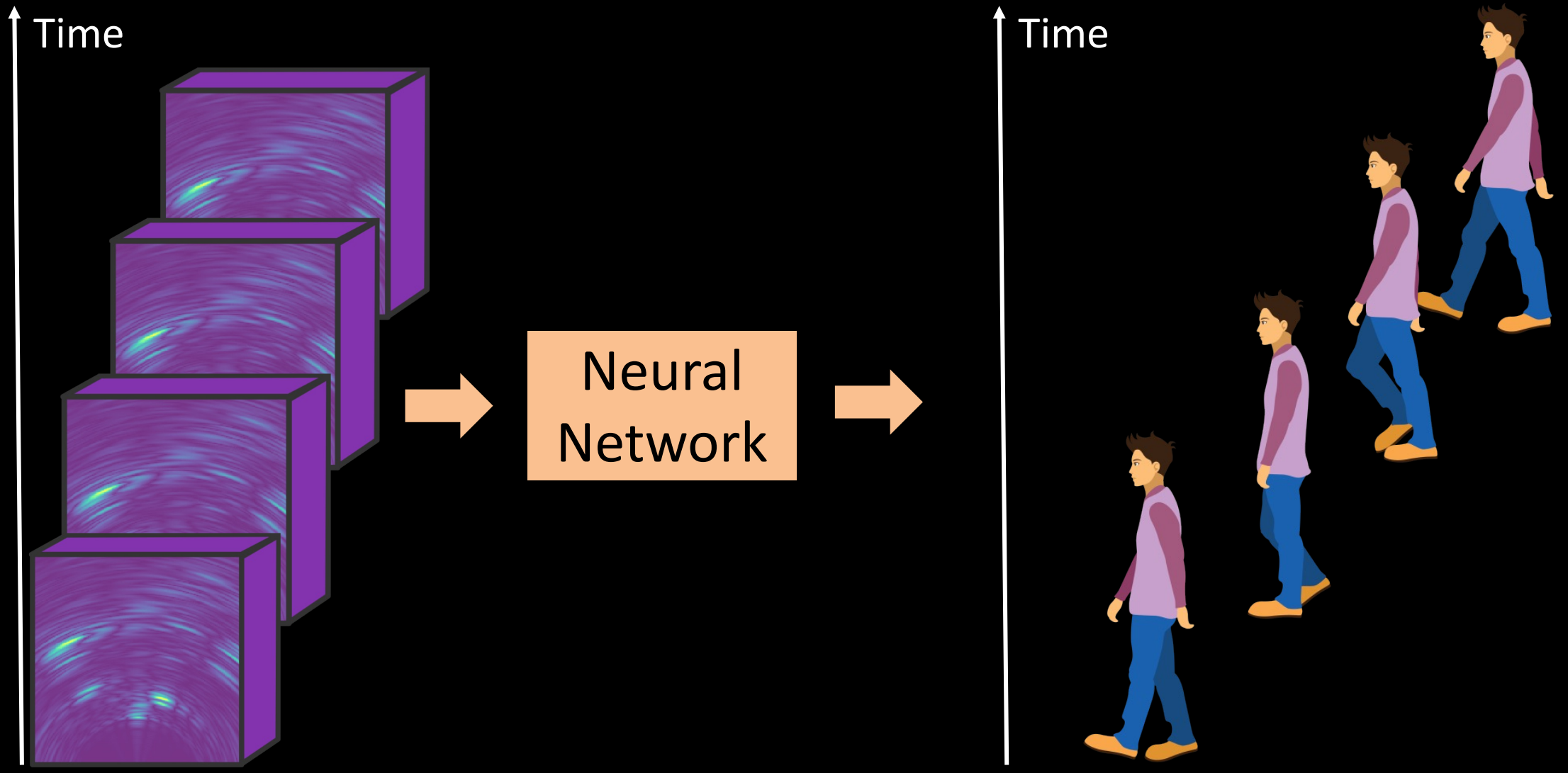
Solution: Use a series of RF snapshots



Solution: Extracts limbs and fills in missing parts



Challenge: 4D signals are too large for NN!

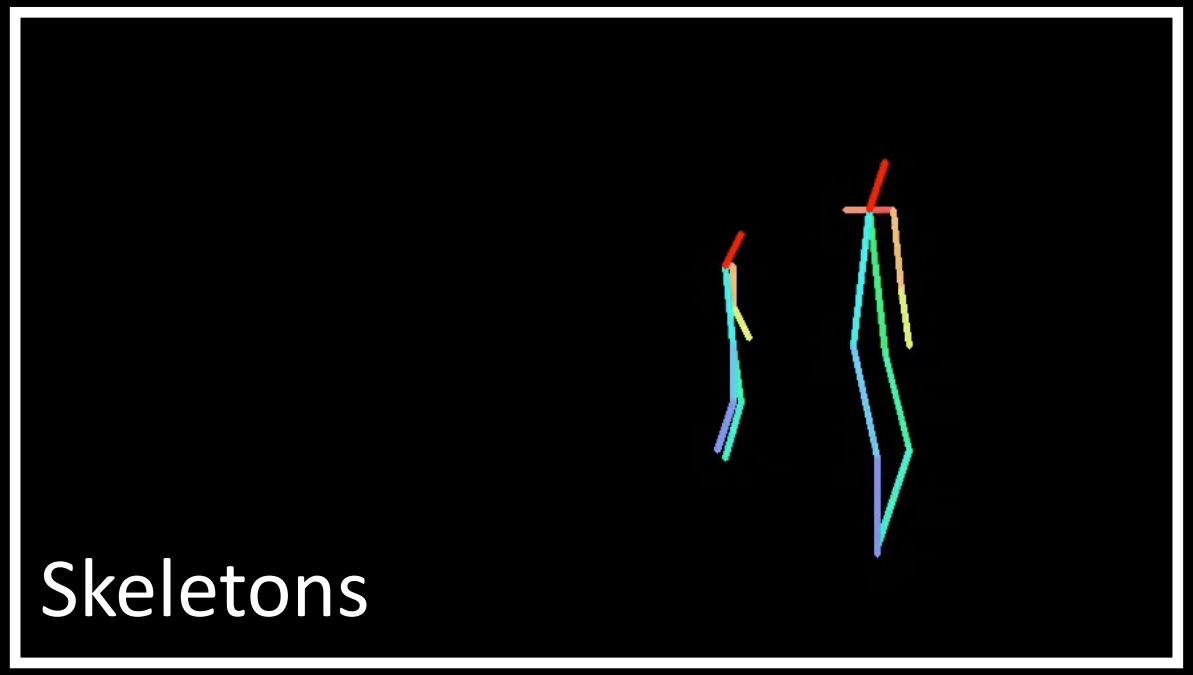


Through-wall poses
using **only** RF

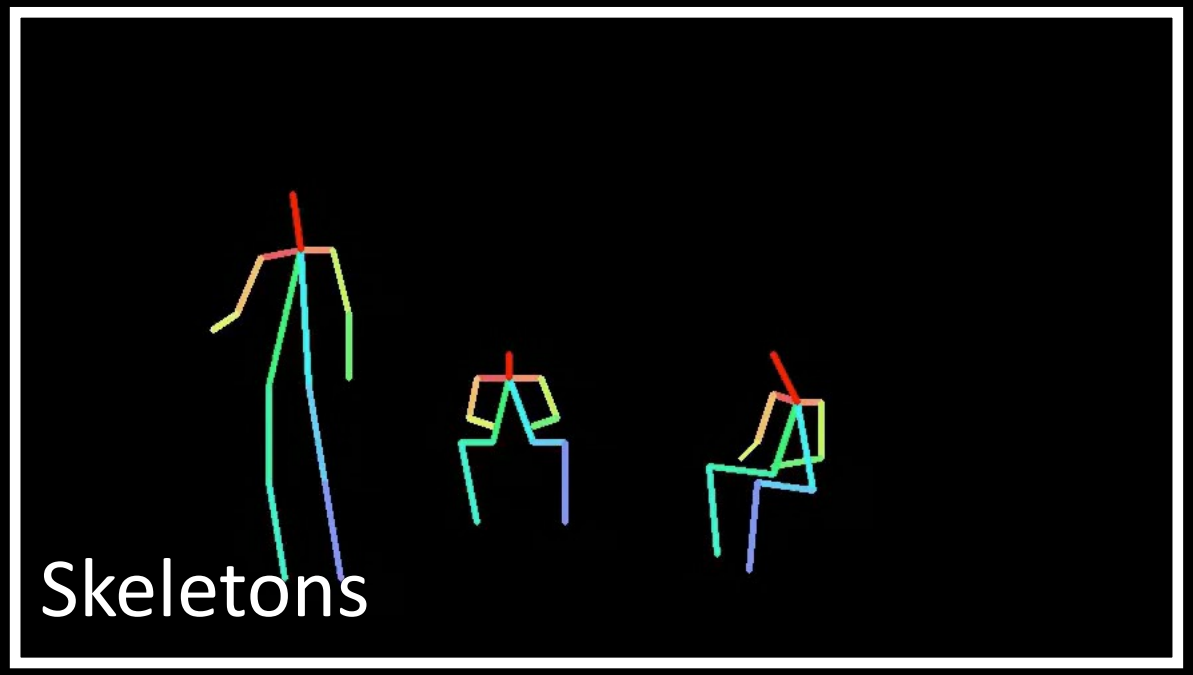
Skeletons

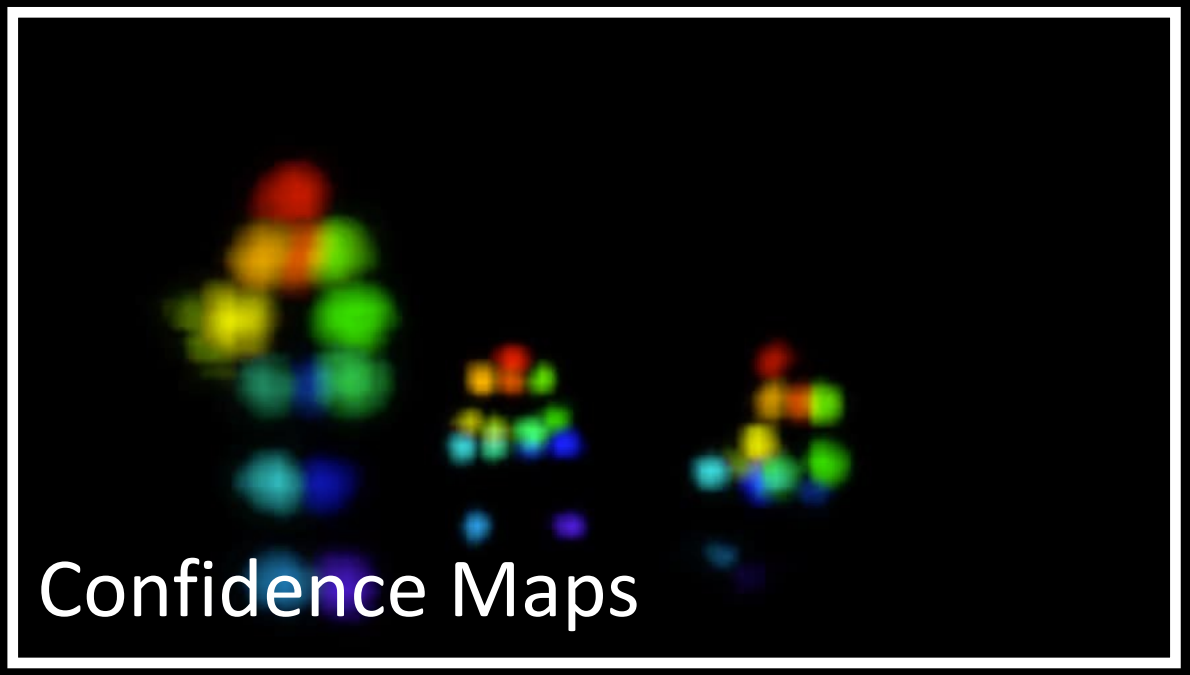
Confidence Maps

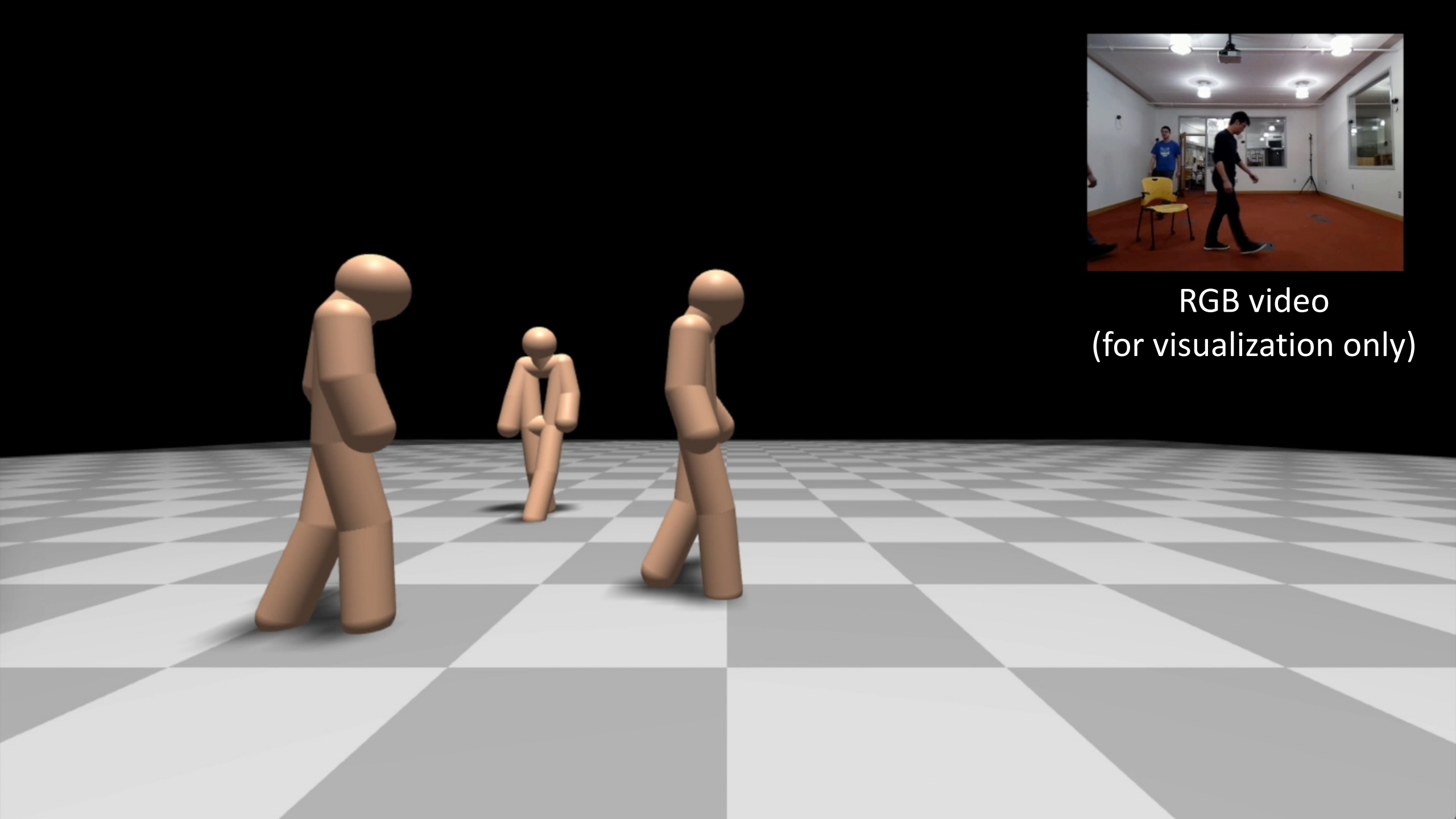
Works in bad lighting



Works with different environment and daily activities

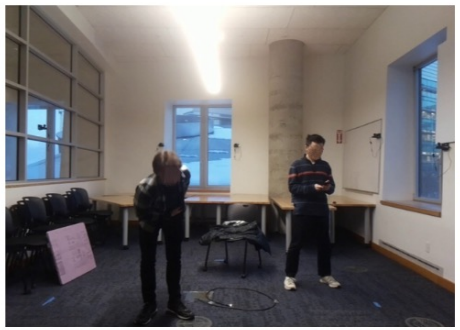


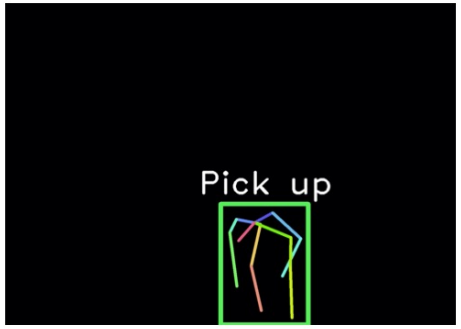


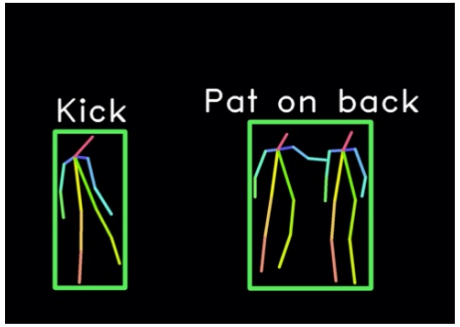


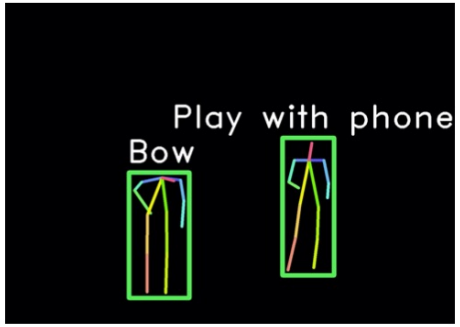
RGB video
(for visualization only)

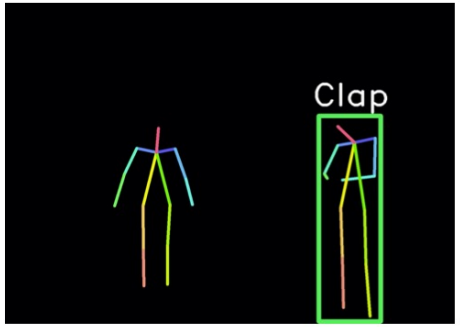
RGB video
(for visualization only)

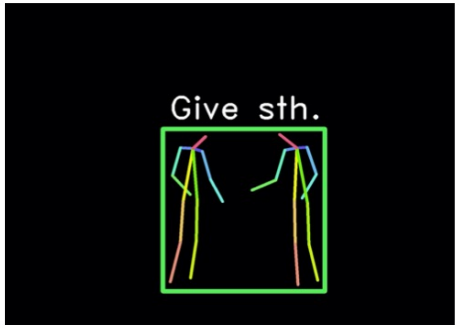


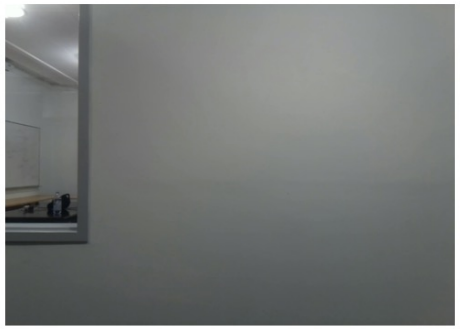

Pick up

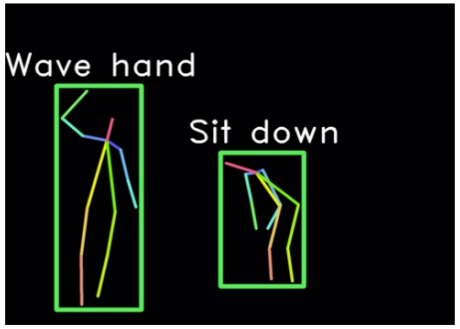

Kick
Pat on back

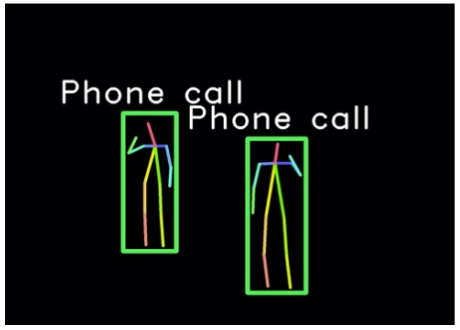

Play with phone
Bow

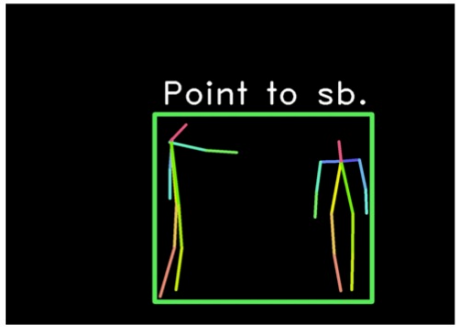

Clap

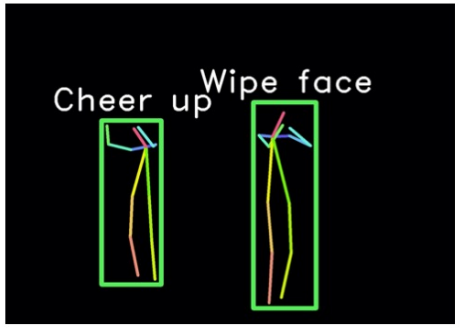

Give sth.

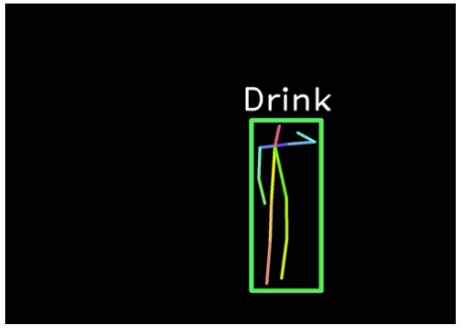



Wave hand
Sit down


Phone call
Phone call


Point to sb.


Cheer up
Wipe face


Drink


Tesla in Fog
38
38


Tesla in Fog
38
38

Tesla in Fog

Millimeter Wave Radar

Radar can function in adverse conditions

Millimeter Wave Radar

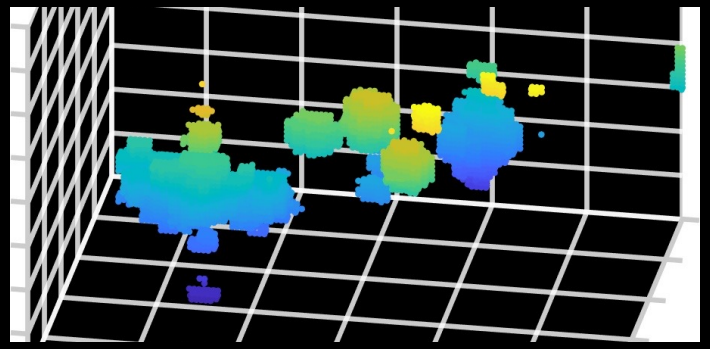
Radar can function in adverse conditions

Can we use millimeter wave radars in scenarios where LiDARs and cameras fail?

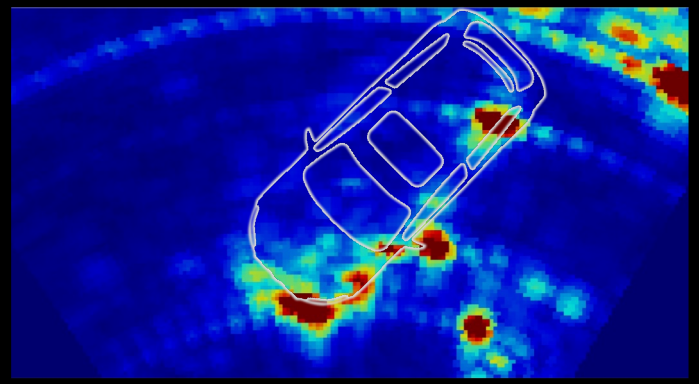
Challenges in Radar Perception

Camera Image

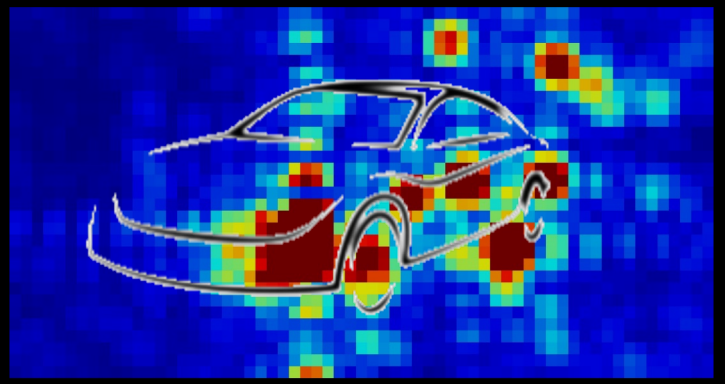
Point Cloud



Top-View



Front-View



Huge Performance Gap Between Radar and Vision!

Challenges in Radar Perception

1. Low Angular Resolution
   - Blobs of reflected power
   - No sharp boundaries/shapes

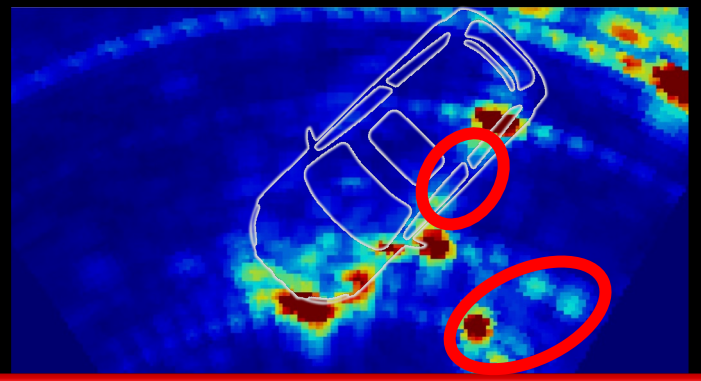
2. Specularity
   - Missing major parts of cars

3. Multipath
   - Spurious Reflections

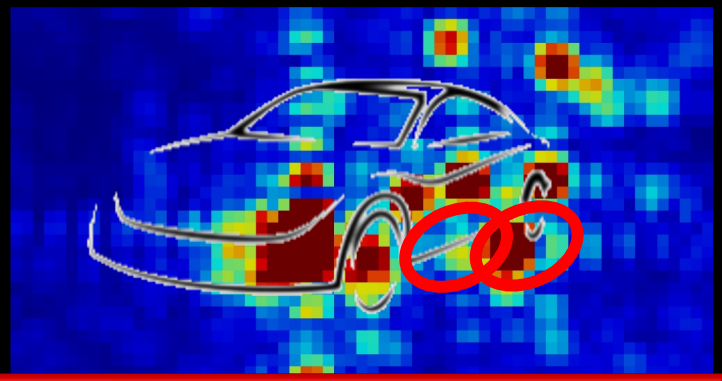
Camera Image

Point Cloud

Top-View



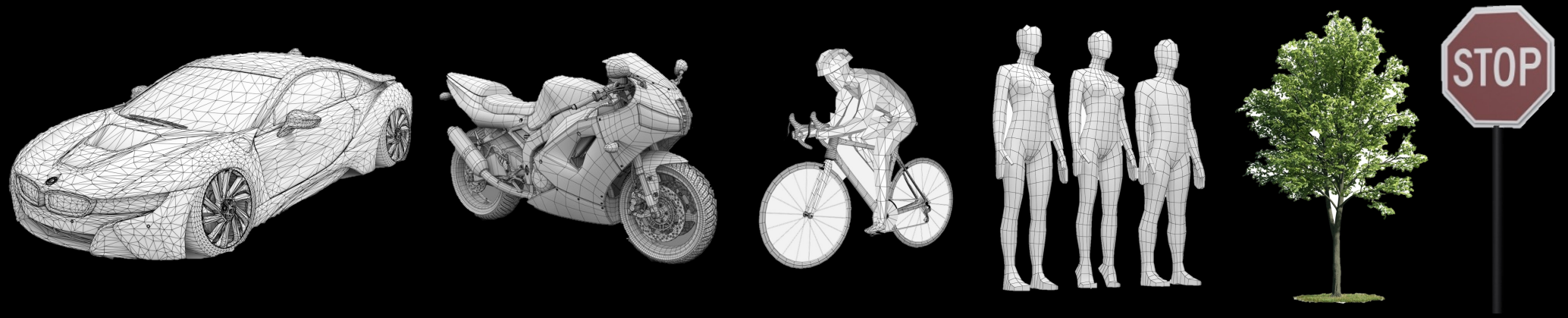
Front-View



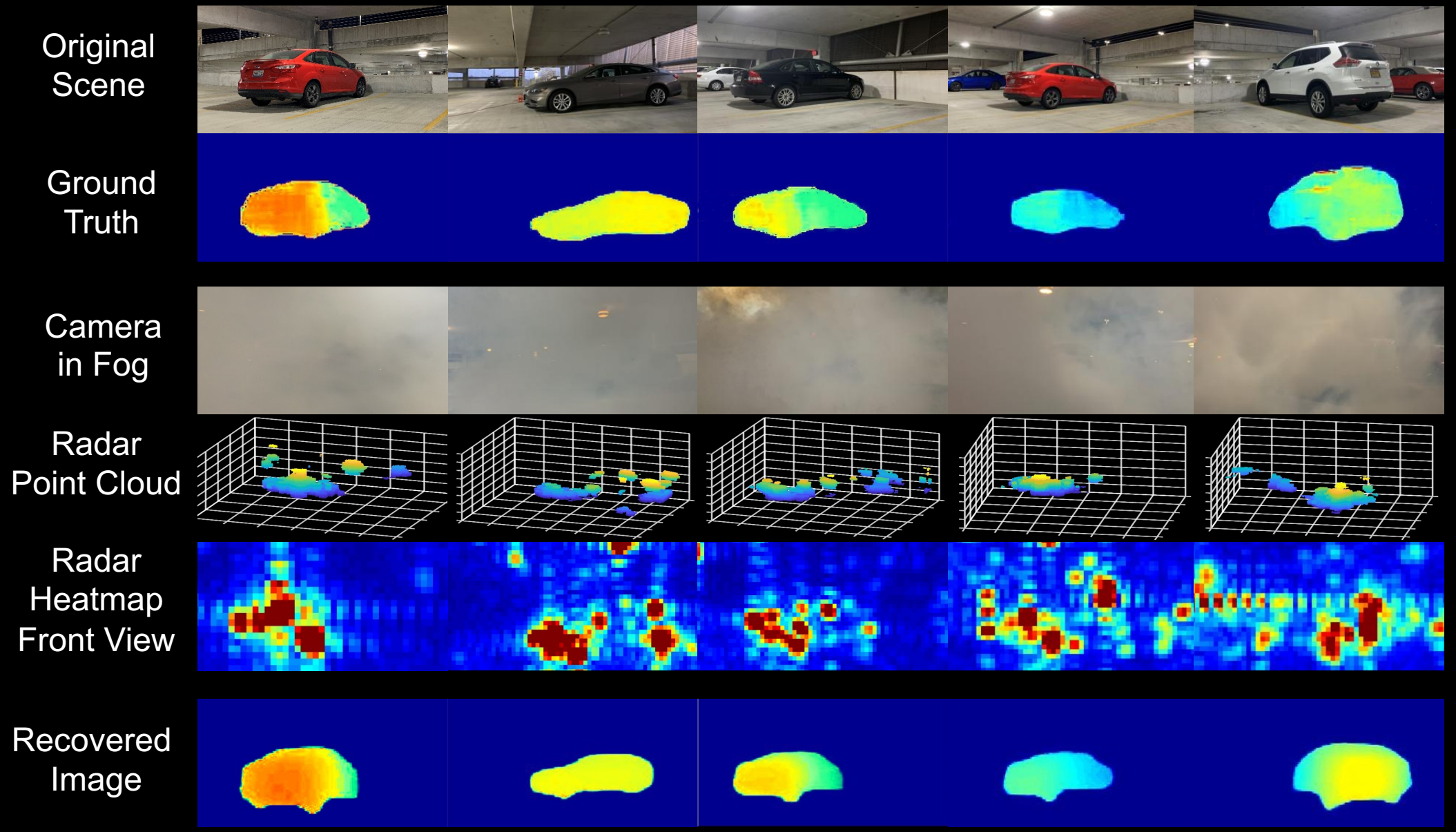
Cast mmWave Radar Perception as a Learning Problem

Our Solution

Learning *geometric priors* on structures of commonly found streetside objects.

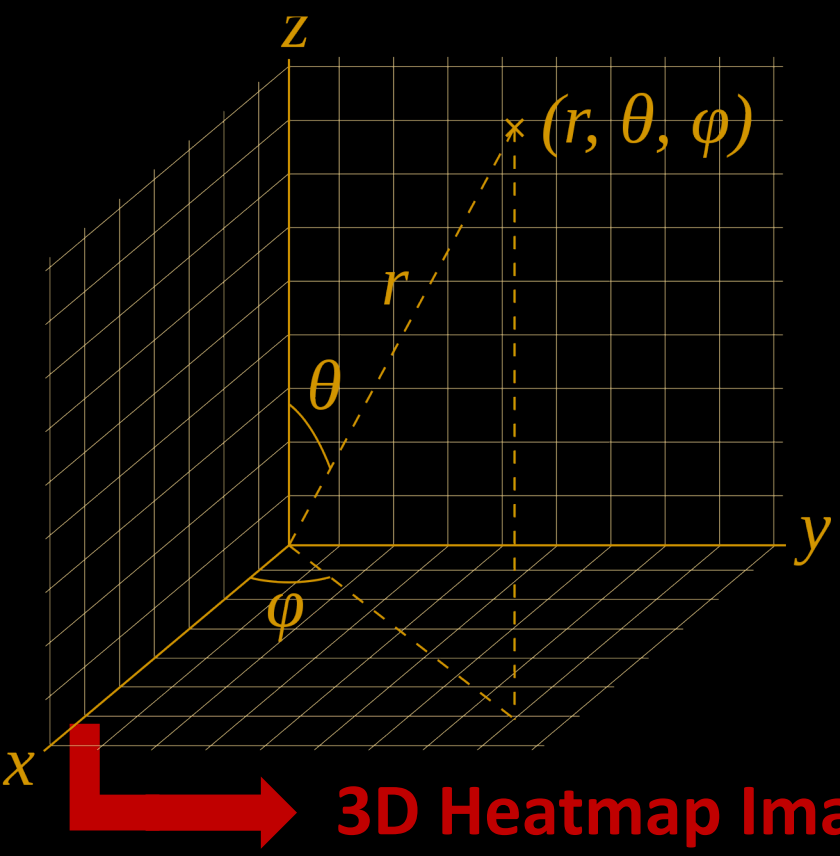


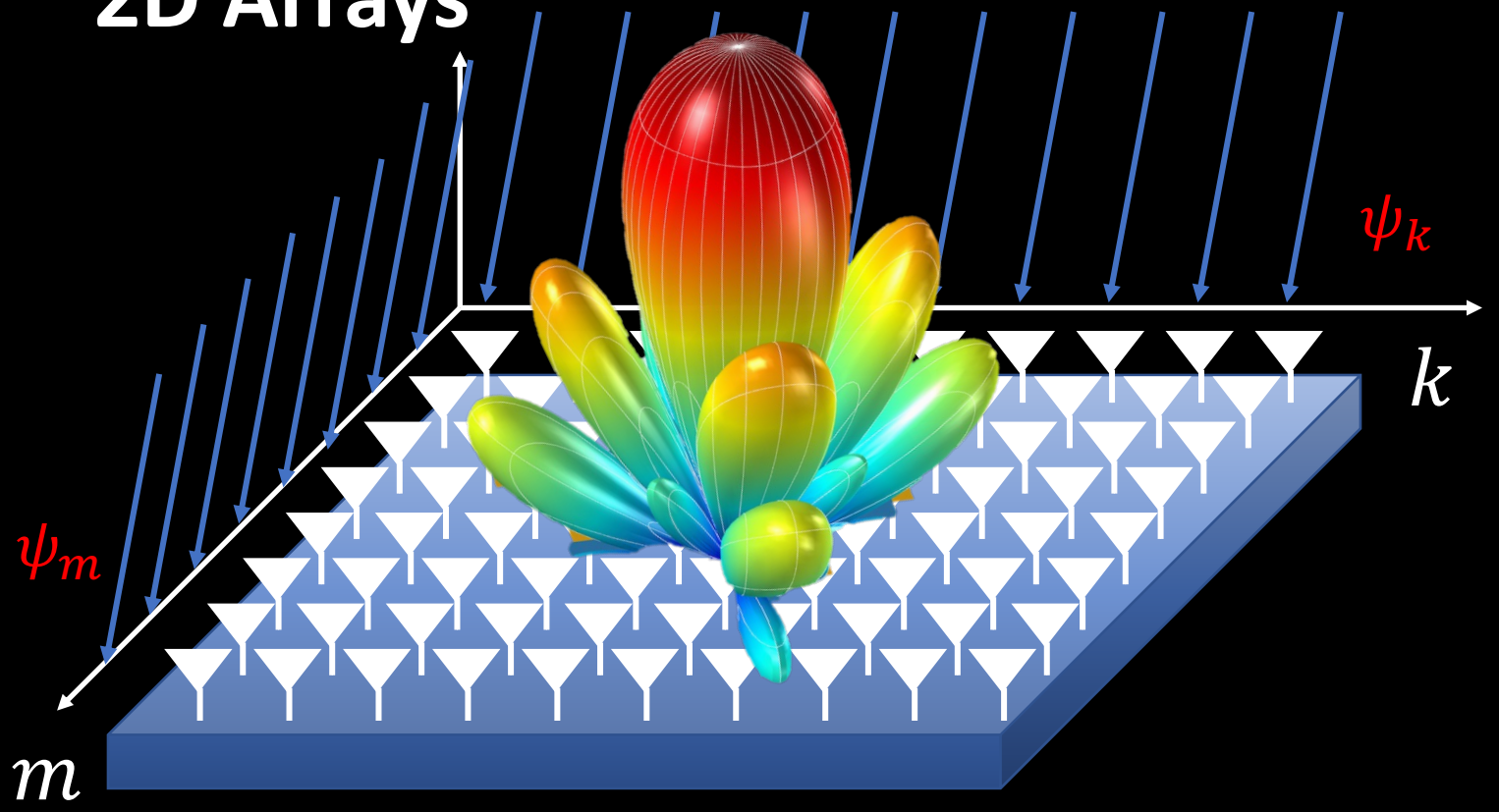
Deep Neural Networks are effective for various computer vision tasks: super-resolution, learning image prior, image style transformation, etc.



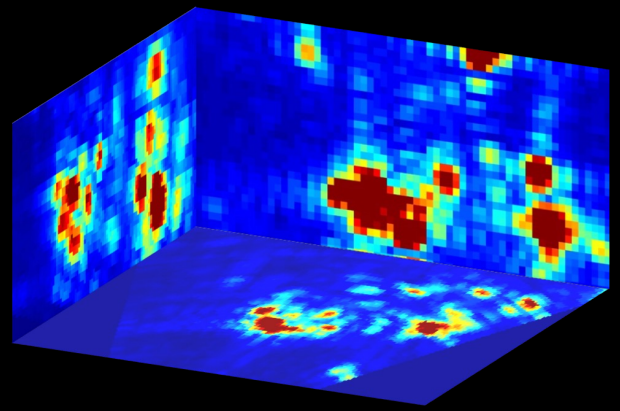
Trained using simulated data and tested using real data.

2D Arrays

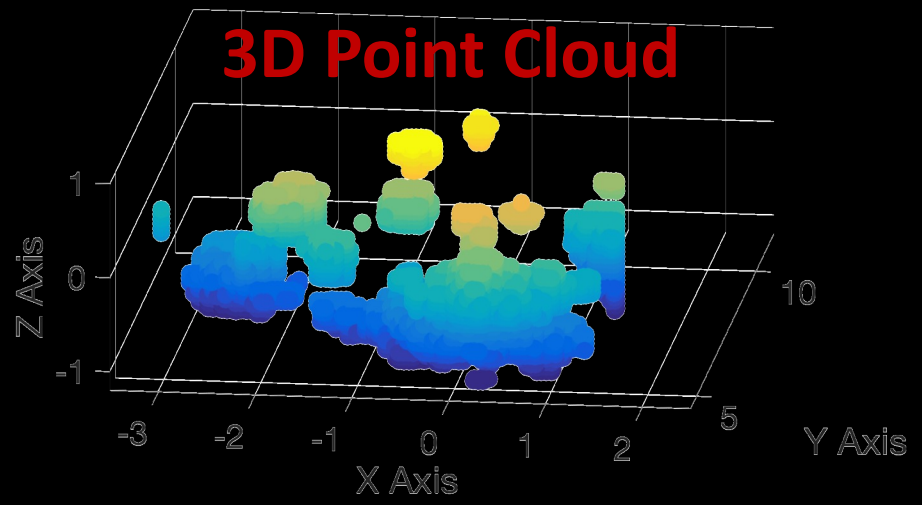




3D Heatmap Image



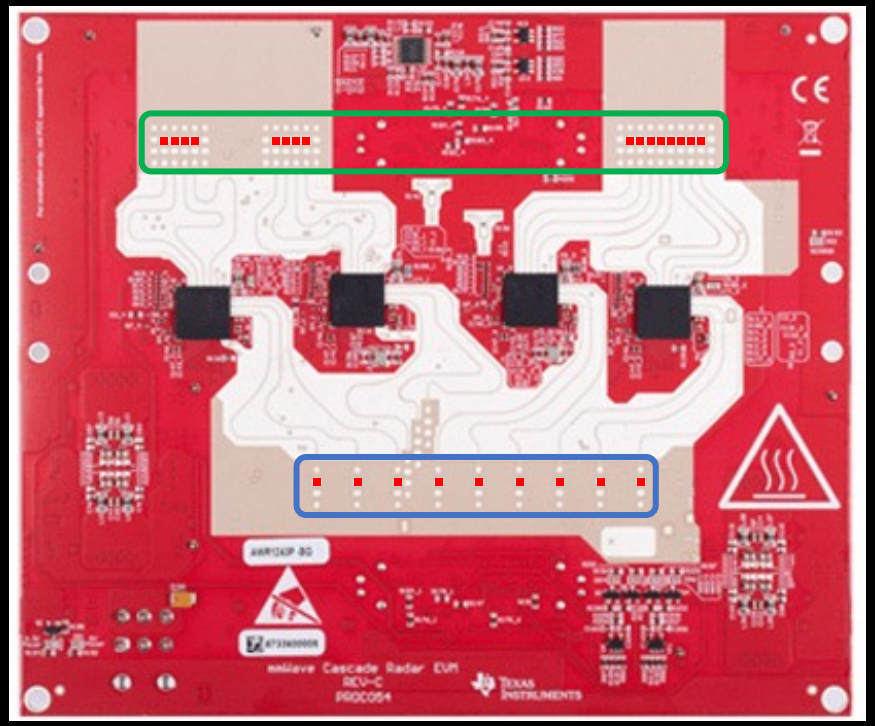
3D Point Cloud



MIMO Radar

Receiver
Array
(16 elements)

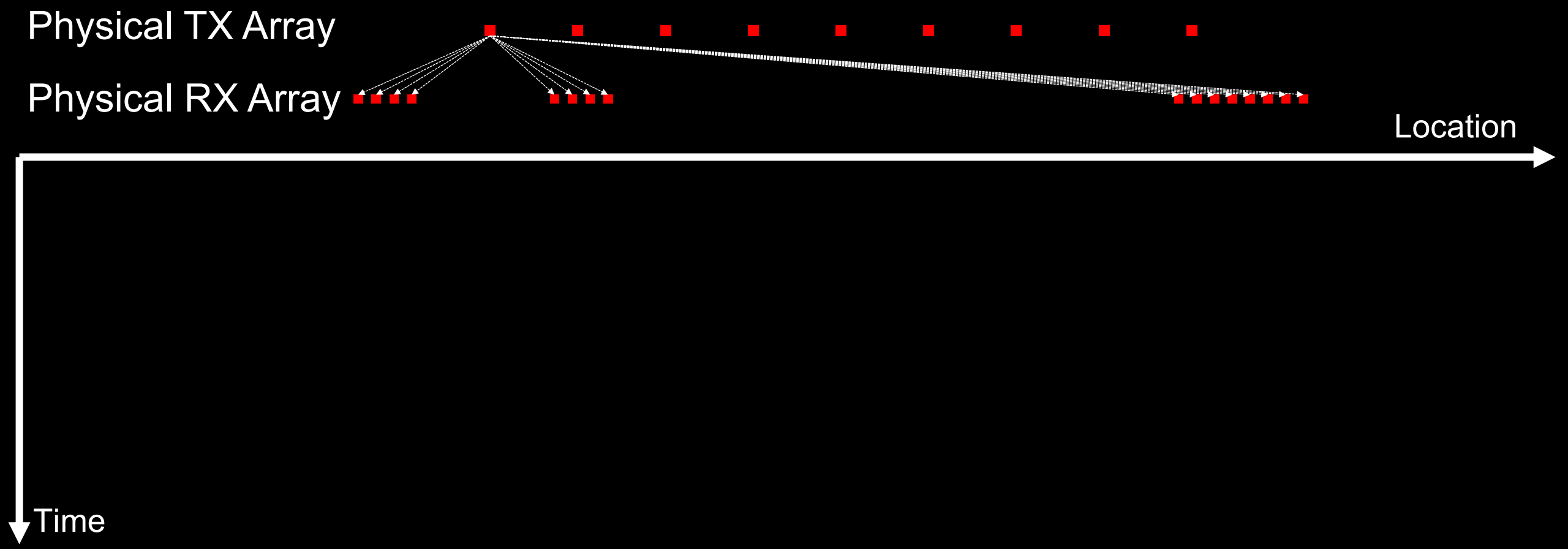
Transmitter
Array
（9 elements）



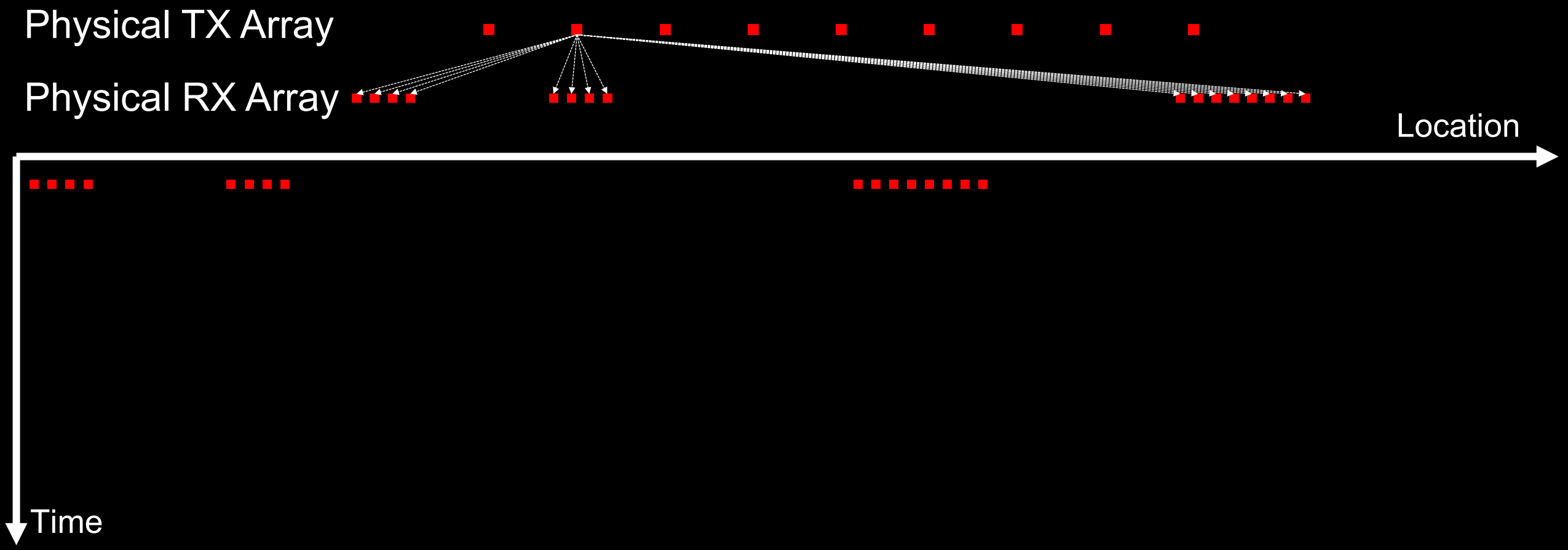
TI
MIMO Radar

Angular resolution of radar is proportional
to antenna array size.

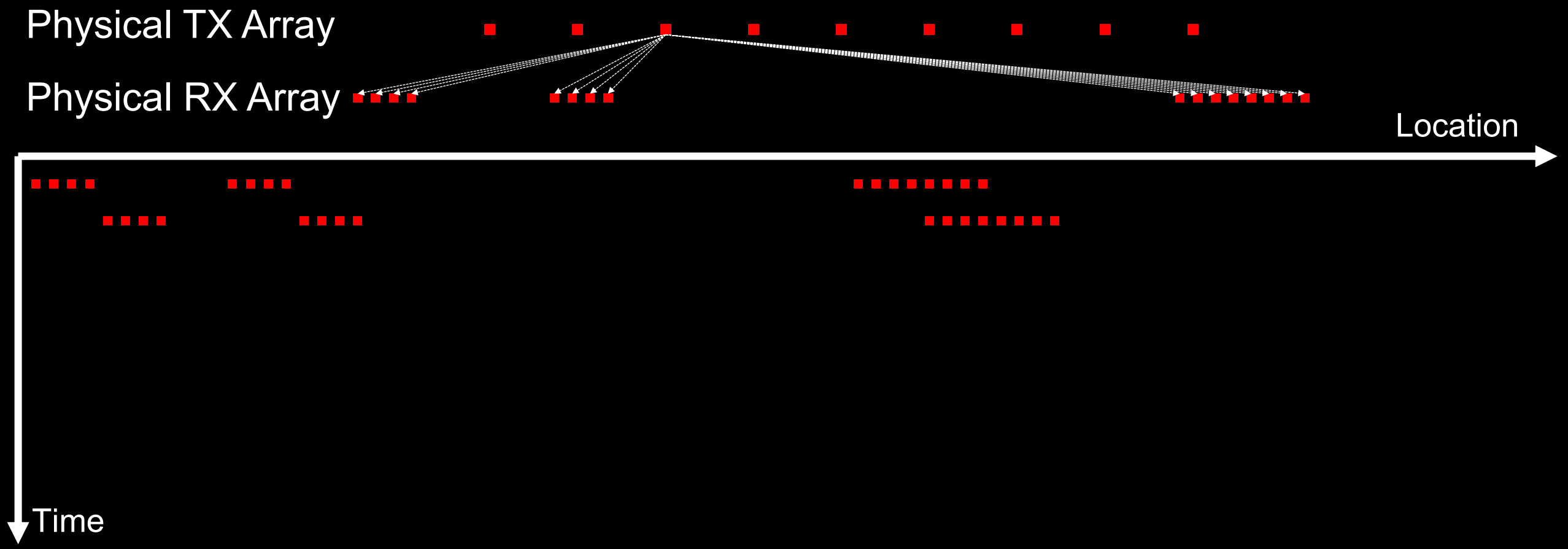
Virtual Antenna Array



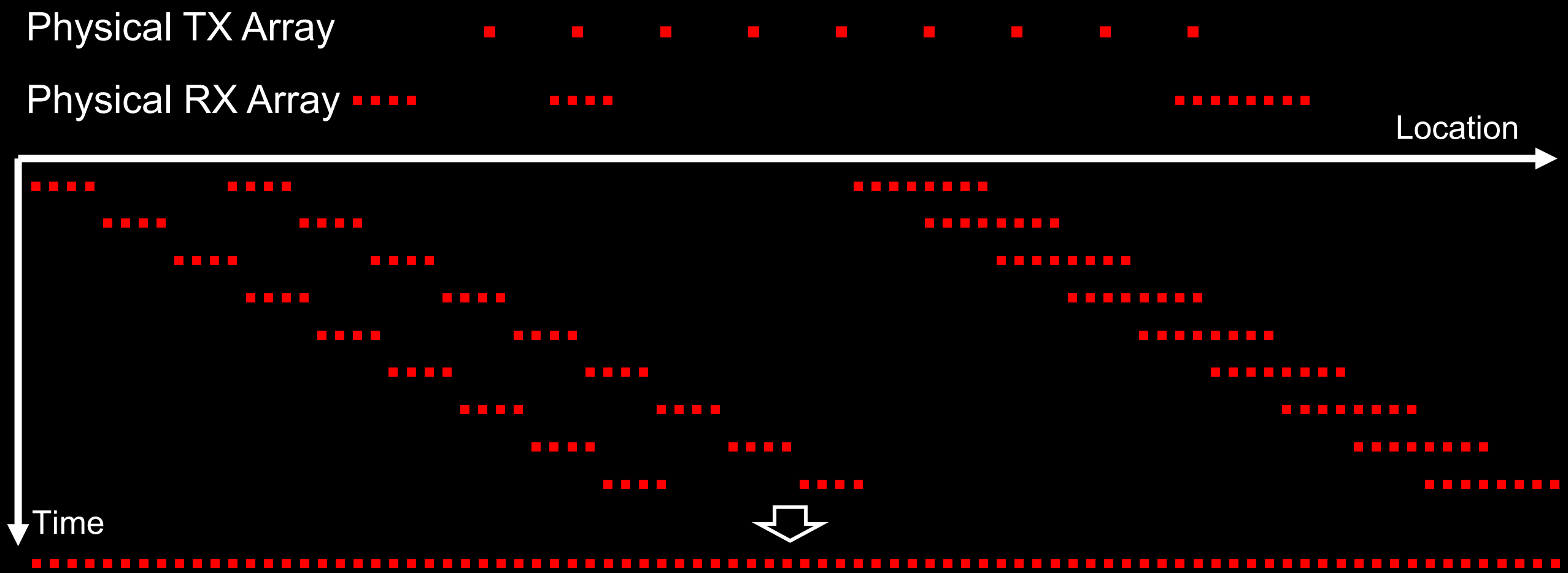
Virtual Antenna Array



Virtual Antenna Array



Virtual Antenna Array



86-element array

1.8º azimuth resolution 10x higher than single-chip radars

Accurate Bounding Box Detection

No Temporal Post Processing
Frame to frame detection in the range of 25 meters.