Accurate RFID Positioning in Multipath Environments

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MIT EECS

Work by Jue Wang

RFIDs

Battery-free RF stickers with unique IDs

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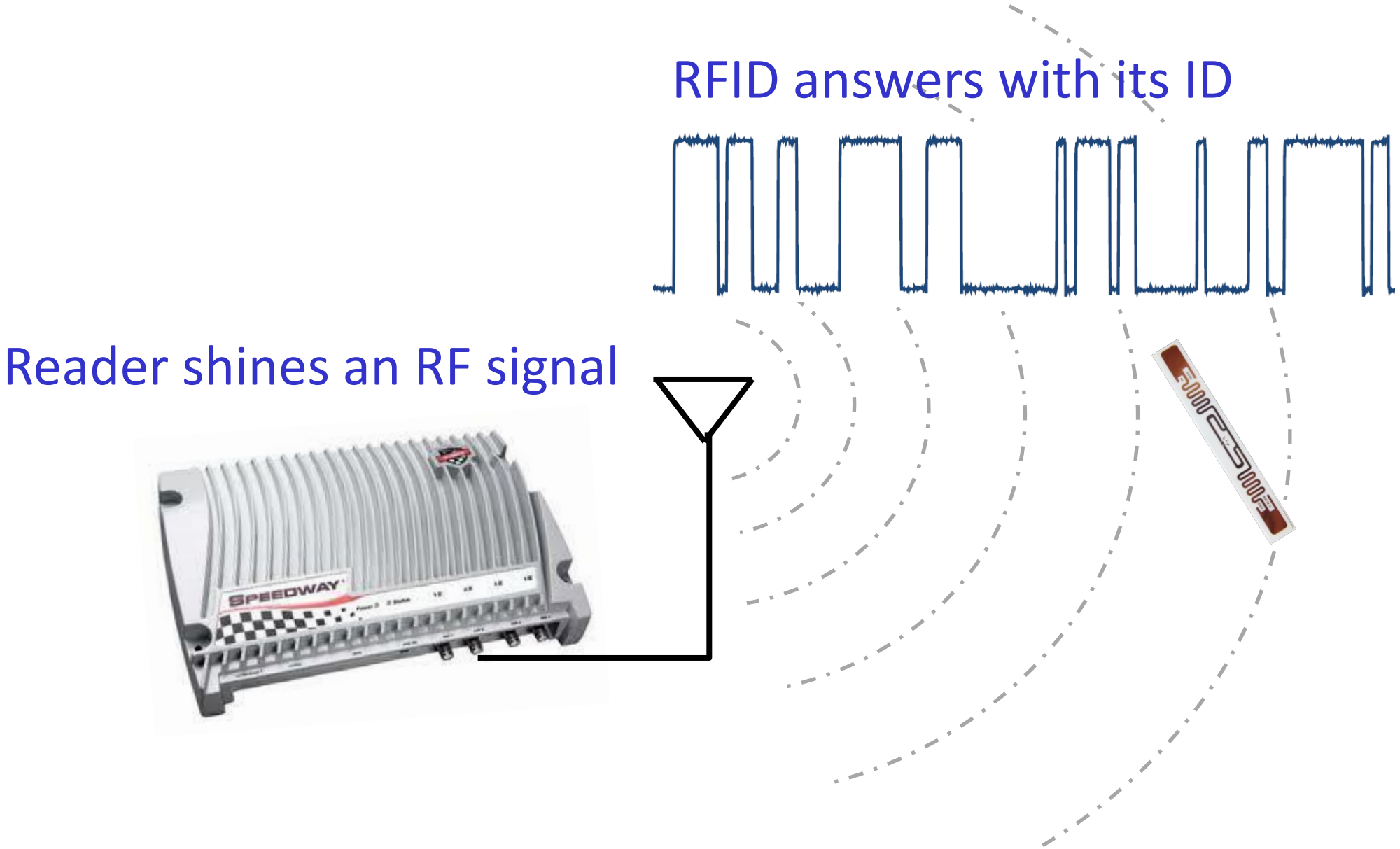
Battery-free RF stickers with unique IDs



RFIDs

Imagine you can localize RFIDs to within 10 to 15 cm!

5-cent stickers to tag any and every object

Reader’s range is ~15m

If we can locate RFID to within 10 to 15cm

No more customer checkout lines

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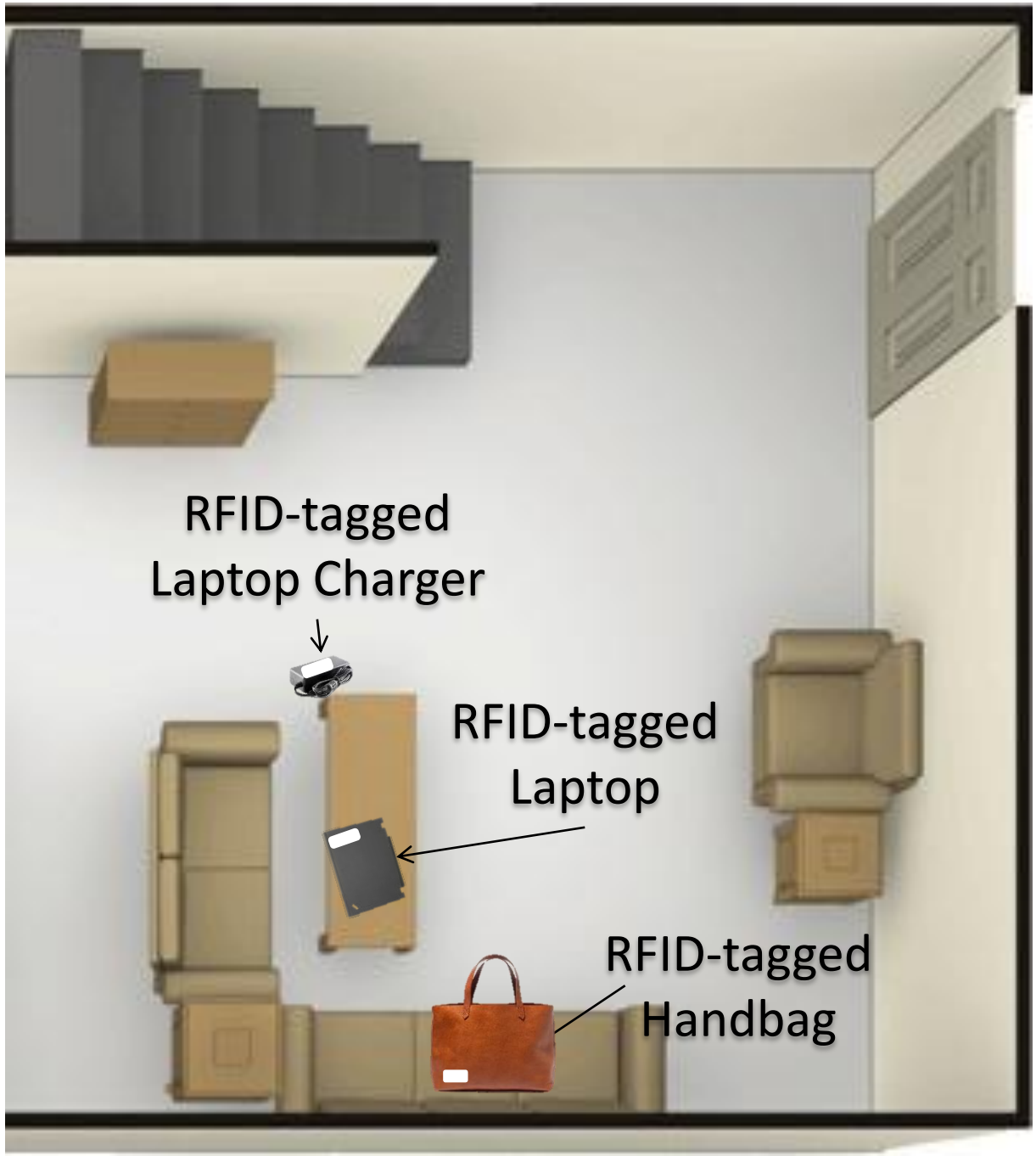
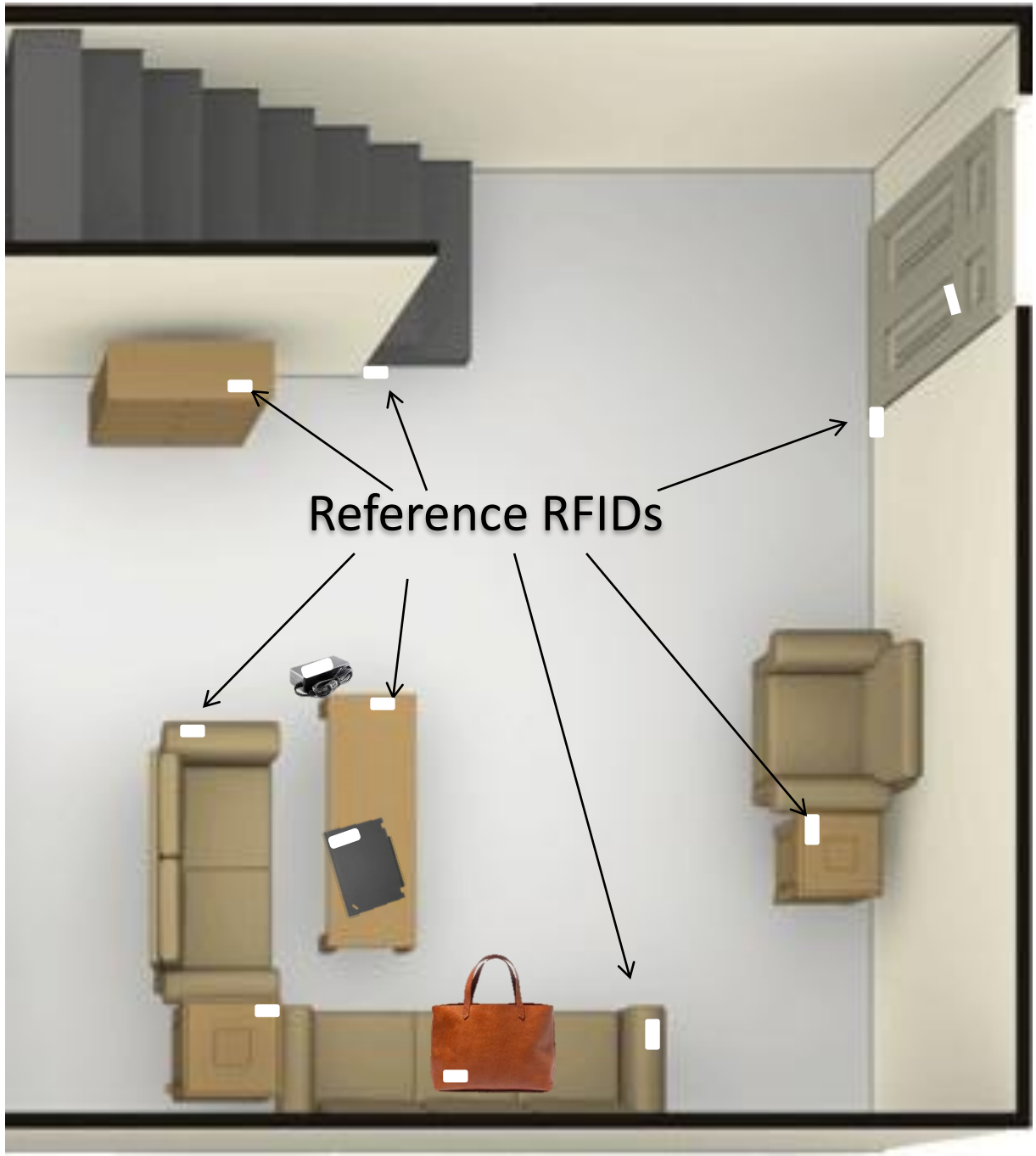
Smart Homes and Smart Objects



If we can locate RFID to within 10 to 15cm

Smart Homes and Smart Objects



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Smart Homes and Smart Objects

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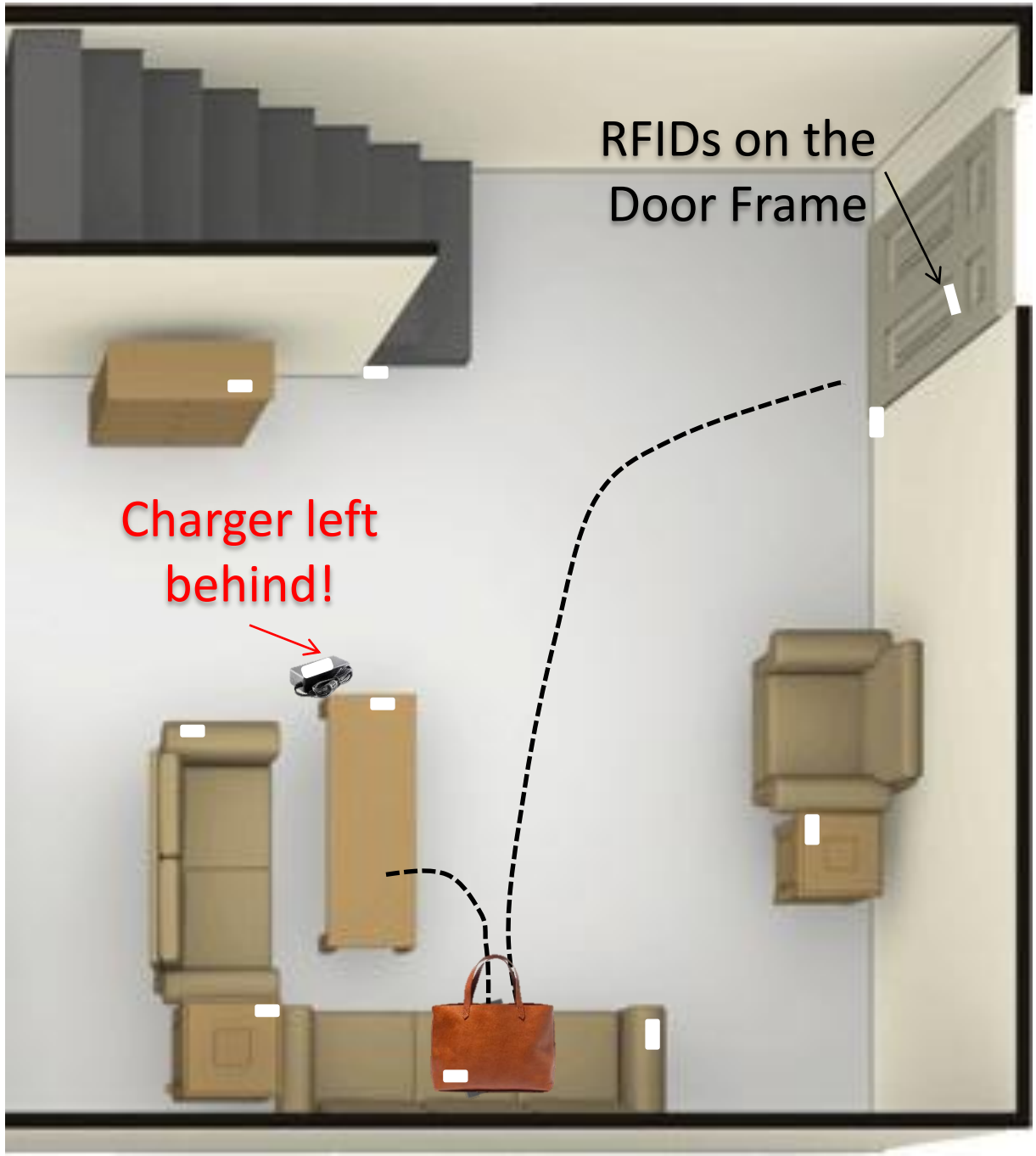
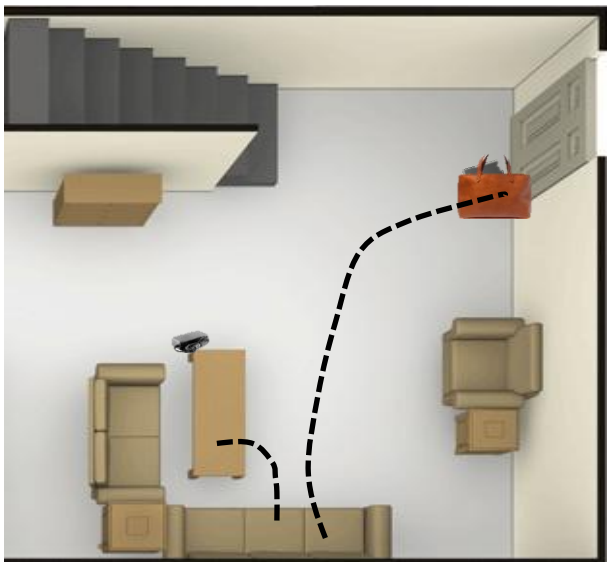


Many applications can be enabled by 10-15 cm RFID localization

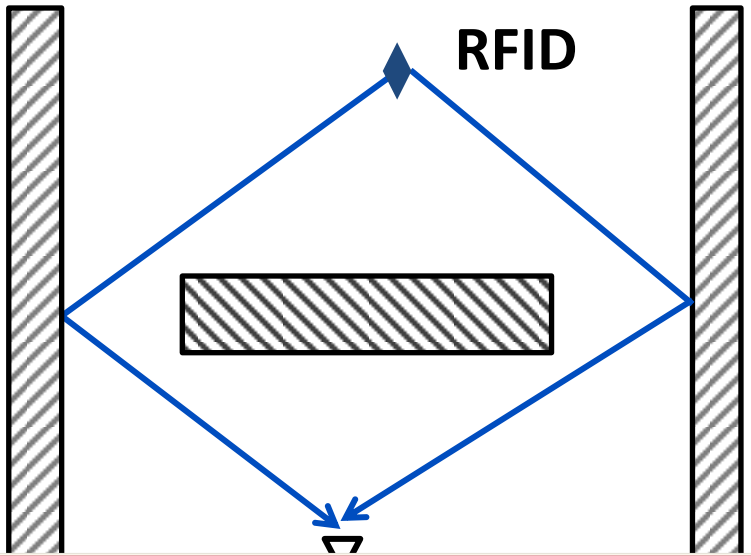


Why don’t we have accurate RFID localization?

The Challenge: Multipath Effect

Localization uses **RSSI** or **Angle-of-Arrival (AoA)**

But, signal bounces off objects in the environment



Multipath propagation limits the accuracy of RFID localizations

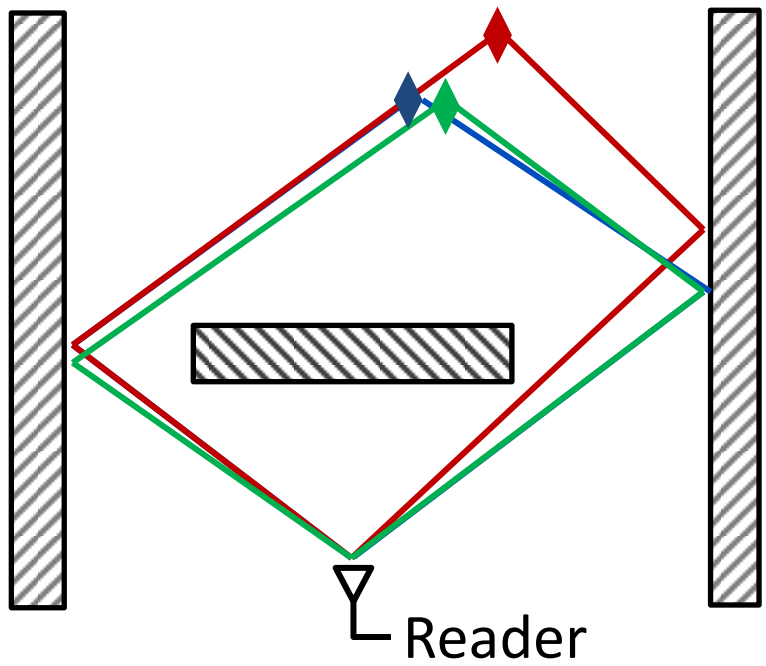
PinIt

Accurate RFID localization (e.g., 10 to 15cm) even in multipath and non-line-of-sight settings

- Focuses on proximity to reference RFIDS
- Exploits multipath effects to increase accuracy

PinIt Exploits Multipath

Signals from nearby RFIDs propagate along closer paths and experience similar reflections



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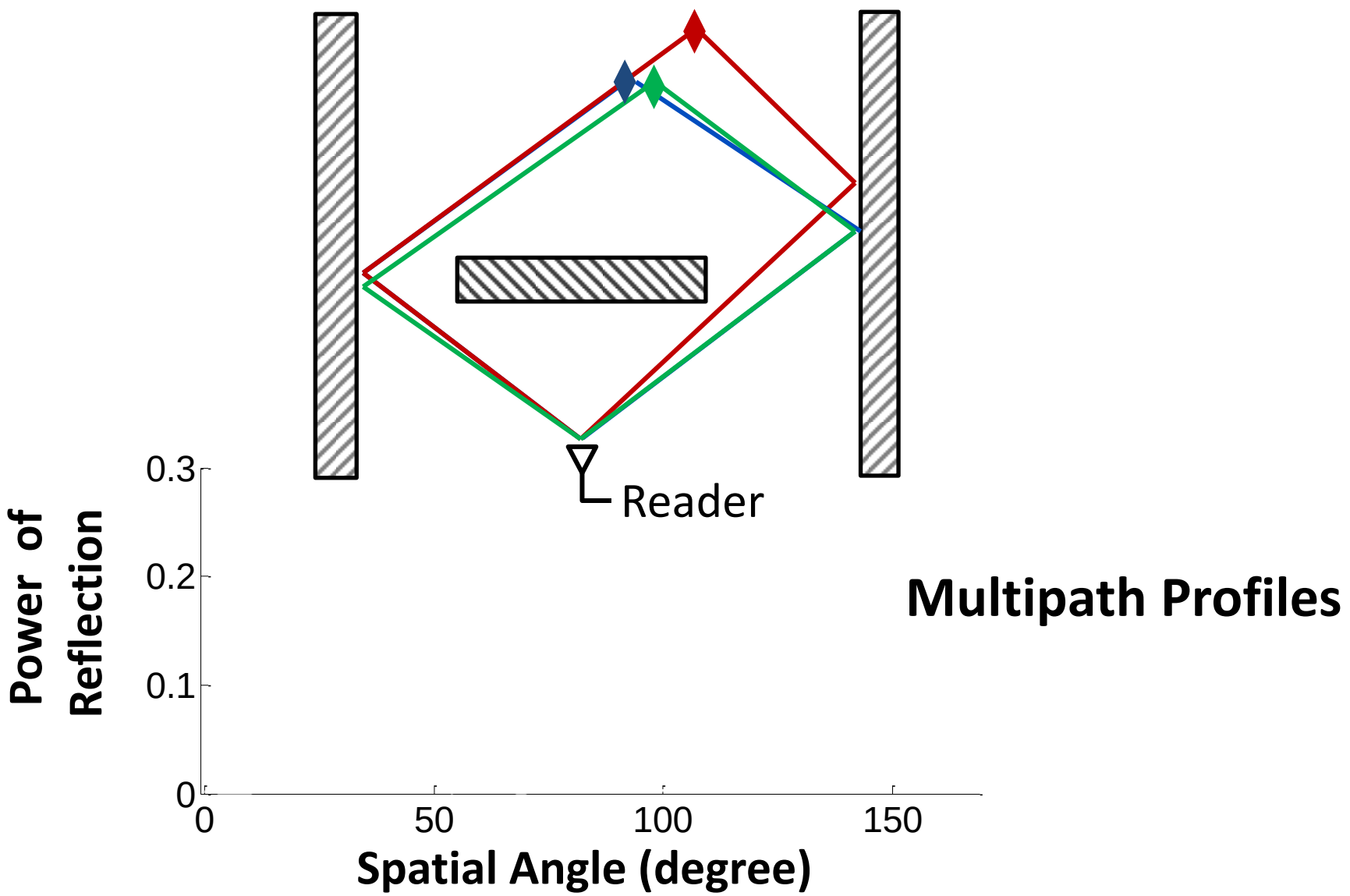

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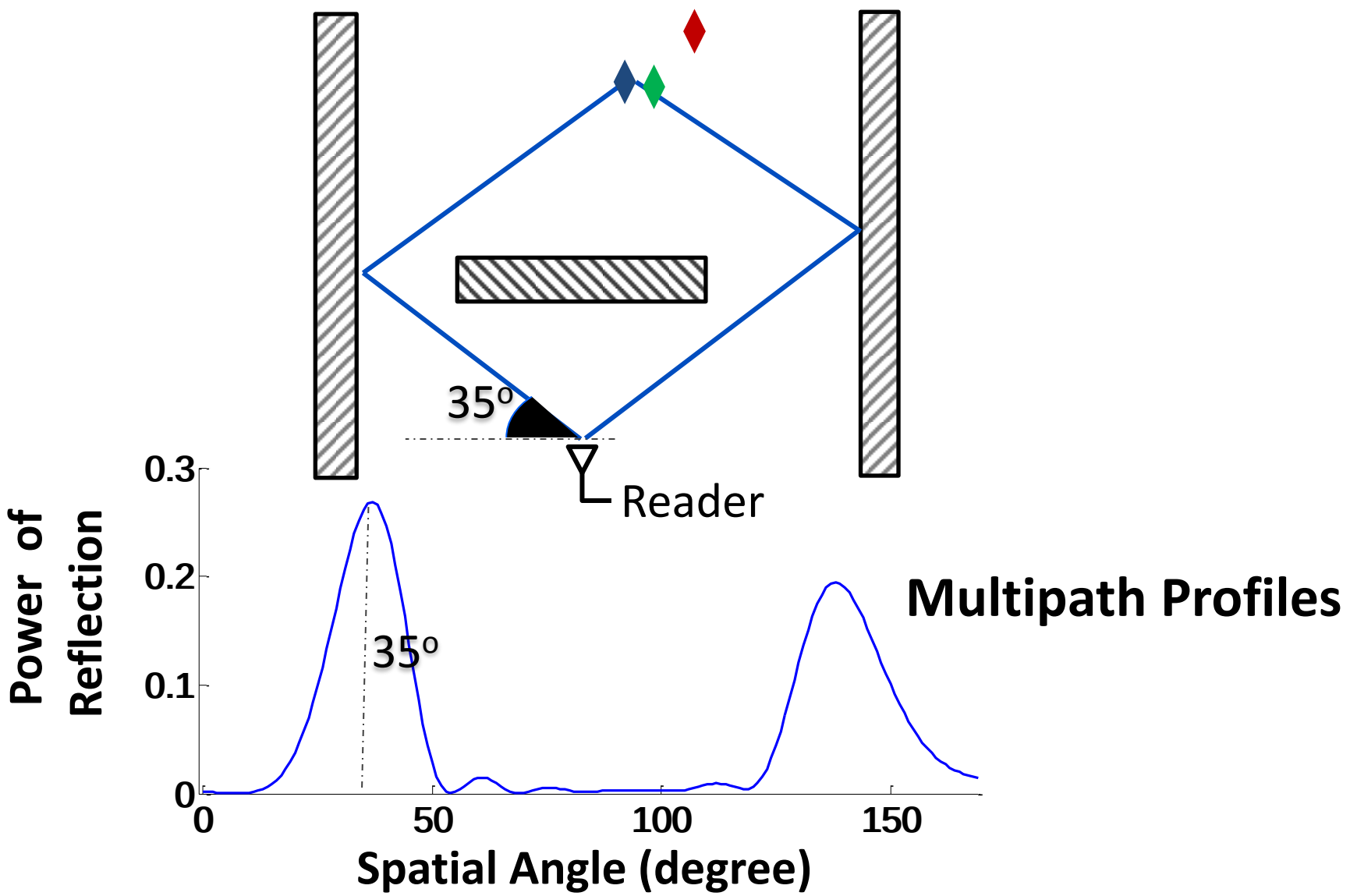

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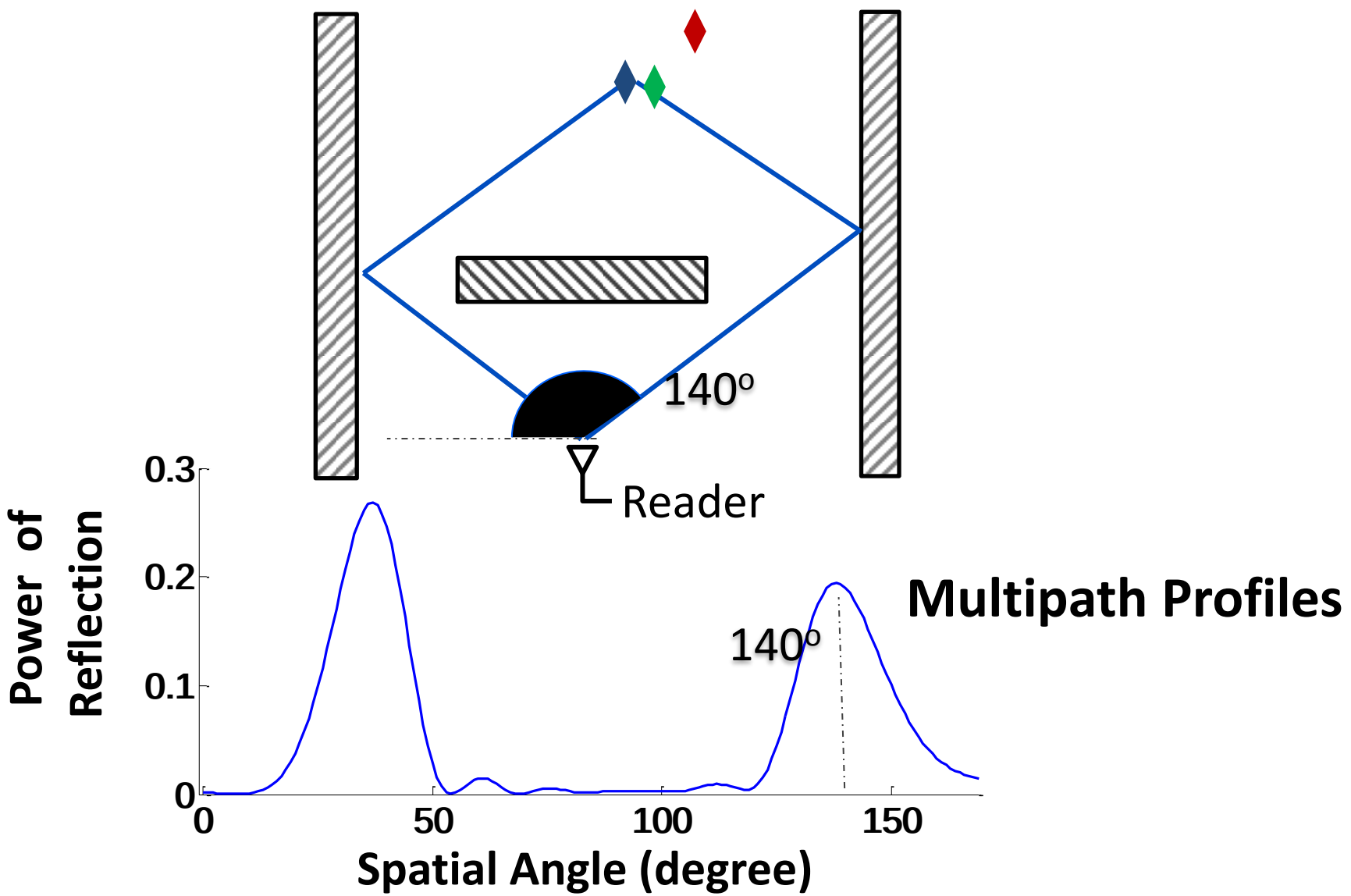
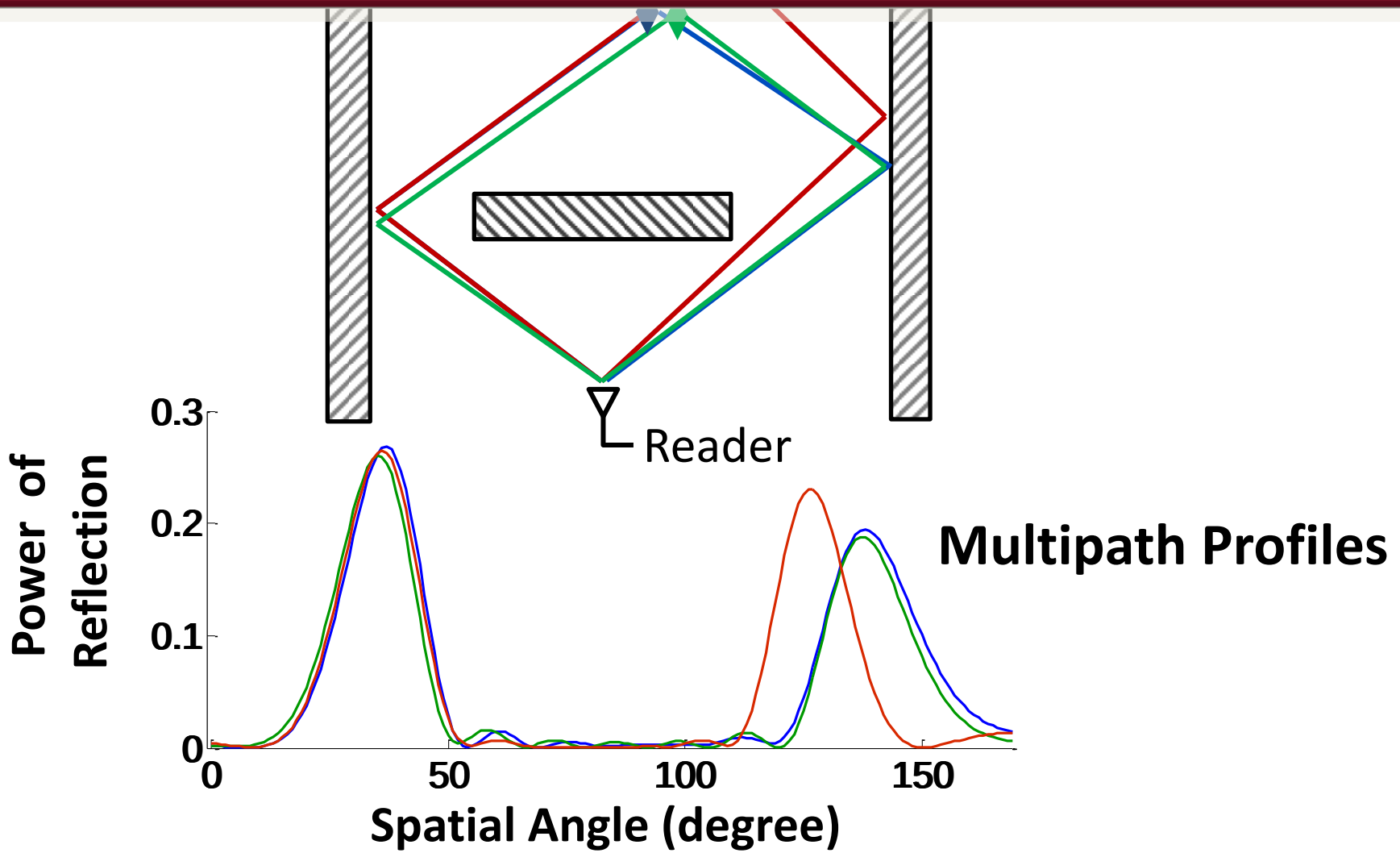
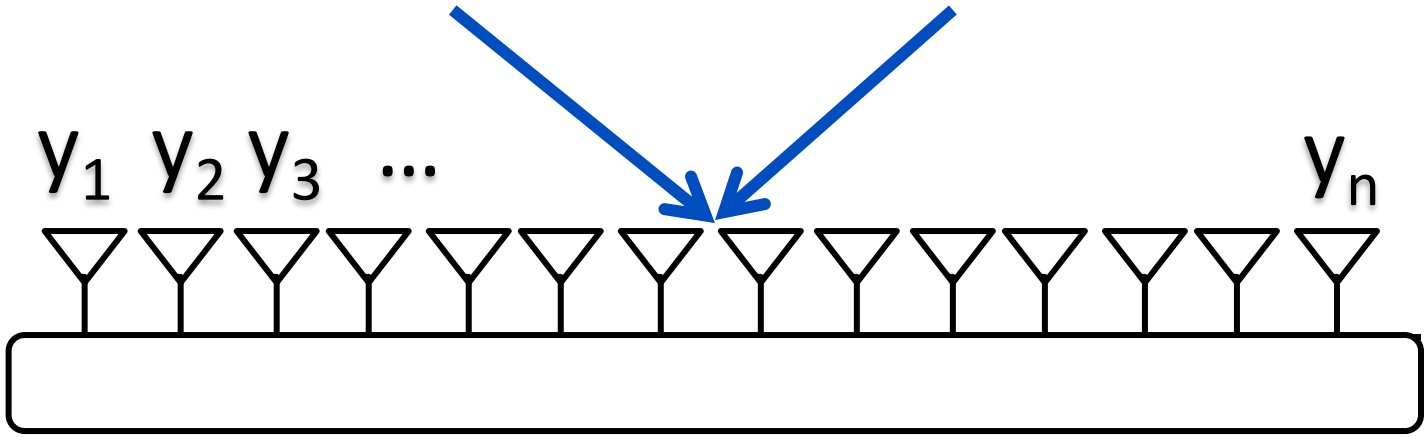


PinIt Exploits Multipath

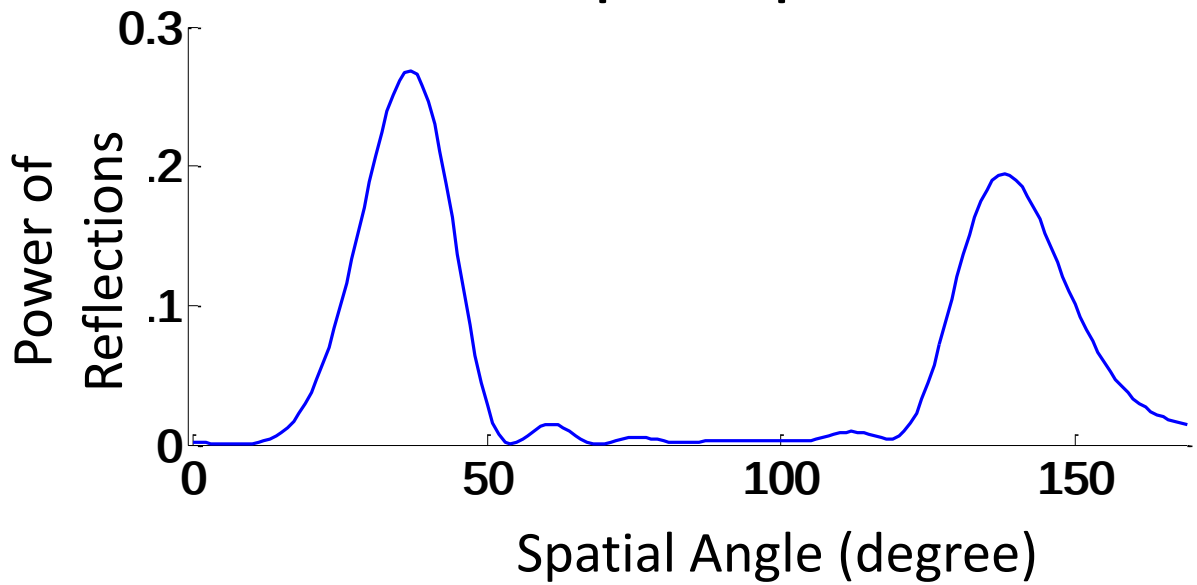
Nearby RFIDs have similar profiles with smaller shifts in the peaks



Capturing Multipath Profiles with an Antenna Array



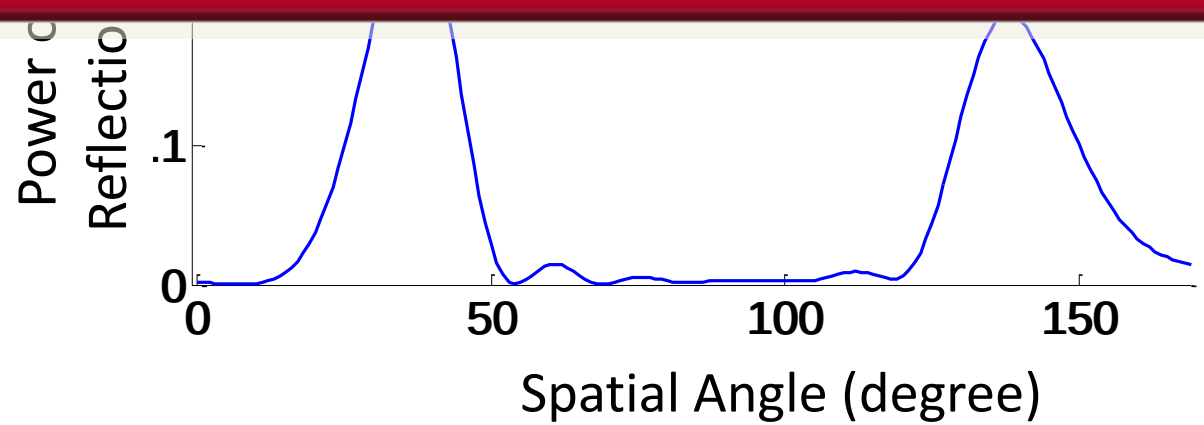
Use textbook equations to process y_1, …, y_n and obtain the multipath profile



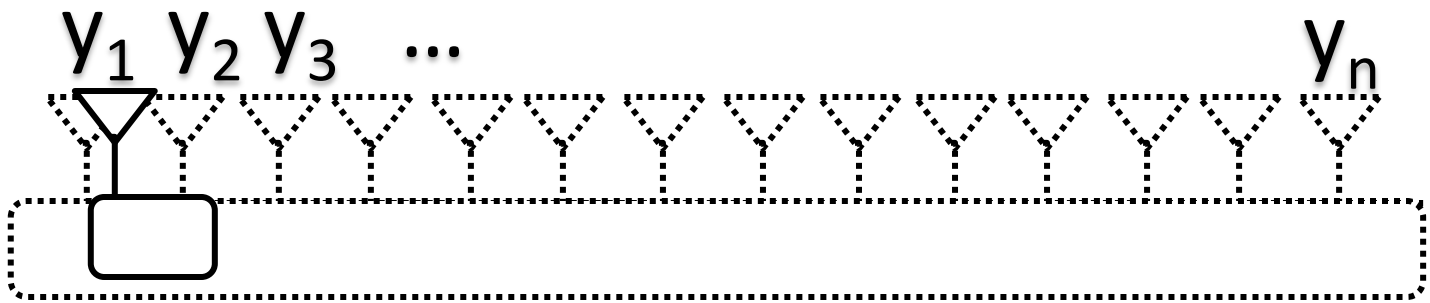
Capturing Multipath Profiles with an Antenna Array

Accurate multipath profiles require many antennas in the array

➔ Array is bulky and expensive



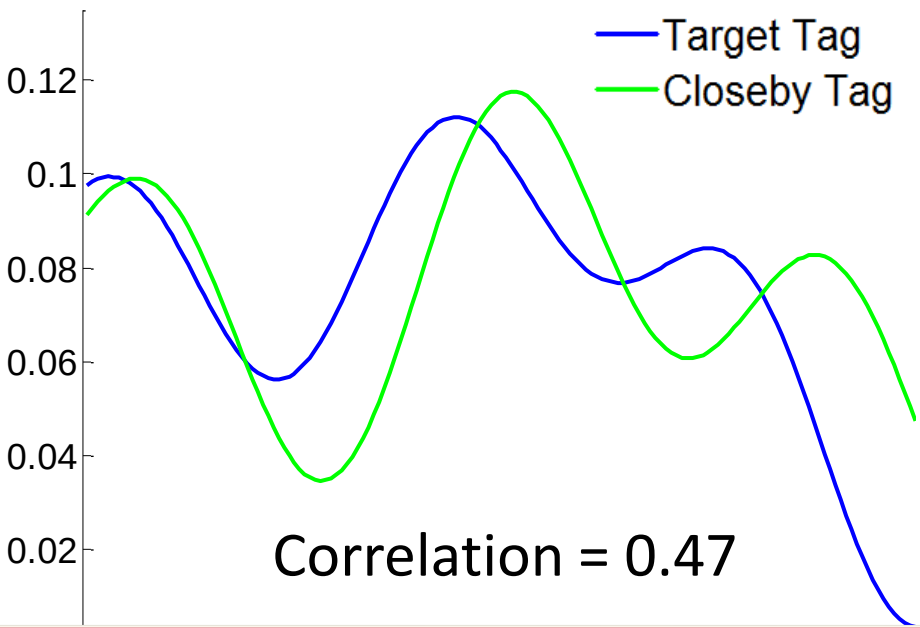
Capturing Multipath with a Sliding Antenna

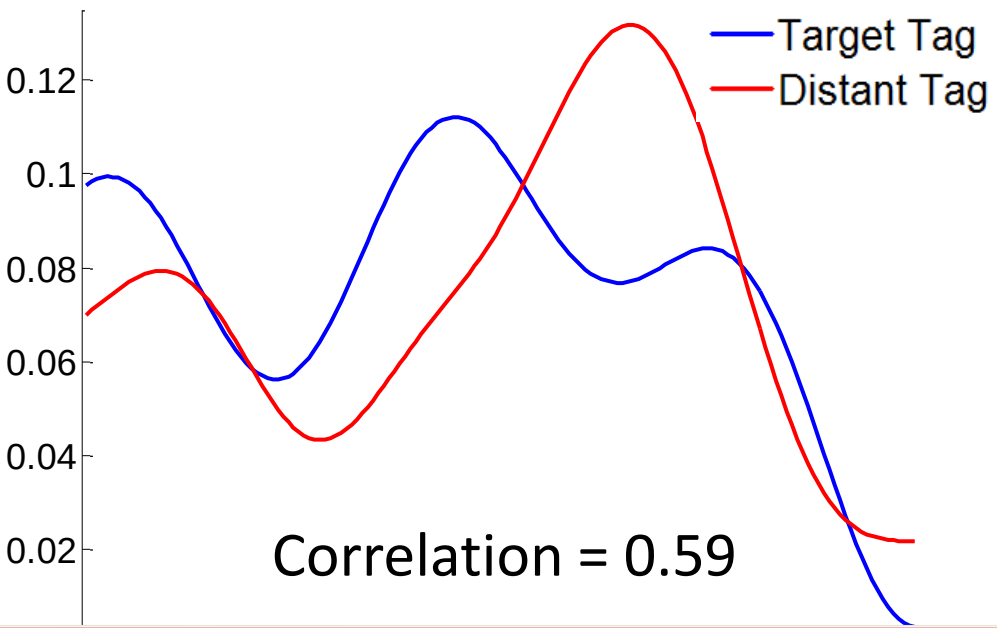


Can capture very accurate multipath profiles with a single sliding antenna

How do we detect proximity from multipath profiles?

Naïve approach: correlate profiles!





Correlation cannot capture peak shifts

How do we detect proximity from multipath profiles?

Borrow from speech recognition!

Dynamic Time Warping (DTW)

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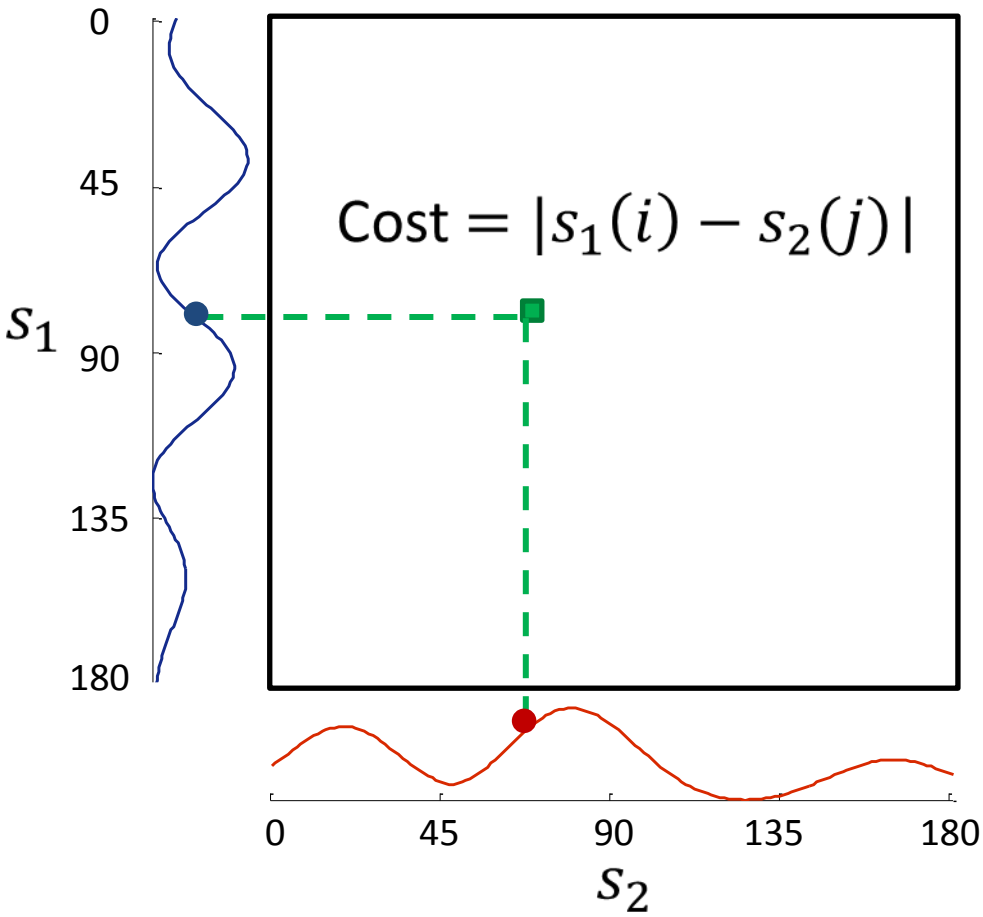
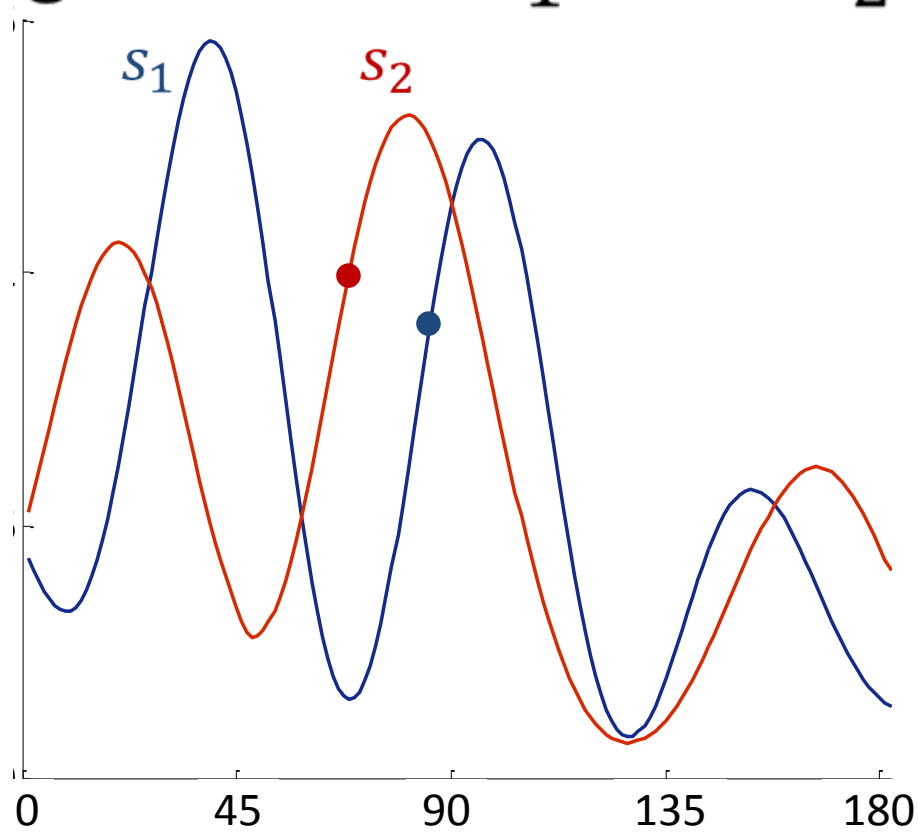
Computes the total warping to obtain s_1 from s_2





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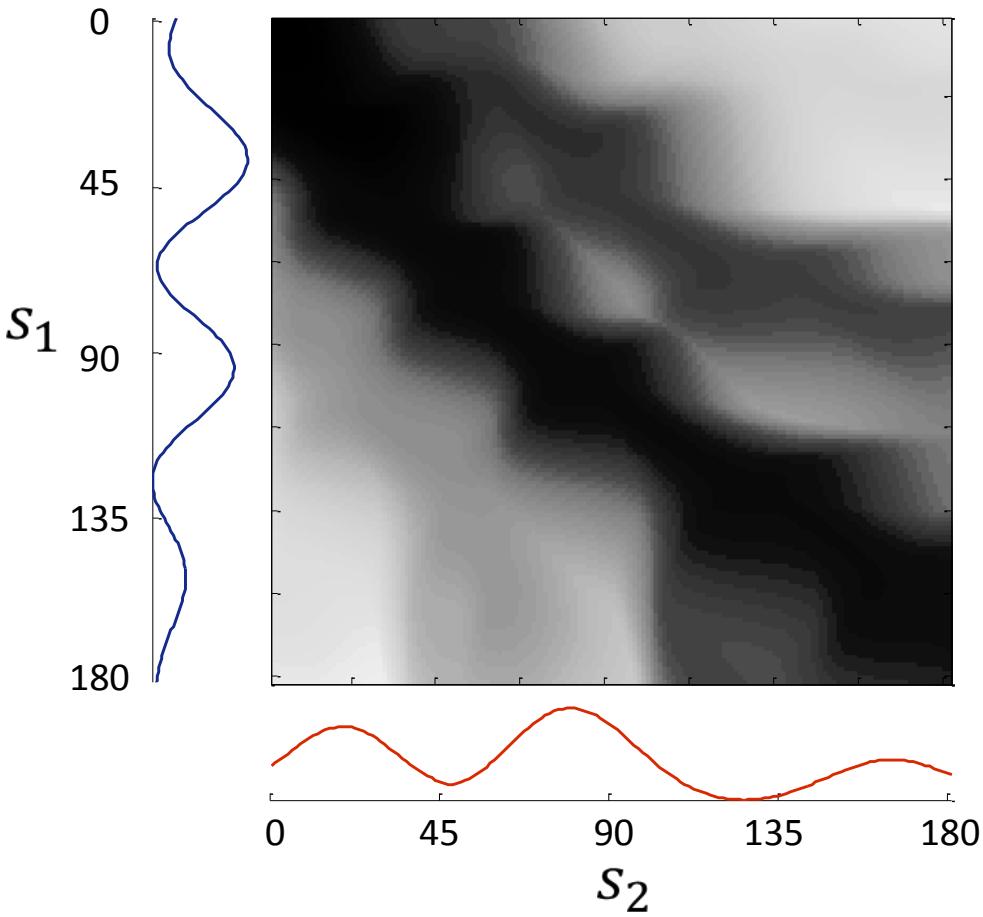

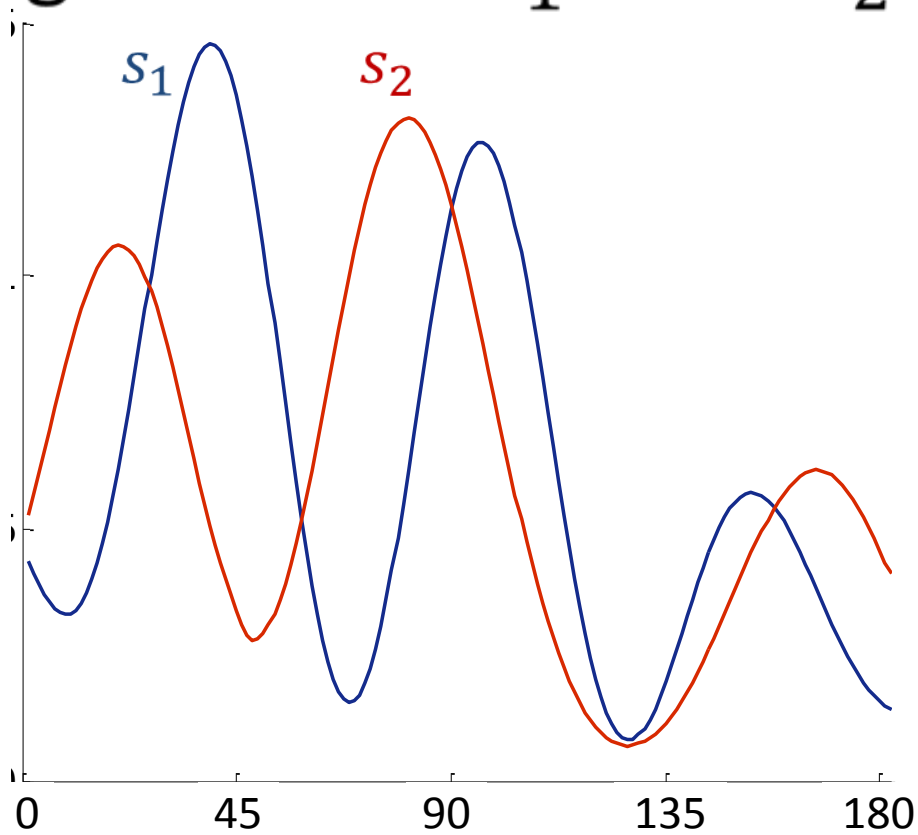

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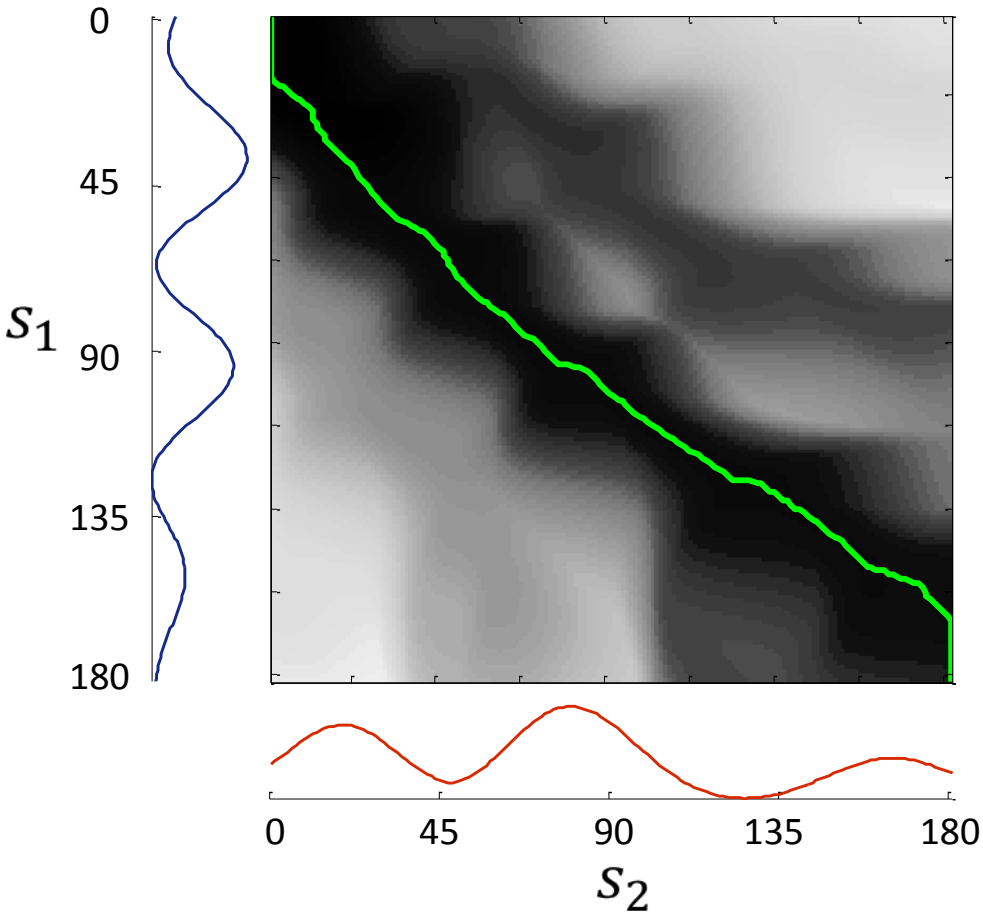
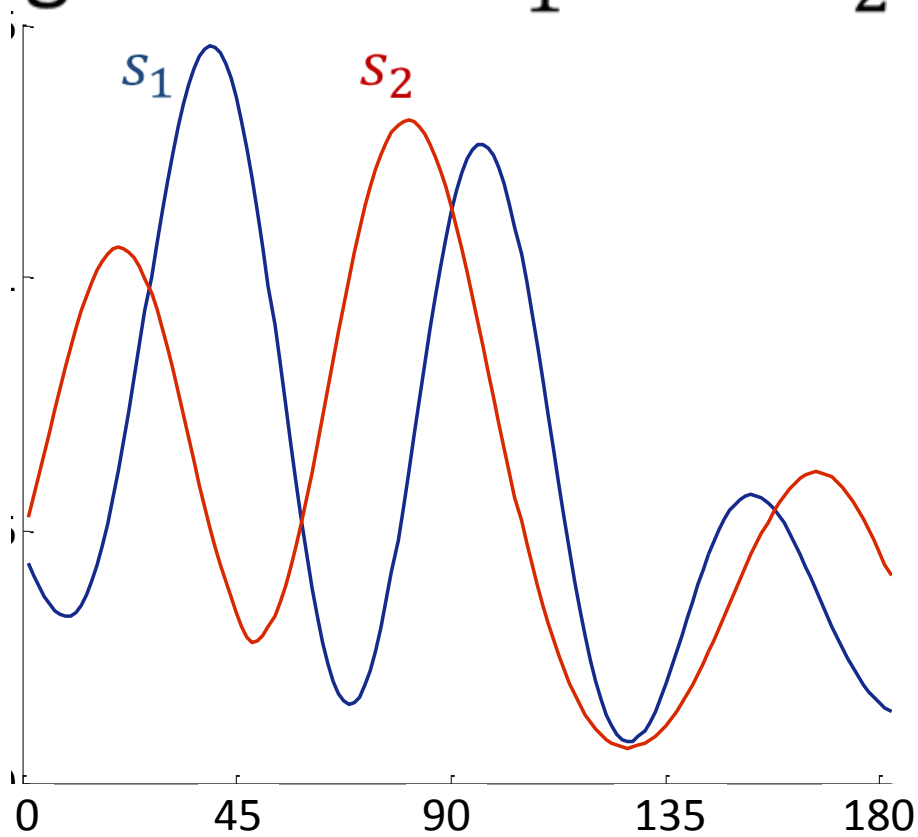
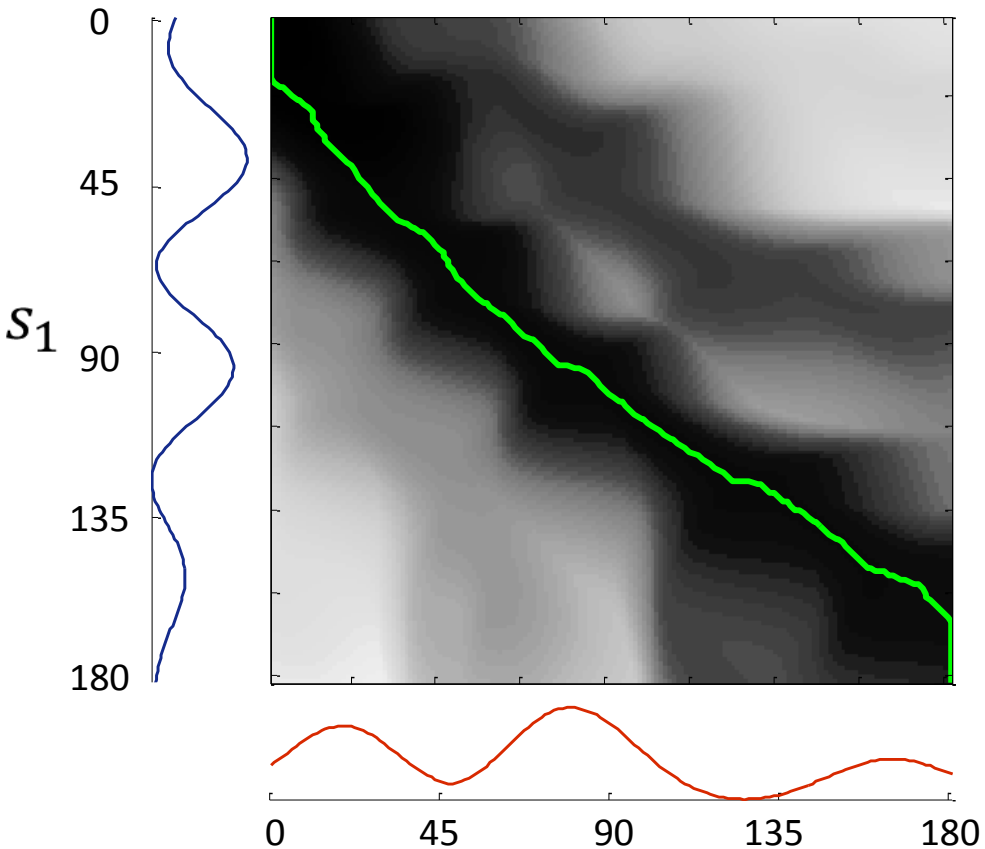


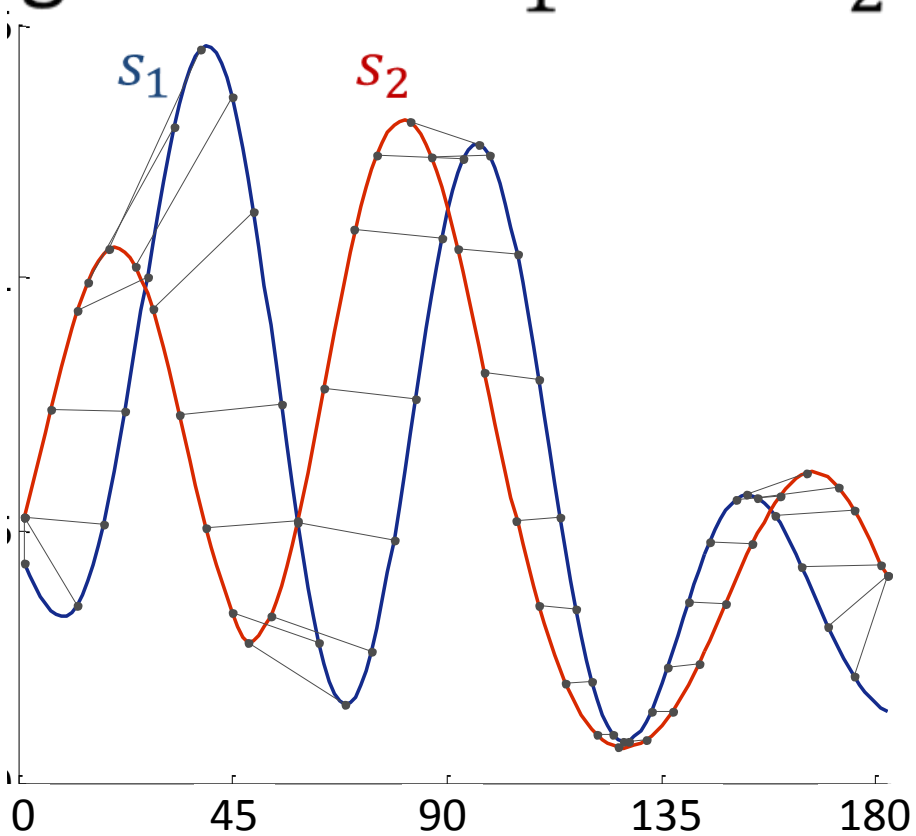


Compute DTW by finding the route with lowest total cost

Dynamic Time Warping (DTW)

Computes the total warping to obtain s_1 from s_2





DTW captures proximity from multipath profiles

Experimental Results

Implementation & Evaluation

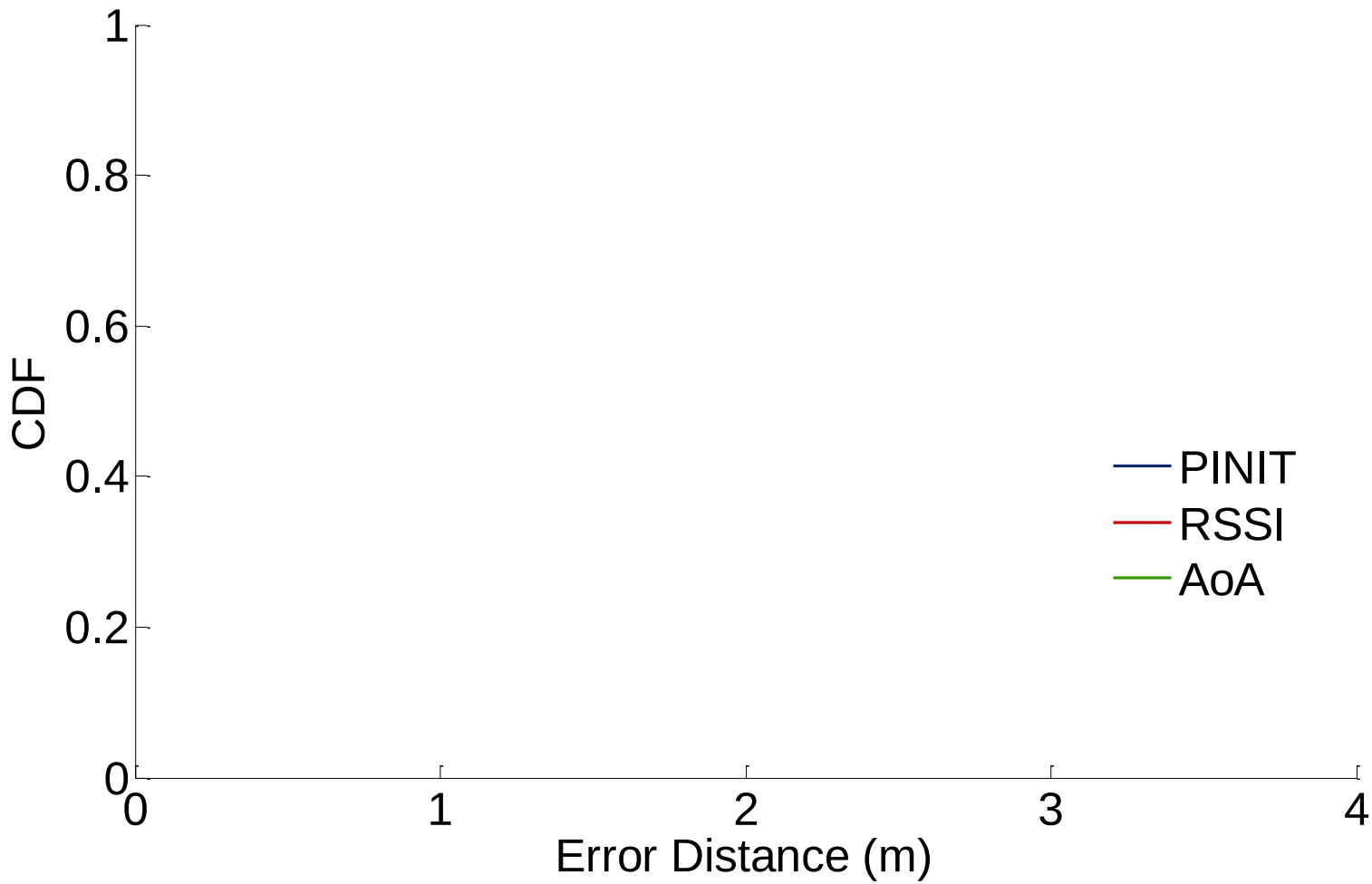
- Implemented a PinIt Reader in USRP
- Commercial off-the-shelf RFIDs

- Mounted the antenna on an iRobot that slides back and forth

Experiment

- 200 RFIDs deployed on the shelves in the library spaced by 15 cm
- Objective: Find randomly placed books by localizing their RFIDs

Positioning Accuracy



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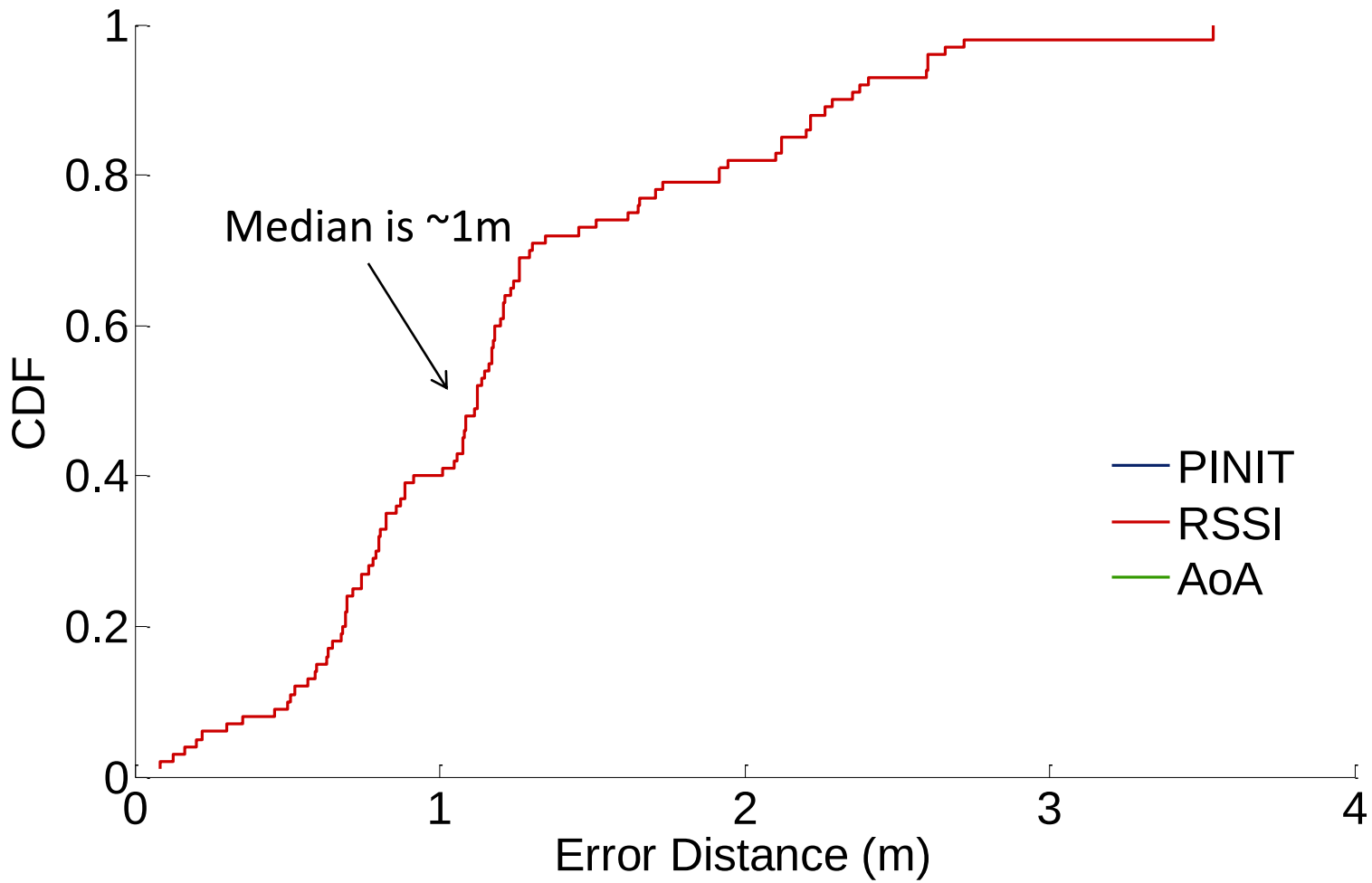

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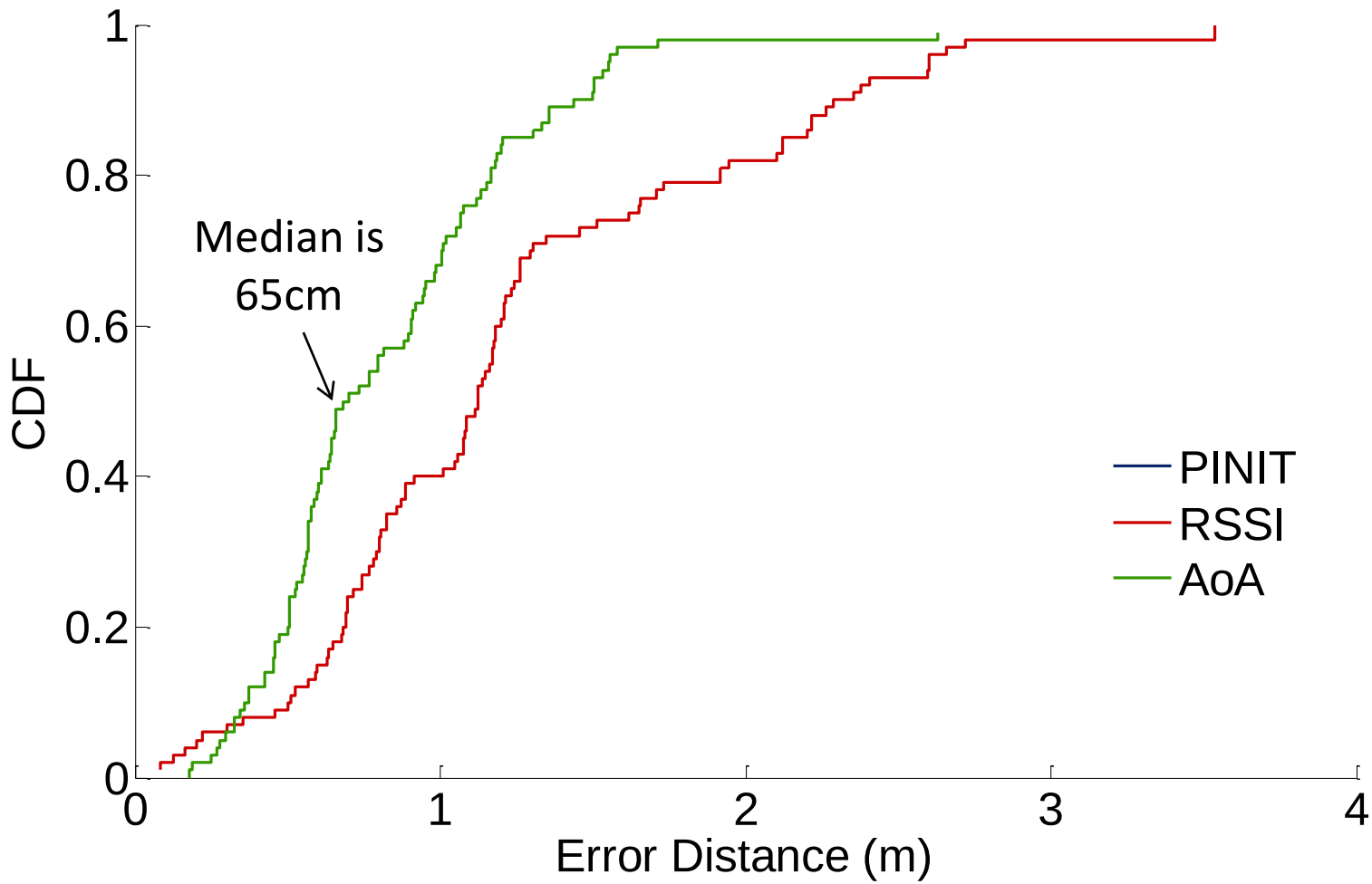

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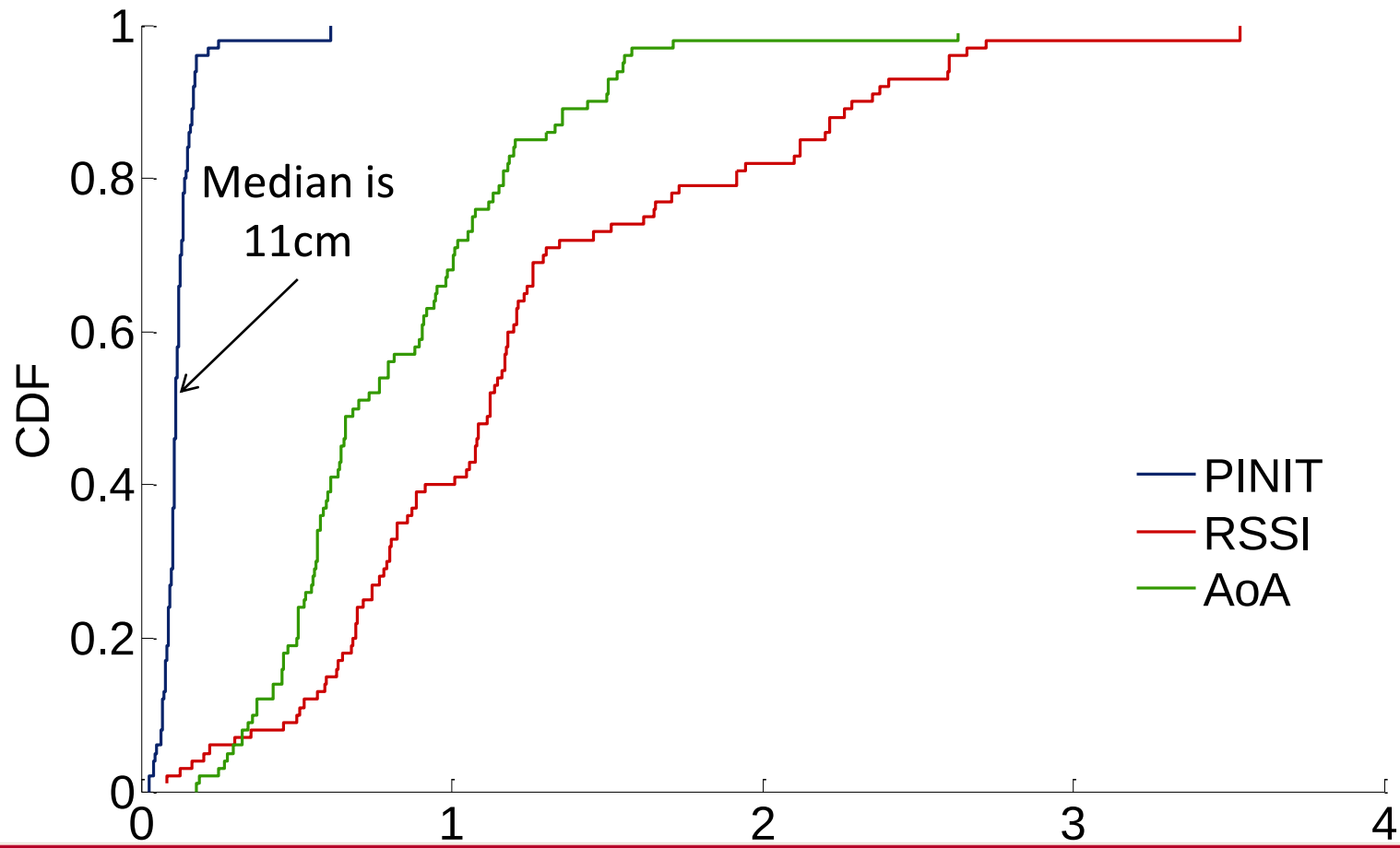
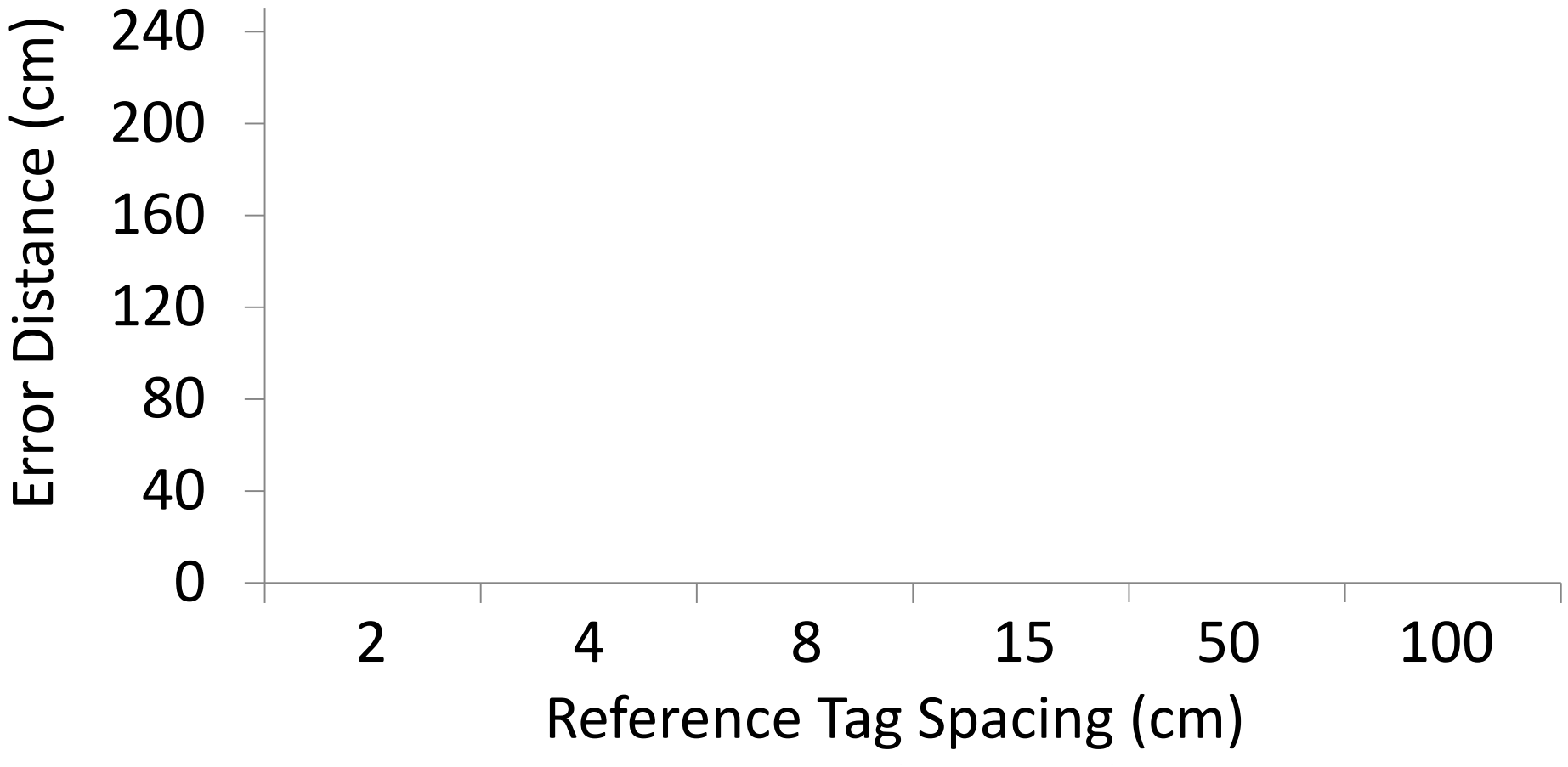


PinIt improve the accuracy by 6x in comparison to AoA and 10x in comparison to RSSI

Accuracy as a Function of Reference Spacing



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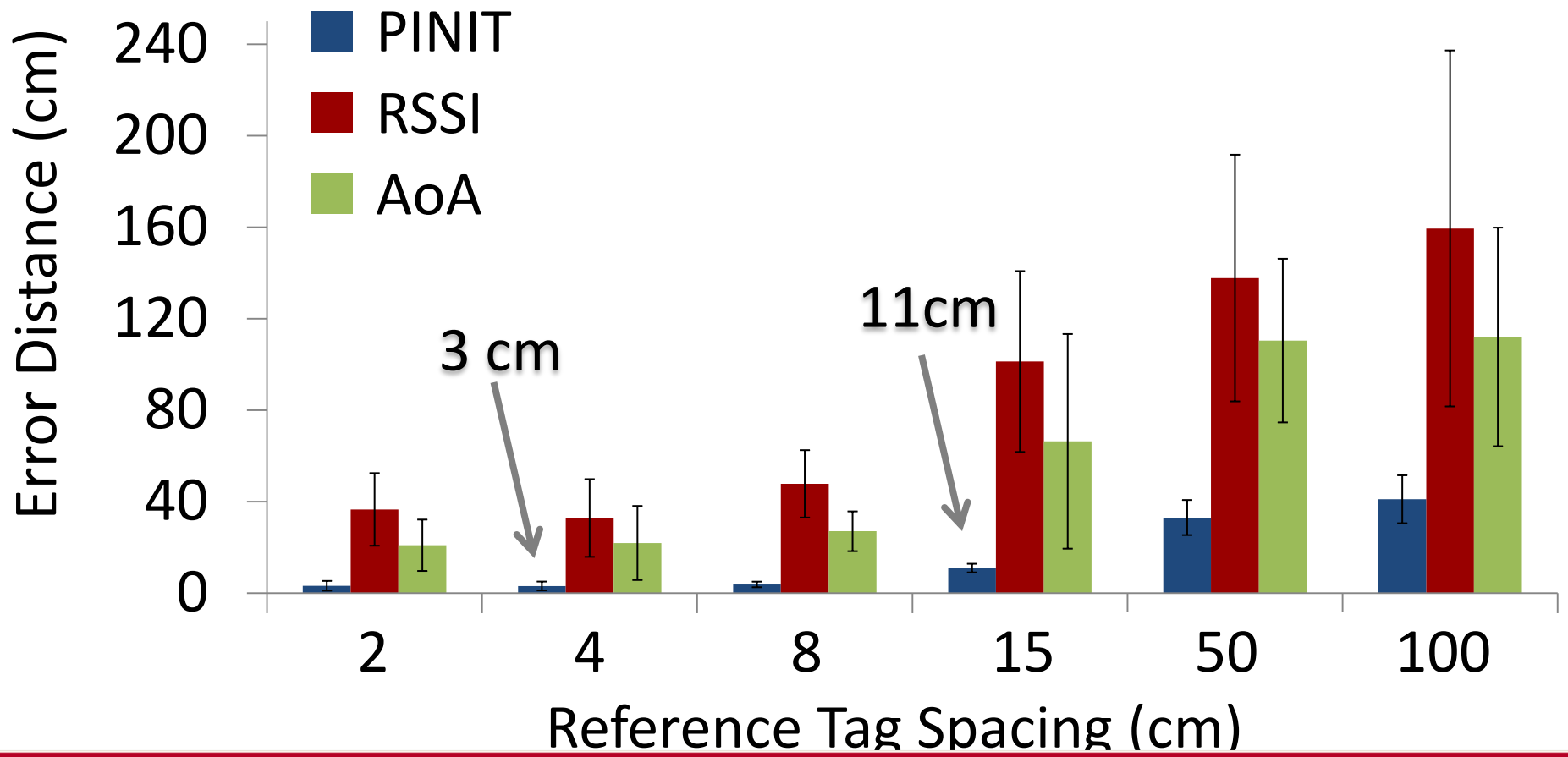


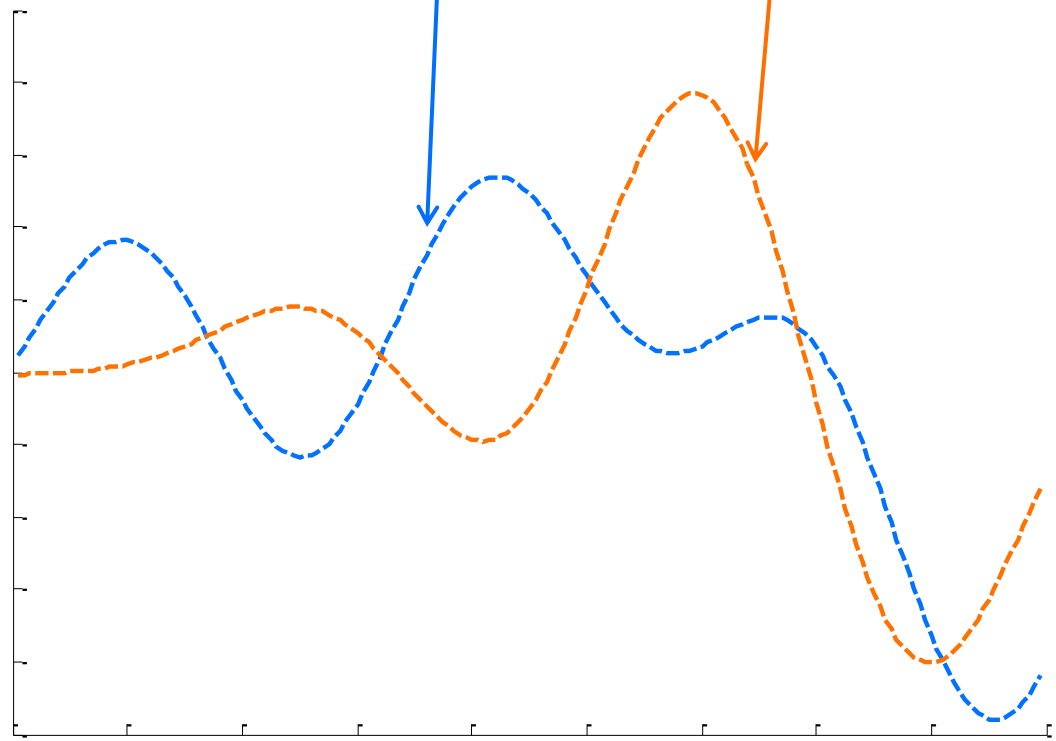
Can pin the accuracy to the nearest neighbor

Automatic Checkout

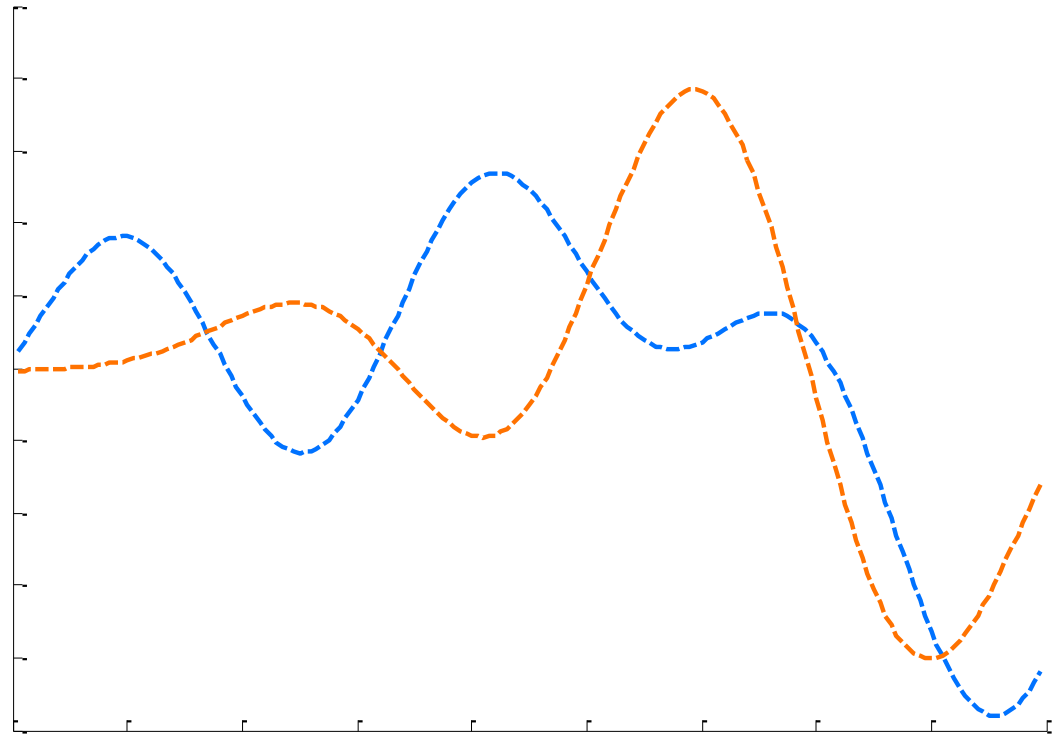
Five items in two adjacent baskets at checkout:

Which Items Belong to Which Basket?

?



Is the Cookie Bag in the Orange or Blue Basket?



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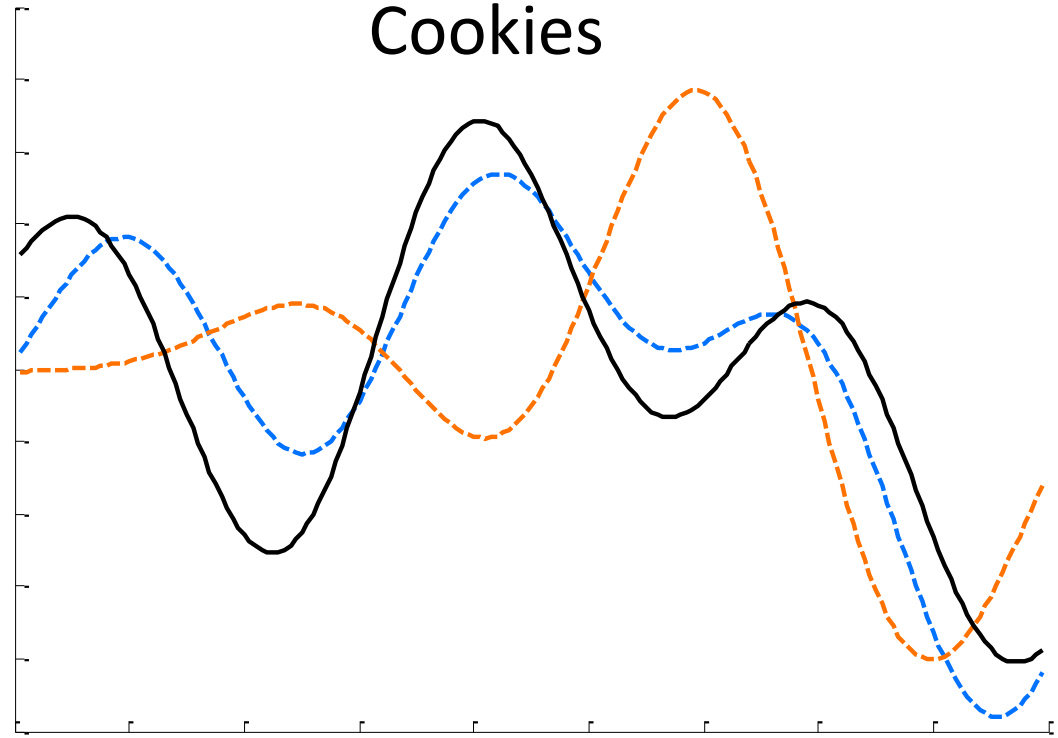

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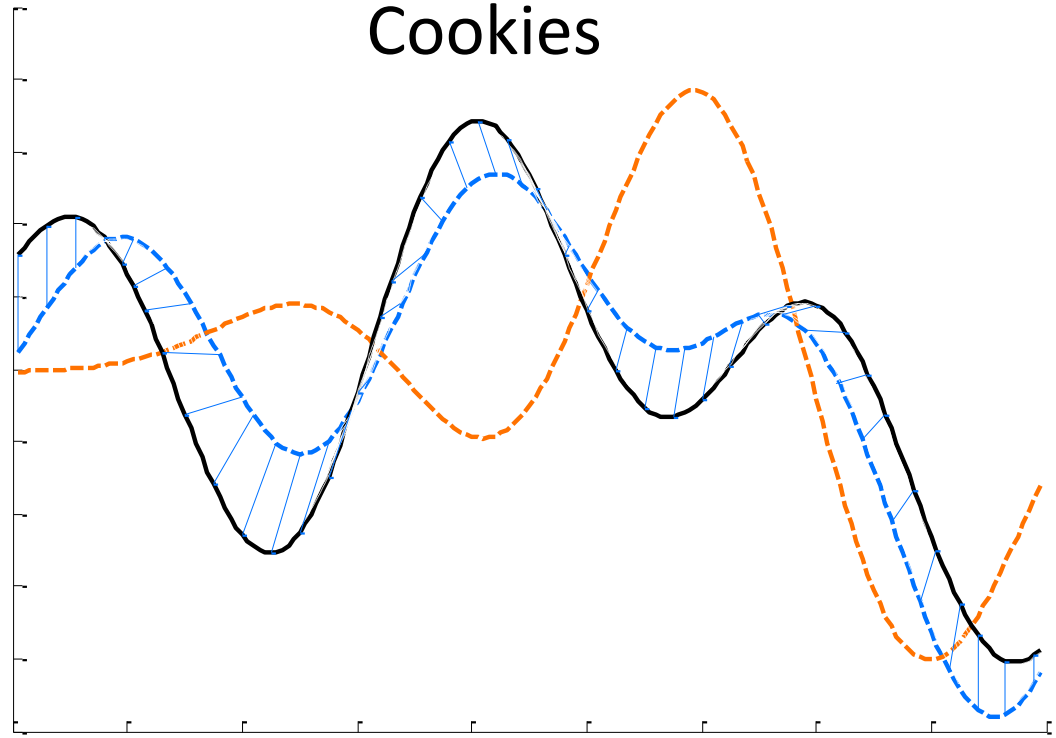
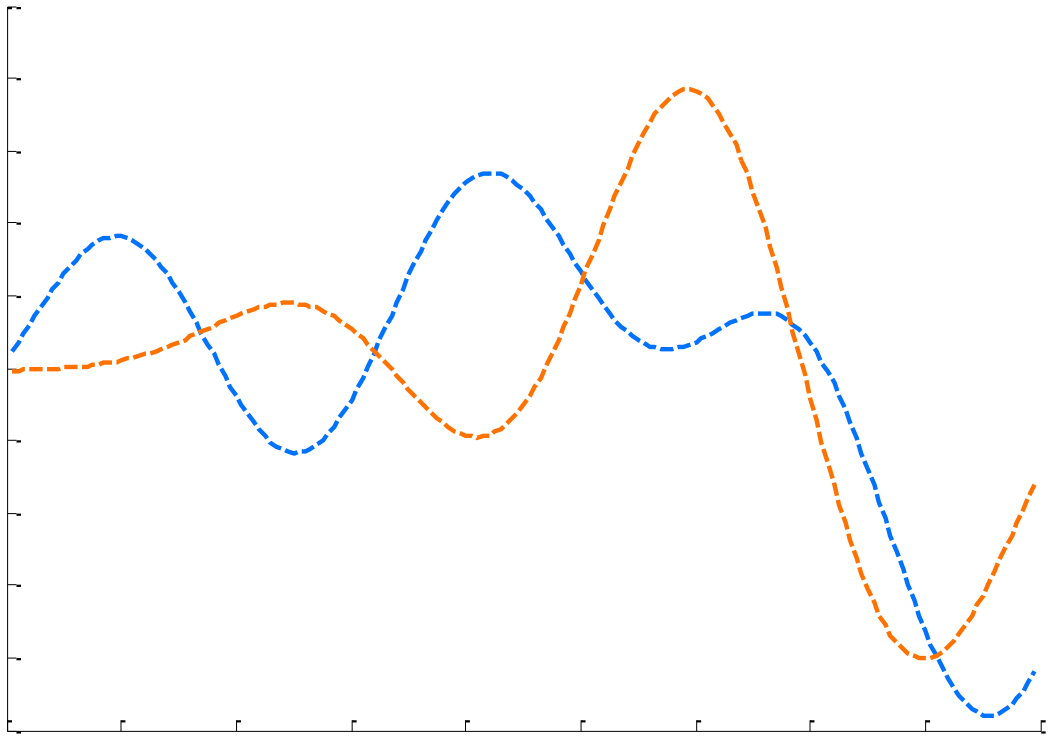


Is the Noodle in the Orange or Blue Basket?



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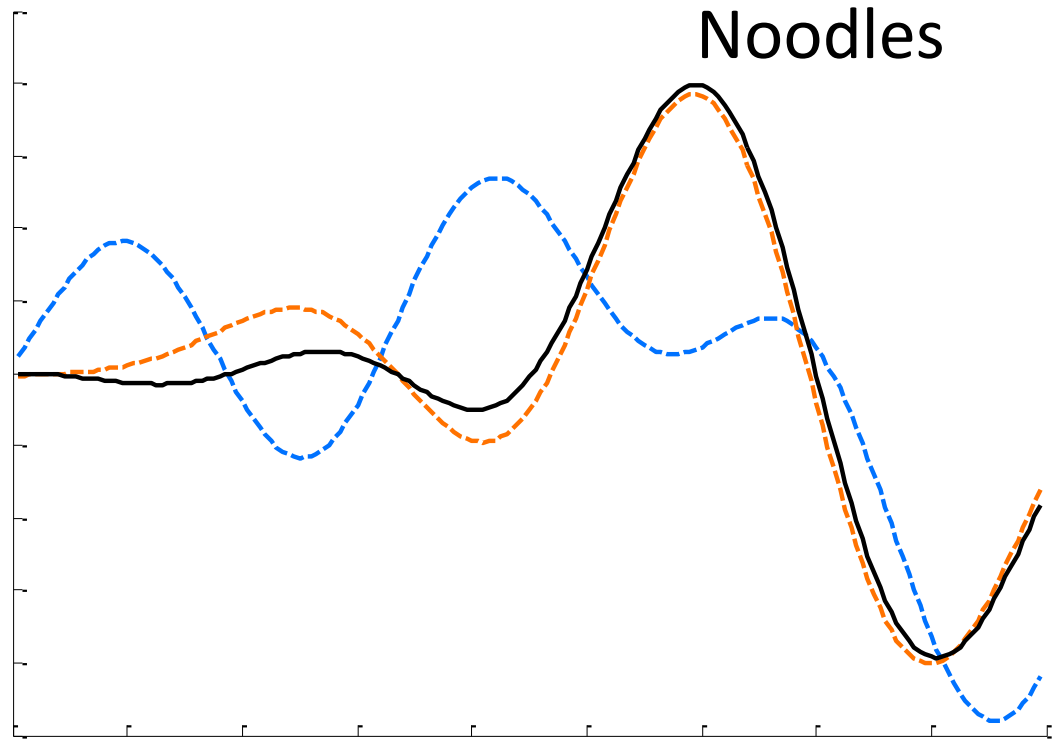

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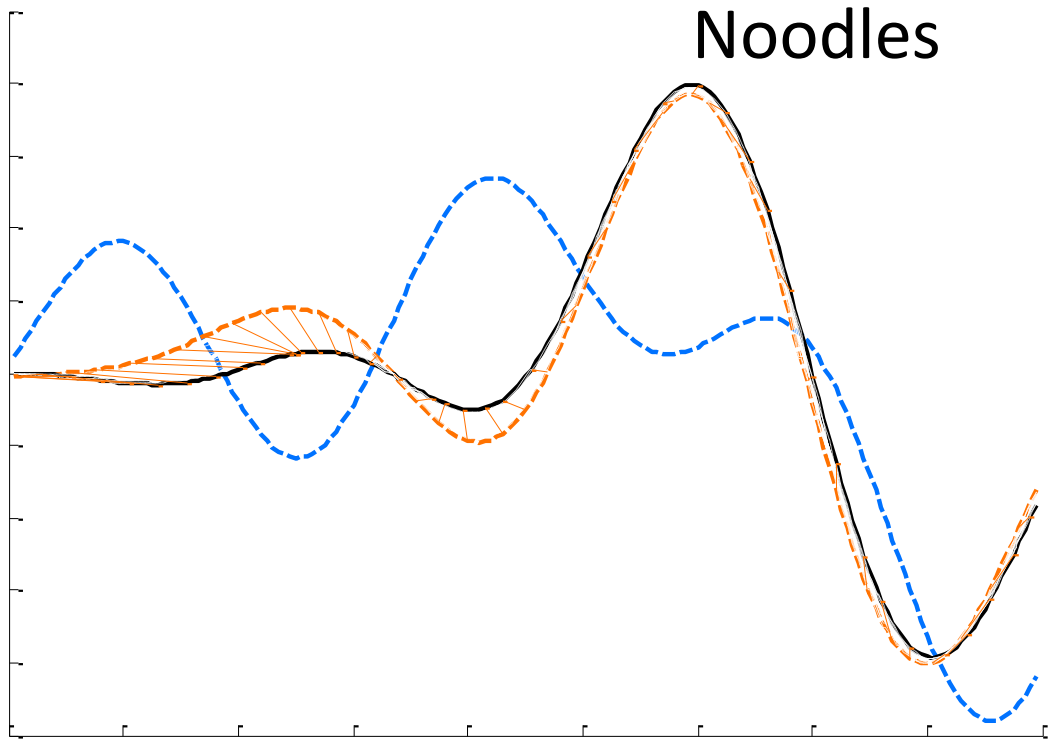



Milano
Enjoy a few quiet moments and a Milano cookie.


CT35

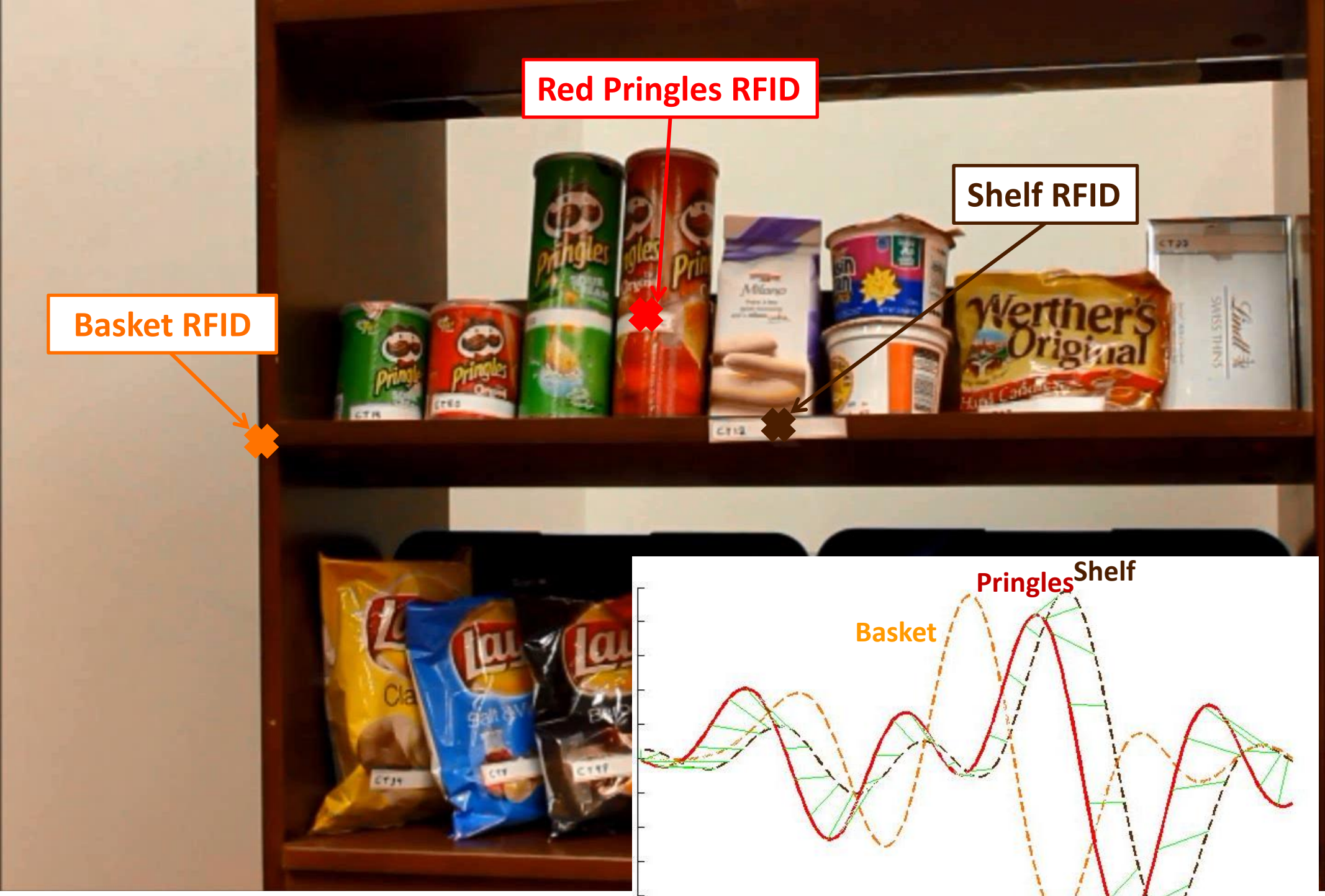

CT36

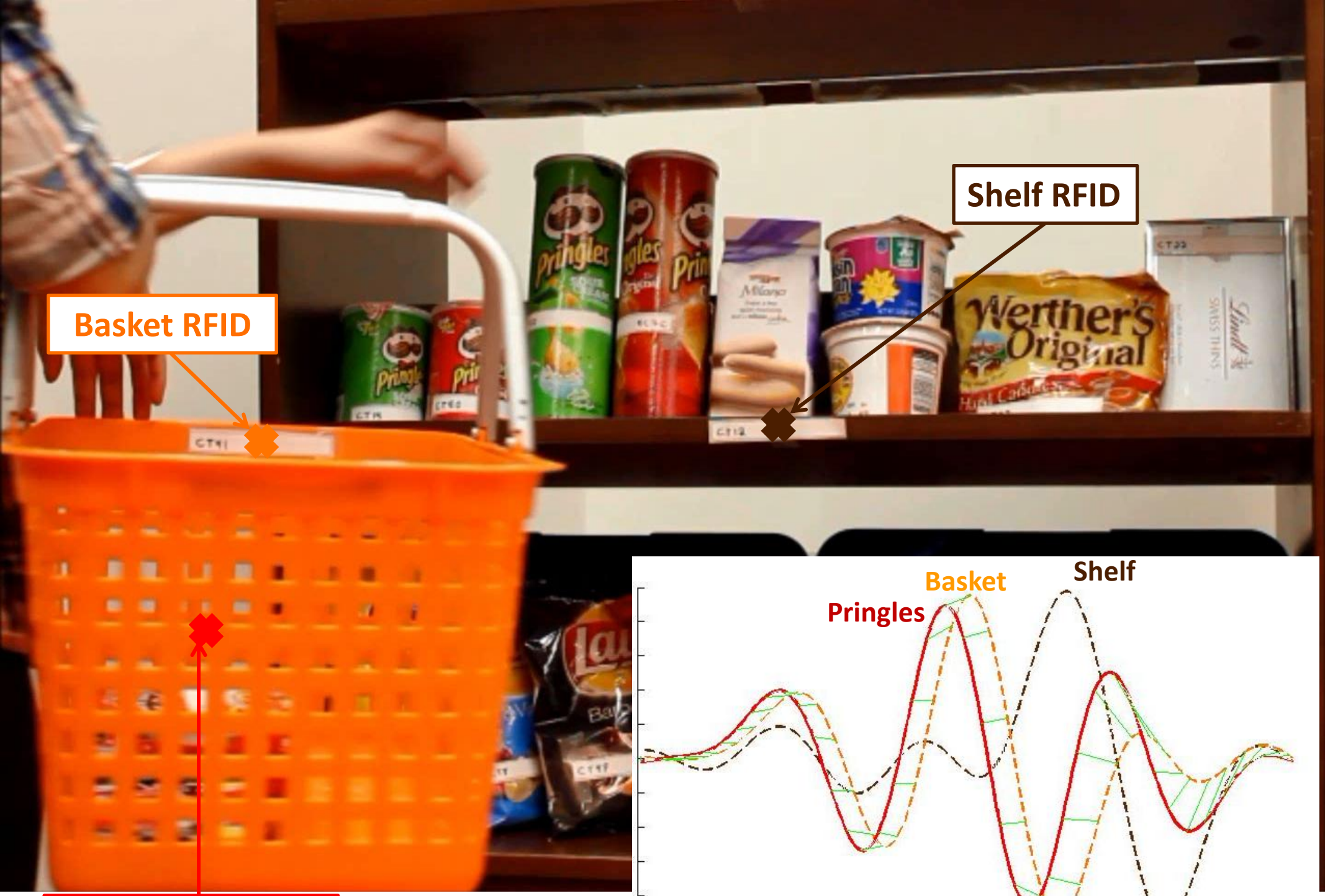

Kellogg's
Raisin Bran
Crunch


Pringles
Original


Detta färg är mycket vacker. Jag tycker om det. Borde bra men hemma bäst !


Detta färg är mycket vacker. Jag tycker om det. Borde bra men hemma bäst !


Red Pringles RFID
Shelf RFID
Basket RFID
Pringles
Shelf
Basket


Shelf RFID
Basket RFID
Red Pringles RFID
Pringles
Basket
Shelf


Pringles
Werther's Original
Lay's
CHEDDAR & SOUR CREAM
Lay's

Conclusion

- PinIt provides accurate RFID positioning even in multipath and NLOS settings
- It uses DTW to compare RFID multipath profiles
- It enables new applications including eliminating checkout lines, object tracking in libraries and pharmacies, smart homes, …