

# TAR - Enabling Fine-Grained Targeted Advertising in Retail Stores

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|--------------|-------------------------------------|
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# In-Store Purchase Still Dominates...

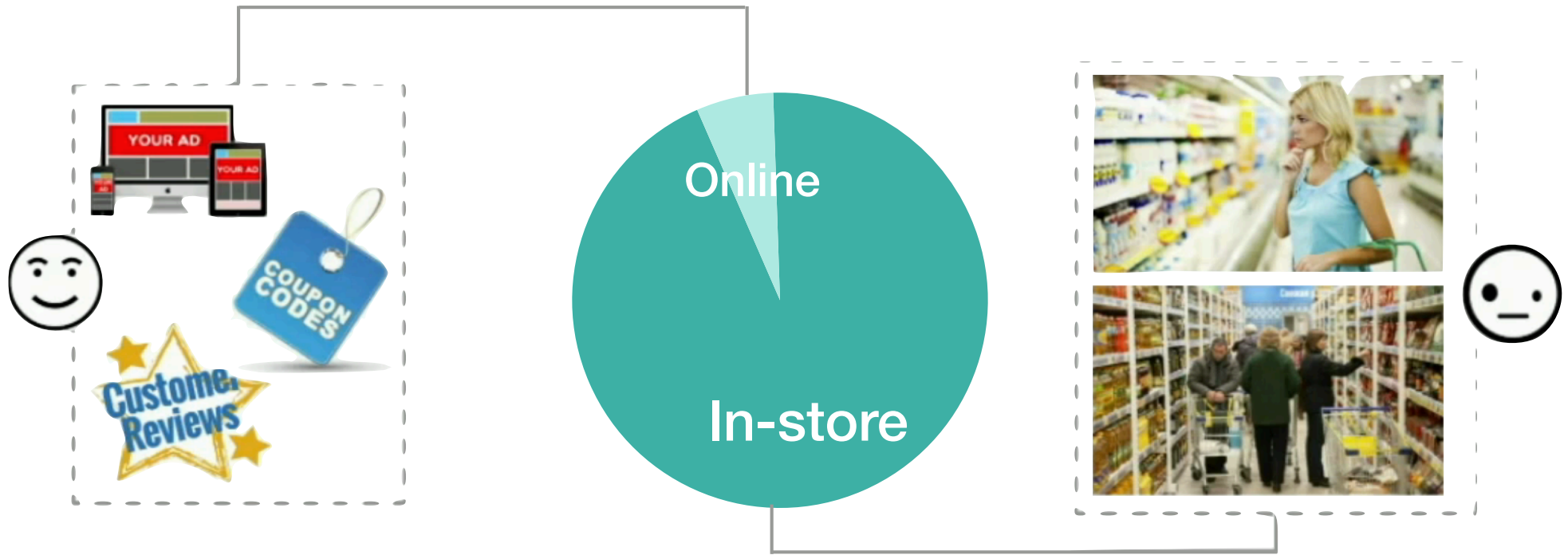
- **94% of retail sales are generated at brick-and-mortar stores**
- **81% purchases of Millennial shoppers are in physical shops**



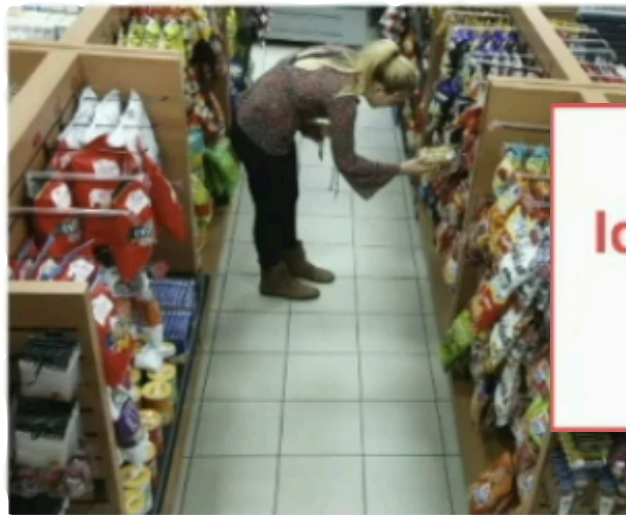
# ...But It Falls Far behind E-Commerce

**Customers know little about products**

**Stores know little about customers**



# Improving Retail Stores with Targeted Ads



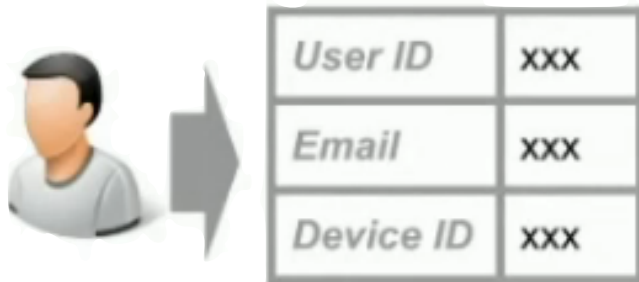
**Customer  
Identification  
&  
Tracking**

User Online ID  
User Interests



# People Identification and Tracking

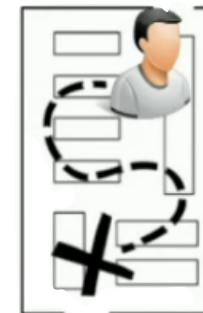
Identification



Tracking

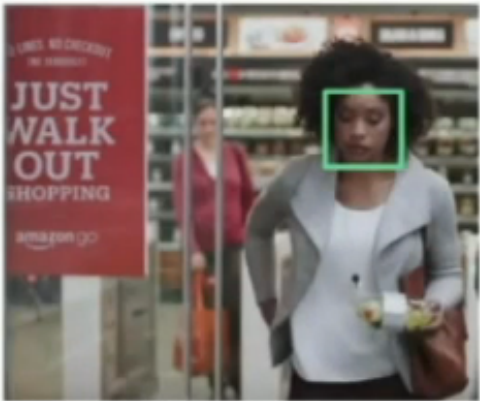


Single-region



Cross-region


# Existing Solutions for Identification and Tracking



Vision-based

**Good for Tracking**

**Accuracy depends on image quality**  
**Privacy Concern**



Sensor-based

**Good for Identification**

**Low Tracking Accuracy**  
**Energy Consumption**

# Challenges

- **Combine vision and sensor info for the same person**

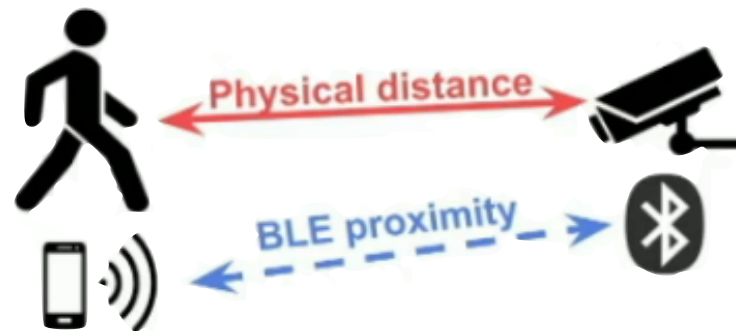


- **Design robust system for various shopper traces**

- **Calibrate all in-store cameras for accurate tracking**

# Insight 1: BLE Proximity

- The proximity can be calculated with received signal strength (RSS)
- BLE Proximity  $\propto$  Physical Distance

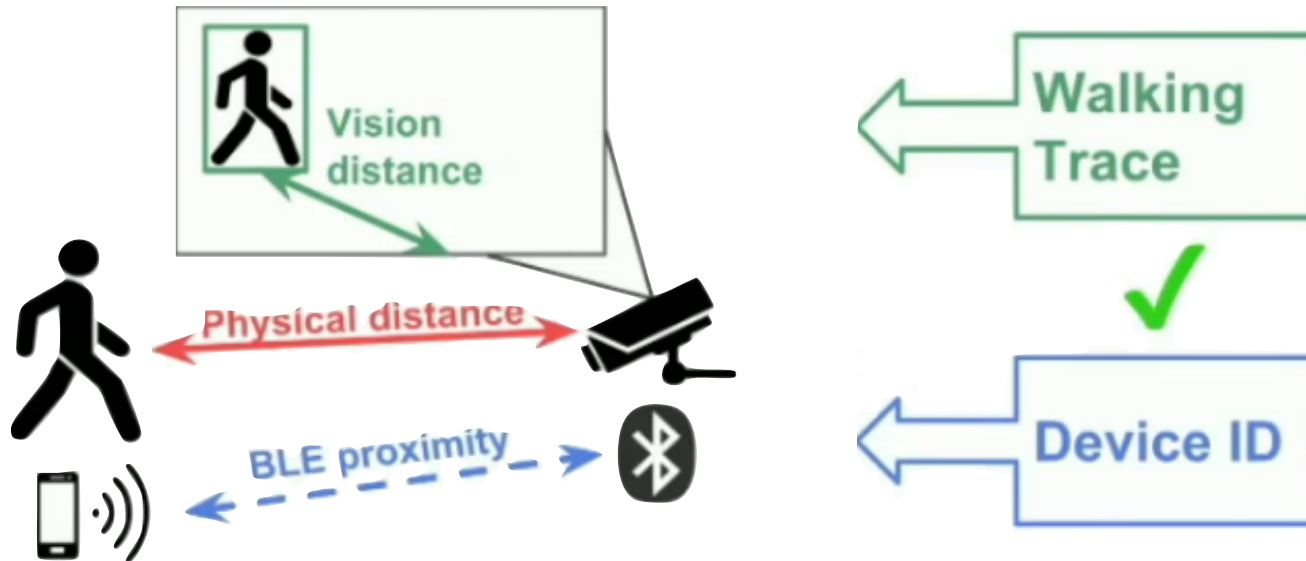


# Insight 2: Visual Distance

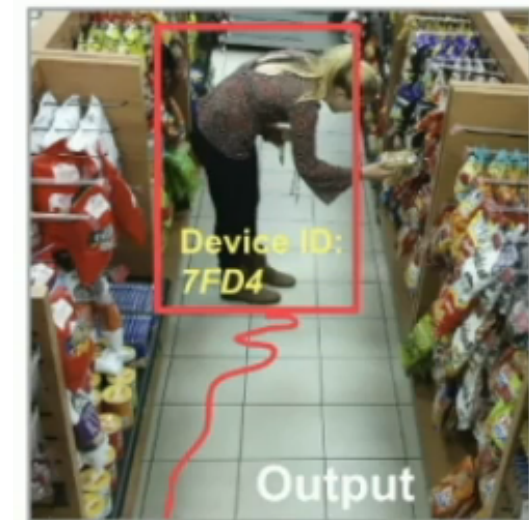
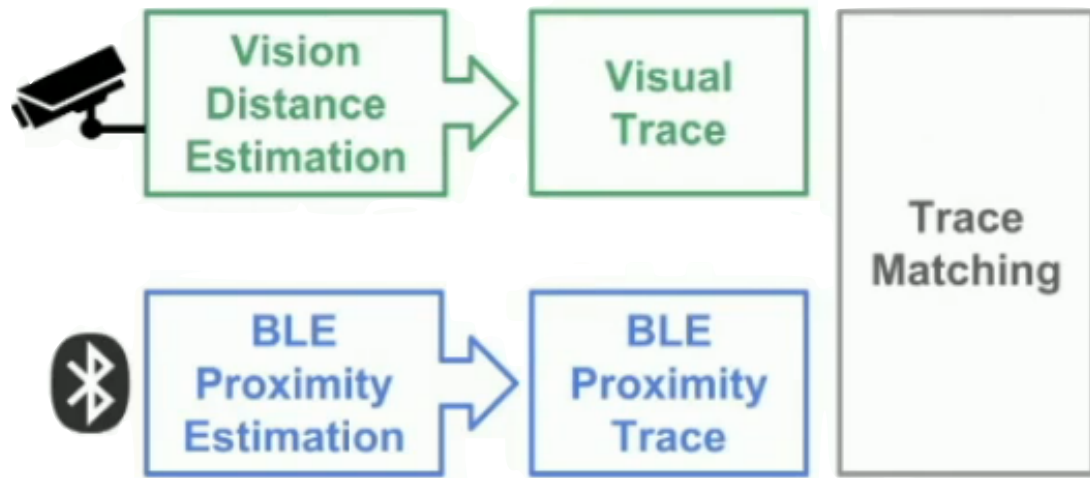
The 3D position of a pixel on the ground can be calculated using camera intrinsic and extrinsic parameters (homography)



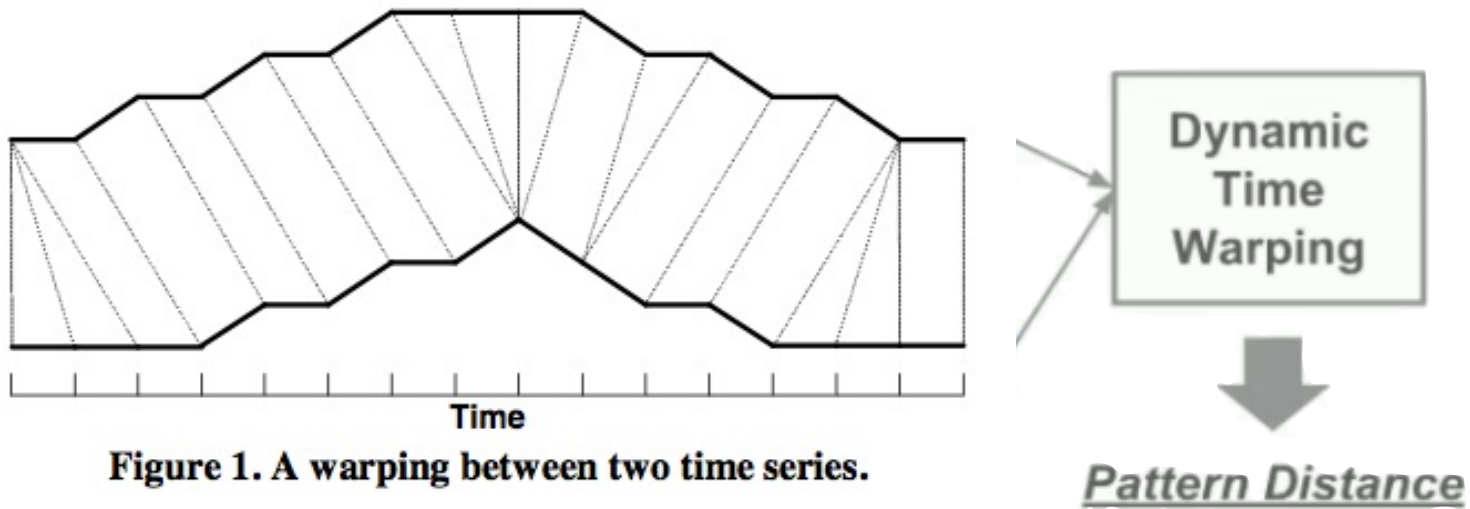
# Combine BLE Proximity and Visual Distance



# Design of TAR



# Matching BLE and Vision Traces



**Figure 1. A warping between two time series.**

# Matching BLE and Vision Traces



|          | BLE-A | BLE-B |
|----------|-------|-------|
| Vision-1 | 0.3   | 0.7   |
| Vision-2 | 0.8   | 0.2   |

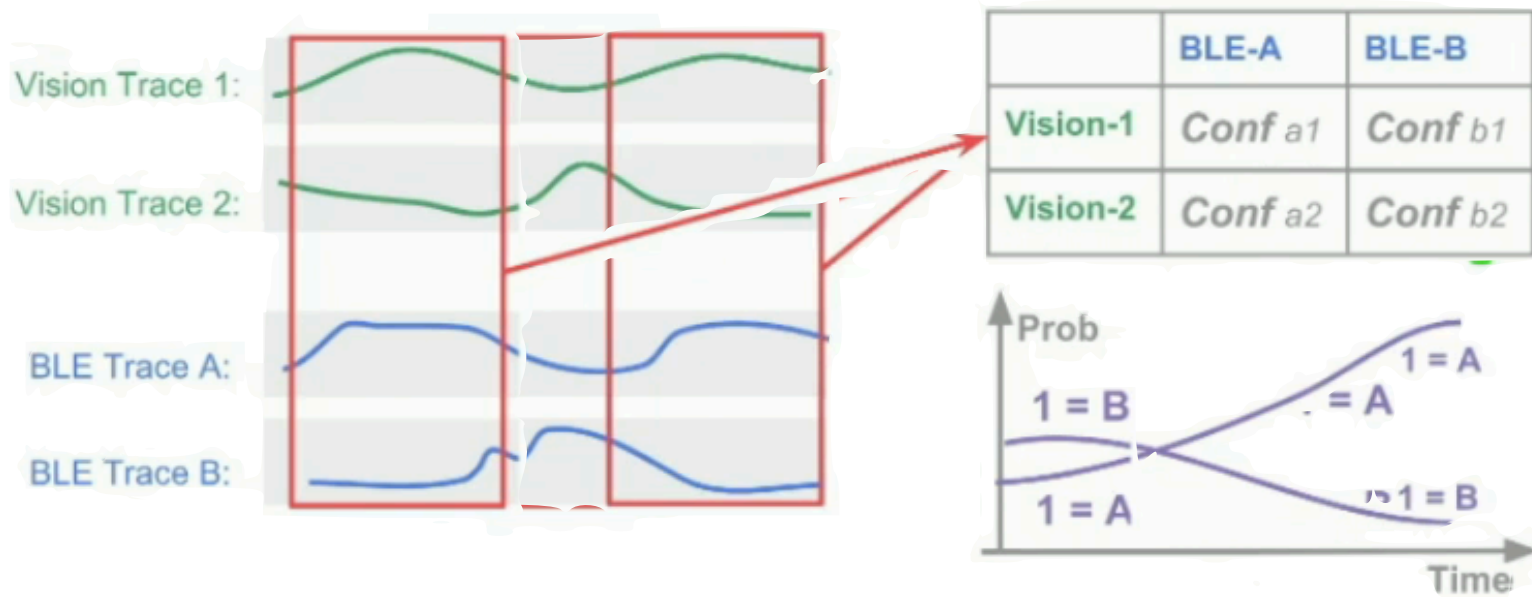
*Pattern Distance Matrix*

# Matching BLE and Vision Traces



$$f_{ij} = e^{\frac{-dt_{ij}}{100}}$$

# Matching BLE and Vision Traces



# Challenges

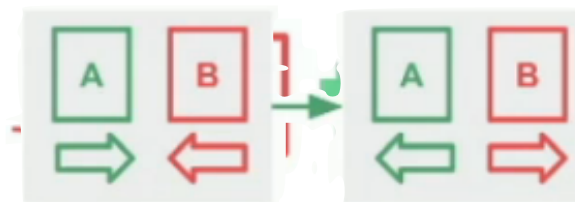
- **Combine vision and sensor info for the same person**
- **Design robust system for various shopper traces**
- **Calibrate all in-store cameras for accurate tracking**



# Keys to Accurate Matching

- **Accurate vision tracking**

- **Vision tracking is not reliable**

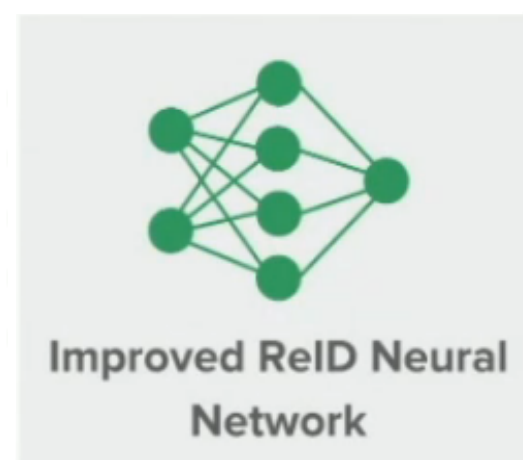
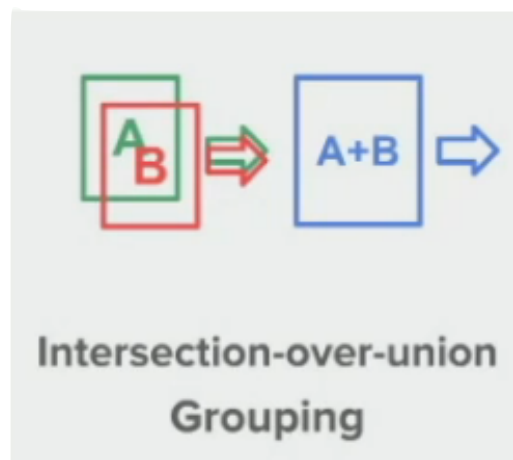
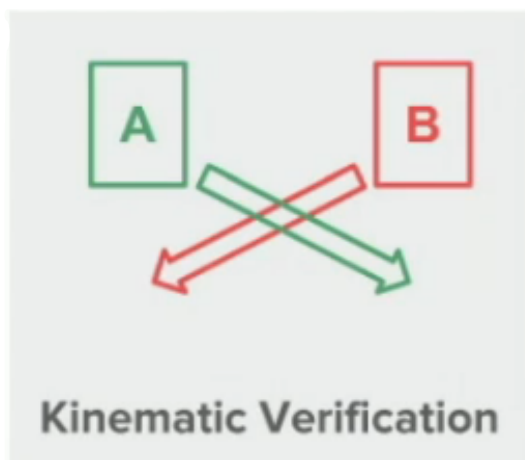


- **Sufficient trace length**

- **Occluded and short traces**



# Improve Vision Tracking



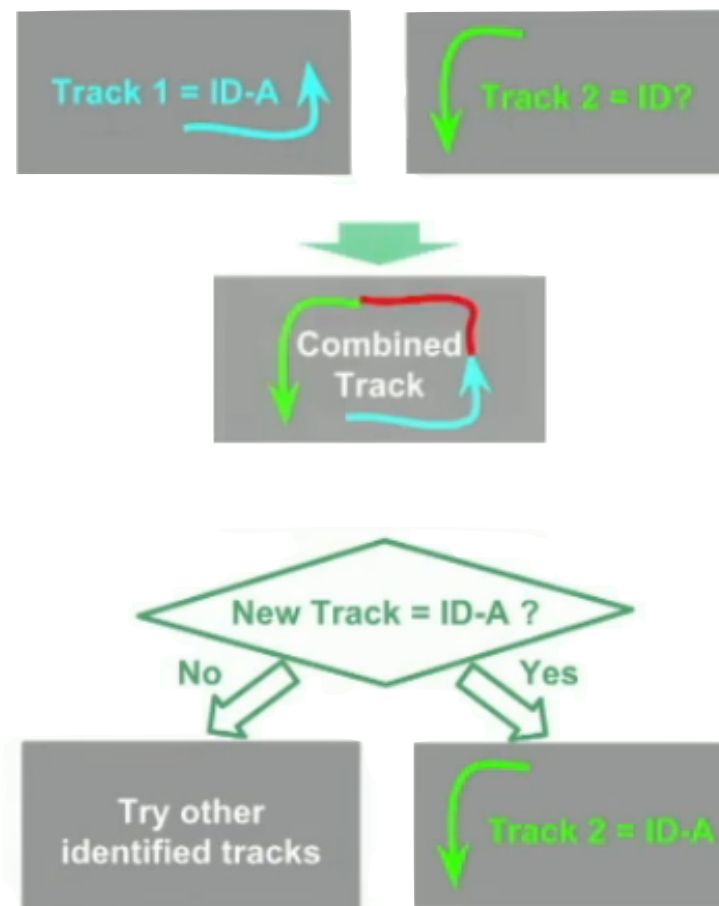
State-of-the-art Online Tracking Algorithm

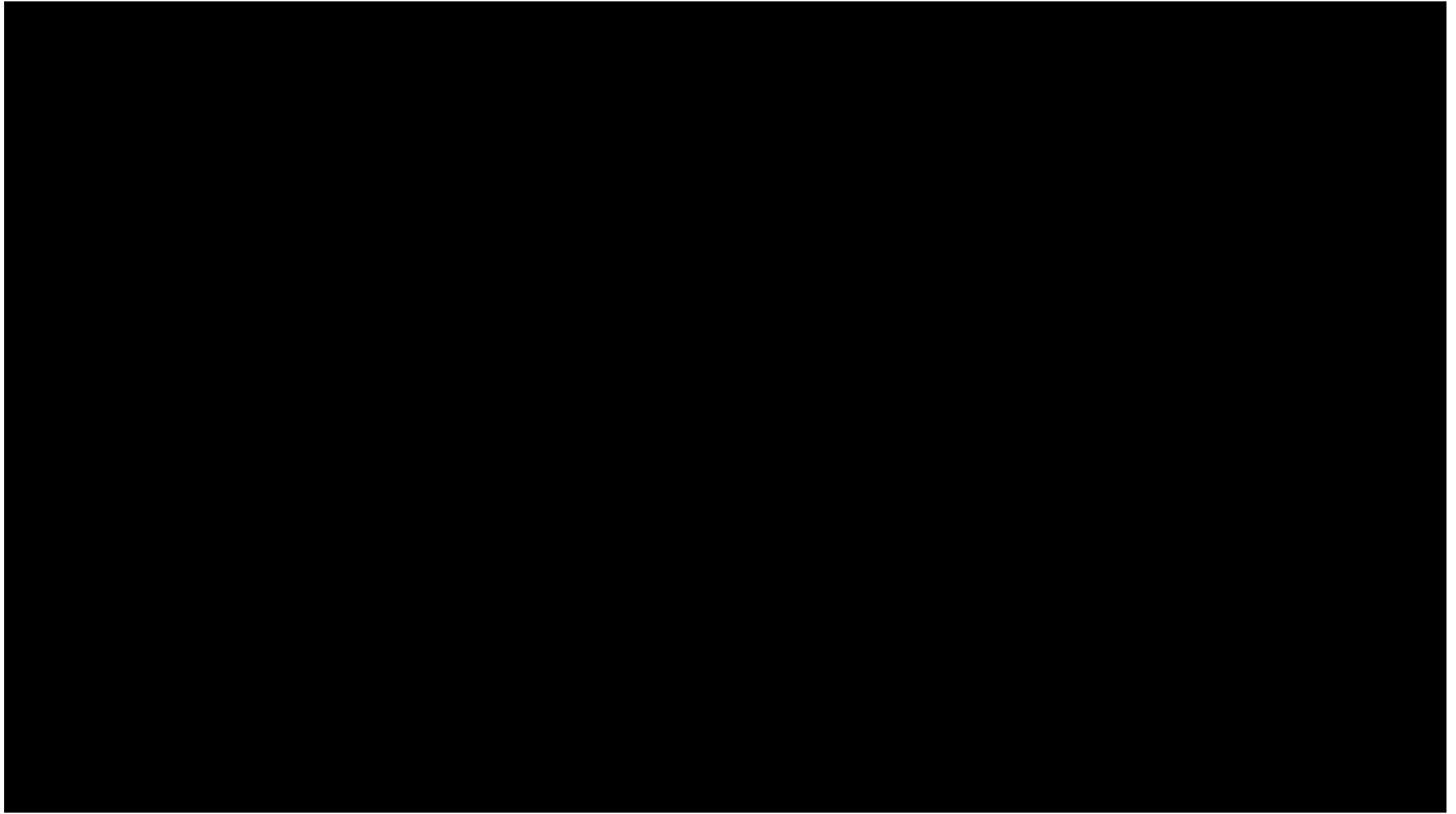
# Handle Broken Traces

Combine short pieces together and test if they can be matched consistently



## Visual Track Sewing





# Challenges

- **Combine vision and sensor info for the same person**
- **Design robust system for various shopper traces**
- **Calibrate all in-store cameras for accurate tracking**



# Problems

- Conflict in BLE ID matching



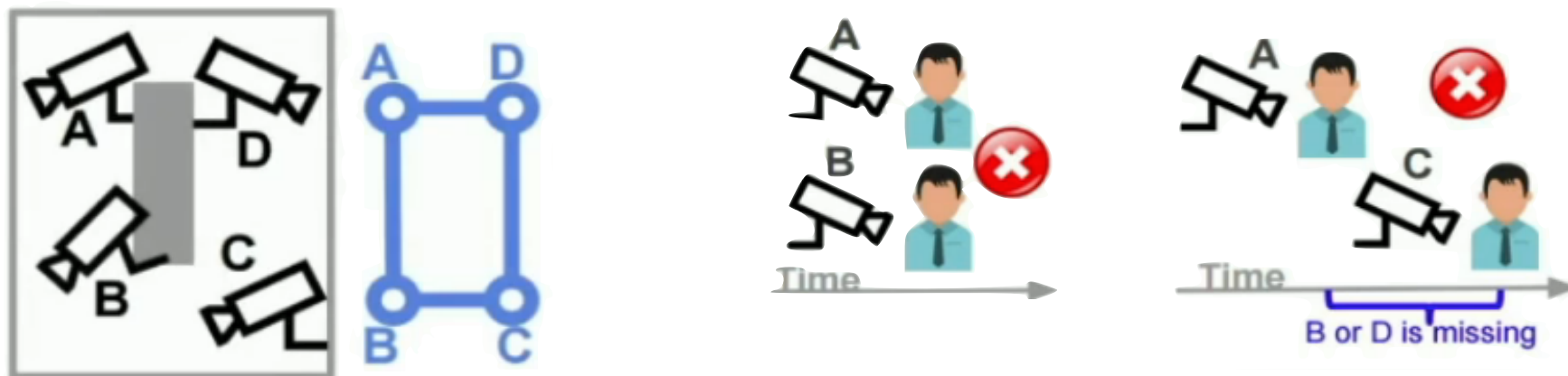
- Many BLE ID candidates in scanning range



## BLE ID Filtering

# Cross-Camera BLE ID Filtering

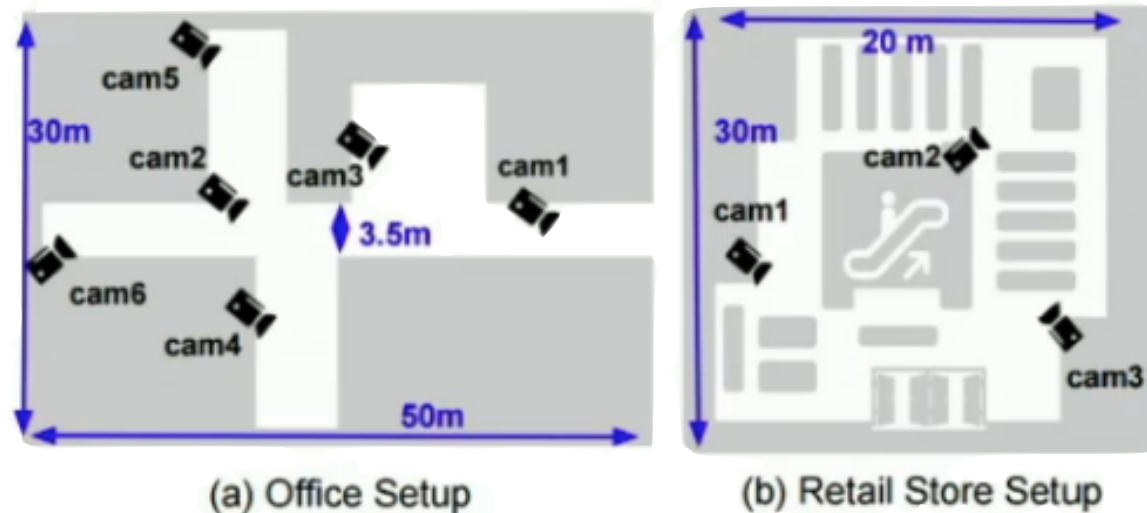
TAR leverages inter-camera track dependency for ID filtering



# Setup for the Evaluation

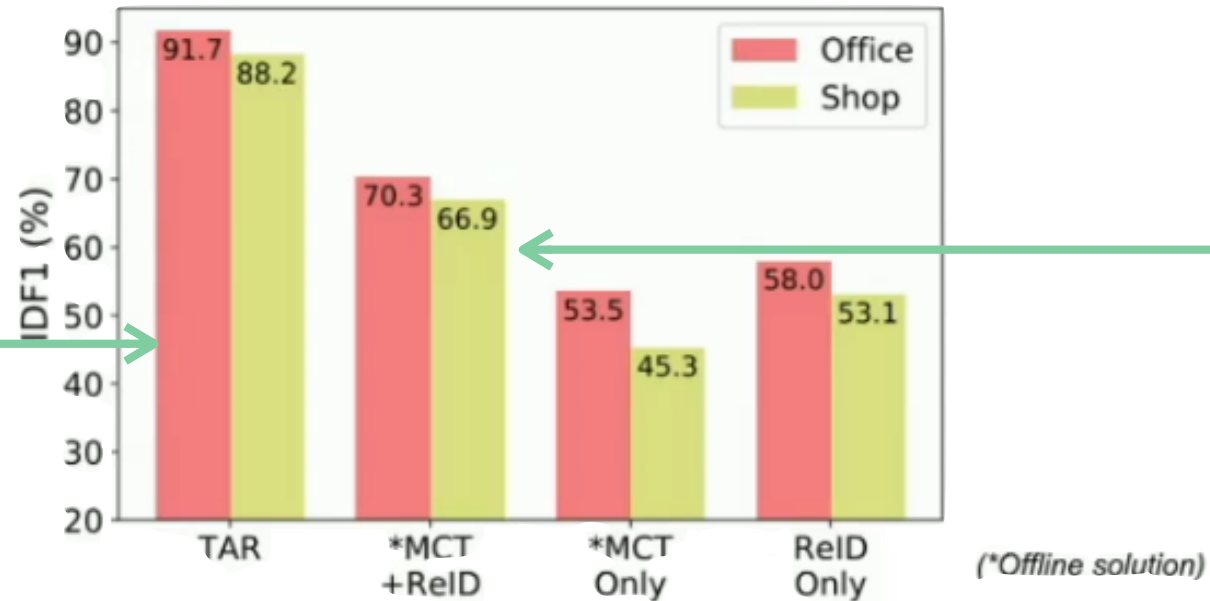
- Two test regions with 20 participants holding TAR-enabled devices
- Up to 27 people being tracked at the same time
- One node (camera + BLE receiver) runs on one GPU-equipped machine

(Per Vision Tracking)



# Accuracy of TAR

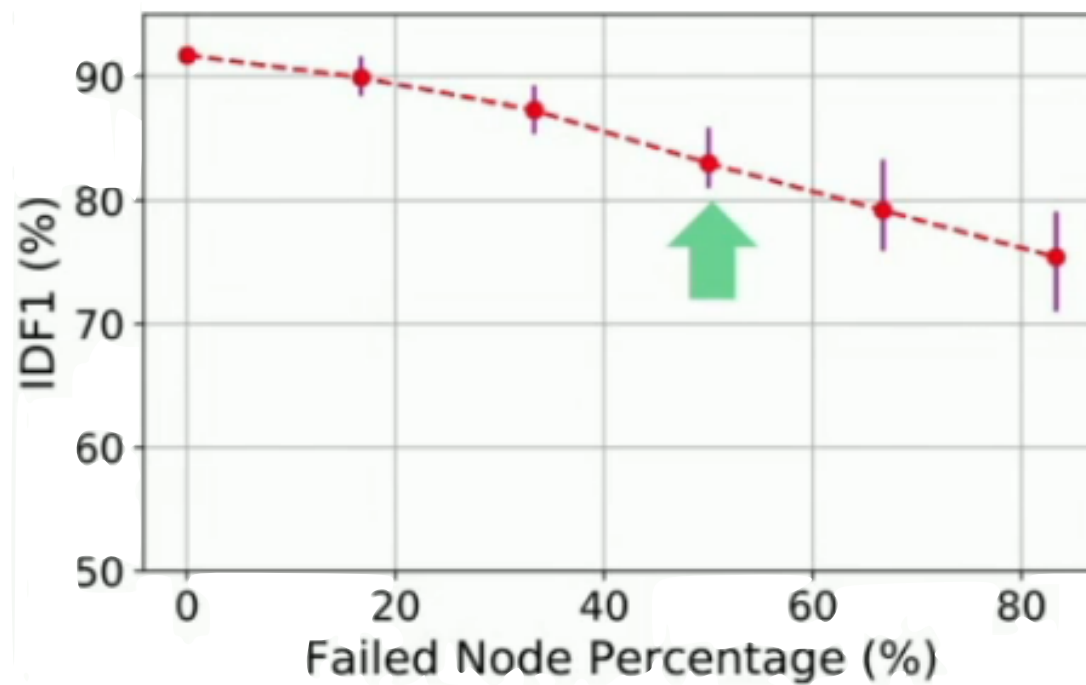
TAR outperforms the state-of-art solutions by 20% in accuracy



**IDF1 = (Correctly identified people) / (All identified people)**  
**(in all frames)**

# Failure Analysis

**TAR's accuracy is still above 80% with half of the nodes failed**



# Conclusion

- Vision-only people identification and tracking are **not reliable**
- TAR combines **BLE and vision** for accurate customer tracking and identification
- TAR leverages **multiple optimizations** to handle challenges like occlusion, short traces, and ID switches
- TAR **outperforms the state-of-the-art** vision solutions

## **Pros:**

- **Handle the most corner cases**
- **Rule-based strategy**
- **Track Sewing**
- **...**

## **Cons:**

- **Performance should be improved(2 DNNs per Vision Tracking)**
- **Some cases may be not dealt well**
- **Too many empirical values**
- **...**

**Thank you**

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