Multiple Object Tracking Systems

Javier Berneche

Senior Machine Learning Engineer

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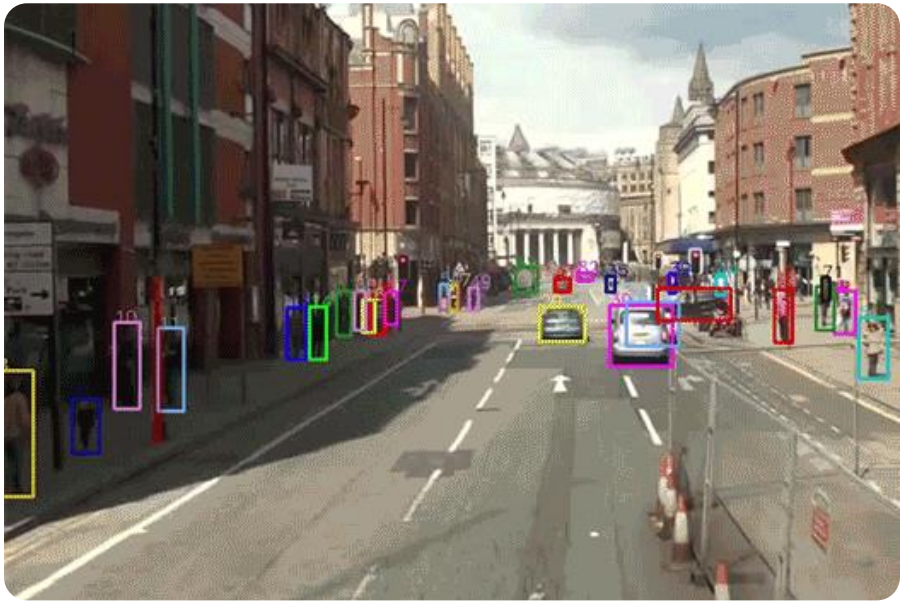
Agenda

1. Introduction to Multiple Object Tracking (MOT)
2. Building blocks
3. Challenges
4. Evaluation and promising research

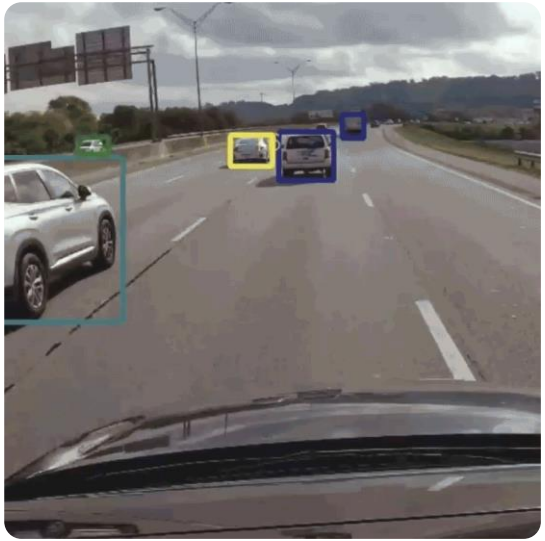
Definition

Multiple Object Tracking (MOT) is the problem of identifying **multiple objects** in a video or live feed and representing them as a set of **trajectories**



Video: MOT Challenge

Applications

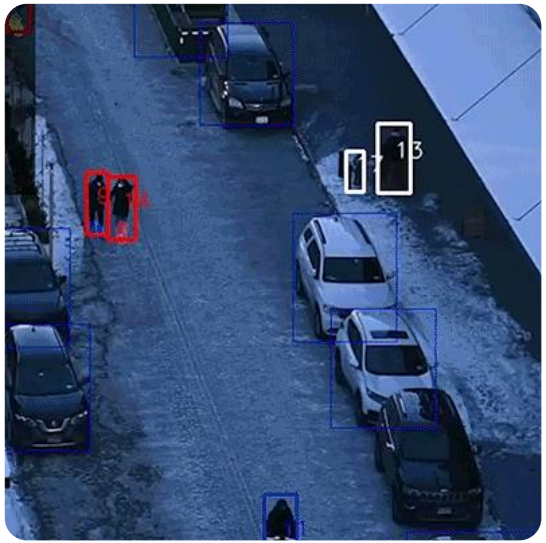


Autonomous navigation systems

Analyze and monitor congestion

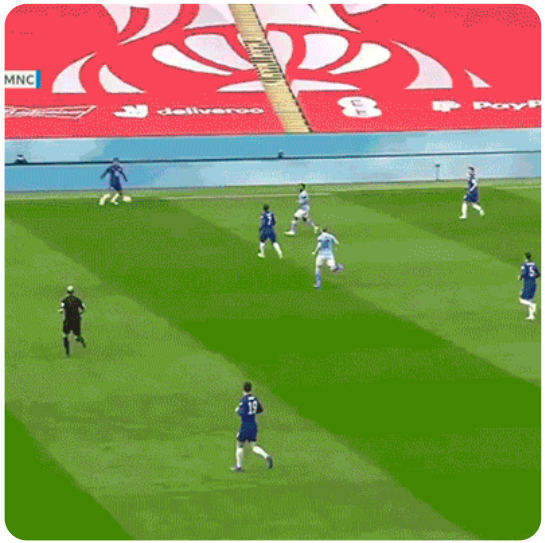
Augmented reality

Applications



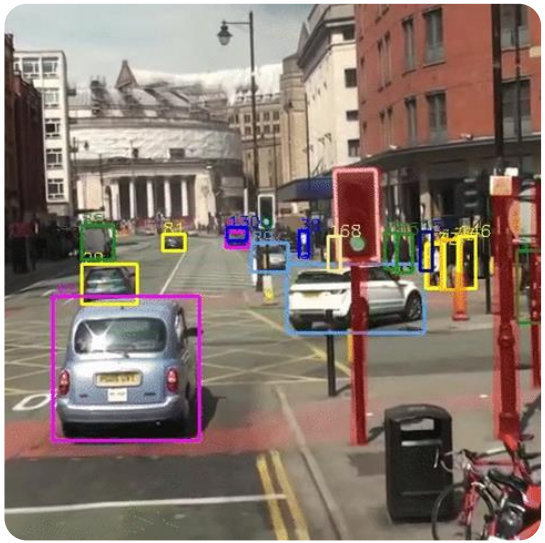
Surveillance

Crowd analysis

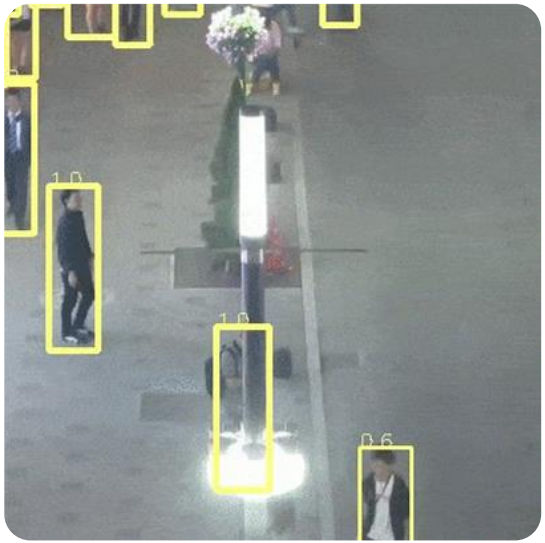


Sports analytics

Challenges



Changes in appearance



Occlusions

Crowded scenes

Building Blocks

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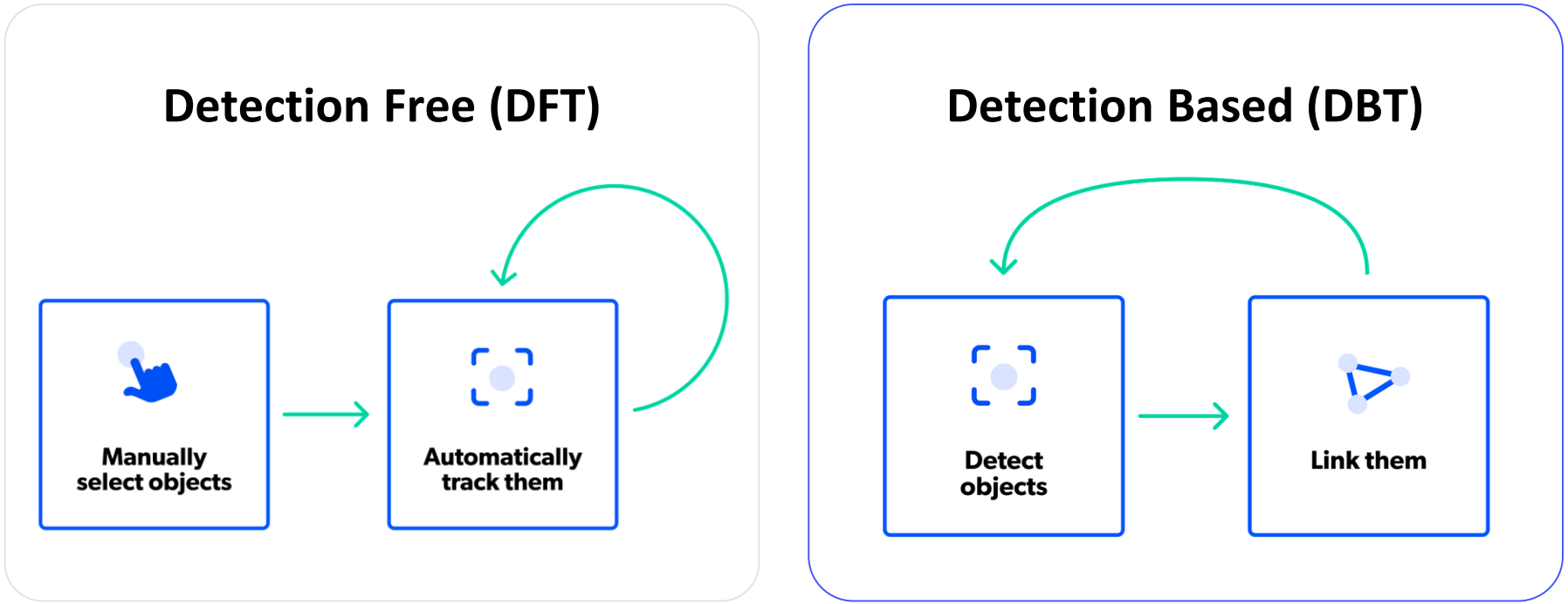
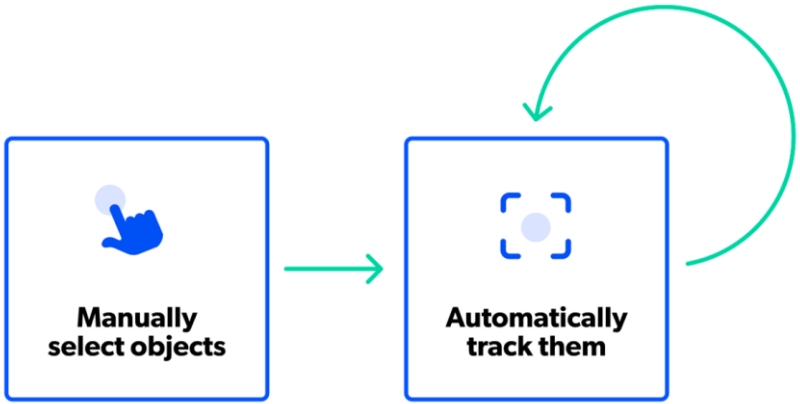
Building Blocks: Initialization



Building Blocks: Initialization

Detection Free (DFT)

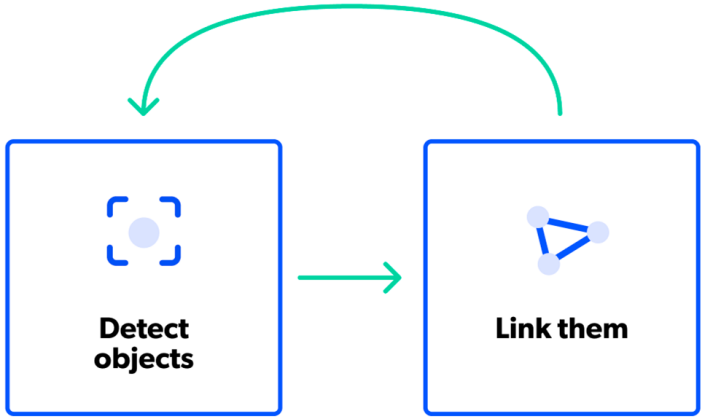


- Automatically track **manually** selected objects
- Can track **any** type of object
- **Can’t** handle new objects coming into the scene

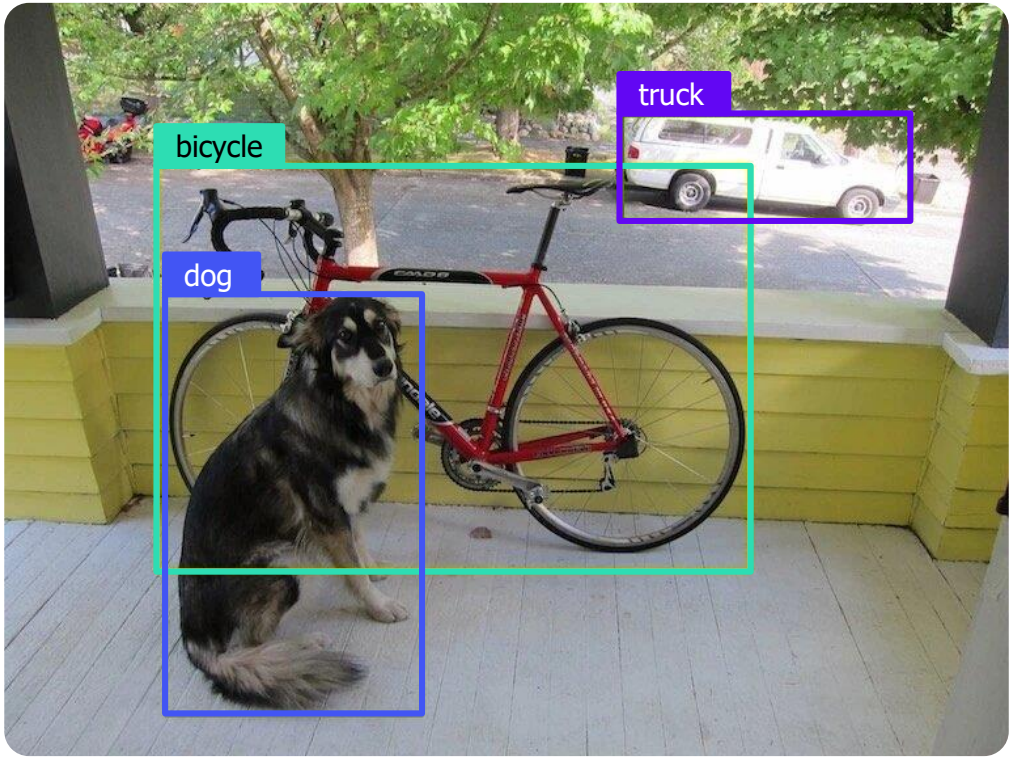
Building Blocks: Initialization

- Detect objects in **each** frame
- New objects are **automatically** discovered
- Object classes need to be **predefined**

Detection Based (DBT)

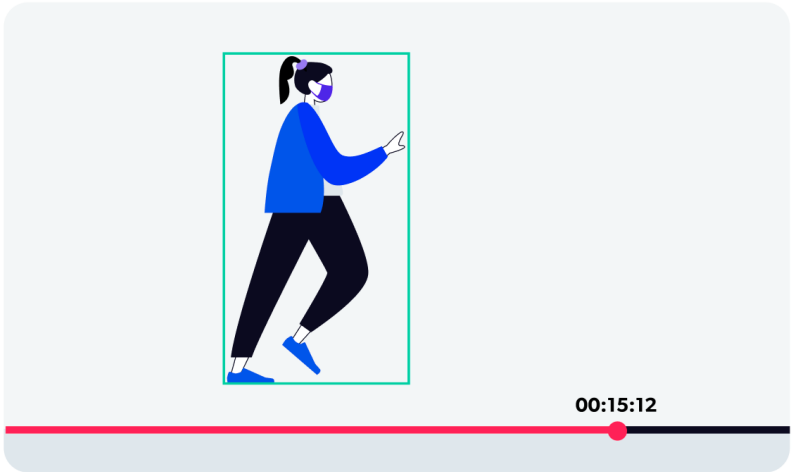


Building Blocks: Detector

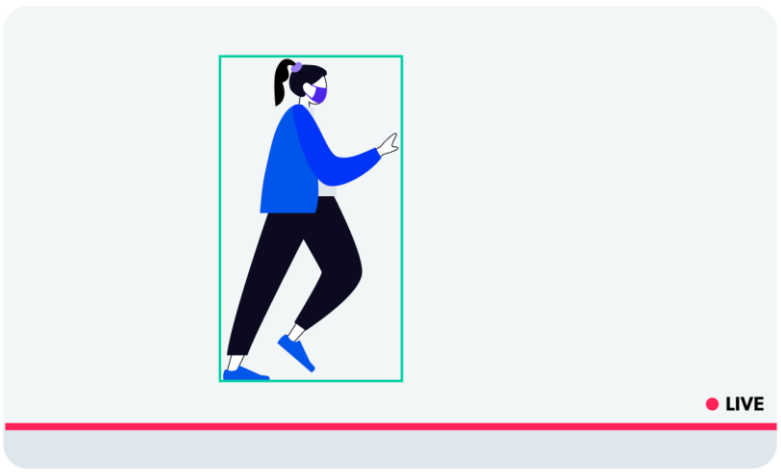


Building Blocks: Processing

Offline

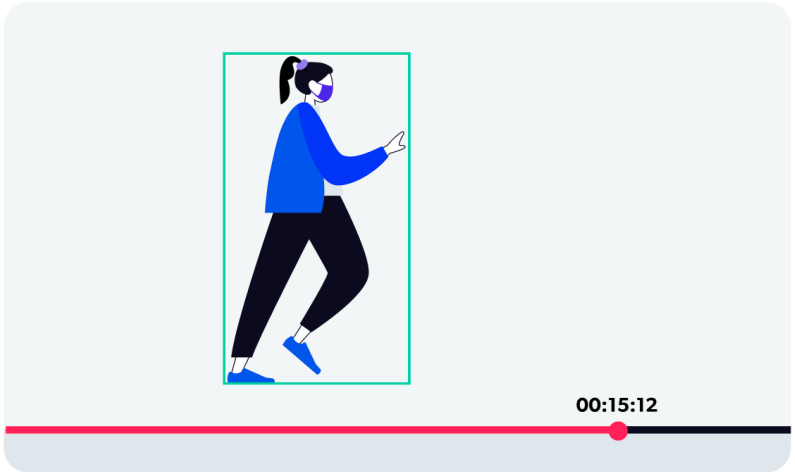


Online



Building Blocks: Processing

Offline

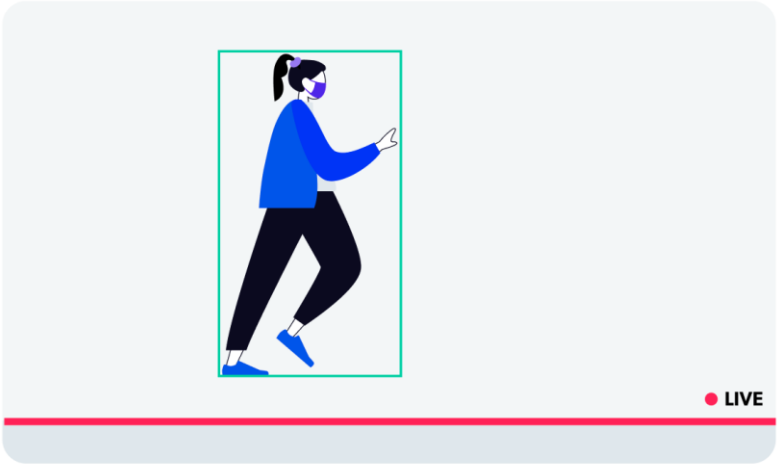


- Information from **future** frames can be used
- **Interpolate** trajectories
- Keep different **hypotheses**
- Can be more **accurate**

Building Blocks: Processing

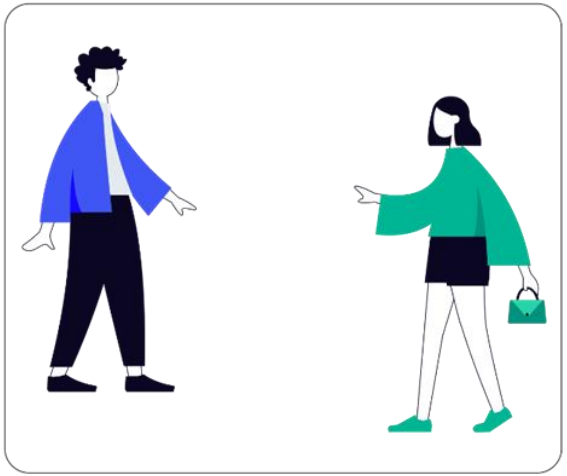
- Only **past** information is used
- **Extrapolate** trajectories
- **Decide** on every frame
- Can be used in **real-time** applications

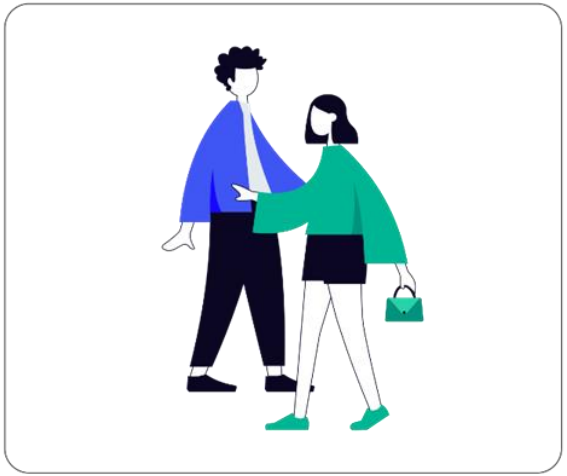
Online

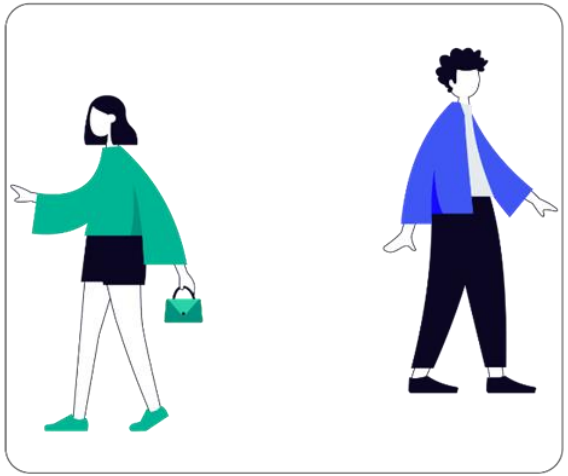


Building Blocks: Positional Cues

Frames





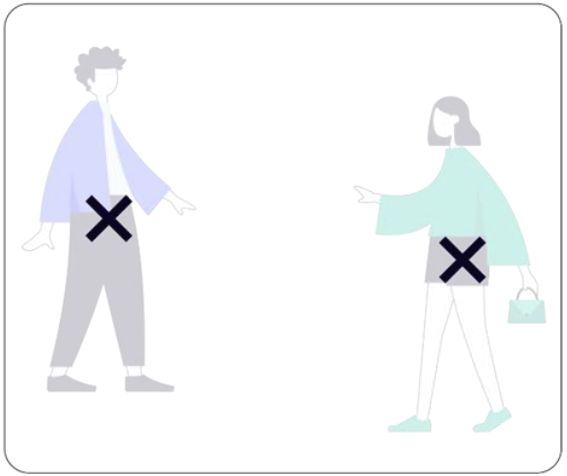


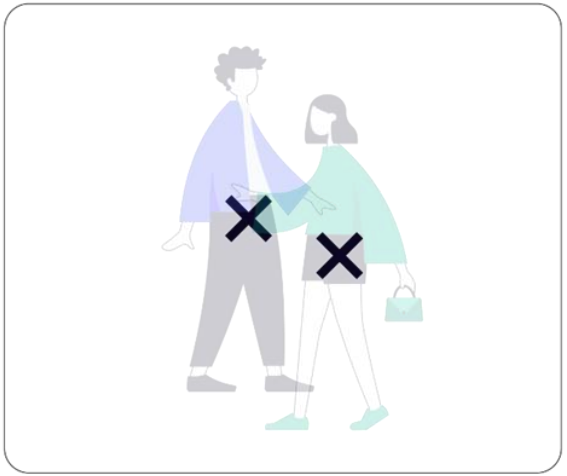
Building Blocks: Positional Cues

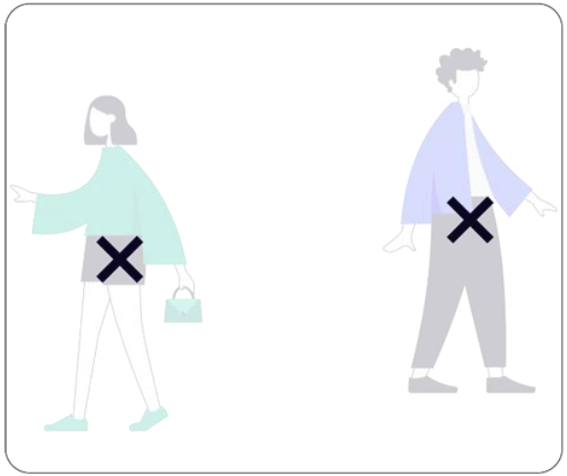
Detection

Building Blocks: Positional Cues

Centroids

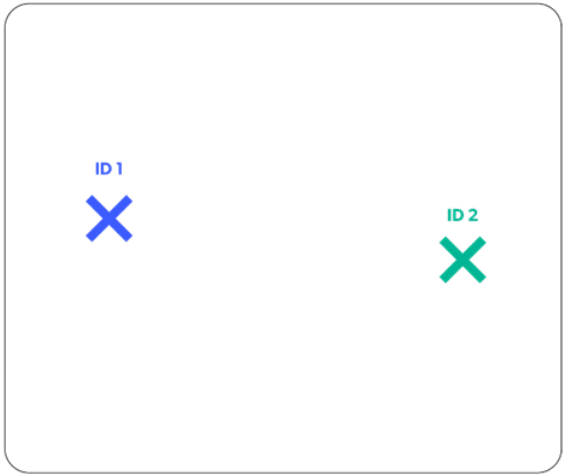


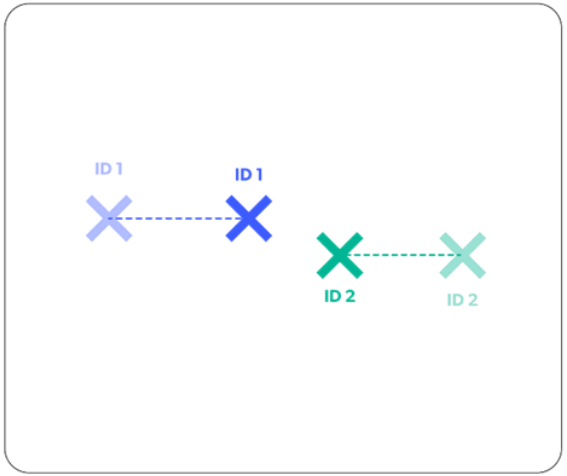


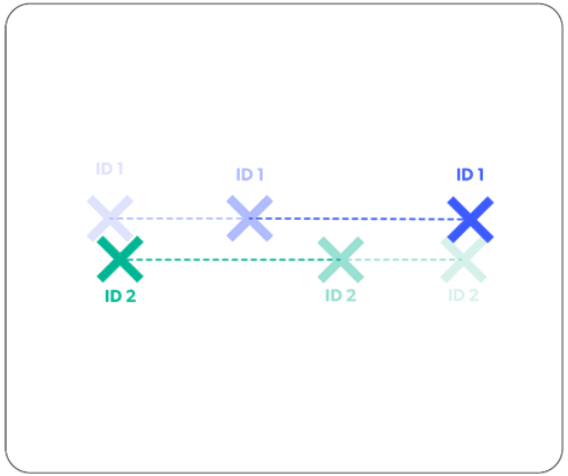


Building Blocks: Positional Cues

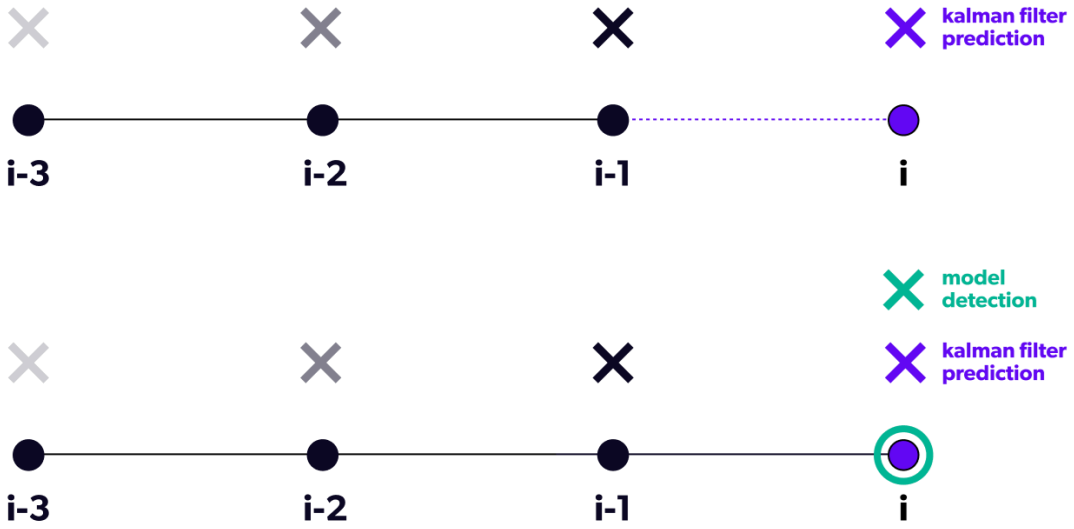
Assignment







Positional Cues: Kalman Filter



Positional Cues: Assignment

Greedy

- Simpler
- Faster

Hungarian

- Minimizes global distance
- Slower

Visual Cues

Important for **recovering** from occlusions and collisions

Helps with **long-term** tracking

Generally used to **complement** the positional cues

Visual Cues: Vectors

Classical approaches can be used

Usually deep-learning **embeddings** are used

Cosine distance is usually used to compare the embeddings

Visual Cues: History

- Decide how to represent an object's embedding considering all **past embeddings**
- Rolling **averages**
- **Clustering** to maintain different versions of the object
- Memory usage and computational **cost** of comparison

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Recap

A complete tracking system

Object Detector

Positional cues for short-term tracking

Visual cues for long-term tracking

Challenges

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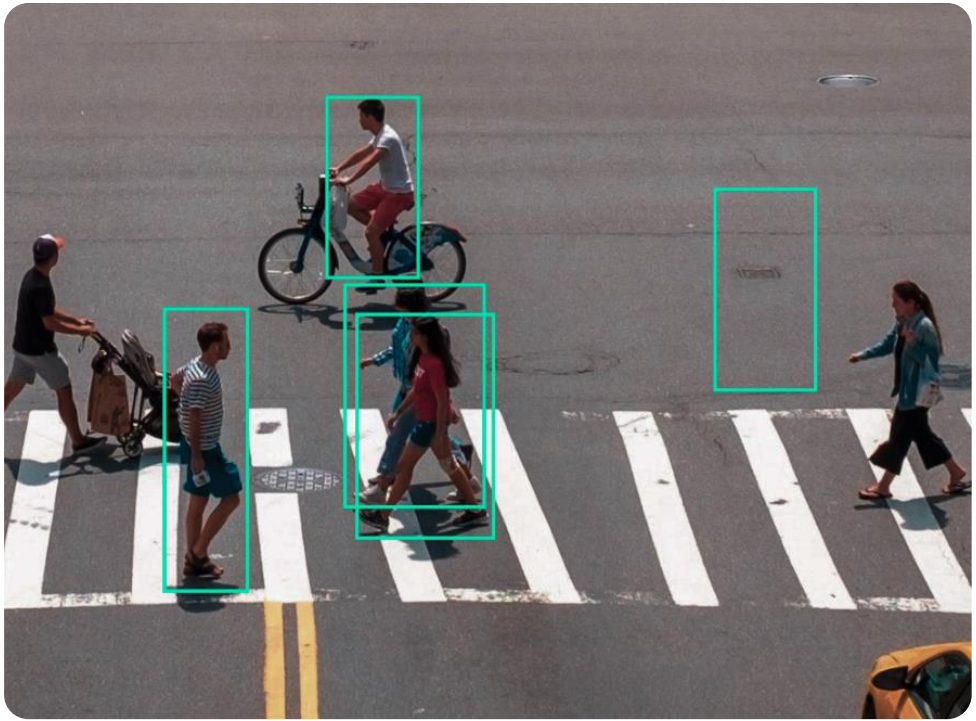
Challenges: Detection Quality



False positives

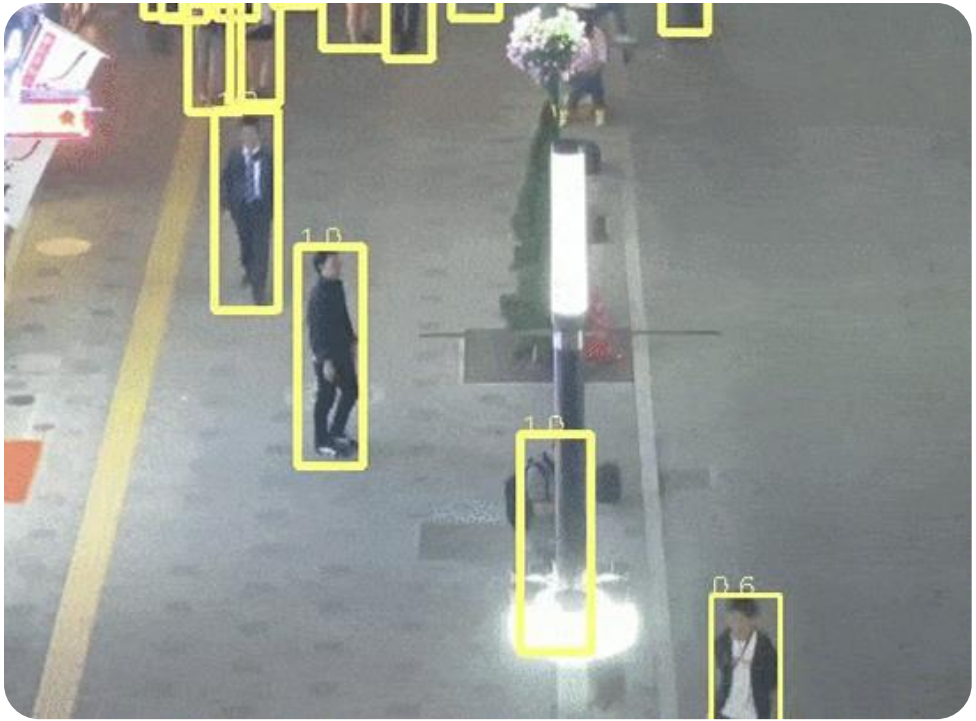
False negatives

Challenges: Movement

Erratic movement of the objects

Camera movement

Challenges: Occlusions



- Causes more false negatives
- Positional tracking can fall apart
- Embeddings of partially occluded objects can be bad

Challenges: Embeddings

Object detectors usually do not yield good **embeddings**

Need to add a **second model** for embeddings

Partial occlusions

No obvious model to start with

Evaluation & Research

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Promising Research

- Improvements to embeddings
- A single model for detections and embeddings
- One-stage models
- More datasets

MOT-Challenge Benchmark

Go-to benchmark for MOT

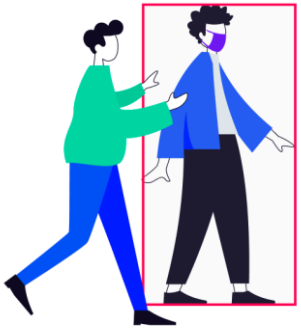
More datasets are added periodically

Few classes

Videos are short

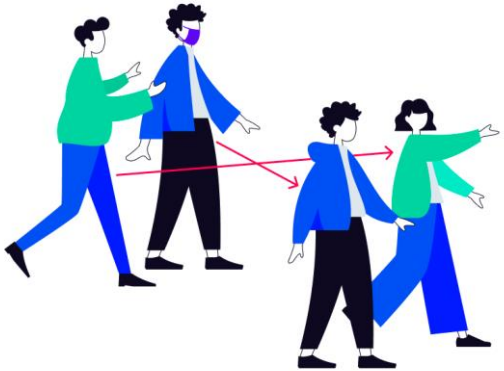
Evaluation Metrics

Detection error



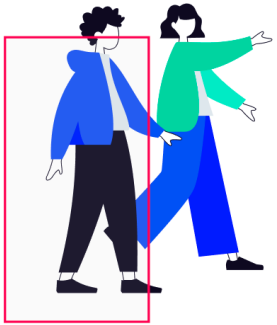
Multi-Object Tracking Accuracy (MOTA)

Association error



Identity F1 (IDF1)

Localization error



High Order Tracking Accuracy (HOTA)

Conclusions

MOT has a huge variety of **applications**

The problem is **challenging**

Solutions involve a number of **components**

Lots of promising **research**

Resources

- MOTChallenge
- Luo et al. 2021 Literature review
- Laura Leal-Taixe
- Object detection
- Hungarian method
- Greedy matching
- Embeddings
- Kalman filter

Open-Source Tools

Trackers

- ByteTrack
- Norfair
- SORT
- DeepSORT

Tools

- MOTMetrics
- YOLO
- OpenMMLab

Trackers

- SORT
- DeepSORT
- BoT-SORT
- ByteTrack
- SMILEtrack
- SUSHI

Thank You!

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