Learning to Track: Online Multi-Object Tracking by Decision Making

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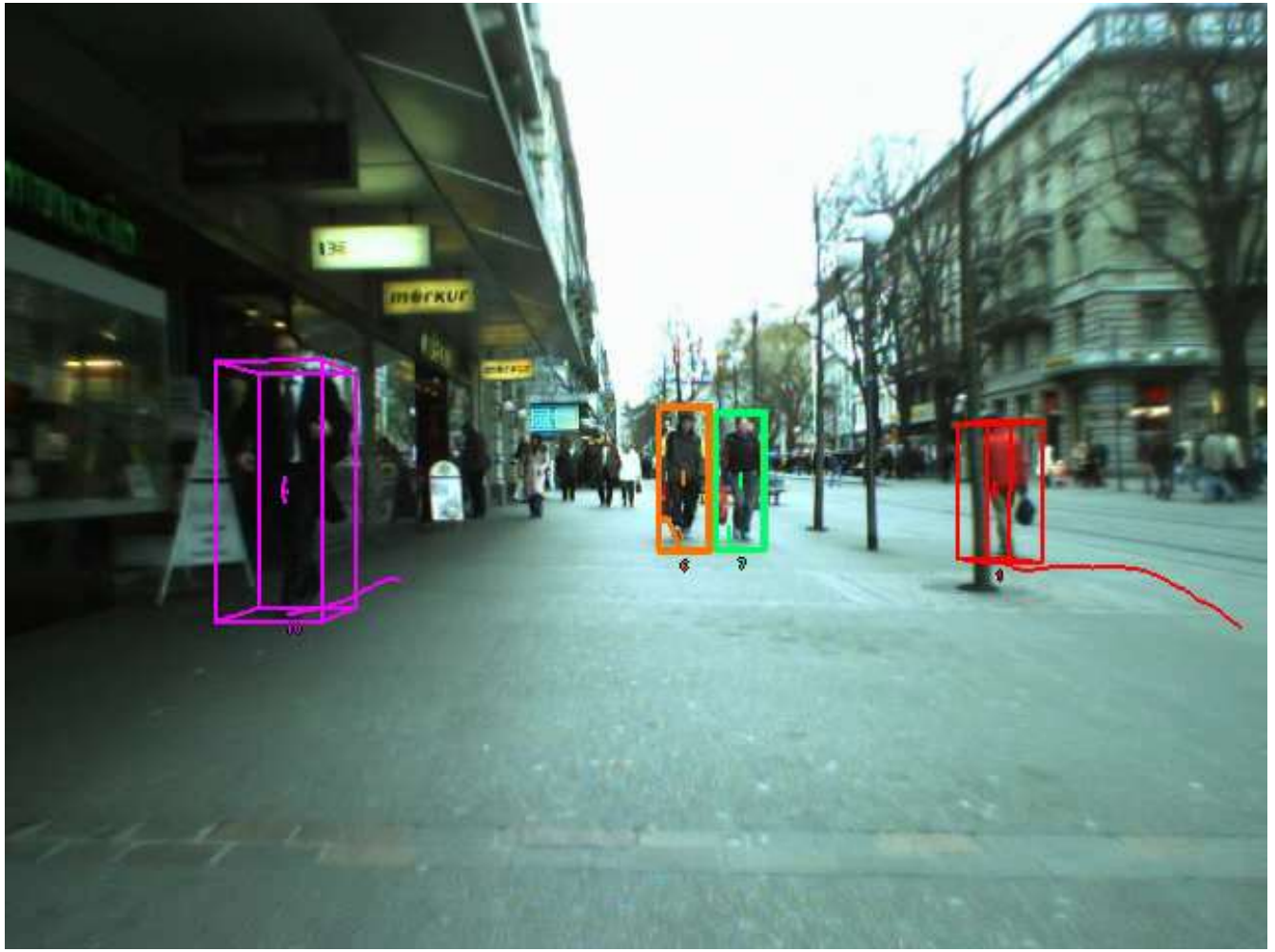
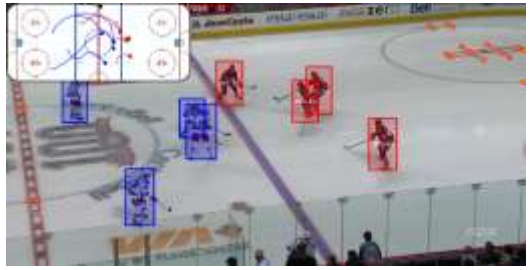
ICCV 2015

Multi-Object Tracking

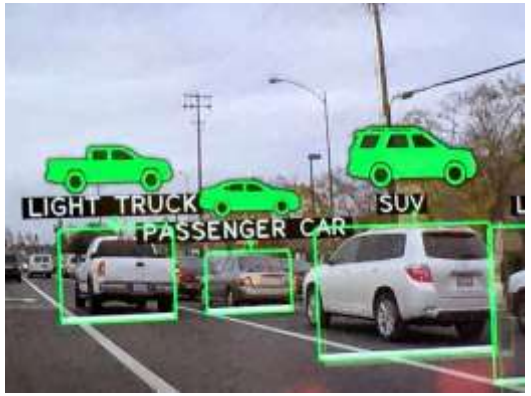
Visual surveillance



Robot navigation



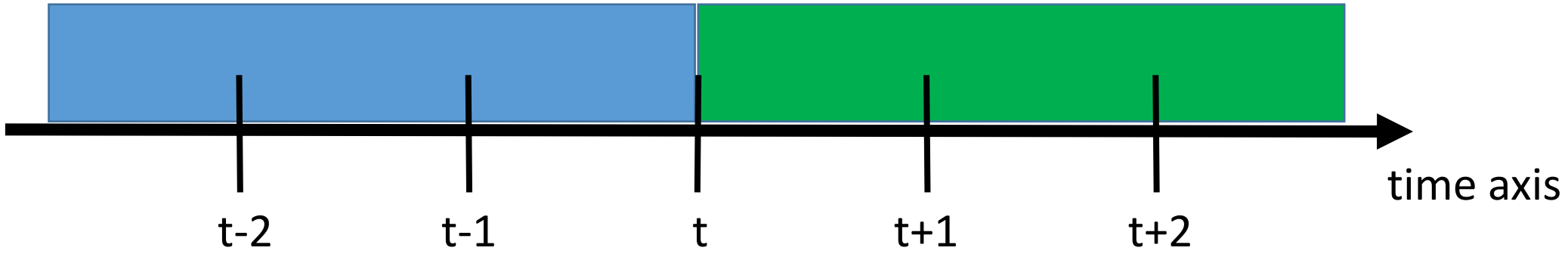
Sport Analysis



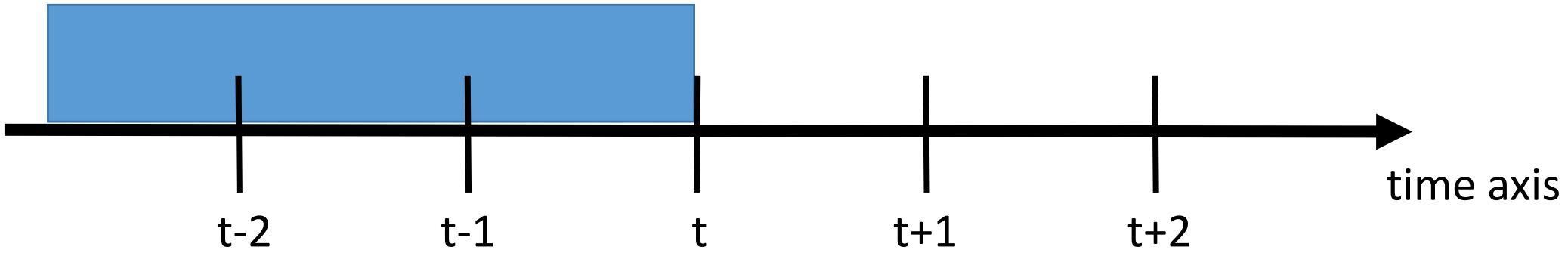
Autonomous driving

Batch Mode vs. Online Mode

- Batch Mode

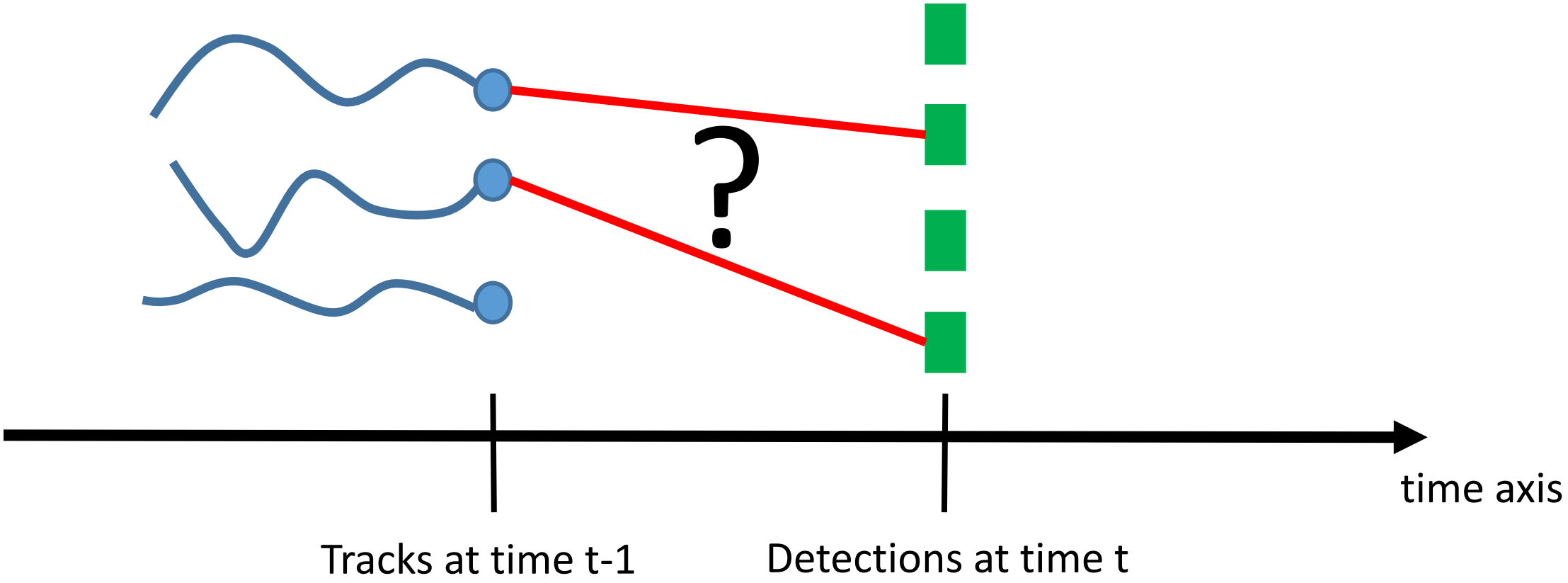


- Online Mode

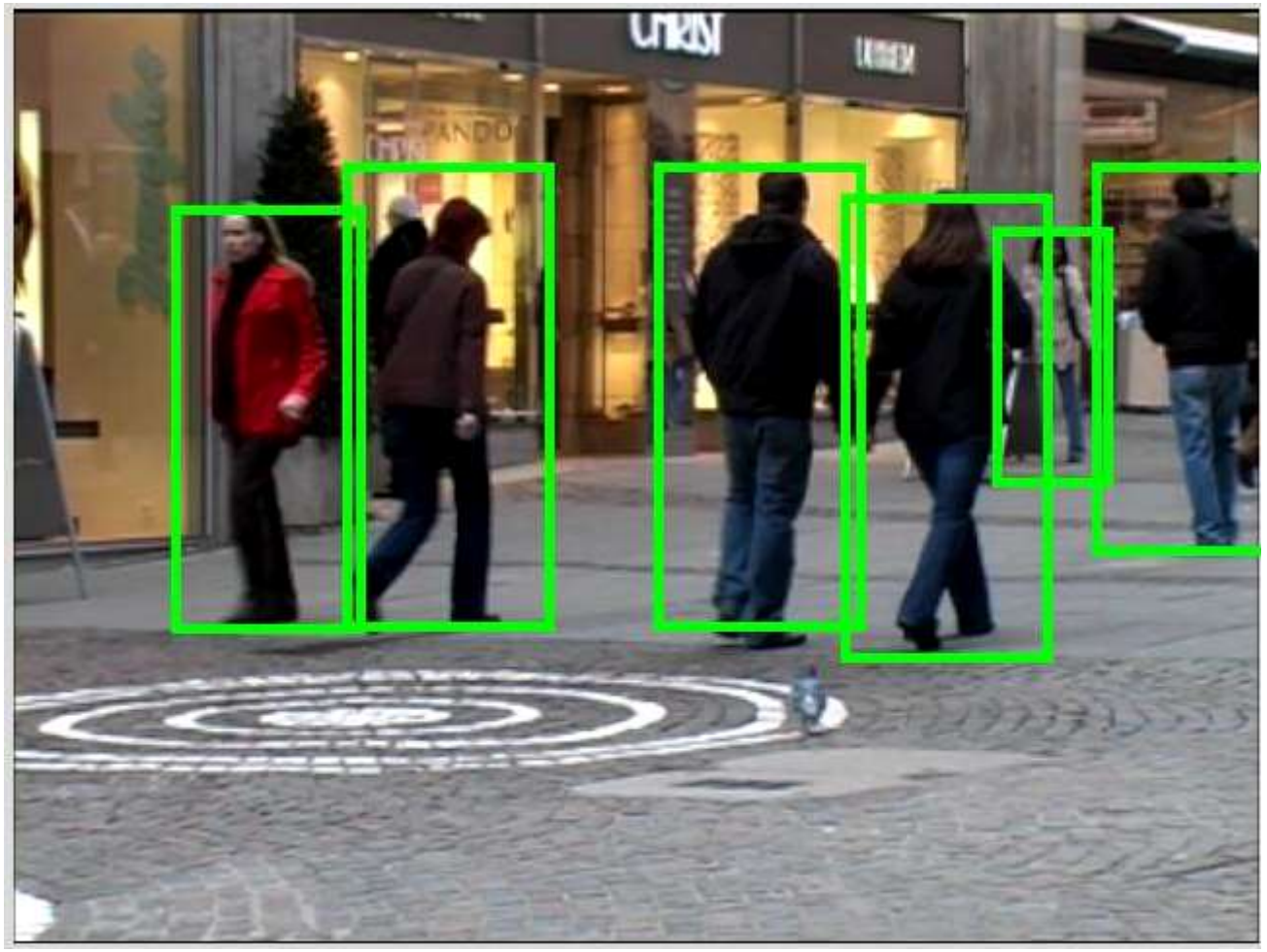


Tracking by Detection

Data Association



Challenges

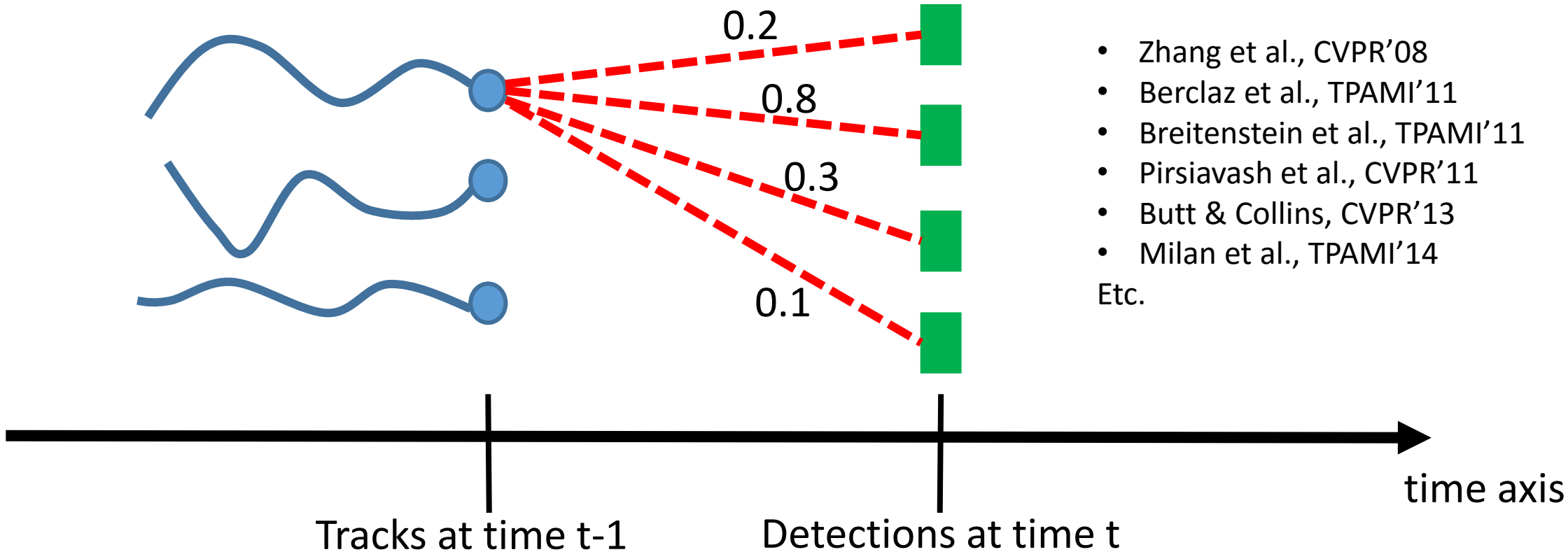


Noisy detection: false alarms and missing detections

Challenges

Occlusion

Similarity Function for Data Association

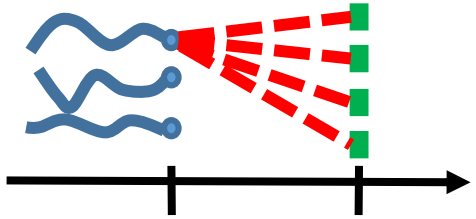


- Zhang et al., CVPR'08
- Berclaz et al., TPAMI'11
- Breitenstein et al., TPAMI'11
- Pirsiavash et al., CVPR'11
- Butt & Collins, CVPR'13
- Milan et al., TPAMI'14

Etc.

Ours Simple similarity measure + Powerful optimization

Learning to Track



Different features/cues between targets and detections

- Appearance
- Location
- Motion

Etc.

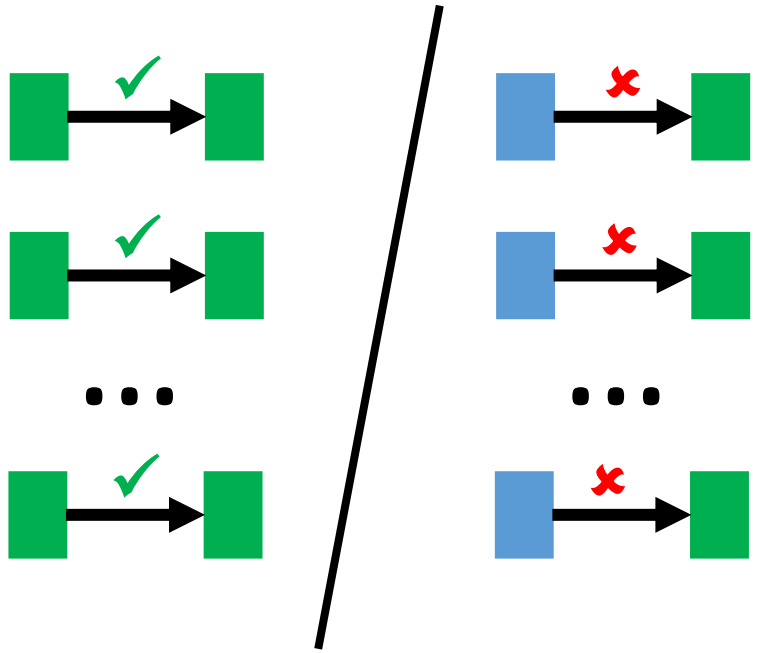
$$\text{Similarity} = w_1\phi_1(\,,\,) + \cdots + w_n\phi_n(\,,\,)$$

Weights to combine different cues (to be learned)

Offline-learning vs. Online-learning

Offline-learning vs. Online-learning

	Offline-learning
Training time	Before Tracking
With supervision	✓
Use history of the target	✗



- Li et al., CVPR'09
- Kim et al., ACCV'12

Etc.

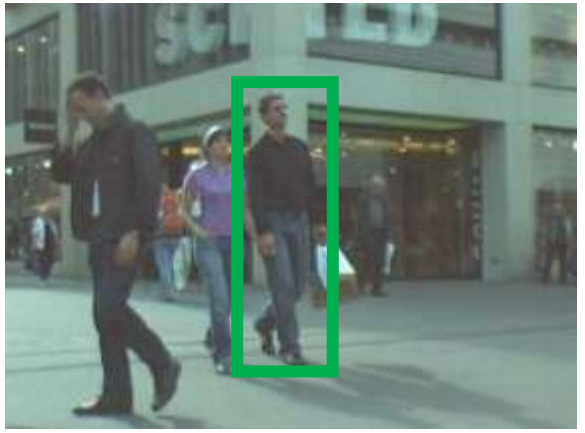
Offline-learning vs. Online-learning

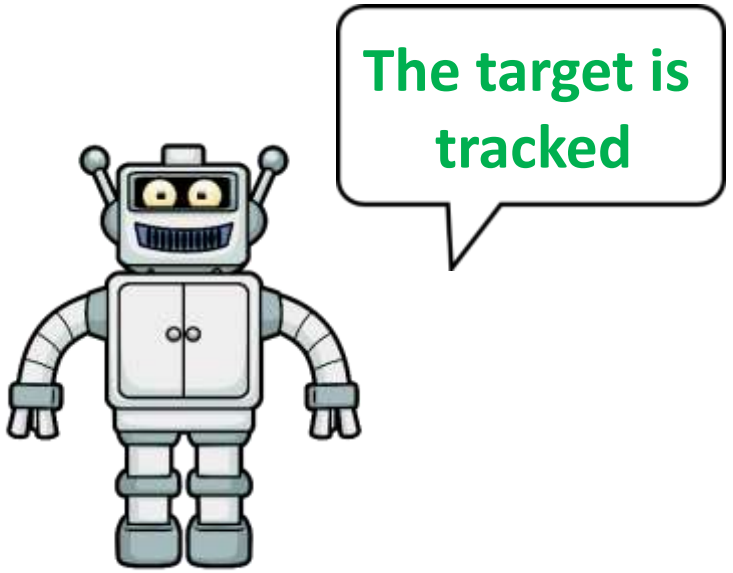
	Offline-learning	Online-learning
Training time	Before Tracking	During Tracking
With supervision	✓	✗
Use history of the target	✗	✓

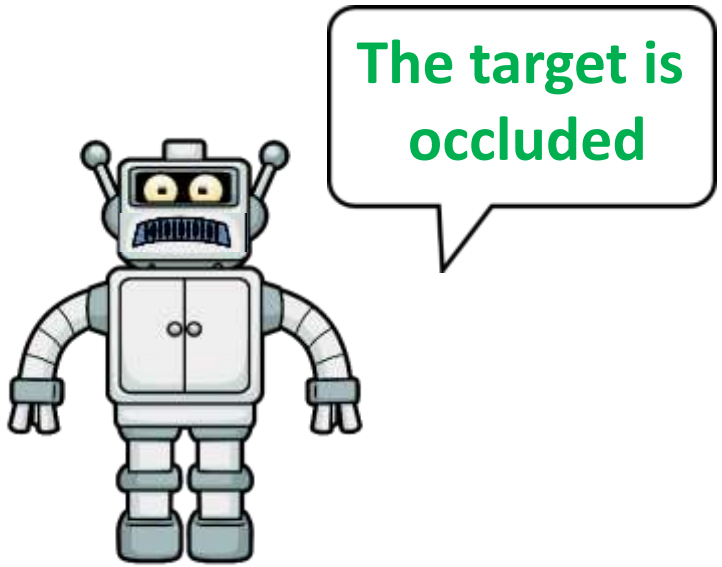
- Song et al., ECCV'08
- Kuo et al., CVPR'10
- Bae et al., CVPR'14

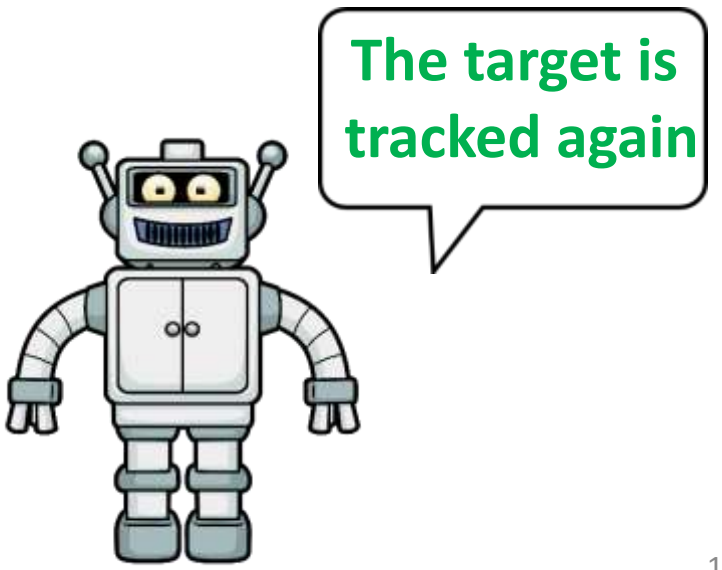
Etc.

Our Solution: Tracking by Decision Making

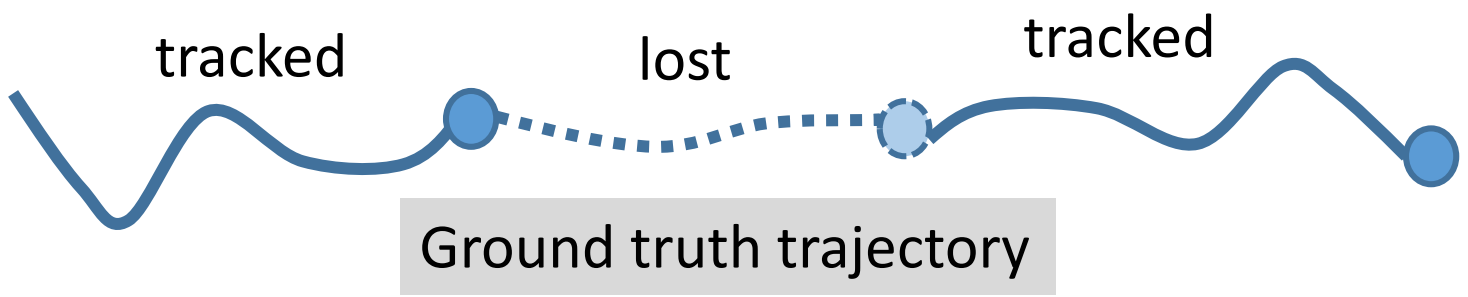






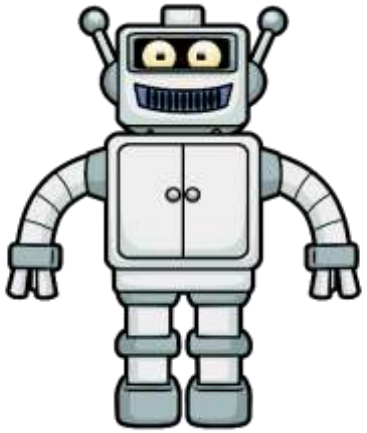


Inverse Reinforcement Learning



Ground truth trajectory

Supervision



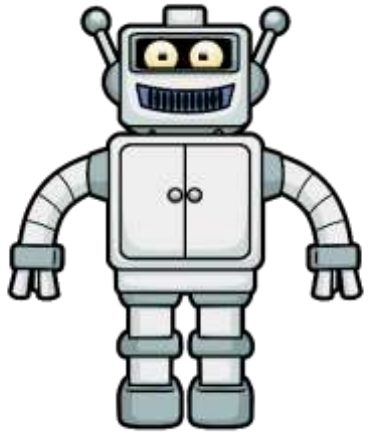
Markov Decision Process (MDP)

Comparison between Different Learning Strategies

	Offline-learning	Online-learning
Training time	Before Tracking	During Tracking
With supervision	✓	✗
Use history of the target	✗	✓

Comparison between Different Learning Strategies

	Offline-learning	Online-learning	Ours
Training time	Before Tracking	During Tracking	Before Tracking
With supervision	✓	✗	✓
Use history of the target	✗	✓	✓



Outline

- Markov Decision Process (MDP) for a Single Target
- Online Multi-Object Tracking with MDPs
- Experiments
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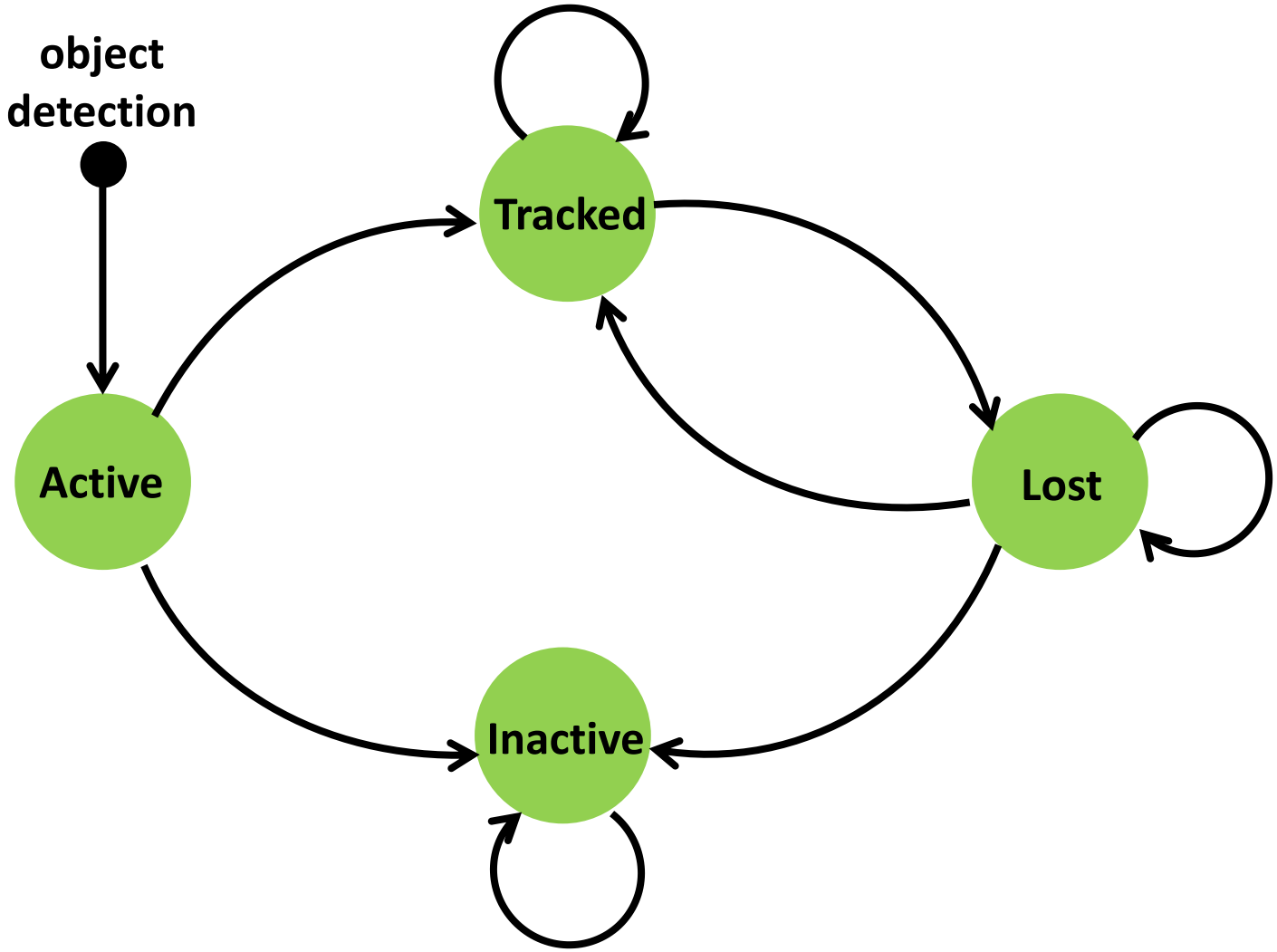

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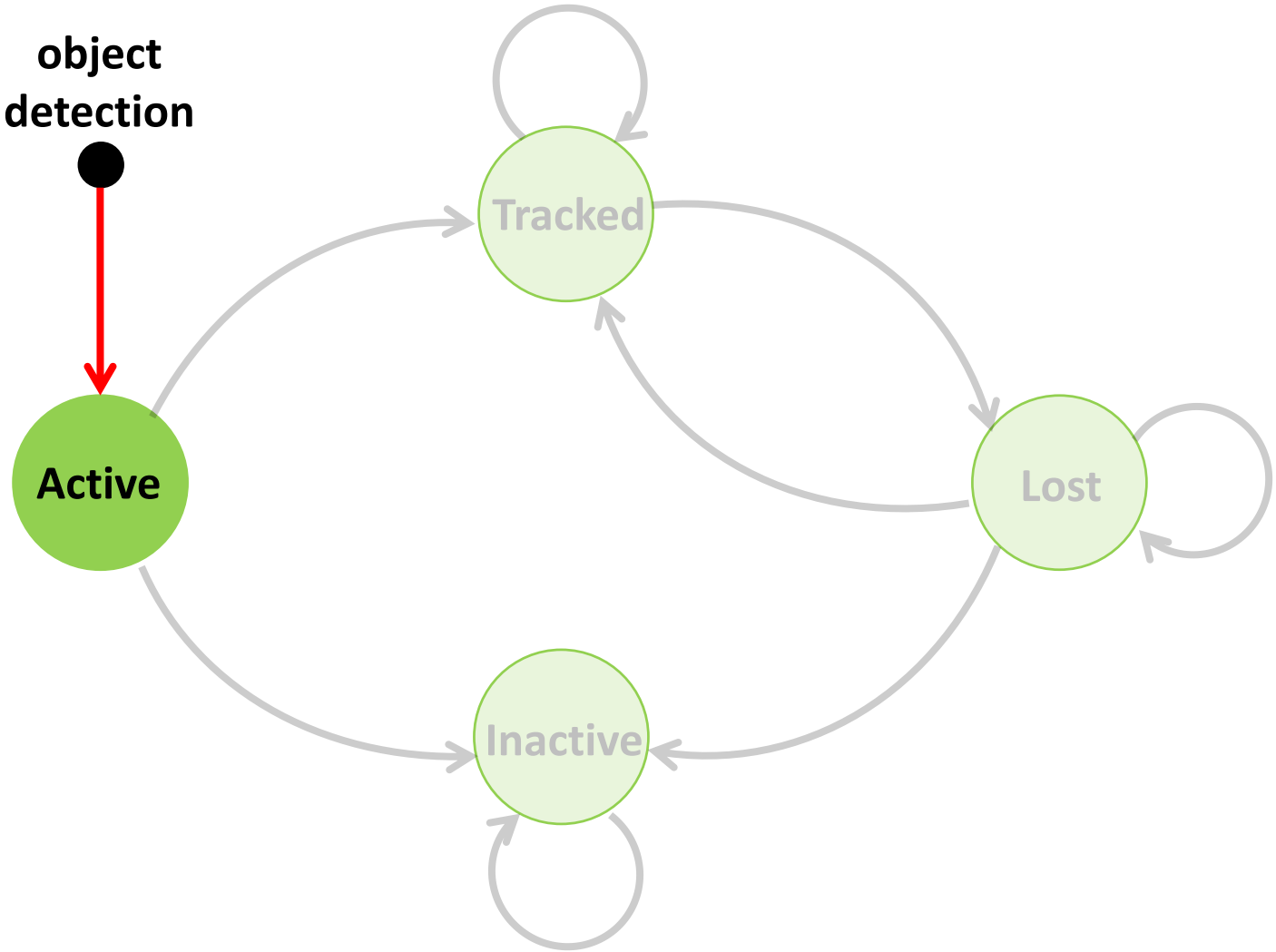

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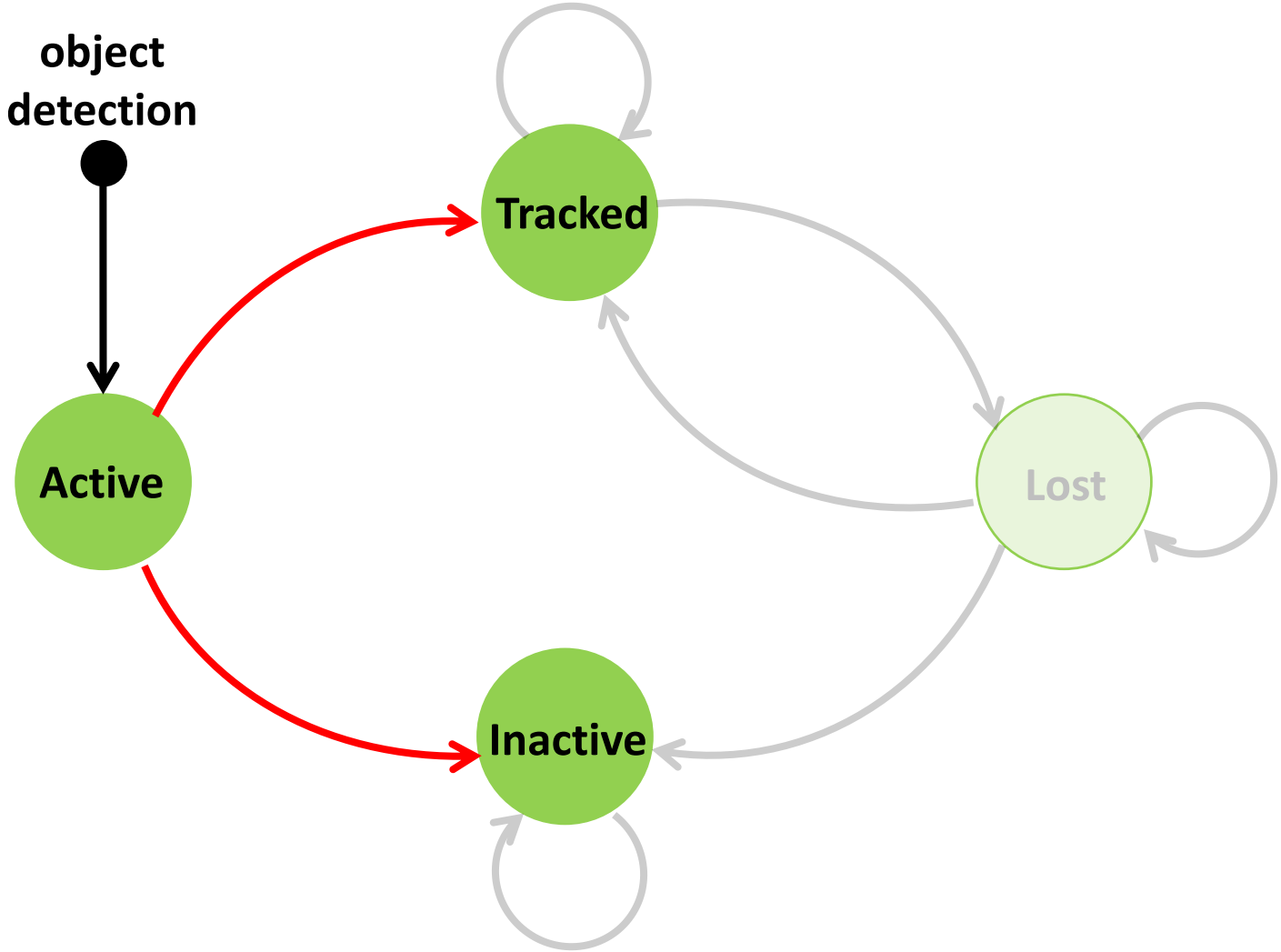

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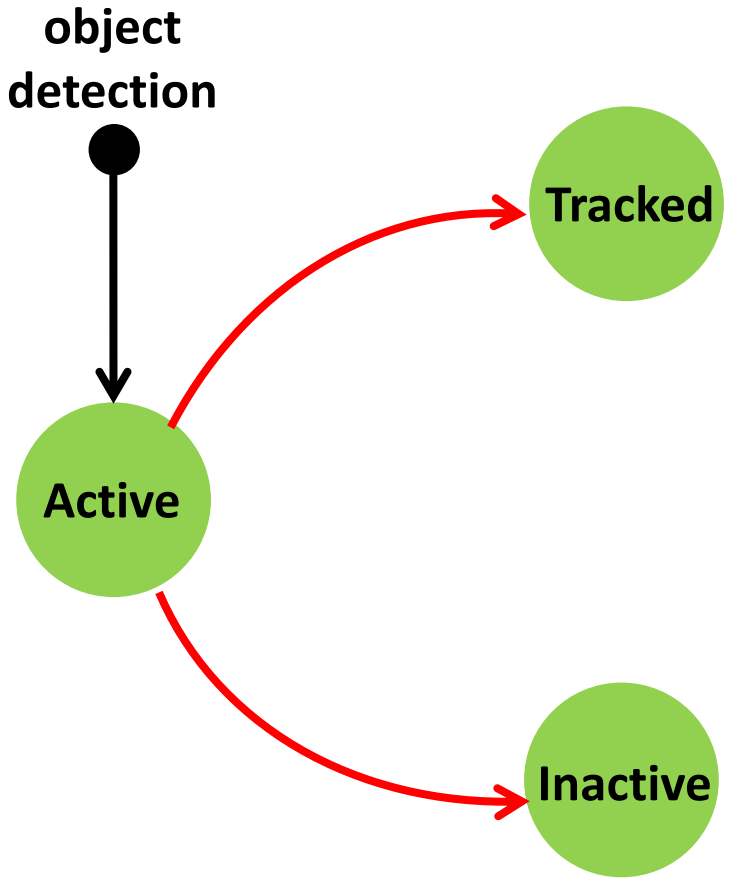

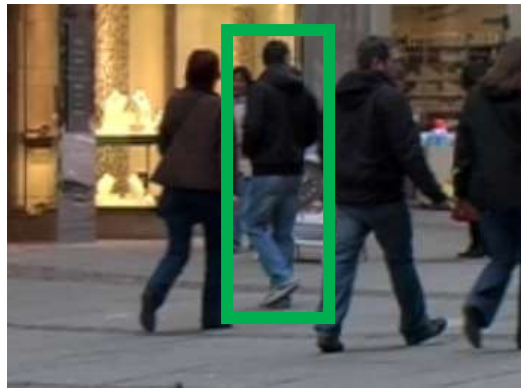

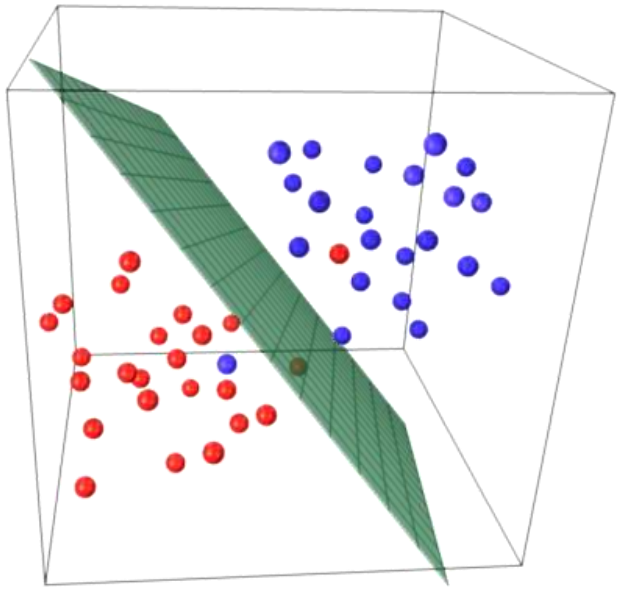

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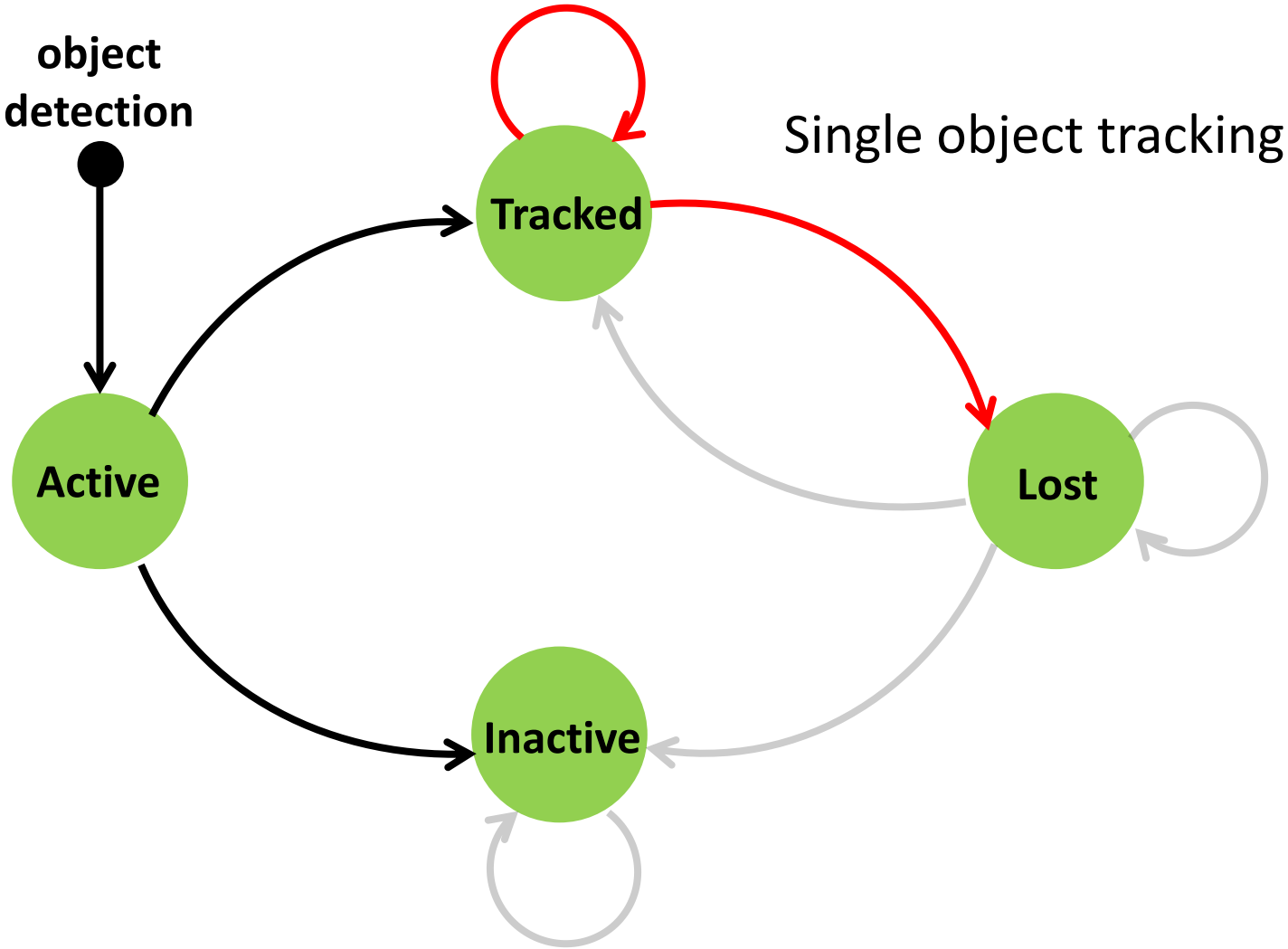

TLD Tracker. Z. Kalal, K. Mikolajczyk, and J. Matas. Tracking-learning-detection. TPAMI, 34(7):1409–1422, 2012.

Template Tracking in Tracked States

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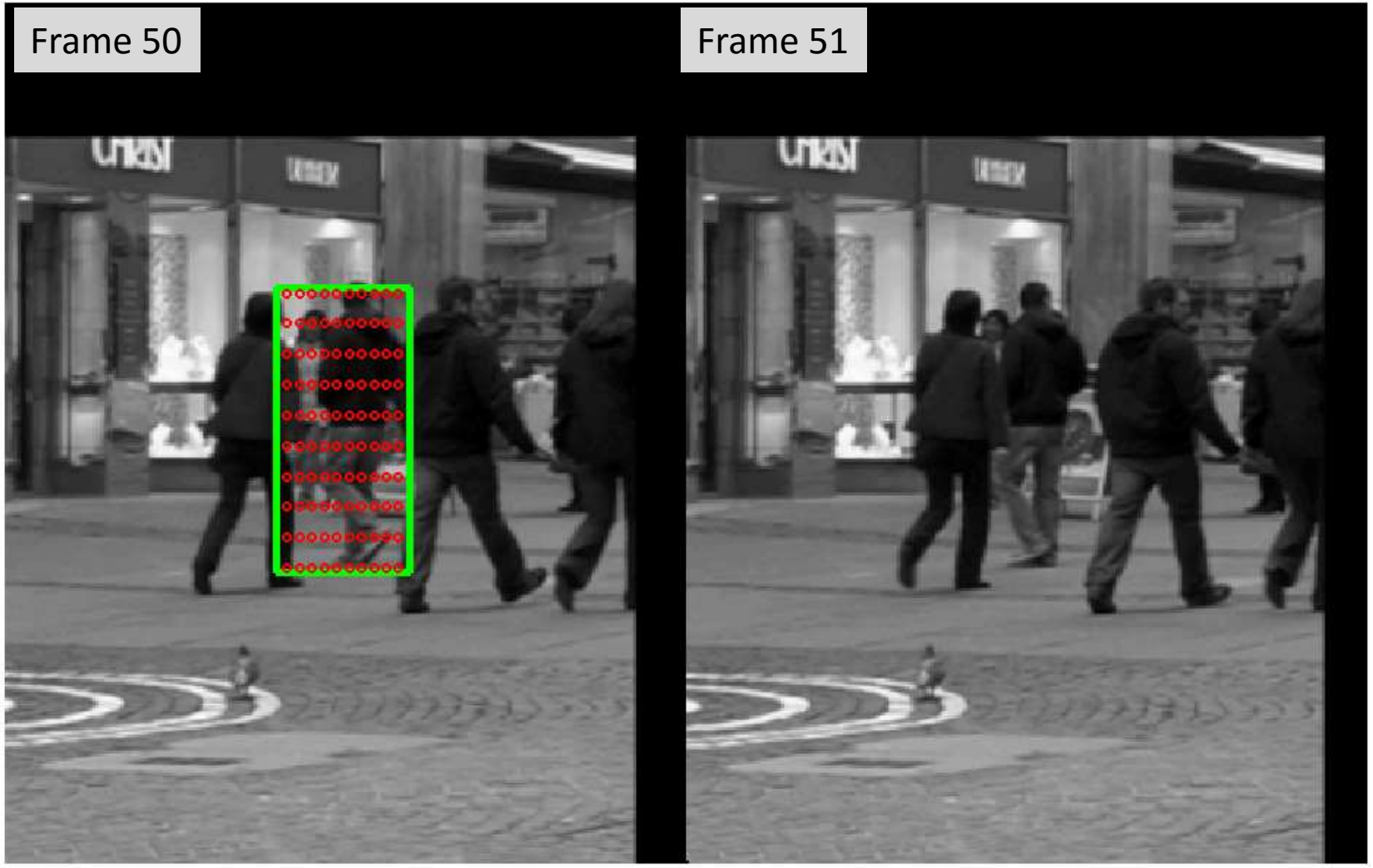

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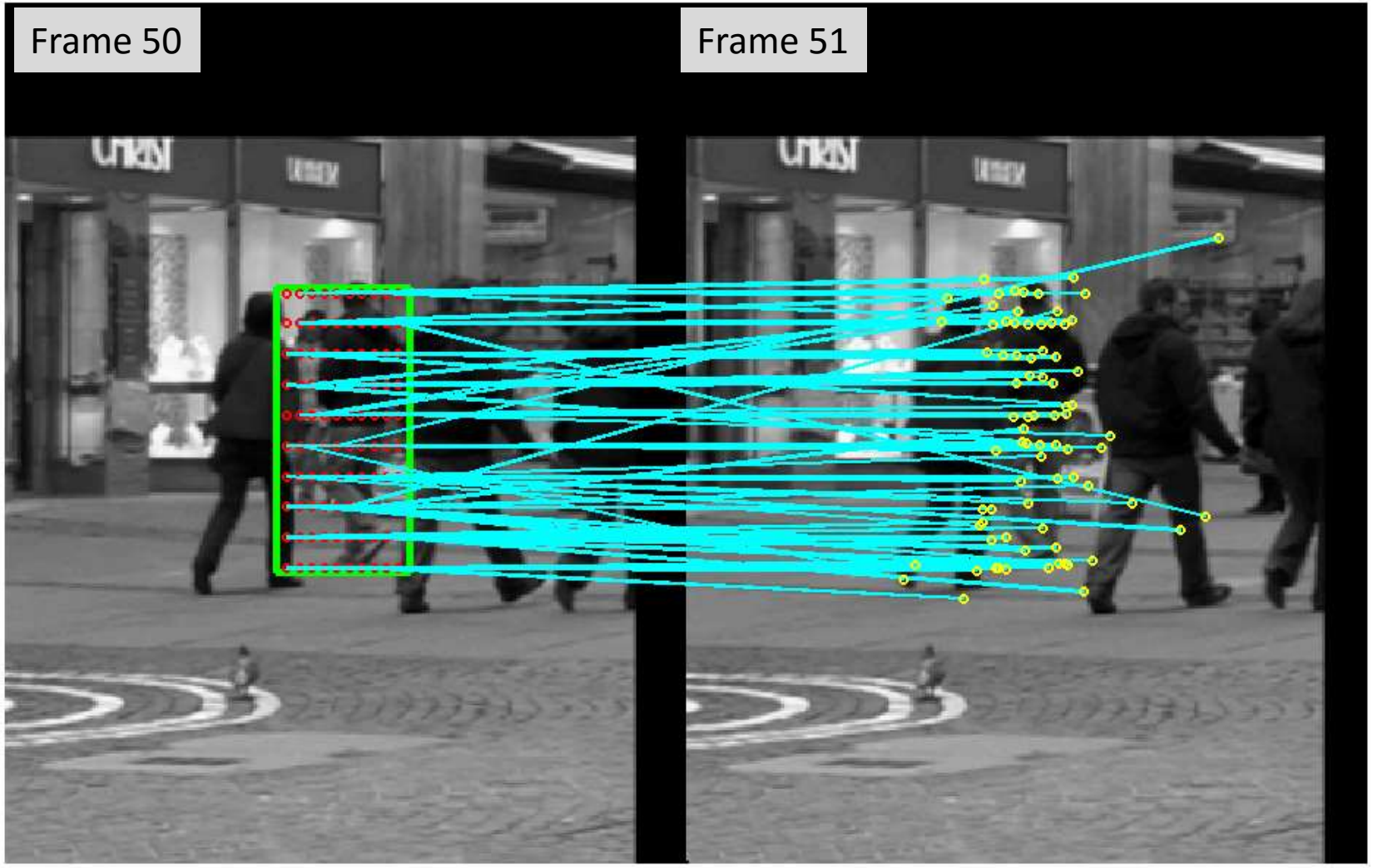

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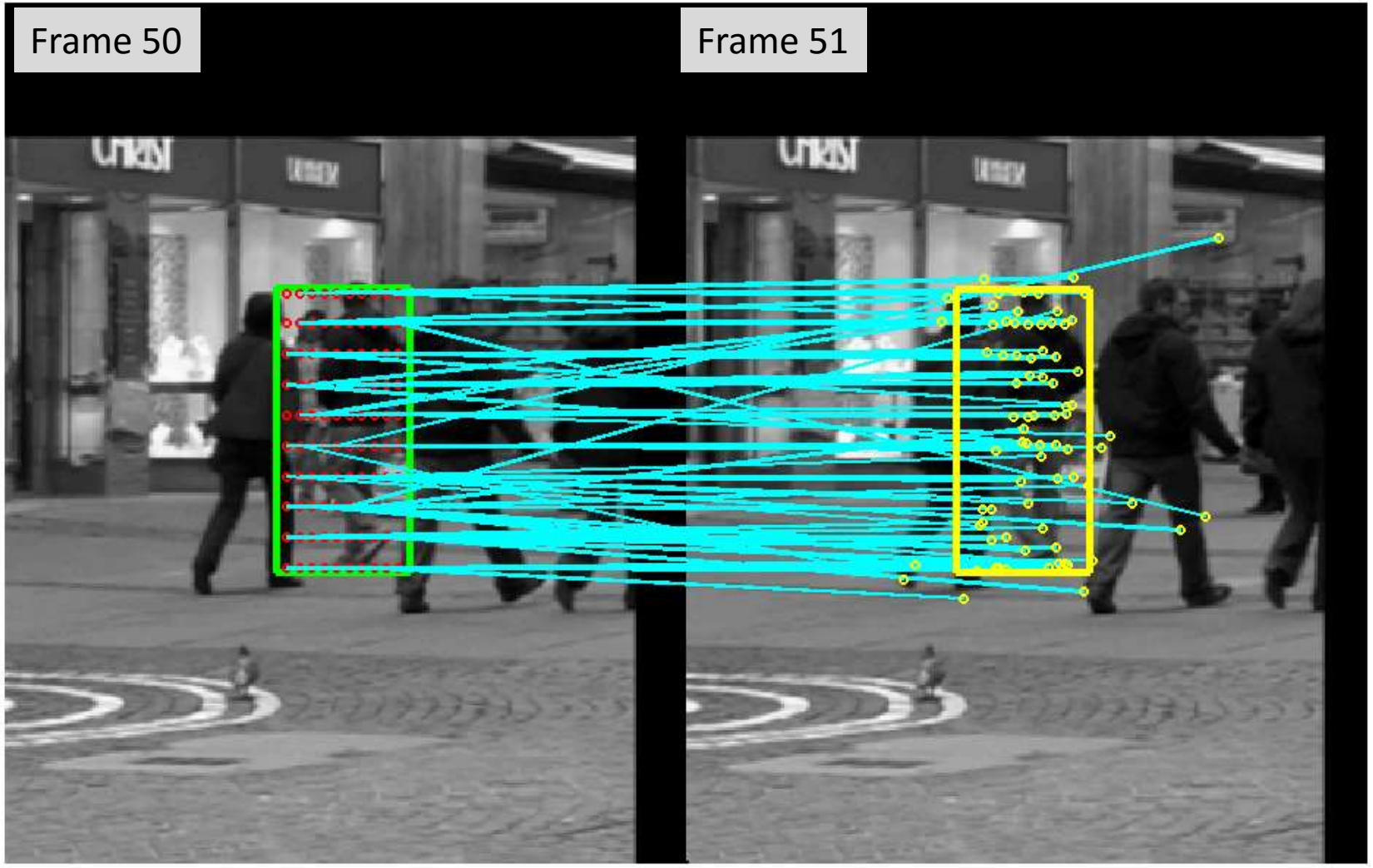

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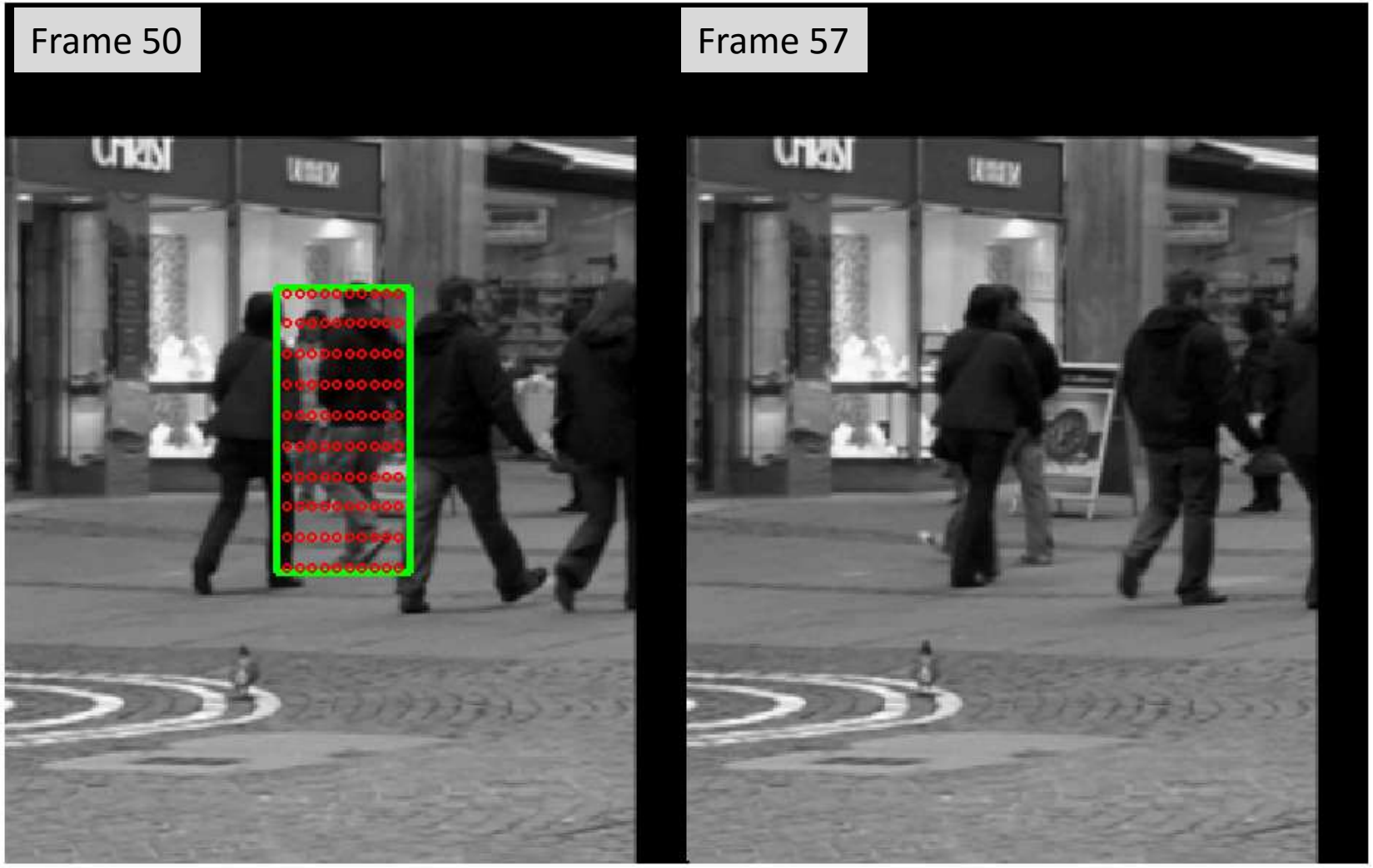

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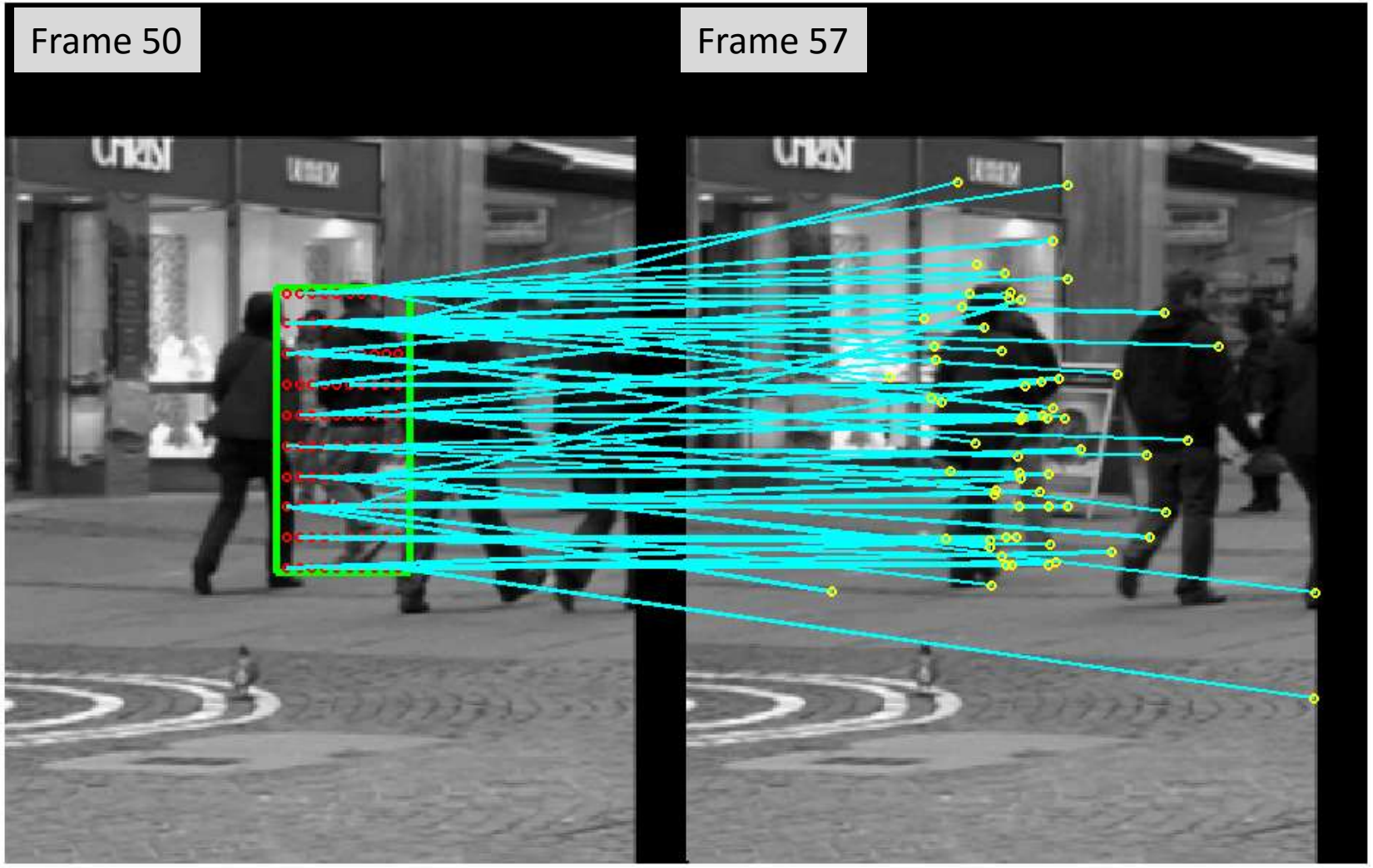

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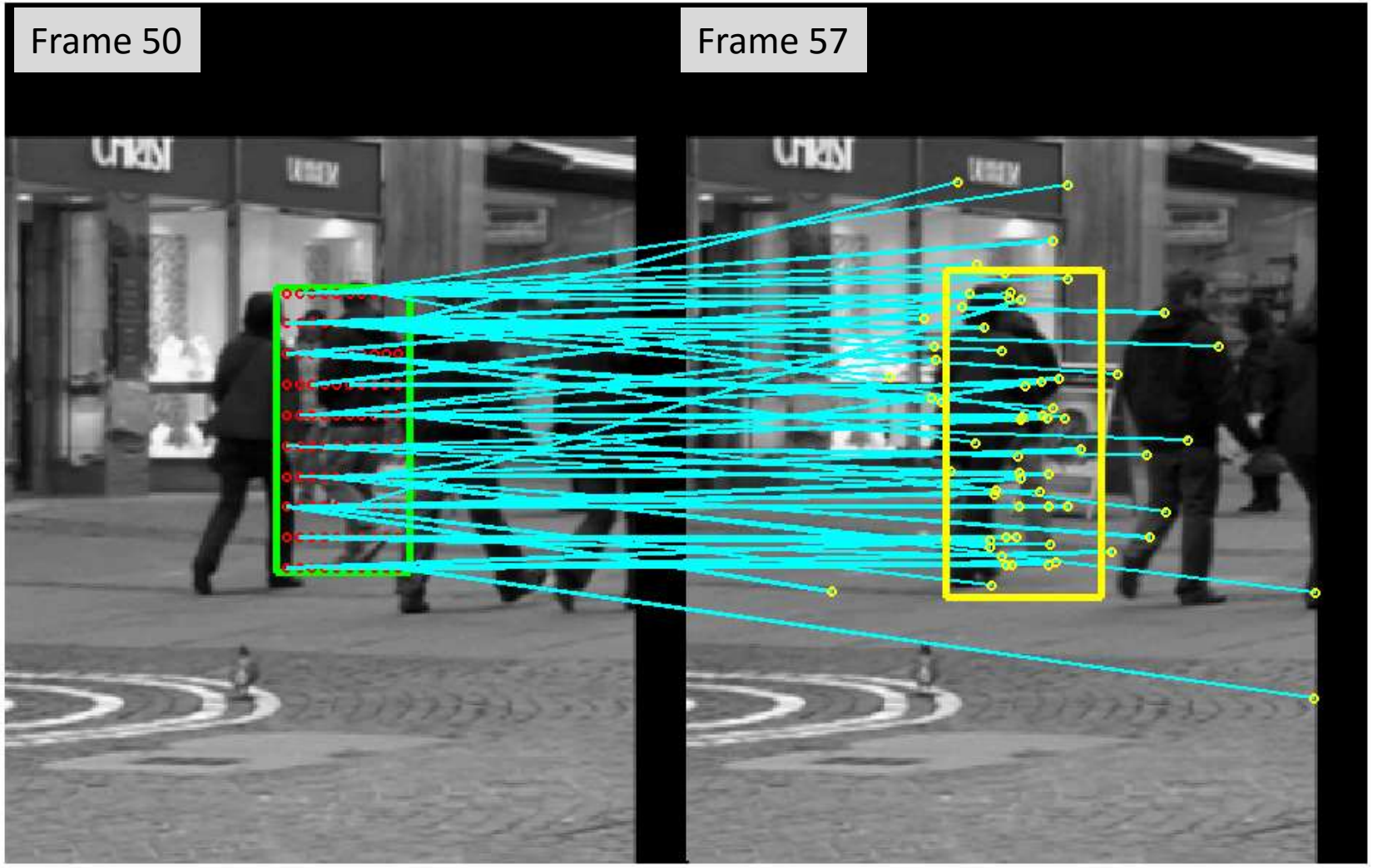
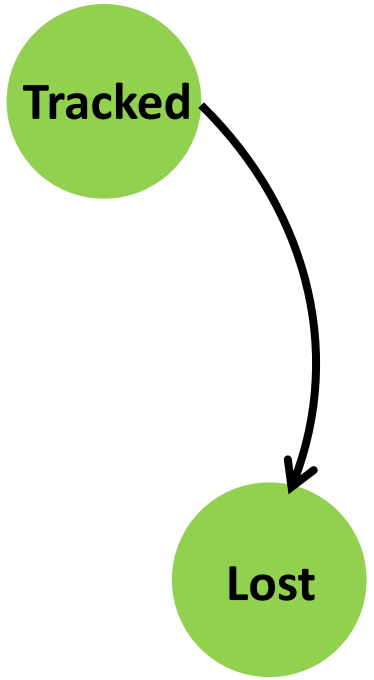
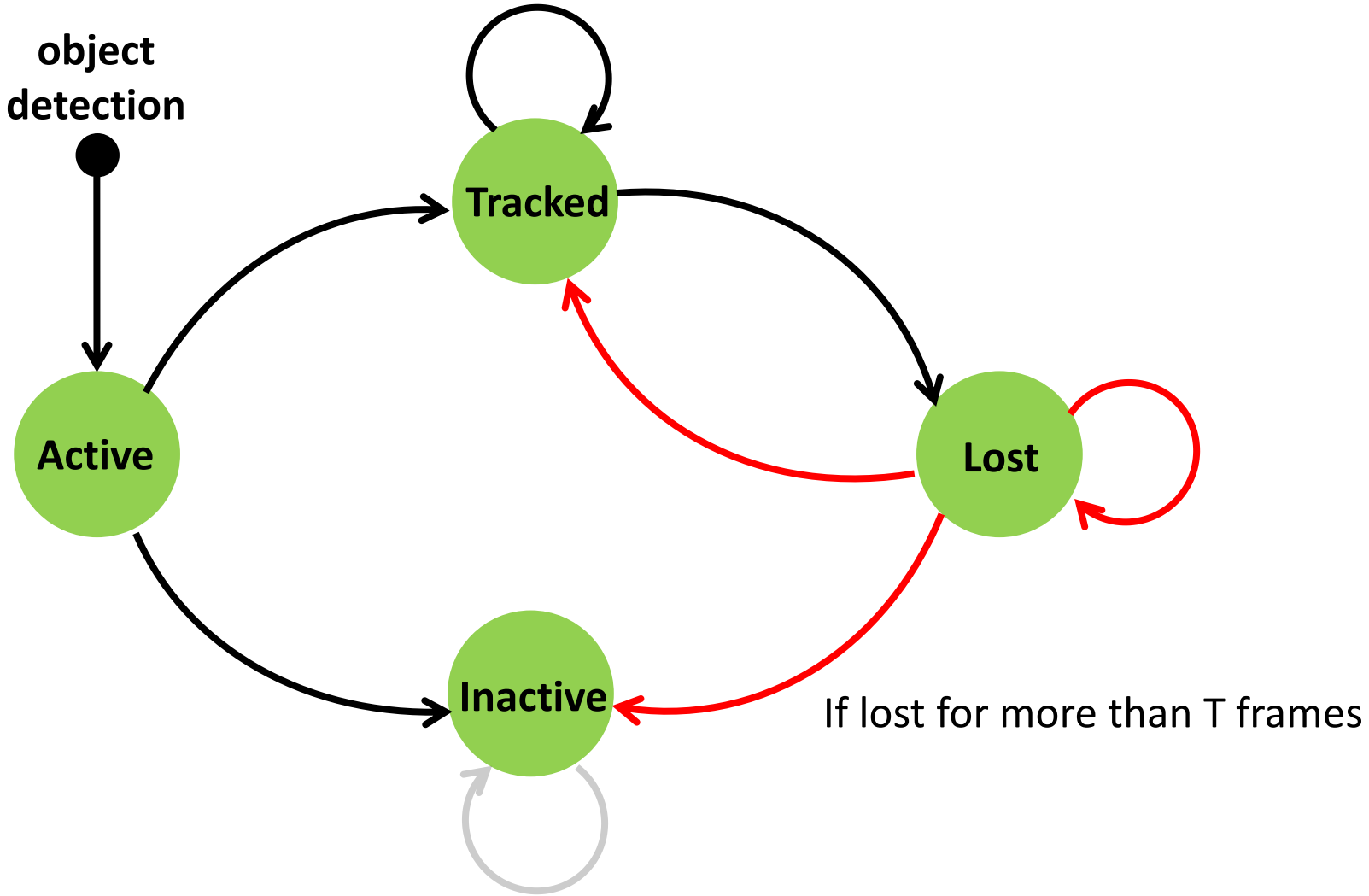
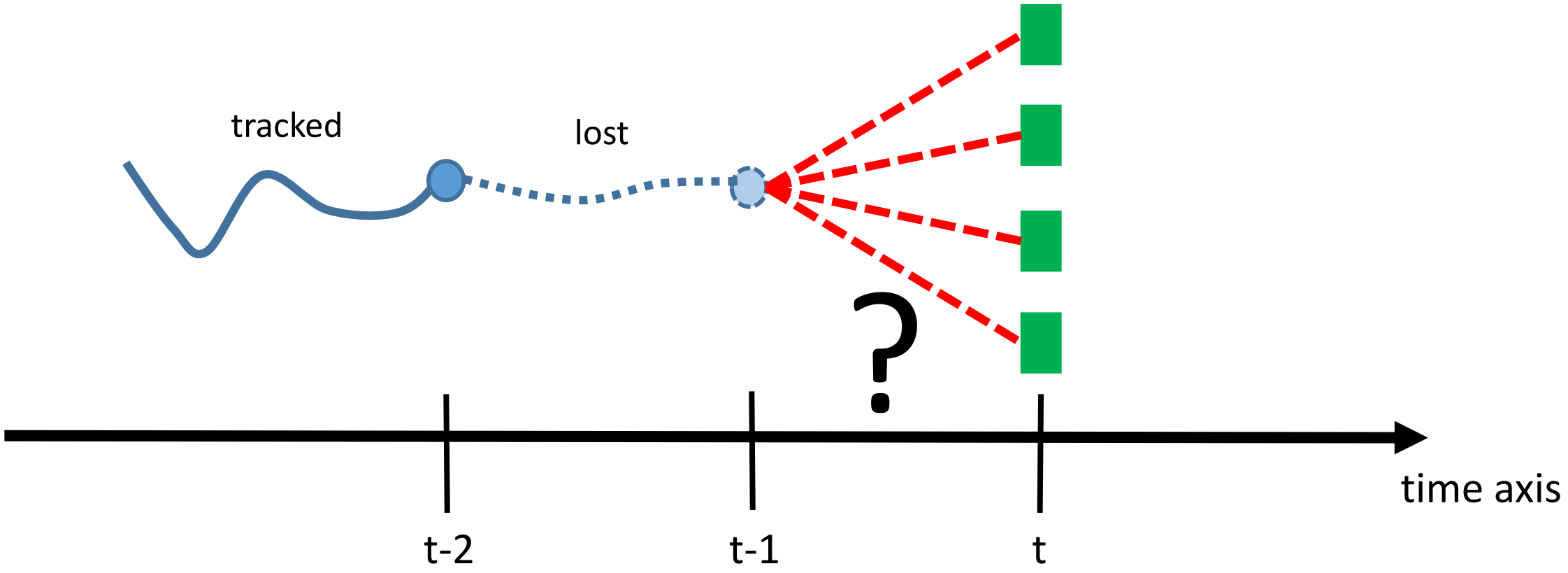




Markov Decision Process for a Single Target



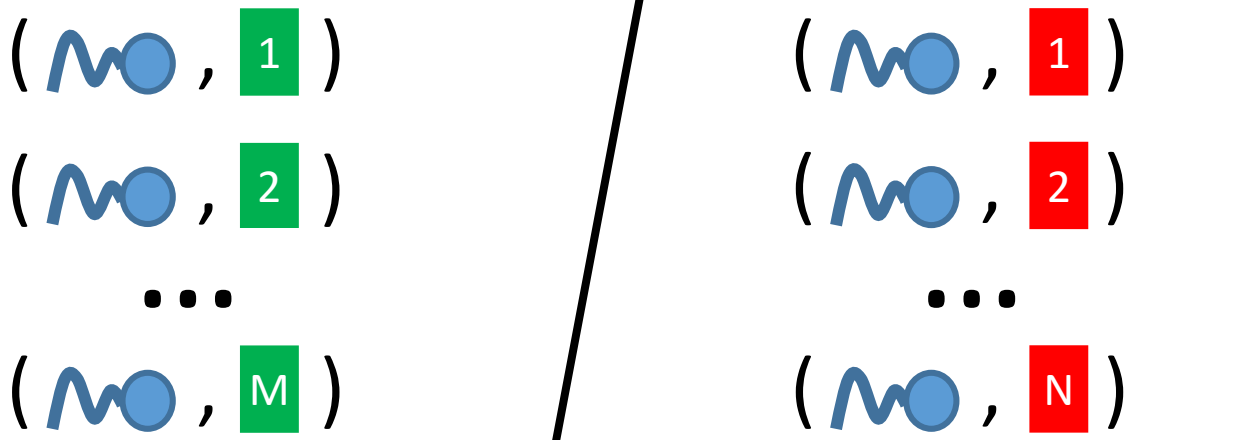
Data Association in Lost States



Learning the Similarity Function

$$\text{Similarity} = w_1\phi_1(\,\text{  }\,,\,\text{}\,) + \cdots + w_n\phi_n(\,\text{  }\,,\,\text{}\,) + b$$

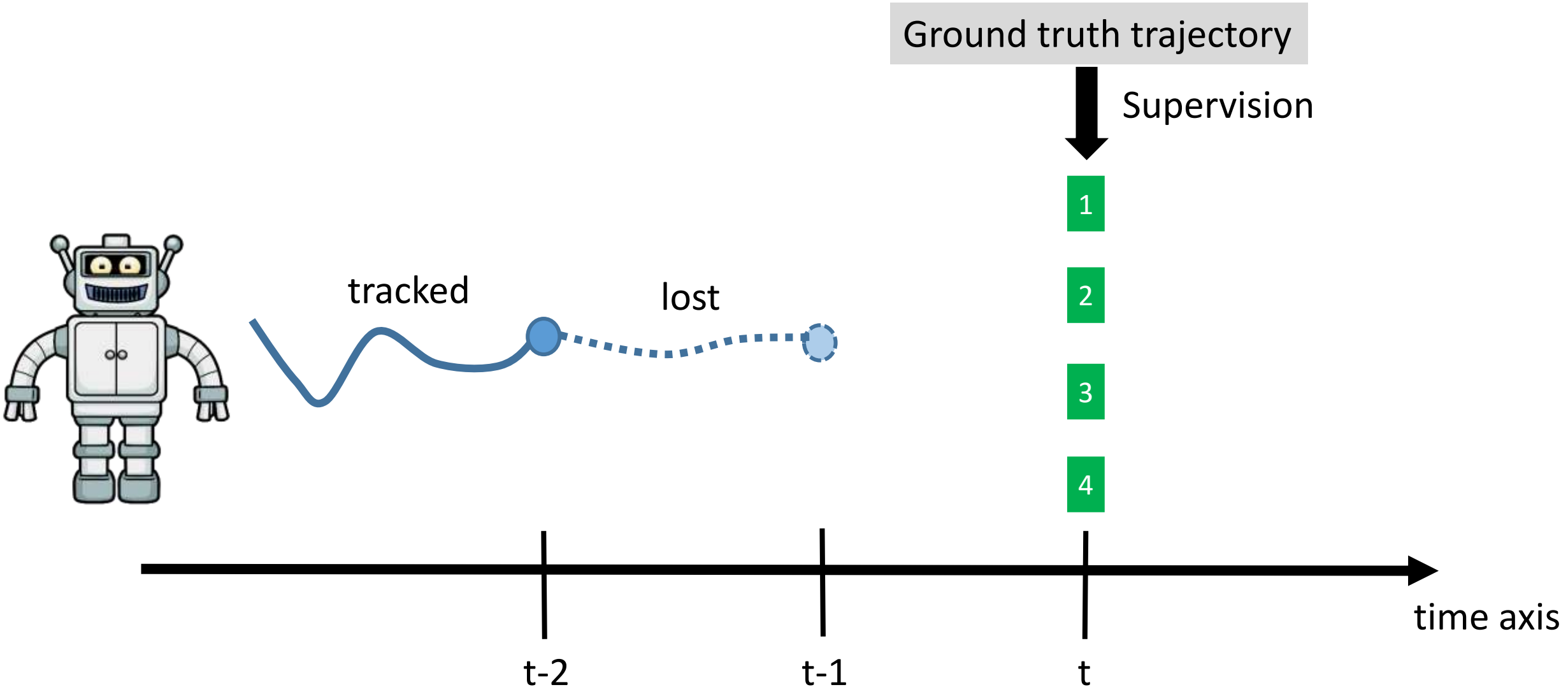
Inverse reinforcement learning: tracking objects in training videos!



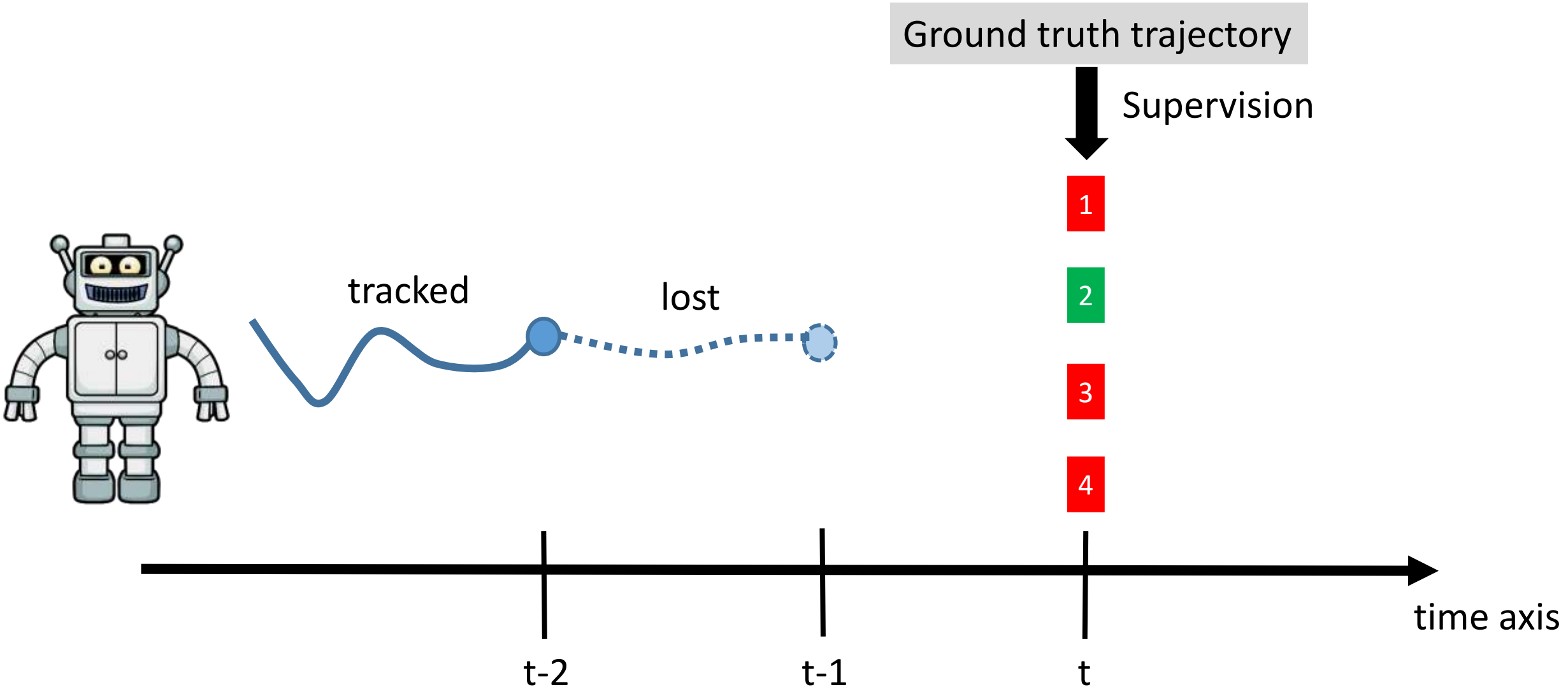
Hard positive examples

Hard negative examples

Inverse Reinforcement Learning



Inverse Reinforcement Learning



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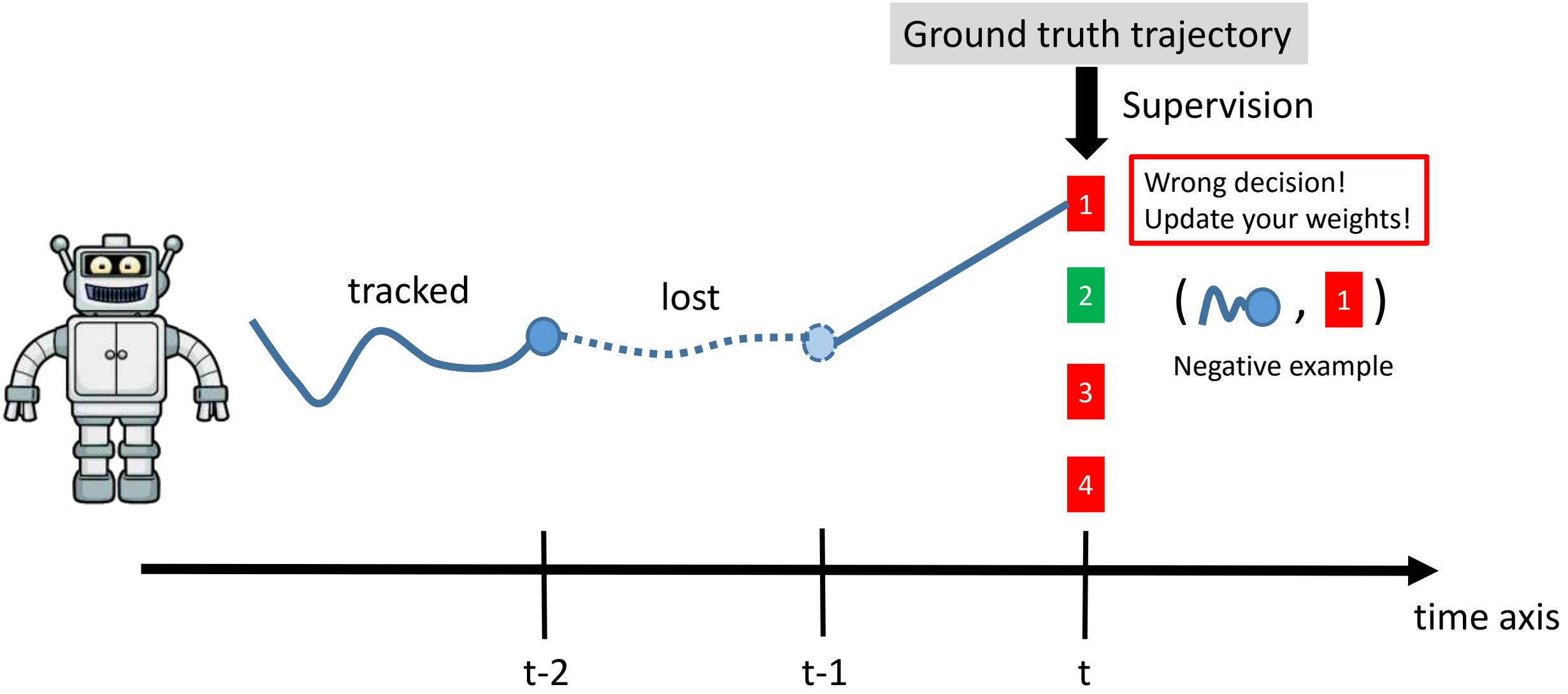

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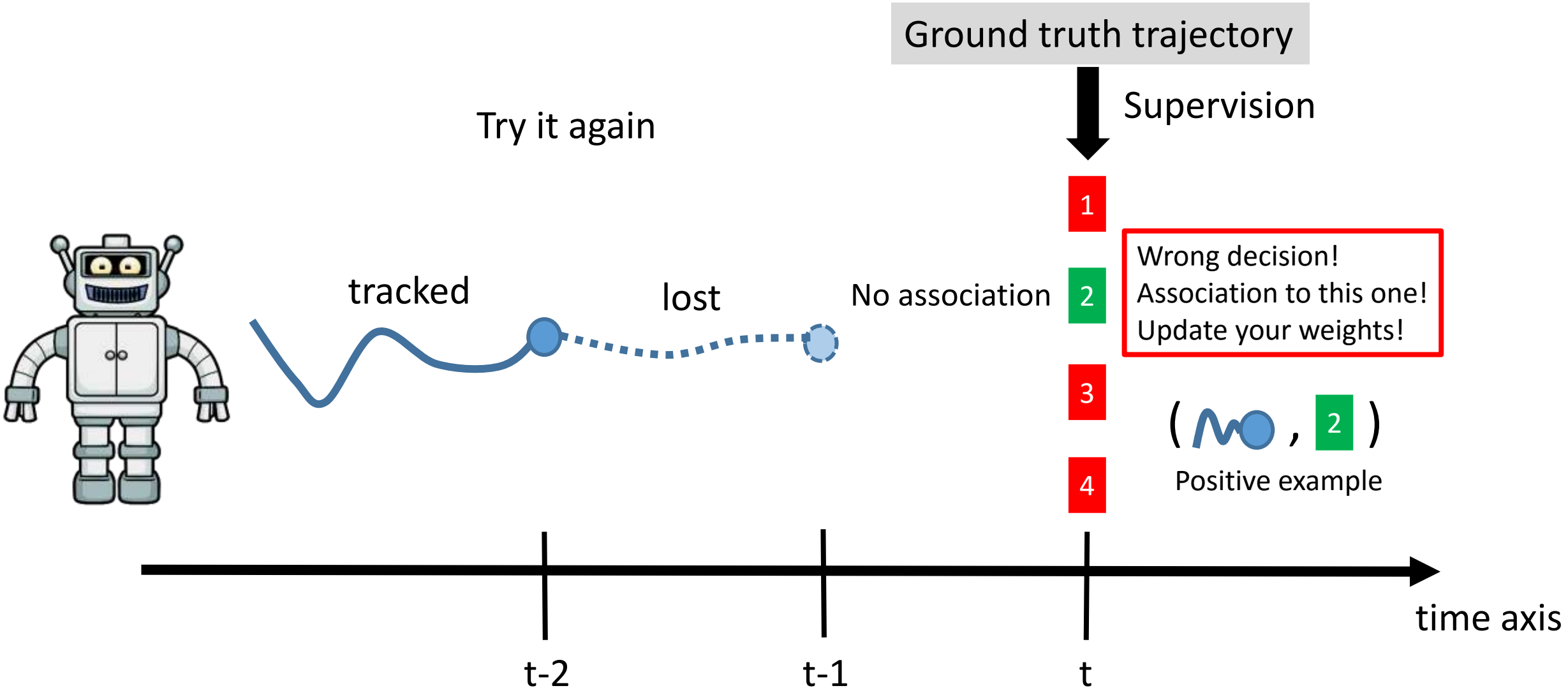

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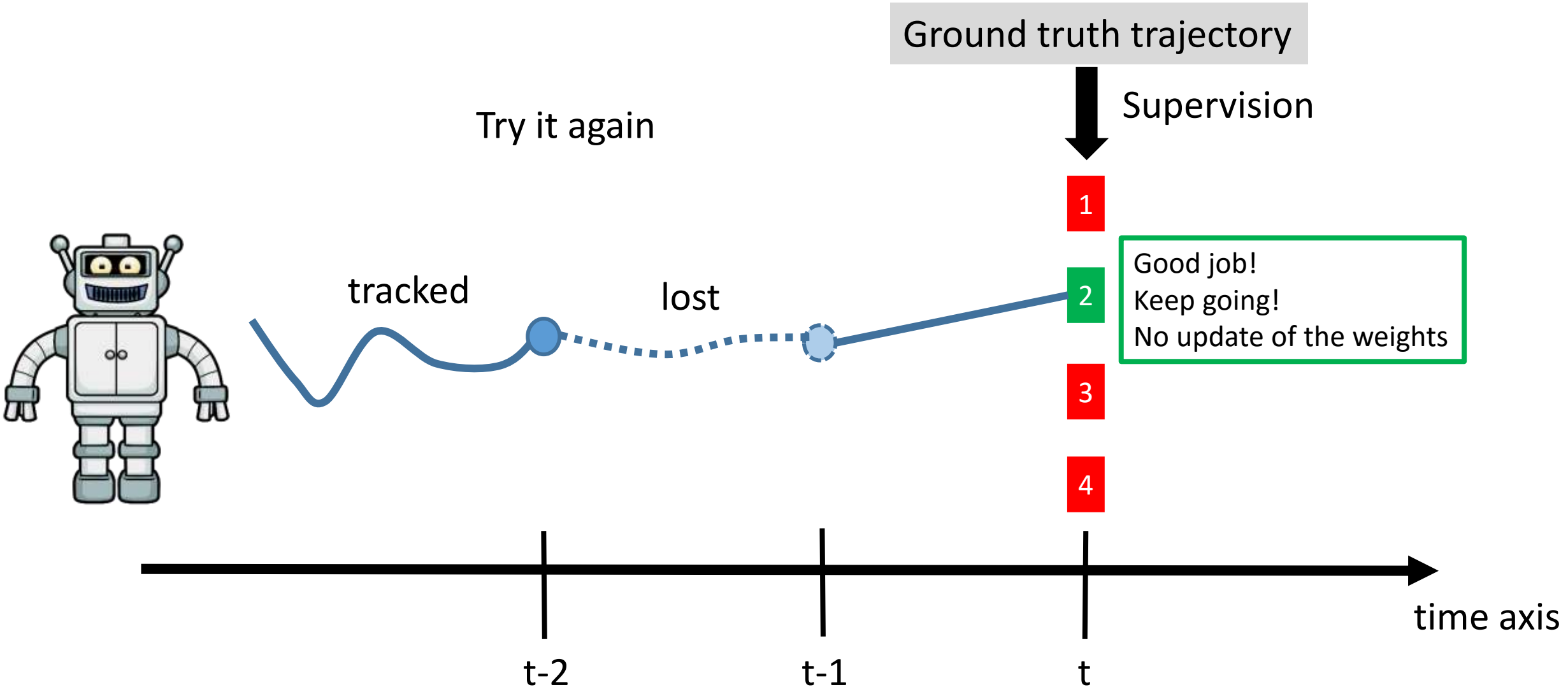
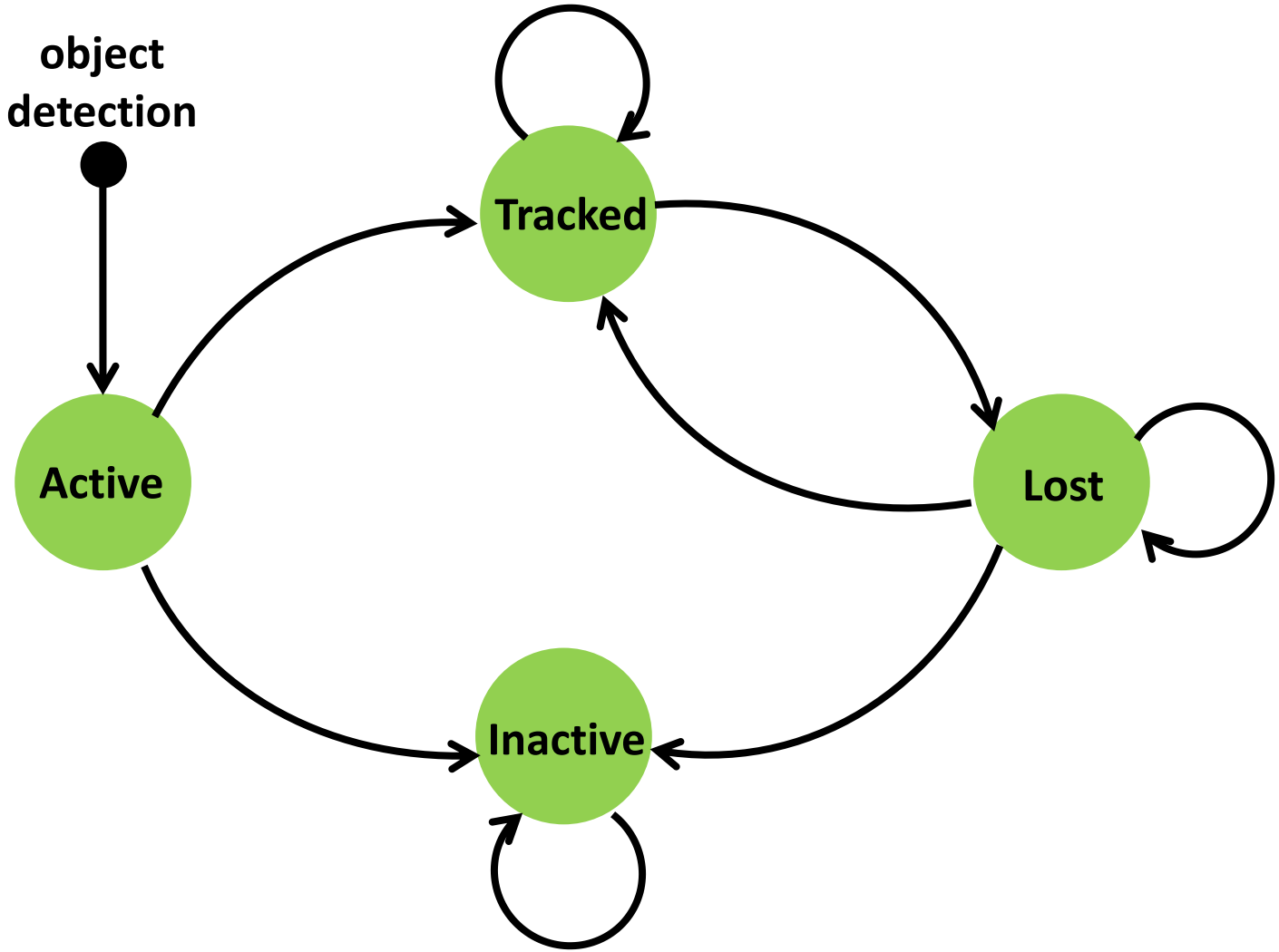


Markov Decision Process for a Single Target



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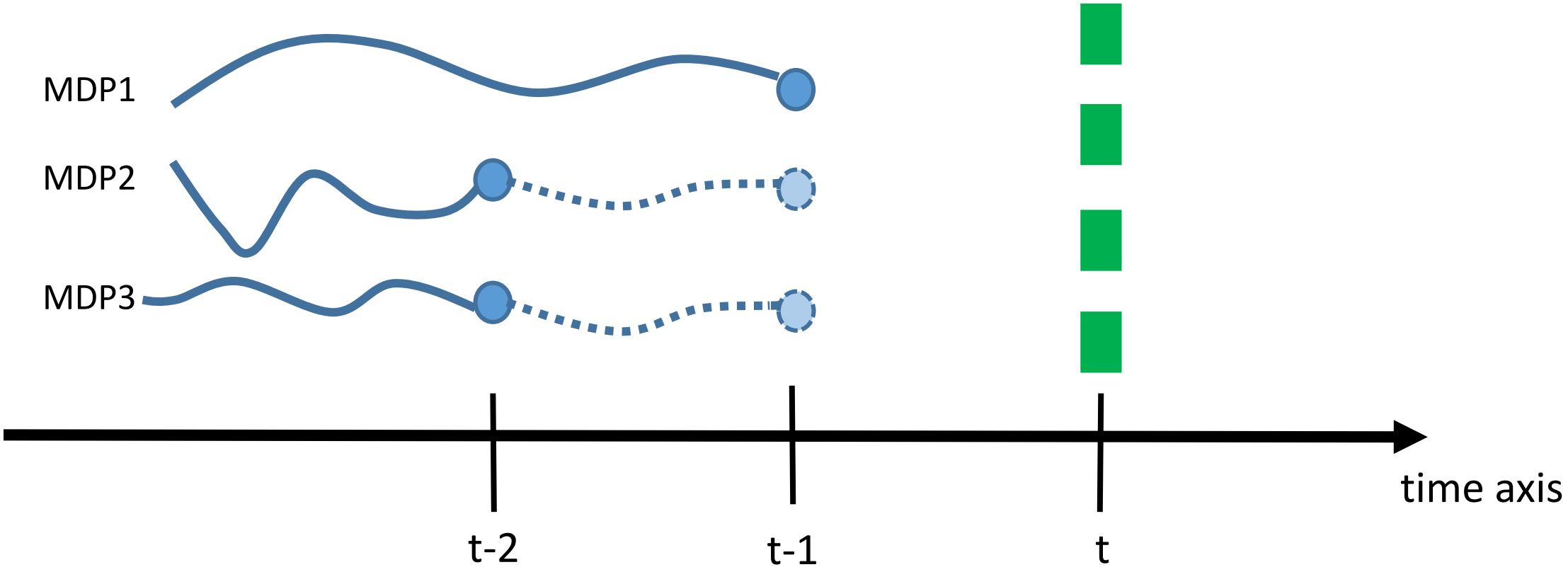
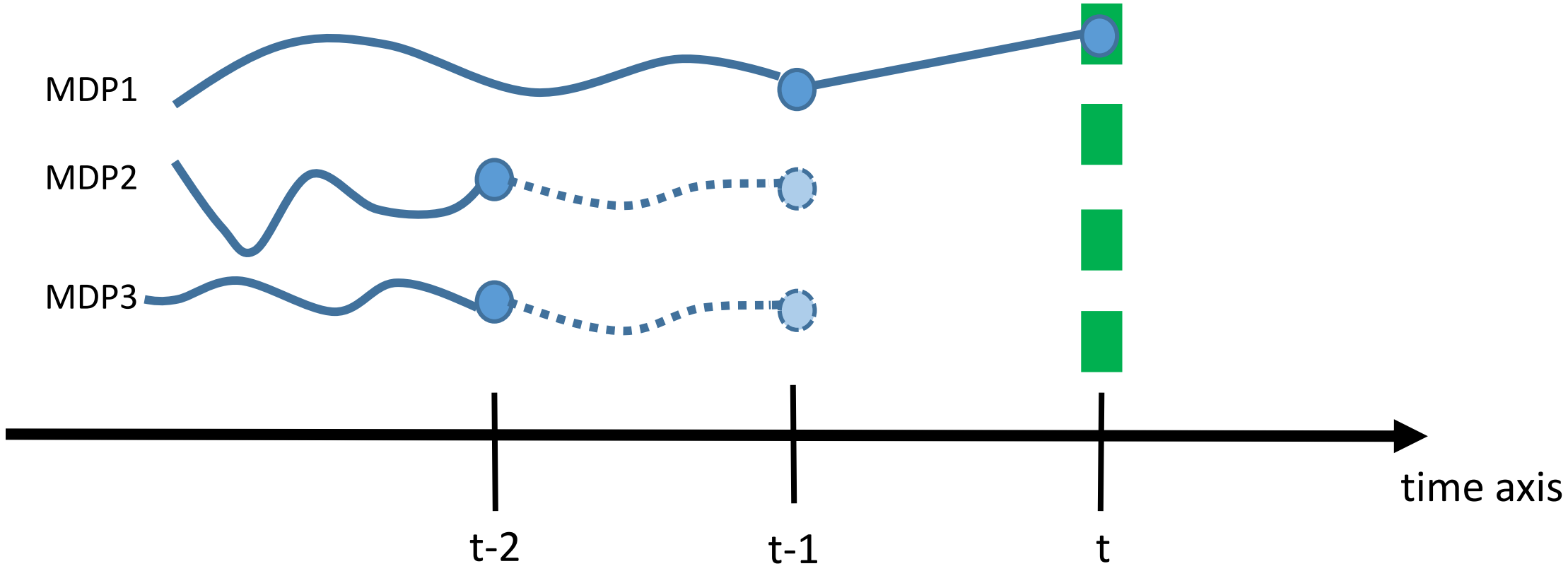
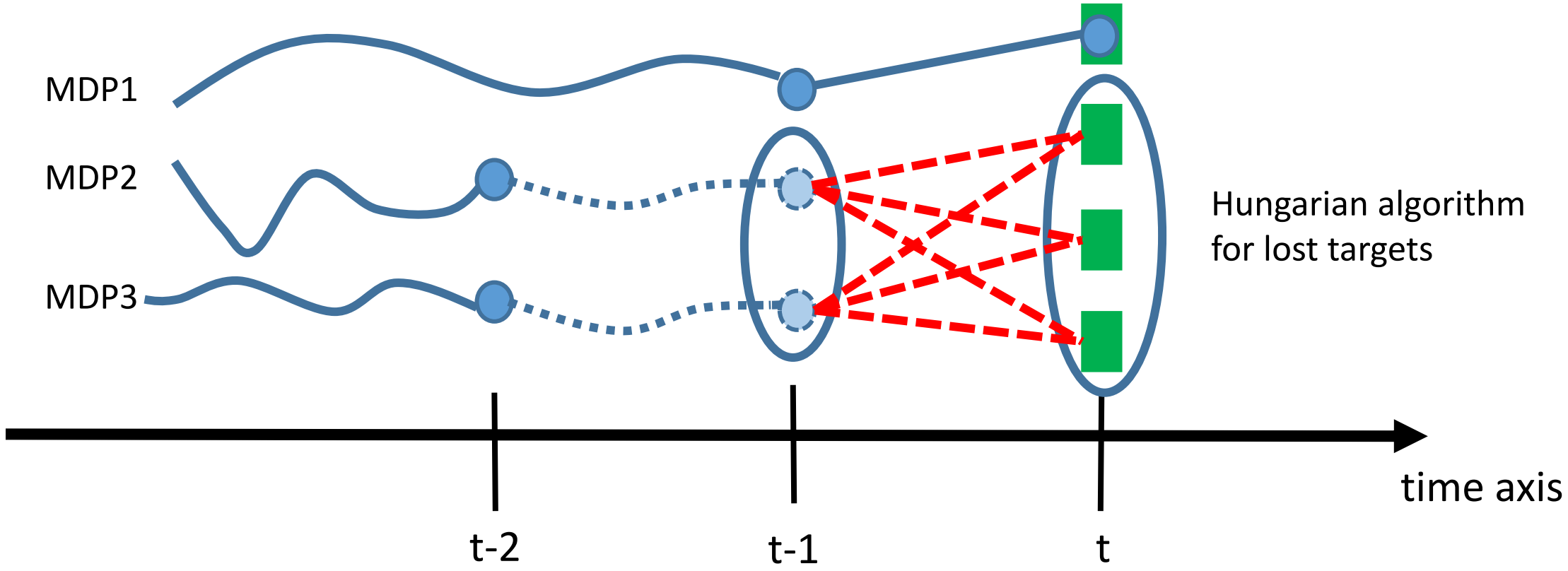
Ensemble MDPs for Online Multi-Object Tracking



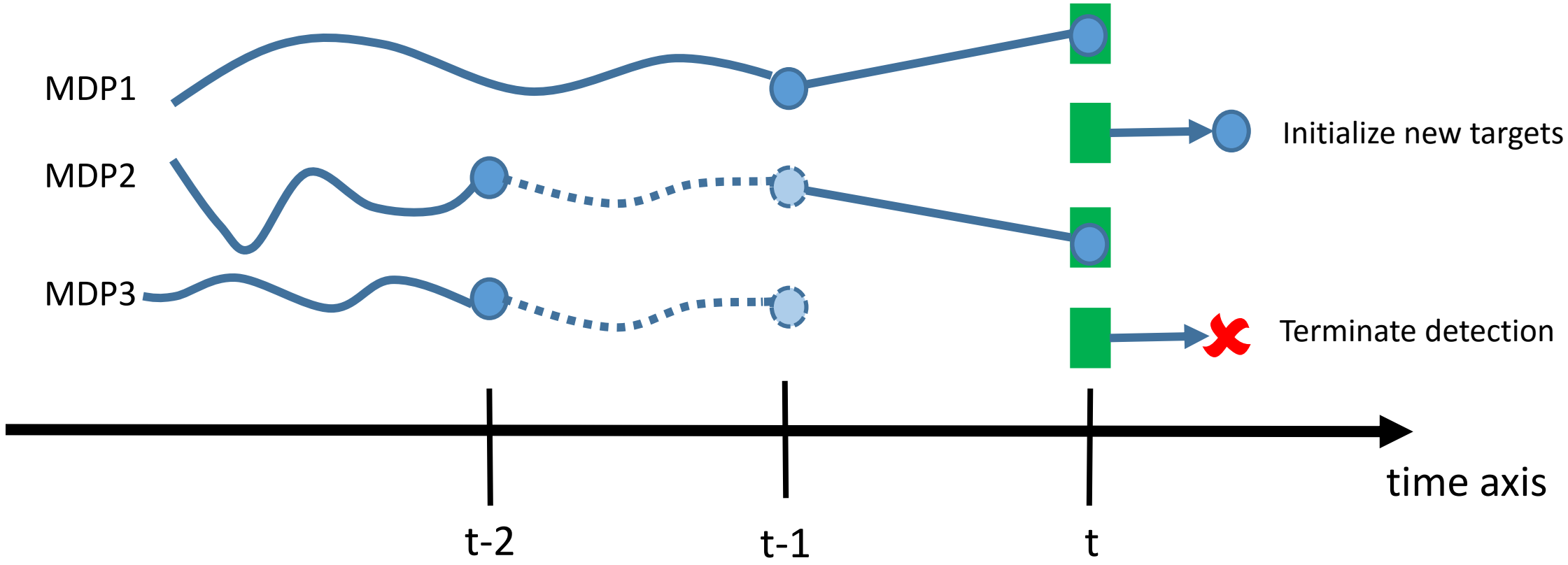
Step 1: Process tracked targets



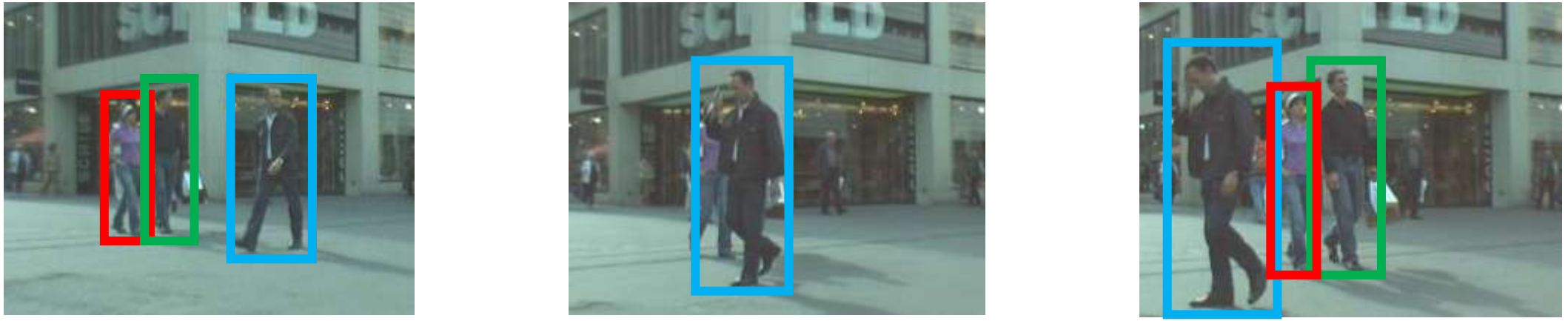
Step 2: Process lost targets

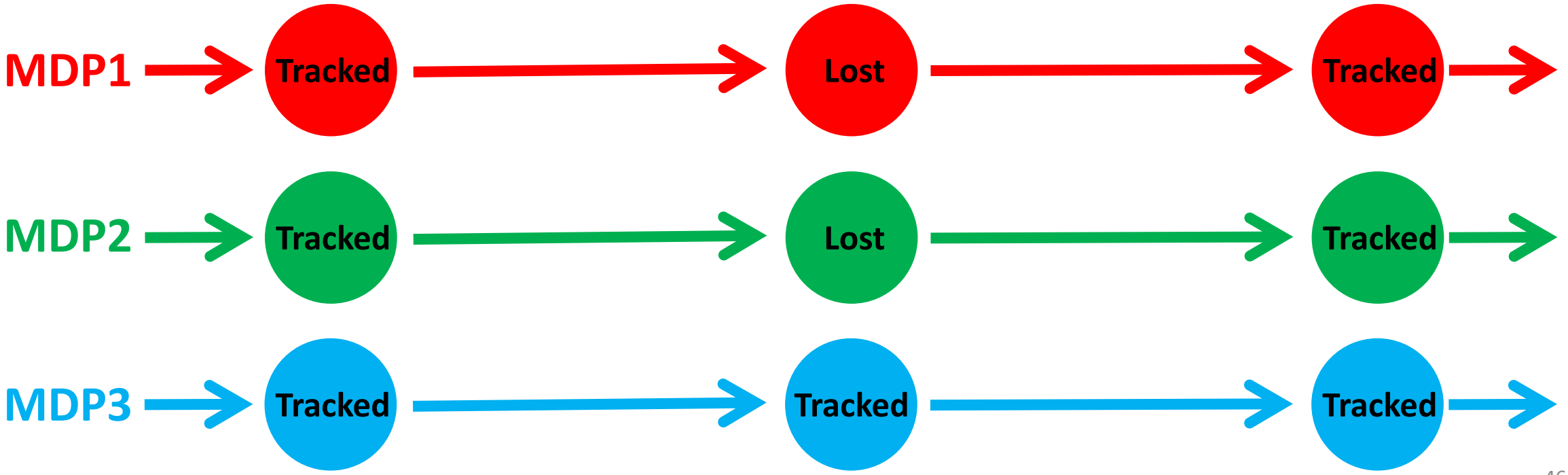


Step 3: Initialize new targets



Online Multi-Object Tracking with MDPs





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Experiments: Dataset

- Multiple Object Tracking Benchmark [1]
  - 11 training sequences
  - 11 test sequences
  - Object detections from the ACF detector [2]




[1] L. Leal-Taixé, A. Milan, I. Reid, S. Roth, and K. Schindler. MOTChallenge 2015: Towards a Benchmark for Multi-Target Tracking. arXiv:1504.01942 [cs], 2015.
[2] P. Dollár, R. Appel, S. Belongie, and P. Perona. Fast feature pyramids for object detection. TPAMI, 36(8):1532–1545, 2014.

Experiments: Analysis on Validation Set

- Contribution of different components

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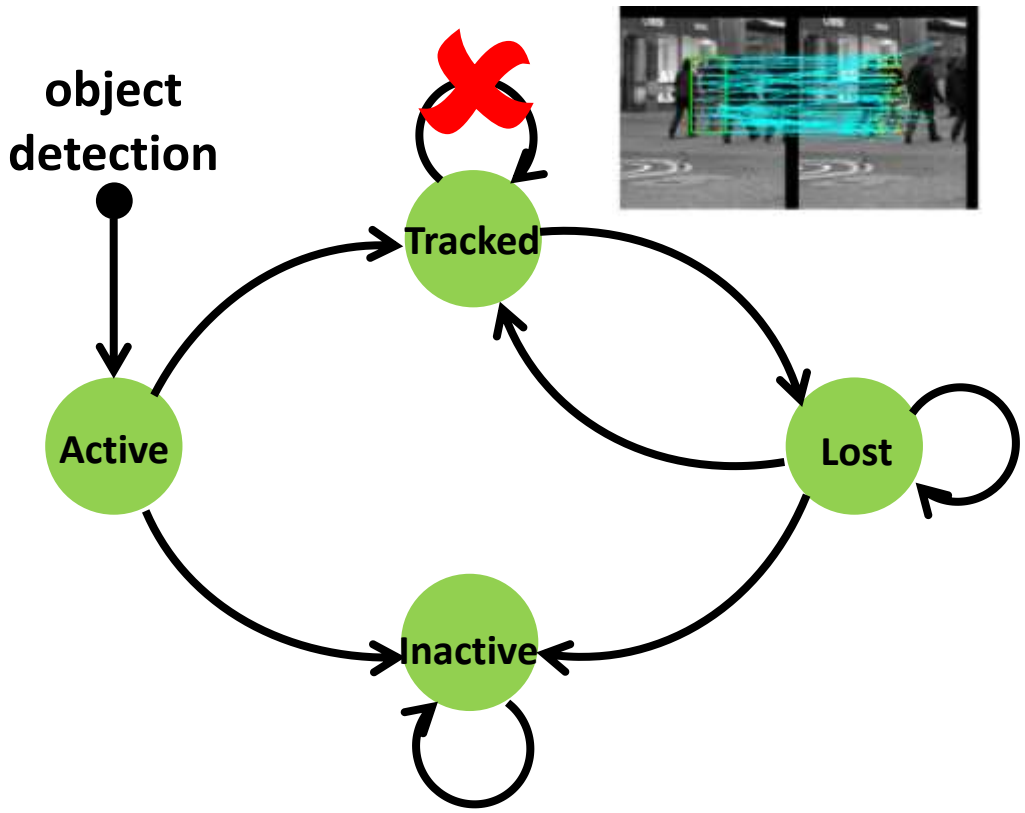
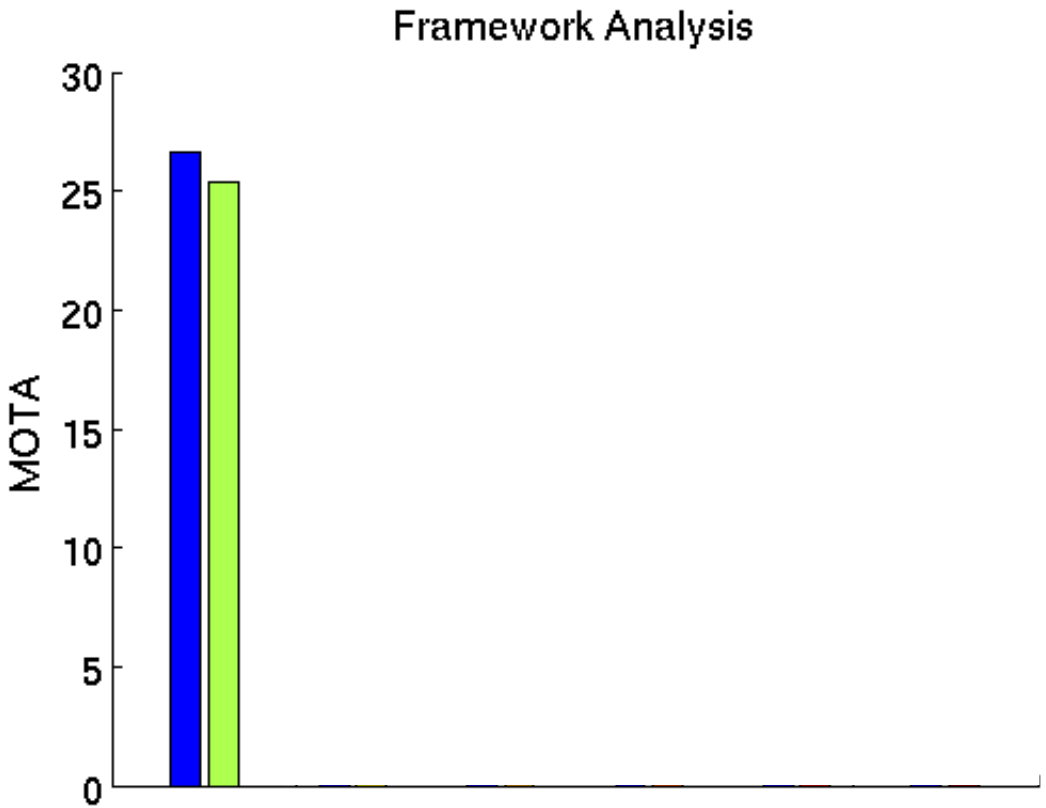
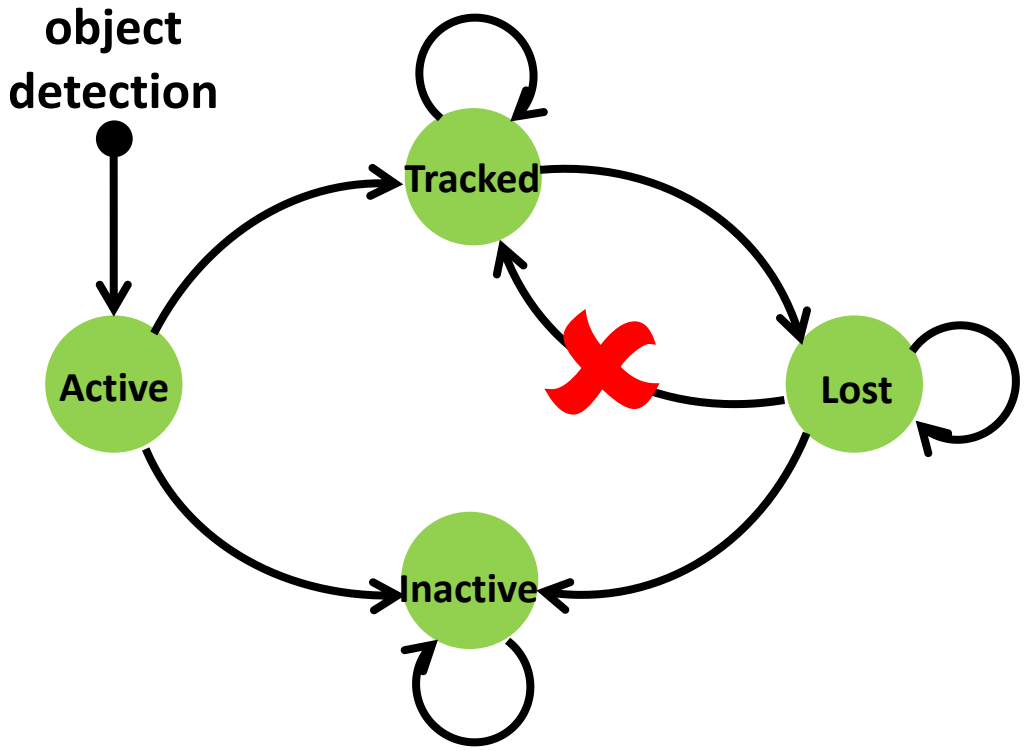


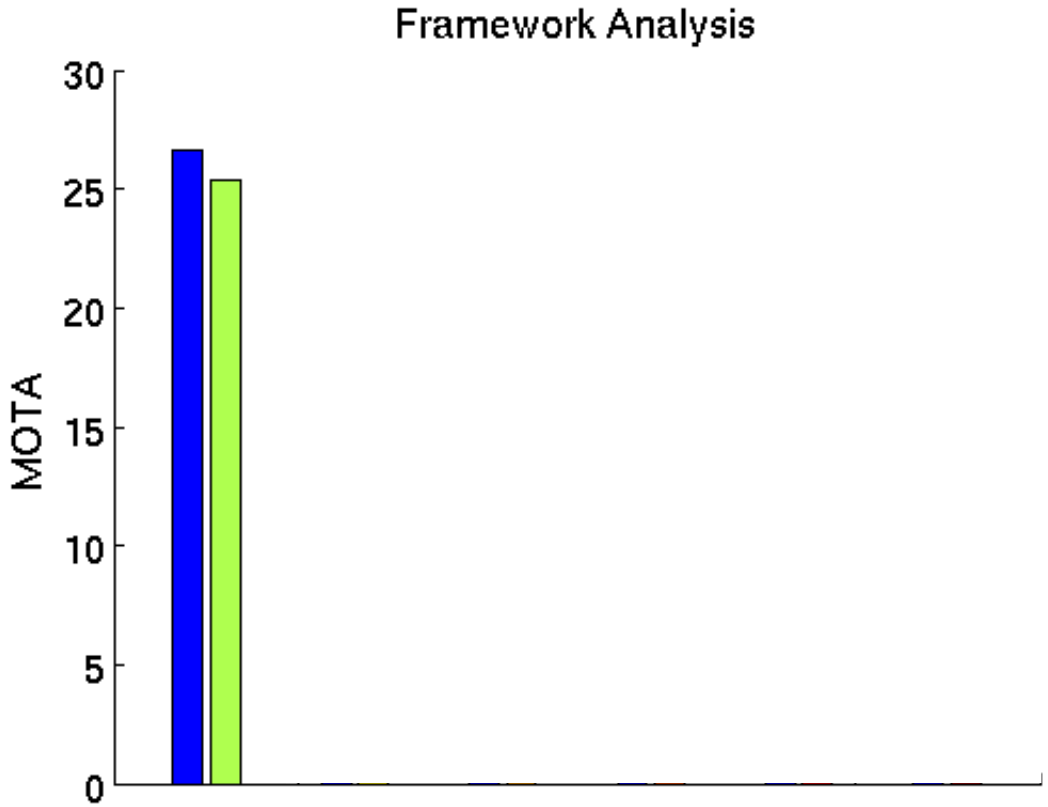


MOTA: multiple object tracking accuracy

Experiments: Analysis on Validation Set

- Contribution of different components





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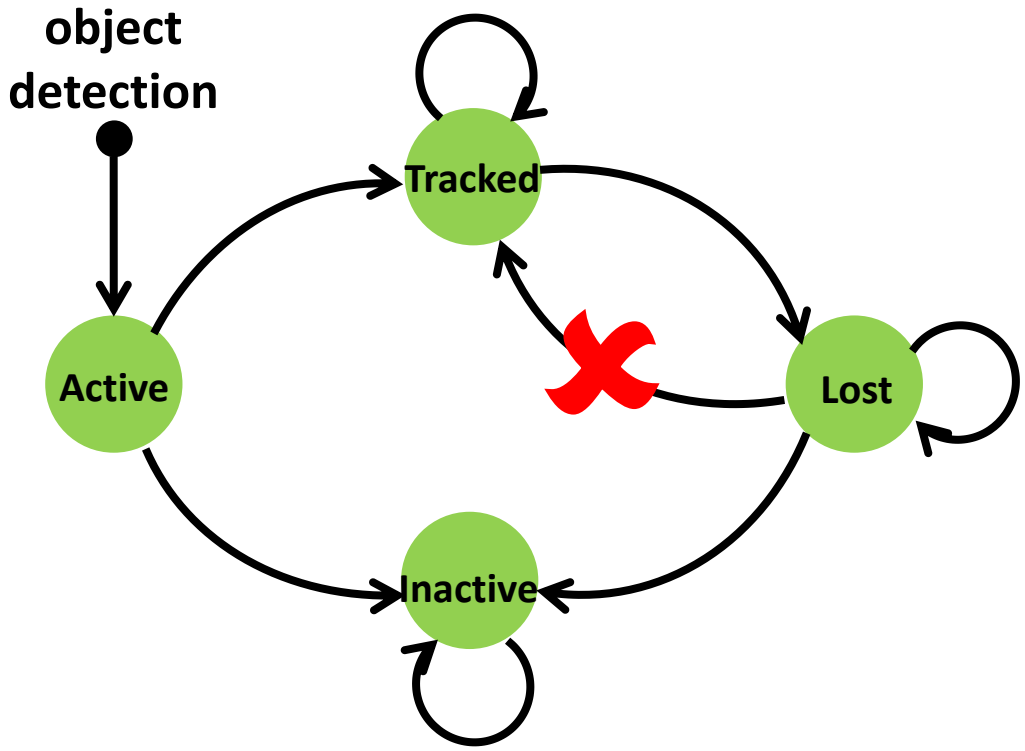

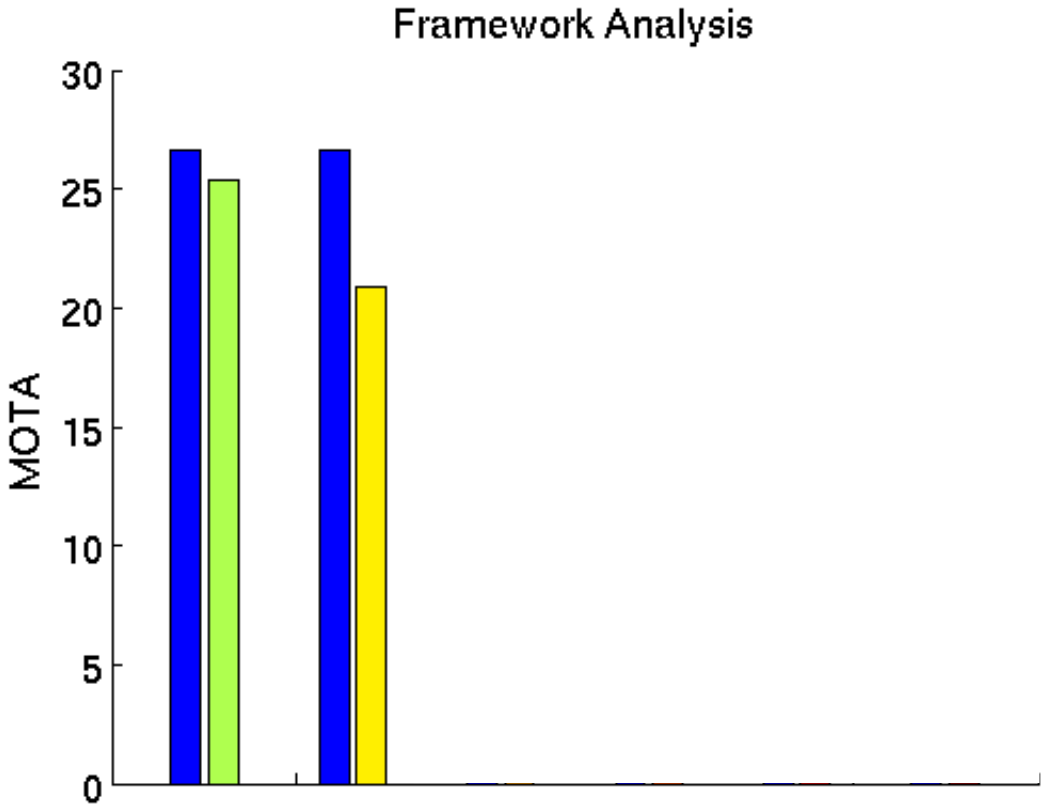

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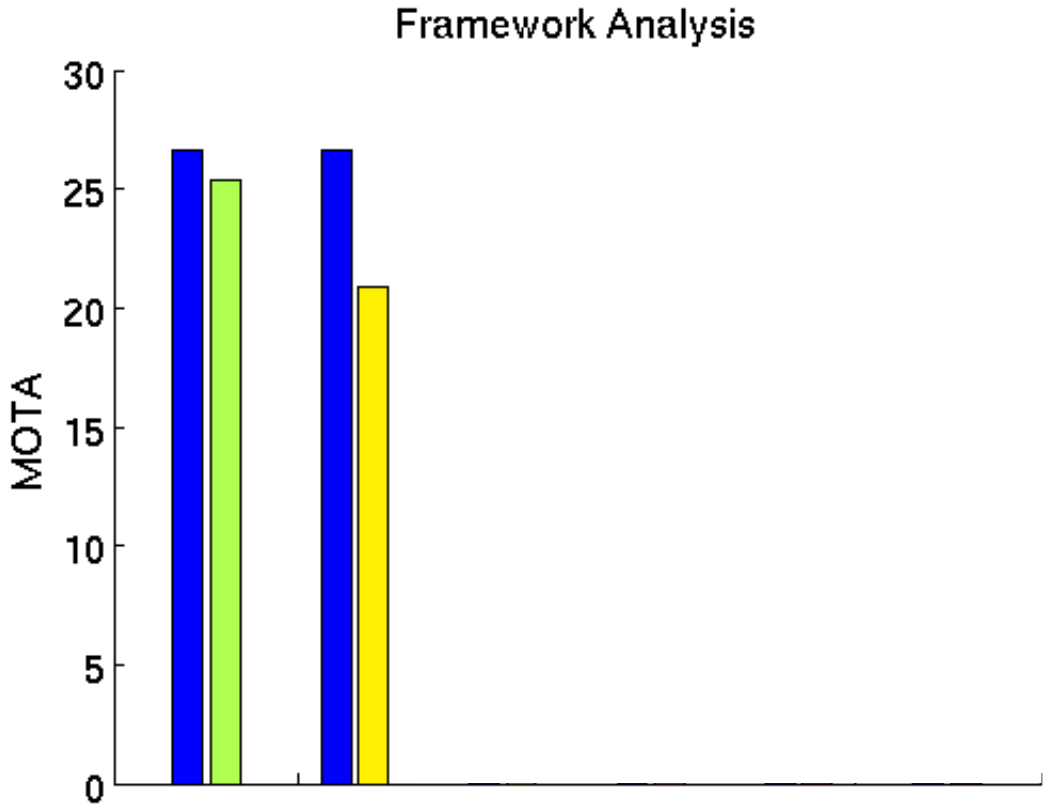
Experiments: Analysis on Validation Set

- Contribution of different components

$$\text{Similarity} = w_1\phi_1(\,,\,) + \cdots + w_n\phi_n(\,,\,) + b$$

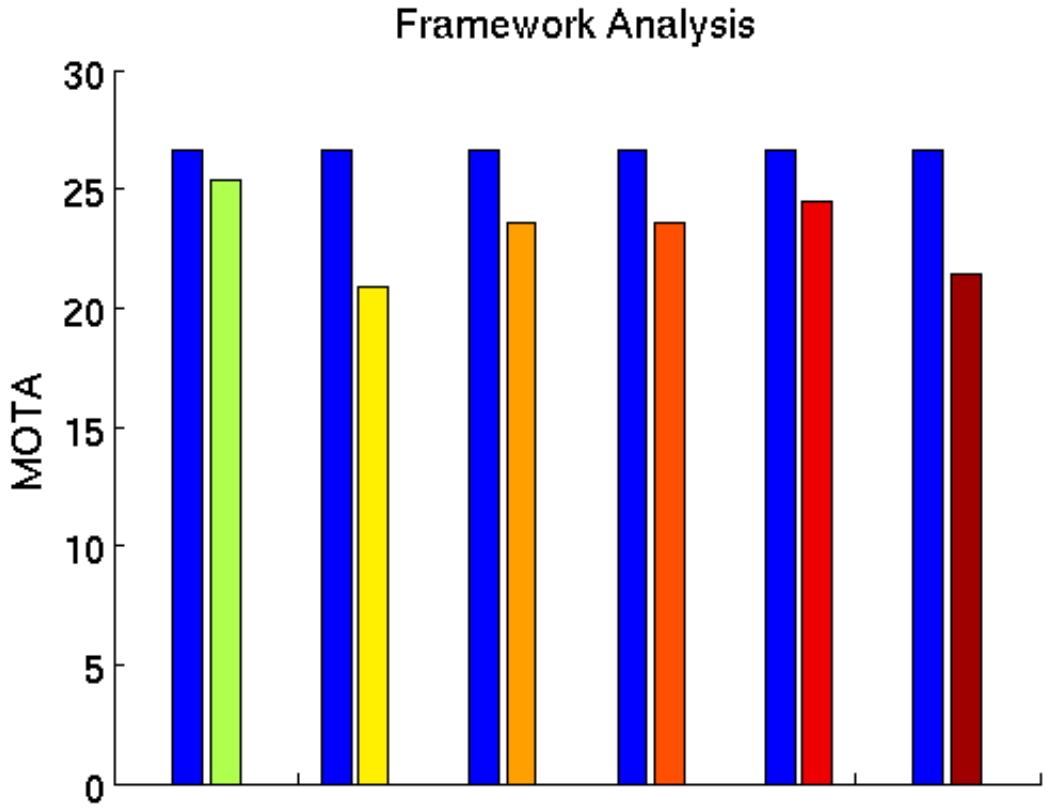


MOTA: multiple object tracking accuracy

Experiments: Analysis on Validation Set

- Contribution of different components

$$\text{Similarity} = w_1\phi_1(\,,\,) + \cdots + w_n\phi_n(\,,\,) + b$$

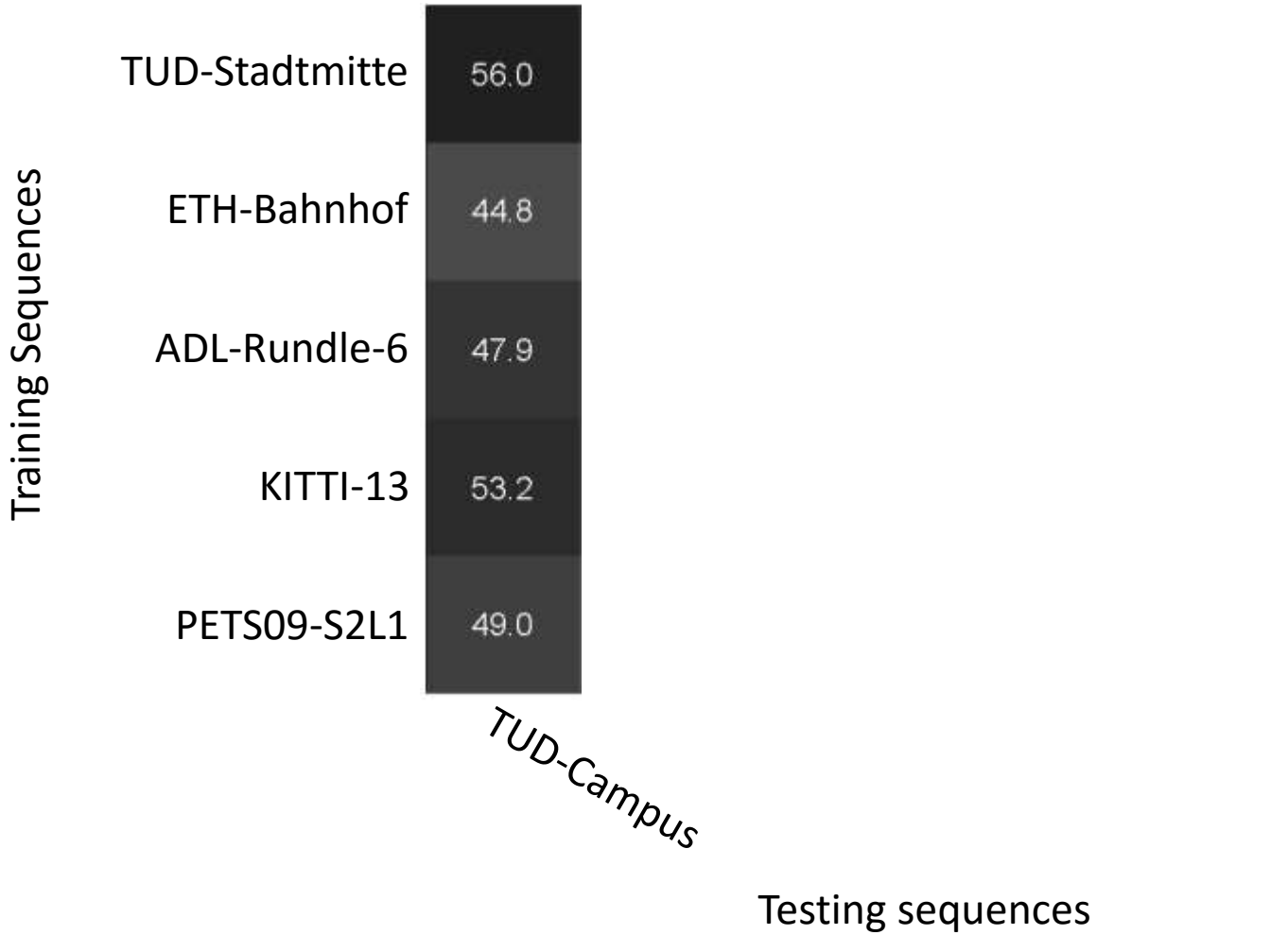


MOTA: multiple object tracking accuracy

Experiments: Analysis on Validation Set

- Cross-domain tracking

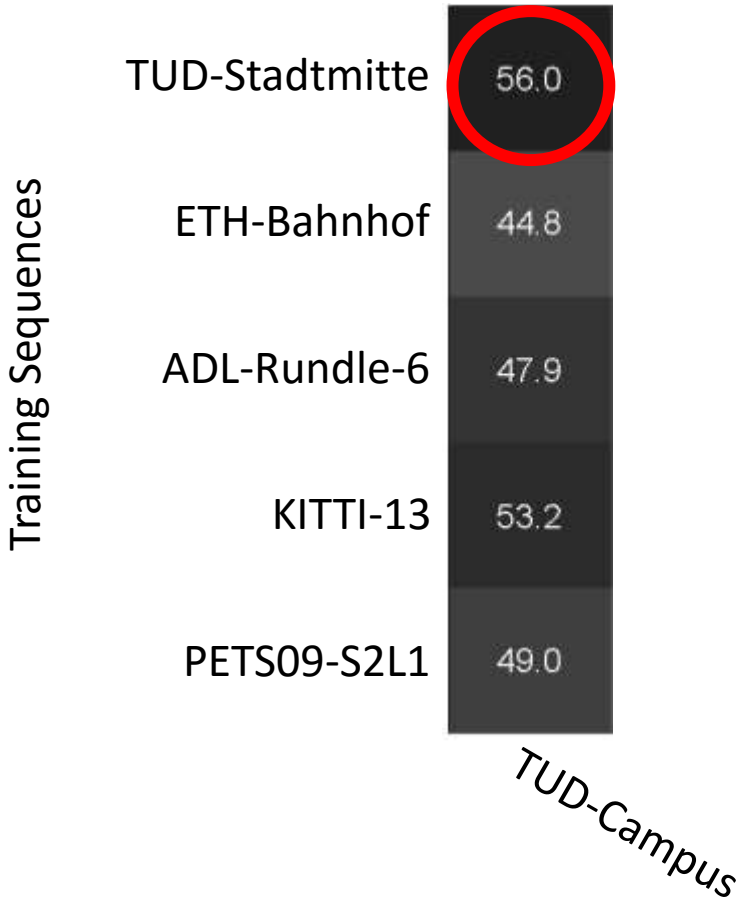
MOTA: multiple object tracking accuracy



Experiments: Analysis on Validation Set

- Cross-domain tracking

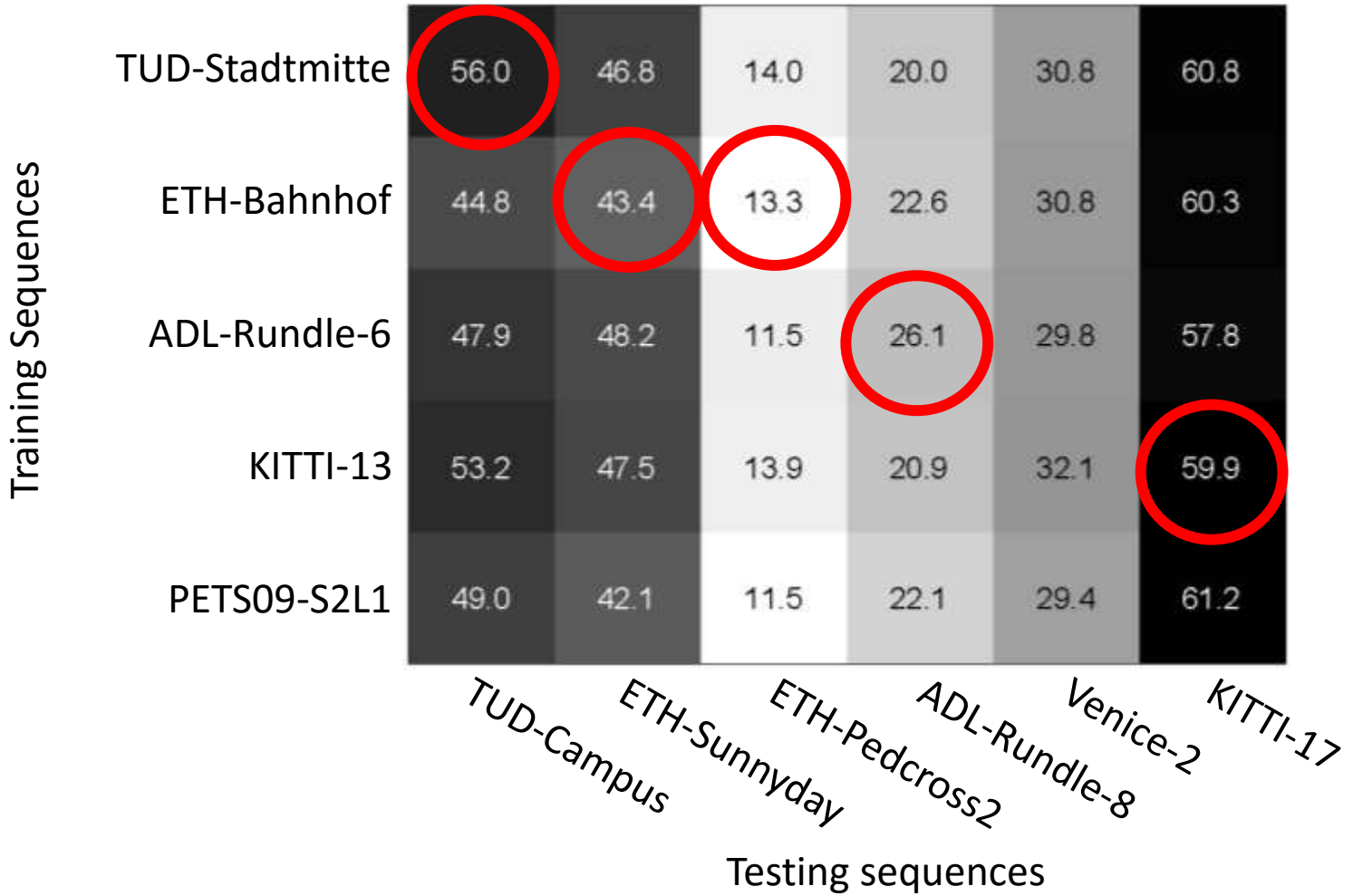
MOTA: multiple object tracking accuracy



Experiments: Analysis on Validation Set

- Cross-domain tracking

MOTA: multiple object tracking accuracy



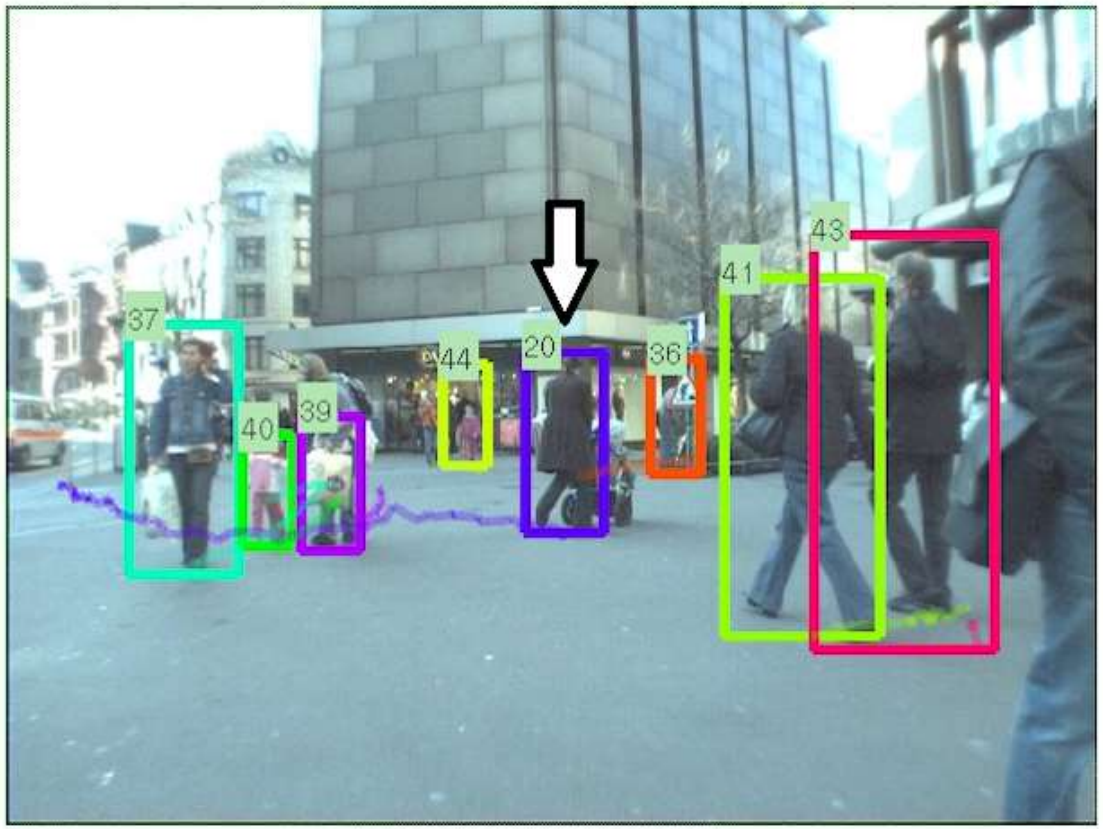
Experiments: Evaluation on Test Set

Tracker	Tracking	Learning	MOTA
DP_NMS [1]	Batch	N/A	14.5
TC_ODAL [2]	Online	Online	15.1
TBD [3]	Batch	Offline	15.9
SMOT [4]	Batch	N/A	18.2
RMOT [5]	Online	N/A	18.6
CEM [6]	Online	N/A	19.3
SegTrack [7]	Batch	Offline	22.5
MotiCon [8]	Batch	Offline	23.1
MDP (Ours)	Online	Online	**30.3**

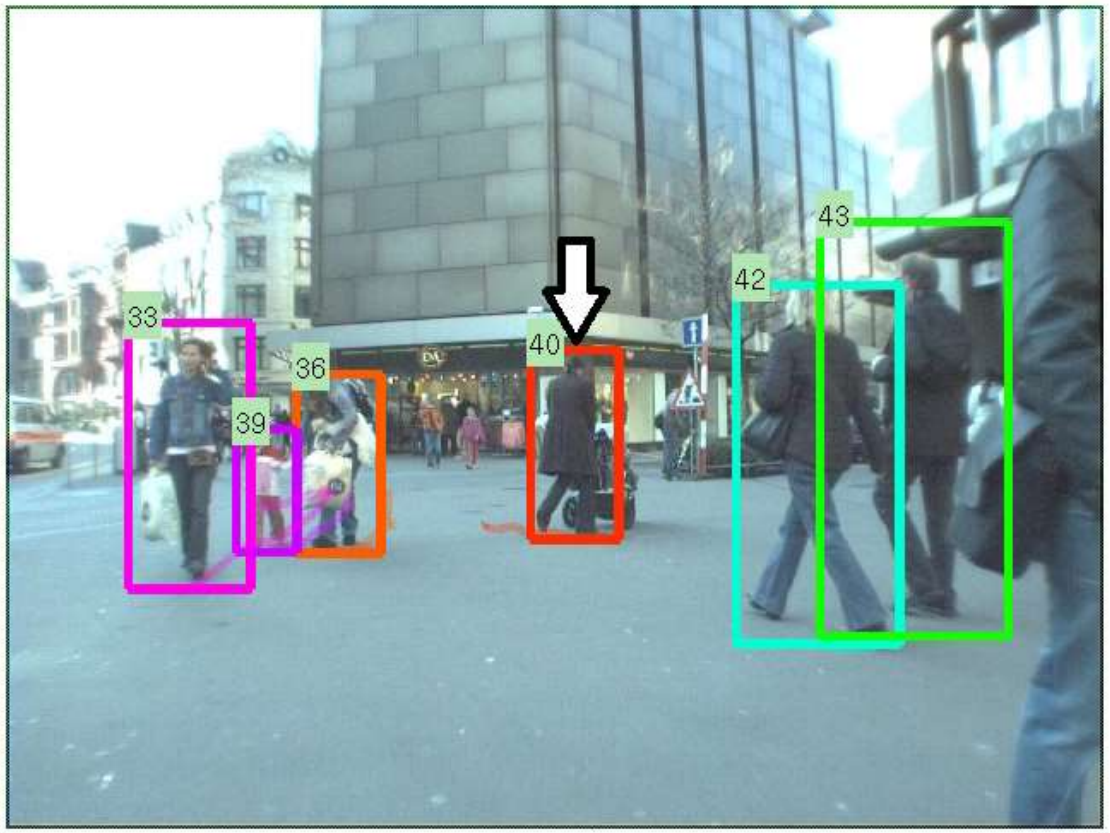
MOTA: multiple object tracking accuracy

[1] Pirsiavash et al., CVPR' 11
[2] Bae et al., CVPR'14
[3] Geiger et al., TPAMI'14
[4] Dicle et al., ICCV'13
[5] Yoon et al., WACV'15
[6] Milan et al., TPAMI'14
[7] Milan et al., CVPR'15
[8] Leal-Taixé et al., CVPR'14

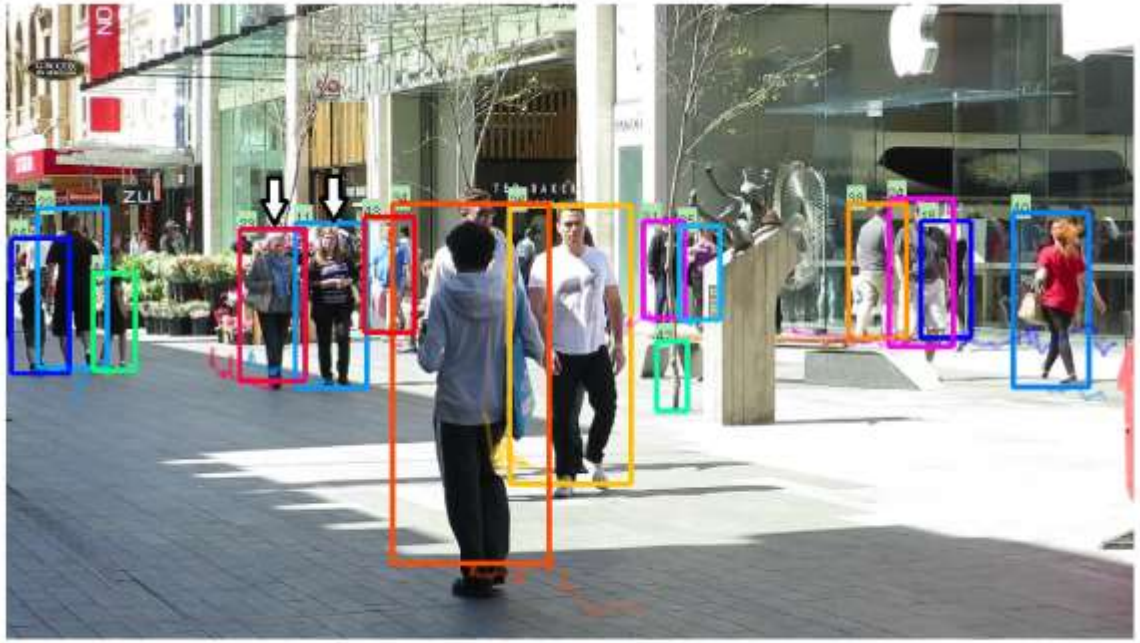
Tracking Results



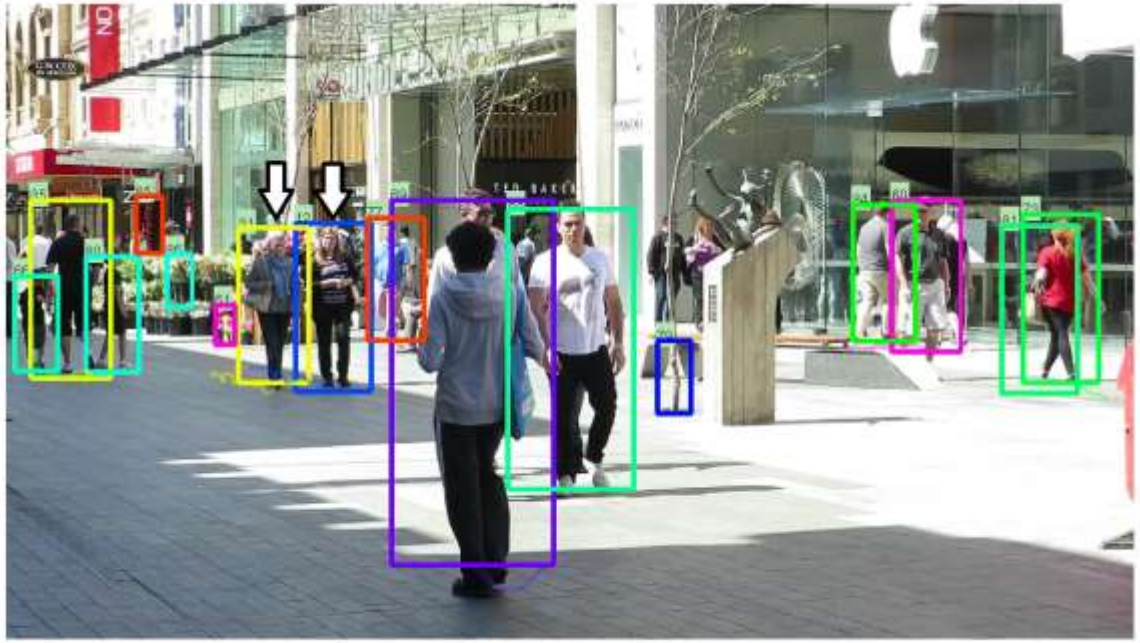
MDP [Ours]



MotiCon [Leal-Taixé et al., CVPR'14]



MDP [Ours]



MotiCon [Leal-Taixé et al., CVPR'14]

MDP [Ours]

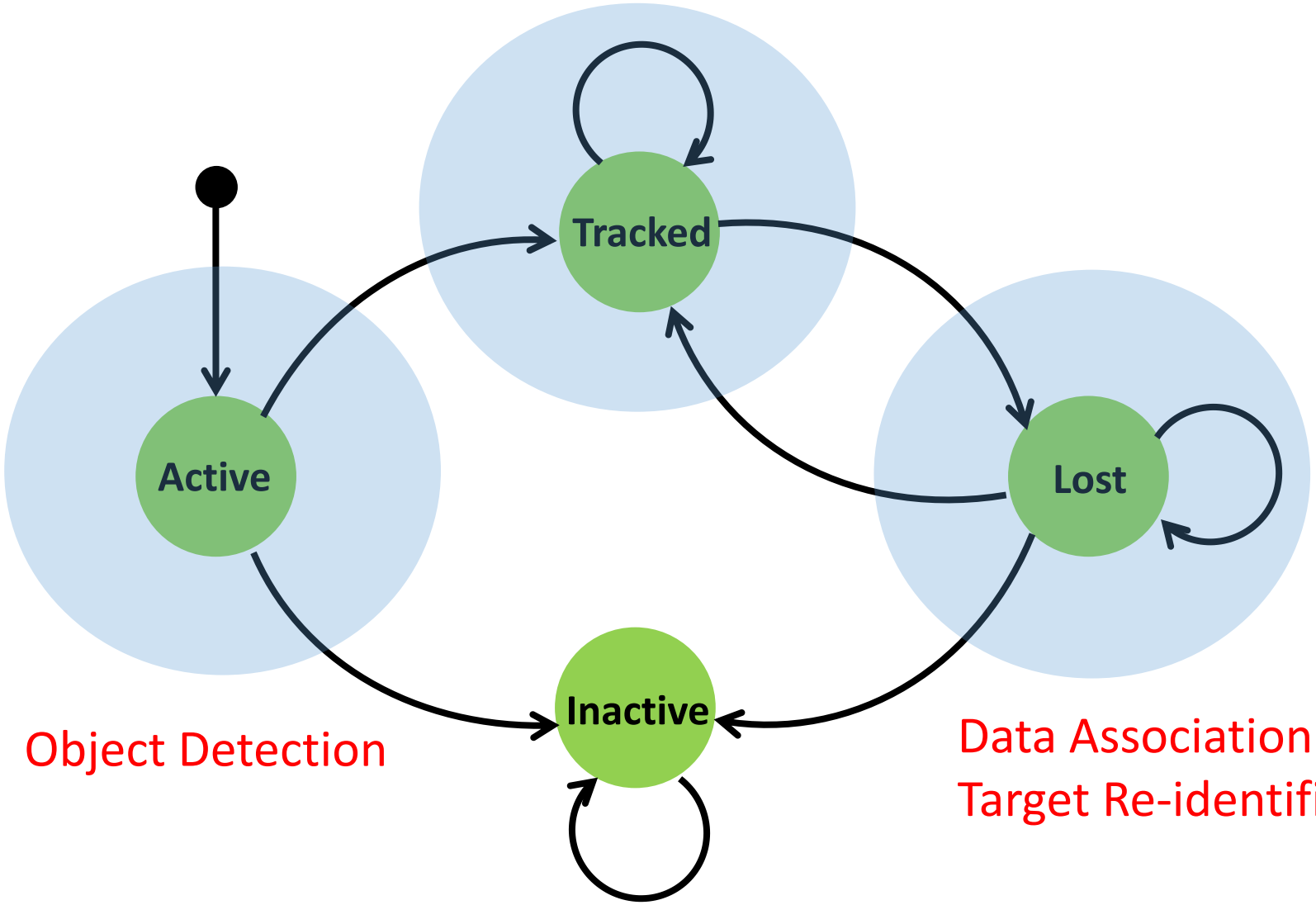
MotiCon [Leal-Taixé et al., CVPR'14]

Outline

- Markov Decision Process (MDP) for a Single Target
- Online Multi-Object Tracking with MDPs
- Experiments
- Conclusion

Conclusion

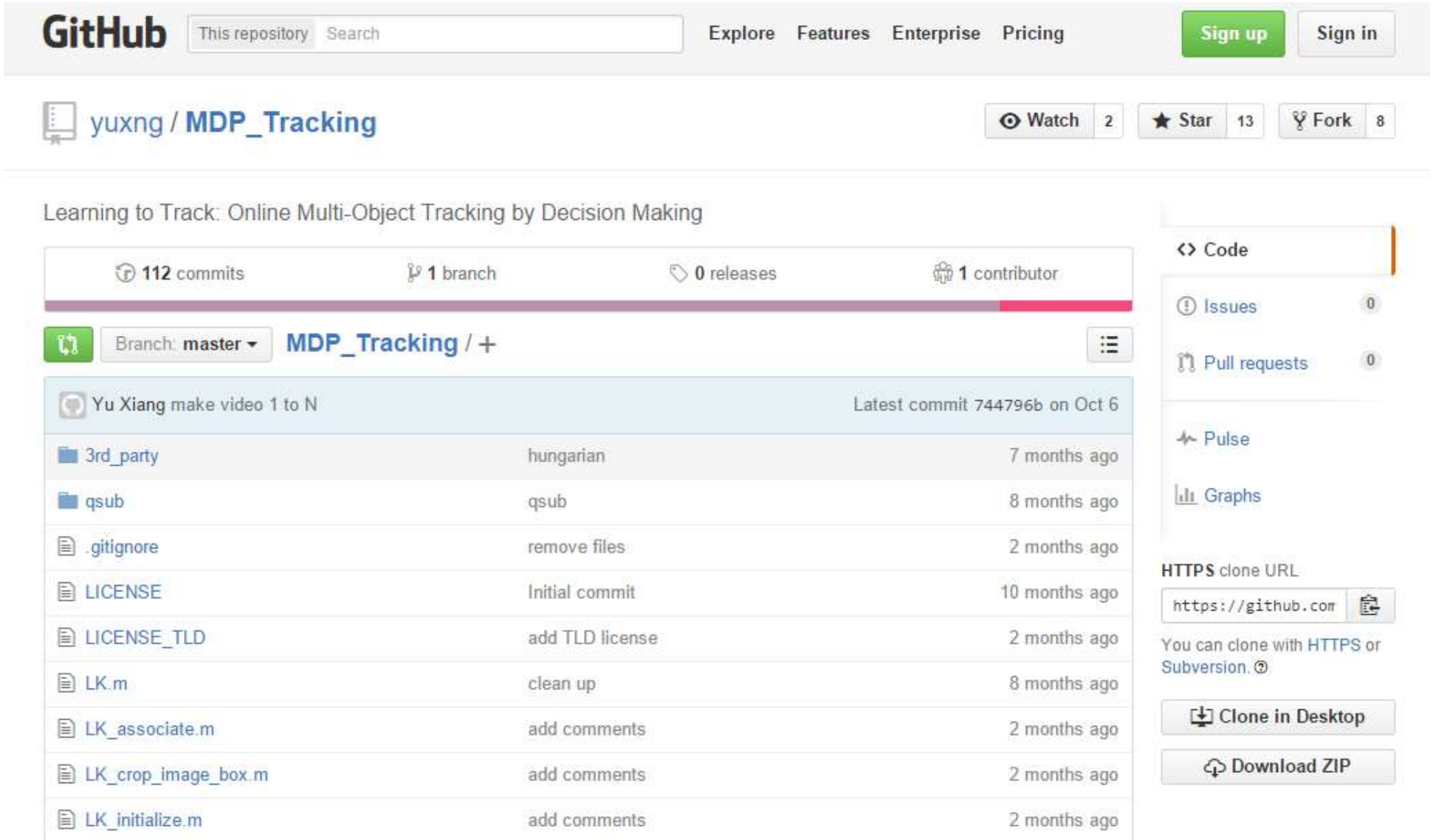
Single Object Tracking



Object Detection

Data Association
Target Re-identification

Code


GitHub
This repository
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Explore
Features
Enterprise
Pricing
Sign up
Sign in
yuxng / MDP_Tracking
Watch 2
Star 13
Fork 8
Learning to Track: Online Multi-Object Tracking by Decision Making
112 commits
1 branch
0 releases
1 contributor
Branch: master
MDP_Tracking / +
Yu Xiang make video 1 to N
Latest commit 744796b on Oct 6
3rd_party hungarian 7 months ago
qsub qsub 8 months ago
.gitignore remove files 2 months ago
LICENSE Initial commit 10 months ago
LICENSE_TLD add TLD license 2 months ago
LK.m clean up 8 months ago
LK_associate.m add comments 2 months ago
LK_crop_image_box.m add comments 2 months ago
LK_initialize.m add comments 2 months ago
Code
Issues 0
Pull requests 0
Pulse
Graphs
HTTPS clone URL
https://github.com
You can clone with HTTPS or Subversion.
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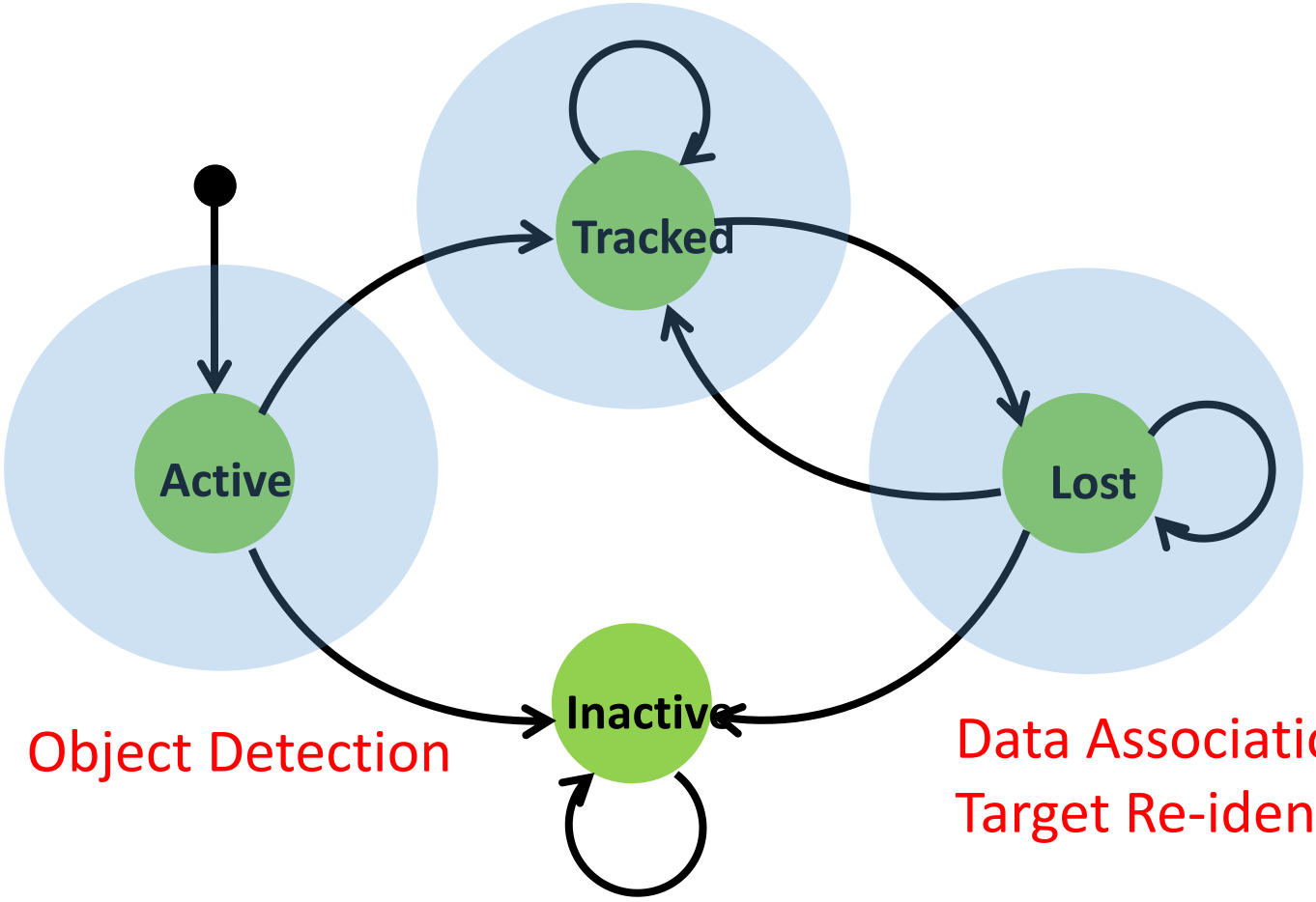
Single Object Tracking



Object Detection

Data Association
Target Re-identification

Thank you!