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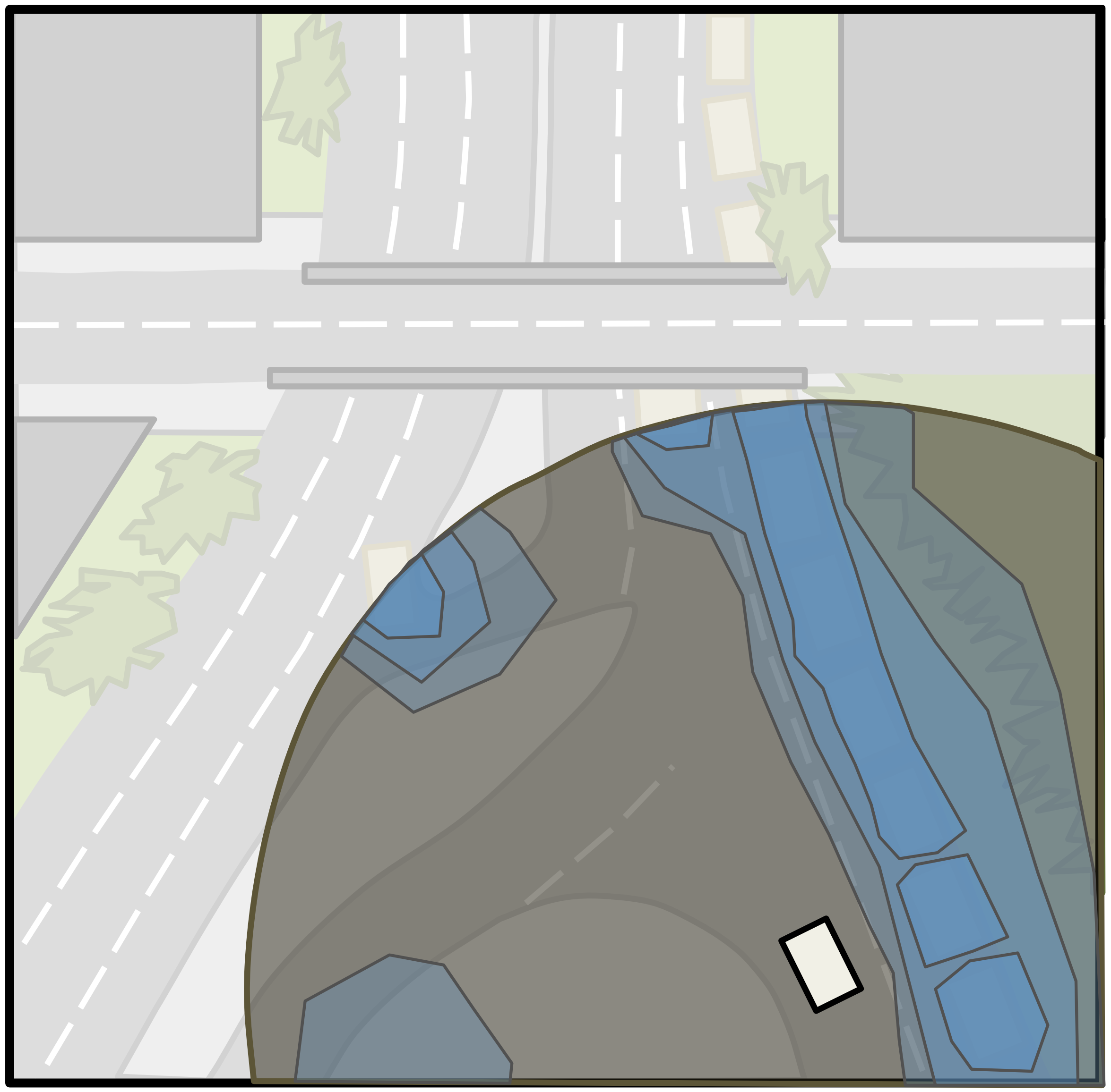
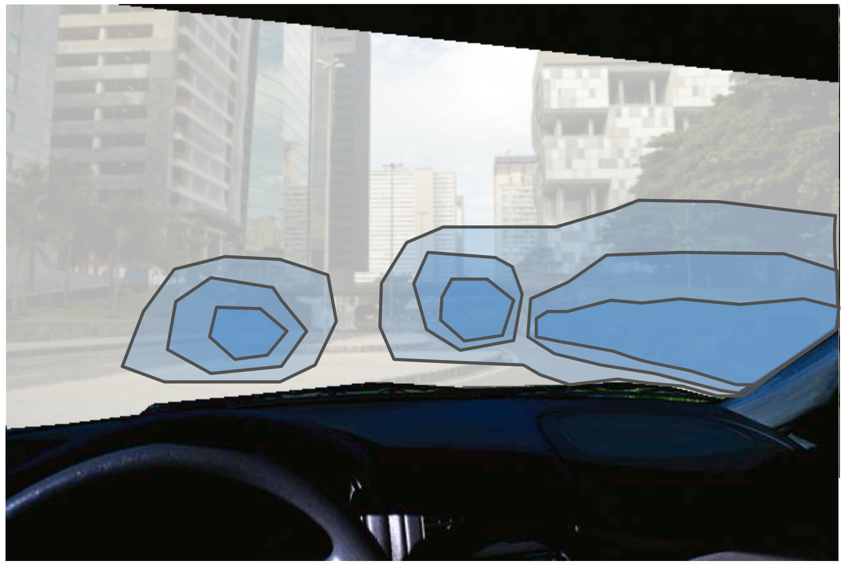
Robust Multi-Target Tracking in Outdoor Traffic Scenarios via Persistence Topology based Robust Motion Segmentation

Somrita Chattopadhyay, **Qian Ge**, Chunpeng Wei, Edgar Lobaton

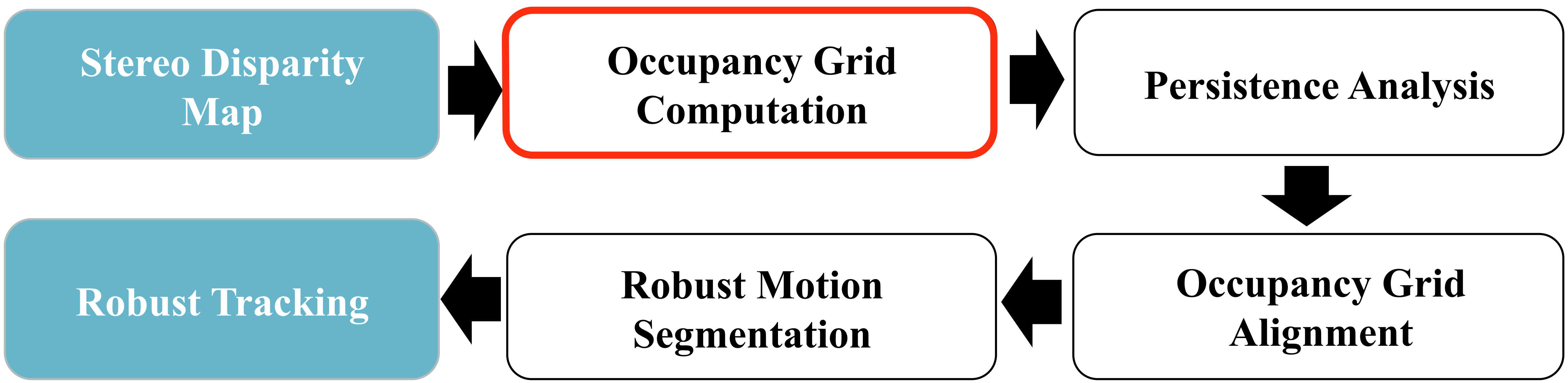
Electrical and Computer Engineering Department
North Carolina State University

Vision system for self-driving car



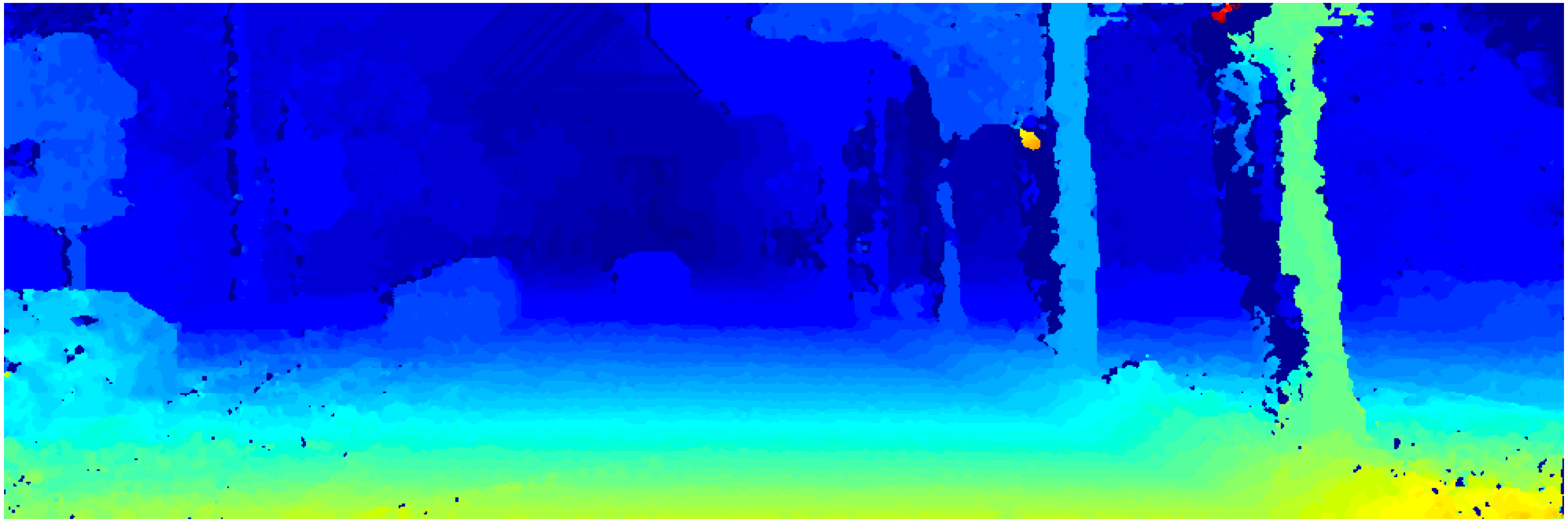


Pipeline


Stereo Disparity Map
Occupancy Grid Computation
Persistence Analysis
Occupancy Grid Alignment
Robust Motion Segmentation
Robust Tracking

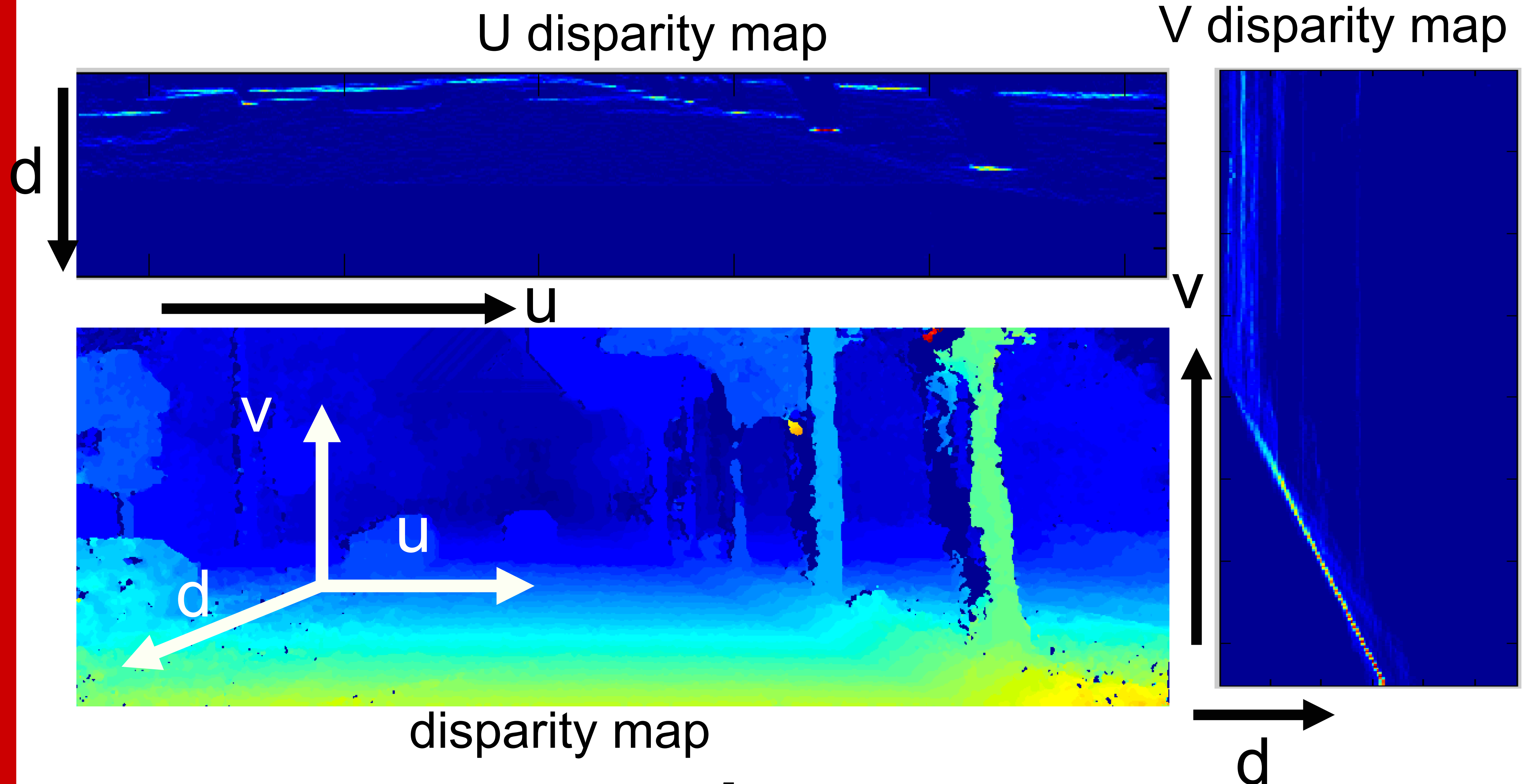
Stereo Disparity Map

- We Use Semi Global Block Matching (SGBM) to compute the disparity map. Higher value means closer to the camera.



Stereo Disparity Map

- UV disparity map



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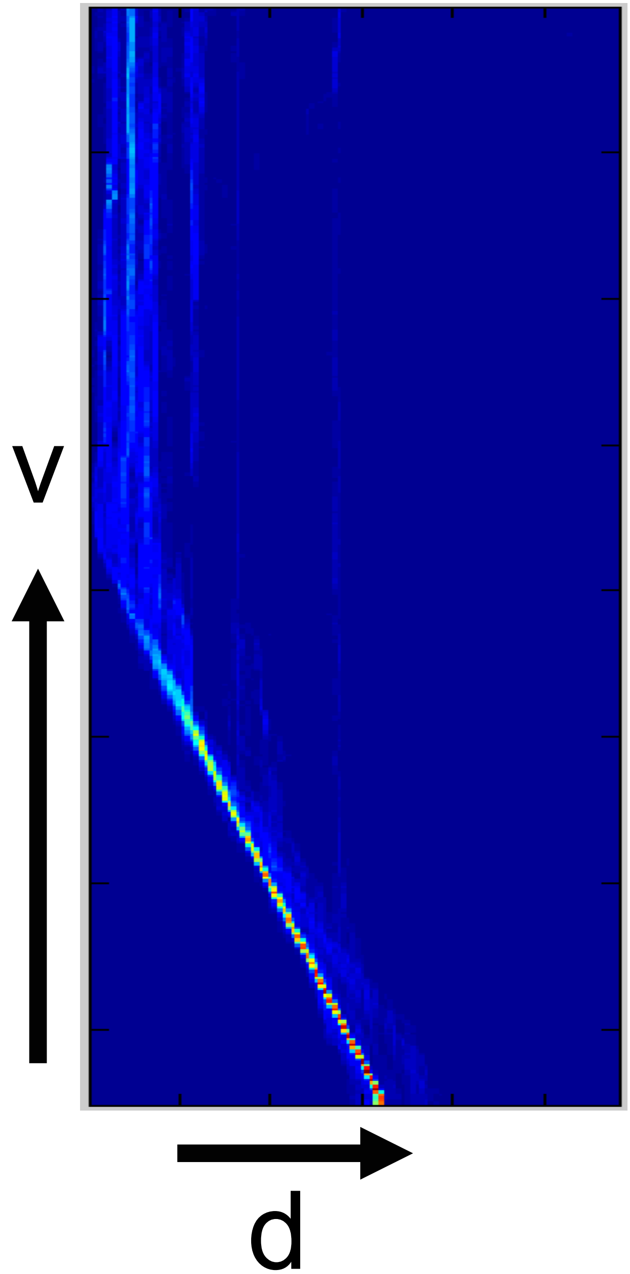
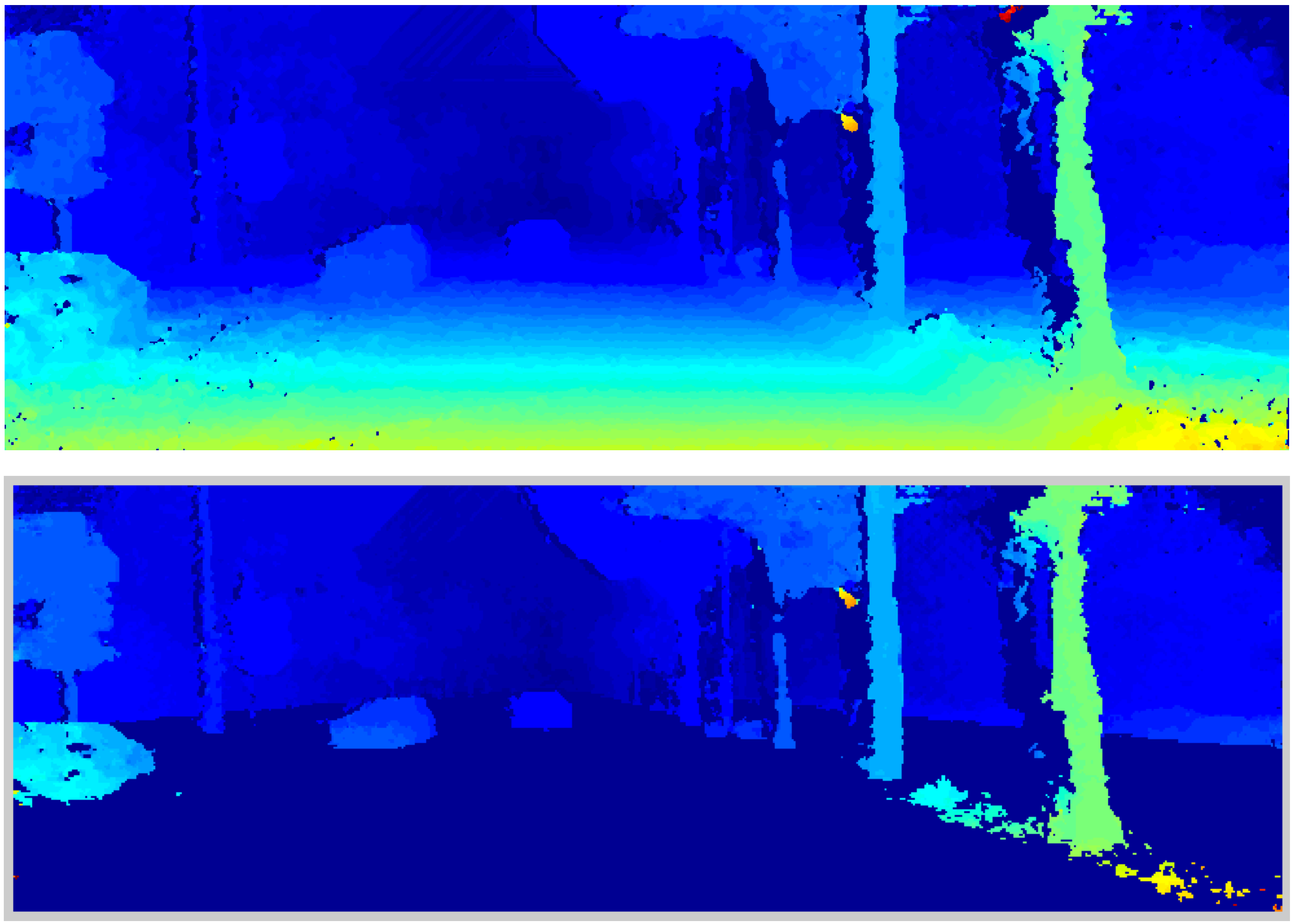
Ground Segmentation

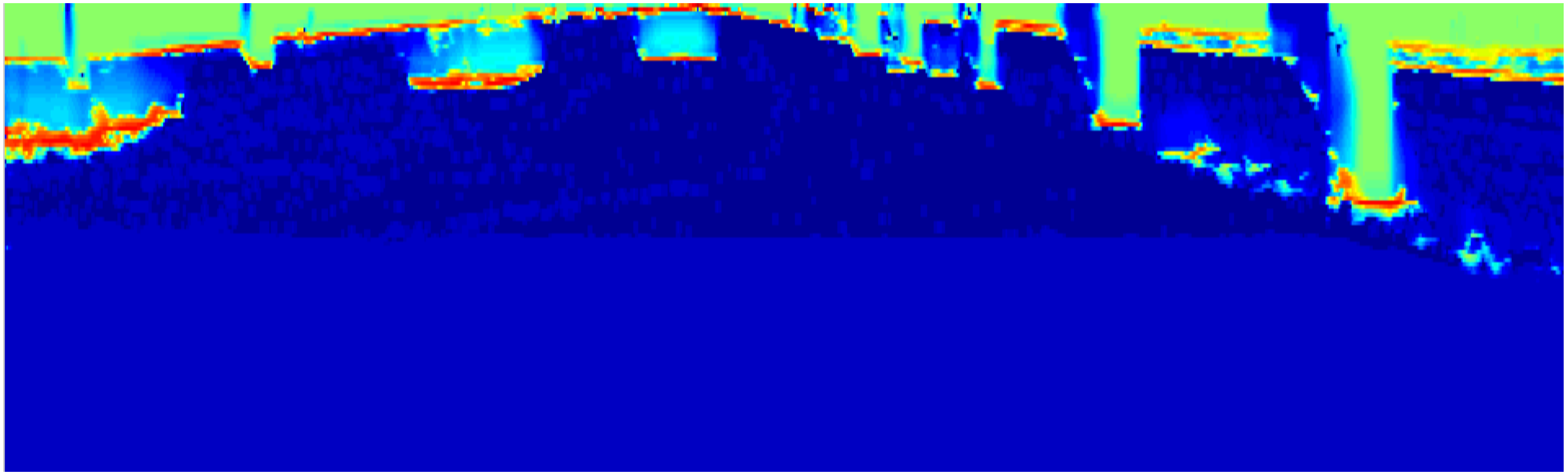
- Fit a line or plane in V-diaprity map.

V disparity map



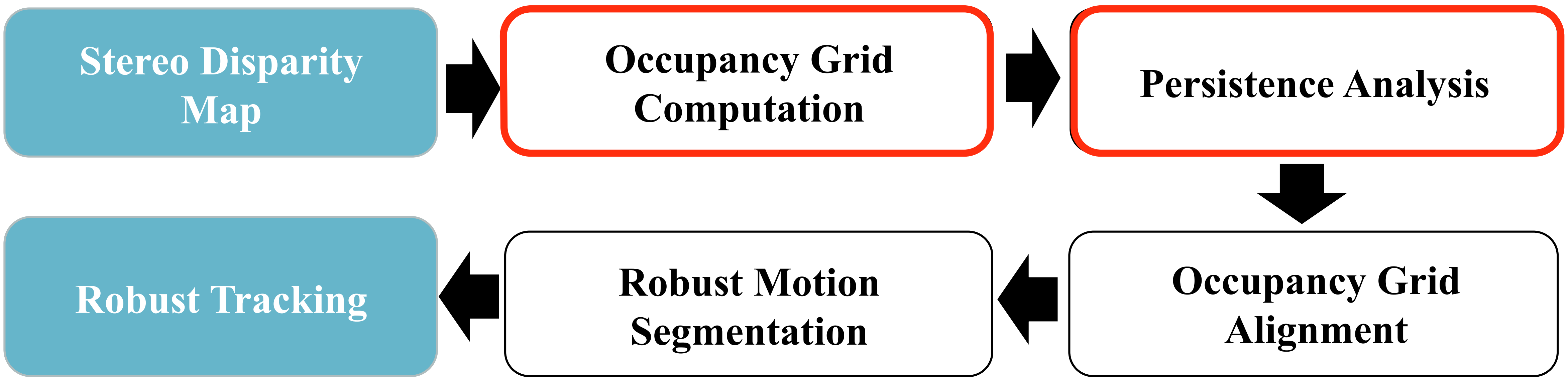


Occupancy Grid Computation



M. Perrollaz, J.-D. Yoder, A. Ne`gre, A. Spalanzani, and C. Laugier, “A visibility-based approach for occupancy grid computation in disparity space,” *Intelligent Transportation Systems, IEEE Transactions on*, vol. 13, no. 3, pp. 1383–1393, 2012

Pipeline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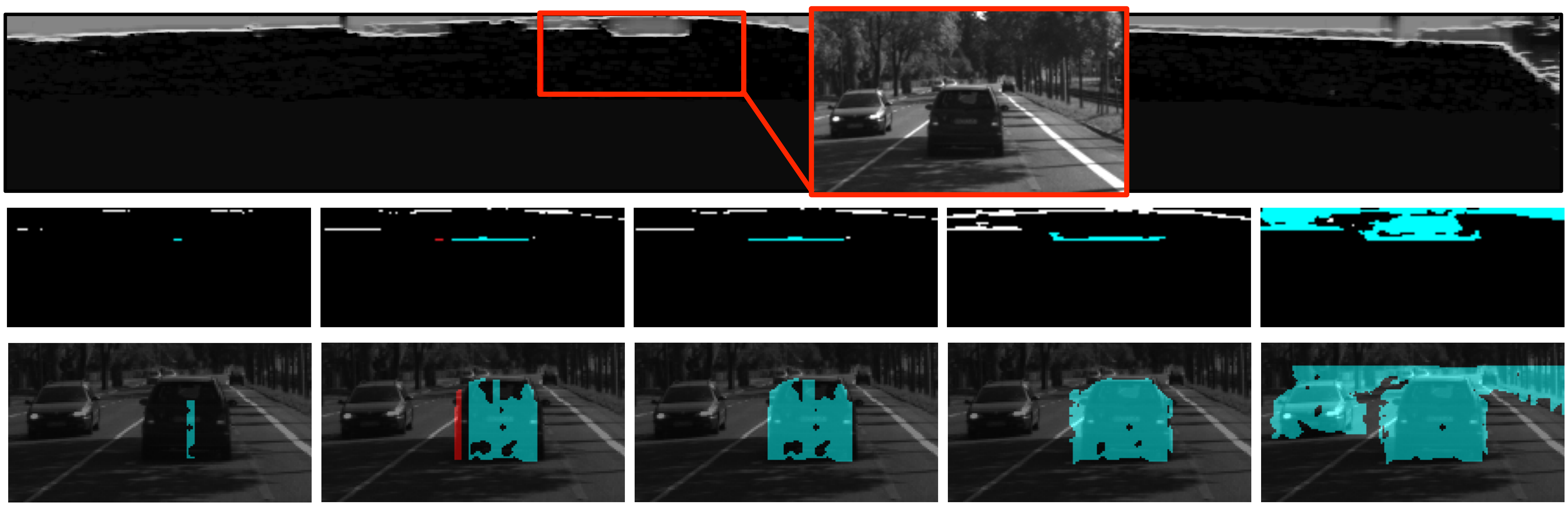
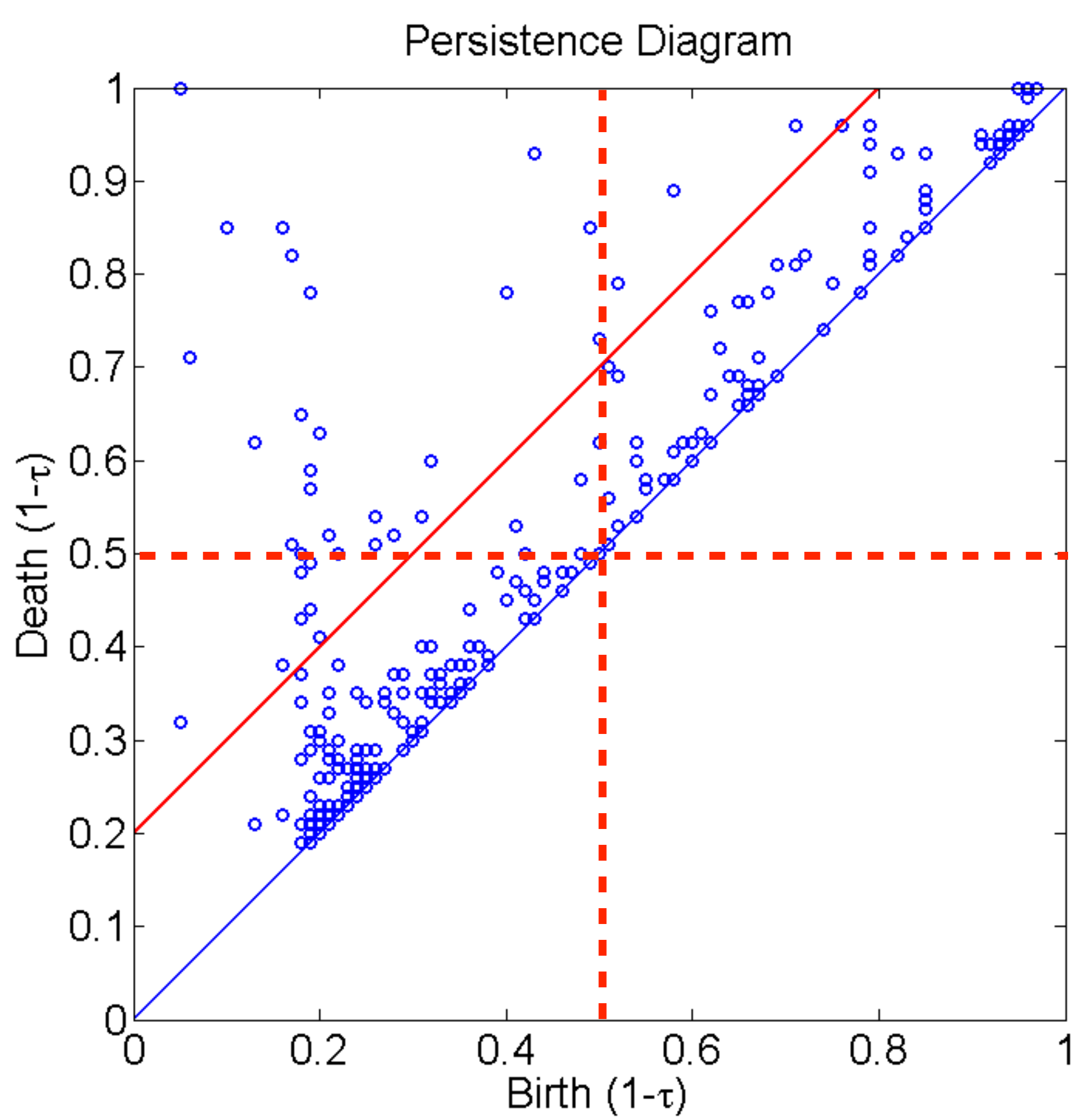
Topological Persistence

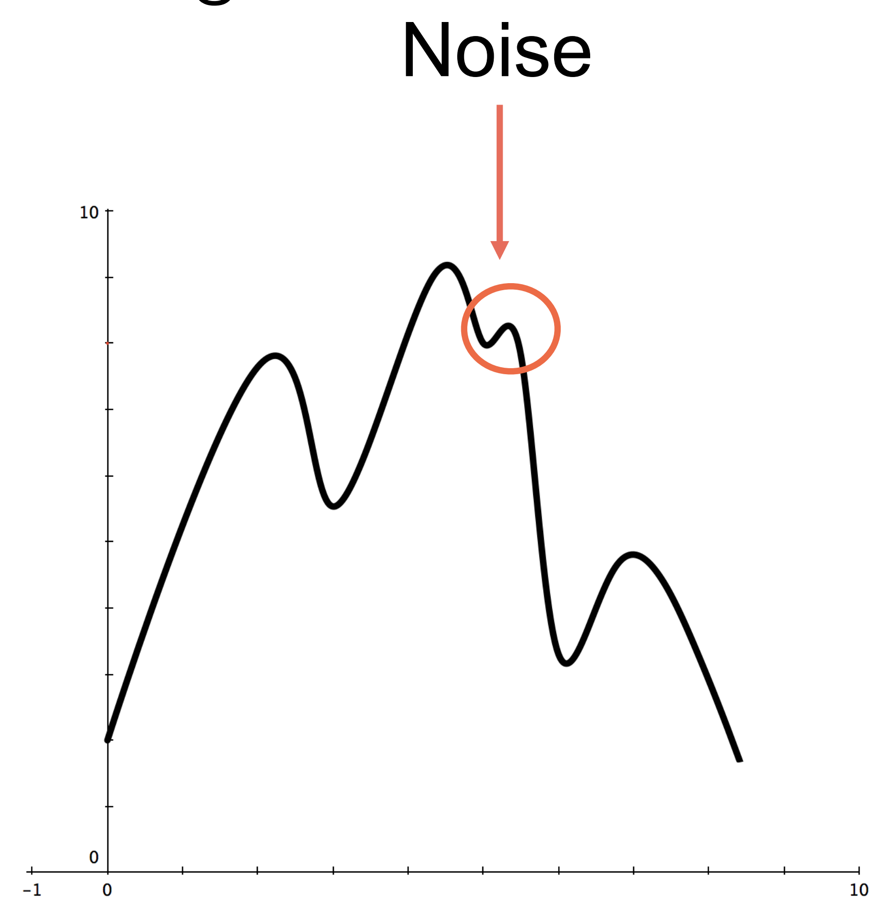


τ = 0.2 τ = 0.24 τ = 0.25 τ = 0.49 τ = 0.64

Persistence Diagram

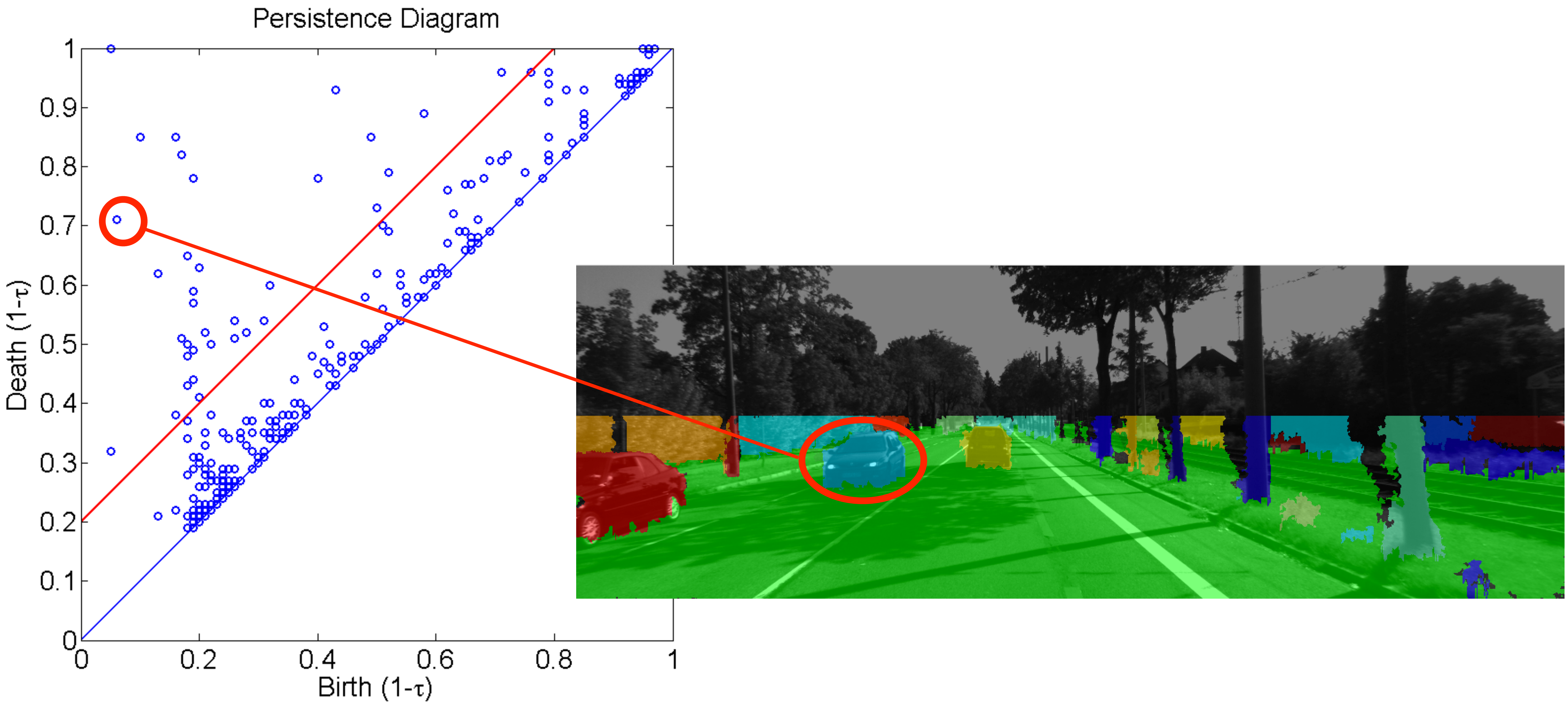
- Apply a threshold to persistence diagram to avoid noise





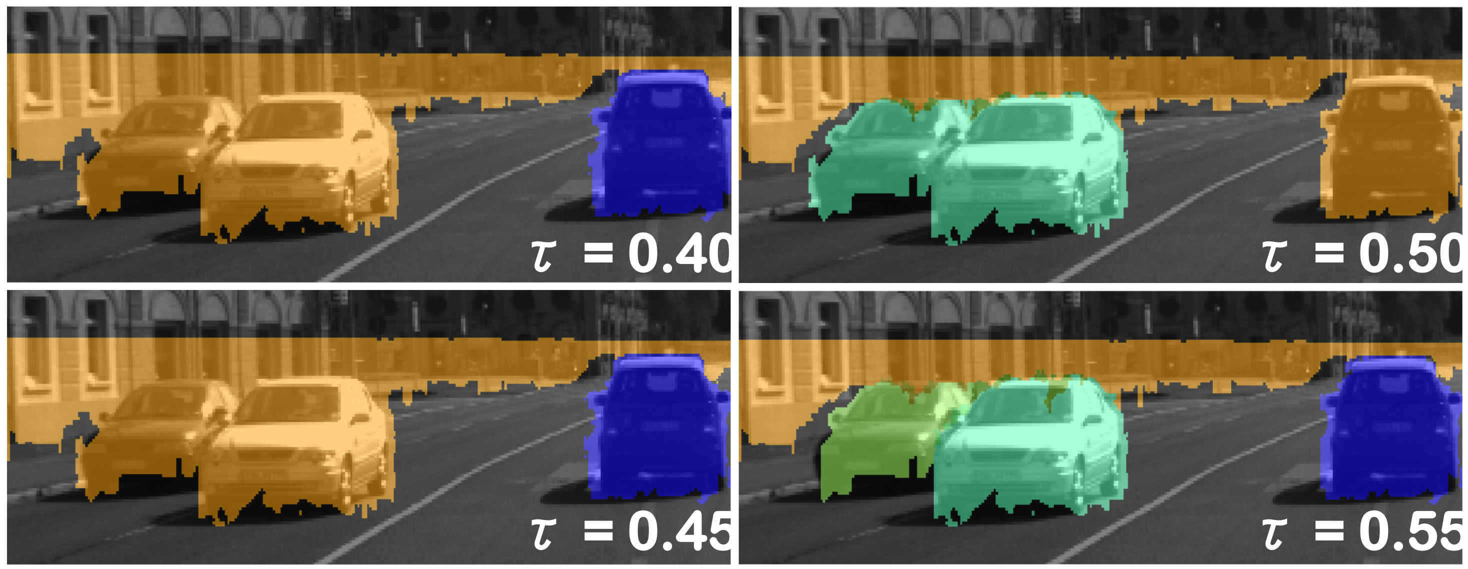
Persistence Diagram

- Regions with high enough persistence are the result regions.

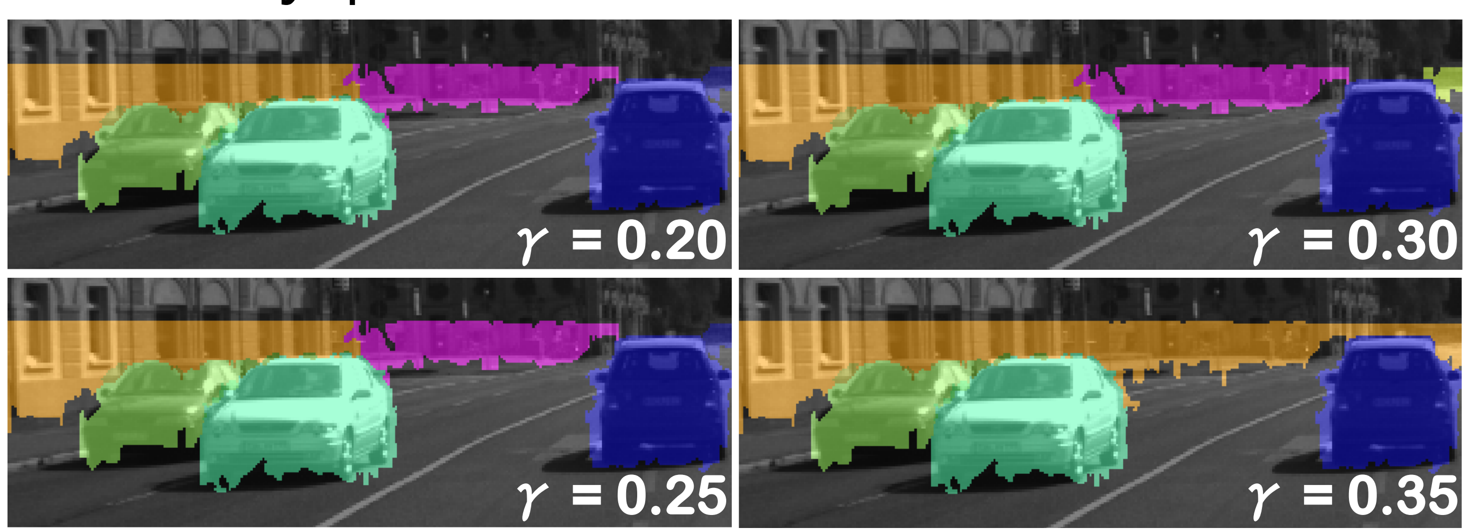


Robust Segmentation

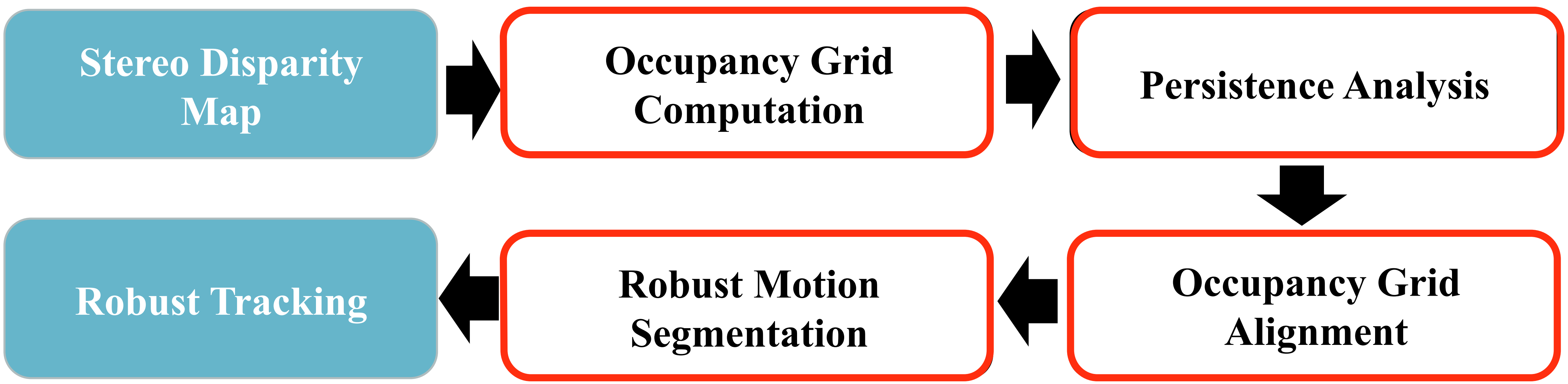
- Segmentation by threshold method



- Segmentation by persistence method



Pipeline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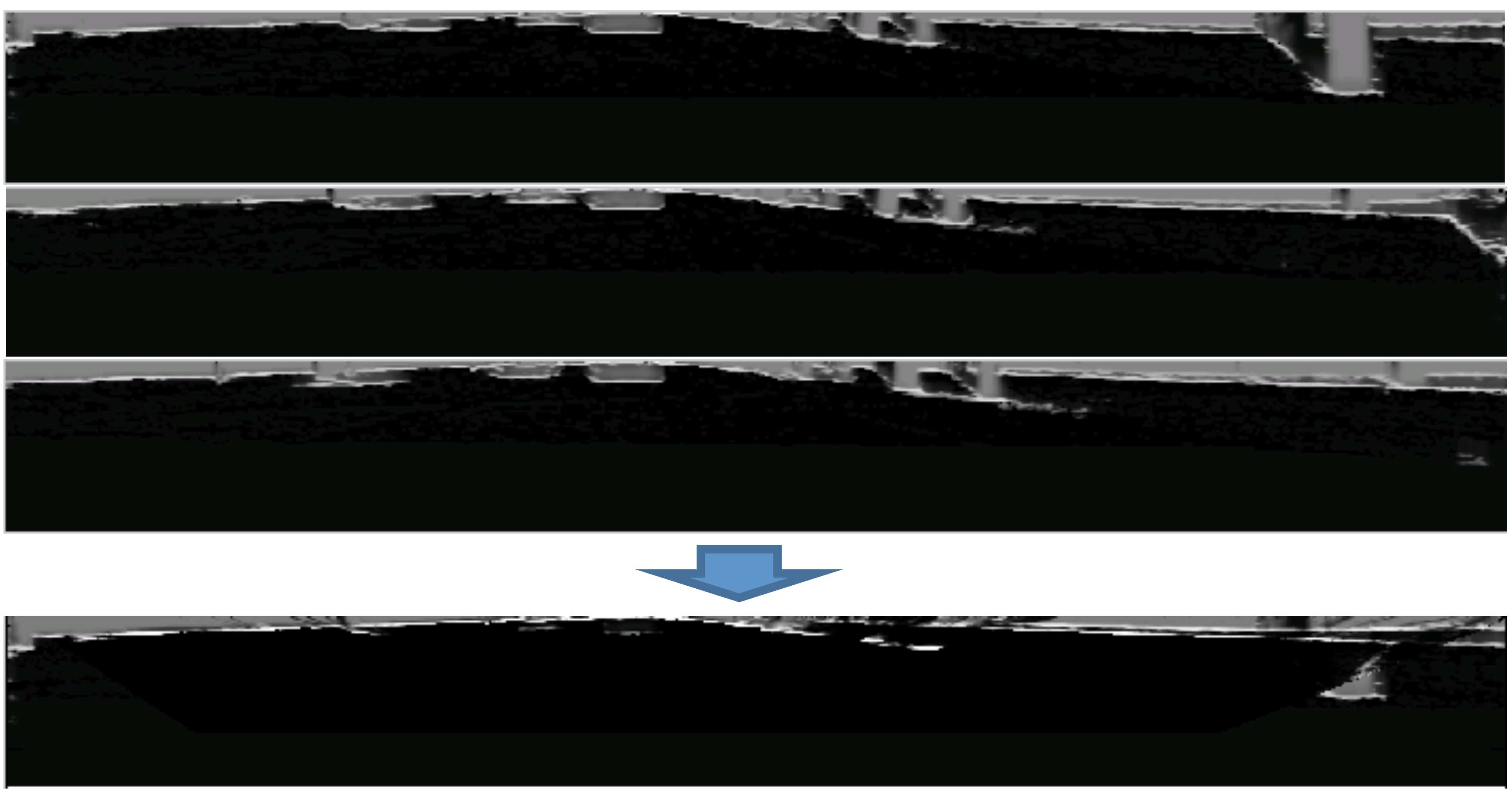
Occupancy Grid Alignment

- Compute the rotation (R) and translation (T) motion between successive images using SIFT
- Use the homograph information to accumulate the occupancy map by a Bayesian filter approach



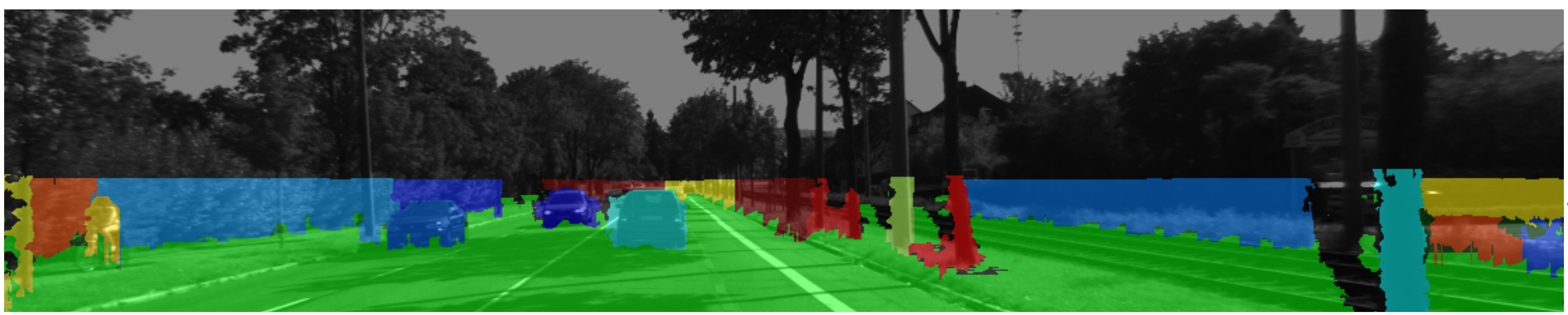
Three successive occupancy maps

Accumulate occupancy map

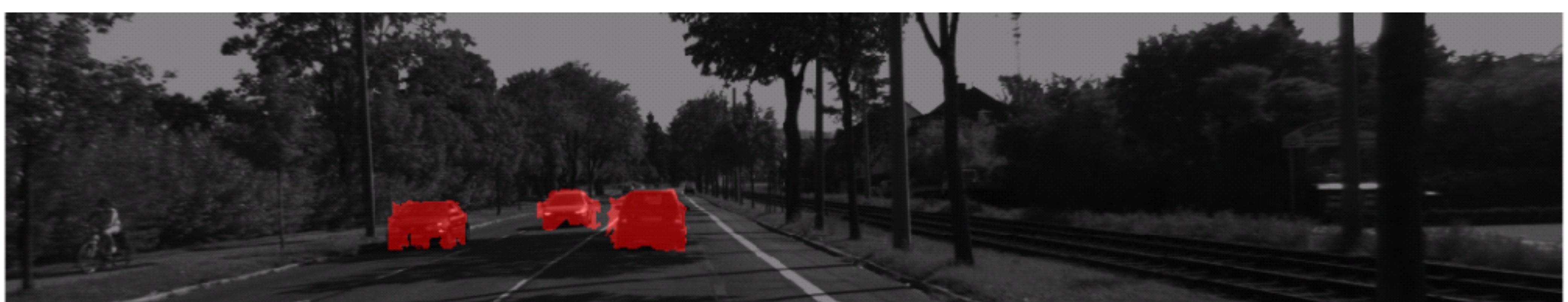
Motion Segmentation

- In the accumulated occupancy grid, the regions with higher probability represent the static object
- The region with low probability are the objects in motion

Occupancy map

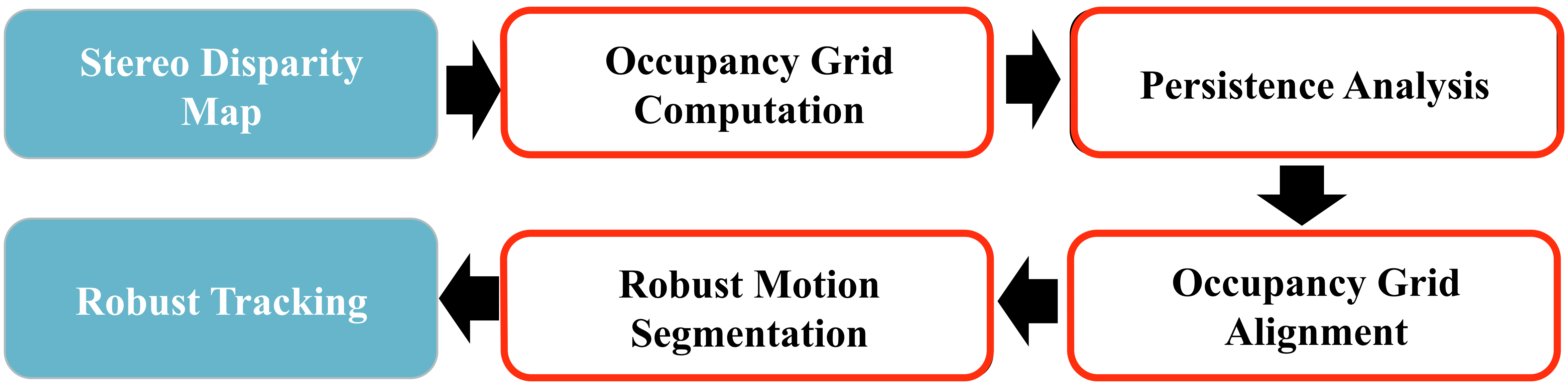


Robust segmentation



Motion segmentation

Pipeline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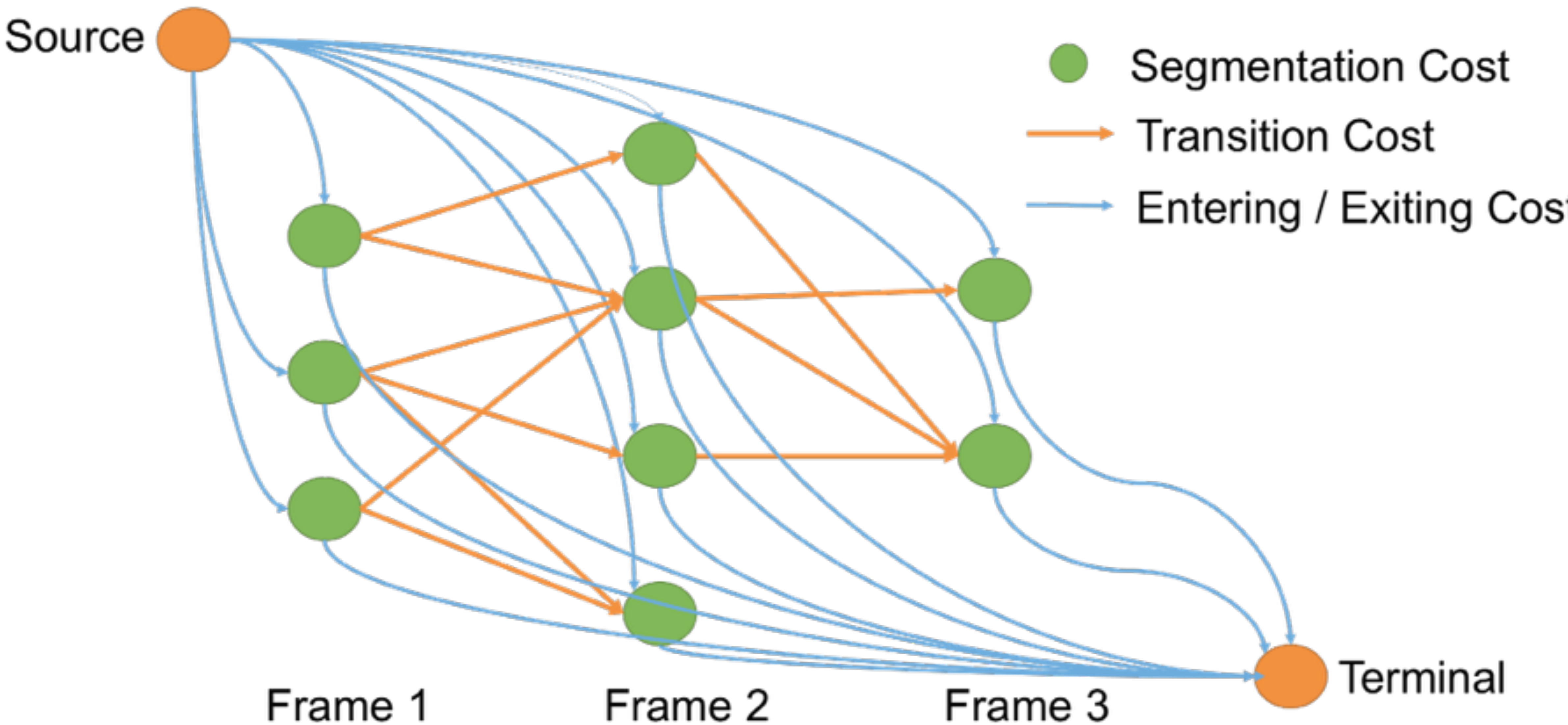
Robust Tracking



L. Zhang, Y. Li, and R. Nevatia, "Global data association for multi- object tracking using network flows," in *Computer Vision and Pattern Recognition, 2008. CVPR 2008. IEEE Conference on*. IEEE, 2008, pp. 1–8.

H. Pirsiavash, D. Ramanan, and C. C. Fowlkes, "Globally-optimal greedy algorithms for tracking a variable number of objects," in *Com- puter Vision and Pattern Recognition (CVPR), 2011 IEEE Conference on*. IEEE, 2011, pp. 1201–1208.

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Robust Tracking

- Solve a maximize a posteriori probability problem

$$T_r = \underset{T}{\operatorname{argmax}}\, P(T|O) = \underset{T}{\operatorname{argmax}}\, P(O|T)P(T)$$

$$T_r = \underset{T}{\operatorname{argmax}} \prod_j P(T_j) \prod_i P(o_i|T)$$

$$T_r = \underset{T}{\operatorname{argmin}} - \left(\sum_j log(P(T_j)) + \sum_i log(P(o_i|T)) \right)$$

$$P(T_j) = P_e^2 P(o_{j_1}, o_{j_2}) P(o_{j_2}, o_{j_3}) ... P(o_{j_{n-1}}, o_{j_n})$$

Robust Tracking

$$T_r = \underset{T}{\operatorname{argmin}} - \left(\sum_j log(P(T_j)) + \sum_i log(P(o_i|T)) \right)$$

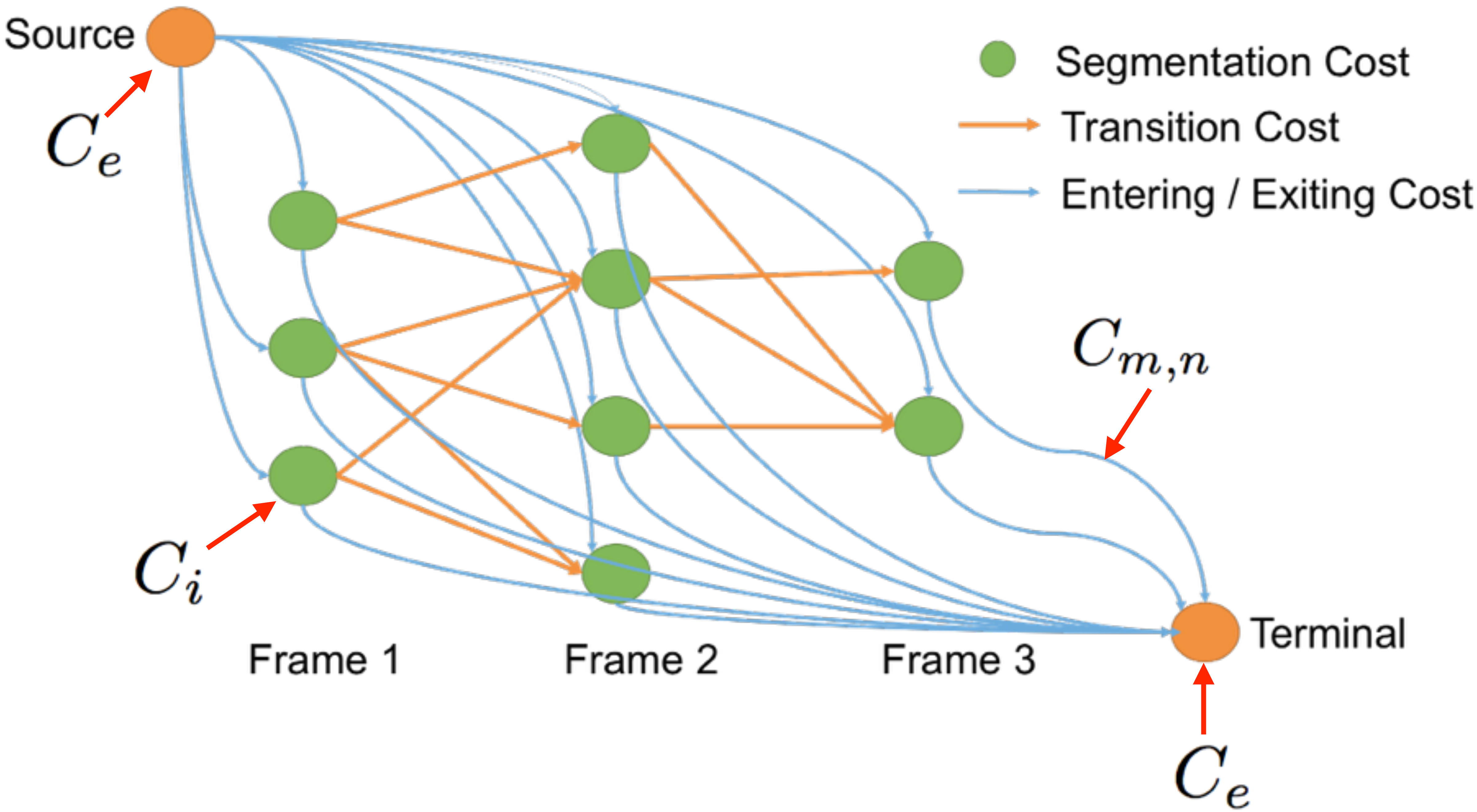
$$T_r = \underset{T}{\operatorname{argmin}} \left(\sum_j C_e + \sum_i C_i + \sum_{m,n} C_{m,n} \right)$$

$$C_e = -log(P_e^2)$$

$$C_i = -log(P(o_i|T))$$

$$C_{m,n} = -log(P(o_m), P(o_n))$$

Robust Tracking



Experiment

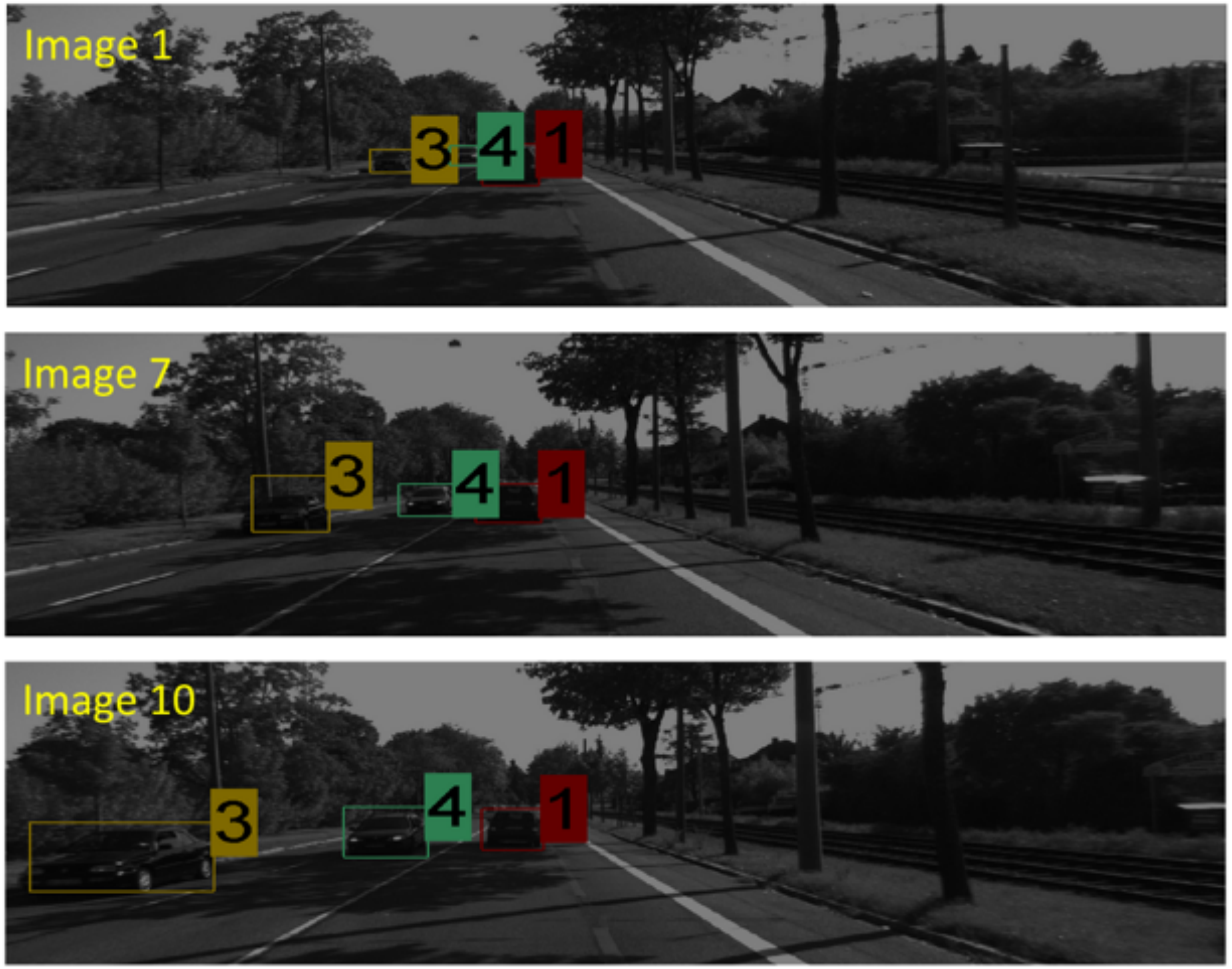
- Implemented in MATLAB
- Use KITTI dataset

  - A: 200 frames represent inner city

  - B: 120 frames represent residential traffic

Experiment

- Tracking results over 10 consecutive frames



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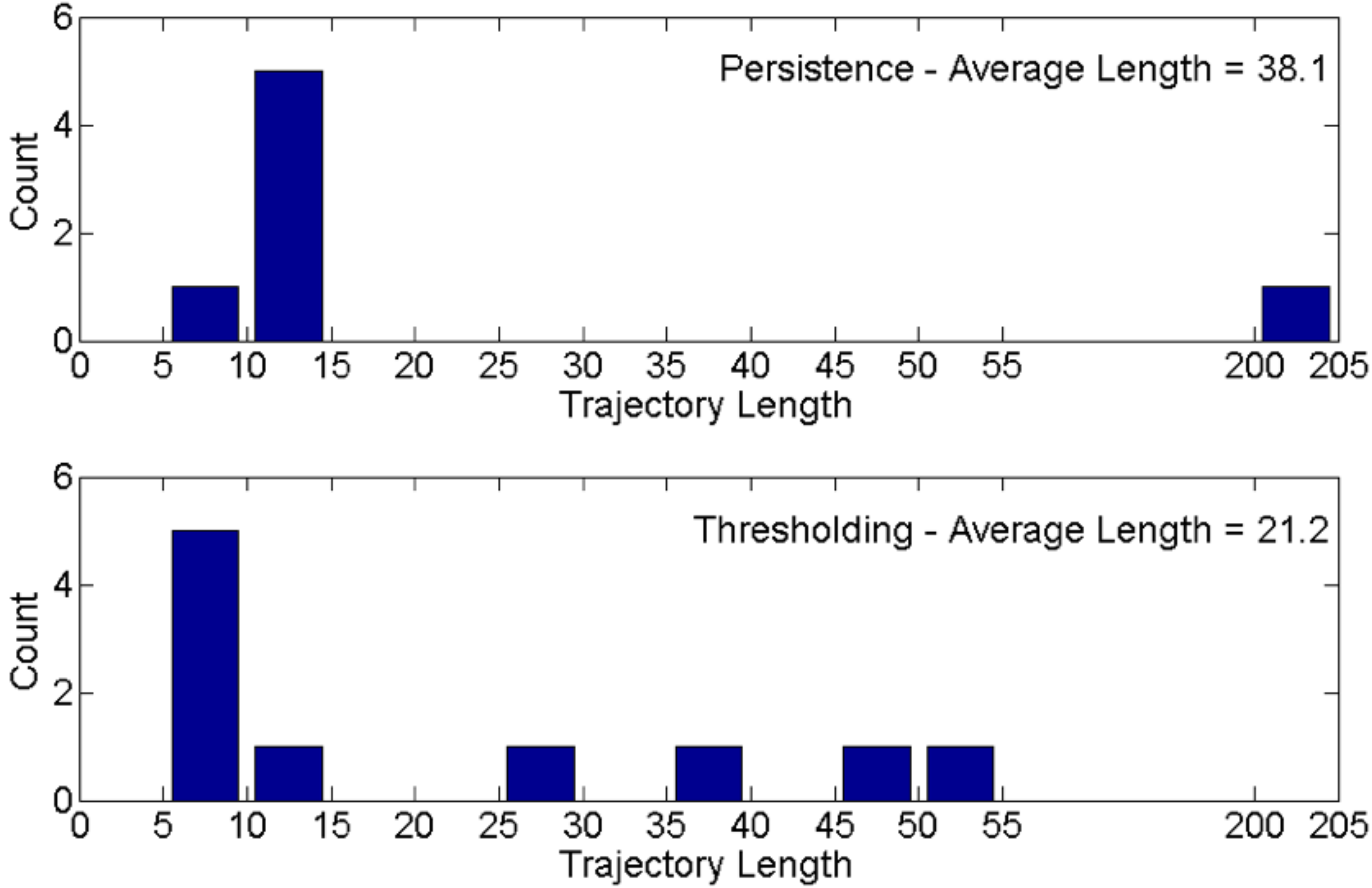
Evaluation

- Motion segmentation

Precision = correct matches / total groundtruth objects
Recall = correct matches / output objects.
FA/Frm = No. of false alarms per frame.

Dataset	Precision	Recall	FA/Frm
A	0.95	0.97	0.25
B	0.91	0.96	0.42

Evaluation


Persistence - Average Length = 38.1
Count
Trajectory Length
0 5 10 15 20 25 30 35 40 45 50 55 200 205
0 2 4 6
Thresholding - Average Length = 21.2
Count
Trajectory Length
0 5 10 15 20 25 30 35 40 45 50 55 200 205
0 2 4 6

Evaluation

- Tracking

Dataset	GT	MT%	MOTA	MOTP	ML%	Fr	IDS
A	7	0.80	1	0.83	0	0	0
B	7	0.86	0.88	0.81	0	0	3

Number of groundtruth trajectories

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Thanks !