Supplementary Material for "Vehicle Tracking in Wide Area Motion Imagery via Stochastic Progressive Association Across Multiple Frames (SPAAM)"

Ahmed Elliethy, *Student Member, IEEE* and Gaurav Sharma, *Fellow, IEEE*

This document provides supplementary material, for the paper [1]. In Section S.I, we provide details about routing on road networks and how the shortest route between given two points is obtained. Section S.II presents results characterizing the dependence of the tracking performance on individual terms of the cost function defined in (5) in the main manuscript.

S.I. Routing on a road network

We obtained the vector road network from Open Street Map (OSM) [2]. Each road in the road network is represented by multiple road segments connecting start and end points specified in the map data by their latitude and longitude coordinates, as shown schematically in Fig. S.1 (a). Additionally, several other properties of each road such as type (highway, residential, etc), two-way or one-way (and direction of travel), number of lanes, etc are included in the OSM data.

As in [3, pp. 2-3], we convert the road network into a directed graph. Segments of one way roads are represented by edges with the corresponding directionality and segments of two way roads are represented by a pair of directed edges for travel in either direction. Specifically, from the road network structure, we first identify the intersection points that connect multiple end points of road segments. Then, we

A. Elliethy is with the Department of Electrical and Computer Engineering, University of Rochester, Rochester, NY 14627, USA (e-mail: ahmed.s.elliethy@rochester.edu).

G. Sharma is with the Department of Electrical and Computer Engineering, Department of Computer Science, and Department of Biostatistics and Computational Biology, University of Rochester, Rochester, NY 14627, USA (e-mail: gaurav.sharma@rochester.edu).

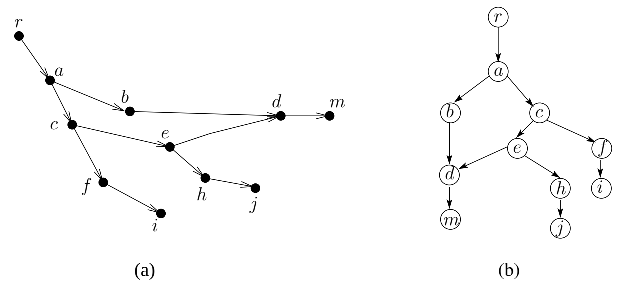

Fig. S.1: Schematic illustrating the road network graph construction for the Dijkstras algorithm.

create a graph such that every intersection point is represented by a graph node and every road segment connecting two intersection points represented as a graph edge. The cost of each edge is the length of the corresponding road segment. The graph corresponding to the road network of Fig. S.1 (a) is shown in Fig. S.1 (b). Given the graph, we can apply the Dijkstra's algorithm [4, pp. 38-39] to estimate the shortest path from any node to any other node. A straigtforward extension allows computation of the road travel distance from any point on the road network (not necessarily a node) to any other point on the road network.

S.II. Contribution of Individual Cost Terms to Tracking Performance

In order to evaluate the effect of each term in Eq. (5) on the overall performance, additional experiments were conducted. Specifically, we have evaluated the tracking performance for situations where, one-by-one, a term is dropped from Eq. (5) by setting the corresponding weighting term to 0. Table S.I lists the tracking results of the SPAAM-EM approach when the cost in (5) is modified by setting one weight factor to 0, while setting the other factors to the default values mentioned in the manuscript. The table shows that, dropping the motion regularity term $\Gamma\left(\varepsilon^i_{k_i,k_{i+1}}\right)$ has the largest negative effect on the tracking performance. Moreover, the road directional term $R_\theta\left(\varepsilon^i_{k_i,k_{i+1}}\right)$ has more effect on the tracking performance for Seq2 compared with Seq3, because Seq2 contains only two-way roads, while Seq3 contains only one-way roads.

References

[1] A. Elliethy and G. Sharma, "Vehicle tracking in wide area motion imagery via stochastic progressive association across multiple frames," *IEEE Trans. Image Proc.*, vol. 27, no. 7, pp. 3644–3656, Jul. 2018.

[2] "OpenStreetMap," http://www.openstreetmap.org, accessed Mar. 2016.

[3] R. Balakrishnan and K. Ranganathan, *A Textbook of Graph Theory*, ser. Universitext (Berlin. Print). Springer New York, 2012.

Seq	Set in Eq. (5)	*MT*↑	*ML*↓	*PT*	*IDS*↓	*Frag*↓	*MOTA*↑
1	$\sigma_m = 0$	72	15	52	226	323	0.884824
	$\sigma_d = 0$	79	15	42	87	151	0.948281
	$\sigma_\theta = 0$	79	13	47	107	176	0.947047
	$\sigma_g = 0$	80	19	40	89	156	0.949801
2	$\sigma_m = 0$	89	0	13	506	598	0.811251
	$\sigma_d = 0$	97	1	4	117	162	0.955281
	$\sigma_\theta = 0$	95	1	6	256	320	0.904356
	$\sigma_g = 0$	97	1	4	116	159	0.955444
3	$\sigma_m = 0$	50	0	4	108	150	0.929033
	$\sigma_d = 0$	51	0	3	45	65	0.973088
	$\sigma_\theta = 0$	54	0	0	38	53	0.976442
	$\sigma_g = 0$	51	0	3	45	65	0.973088

TABLE S.I: Tracking results of the SPAAM-EM approach when the cost in (5) is modified by setting one weight factor to 0 and setting the other weighting factors to the default values mentioned in the manuscript.

[4] D. Medhi and K. Ramasamy, *Network Routing: Algorithms, Protocols, and Architectures*. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., 2007.