

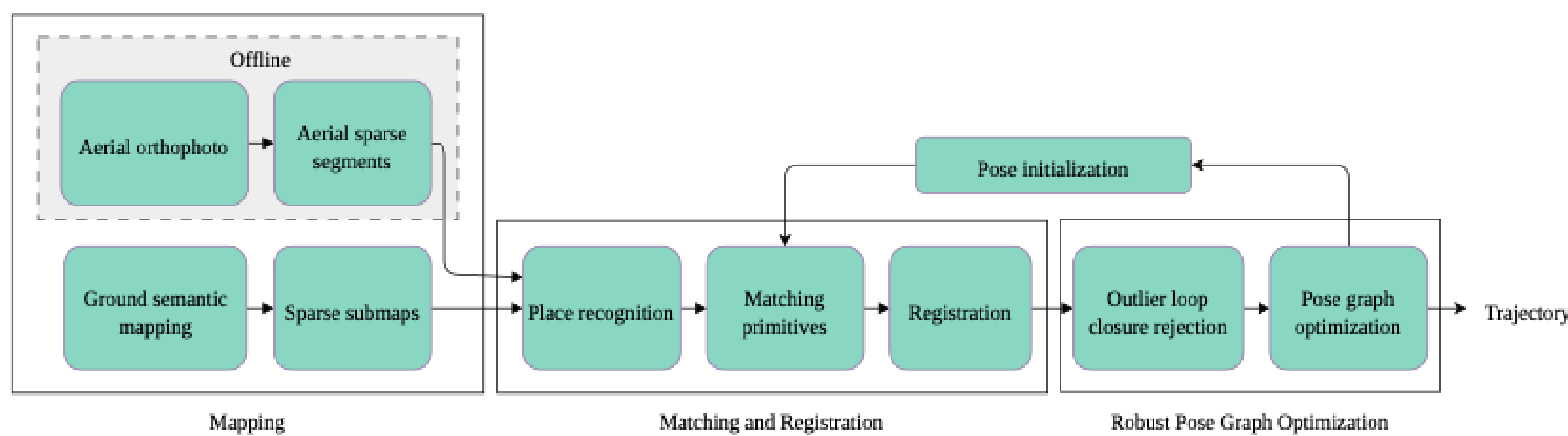
Cross-View Localization Beyond Urban Environments via Metric-Semantic Primitive Matching



Mason Peterson*, Qingyuan Li*, Yixuan Jia, Fernando Cladera, Camillo Jose Taylor, Jonathan P. How

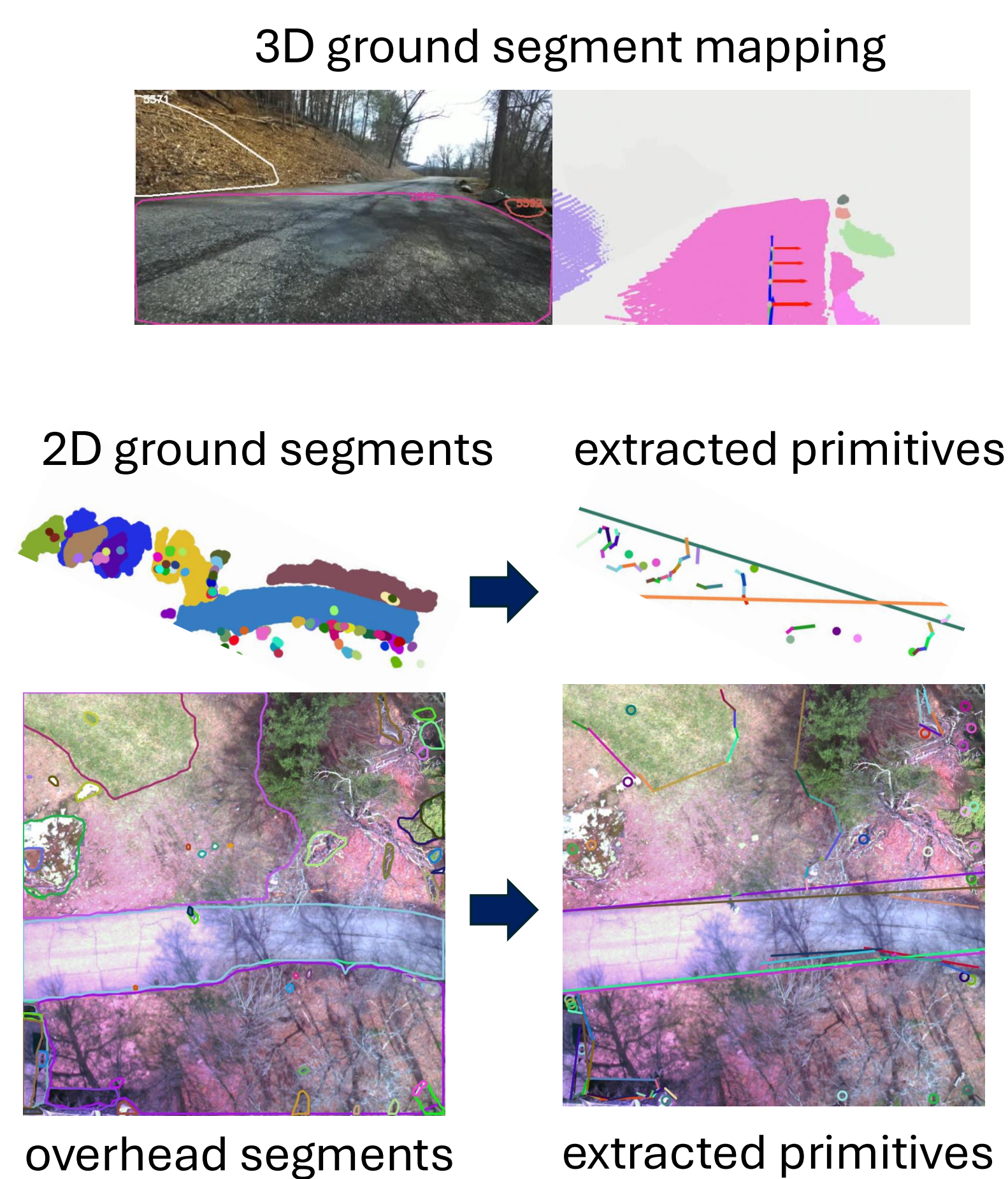
Motivation & Challenges

- Localizing within a global coordinate frame is critical for field deployment of autonomous systems
- Using an overhead image gives rich access to global information but has seen limited applications in unstructured, natural environments due to:
 - Reliance on training environment-specific models without the ability to generalize
 - Challenging repetitive geometries and/or feature-sparse landscapes



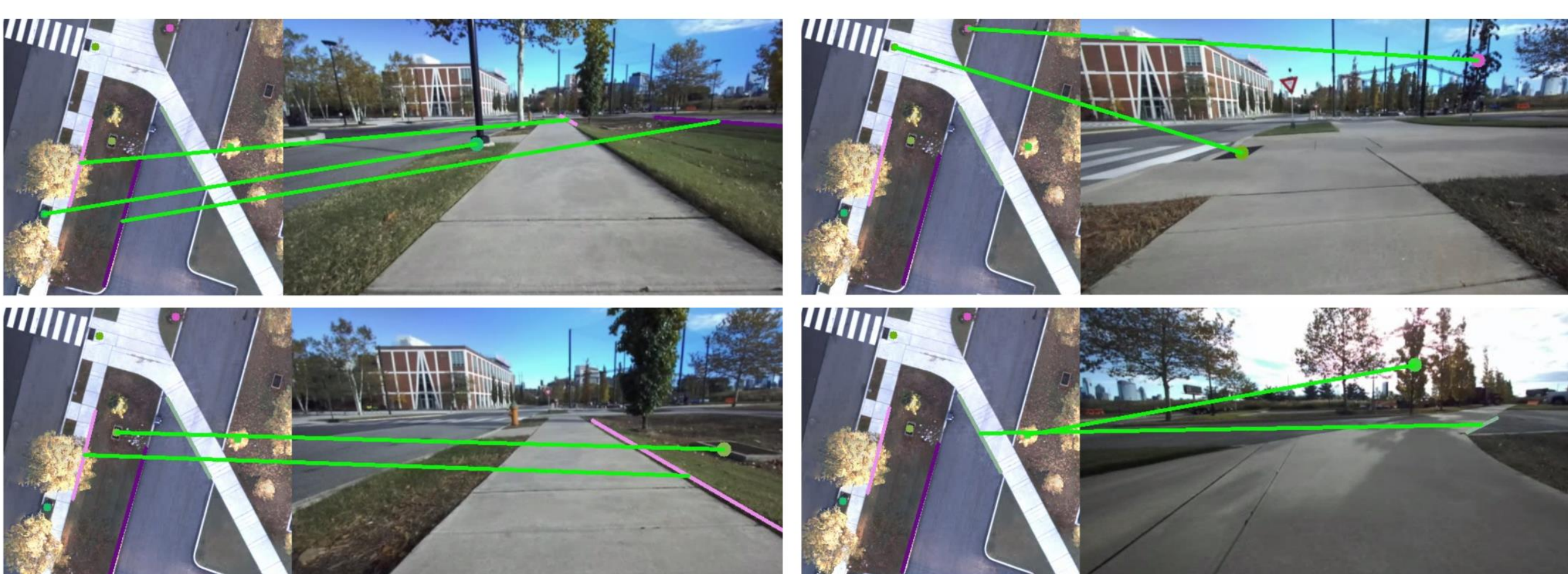
Primitive mapping

- 3D mapped segments are projected to 2D
- Small aerial / ground segments become points
- Borders of aerial / ground segments become lines



Primitive matching

- Points and lines are matched via outlier-robust graph-theoretic data association
- Association consistency is represented by:
 - Uncertainty-weighted consistency of minimum distances between pairs of primitives
 - DINOv2 semantic similarity



Key Takeaway

High-level point and line matching enables fine-grained cross-view geo-localization across diverse environments. No retraining, algorithmic changes, or initial pose information required.

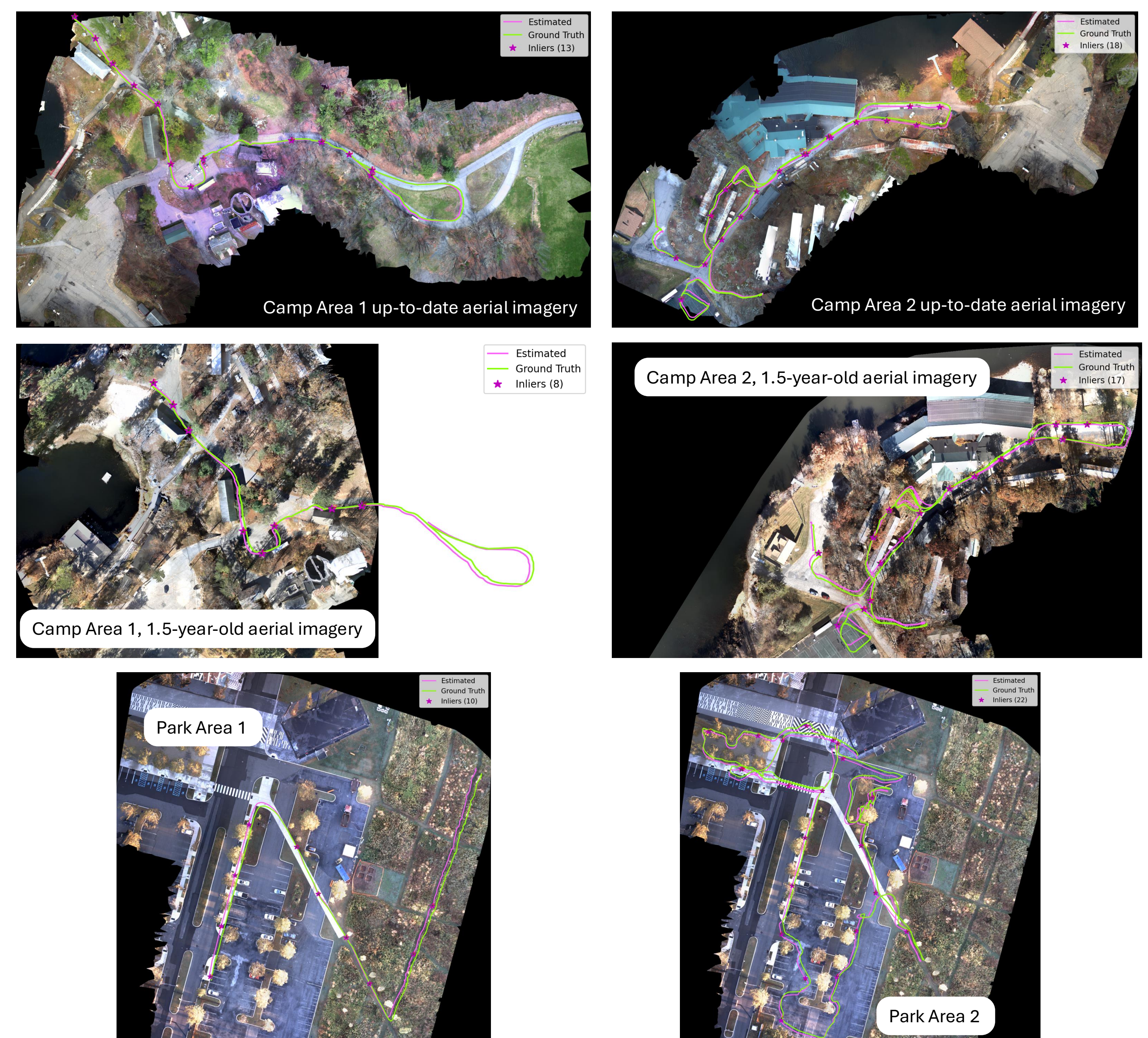
Overview

- Large segmentation and semantic models are used to extract high-level objects (points) and region borders (line segments) in any environment
- Point/line primitives are grouped into submaps and matched across aerial and ground views (represented as pose measurement distributions)
- Outlier rejection applied to pose measurements

Results

Trajectory estimation error (m) on self-collected data

Area	Sequence	Length (m)	Trajectory Estimation Error (m)	
			Up-to-date Aerial Imagery	1.5-year-old Aerial Imagery
Camp Area	1	460	1.2	2.0
	2	760	1.5	3.2
	3	540	2.1	2.2
	4	1000	3.2	4.6
	5	1430	3.0	3.1
Park Area	1	280	1.9	1.9 (1-year-old)
	2	690	1.4	2.1 (1-year-old)
Mean/Std			2.0±0.7	2.7±0.9



Trajectory estimation error (m) on KITTI Sequence 00

Localization Source	Method	RMS ATE (m)
OpenStreetMap	OSM-SLAM	3.8
OpenStreetMap	Przewodowski et al.	2.8
OpenStreetMap	Li et al.	1.6
Aerial Image	Miller et al.	2.0
Aerial Image	Ankenbauer et al.	3.5
Aerial Image	Proposed	1.5

*Equal Contribution