Temporal- and Viewpoint-Invariant Registration for Under-Canopy Footage using Deep-Learning-based Bird's Eye View Prediction



Jiawei Zhou¹, Ruben Mascaro¹, Cesar Cadena², Margarita Chli¹, Lucas Teixeira¹ ¹V4RL - University of Cyprus and ETH Zürich ²RSL - ETH Zürich



1. Motivation

Achieving precise registration between successive data capture sessions is essential in smart farming. This work focuses on aligning noisy, sparse point clouds reconstructed from multiple geo-referenced RGB image sequences collected in areas covered by trees.

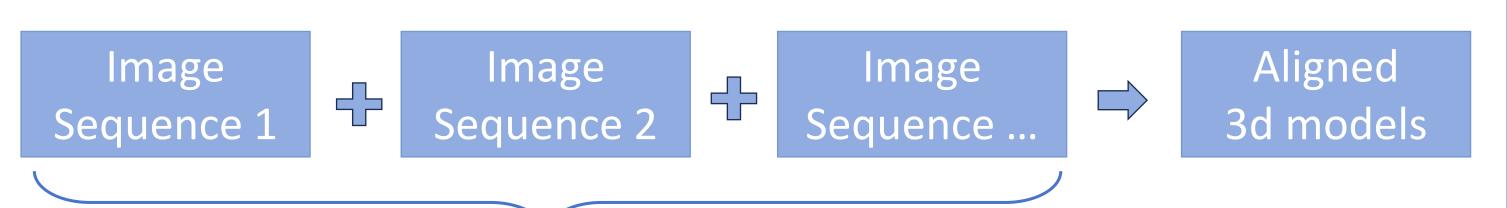


Image sequences collected in the same tree-covered area. Presence of temporal and seasonal changes across sequences.

2. Contribution

- Deployment of learning-based perspective to bird's-eye view image conversion for estimating the position of trees.
- Feature extraction strategy that targets the clean segmentation of trunk and ground points.
- Iterative alignment process that alternates focus between the segmented ground and the estimated tree centers for enhanced precision.
- Strategic division of the 3D models into batches, followed by a local refinement phase to fine-tune the alignment results for each batch.

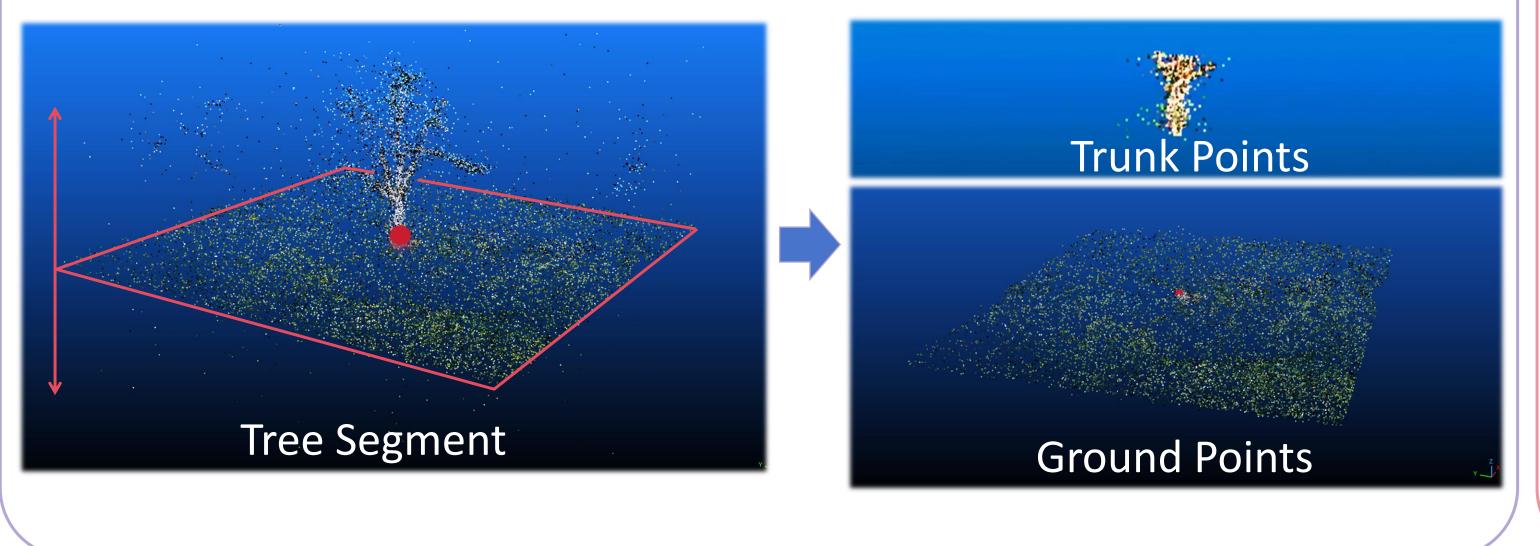
Geo-referenced tree locations, if available **Images** Reference Feature Stage Geo-referenced Sparse Features Reference Training Camera Reconstruction Robust poses Tree areas Ground points PV2BEV PV2BEV Natural Feature & Tree centers Weights Segmentation Geo-registration, SfM Images & Extraction PPK-GPS or GCPs (COLMAP) and spliting Single Sparse Map Submodels model Merging Query (Other Per Query Sub-Model viewpoint / days) Alignment Stage Aligned Models Geo-referenced Initial Batch Images Cameras and Ground points Loop Sparse & GPS Sub-models & Tree centers Stage Alignment Alignment Sparse map) Alignment Reconstruction Images

I Sparse Reconstruction Reconstruction using **SfM** Initial alignment with **GPS**

II Perspective View to Bird's Eye View Top View Tree Positions **PV2BEV**

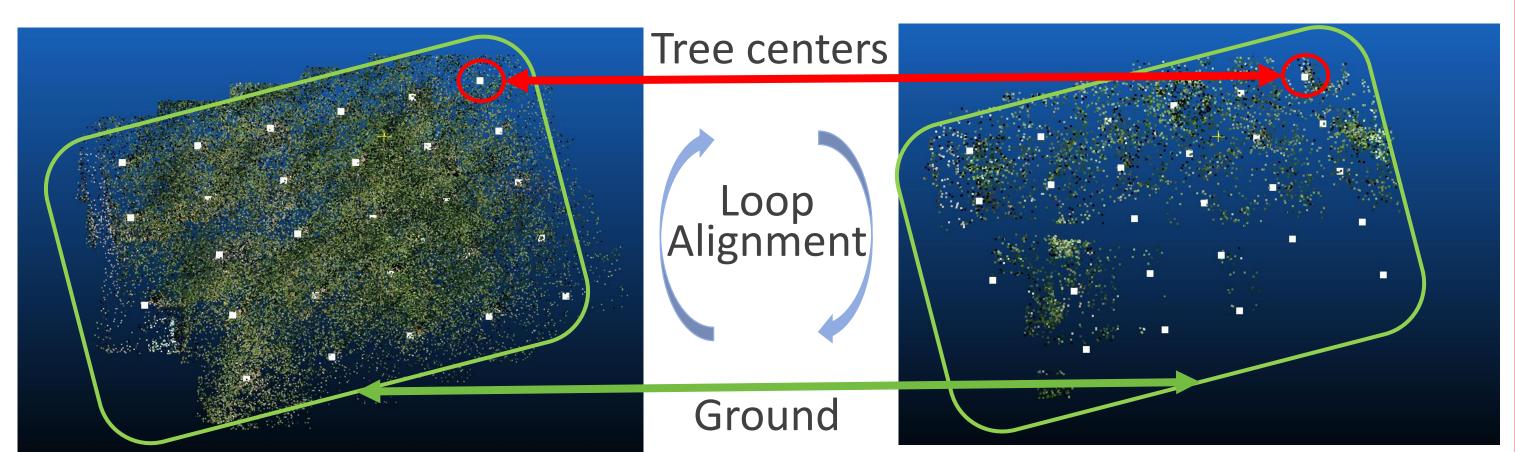
III Feature Stage

- 1. Tree Area Segmentation: Area extraction around each tree center.
- 2. Robust Natural Feature Extraction: Slicing and Gaussian fitting for trunk segmentation, and DBSCAN for outlier removal.



IV Alignment Stage

- 1. Initial Alignment: ICP alignment of extracted ground points.
- 2. Loop Alignment: Alternation between tree centers and ground points.



3. Batch Alignment: Clustering of tree centers into well-defined groups, which are refined locally to address accumulated drift.

4. Experiments

Evaluation Metric	a) Different Seasons Case						b) Perpendicular Viewpoints Case						c) Opposite Viewpoints Case					
	Ours	ICP ¹	FGR ²	FICP ³	RICP ³	TEASER ⁴	Ours	ICP ¹	FGR ²	FICP ³	RICP ³	TEASER ⁴	Ours	ICP ¹	FGR ²	FICP ³	RICP ³	TEASER ⁴
Camera Translation Error [m]	0.44	1.77	4.66	5.88	5.65	22.58	0.26	0.88	6.49	4.62	0.83	46.28	0.40	15.83	118.37	23.75	14.80	200.77
Camera Rotation Error [°]	0.74	2.48	0.77	6.82	7.50	19.62	0.18	0.39	1.33	10.60	0.28	165.44	0.54	3.64	1.29	3.92	2.35	158.65
Tree Centers 3D Error [m]	0.28	1.88	4.77	5.39	4.95	21.77	0.20	0.84	6.53	4.94	0.73	36.00	0.32	14.93	107.92	22.91	14.06	203.17

References:

- 1. P.J. Besl and N.D. McKay, "A method for registration of 3-D shapes", TPAMI 1992
- 2. Q.Y. Zhou et al., "Fast Global Registration", ECCV 2016
- 3. J. Zhang et al., "Fast and Robust Iterative Closest Point", TPAMI 2021
- 4. H. Yang et al., "TEASER: Fast and Certifiable Point Cloud Registration, T-RO 2020

