Moving Object Segmentation in Point Cloud Data using Hidden Markov Models

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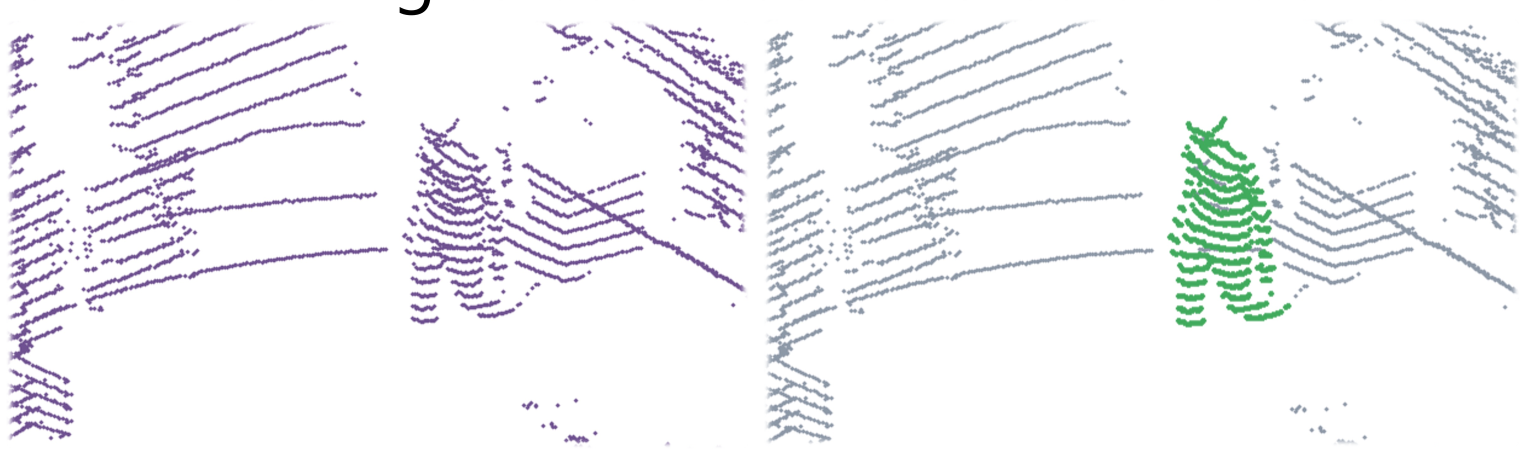
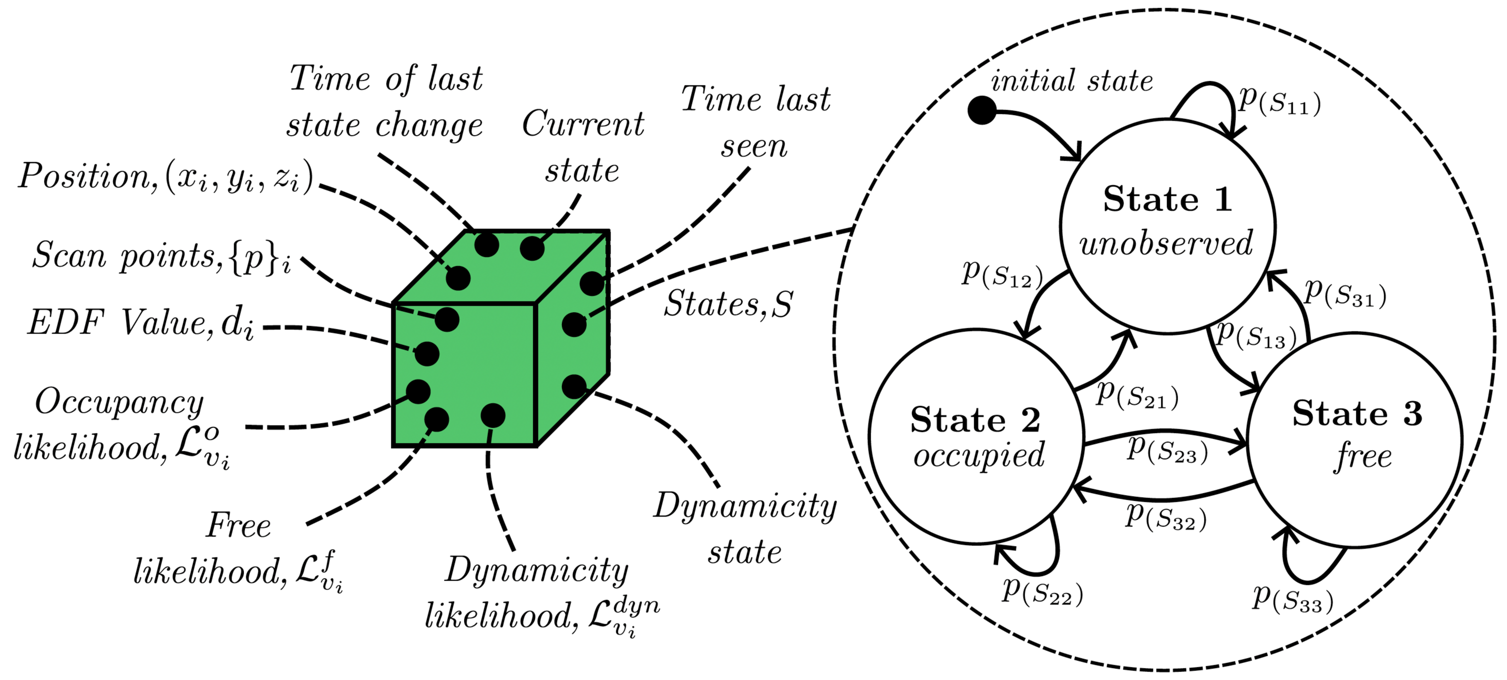
The Problem: Moving Object Segmentation

- Autonomous agents require the capability to identify dynamic objects in their environment for safe planning and navigation.
- Erroneous dynamic detections jeopardize the agent's ability to accomplish its task.
- MOS is a challenging problem due to the numerous sources of uncertainty inherent in the problem's inputs and the variety of applications, often leading to use-case-tailored solutions.



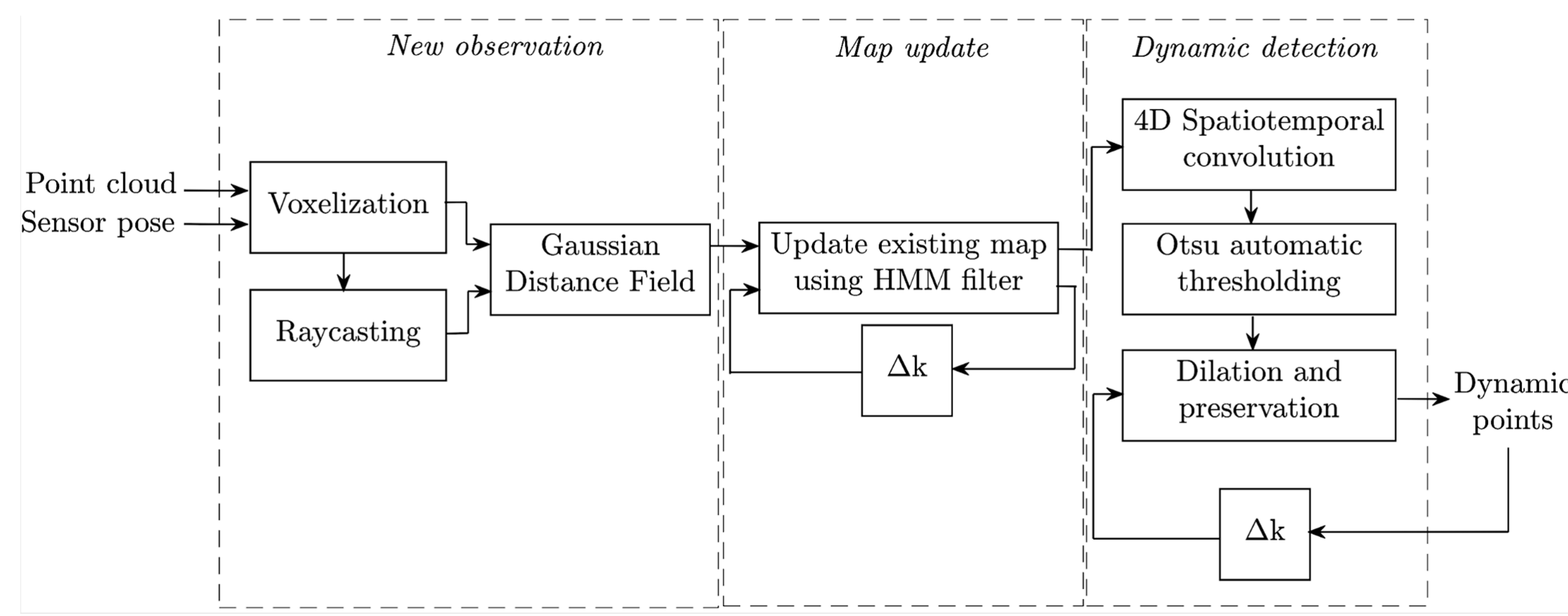
per-point *labelling of* ***static*** *and* ***dynamic*** *points*

- We propose a robust learning-free approach to segment moving objects that generalizes among sensor types and applications.
- The approach models each voxel using a hidden Markov model and probabilistically integrates beliefs into a map using an HMM filter.

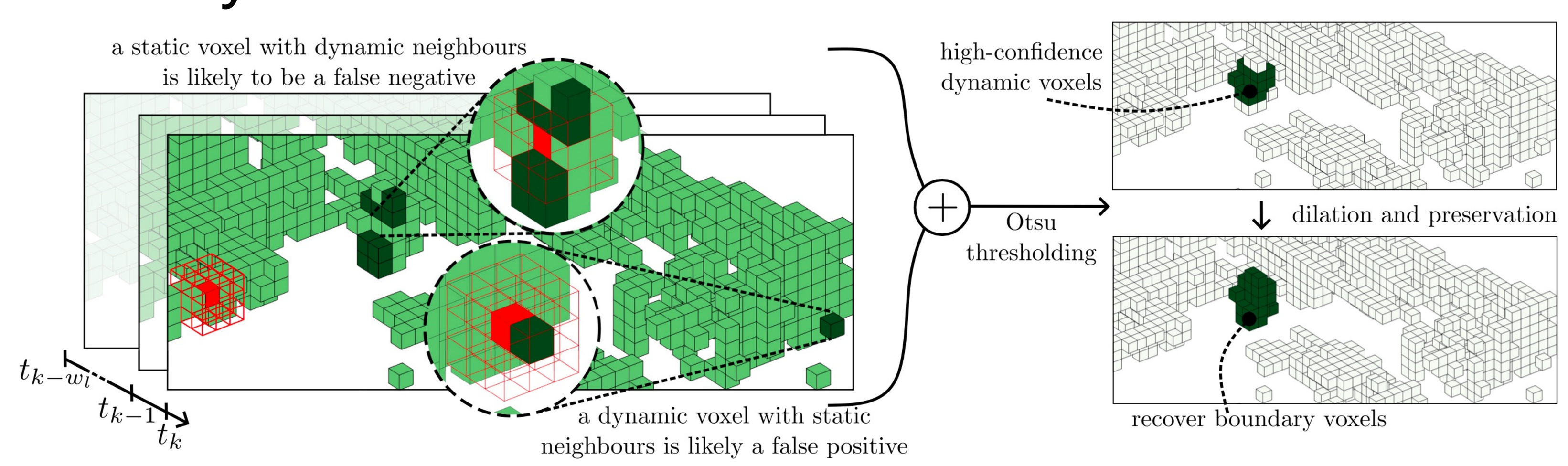


A Solution: HMM-MOS

- A simple three-stage process is used to segment moving objects consisting of scan voxelization, updating a global map, and a dynamic detection module using 4D spatiotemporal convolutions.



- 4D Spatiotemporal convolutions increase true detections while minimizing false positives.
- Automatic Otsu thresholding separates noisy and true dynamic detections.



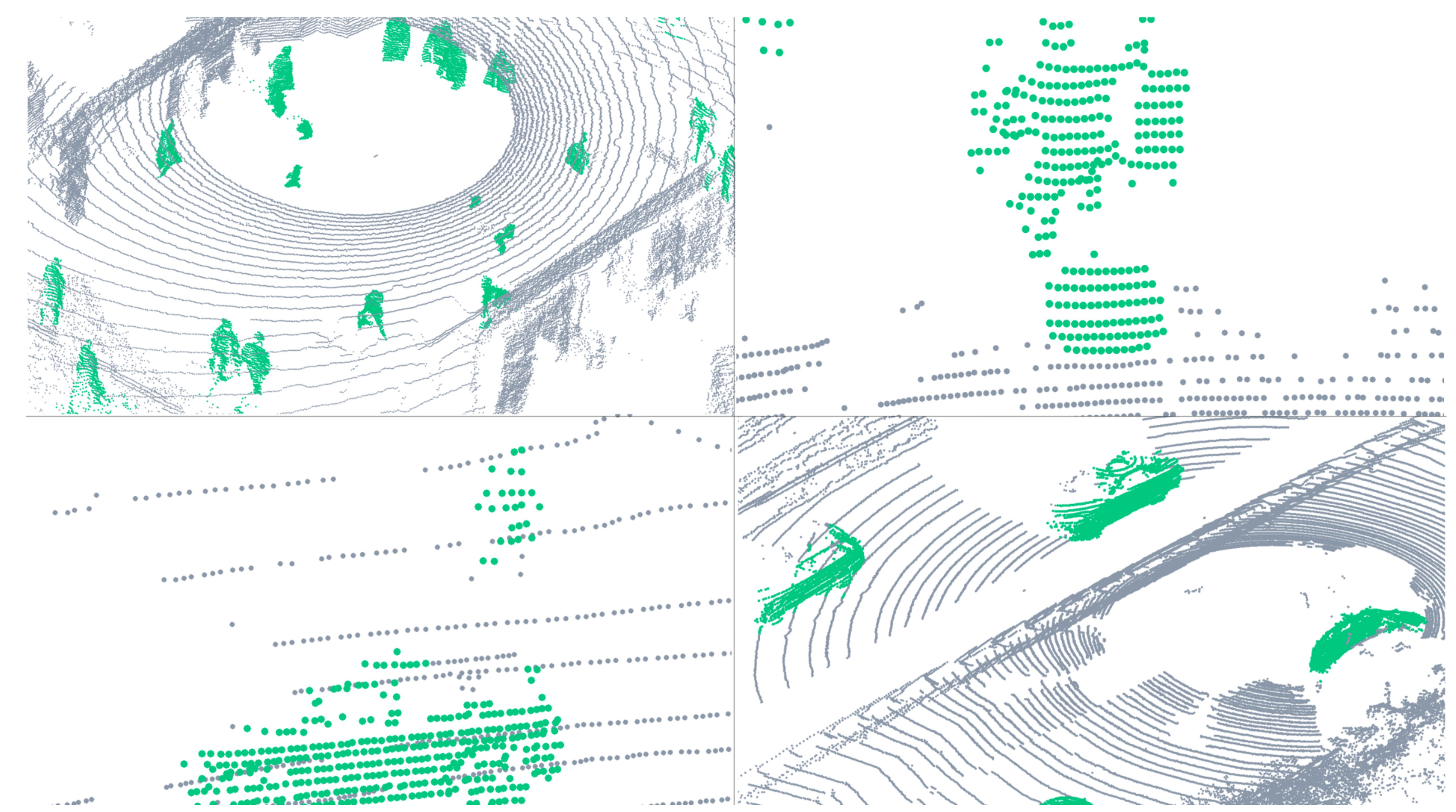
Find extensive results, demo videos, and the open-source repository here!

github.com/vb44/HMM-MOS

Algorithm Performance

- We achieve state-of-the-art performance on datasets with various sensor characteristics, platform dynamics, and diverse objects.
- Results on the *HeLiMOS* dataset demonstrate strong generalized performance in all scenarios.

		Solid state		Omnidirectional		Total
	Method	**Livox**	**Aeva**	**OS-128**	**VLP-16**	
HeLiMOS	4DMOS, online	52.1	54.0	64.2	4.7	43.7
	4DMOS, delayed	59.0	58.3	70.4	5.4	48.3
	MapMOS, Scan	58.9	63.2	81.4	4.3	52.0
	MapMOS, Volume	**62.7**	66.6	**82.9**	5.8	54.5
	Proposed Approach, online	51.3	69.8	75.0	35.0	57.8
	Proposed Approach, delayed	57.6	**70.0**	73.4	**53.9**	**63.7**



Next Steps

- Current results are real-time for 20-50m ranges depending on sensor sparsity. There is ongoing work to improve the computational feasibility.
- We are also exploring the means to reflect the varying dynamicity of objects.