

Drift-Free Visual Compass Leveraging Digital Twins for Cluttered Environments



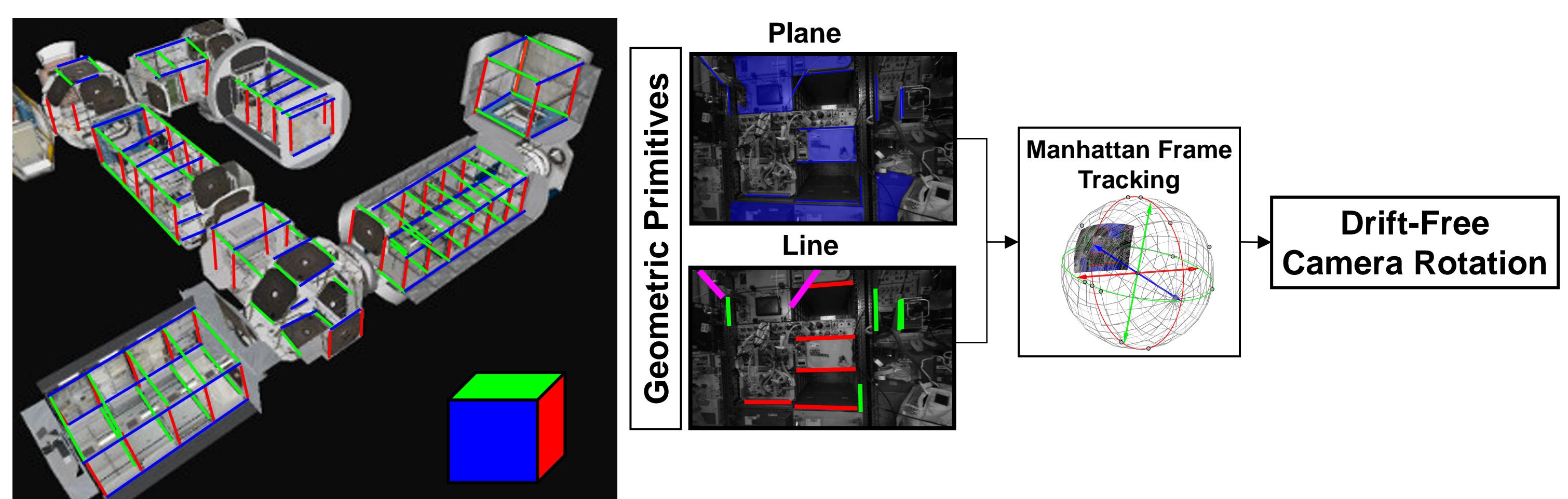
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Motivation



- Accurate, drift-free 3-DoF rotation tracking is one of the significant building blocks for visual navigation in microgravity, where unrestricted 360° rotational motion is intrinsic.

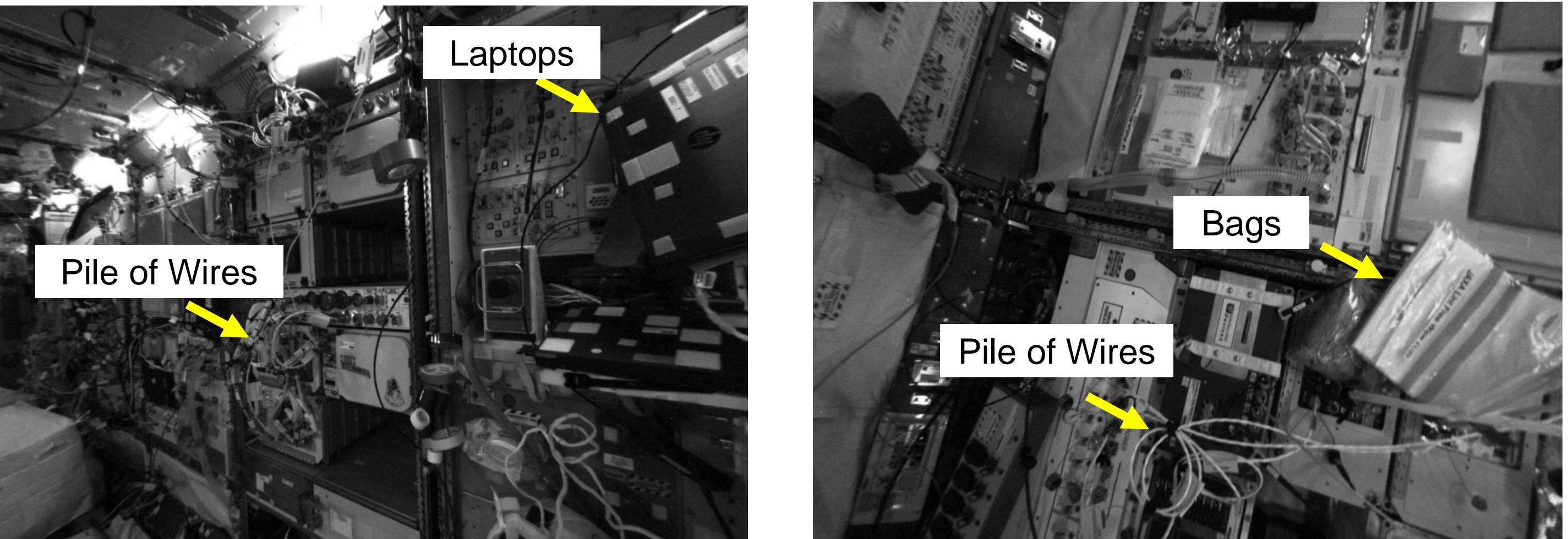


- Manhattan World (MW) assumption enables accurate, drift-free 3-DoF rotation in structured environments such as the ISS.

Contributions

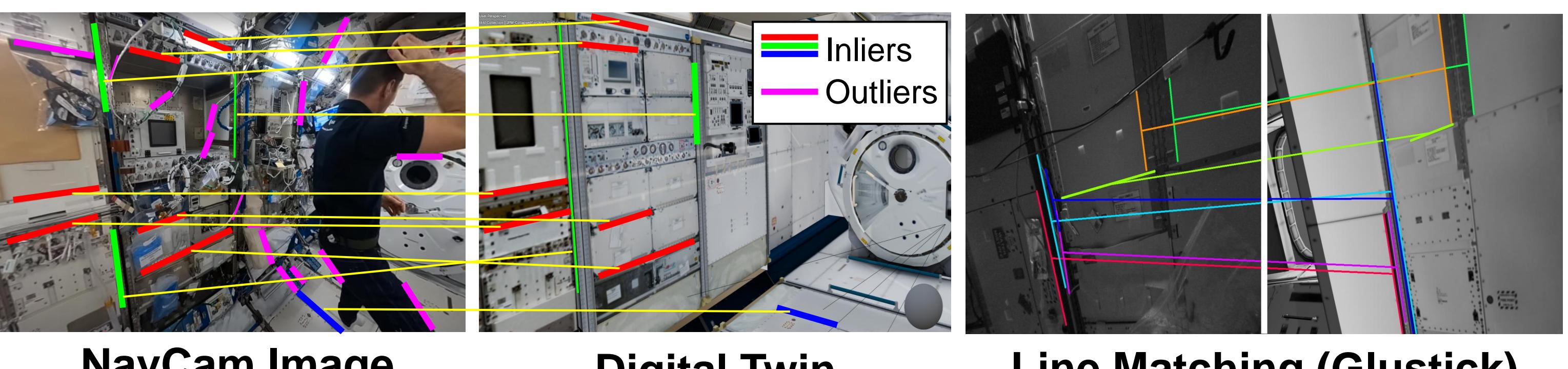
- We leverage a digital twin to overcome **cluttered and dynamic environments**.
- We propose **drift-free 3-DoF rotation estimation** from a single line and plane via robust MW inference.
- We demonstrate significantly superior rotational accuracy in a real **ISS environment**.

Challenges



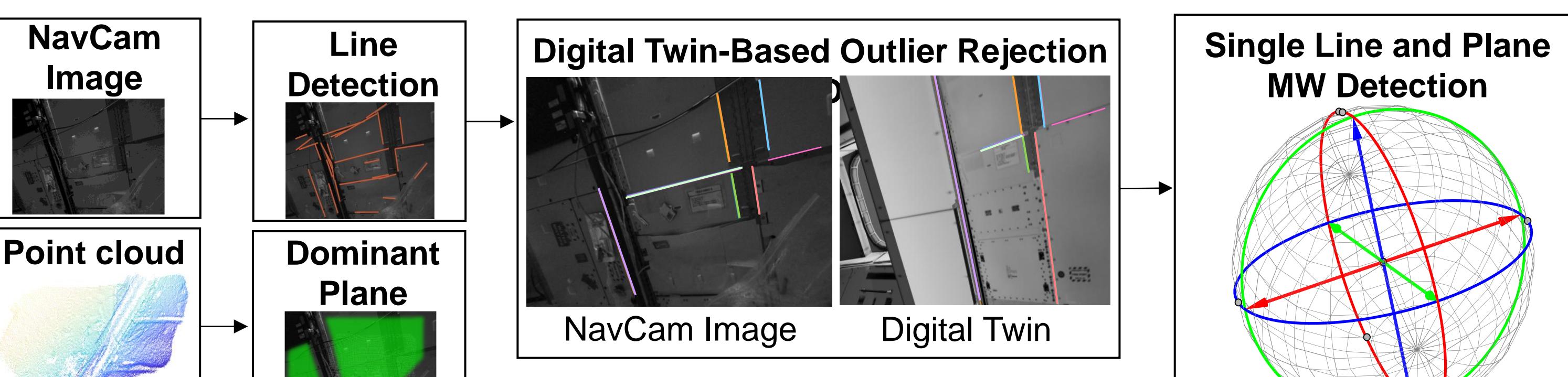
- Excessive outliers caused by dynamic and cluttered objects make existing MW tracking methods fail.

Digital Twin-Based Outlier Rejection (DTOR)



- We extract reliable lines by matching LSD lines to digital twin lines via **GlueStick**, a descriptor-free geometric line matching method.

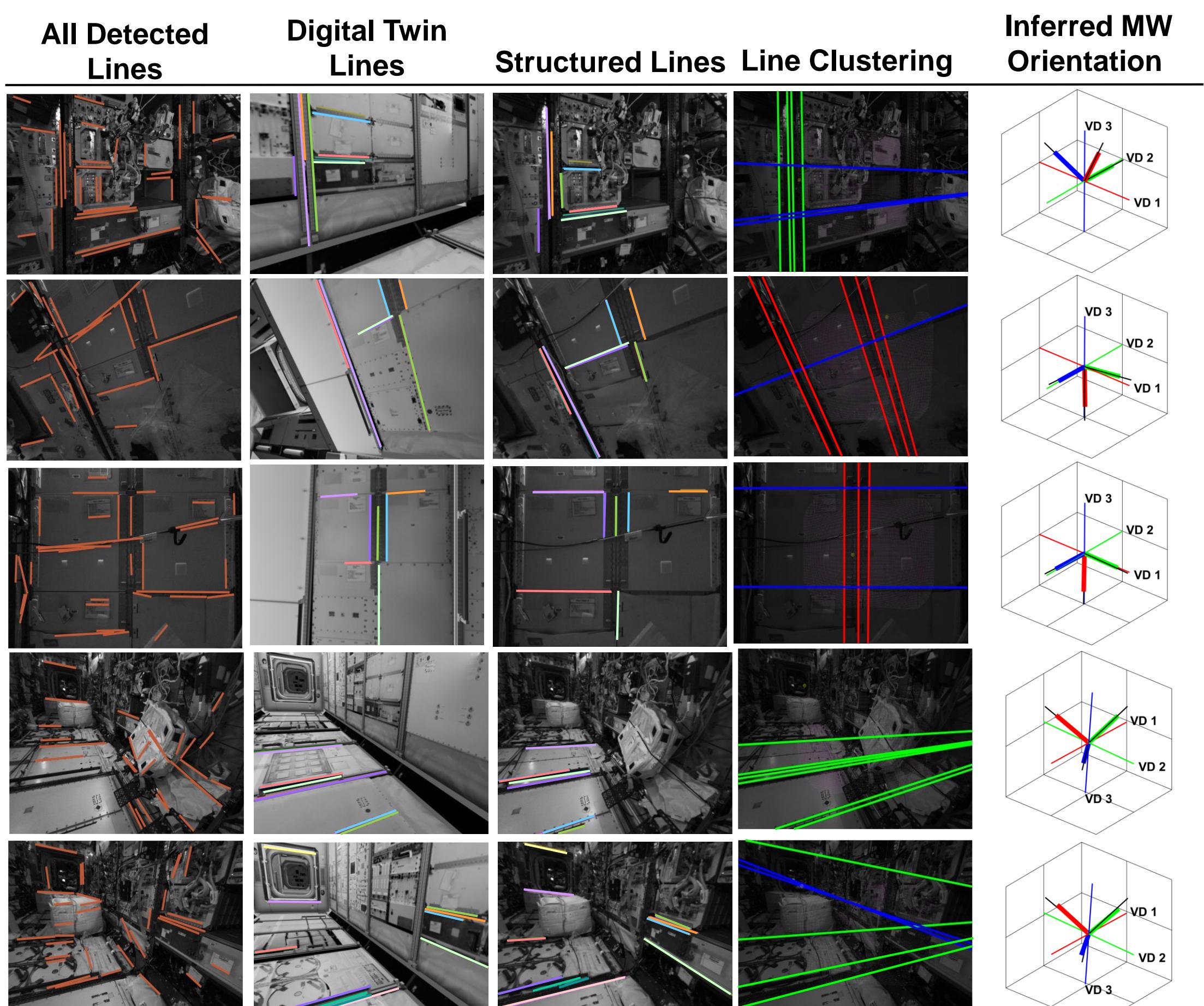
3D Visual Compass



- DTOR enables drift-free rotation estimation in the ISS environment.

Evaluation on Astrobee ISS Dataset

Qualitative Results



Quantitative Results

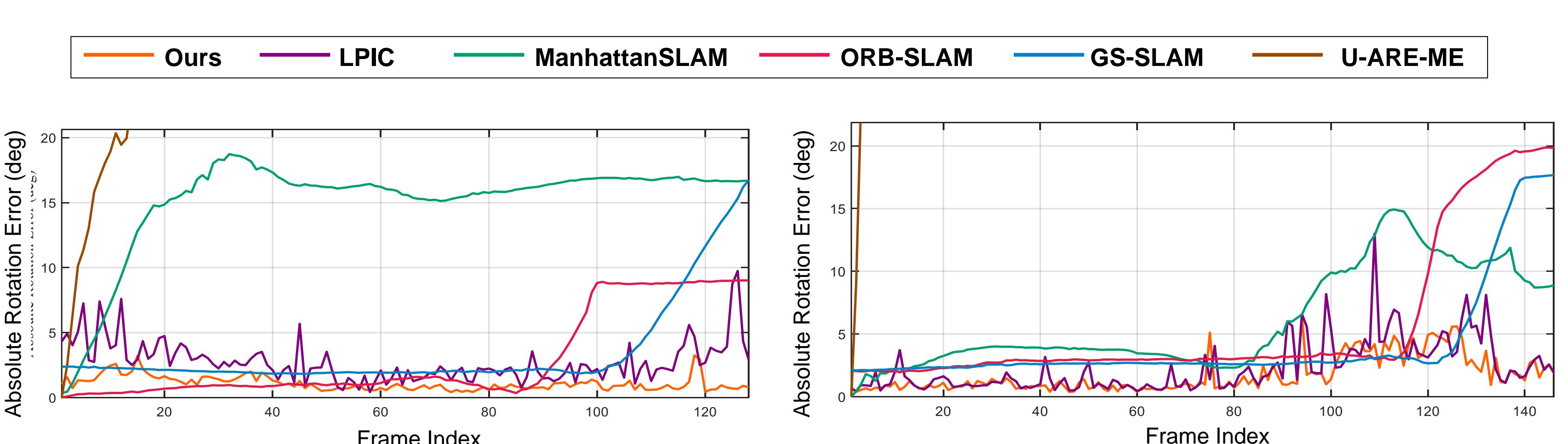


Table I. Absolute Rotation Error Comparison (unit: degree)

Dataset	Structural Model-based Methods				General-purpose Methods	
	Proposed	LPIC	ManhattanSLAM	U-ARE-ME	GS-SLAM	ORB-SLAM3
Astrobee Dataset	kibo_rot 1	1.75	2.32	4.26	63.67	7.17
	kibo_rot 2	1.09	2.74	2.94	49.56	14.53
	kibo_trans	1.44	3.56	1.66	32.03	1.17
Average	1.43	2.87	2.95	48.42	7.62	2.99

Takeaway Messages

- On the ISS, free rotation and clutter make visual navigation challenging.
- Remember our DTOR—it removes clutter to achieve drift-free rotation estimation in space. ☺