UniQuadric: A SLAM Backend for Unknown Rigid Object 3D Tracking and Light-Weight Modeling

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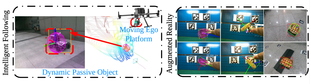
Overview

Task: Simultaneous Localization, Mapping and Moving Object Tracking and Modelling

Application:



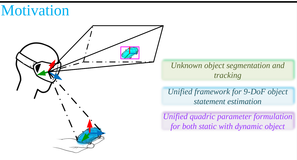
Contribution:

SAM has been integrated into AOT and is capable of accomplishing near real-time detection and tracking of unknown objects, guided by various predefined tasks and prompts.

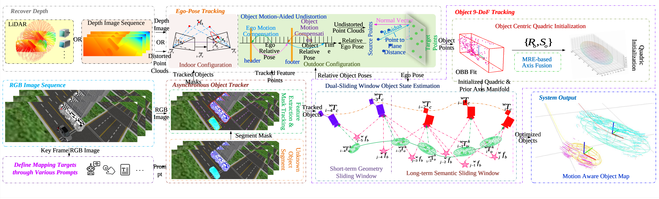
A novel object-centric quadric parameterization is proposed to unify the modeling of static and dynamic objects in the scene. Additionally, we propose **a tightly coupled dual-sliding window optimization framework** that leverages both semantic and geometric information, enabling us to **achieve precise 9 degrees of freedom (9-DoF) estimations for rigid objects**.

We propose the UniQuadric, which **extends the SLAMMOT system for 3D tracking and light-weight modeling of unknown rigid objects, while simultaneously providing ego-localization**. Additionally, our system supports both visual and visual-LiDAR fusion configurations, making it suitable for indoor and outdoor scenes.

Motivation

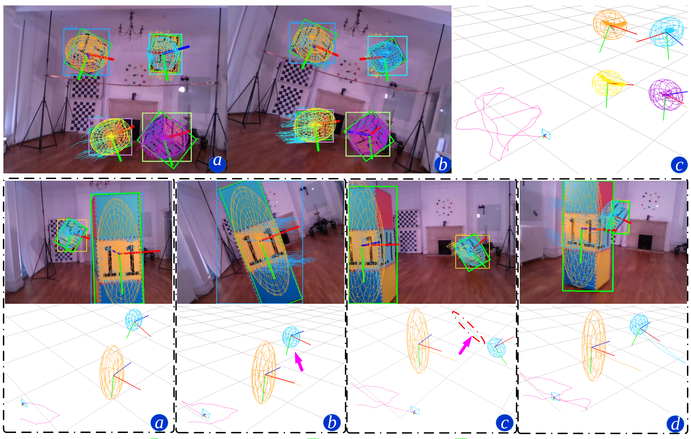


Method



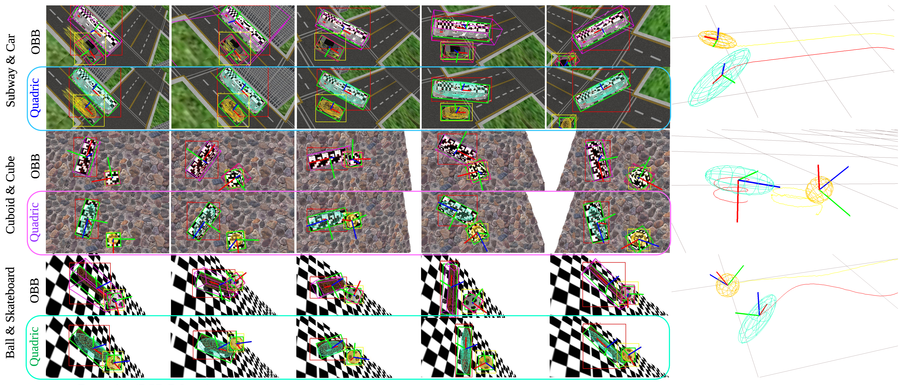
Experiment

Oxford Multimotion dataset(OMD) Evaluation



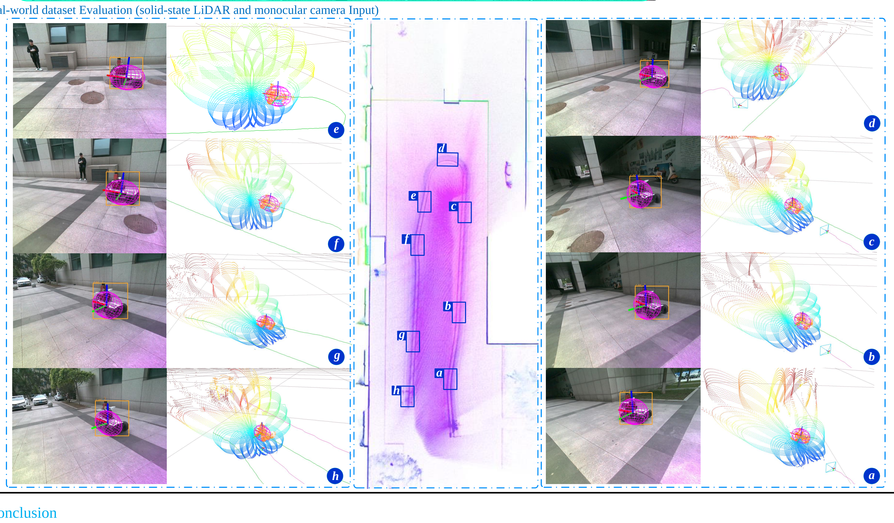
Sequence	ClusterVO [9]				DymSLAM [29]				MVO [40]				Proposed Approach			
	Trans(m)	Roll(°)	Yaw(°)	Pitch(°)	Trans(m)	Roll(°)	Yaw(°)	Pitch(°)	Trans(m)	Roll(°)	Yaw(°)	Pitch(°)	Trans(m)	Roll(°)	Yaw(°)	Pitch(°)
SW4-Ego	0.62	-4.97	2.53	0.448	0.04	-0.78	-1.6	-0.7	0.93	-6.82	3.13	0.16	0.29	0.31	1.9	0.51
SW4-C1	0.24	0.65	6.05	0.145	0.11	-5.87	-9.09	-2.77	0.36	3.09	6.51	0.16	0.23	0.75	4.12	0.16
SW4-C2	0.448	23.19	-62.53	0.99	0.13	7.13	-2.75	-6.88	0.64	25.26	-55.83	1.46	0.10	6.05	-3.22	1.08
SW4-C3	0.243	-13.96	0.48	5.54	0.16	3.66	-4.65	3.56	0.45	-11.35	0.53	4.08	0.11	2.5	0.35	5.13
SW4-C4	4.69	243.25	23.65	-101.05	0.05	-3.29	-2.43	1.8	5.94	93.56	5.77	-53.75	0.51	6.53	2.8	1.12
O2-Ego	0.24	1.00	-0.225	0.484	-	-	-	-	0.31	3.45	-3.21	1.73	0.19	0.65	1.1	0.51
O2-Cuboid	0.19	1.42	-8.45	0.44	-	-	-	-	0.51	1.94	-22.83	1.75	0.15	0.95	6.77	0.80
O2-Cube	0.48	19.35	-7.23	12.03	-	-	-	-	1.41	37.22	-27.83	19.72	0.80	10.35	5.13	9.56

Synthesized Multimotion and Modeling dataset(SMMD) Evaluation



Real-world dataset Evaluation (RGB-D Input)

Real-world dataset Evaluation (solid-state LiDAR and monocular camera Input)



Conclusion

We present a novel optimization framework that integrates the 3D tracking and modeling of both static and dynamic rigid objects. Through a comprehensive analysis, we identify the limitations of the original global parameterization method for quadric in the dynamic object modeling problem. To address these limitations, we introduce an object-centric dual quadric parameterization, which allows for the estimation of both static and dynamic quadric within a unified model. Our framework outperforms existing methods on diverse datasets by leveraging the SQI algorithm and a 9 DoF object state estimation algorithm based on the dual sliding window framework with hybrid constraints. Moreover, we extend the applicabilityof our framework to indoor and outdoor environments by proposing solutions that combine pure vision and visual LiDAR fusion.