Optimized Adaptive System for Intelligent SLAM (OASIS)

Alles Rebel

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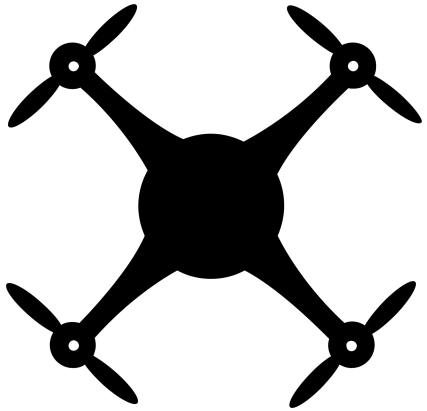
Mobile Autonomous Systems

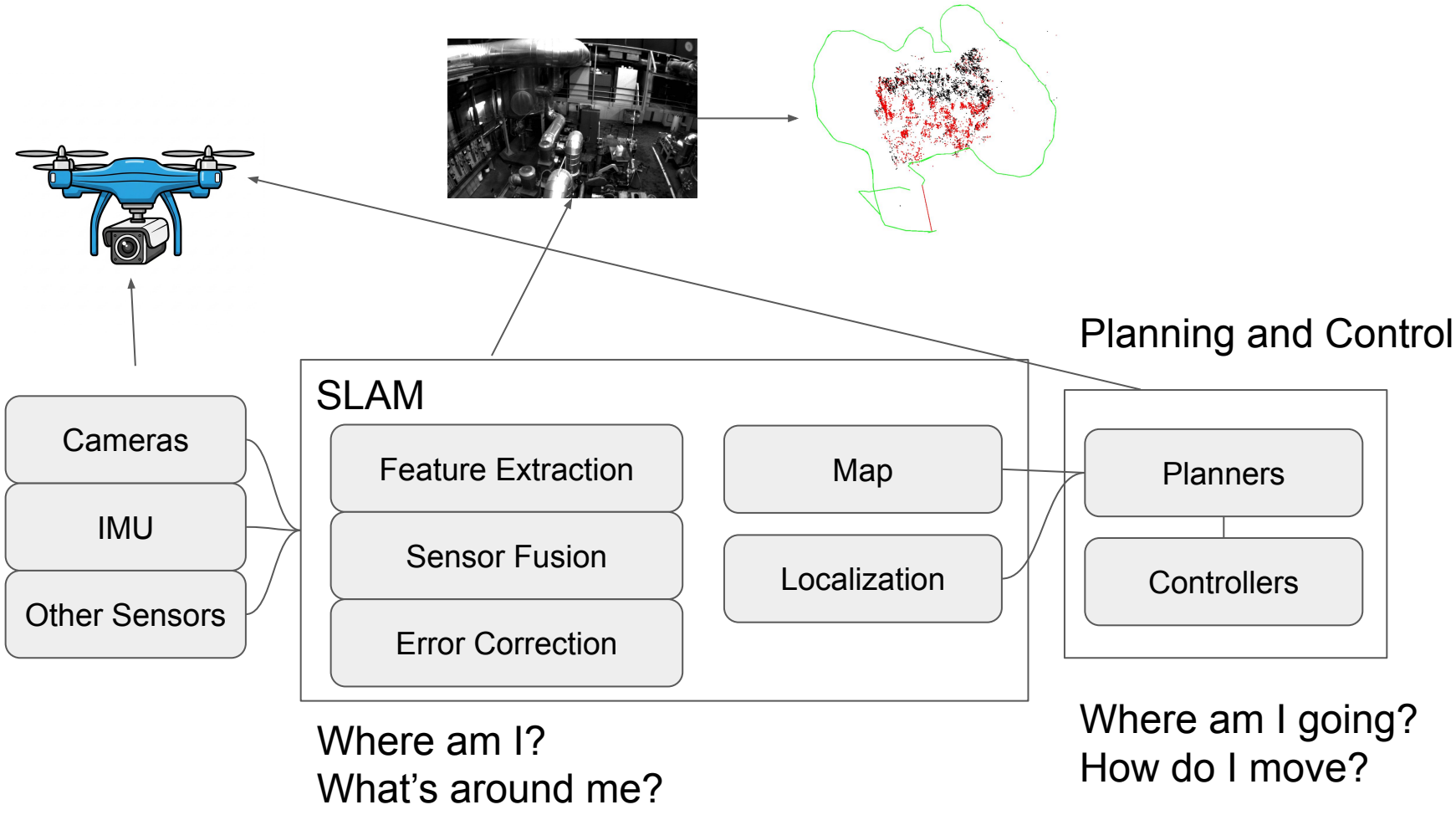


A cyber physical system capable of:

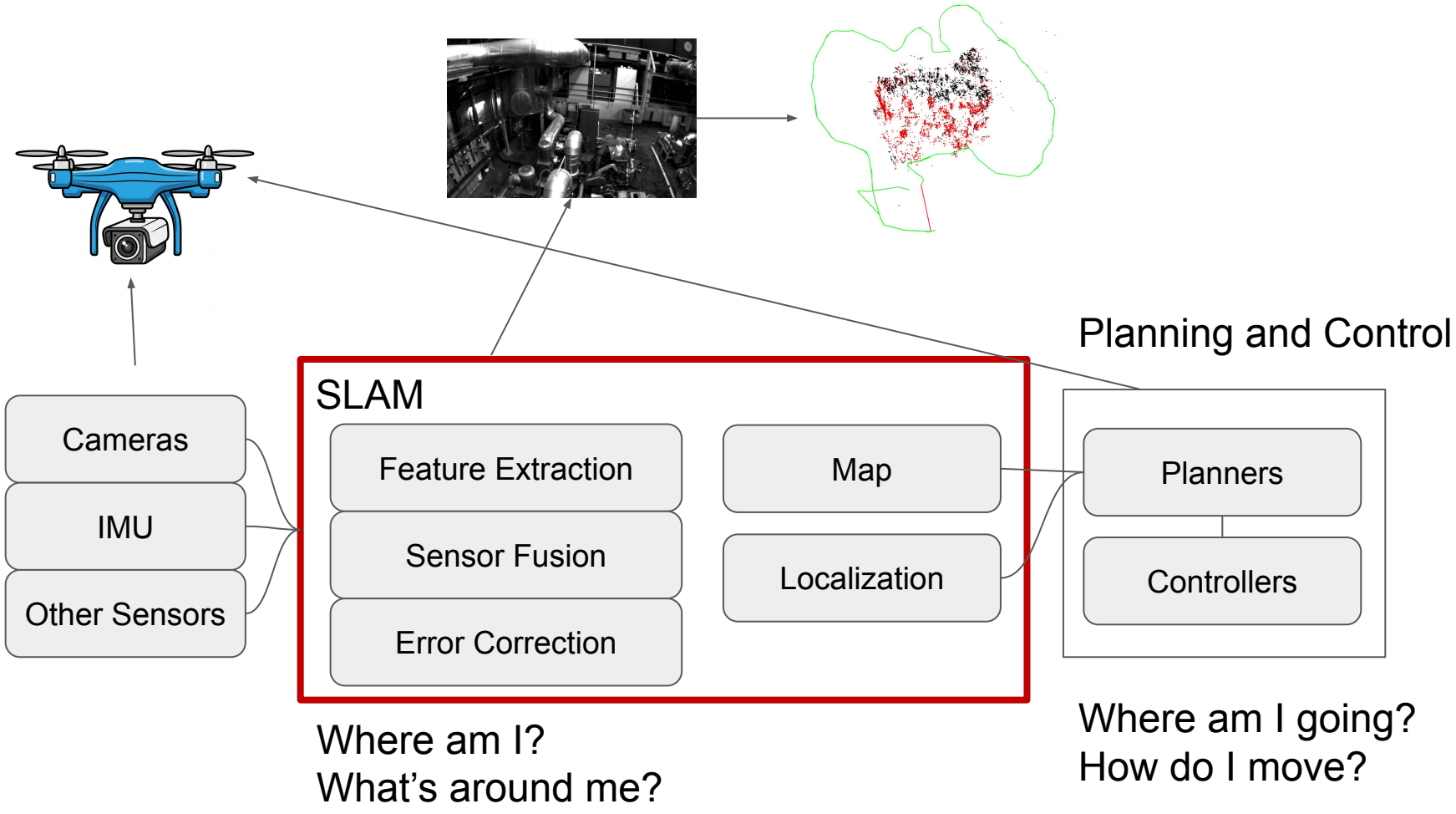
- Perceiving
- Reasoning
- Acting

Without Human Intervention!

Mobile Autonomy

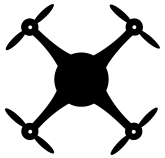


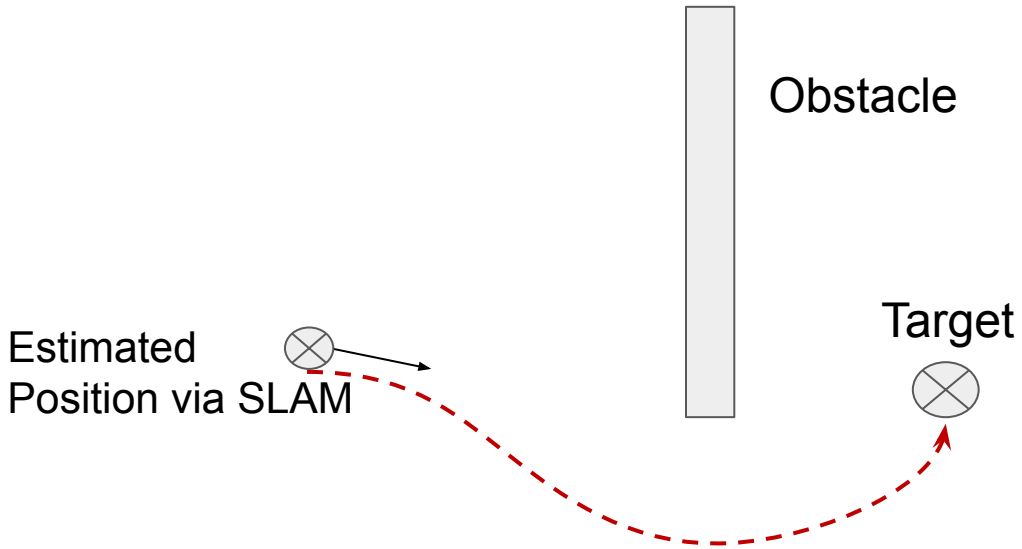
Mobile Autonomy



SLAM Error Impact on Planning

MAV Navigation using
Mean Error + Vehicle
Size Constraint

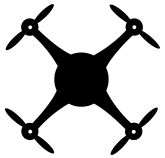


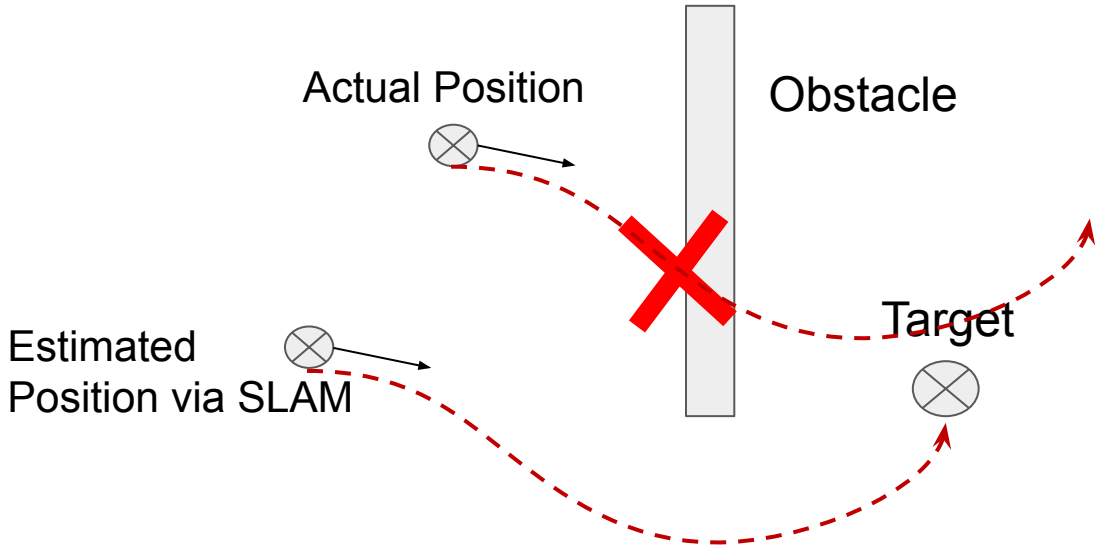


Planned Trajectory

SLAM Error Impact on Planning

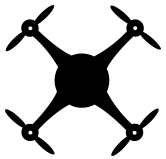
MAV Navigation using
Mean Error + Vehicle
Size Constraint





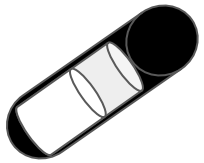
Planned Trajectory

System Constraints



Micro
Aerial
Vehicle

Compact
Ground
Robot



Micro
Autonomous
Underwater
Vehicle

	Weight	Power	Dimensions
MAV	~250 g	~2.4 Ah	30 × 30 × 10 cm
CGR	~2.5 Kg	~2.5 Ah	40 × 30 × 20 cm
MAUV	~5 Kg	~0.5 Ah	45 x 12 x 12 cm

ORB-SLAM

ORB-SLAM

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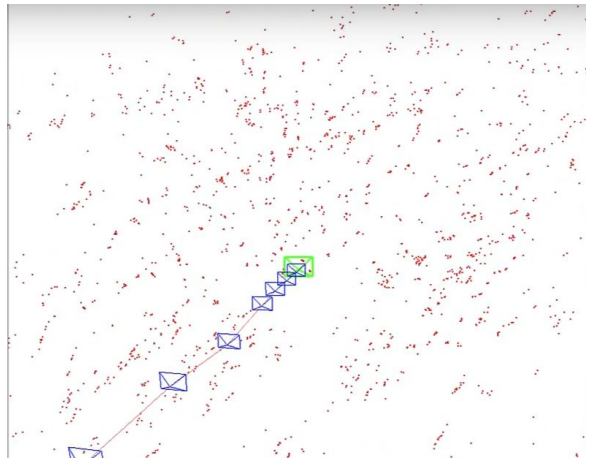
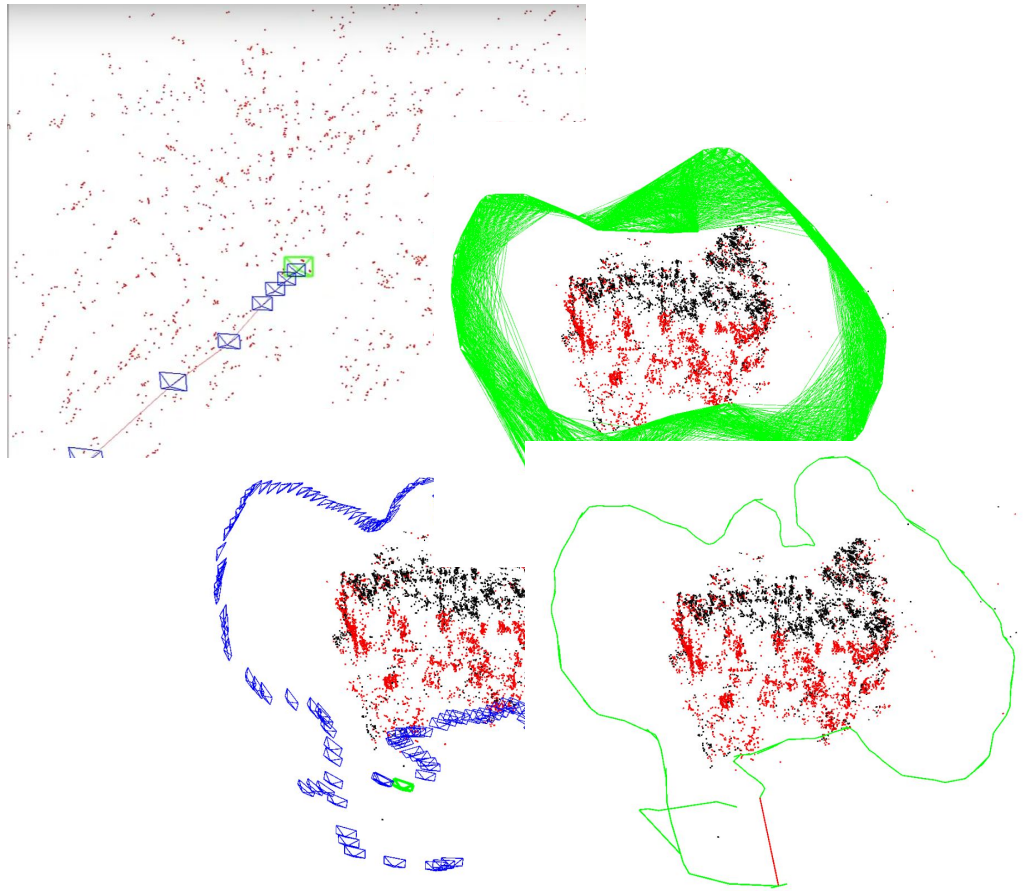
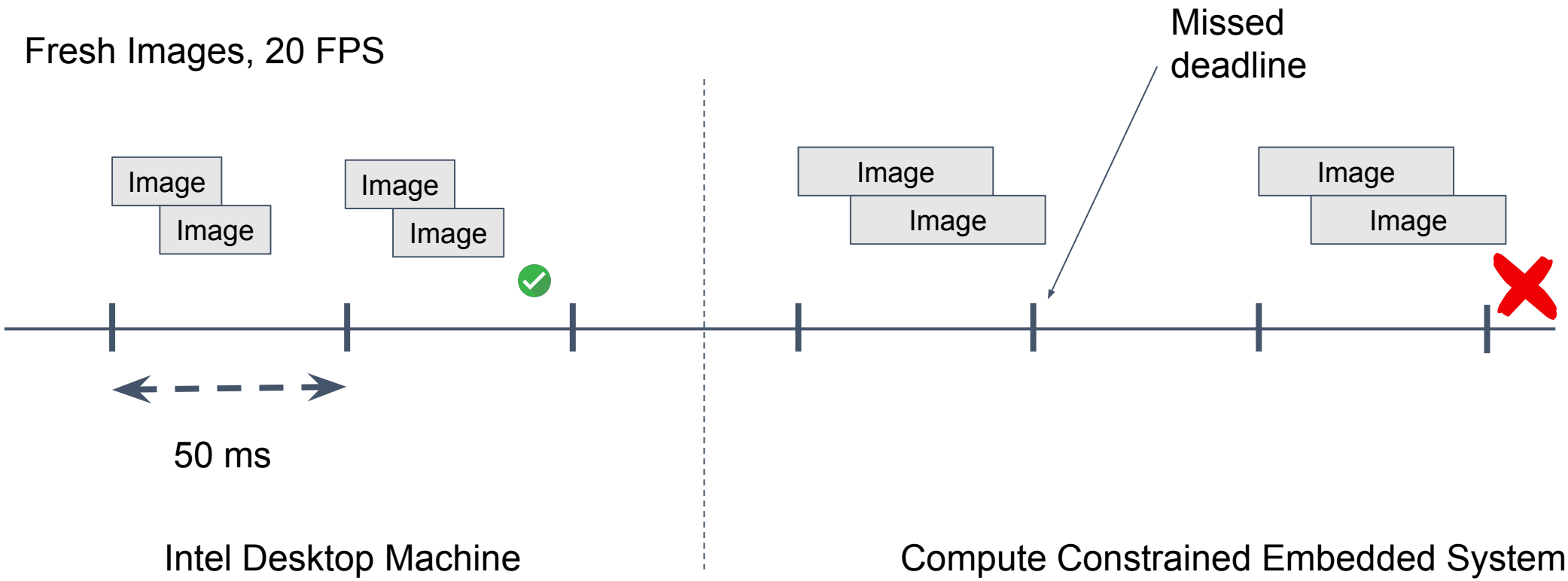


ORB-SLAM



Motivation - Realtime Deadlines



Motivation - Realtime Deadlines

Dataset	Frames	Intel Dropped (%)	Intel FPS	Intel Max ATE (m)	Jetson Dropped (%)	Jetson FPS	Jetson Max ATE (m)
MH01	3682	4.1 (0.11%)	19.98	0.14362	943.1 (25.61%)	15.83	0.27469
MH02	3040	0.8 (0.03%)	19.99	0.1385	848.9 (27.92%)	15.36	0.33743
MH03	2700	0.5 (0.02%)	20.0	0.12137	52.3 (1.94%)	19.79	1.53252
MH04	2033	0.6 (0.03%)	19.99	0.2122	147.5 (7.26%)	20.0	0.50394
MH05	2273	1.7 (0.07%)	19.98	0.15516	113.2 (4.98%)	19.17	0.25416
V101	2912	0.0 (0.00%)	20.0	0.07487	236.1 (8.11%)	18.67	0.44819
V102	1710	0.0 (0.00%)	20.0	0.09623	328.6 (19.22%)	16.77	0.1422
V103	2149	0.0 (0.00%)	20.0	0.12213	174.9 (8.14%)	18.61	0.84995
V201	2280	0.0 (0.00%)	20.0	0.10536	207.0 (9.08%)	18.86	1.53285
V202	2348	0.0 (0.00%)	20.0	0.12008	178.2 (7.59%)	18.78	0.39721
V203	1922	0.0 (0.00%)	20.0	0.23502	119.3 (6.21%)	18.88	0.33233

Dataset	Frames	Intel Dropped (%)	Intel FPS	Intel Max ATE (m)	Jetson Dropped (%)	Jetson FPS	Jetson Max ATE (m)
Average	-	0.7 (0.0%)	20.0	0.1386	304.5 (11.5%)	18.1	0.92824

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FPS drops → increased max error!

~2 FPS drop → worst case trajectory error increased **~0.8 m**

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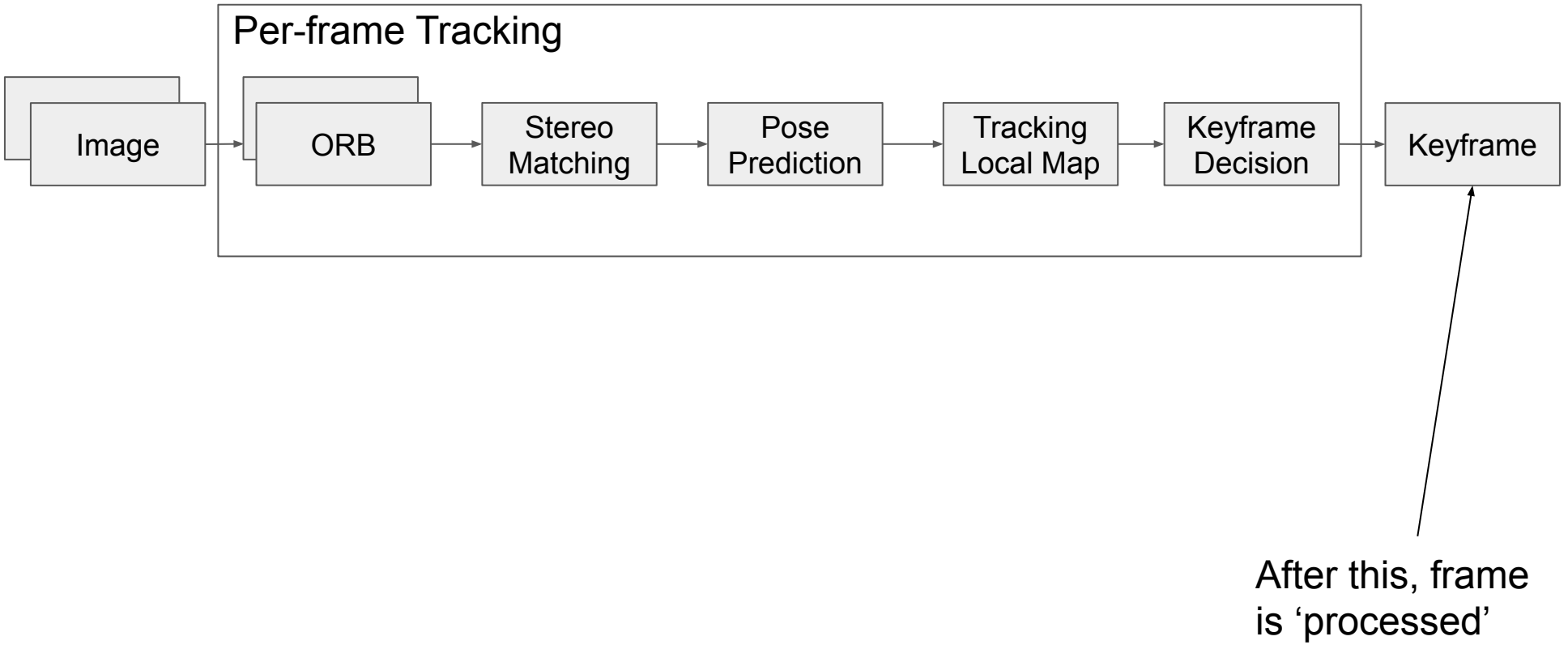
ORB-SLAM Tracking

Simultaneous **L**ocalization **a**nd **M**apping



ORB-SLAM Tracking

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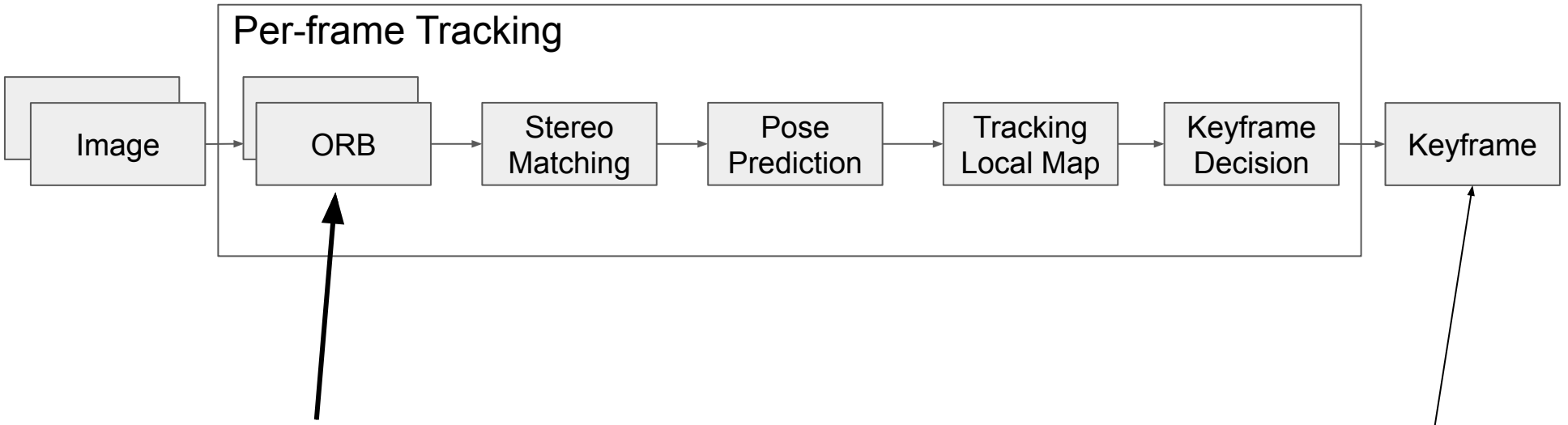
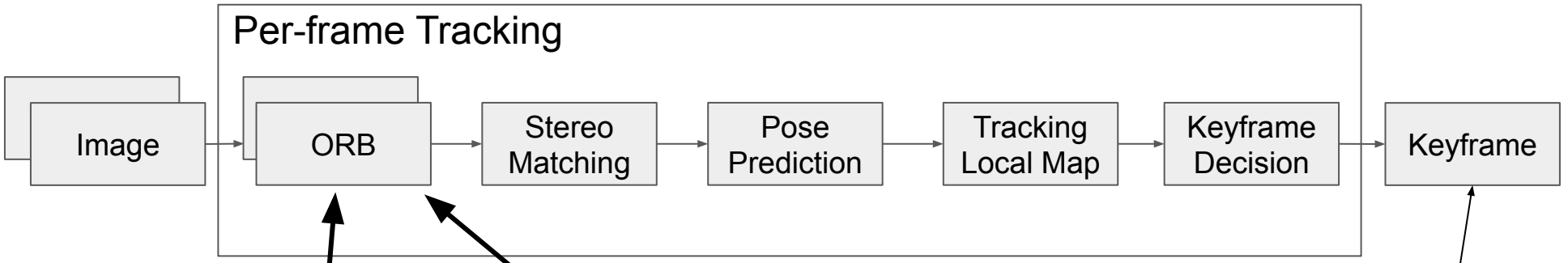


Dominates computational budget

After this, frame is ‘processed’

ORB-SLAM Tracking

Simultaneous **L**ocalization **a**nd **M**apping

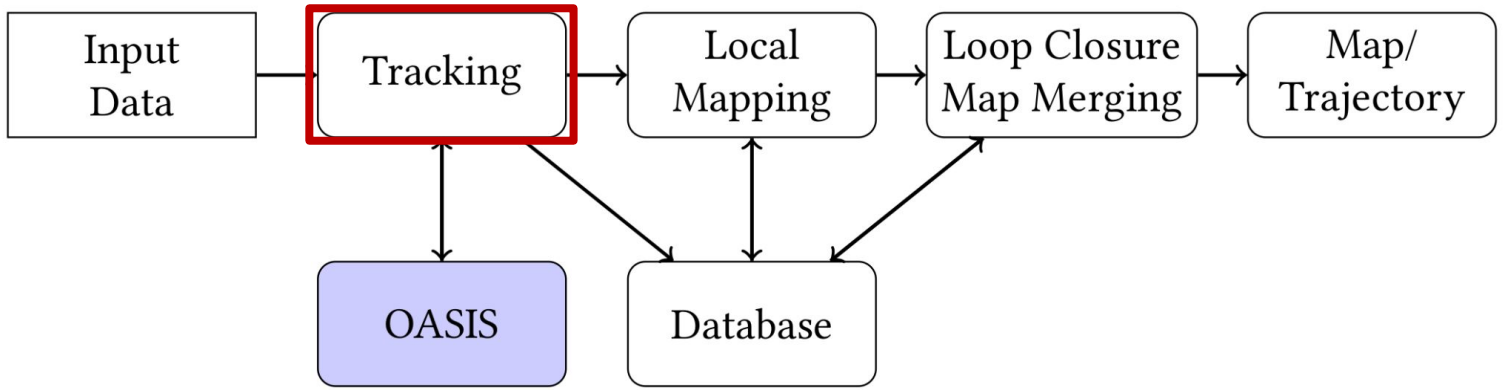


Dominates computational budget

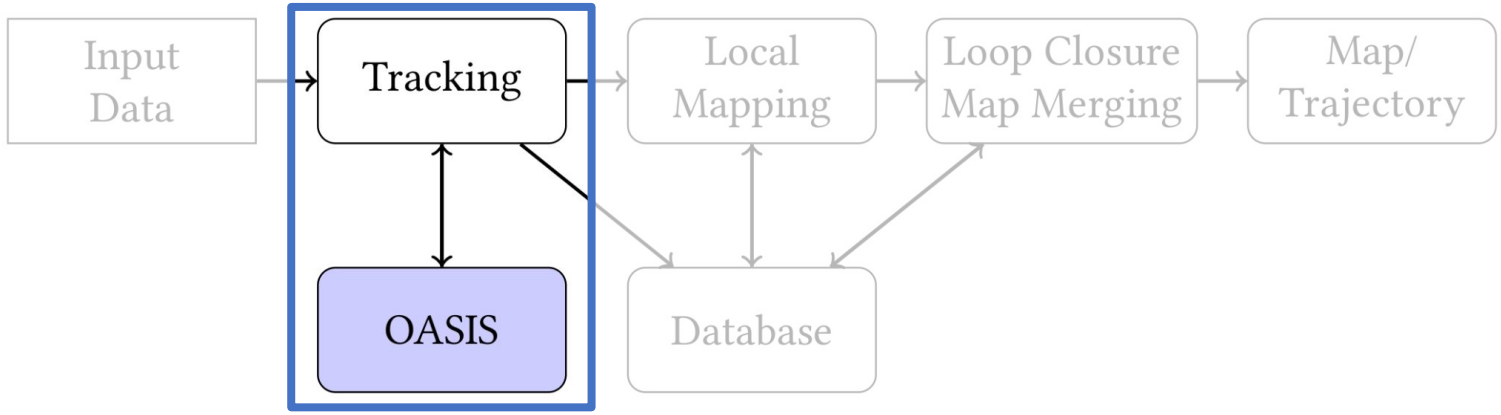
Varies with scene complexity

After this, frame is ‘processed’

OASIS


Input Data
Tracking
Local Mapping
Loop Closure Map Merging
Map/ Trajectory
OASIS
Database

OASIS


Input Data
Tracking
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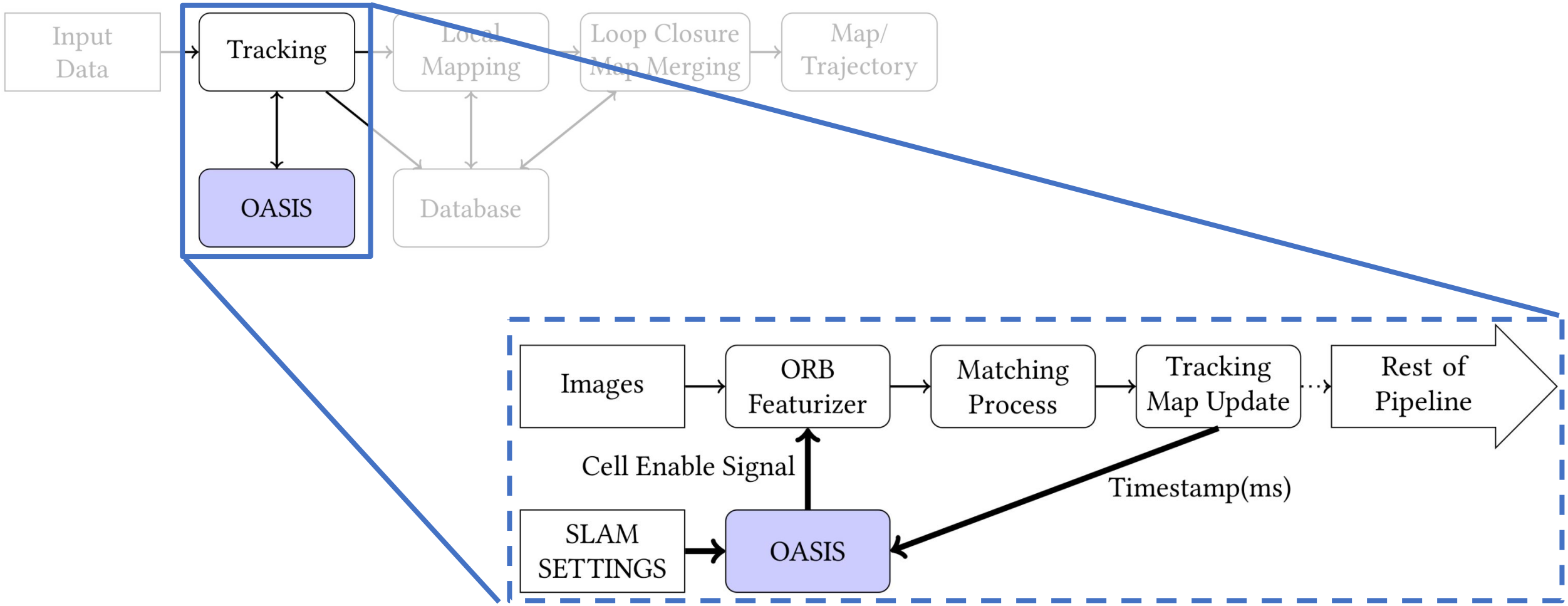
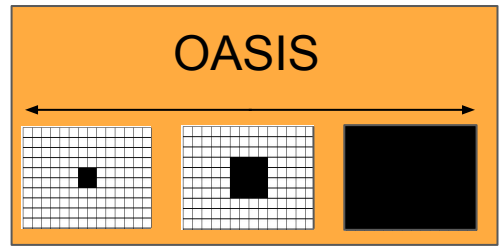
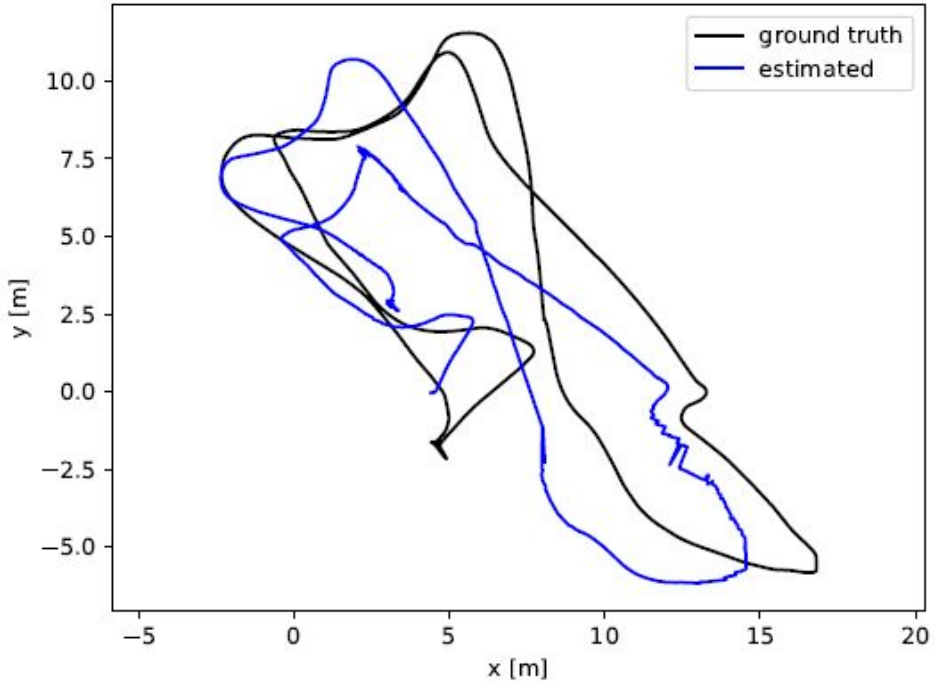
OASIS


Input Data
Tracking
Local Mapping
Loop Closure Map Merging
Map/ Trajectory
OASIS
Database
Images
ORB Featurizer
Matching Process
Tracking Map Update
Rest of Pipeline
Cell Enable Signal
Timestamp(ms)
SLAM SETTINGS
OASIS

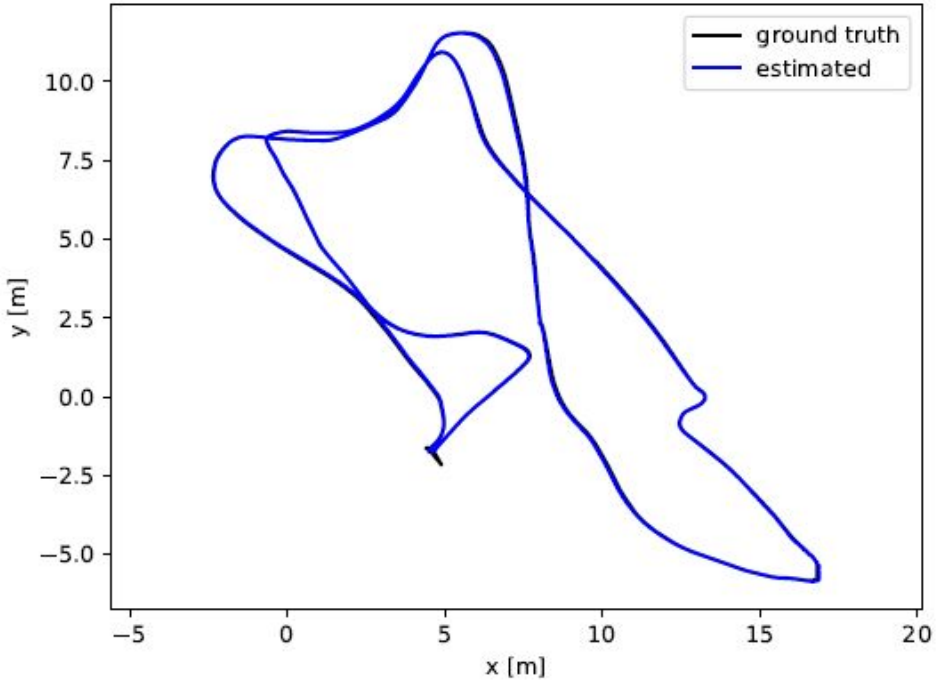
OASIS - Dynamic Masking



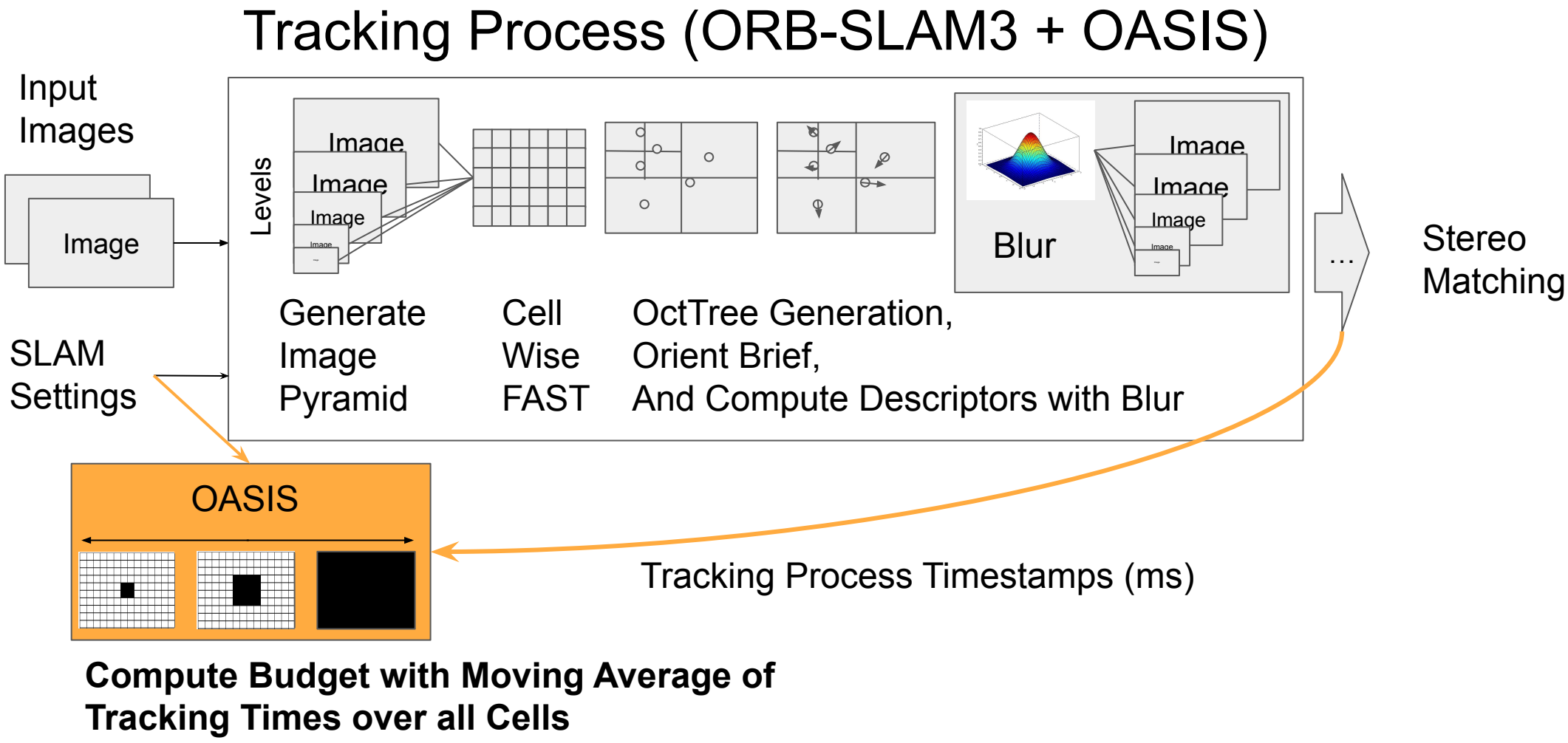
MH05 - Jetson - 2x2 Mask



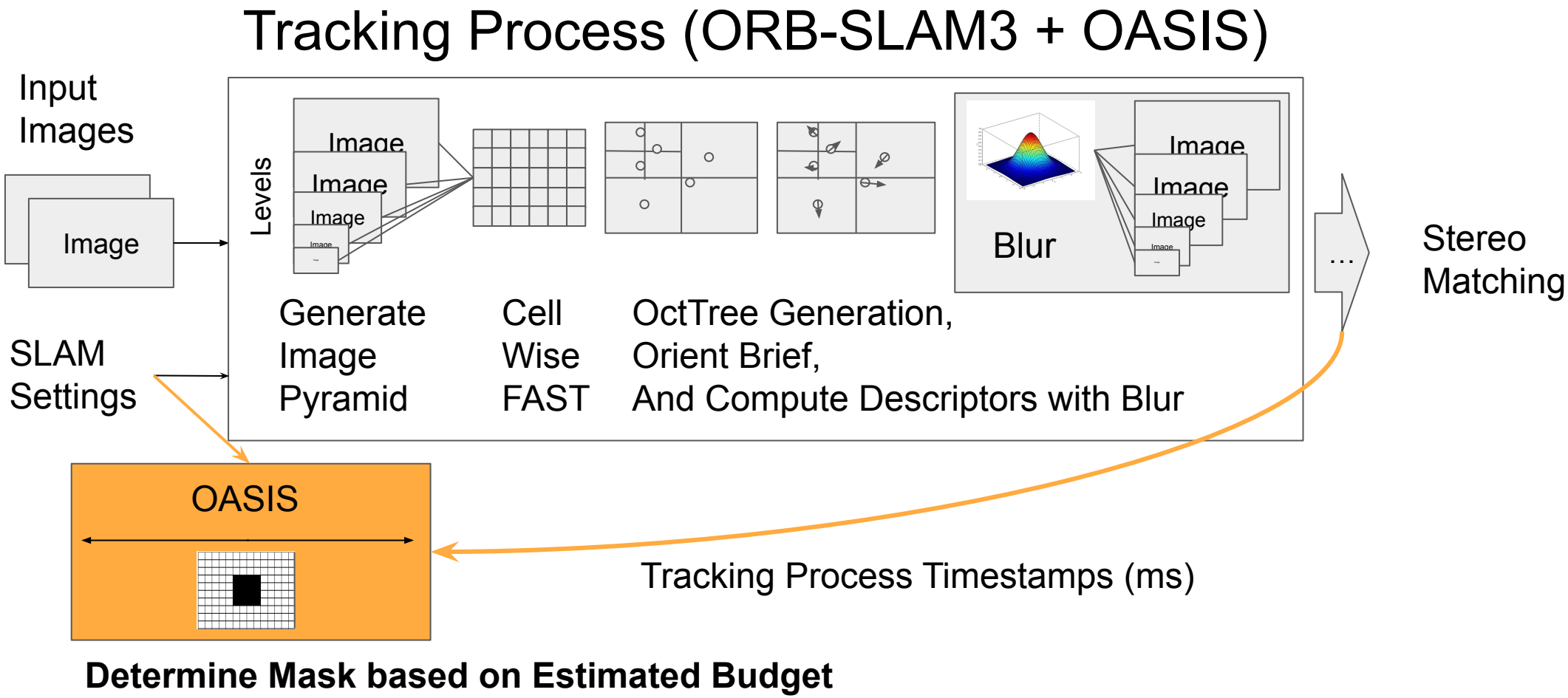
MH05 - Jetson - 12x12 Mask



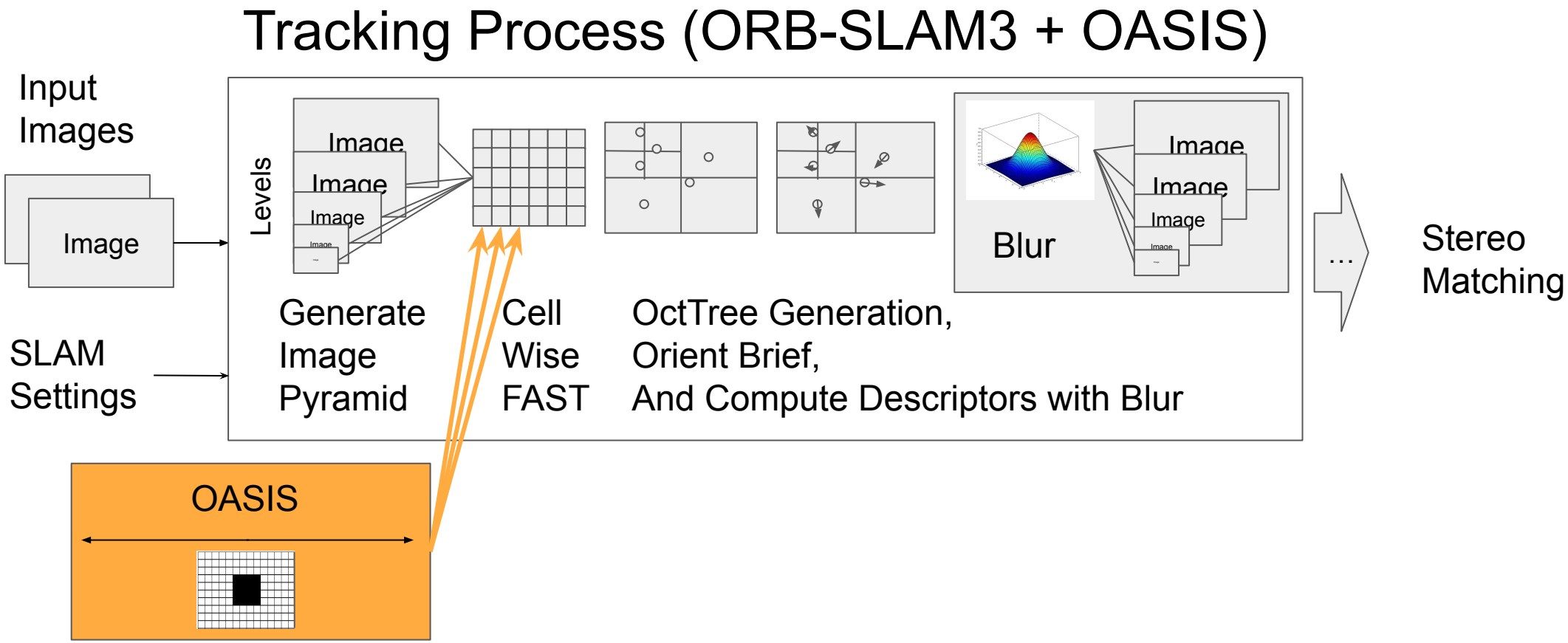
OASIS - Dynamic Masking



OASIS - Dynamic Masking

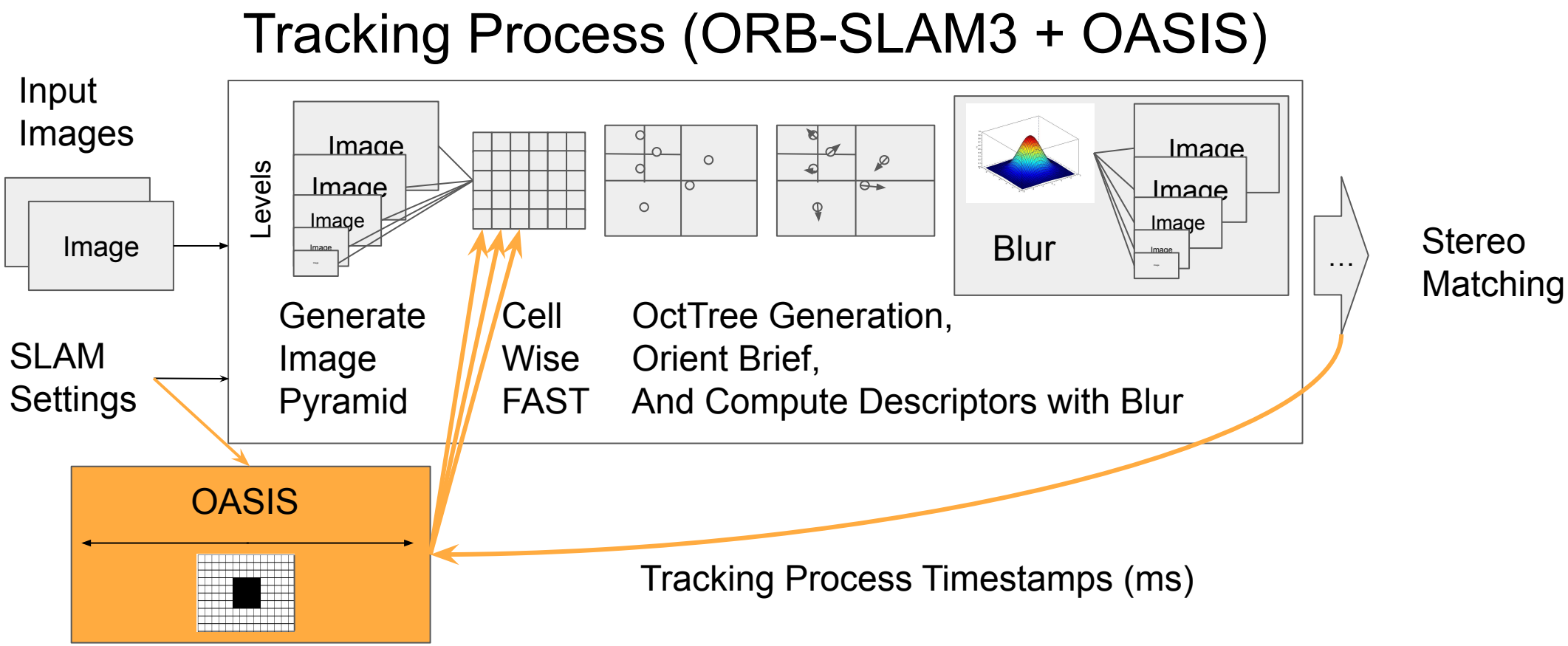


OASIS - Dynamic Masking



Binary Signal for Cells during Frame Processing (based on Mask)

OASIS - Dynamic Masking



Evaluation - Setup

ETH Zurich EuRoC MAV Dataset

- 11 Indoor Industrial Captures + Camera Calibration and Intrinsics
- 20 FPS, 752 x 480 Stereo Images
- 200 Hz IMU Samples
- Ground truth measurements

Running ORB-SLAM3 on two platforms:

Specification	Details
Jetson Orin NX 16GB Developer Kit	
CPU	8-core Arm Cortex-A78AE
Memory	16 GB 128-bit LPDDR5
Power Limit	25W
Host Machine	
CPU	10-core Intel Core i7-6950X
Memory	64 GB 256-bit DDR4
Power Limit	140W

Each Trial Configuration Performed 10 times
Randomized Trial Execution
Same SLAM Configuration used across all trials

Evaluation - Jetson Baseline

Jetson Orin NX 16GB Developer Kit											
Dataset	Realtime Baseline			OASIS		Mean ATE (m)		Max ATE (m)		Improvement (%)	
	Frames	Dropped (%)	FPS	Mask (Mean ± Std)	Dropped (%)	Realtime	OASIS	Realtime	OASIS	Mean ATE	Max ATE
MH01	3682	943.1 (25.61%)	15.83	12.23 ± 4.51	**0.0 (0.00%)**	**0.06805**	0.07001	0.27469	**0.18119**	**-2.9%**	**34.0%**
MH02	3040	848.9 (27.92%)	15.36	14.37 ± 5.38	**0.0 (0.00%)**	0.07195	**0.04817**	0.33743	**0.13826**	**33.0%**	**59.0%**
MH03	2700	52.3 (1.94%)	19.70	18.64 ± 4.37	**0.0 (0.00%)**	0.07155	**0.04998**	1.53252	**0.12712**	**30.1%**	**91.7%**
MH04	2033	147.5 (7.26%)	18.79	18.35 ± 4.34	**0.0 (0.00%)**	0.07345	**0.06078**	0.50904	**0.20357**	**17.3%**	**60.0%**
MH05	2273	113.2 (4.98%)	19.17	19.29 ± 3.94	**0.0 (0.00%)**	0.10554	**0.05956**	0.25416	**0.15856**	**43.6%**	**37.6%**
V101	2912	236.1 (8.11%)	18.67	18.51 ± 4.37	**0.0 (0.00%)**	0.05487	**0.02746**	0.44819	**0.06578**	**49.9%**	**85.3%**
V102	1710	328.6 (19.22%)	16.77	16.69 ± 4.61	**0.0 (0.00%)**	0.06395	**0.05821**	0.14220	**0.12282**	**9.0%**	**13.6%**
V103	2149	174.9 (8.14%)	18.61	18.96 ± 4.02	**0.0 (0.00%)**	0.10260	**0.04890**	0.84995	**0.12019**	**52.3%**	**85.9%**
V201	2280	207.0 (9.08%)	18.56	14.00 ± 4.80	**0.0 (0.00%)**	0.22014	**0.05833**	5.13288	**0.10164**	**73.5%**	**98.0%**
V202	2348	178.2 (7.59%)	18.78	15.59 ± 4.95	**0.0 (0.00%)**	0.06498	**0.05642**	0.39721	**0.12036**	**13.2%**	**69.7%**
V203	1922	119.3 (6.21%)	18.88	19.46 ± 3.77	**0.0 (0.00%)**	0.07924	**0.06357**	0.33233	**0.17238**	**19.8%**	**48.1%**
Average	–	304.5 (11.5%)	18.10	16.92 ± 4.46	**0.0 (0.00%)**	0.08876	**0.05467**	0.92824	**0.13744**	**30.8%**	**62.1%**

Evaluation - Jetson Baseline

Jetson Orin NX 16GB Developer Kit											
Dataset	Realtime Baseline			OASIS		Mean ATE (m)		Max ATE (m)		Improvement (%)	
	Frames	Dropped (%)	FPS	Mask (Mean ± Std)	Dropped (%)	Realtime	OASIS	Realtime	OASIS	Mean ATE	Max ATE
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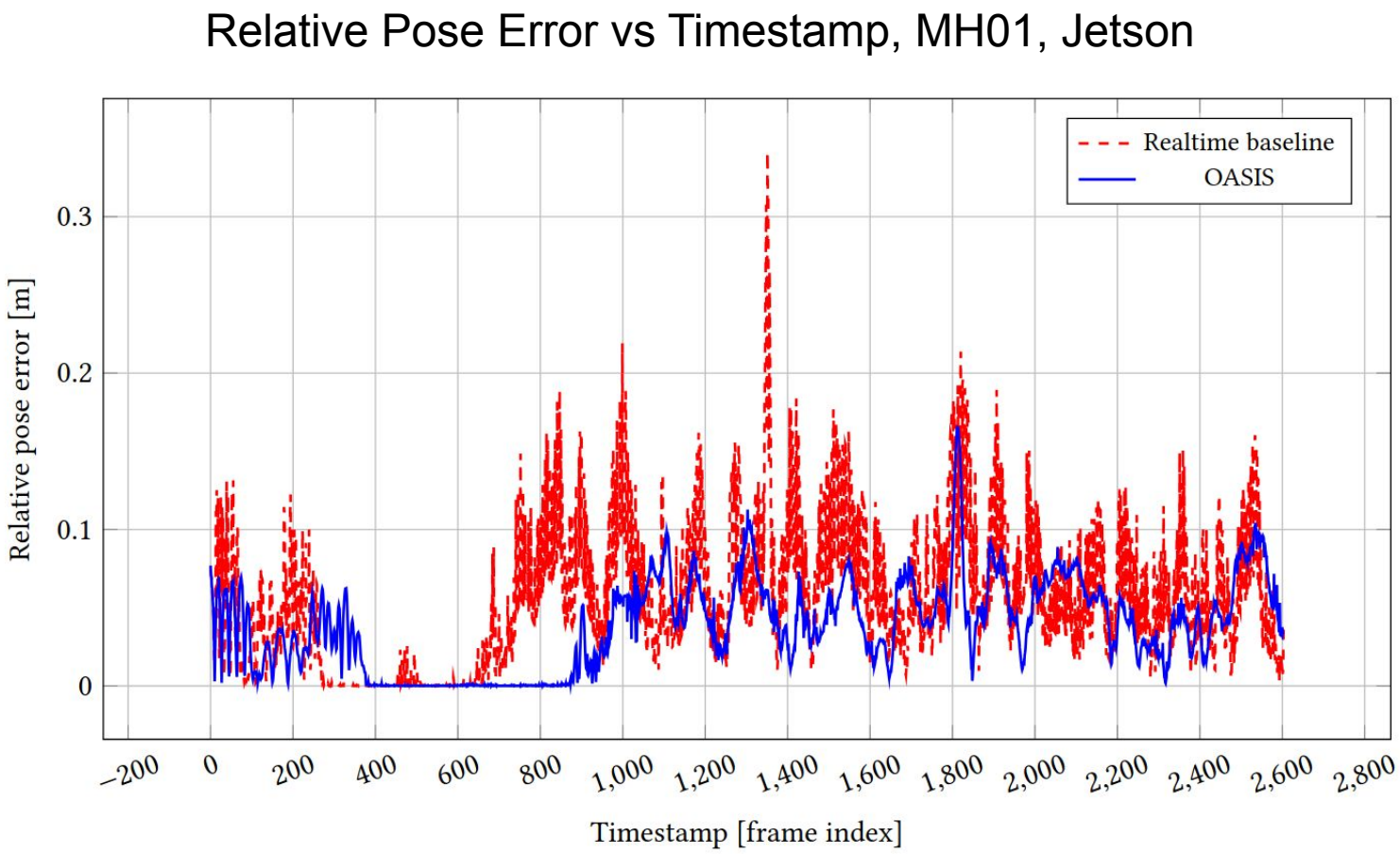
MH03	2700	52.3 (1.94%)	19.70	18.64 ± 4.37	0.0 (0.00%)	0.07155	**0.04998**	1.53252	**0.12712**	**30.1%**	**91.7%**
MH04	2033	147.5 (7.26%)	18.79	18.35 ± 4.34	0.0 (0.00%)	0.07345	**0.06078**	0.50904	**0.20357**	**17.3%**	**60.0%**
MH05	2273	113.2 (4.98%)	19.17	19.29 ± 3.94	0.0 (0.00%)	0.10554	**0.05956**	0.25416	**0.15856**	**43.6%**	**37.6%**
V101	2912	236.1 (8.11%)	18.67	18.51 ± 4.37	0.0 (0.00%)	0.05487	**0.02746**	0.44819	**0.06578**	**49.9%**	**85.3%**
V102	1710	328.6 (19.22%)	16.77	16.69 ± 4.61	0.0 (0.00%)	0.06395	**0.05821**	0.14220	**0.12282**	**9.0%**	**13.6%**
V103	2149	174.9 (8.14%)	18.61	18.96 ± 4.02	0.0 (0.00%)	0.10260	**0.04890**	0.84995	**0.12019**	**52.3%**	**85.9%**
V201	2280	207.0 (9.08%)	18.56	14.00 ± 4.80	0.0 (0.00%)	0.22014	**0.05833**	5.13288	**0.10164**	**73.5%**	**98.0%**
V202	2348	178.2 (7.59%)	18.78	15.59 ± 4.95	0.0 (0.00%)	0.06498	**0.05642**	0.39721	**0.12036**	**13.2%**	**69.7%**
V203	1922	119.3 (6.21%)	18.88	19.46 ± 3.77	0.0 (0.00%)	0.07924	**0.06357**	0.33233	**0.17238**	**19.8%**	**48.1%**
Average	–	304.5 (11.5%)	18.10	16.92 ± 4.46	0.0 (0.00%)	0.08876	**0.05467**	0.92824	**0.13744**	**30.8%**	**62.1%**

Evaluation - Jetson Baseline

Jetson Orin NX 16GB Developer Kit											
Dataset	Realtime Baseline			OASIS		Mean ATE (m)		Max ATE (m)		Improvement (%)	
	Frames	Dropped (%)	FPS	Mask (Mean ± Std)	Dropped (%)	Realtime	OASIS	Realtime	OASIS	Mean ATE	Max ATE
MH01	3682	943.1 (25.61%)	15.83	12.23 ± 4.51	0.0 (0.00%)	0.06805	0.07001	0.27469	0.18119	-2.9%	34.0%
V201	2280	207.0 (9.08%)	18.56	14.00 ± 4.80	0.0 (0.00%)	0.22014	0.05833	5.13288	0.10164	73.5%	98.0%
V202	2348	178.2 (7.59%)	18.78	15.59 ± 4.95	0.0 (0.00%)	0.06498	0.05642	0.39721	0.12036	13.2%	69.7%
V203	1922	119.3 (6.21%)	18.88	19.46 ± 3.77	0.0 (0.00%)	0.07924	0.06357	0.33233	0.17238	19.8%	48.1%
Average	–	304.5 (11.5%)	18.10	16.92 ± 4.46	0.0 (0.00%)	0.08876	0.05467	0.92824	0.13744	30.8%	62.1%

11.5% →0% deadline misses with OASIS
reduced mean ATE 30%, max ATE 60% over baseline

OASIS Localization Results



OASIS vs SotA Realtime

Dataset	Realtime PID		Realtime ω		OASIS	
	Mean	Max	Mean	Max	Mean	Max
MH01	**0.05580**	0.22561	0.06893	0.19881	0.07001	0.18119
MH02	0.05345	0.18994	0.04654	0.18109	0.04817	0.13826
MH03	0.06769	0.90827	0.07157	1.47305	0.04998	0.12712
MH04	0.07906	0.68295	0.06967	0.66827	0.06078	0.20357
MH05	0.09816	0.26446	0.09723	0.22950	**0.05956**	0.15856
V101	0.03684	0.36629	0.03325	0.20681	0.02746	0.06578
V102	0.05947	0.11463	0.05952	0.11700	**0.05821**	0.12282
V103	0.07280	0.92312	0.11447	0.47894	**0.04890**	0.12019
V201	0.17931	3.68673	0.14795	2.84008	0.05833	**0.10164**
V202	0.06879	0.59796	0.06419	0.67893	0.05642	0.12036
V203	0.07344	0.51727	0.09092	0.50070	**0.06357**	**0.17238**
Average	**0.07680**	**0.77066**	**0.07857**	**0.68847**	**0.05467**	**0.13744**

OASIS vs SotA Realtime

Dataset	Realtime PID		Realtime ω		OASIS	
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Average	**0.07680**	**0.77066**	**0.07857**	**0.68847**	**0.05467**	**0.13744**

OASIS reduces mean error by ~30% and worst-case error by ~70%

OASIS vs SotA Optimal

Dataset	PID		ω		Fixed Mask 4x4		Fixed Mask 6x6		OASIS	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
MH01	0.06193	0.15124	0.06121	**0.14756**	0.08646	0.19617	0.07071	0.17034	0.07001	0.18119
MH02	**0.04124**	**0.10936**	0.04174	0.11118	0.07912	0.50470	0.04637	0.14912	0.04817	0.13826
MH03	0.04776	0.12344	**0.04655**	**0.11926**	0.06321	0.14696	0.05001	0.12843	0.04998	0.12712
MH04	0.06180	0.21851	**0.05398**	0.22250	0.10116	0.36963	0.07072	**0.20209**	0.06078	0.20357
MH05	0.06023	**0.14615**	0.07123	0.16950	0.16432	0.39614	0.09982	0.25447	**0.05956**	0.15856
V101	0.02891	0.06886	0.02676	0.07098	0.03152	0.07574	**0.02572**	**0.06246**	0.02746	0.06578
V102	0.05920	0.09761	0.05953	**0.09623**	0.06105	0.13819	0.06002	0.11030	**0.05821**	0.12282
V103	0.04905	0.12569	0.04909	**0.11564**	0.05336	0.20734	0.05116	0.23117	**0.04890**	0.12019
V201	0.06395	0.11781	0.06643	0.11122	**0.05513**	0.11418	0.05584	0.11149	0.05833	**0.10164**
V202	**0.05468**	0.11710	0.05507	**0.11506**	0.05864	0.28833	0.05683	0.13271	0.05642	0.12036
V203	0.06807	0.49457	0.07169	0.23764	0.12834	2.10927	0.09207	0.38178	**0.06357**	**0.17238**
Average	**0.05426**	**0.16094**	**0.05484**	**0.13789**	**0.08021**	**0.41333**	**0.06175**	**0.17585**	**0.05467**	**0.13744**

OASIS vs SotA Optimal

Dataset	PID		ω		Fixed Mask 4x4		Fixed Mask 6x6		OASIS	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
MH01	0.06193	0.15124	0.06121	**0.14756**	0.08646	0.19617	0.07071	0.17034	0.07001	0.18119
MH02	**0.04124**	**0.10936**	0.04174	0.11118	0.07912	0.50470	0.04637	0.14912	0.04817	0.13826
MH03	0.04776	0.12344	**0.04655**	**0.11926**	0.06321	0.14696	0.05001	0.12843	0.04998	0.12712
MH04	0.06180	0.21851	**0.05398**	0.22250	0.10116	0.36963	0.07072	**0.20209**	0.06078	0.20357
MH05	0.06023	**0.14615**	0.07123	0.16950	0.16432	0.39614	0.09982	0.25447	**0.05956**	0.15856
V101	0.02891	0.06886	0.02676	0.07098	0.03152	0.07574	**0.02572**	**0.06246**	0.02746	0.06578
V102	0.05920	0.09761	0.05953	**0.09623**	0.06105	0.13819	0.06002	0.11030	**0.05821**	0.12282
V103	0.04905	0.12569	0.04909	**0.11564**	0.05336	0.20734	0.05116	0.23117	**0.04890**	0.12019
V201	0.06395	0.11781	0.06643	0.11122	**0.05513**	0.11418	0.05584	0.11149	0.05833	**0.10164**
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OASIS vs SotA Optimal

Dataset	PID		ω		Fixed Mask 4x4		Fixed Mask 6x6		OASIS	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
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V103	0.04905	0.12569	0.04909	**0.11564**	0.05336	0.20734	0.05116	0.23117	**0.04890**	0.12019
V201	0.06395	0.11781	0.06643	0.11122	**0.05513**	0.11418	0.05584	0.11149	0.05833	**0.10164**
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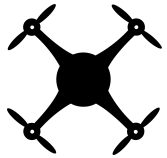
OASIS is near optimal w.r.t. SotA!

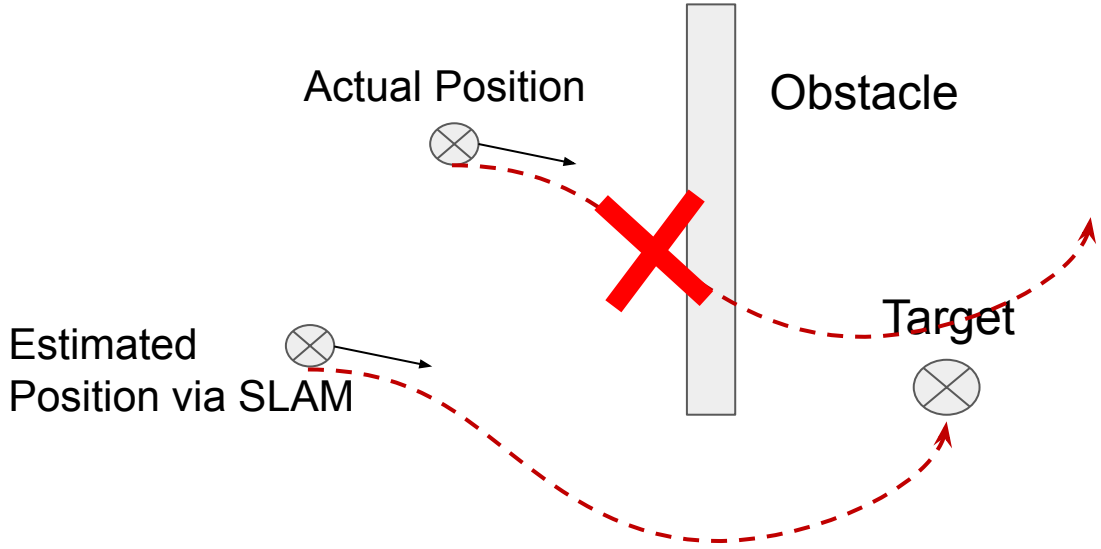
Summary

- Missed deadlines are bad
- OASIS prevents missed deadlines with runtime control
- OASIS improves worst case pose error

Revisiting Planning

MAV Navigation using
Mean Error + Vehicle
Size Constraint

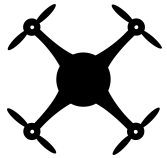


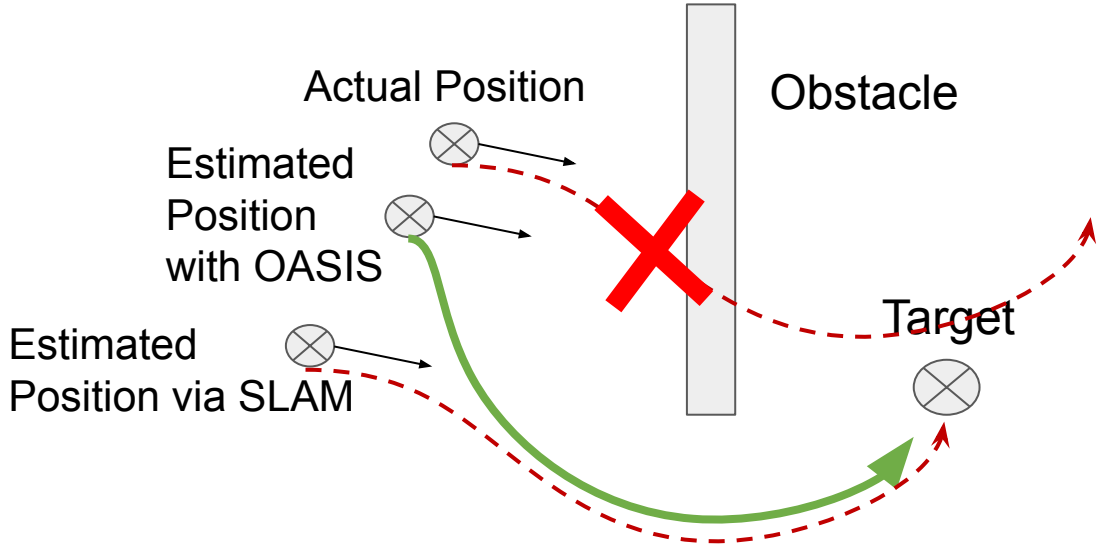


Planned Trajectory w/ SLAM

Revisiting Planning

MAV Navigation using
Mean Error + Vehicle
Size Constraint





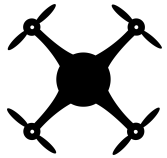
Collision Avoided!

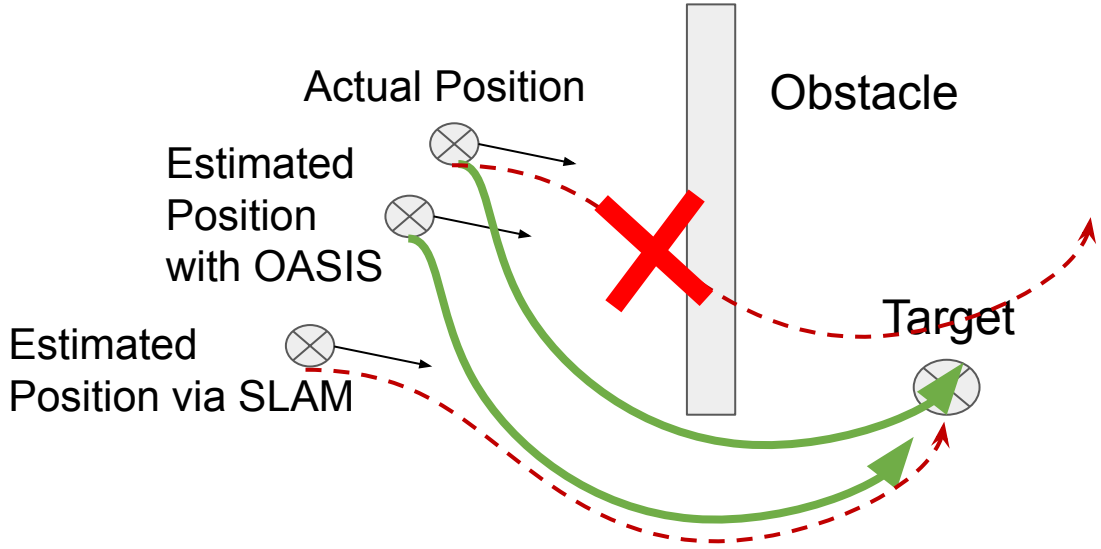
Planned Trajectory w/ SLAM

Planned Trajectory w/ OASIS

Revisiting Planning

MAV Navigation using
Mean Error + Vehicle
Size Constraint





Collision Avoided!

Planned Trajectory w/ SLAM

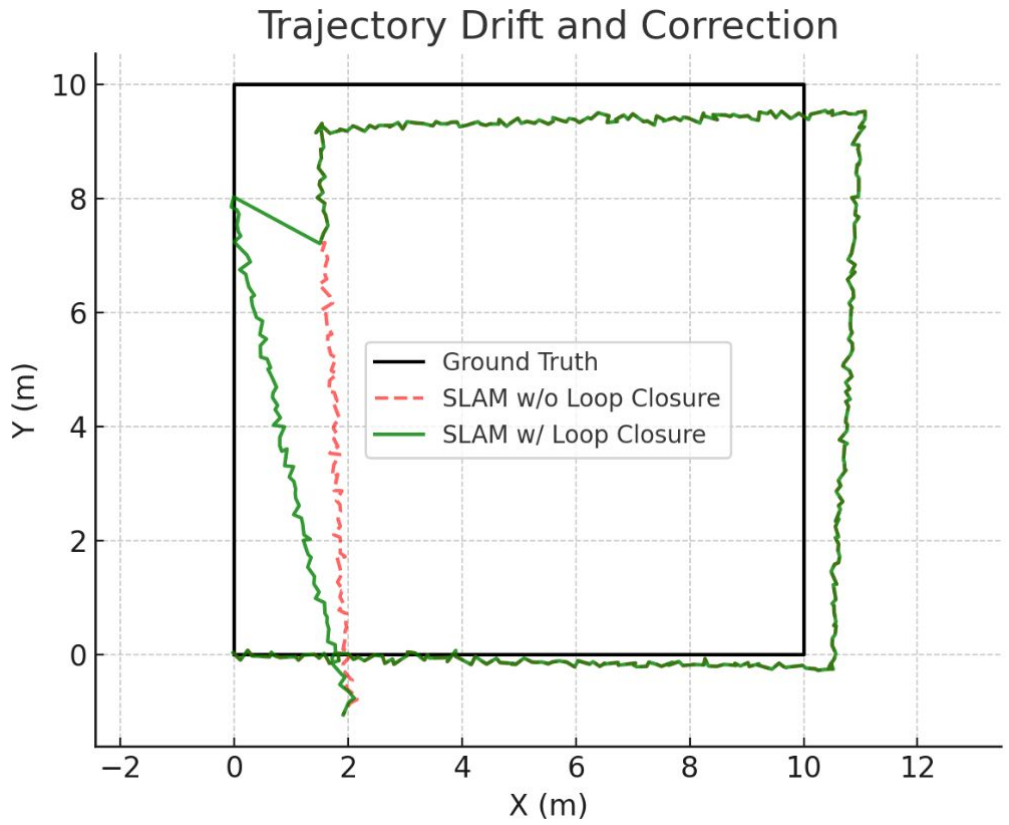
Planned Trajectory w/ OASIS

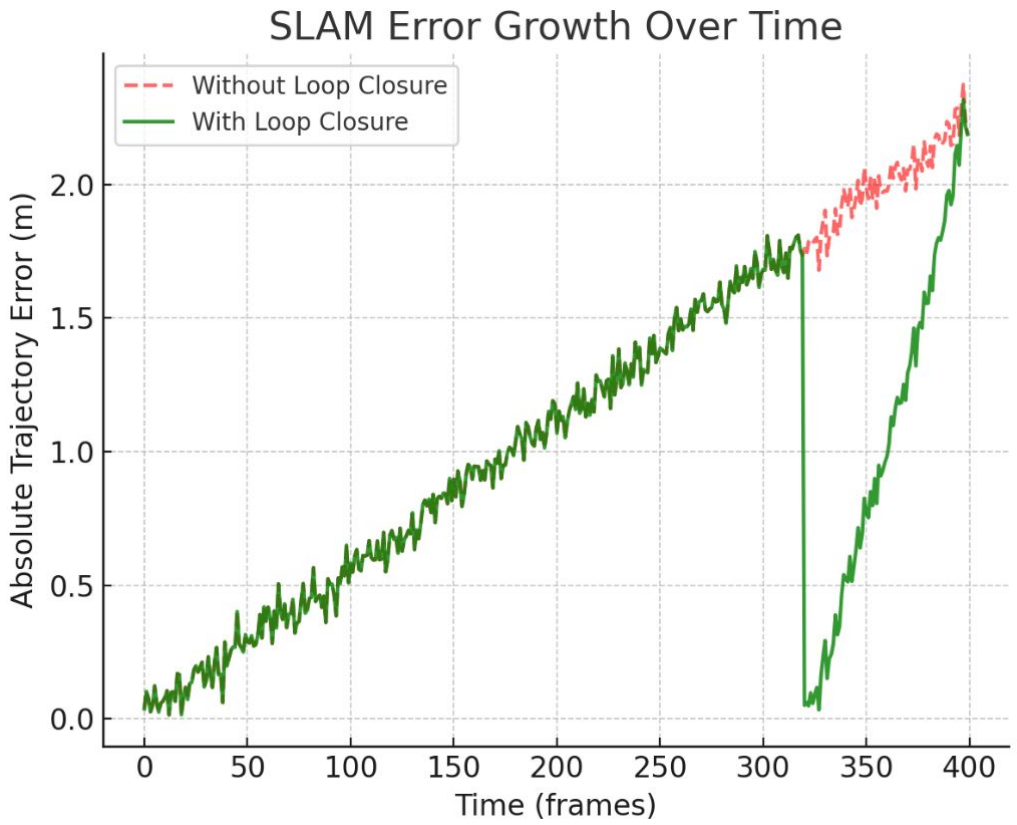
Thank you! Questions?

BACKUP

SLAM Error Accumulation

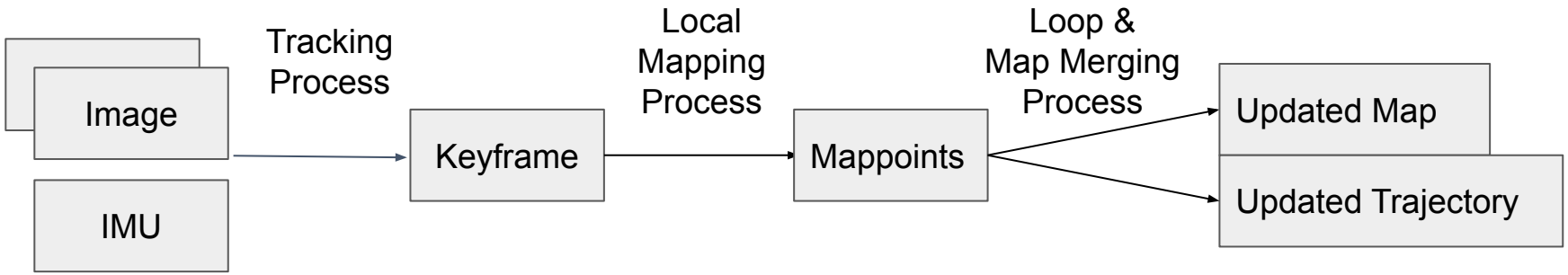
Simultaneous **L**ocalization **a**nd **M**apping

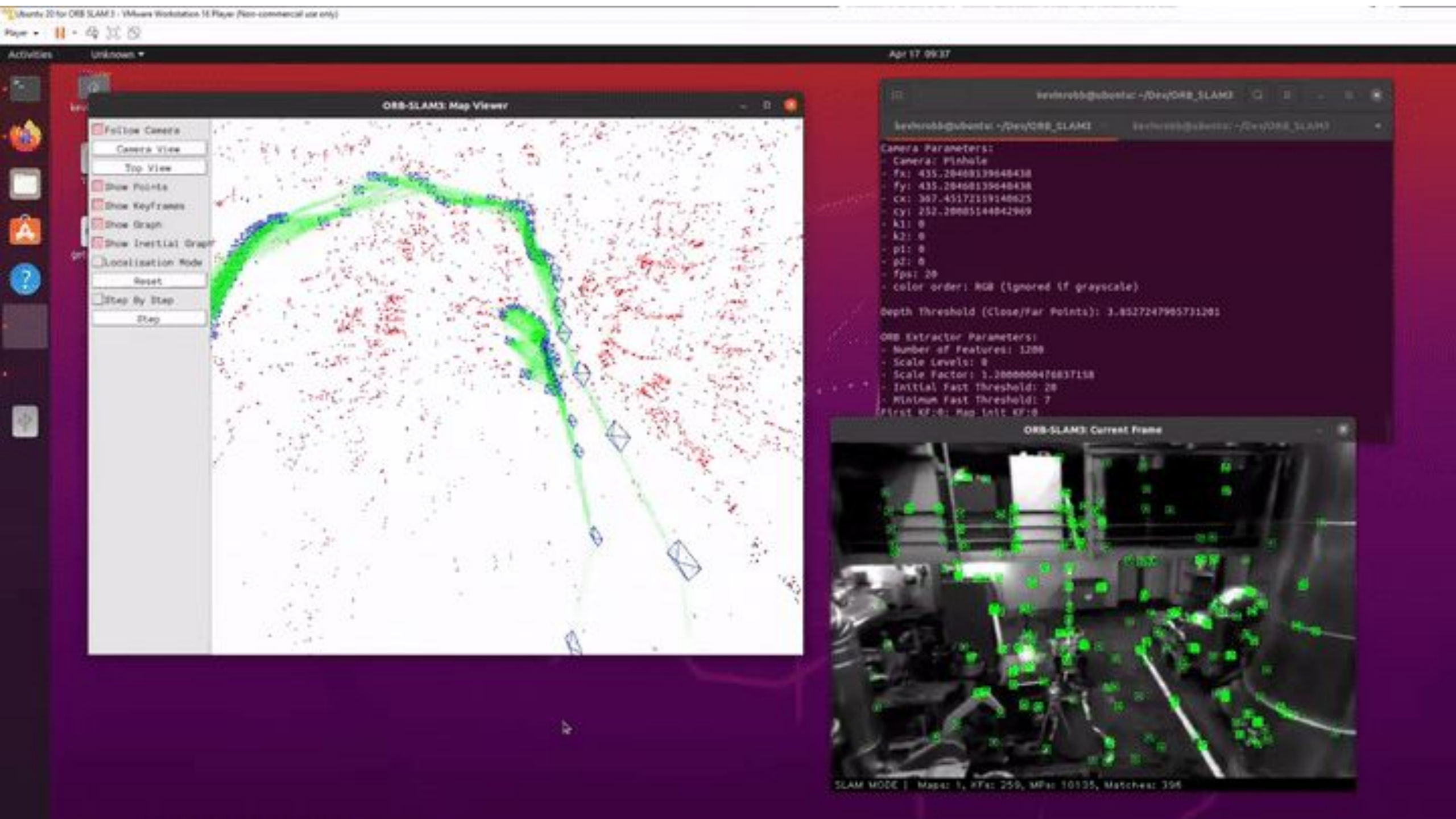




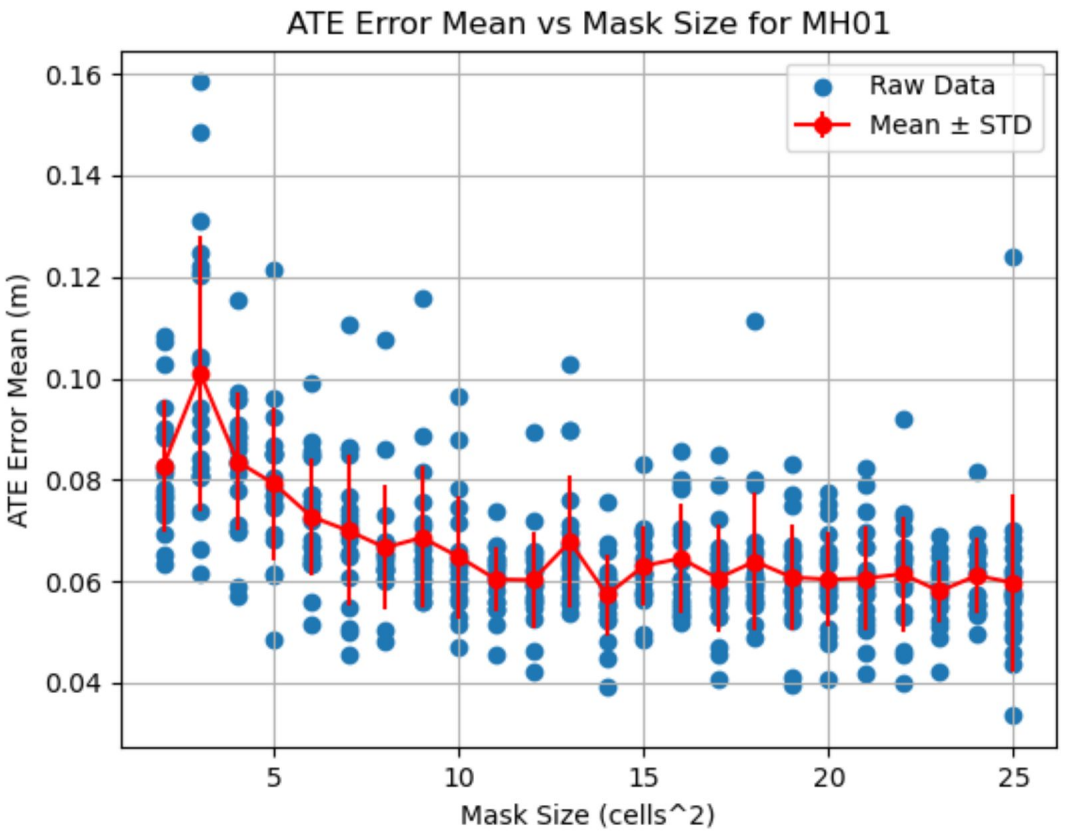
Keyframe SLAM

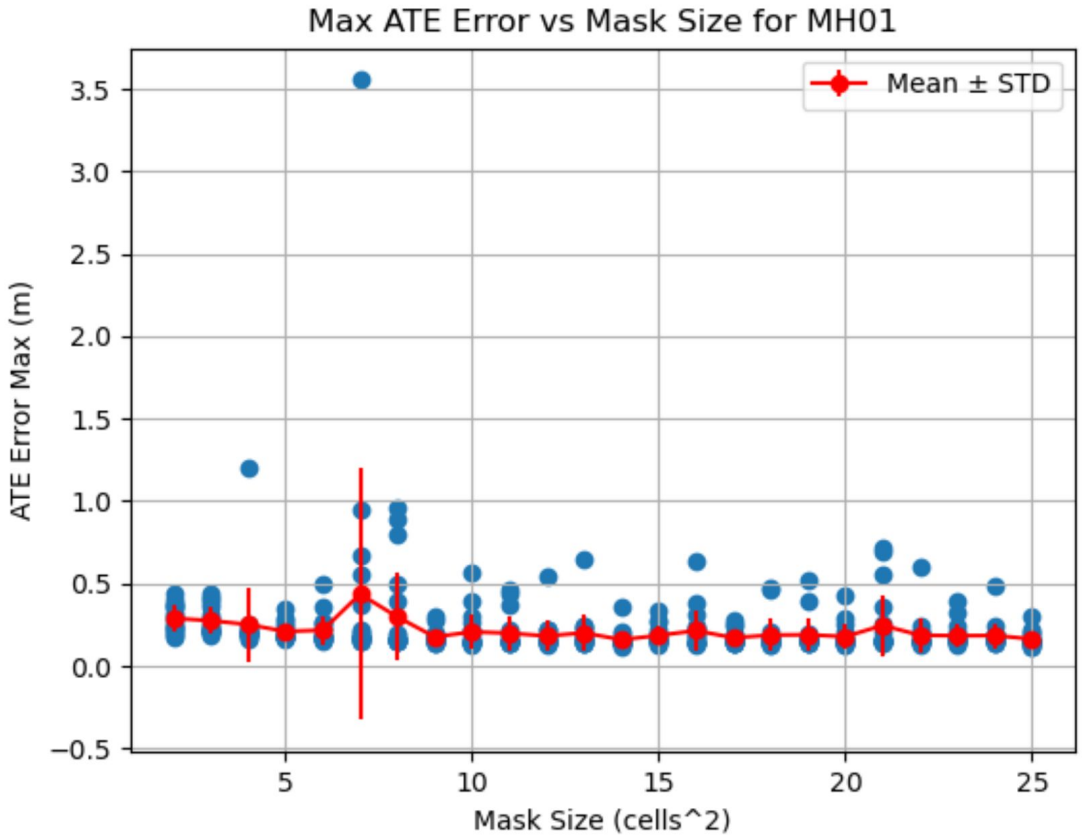
Simultaneous **L**ocalization **a**nd **M**apping



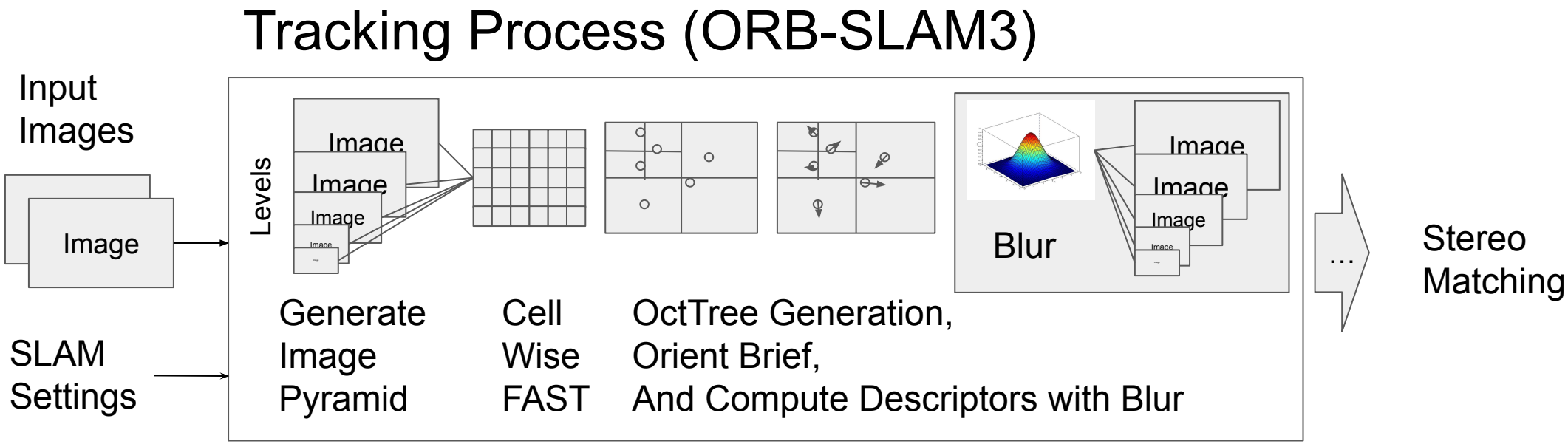

Activities
Unknown
Apr 17 09:37
ORB-SLAM3: Map Viewer
Follow Camera
Camera View
Top View
Show Points
Show KeyFrames
Show Graph
Show Inertial Graph
Localisation Mode
Reset
Step By Step
Step
Camera Parameters:
- Camera: Pinhole
- fx: 435.20468139648438
- fy: 435.20468139648438
- cx: 367.45172119140625
- cy: 252.20885144042969
- k1: 0
- k2: 0
- p1: 0
- p2: 0
- fps: 20
- color order: RGB (ignored if grayscale)
Depth Threshold (Close/Far Points): 3.852724790573120
ORB Extractor Parameters:
- Number of Features: 1200
- Scale Levels: 8
- Scale Factor: 1.200000047683716
- Initial Fast Threshold: 20
- Minimum Fast Threshold: 7
ORB-SLAM3: Current Frame
SLAM MODE | Maps: 1, KFs: 259, MPs: 10135, Matches: 396

OASIS - Dynamic Masking





ORB-SLAM3 Input Tracking



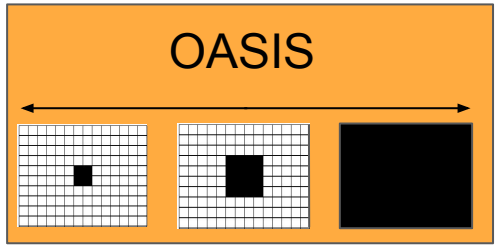
OASIS - Budgeting / Mask Selection

At Runtime:

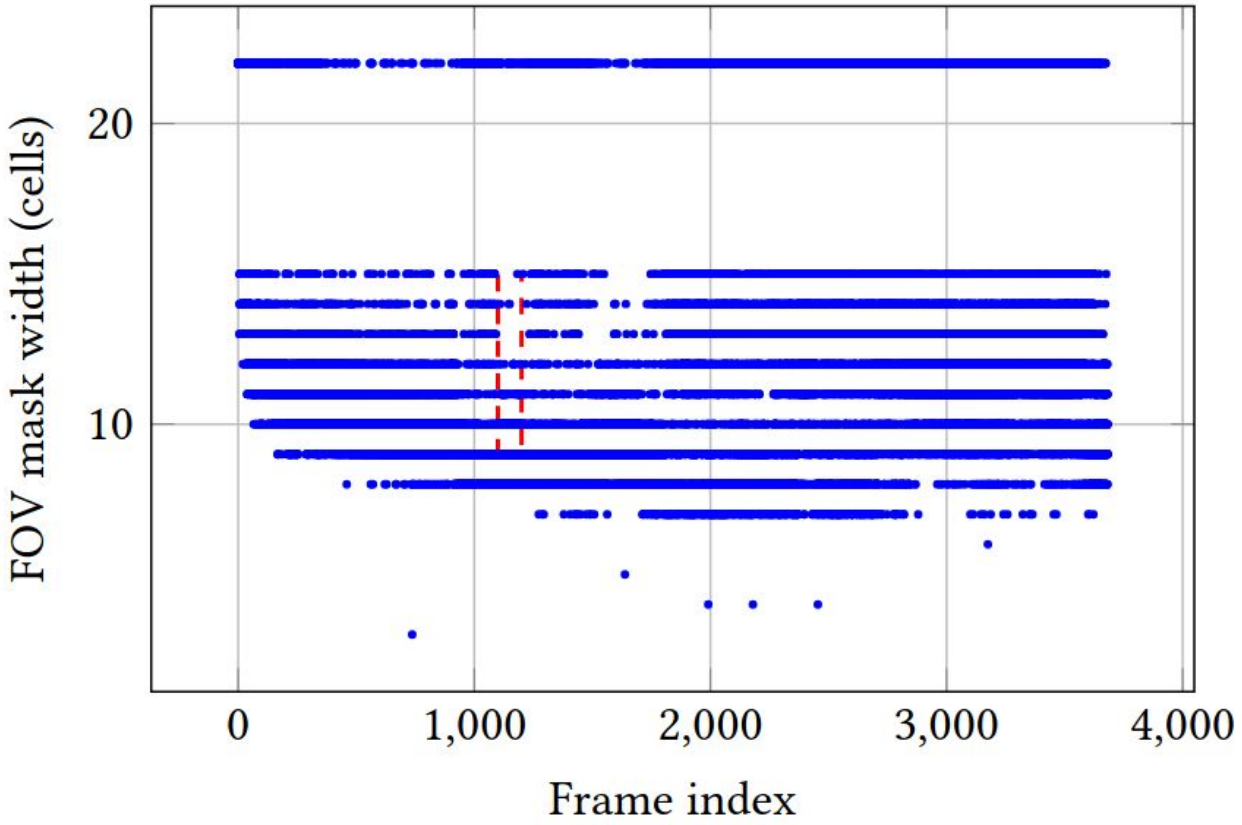
- Per frame Tracking Process Timestamps (ms) and SLAM Settings used as inputs into estimator
- Binary signal from controller, indicating process or skip cell during feature extraction

Controller chooses mask size based a moving average estimator

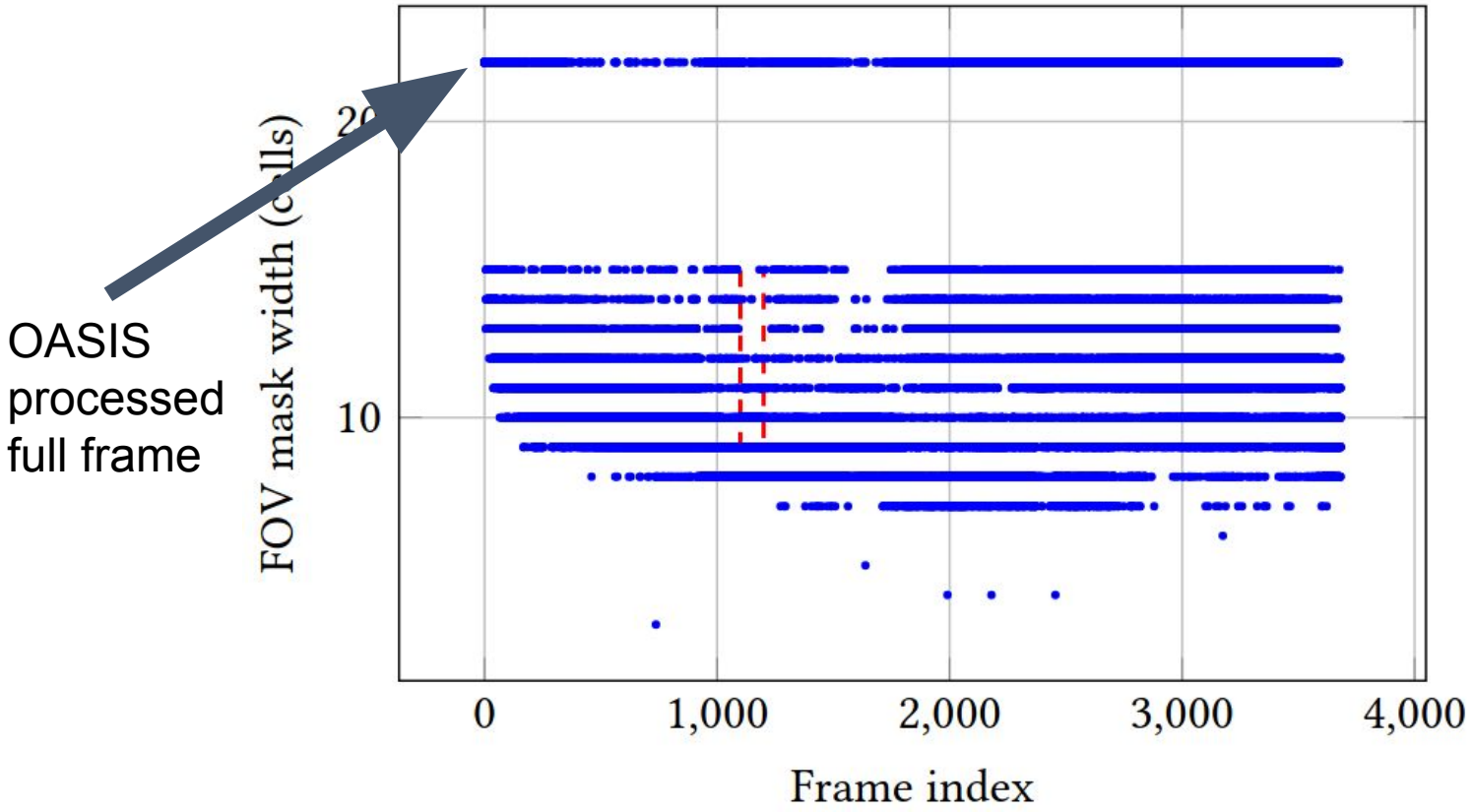
- Total cells derived from SLAM configuration, size of layers of image pyramid
- Infer time per cell from last Tracking timestamp
- Estimate frame budget with moving average of prior Tracking Process Timestamps
- Choose mask (growing from center) to fit into budget



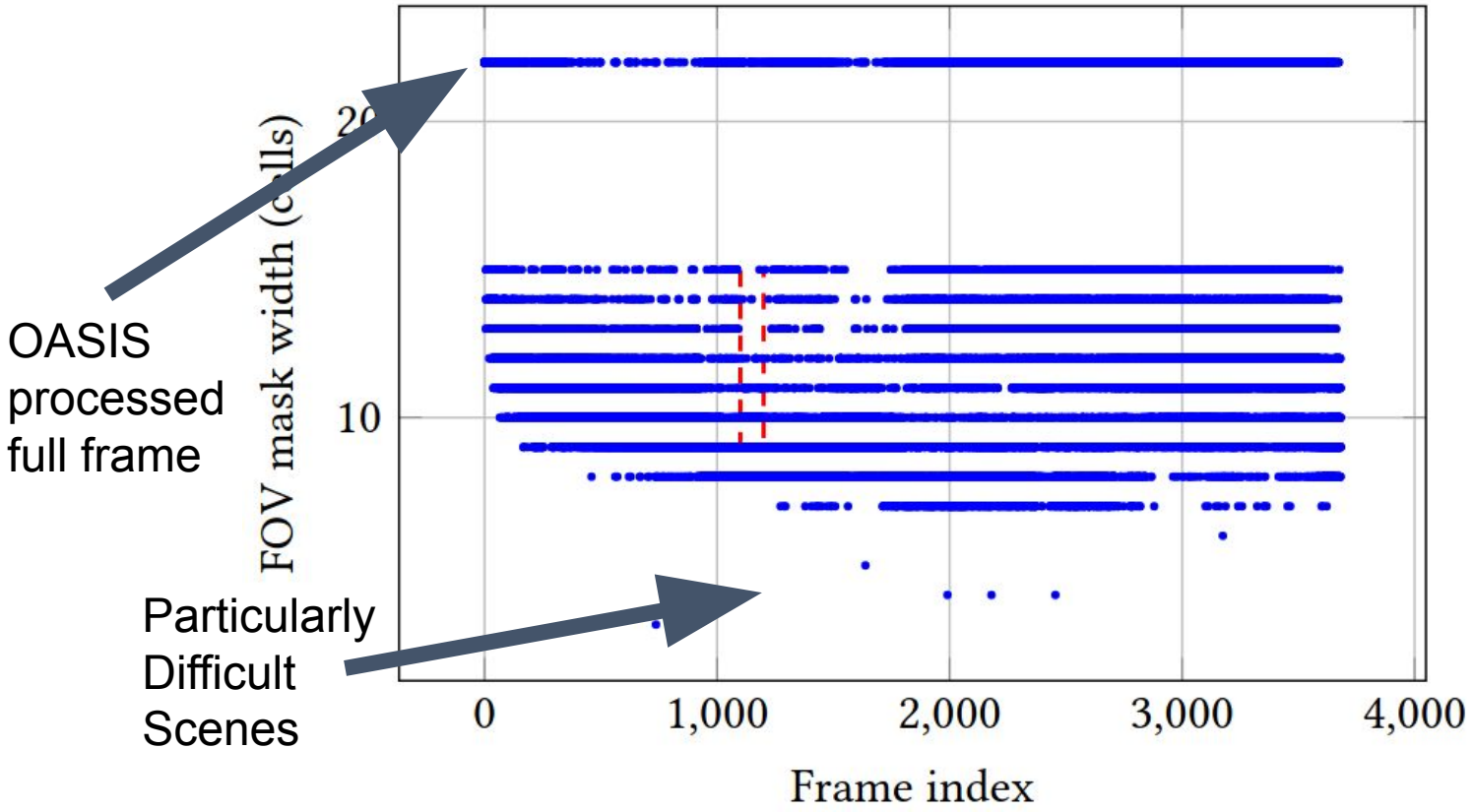
Evaluation - Jetson OASIS Mask



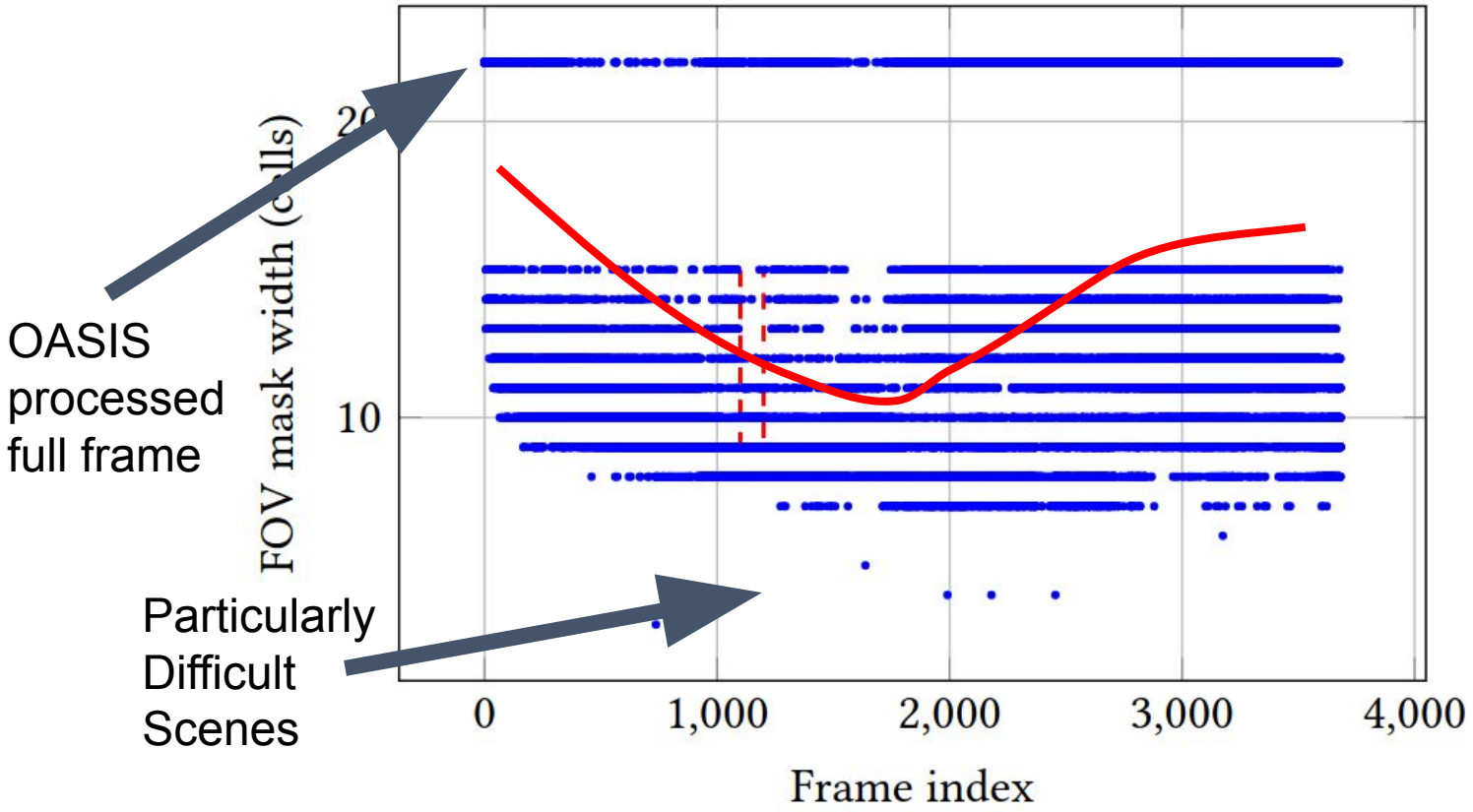
Evaluation - Jetson OASIS Mask



Evaluation - Jetson OASIS Mask



Evaluation - Jetson OASIS Mask



OASIS Against SotA

Jetson Orin NX 16GB Developer Kit														
Dataset	**PID**		**Realtime PID**		**ω**		**Realtime ω**		**Fixed Mask 4x4**		**Fixed Mask 6x6**		**OASIS**	
	Mean	**Max**	**Mean**	**Max**	**Mean**	**Max**	**Mean**	**Max**	**Mean**	**Max**	**Mean**	**Max**	**Mean**	**Max**
MH01	0.06193	0.15124	**0.05580**	0.22561	0.06121	**0.14756**	0.06893	0.19881	0.08646	0.19617	0.07071	0.17034	0.07001	0.18119
MH02	**0.04124**	**0.10936**	0.05345	0.18994	0.04174	0.11118	0.04654	0.18109	0.07912	0.50470	0.04637	0.14912	0.04817	0.13826
MH03	0.04776	0.12344	0.06769	0.90827	**0.04655**	**0.11926**	0.07157	1.47305	0.06321	0.14696	0.05001	0.12843	0.04998	0.12712
MH04	0.06180	0.21851	0.07906	0.68295	**0.05398**	0.22250	0.06967	0.66827	0.10116	0.36963	0.07072	**0.20209**	0.06078	0.20357
MH05	0.06023	**0.14615**	0.09816	0.26446	0.07123	0.16950	0.09723	0.22950	0.16432	0.39614	0.09982	0.25447	**0.05956**	0.15856
V101	0.02891	0.06886	0.03684	0.36629	0.02676	0.07098	0.03325	0.20681	0.03152	0.07574	**0.02572**	**0.06246**	0.02746	0.06578
V102	0.05920	0.09761	0.05947	0.11463	0.05953	**0.09623**	0.05952	0.11700	0.06105	0.13819	0.06002	0.11030	**0.05821**	0.12282
V103	0.04905	0.12569	0.07280	0.92312	0.04909	**0.11564**	0.11447	0.47894	0.05336	0.20734	0.05116	0.23117	**0.04890**	0.12019
V201	0.06395	0.11781	0.17931	3.68673	0.06643	0.11122	0.14795	2.84008	**0.05513**	0.11418	0.05584	0.11149	0.05833	**0.10164**
V202	**0.05468**	0.11710	0.06879	0.59796	0.05507	**0.11506**	0.06419	0.67893	0.05864	0.28833	0.05683	0.13271	0.05642	0.12036
V203	0.06807	0.49457	0.07344	0.51727	0.07169	0.23764	0.09092	0.50070	0.12834	2.10927	0.09207	0.38178	**0.06357**	**0.17238**
Average	**0.05426**	**0.16094**	**0.07680**	**0.77066**	**0.05484**	**0.13789**	**0.07857**	**0.68847**	**0.08021**	**0.41333**	**0.06175**	**0.17585**	**0.05467**	**0.13744**

SotA Adaptive SLAM

Dataset	Jetson Orin NX 16GB Developer Kit									
	PID		Realtime PID		ω		Realtime ω		Fixed Mask 4x4	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
MH01	0.06193	0.15124	**0.05580**	0.22561	0.06121	**0.14756**	0.06893	0.19881	0.08646	0.19617
MH02	**0.04124**	**0.10936**	0.05345	0.18994	0.04174	0.11118	0.04654	0.18109	0.07912	0.50470
MH03	0.04776	0.12344	0.06769	0.90827	**0.04655**	**0.11926**	0.07157	1.47305	0.06321	0.14696
MH04	0.06180	0.21851	0.07906	0.68295	**0.05398**	0.22250	0.06967	0.66827	0.10116	0.36963
MH05	0.06023	**0.14615**	0.09816	0.26446	0.07123	0.16950	0.09723	0.22950	0.16432	0.39614
V101	0.02891	0.06886	0.03684	0.36629	0.02676	0.07098	0.03325	0.20681	0.03152	0.07574
V102	0.05920	0.09761	0.05947	0.11463	0.05953	**0.09623**	0.05952	0.11700	0.06105	0.13819
V103	0.04905	0.12569	0.07280	0.92312	0.04909	**0.11564**	0.11447	0.47894	0.05336	0.20734
V201	0.06395	0.11781	0.17931	3.68673	0.06643	0.11122	0.14795	2.84008	**0.05513**	0.11418
V202	**0.05468**	0.11710	0.06879	0.59796	0.05507	**0.11506**	0.06419	0.67893	0.05864	0.28833
V203	0.06807	0.49457	0.07344	0.51727	0.07169	0.23764	0.09092	0.50070	0.12834	2.10927
Average	**0.05426**	**0.16094**	**0.07680**	**0.77066**	**0.05484**	**0.13789**	**0.07857**	**0.68847**	**0.08021**	**0.41333**

SotA Adaptive SLAM

Jetson Orin NX 16GB Developer Kit										
Dataset	PID		Realtime PID		ω		Realtime ω		Fixed Mask 4x4	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
MH01	0.06193	0.15124	**0.05580**	0.22561	0.06121	**0.14756**	0.06893	0.19881	0.08646	0.19617
MH02	**0.04124**	**0.10936**	0.05345	0.18994	0.04174	0.11118	0.04654	0.18109	0.07912	0.50470
MH03	0.04776	0.12344	0.06769	0.90827	**0.04655**	**0.11926**	0.07157	1.47305	0.06321	0.14696
MH04	0.06180	0.21851	0.07906	0.68295	**0.05398**	0.22250	0.06967	0.66827	0.10116	0.36963
MH05	0.06023	**0.14615**	0.09816	0.26446	0.07123	0.16950	0.09723	0.22950	0.16432	0.39614
V101	0.02891	0.06886	0.03684	0.36629	0.02676	0.07098	0.03325	0.20681	0.03152	0.07574
V102	0.05920	0.09761	0.05947	0.11463	0.05953	**0.09623**	0.05952	0.11700	0.06105	0.13819
V103	0.04905	0.12569	0.07280	0.92312	0.04909	**0.11564**	0.11447	0.47894	0.05336	0.20734
V201	0.06395	0.11781	0.17931	3.68673	0.06643	0.11122	0.14795	2.84008	**0.05513**	0.11418
V202	**0.05468**	0.11710	0.06879	0.59796	0.05507	**0.11506**	0.06419	0.67893	0.05864	0.28833
V203	0.06807	0.49457	0.07344	0.51727	0.07169	0.23764	0.09092	0.50070	0.12834	2.10927
Average	**0.05426**	**0.16094**	**0.07680**	**0.77066**	**0.05484**	**0.13789**	**0.07857**	**0.68847**	**0.08021**	**0.41333**

OASIS vs SotA

Dataset	PID		Realtime PID		ω		Realtime ω		Fixed Mask 4x4	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
Jetson Orin NX 16GB Developer Kit										
MH01	0.06193	0.15124	**0.05580**	0.22561	0.06121	**0.14756**	0.06893	0.19881	0.08646	0.19617
MH02	**0.04124**	**0.10936**	0.05345	0.18994	0.04174	0.11118	0.04654	0.18109	0.07912	0.50470
V103	0.04905	0.12569	0.07280	0.92312	0.04909	**0.11564**	0.11447	0.47894	0.05336	0.20734
V201	0.06395	0.11781	0.17931	3.68673	0.06643	0.11122	0.14795	2.84008	**0.05513**	0.11418
V202	**0.05468**	0.11710	0.06879	0.59796	0.05507	**0.11506**	0.06419	0.67893	0.05864	0.28833
V203	0.06807	0.49457	0.07344	0.51727	0.07169	0.23764	0.09092	0.50070	0.12834	2.10927
Average	**0.05426**	**0.16094**	**0.07680**	**0.77066**	**0.05484**	**0.13789**	**0.07857**	**0.68847**	**0.08021**	**0.41333**

SotA solutions still suffer from deadline misses

Adding Periodic Stress

Dataset	Data Ready with Periodic Stress				Realtime with Periodic Stress				OASIS with Periodic Stress			
	Intel		Jetson		Intel		Jetson		Intel		Jetson	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
MH01	0.05820	0.14950	0.05982	0.15285	0.05839	0.15657	0.05572	0.27804	0.06090	0.16455	0.06592	0.17073
MH02	0.04098	0.09811	0.04248	0.10159	0.04353	0.10591	0.05705	0.78745	0.04444	0.11971	0.04715	0.14499
MH03	0.04785	0.12239	0.04775	0.12155	0.04785	0.12090	0.09187	1.04494	0.04738	0.12229	0.04962	0.12498
MH04	0.05768	0.21354	0.05885	0.21290	0.07674	0.97332	0.09286	0.18171	0.06334	0.20355	0.06726	0.21080
MH05	0.06246	0.15796	0.05848	0.14623	0.05375	0.12361	0.11216	0.31176	0.07311	0.18701	0.06780	0.17571
V101	0.02782	0.06754	0.02761	0.06914	0.02795	0.08503	0.03578	0.10612	0.02673	0.06731	0.02699	0.06554
V102	0.05923	0.10827	0.05881	0.10015	0.05674	0.09492	0.05887	0.11145	0.06000	0.10632	0.05937	0.11455
V103	0.04853	0.11535	0.04953	0.12442	0.15723	0.59109	0.17527	1.43372	0.06002	0.18909	0.05001	0.12309
V201	0.06605	0.10776	0.06483	0.10922	0.05722	0.10928	0.43918	9.90185	0.05707	0.10655	0.05820	0.10533
V202	0.05539	0.11692	0.05520	0.13055	0.05669	0.11944	0.06510	0.21835	0.05630	0.13906	0.05580	0.12957
V203	0.07608	0.23701	0.06911	0.16952	0.06641	0.24901	0.08951	0.32356	0.11471	0.29116	0.07152	0.32726
Average	0.05457	0.13585	0.05386	0.13074	0.06386	0.24810	0.11576	1.33627	0.06036	0.15424	0.05633	0.15387

Table 5. Mean and maximum absolute trajectory error (ATE) for Intel and Jetson under random periodic stress. Each run-type is executed on both systems; lower values are better. Periodic stress of full compute load was produced at a 10% duty cycle over 10 second period. All measurements are in meters.

Summary

- **Missed deadlines** can have significant impacts to realtime machine perception pipeline
- We introduce a **fully online controller** that budgets per-frame approximation via spatial masking to process the regions with most information (center of frame)
- We find OASIS preserves mean performance while **significantly improving worst case performance** of ORB-SLAM3 on the complete EuRoC dataset.

Outline

- Outline
- Background
  - Autonomous System and Machine Perception / SLAM
- Motivation
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