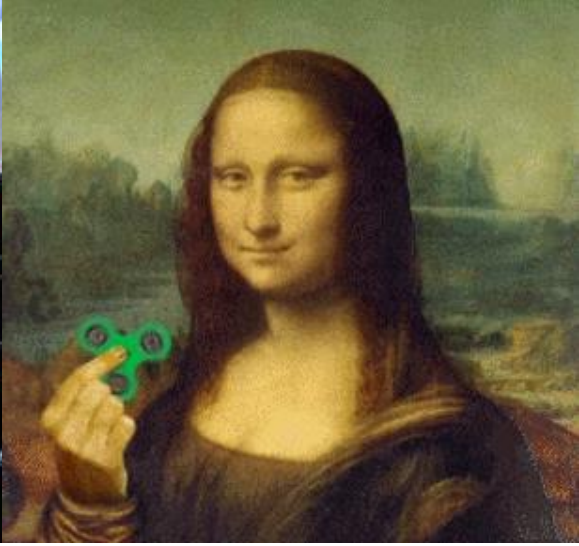


SLAM for Dynamic Environments

David Schmidig

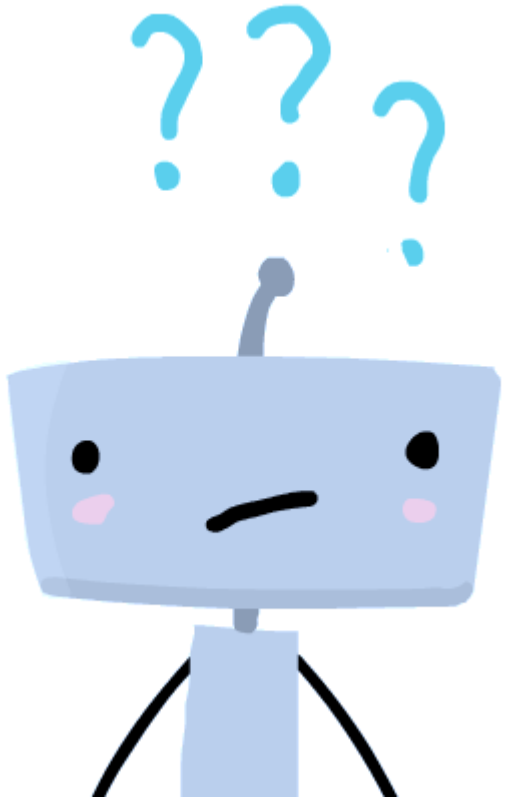
Supervised by
Patrik Schmuck
Marco Karrer
Margarita Chli

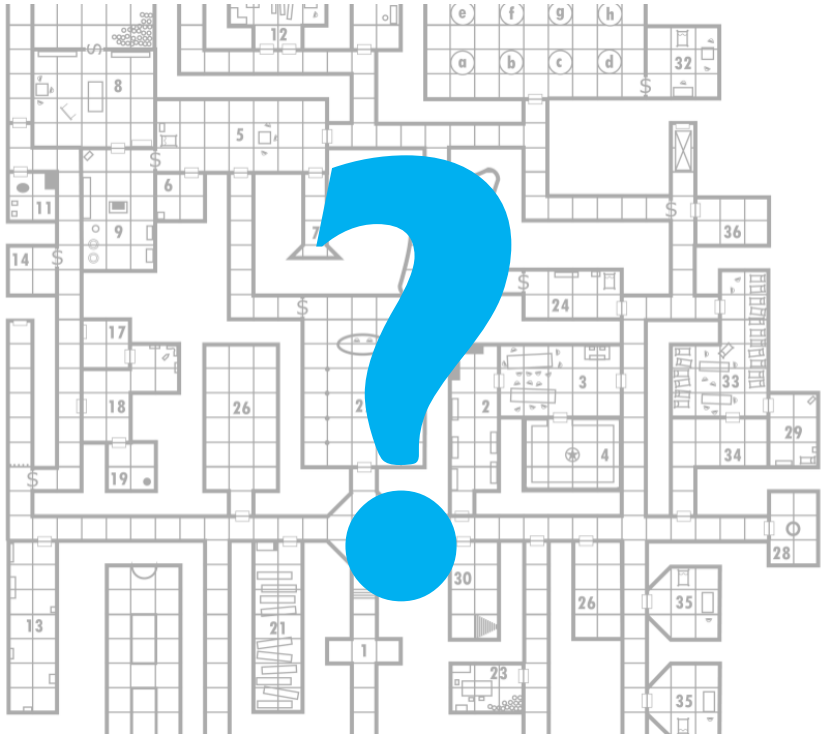
V4RL
VISION FOR ROBOTICS LAB

SLAM for Dynamic Environments

SLAM for Dynamic Environments

SLAM for Dynamic Environments



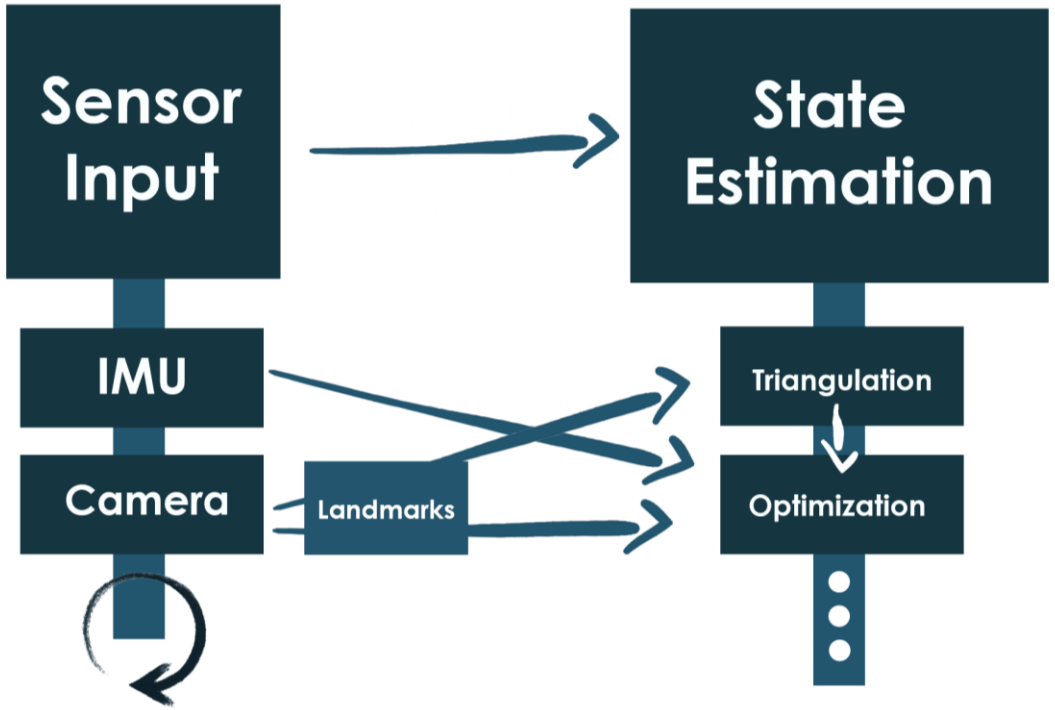


SLAM for Dynamic Environments

Simultaneous Localization and Mapping

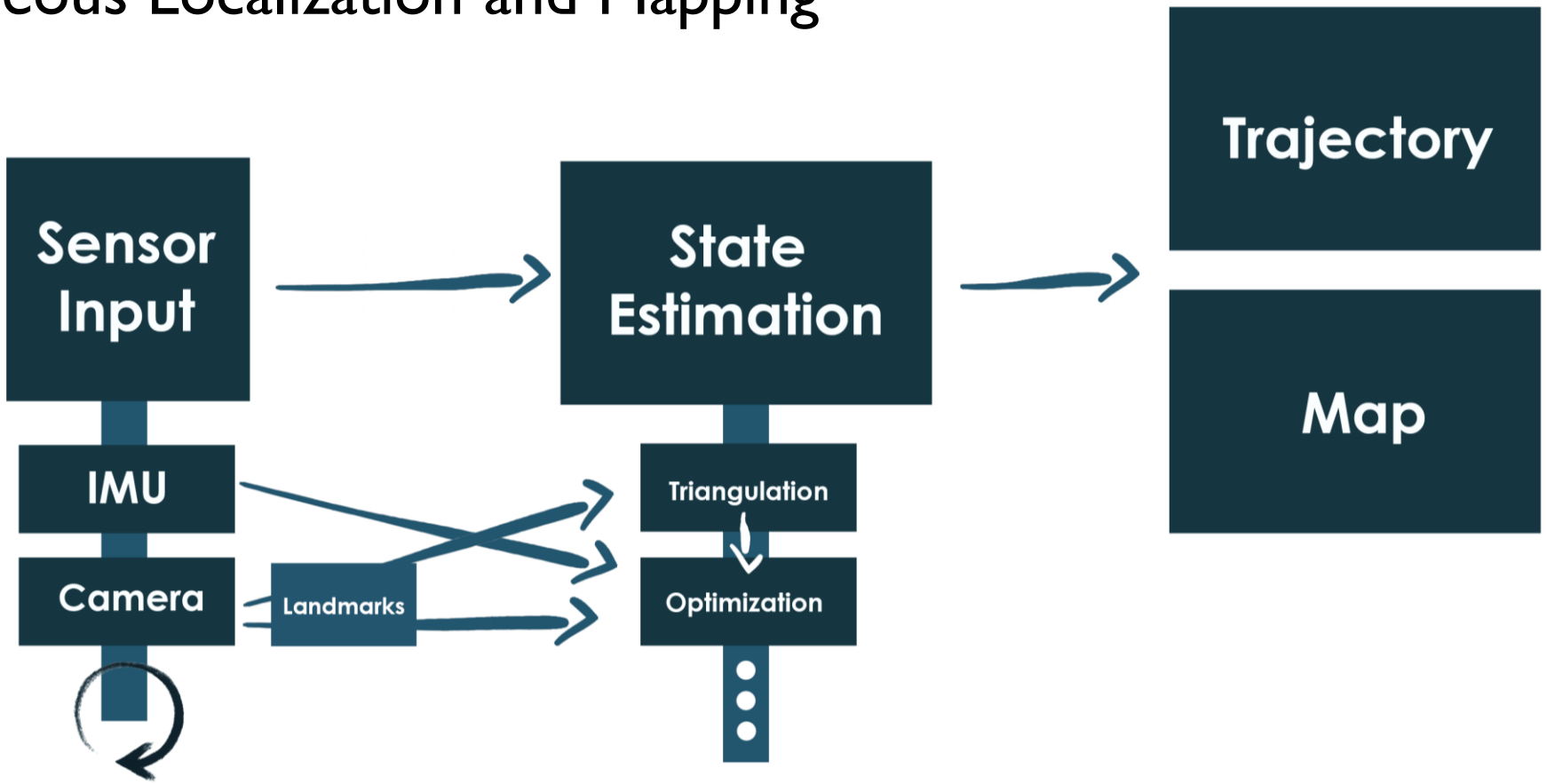
SLAM for Dynamic Environments

Simultaneous Localization and Mapping



SLAM for Dynamic Environments

Simultaneous Localization and Mapping



SLAM for Dynamic Environments

Simultaneous Localization and Mapping

Trajectory

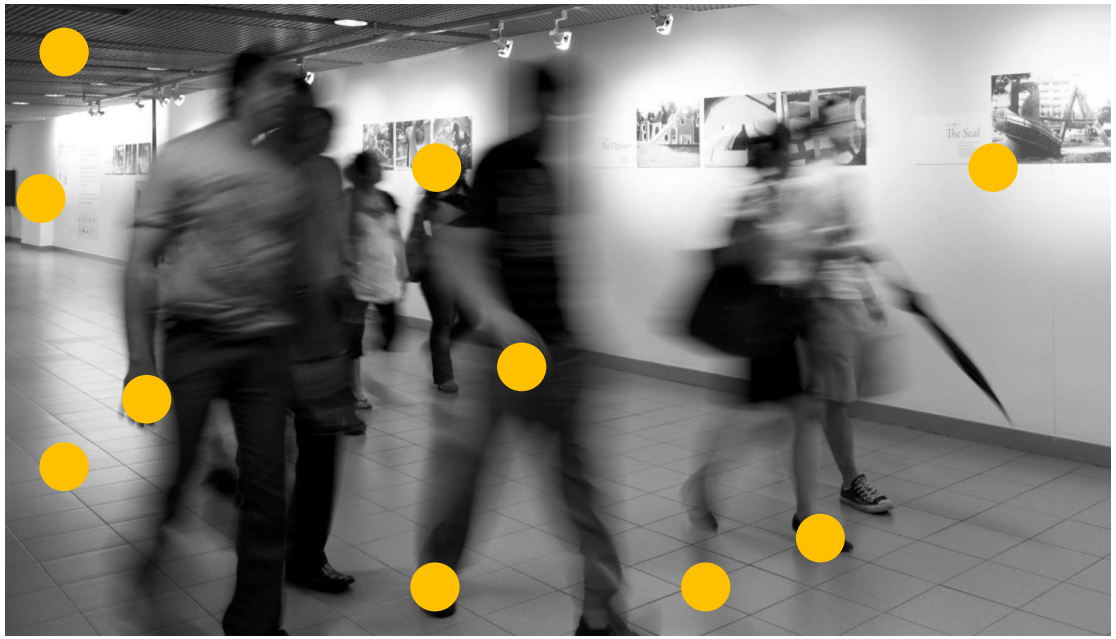
Map

SLAM for Dynamic Environments

SLAM for Dynamic Environments

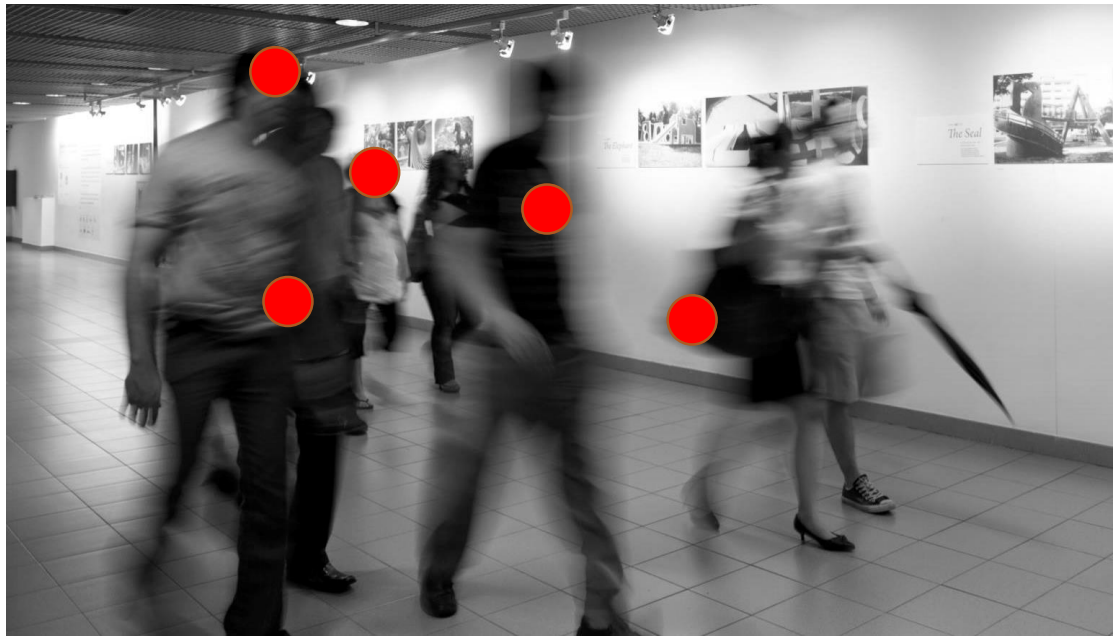
SLAM for Dynamic Environments
Challenges

- What is reliable for state estimation



SLAM for Dynamic Environments
Challenges

- What is reliable for state estimation
- Consistent movement of dynamic objects
  (no outlier removal)



SLAM for Dynamic Environments
Challenges

- What is reliable for state estimation
- Consistent movement of dynamic objects
  (no outlier removal)

SLAM for Dynamic Environments
Challenges

- What is reliable for state estimation
- Consistent movement of dynamic objects
  (no outlier removal)
- Inconsistent object type

SLAM for Dynamic Environments
Challenges

- What is reliable for state estimation
- Consistent movement of dynamic objects
  (no outlier removal)
- Inconsistent object type
- System initialization

SLAM for Dynamic Environments
Challenges

- What is reliable for state estimation
- Consistent movement of dynamic objects
  (no outlier removal)
- Inconsistent object type
- System initialization
- Realtime

SLAM for Dynamic Environments

Possibilities

- More robust SLAM systems

SLAM for Dynamic Environments

Possibilities

- More robust SLAM systems
- Autonomous robots in dynamic environments

Existing Work

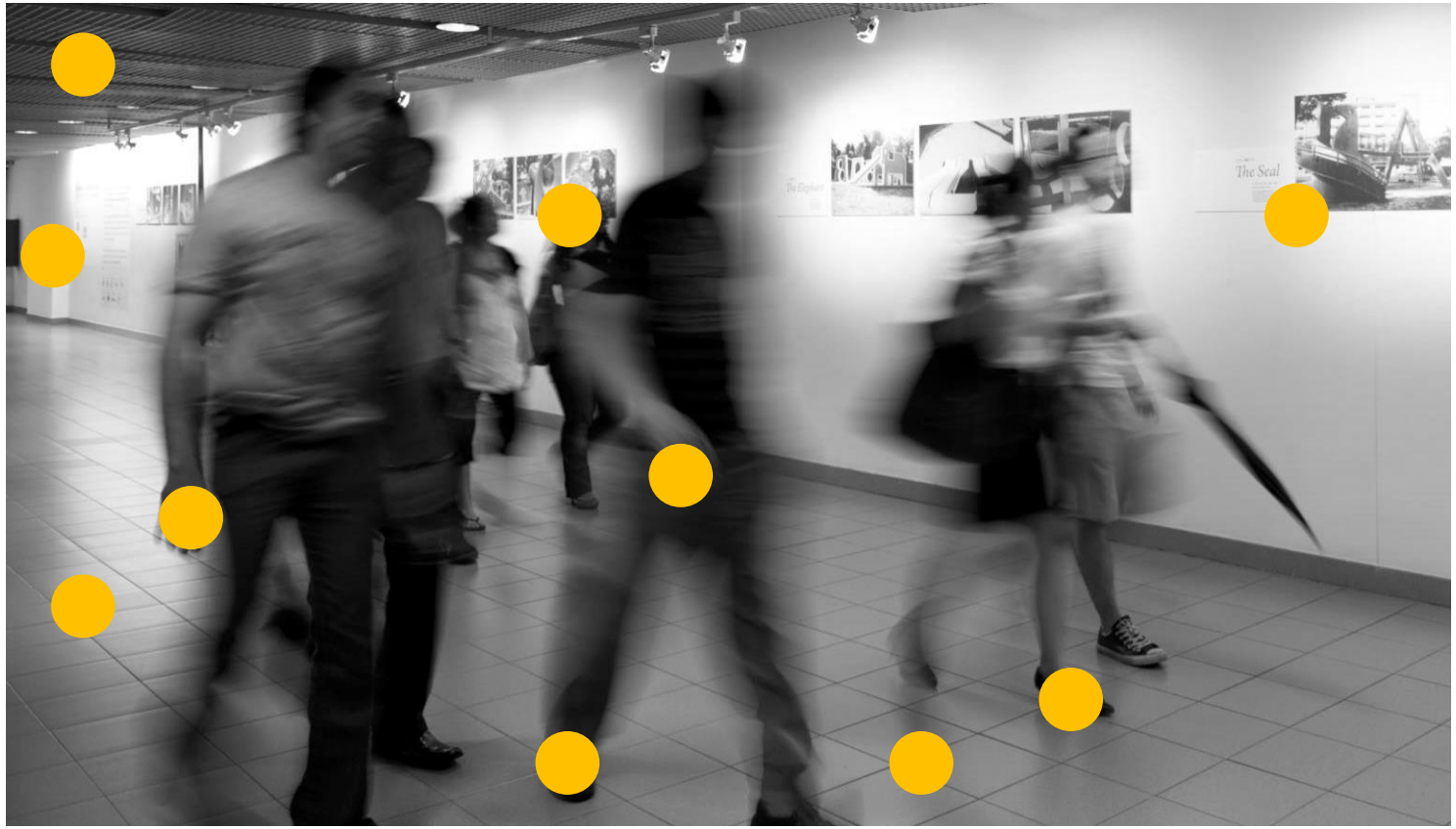
- CoSLAM,
D. Zou and P. Tan, 2013
  - Multiple cameras needed

- Mobile Robot SLAM in Dynamic Environments,
D. Wolf and G. S. Sukhatme, 2005
  - 2D Scene

- Robust vSLAM in Dynamic Scenes,
P. F. Alcantarilla et al., 2011
  - AR setup, No Quantitative Evaluation

- Robust Monocular SLAM in Dynamic Environemnts,
Wei Tan et al., 2013
  - AR setup, No Quantitative Evaluation

Approach
General Idea

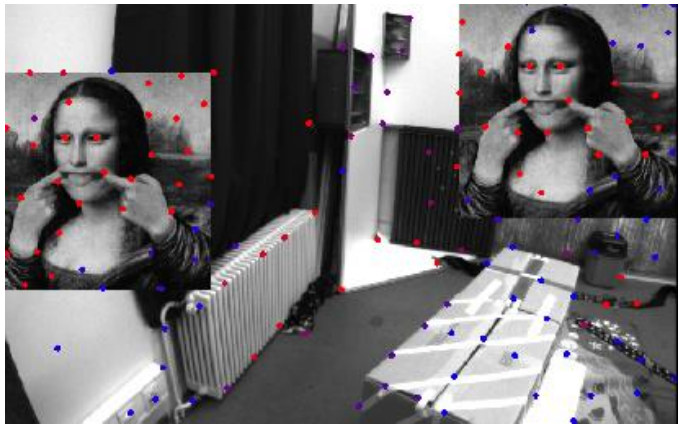


Approach
General Idea

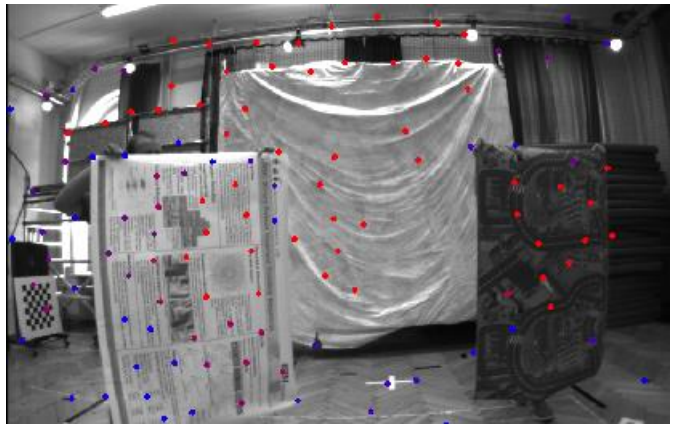
Approach
General Idea

Approach
General Idea non-binary classifier

Approach
Datasets



Mixed Reality, EUROC

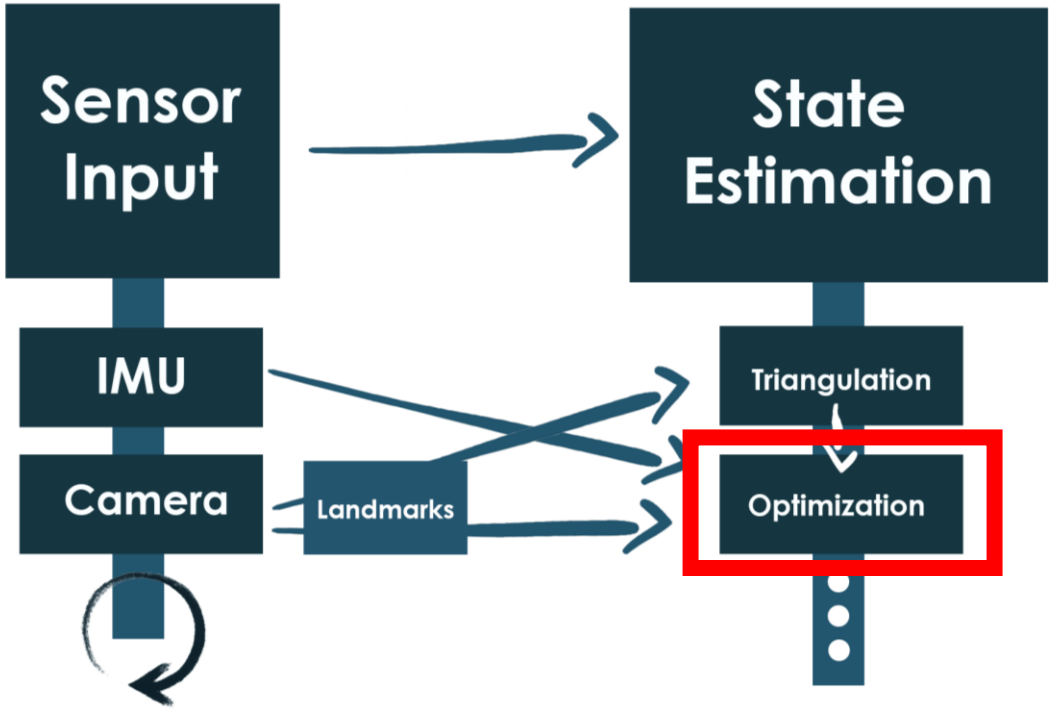


Vicon-Room, ETHZ

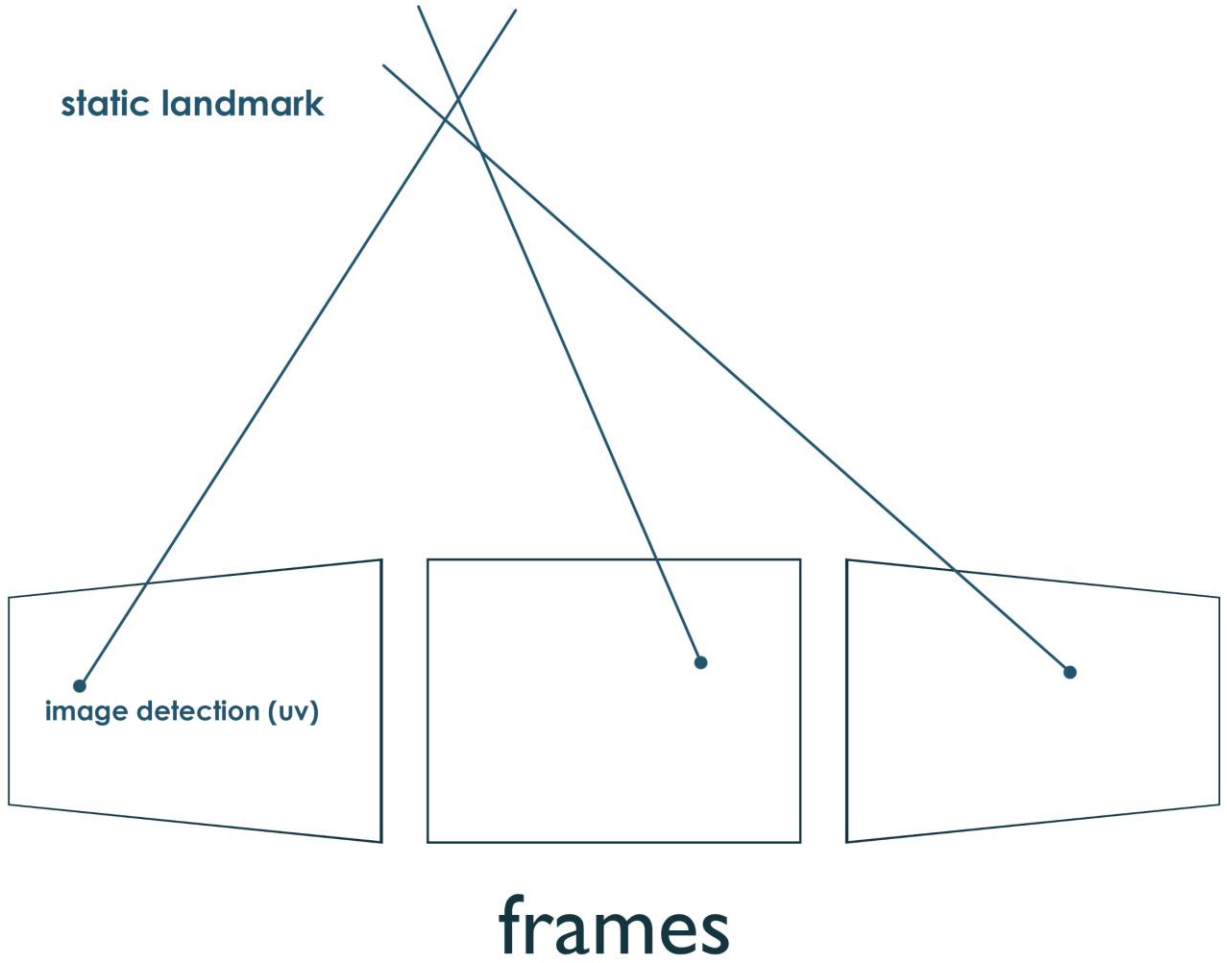
Bahnhofstrasse, Zurich

Approach
Algorithm Design

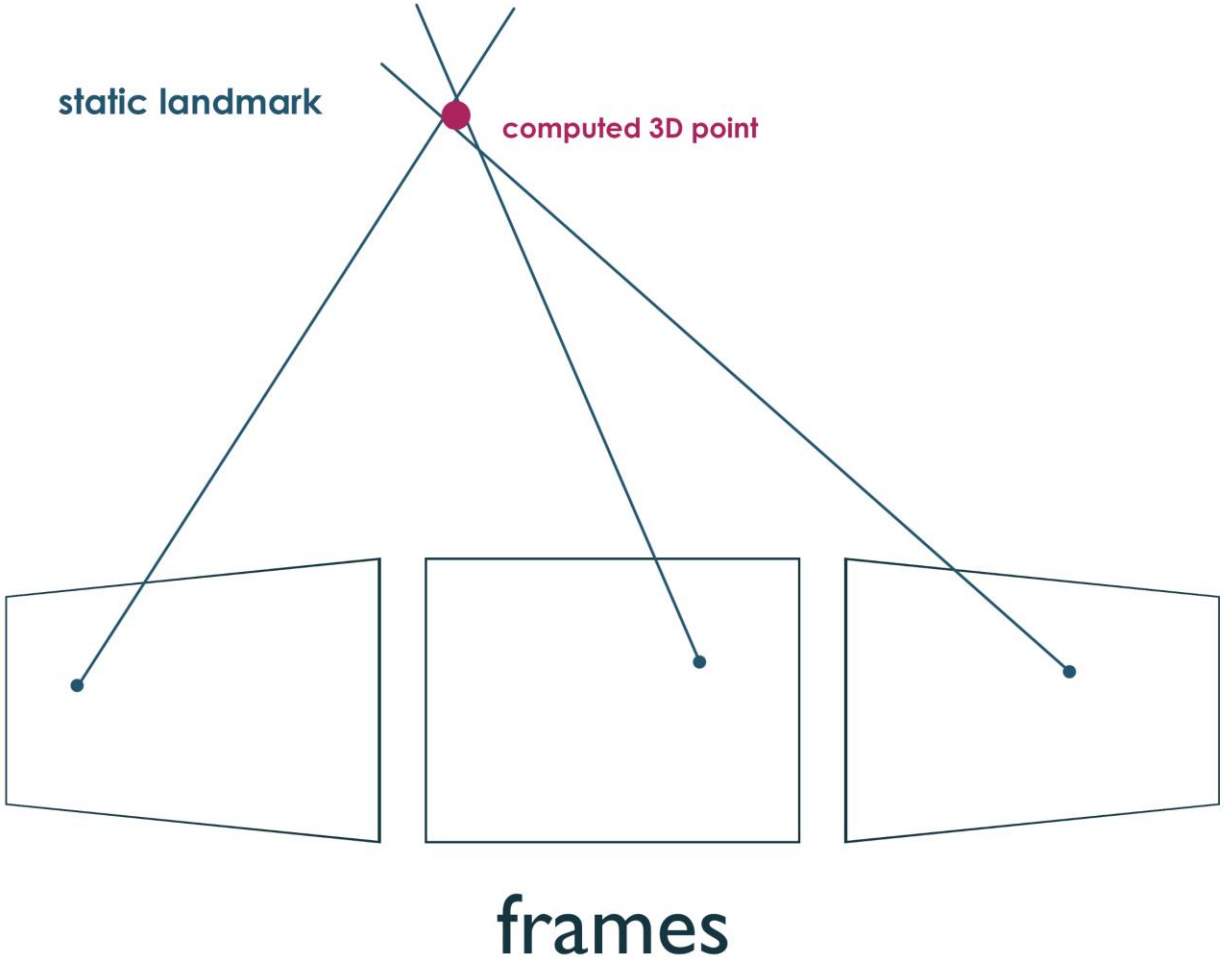
Approach
Algorithm Design



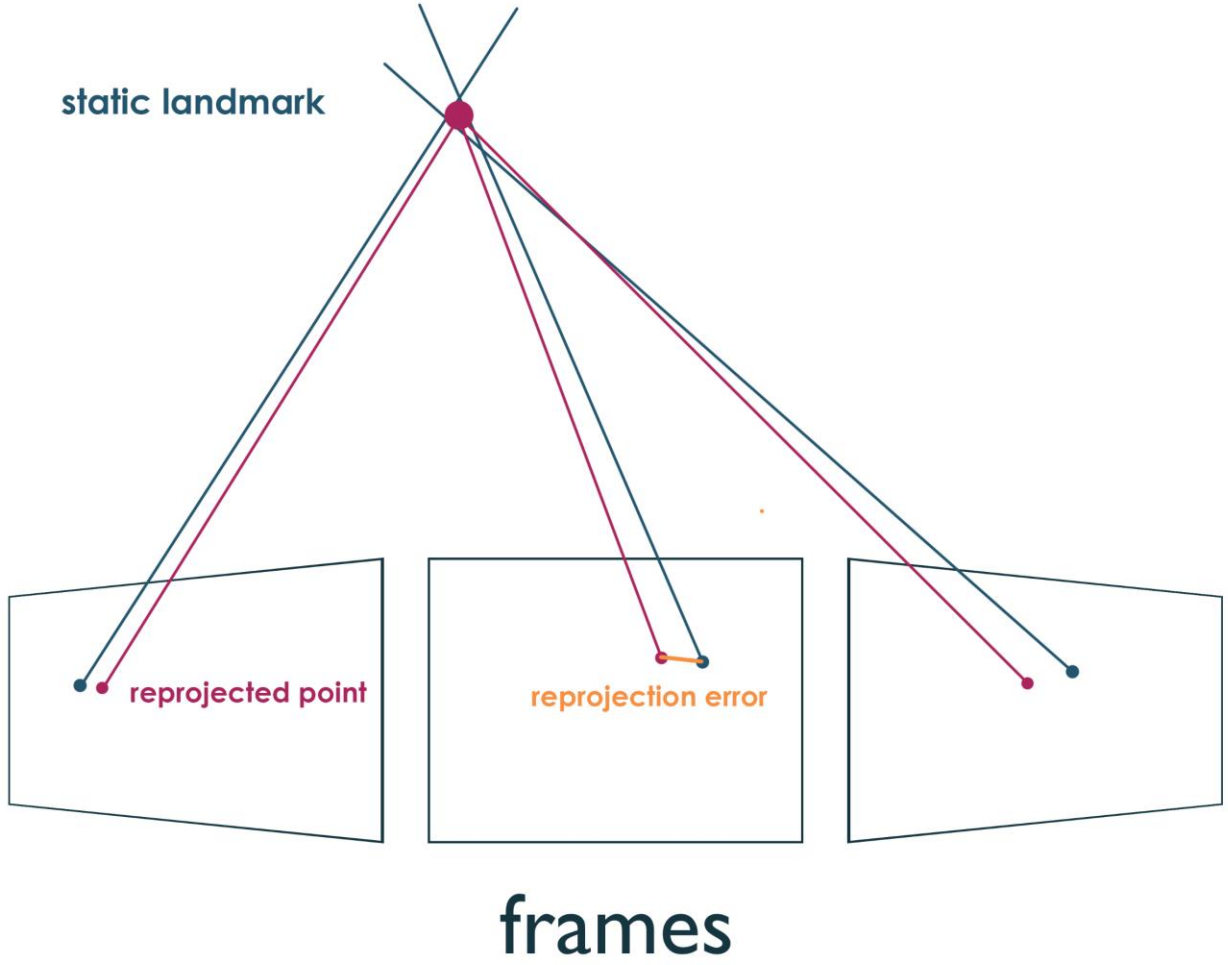
Approach
Reprojection Error



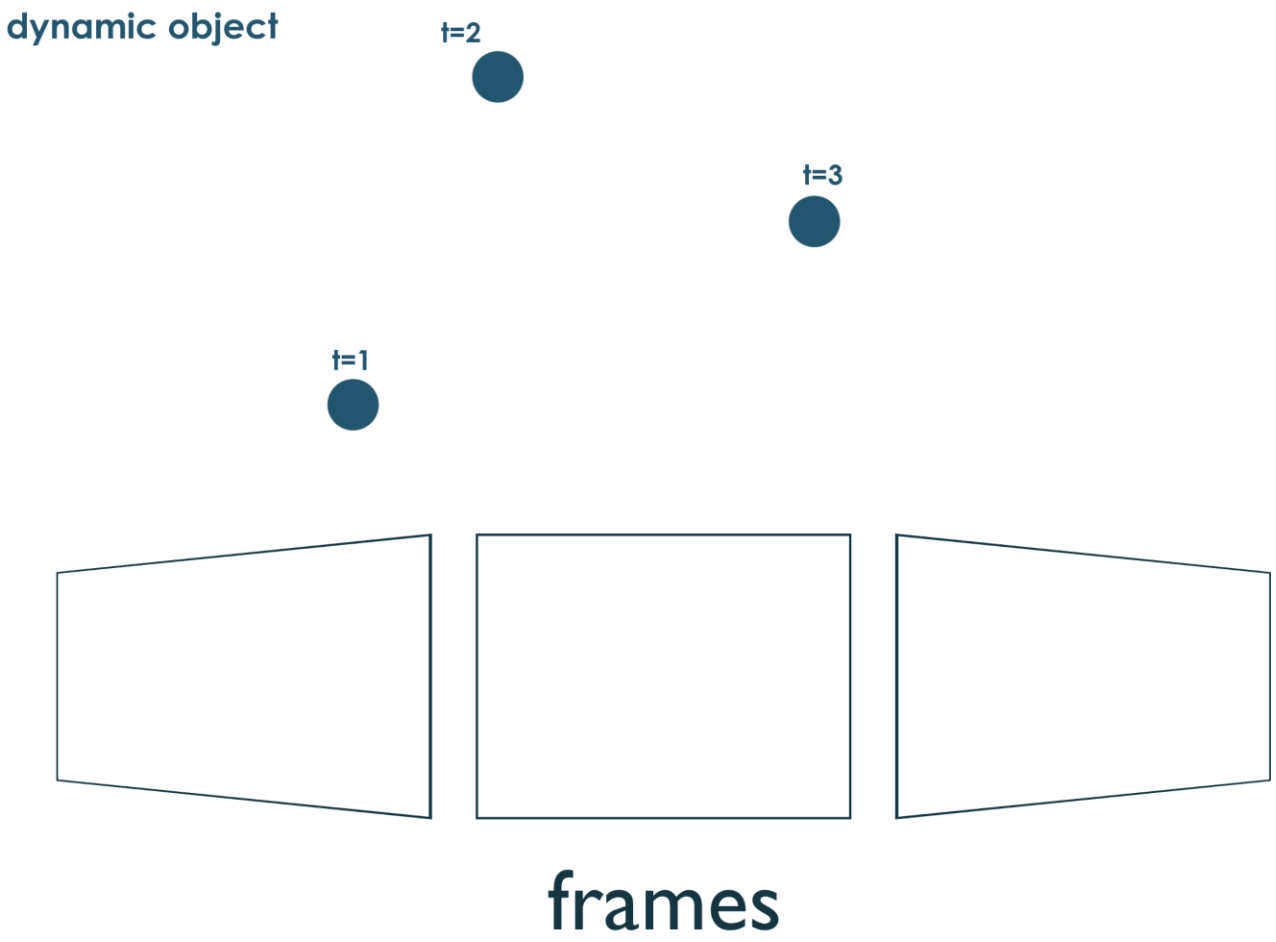
Approach
Reprojection Error



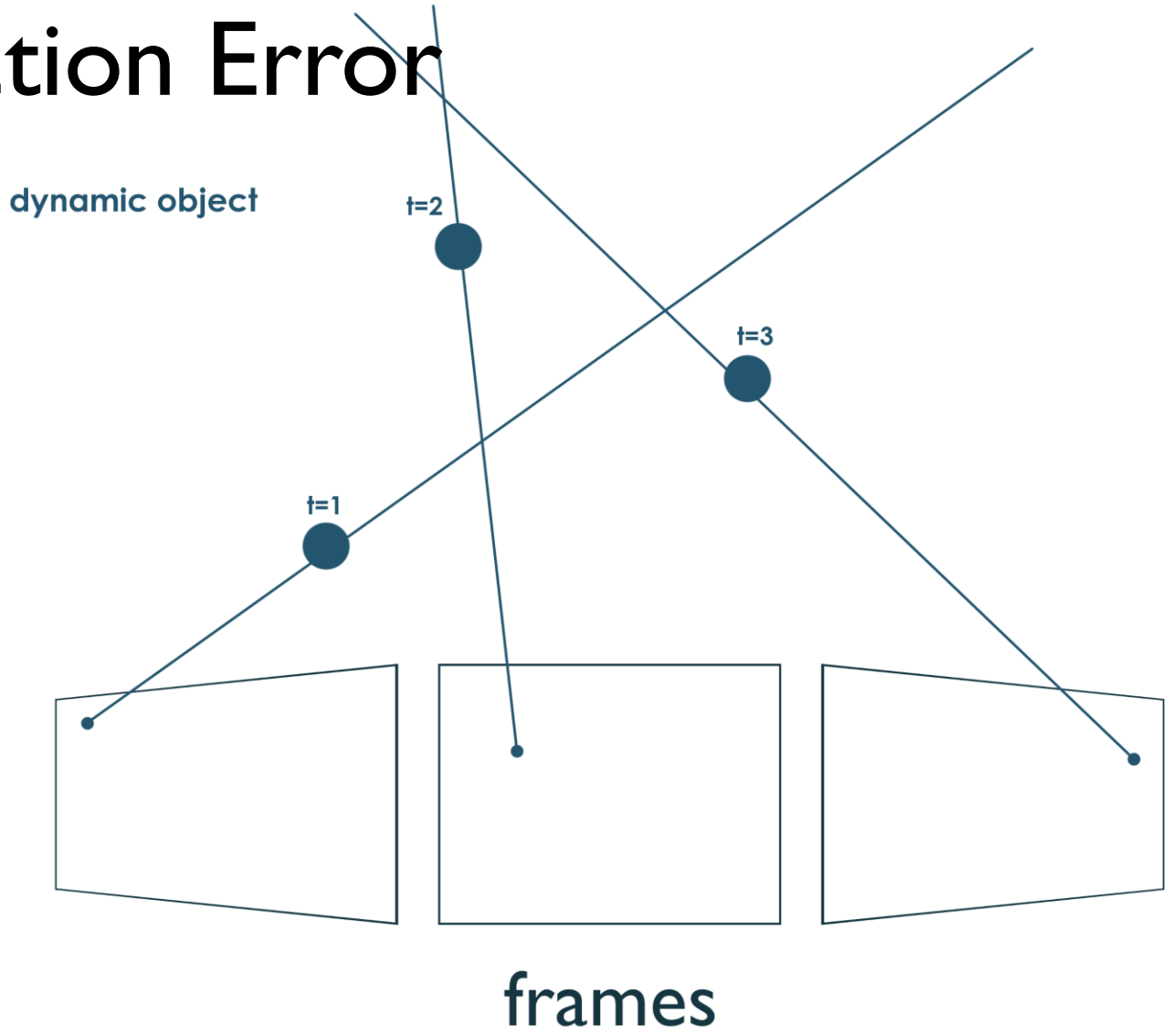
Approach
Reprojection Error



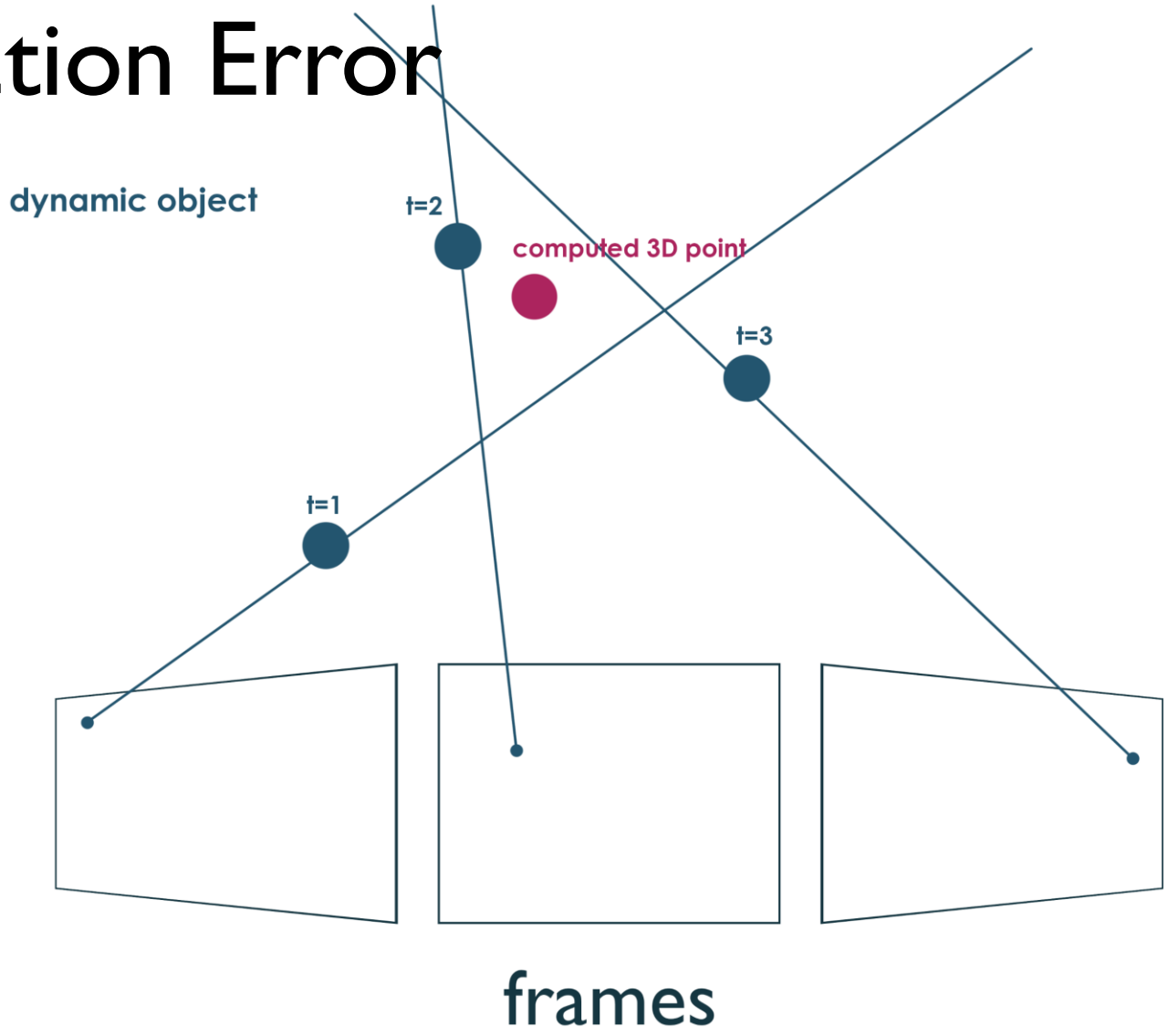
Approach
Reprojection Error



Approach
Reprojection Error



Approach
Reprojection Error



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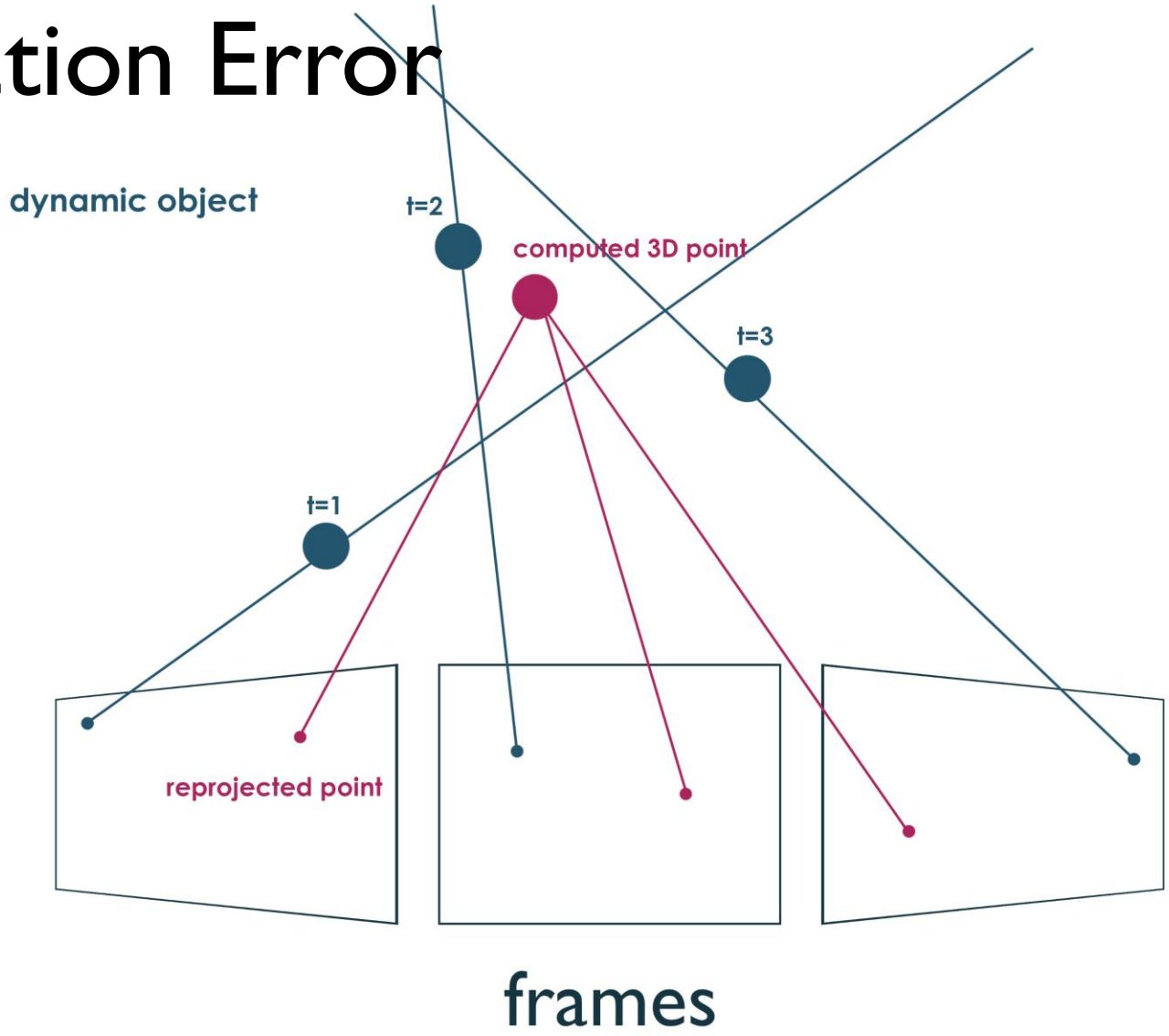
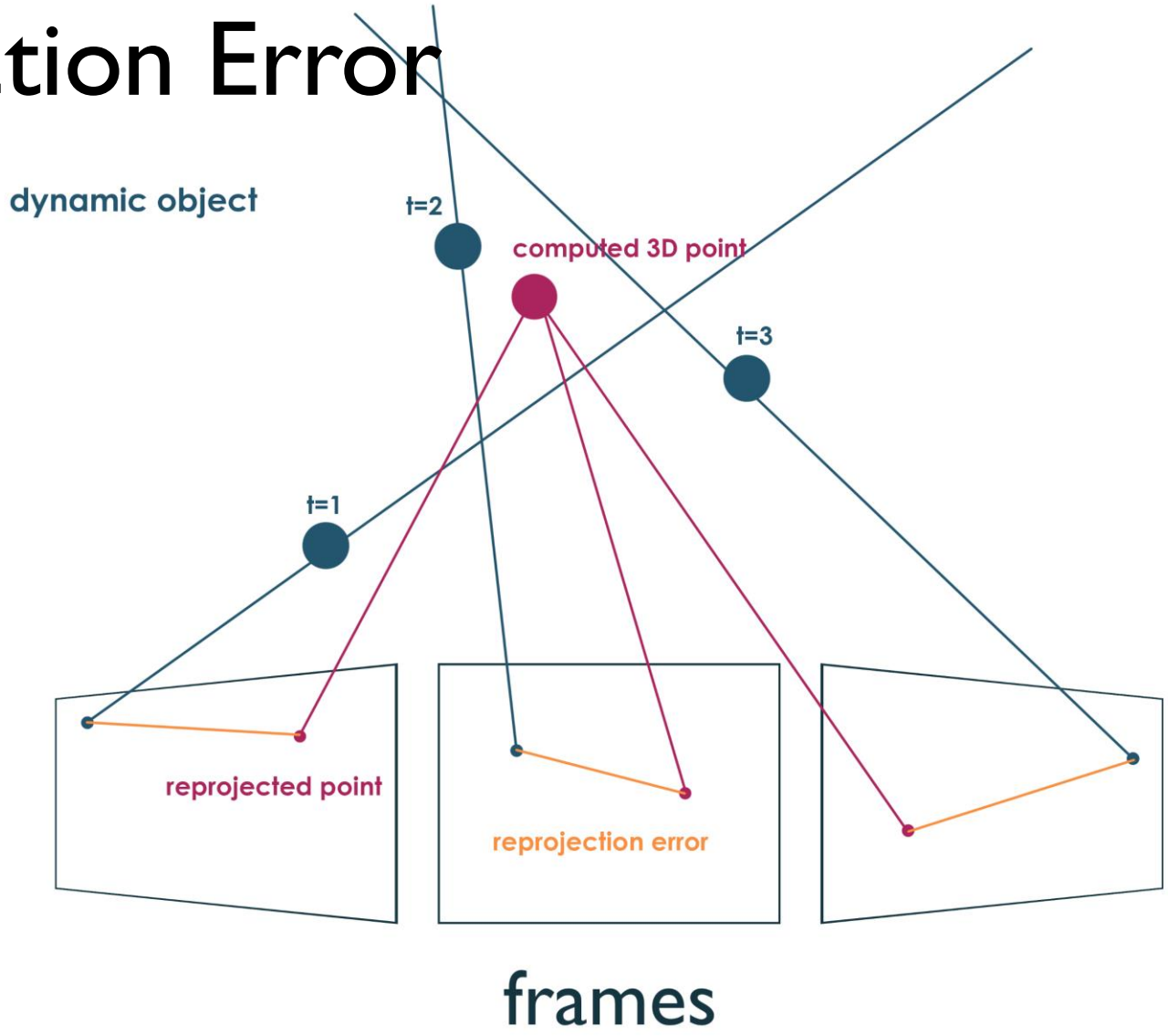
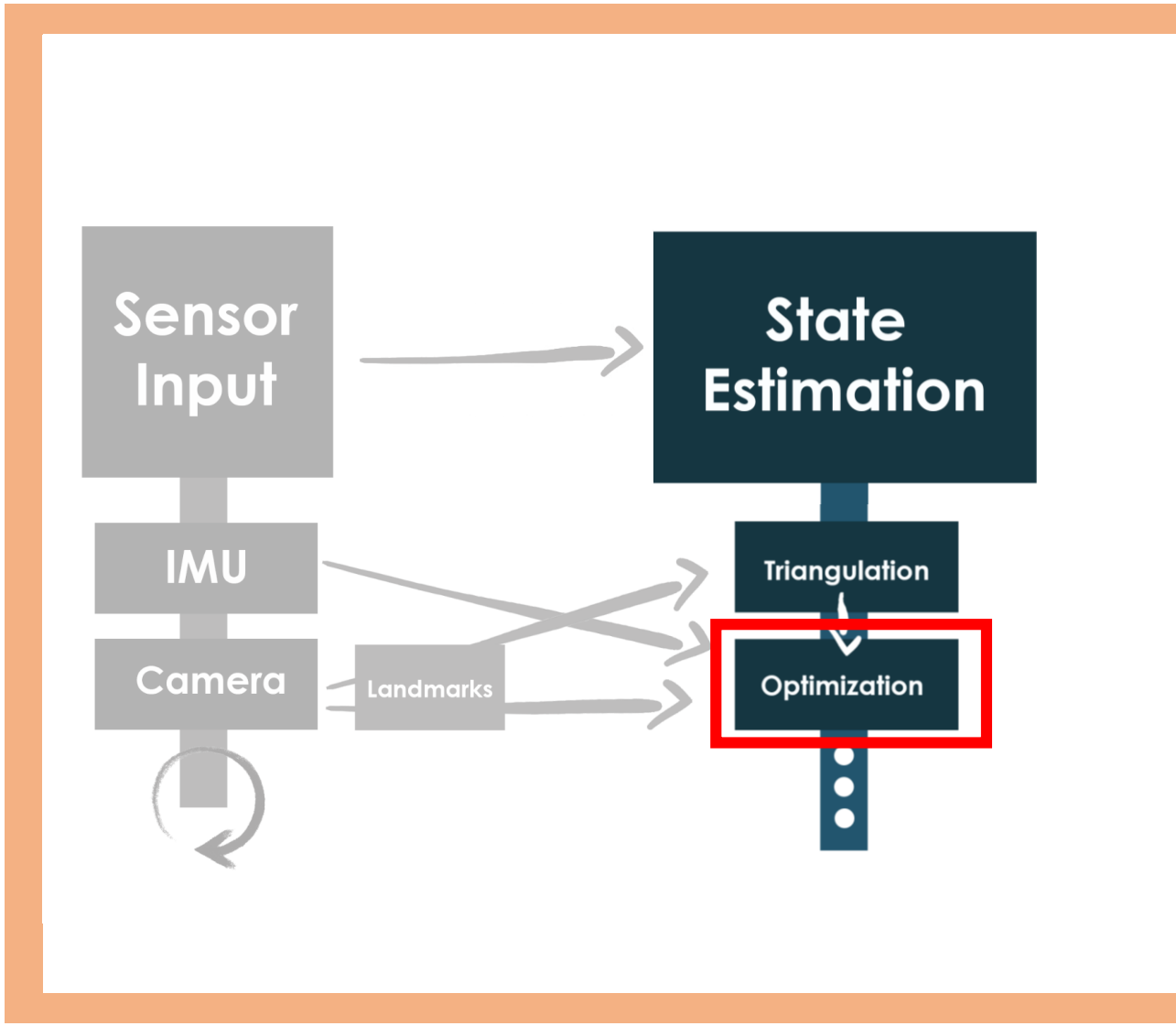
Reprojection Error



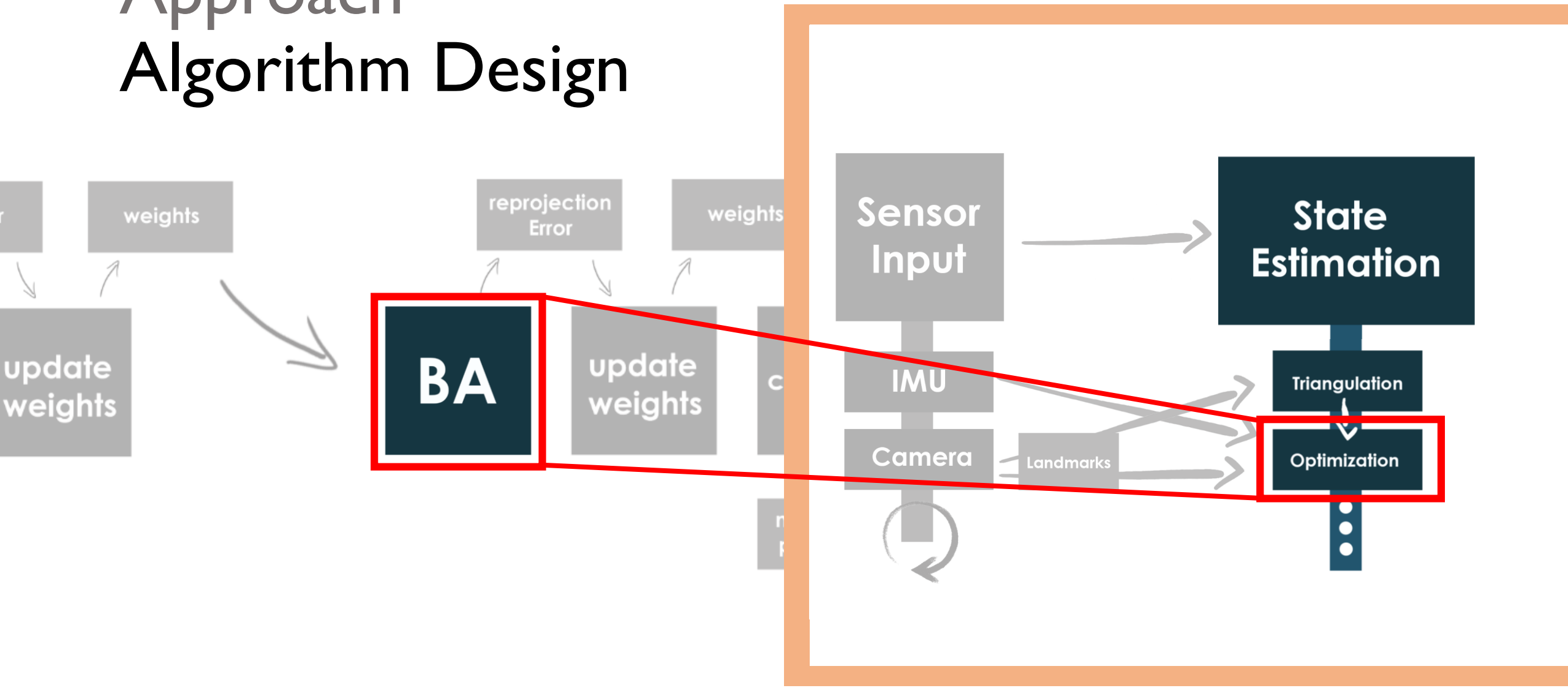
Approach
Reprojection Error



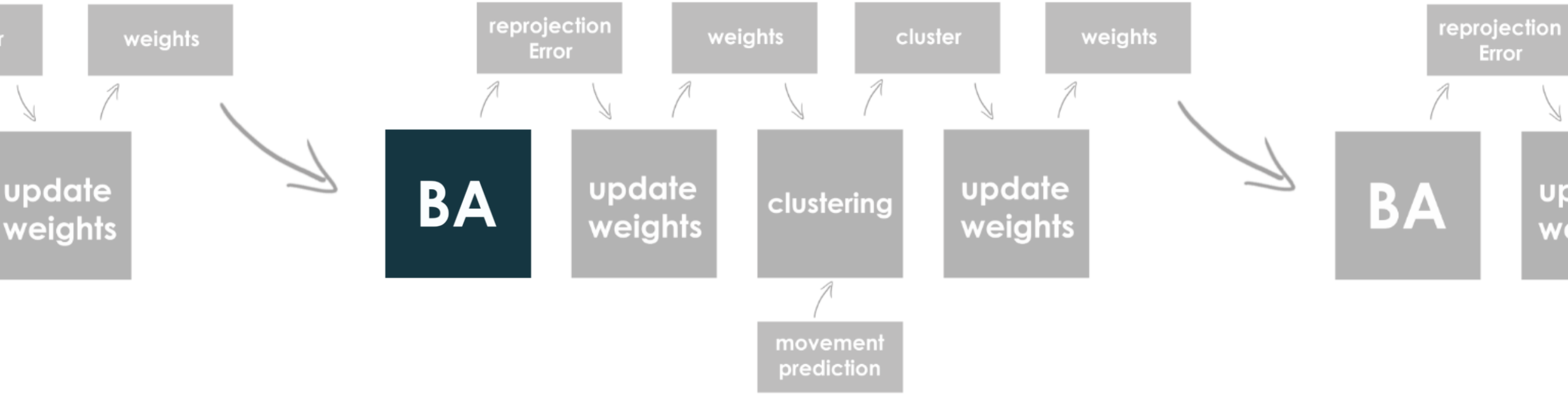
Approach
Algorithm Design



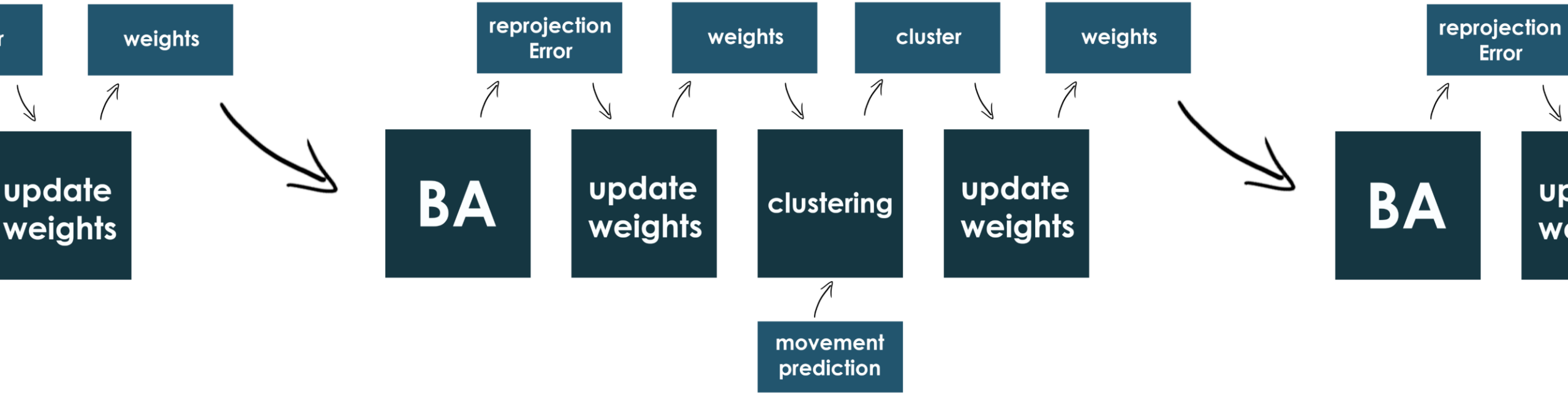
Approach
Algorithm Design

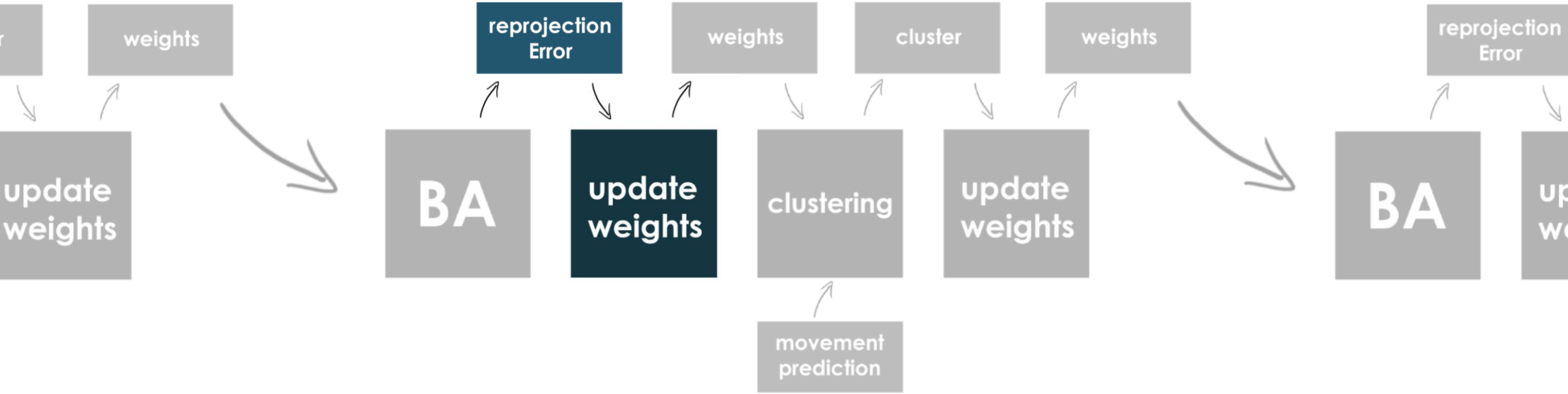


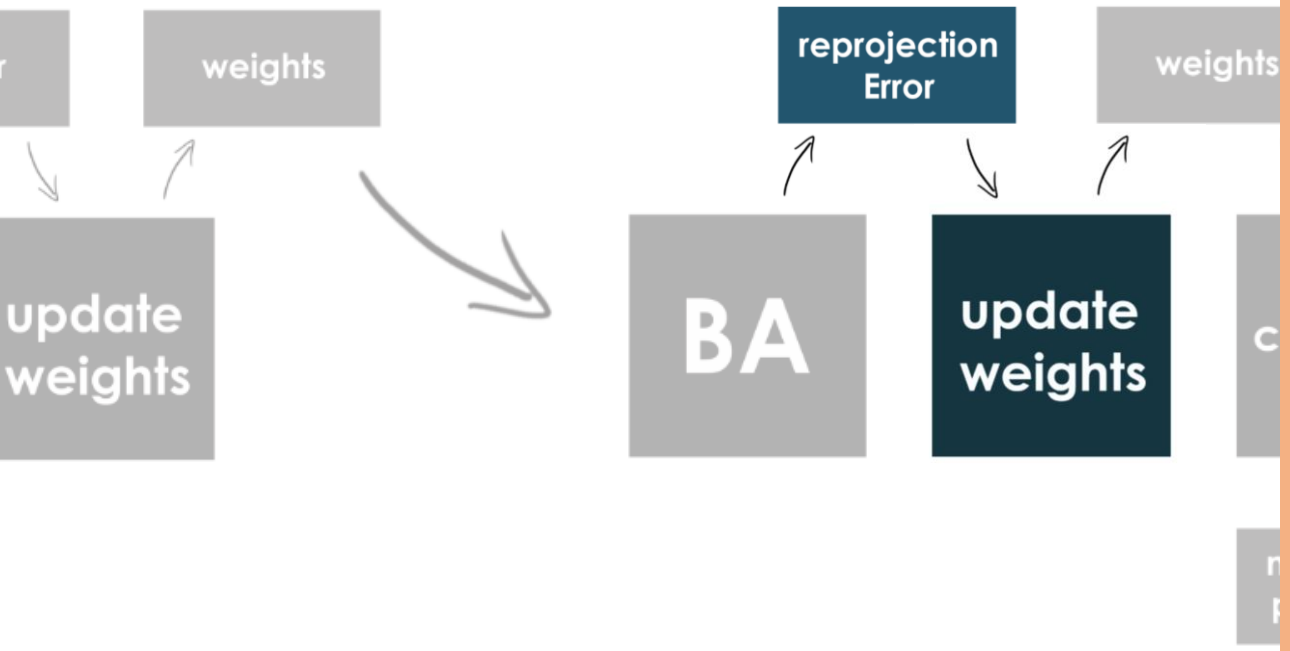
Approach
Algorithm Design



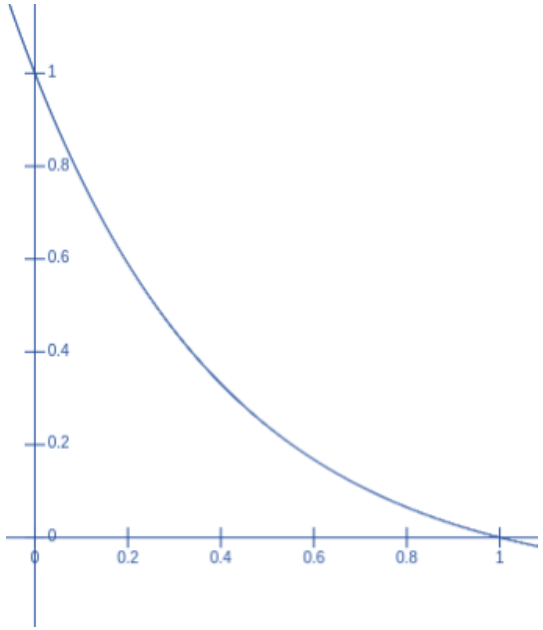
Approach
Algorithm Design

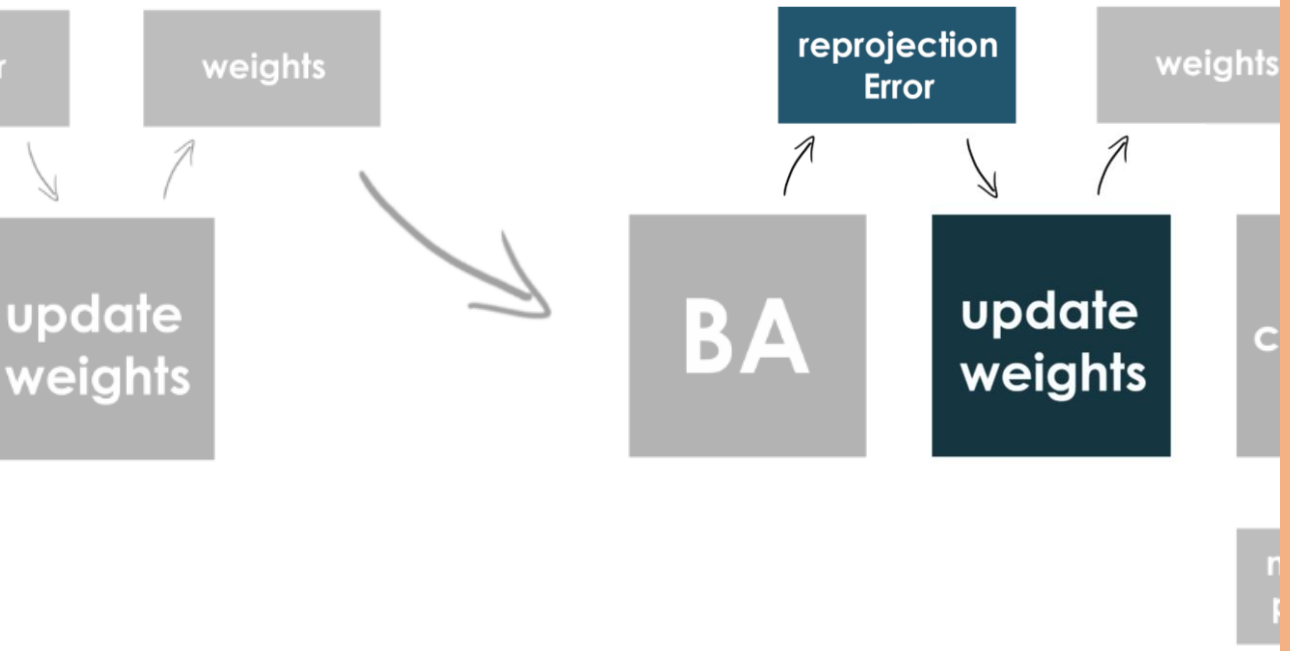



weights
update weights
BA
reprojection Error
update weights
weights
clustering
movement prediction
cluster
update weights
weights
BA
reprojection Error



$$W_t(W_{t-1}, e_t) = \frac{1}{2}W_{t-1} + \frac{1}{2}F(e_t)$$





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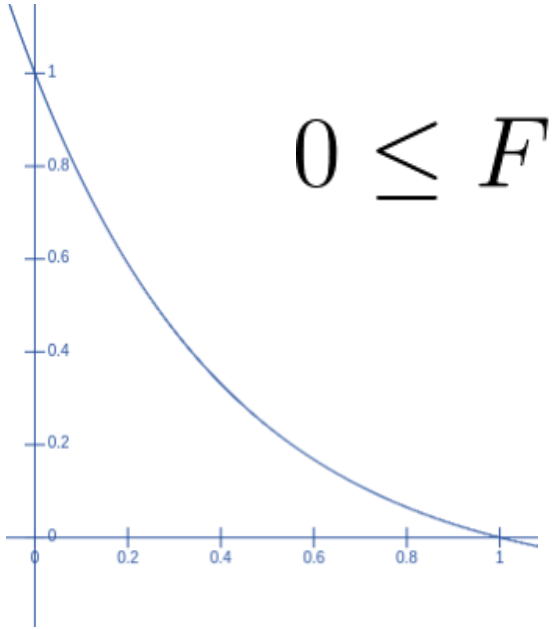
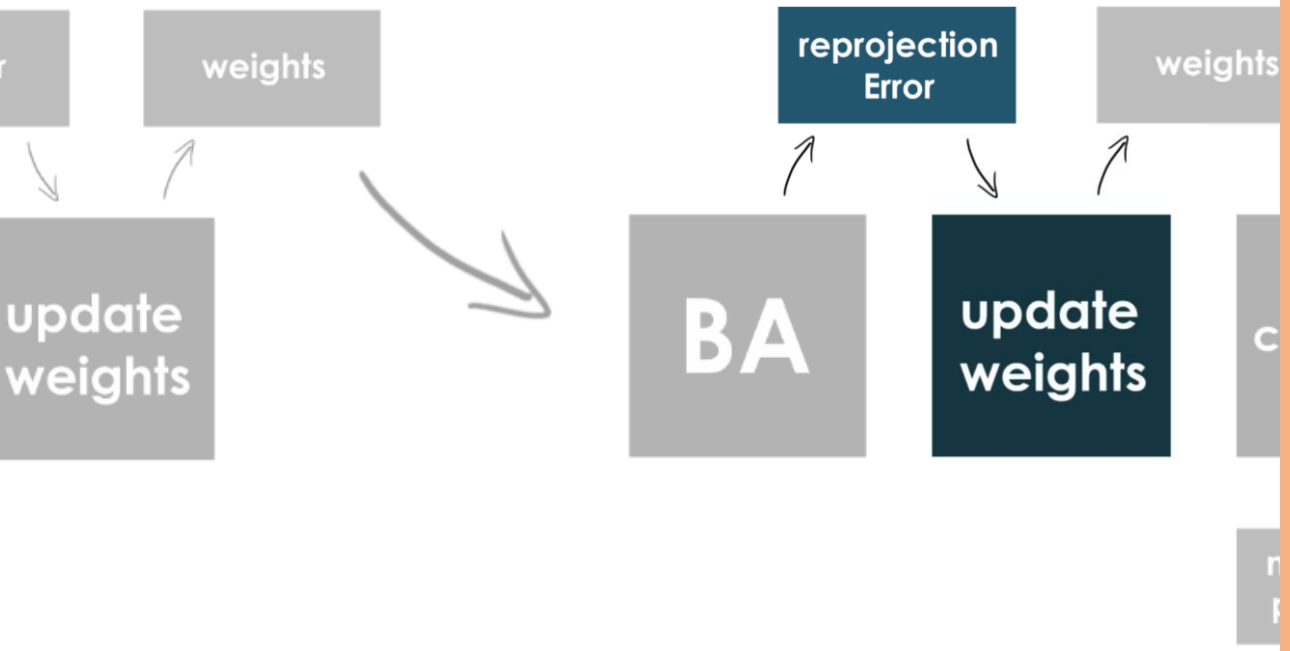


$$0 \leq F(e_t) \leq 1$$

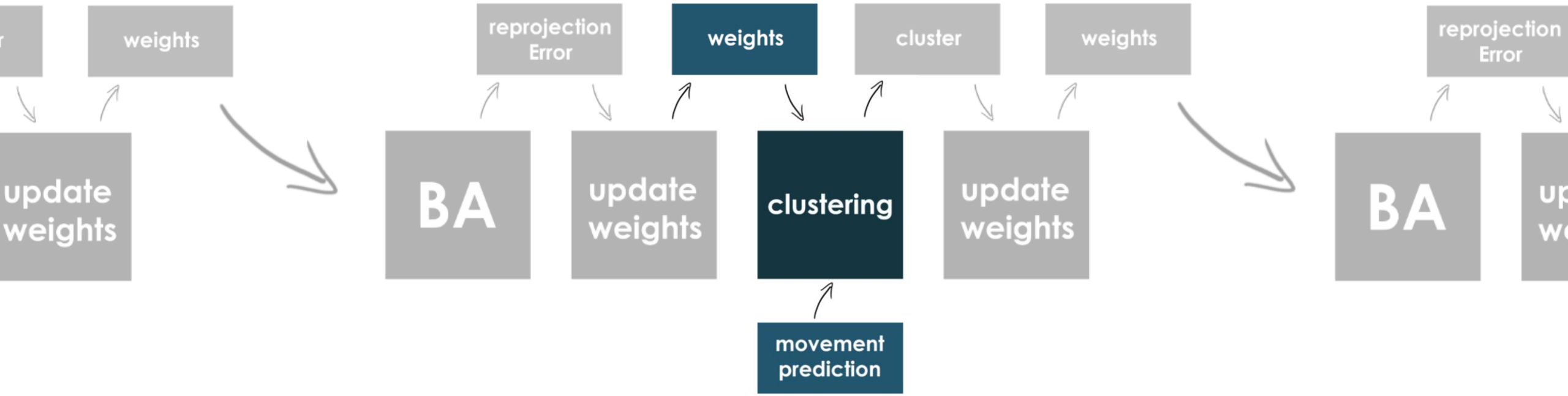


$$W_t(W_{t-1}, e_t) = \frac{1}{2}W_{t-1} + \frac{1}{2}F(e_t)$$

$$0 \leq F(e_t) \leq 1$$

$$e_t = \frac{\hat{e}_t}{e_{max}}$$

Threshold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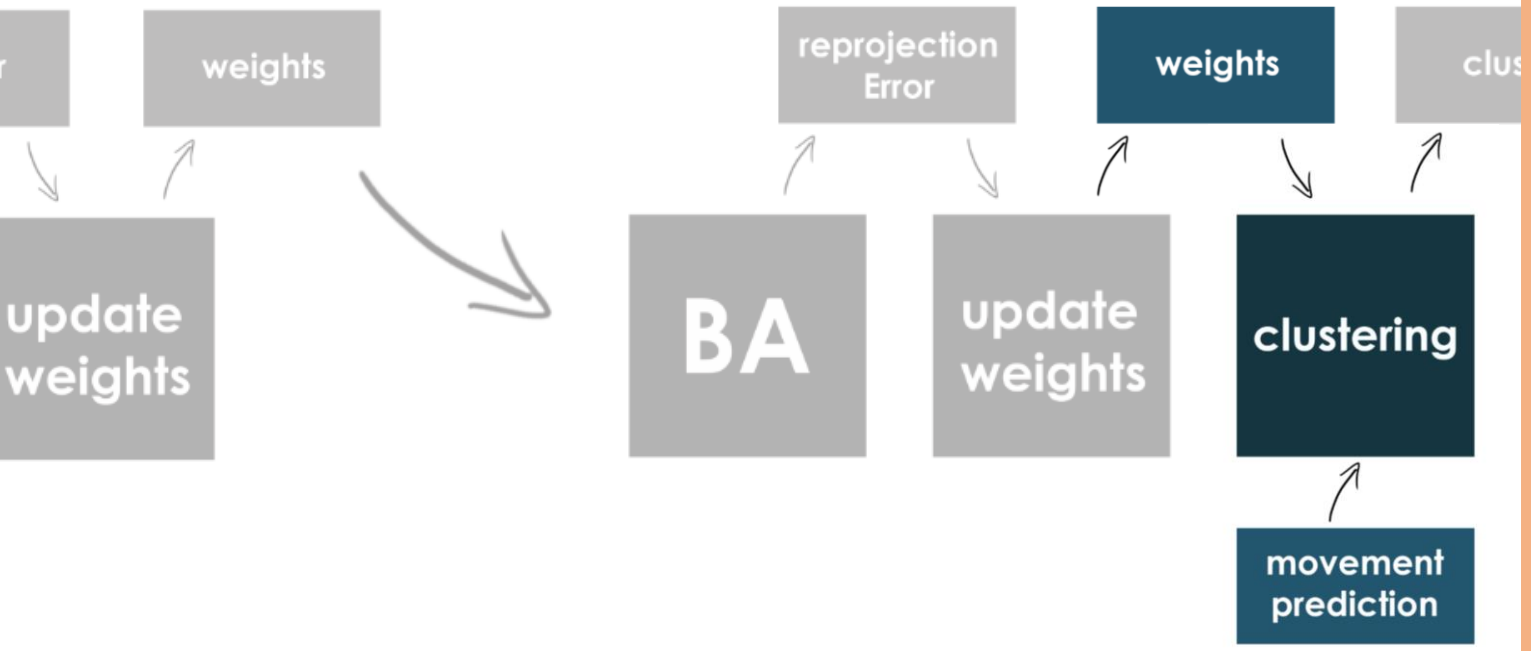
update weights
BA
reprojection Error
update weights
weights
clustering
movement prediction
cluster
update weights
weights
BA
reprojection Error


weights
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reprojection Error
BA
weights
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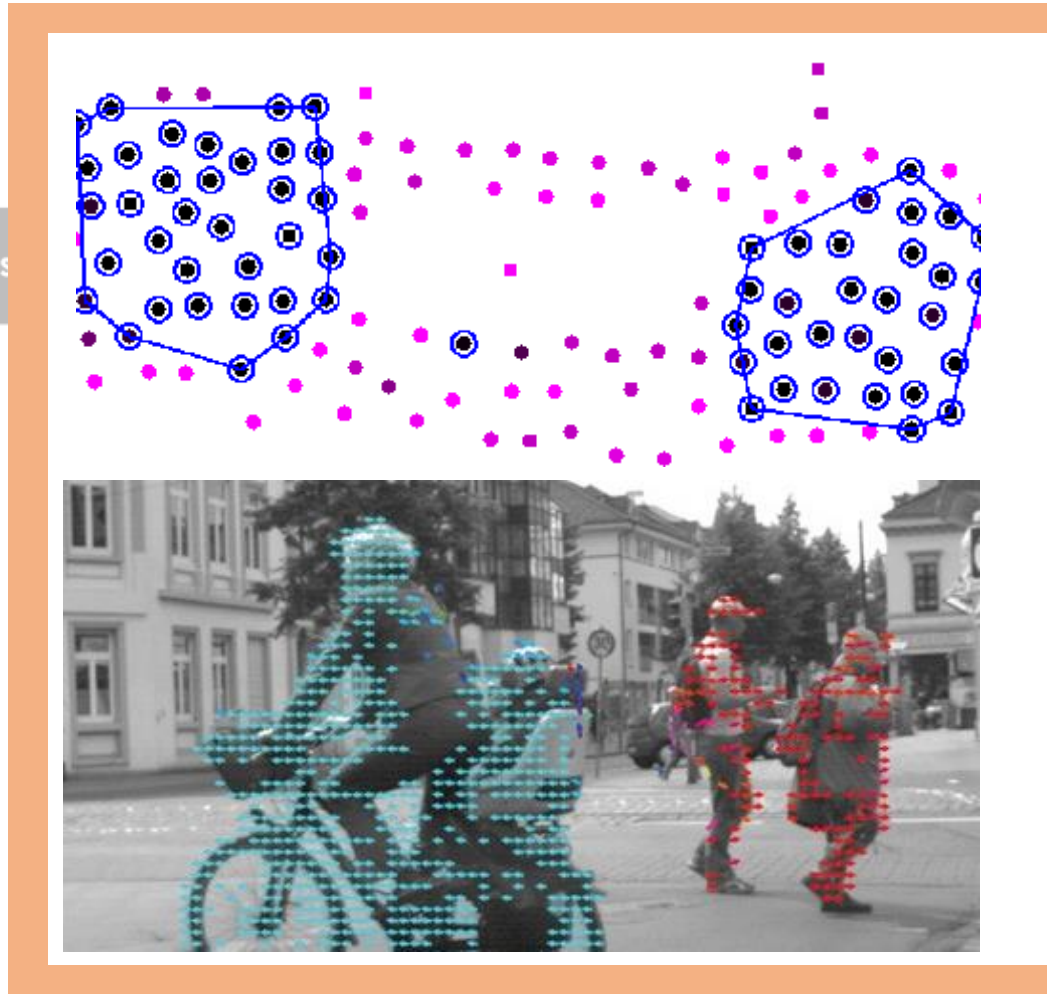

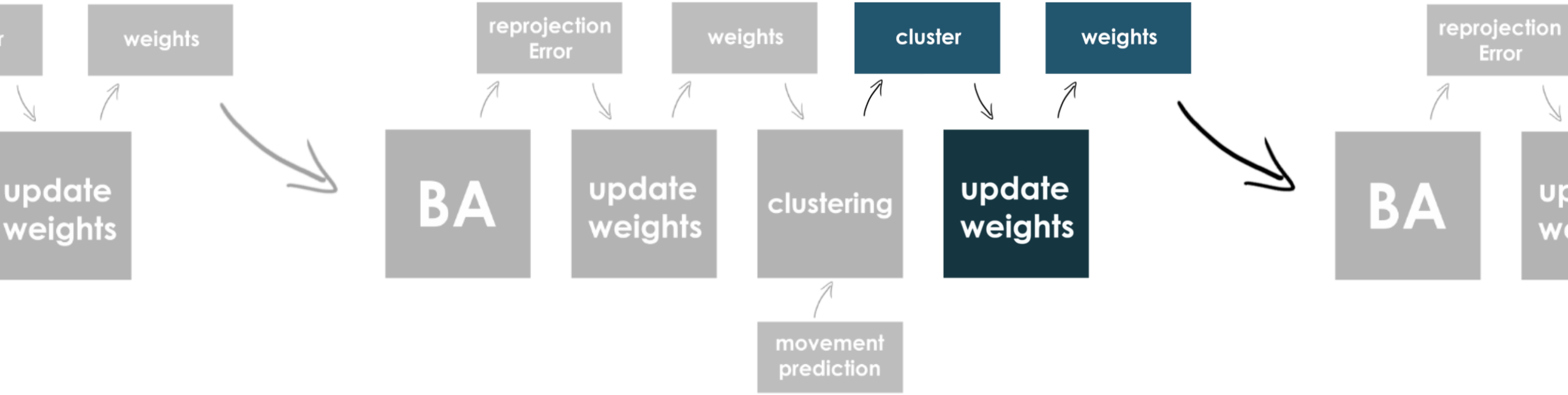
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clustering
movement prediction
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update weights
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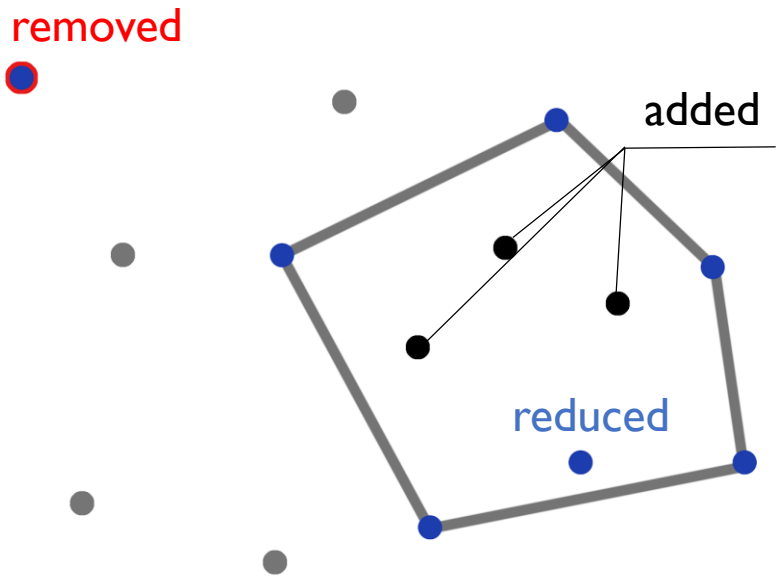
reprojection Error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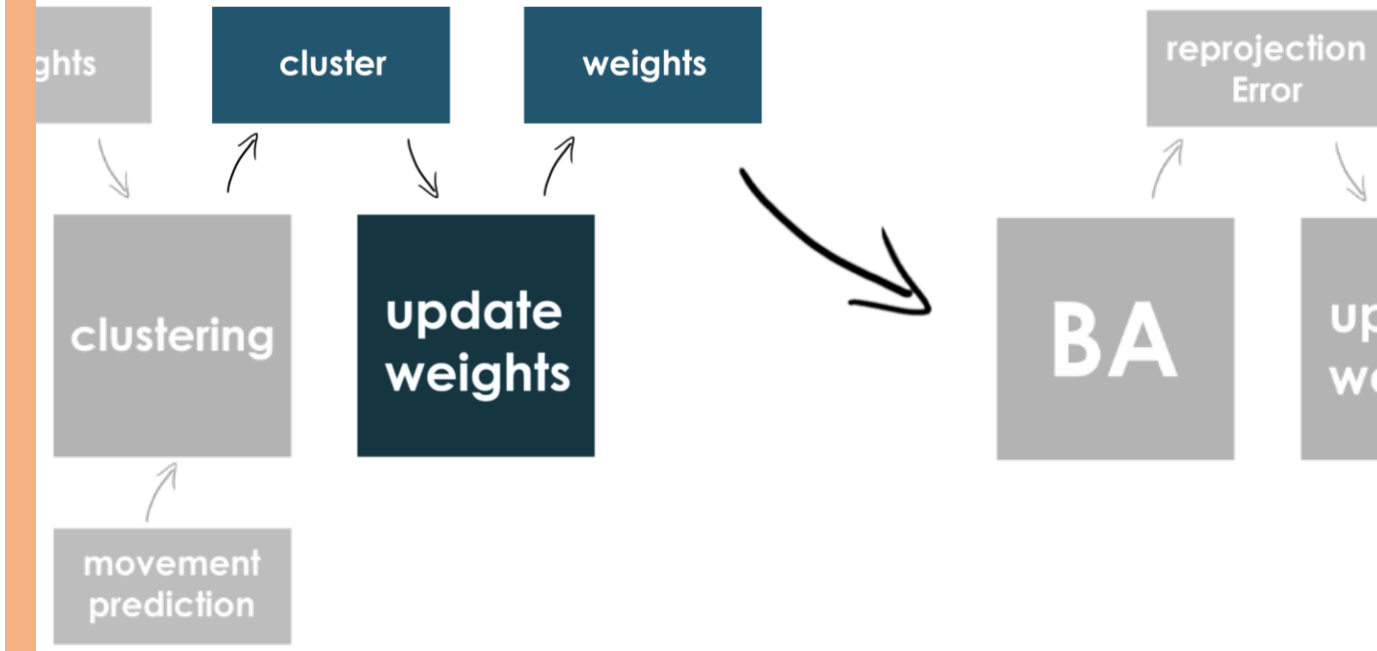
ghts
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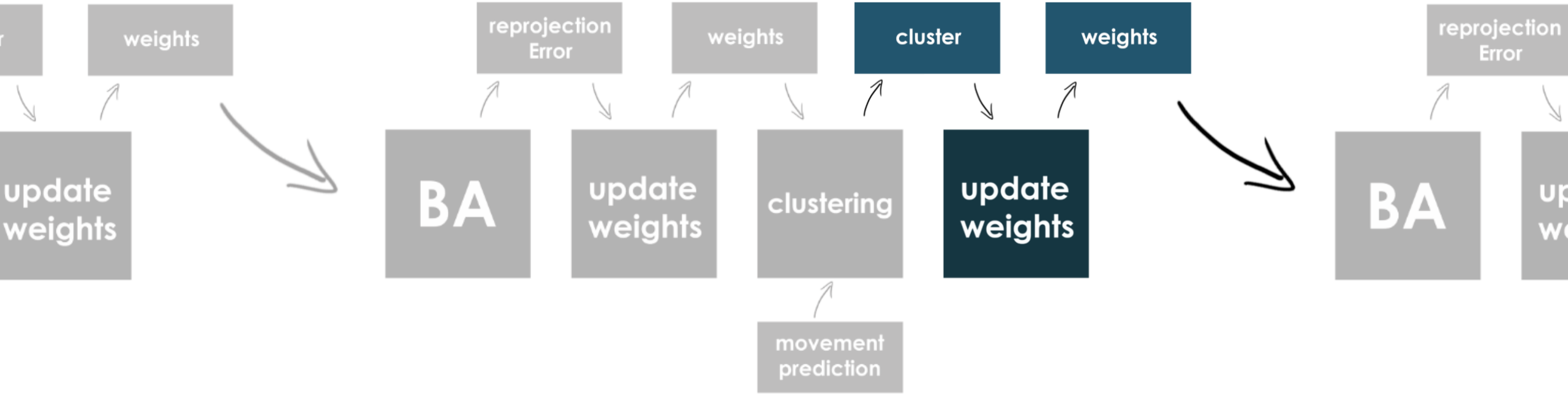
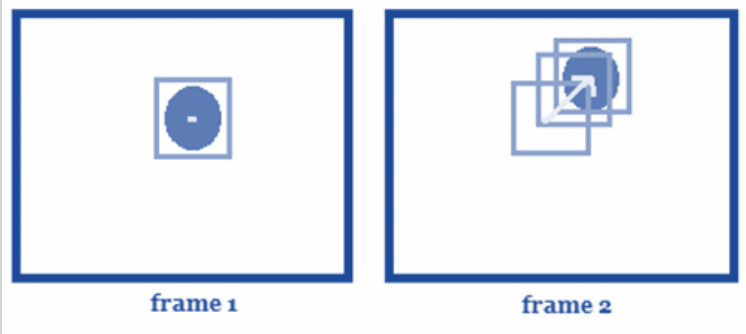
clustering
update weights
BA
movement prediction


weights
update weights
BA
reprojection Error
update weights
weights
clustering
movement prediction
cluster
update weights
weights
BA
reprojection Error

Experiments & Results

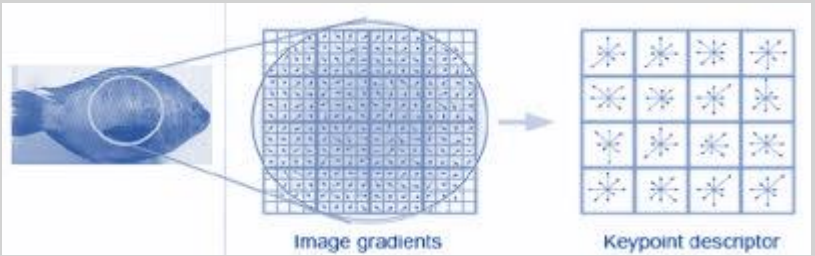
Tracking Based Feature Matching

- VINS-Mono

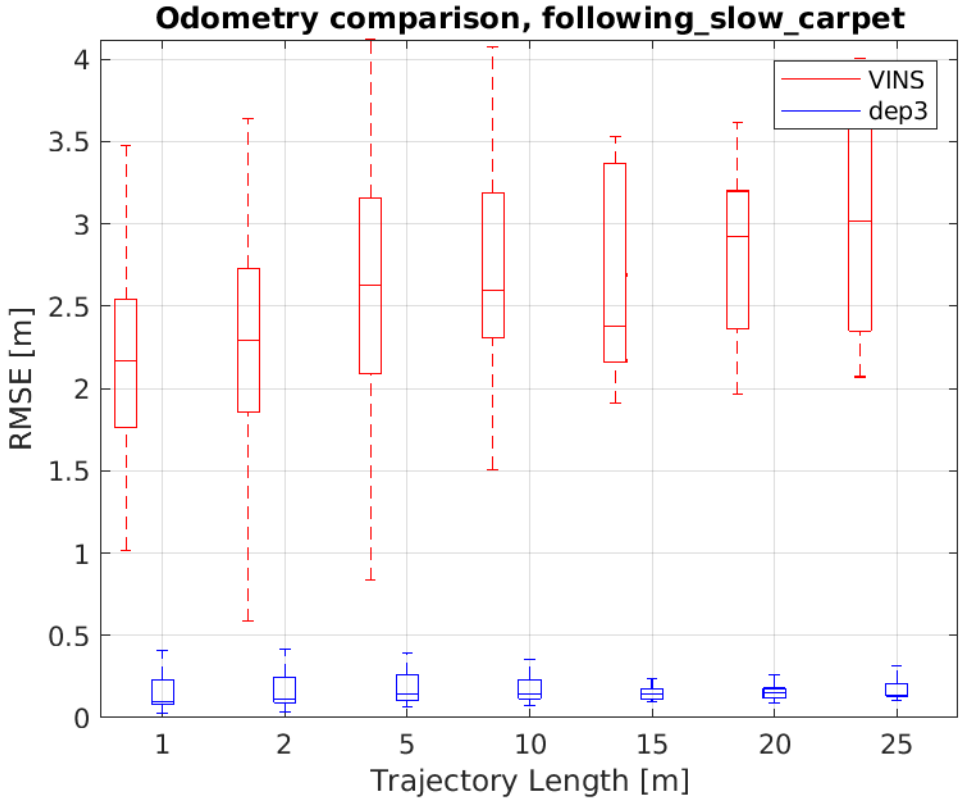


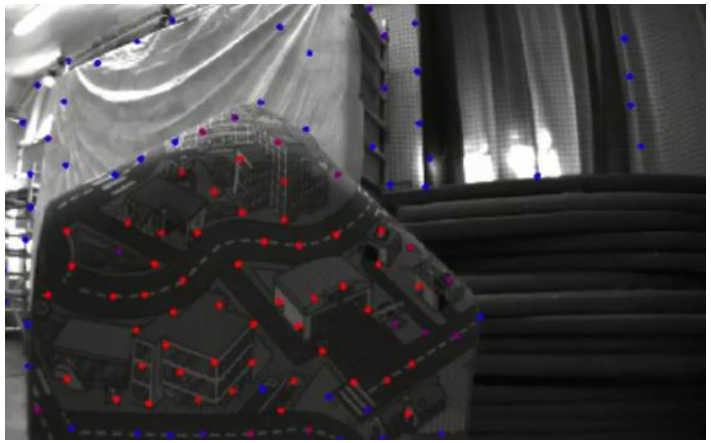
Descriptor Based Feature Matching

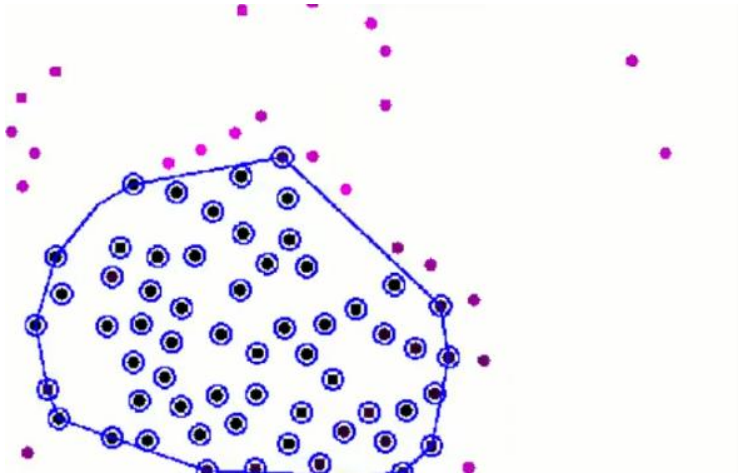
- OKVIS



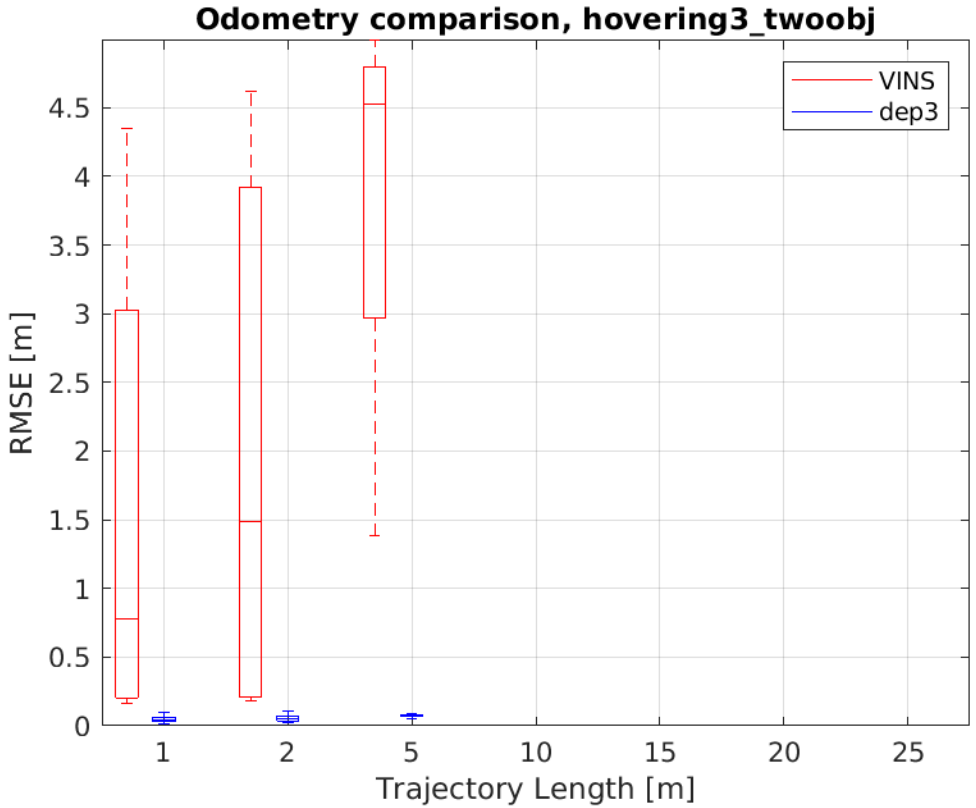
Experiments & Results
VINS-Mono

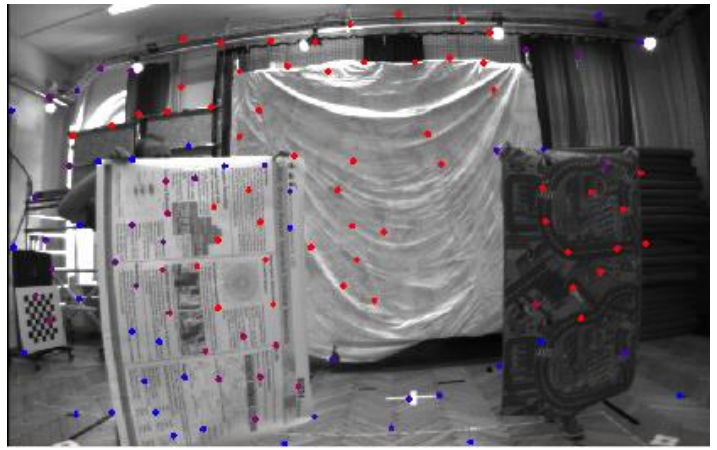


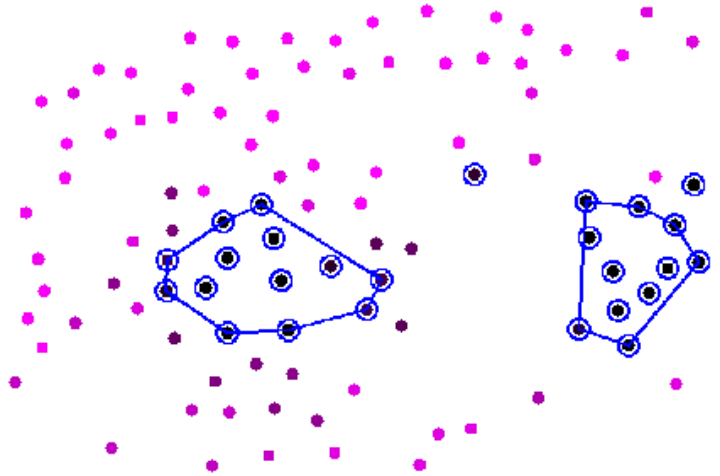




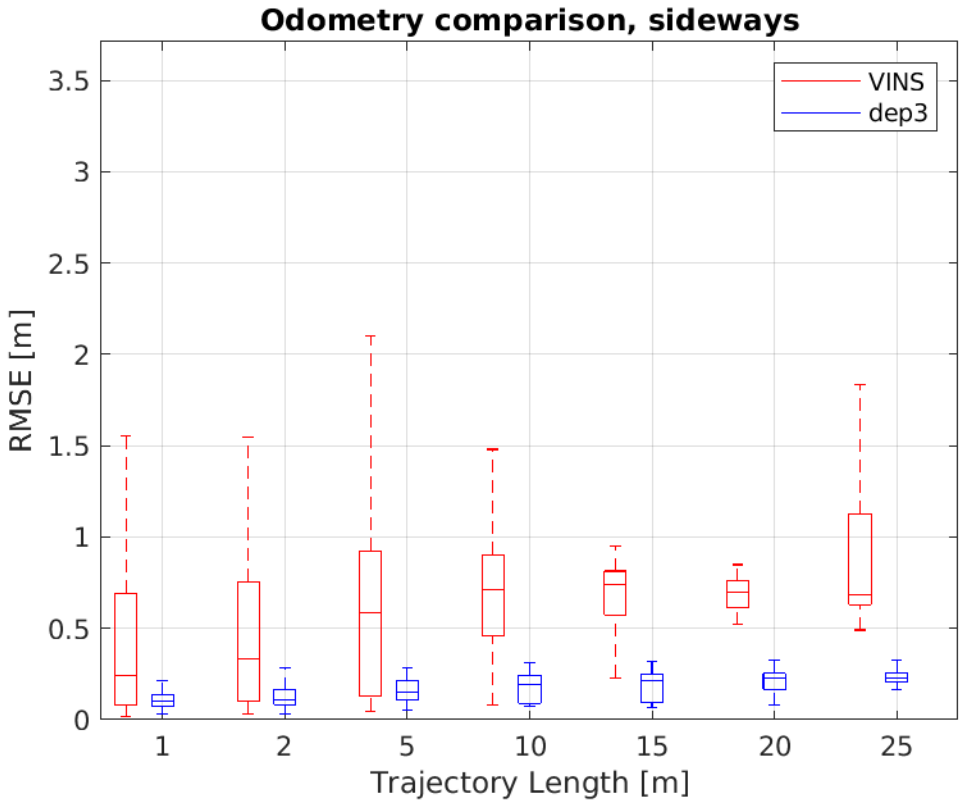
Experiments & Results
VINS-Mono

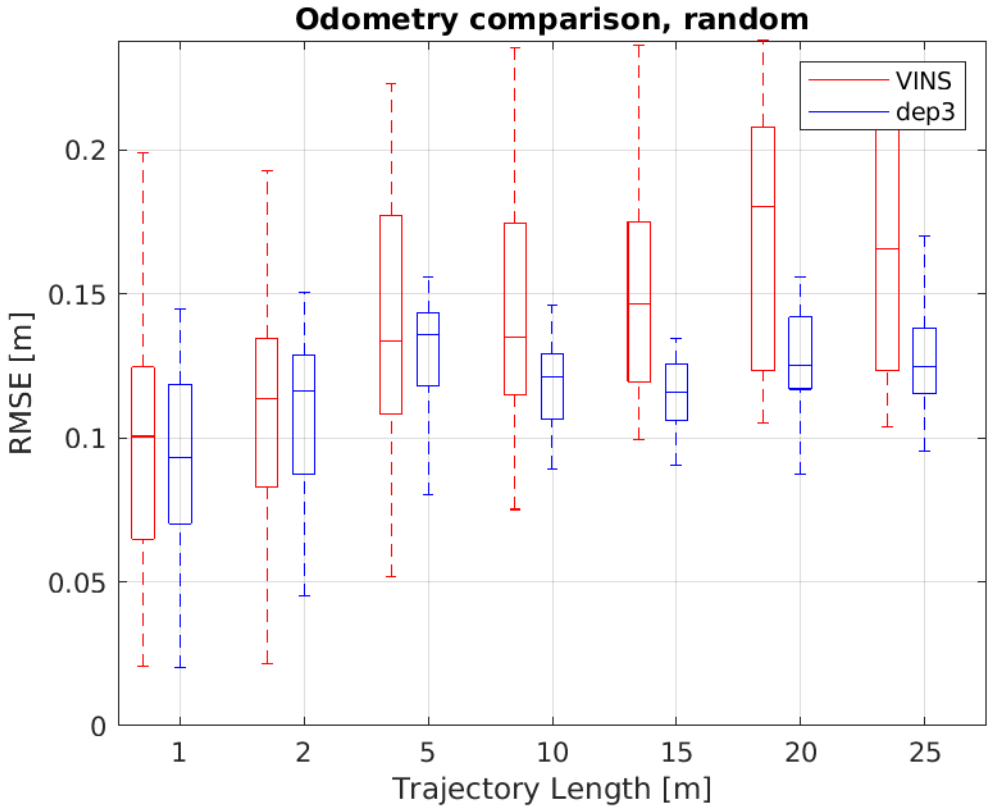




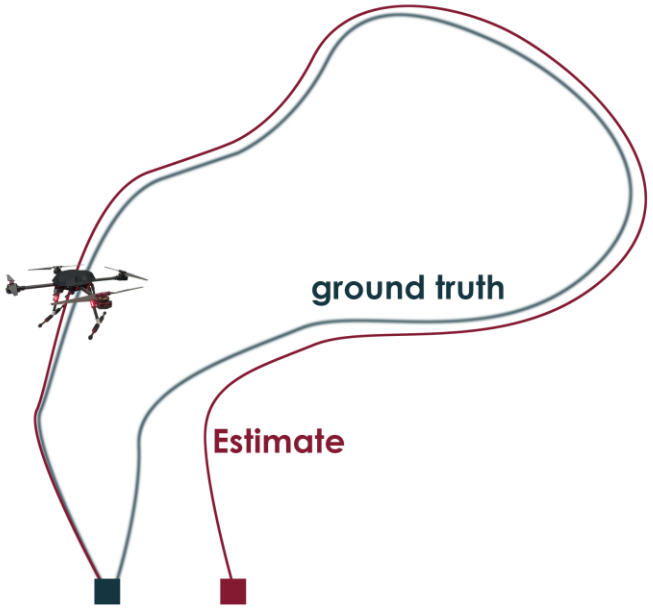


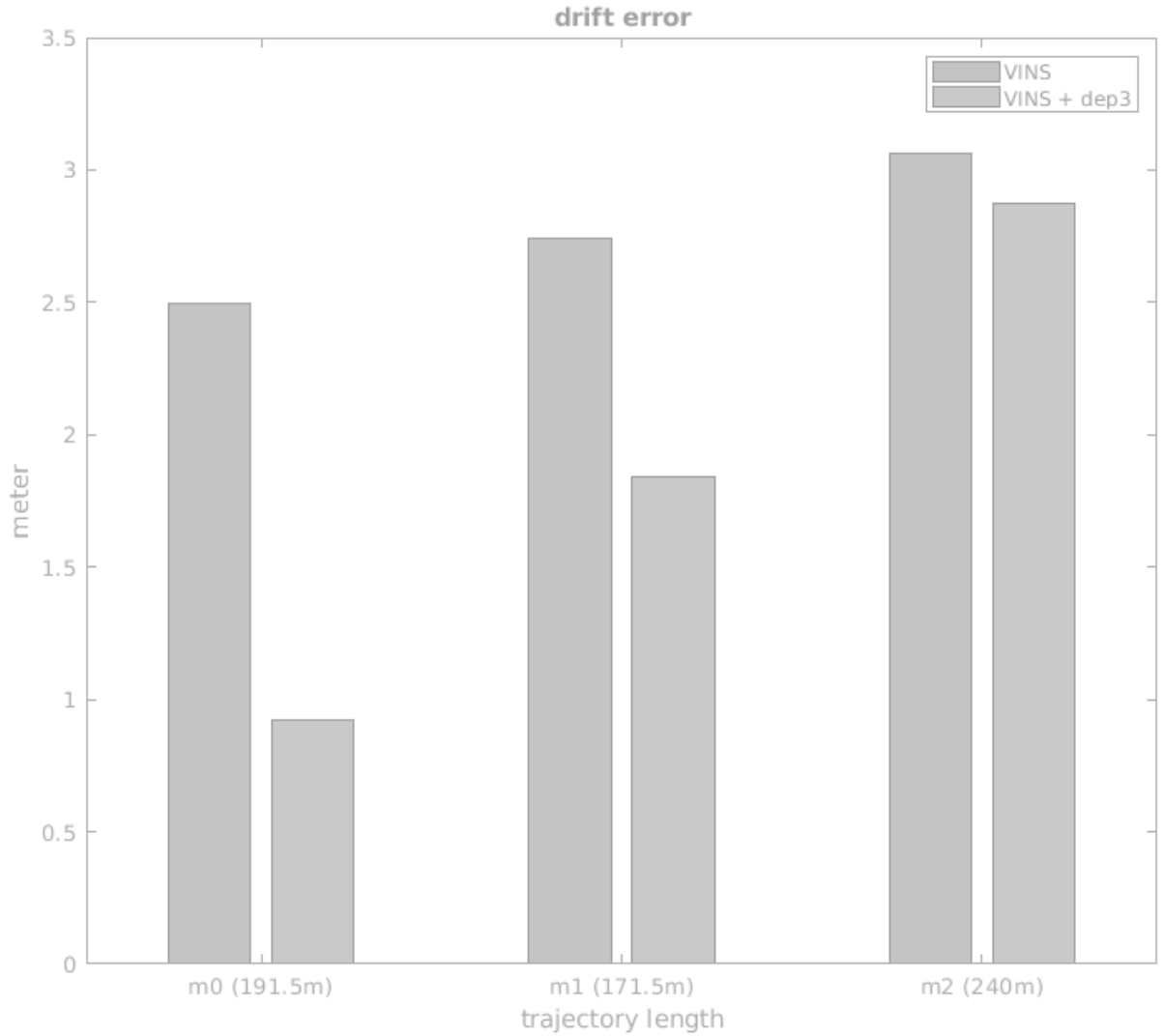
Experiments & Results
VINS-Mono



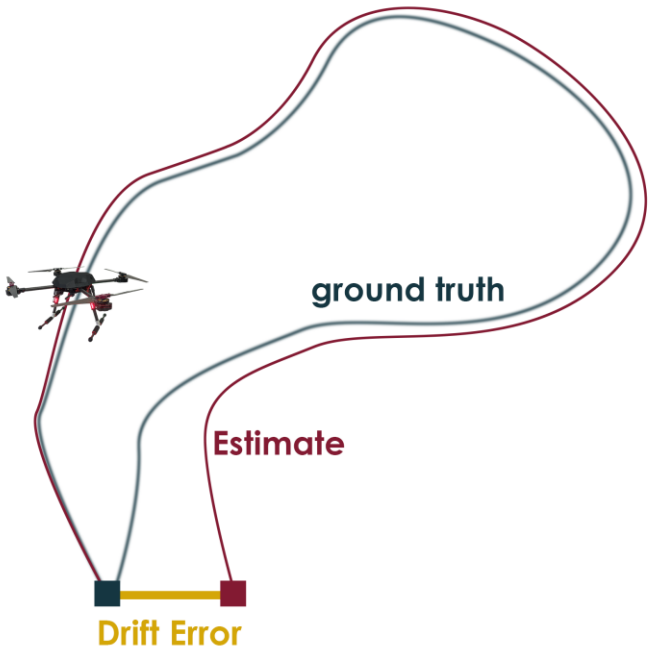


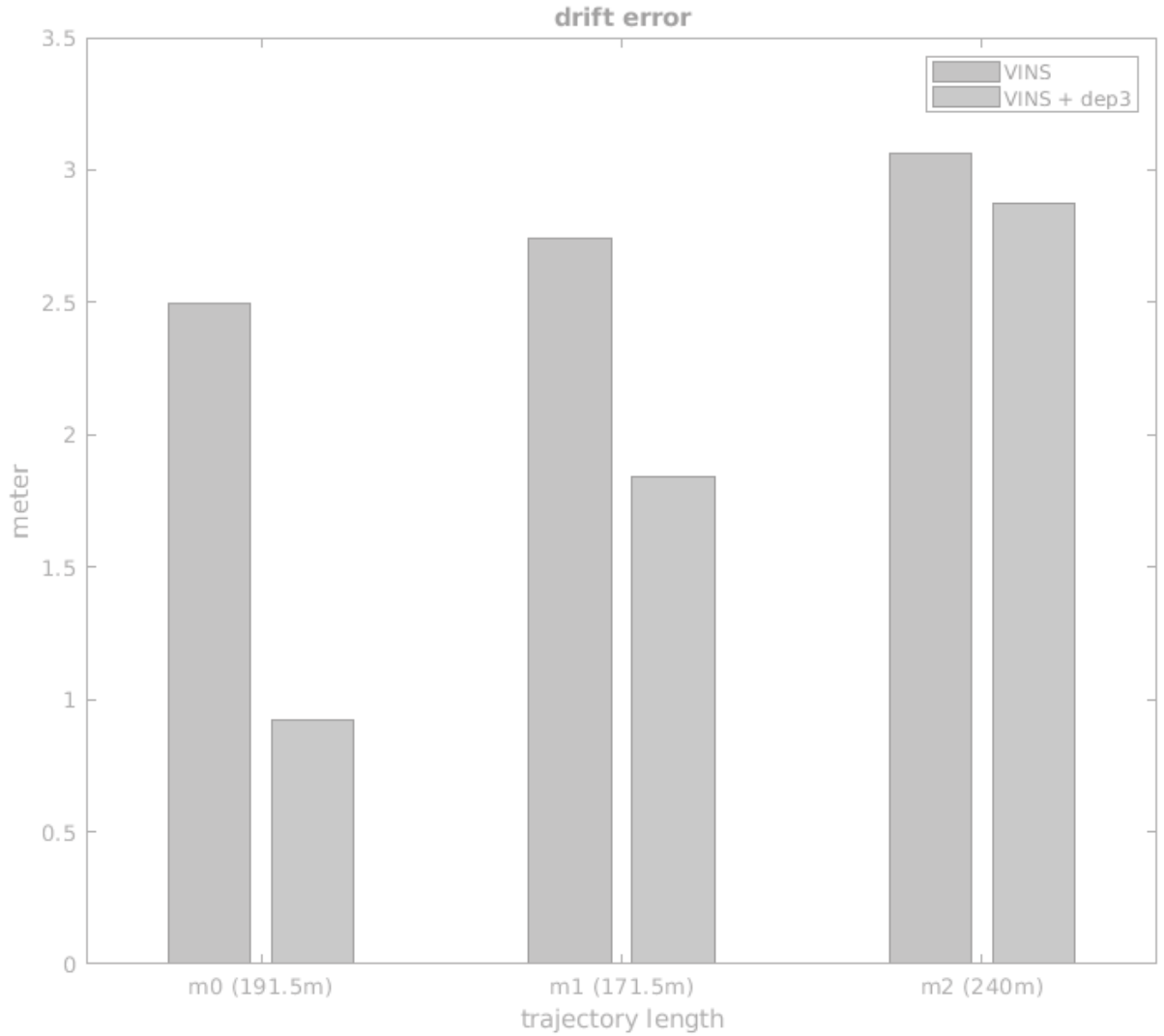
Experiments & Results
VINS-Mono



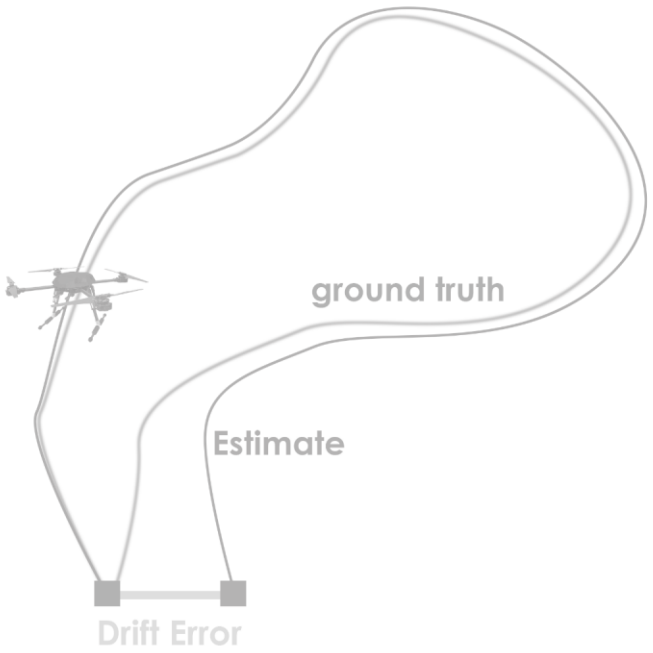


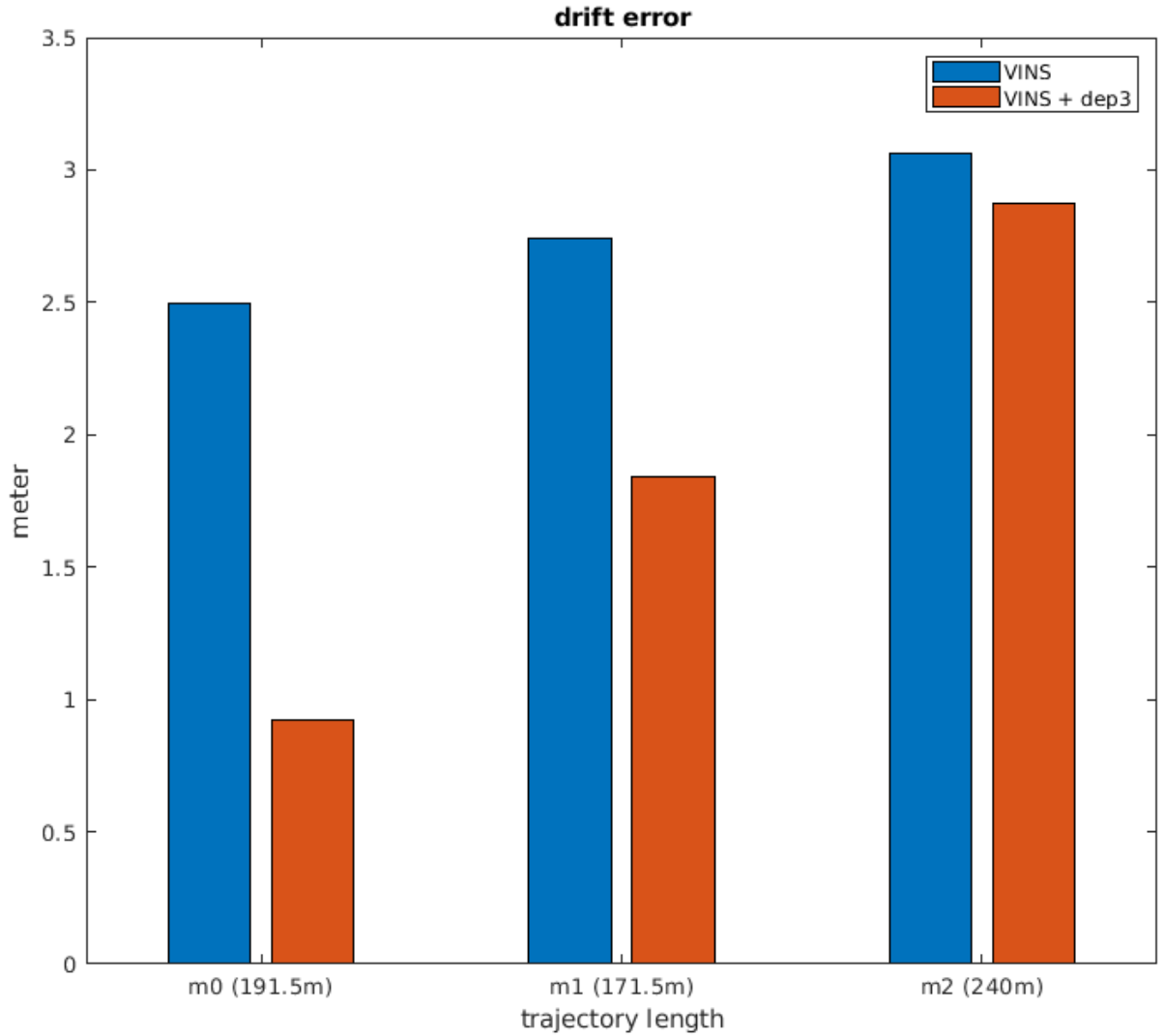
Experiments & Results
VINS-Mono



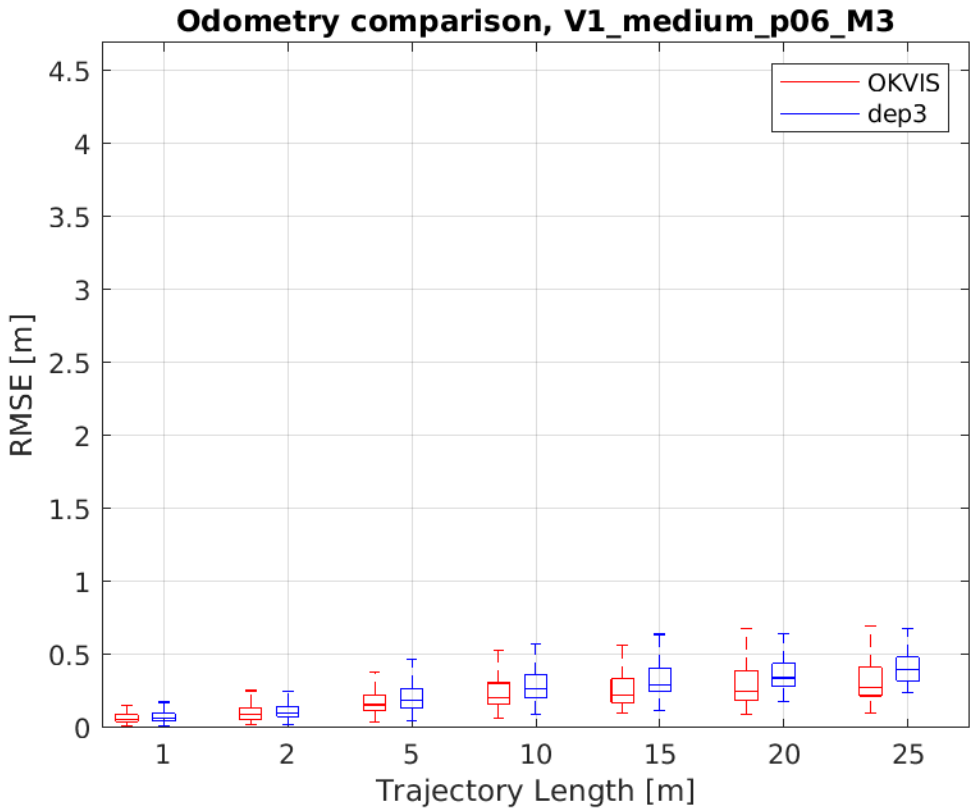


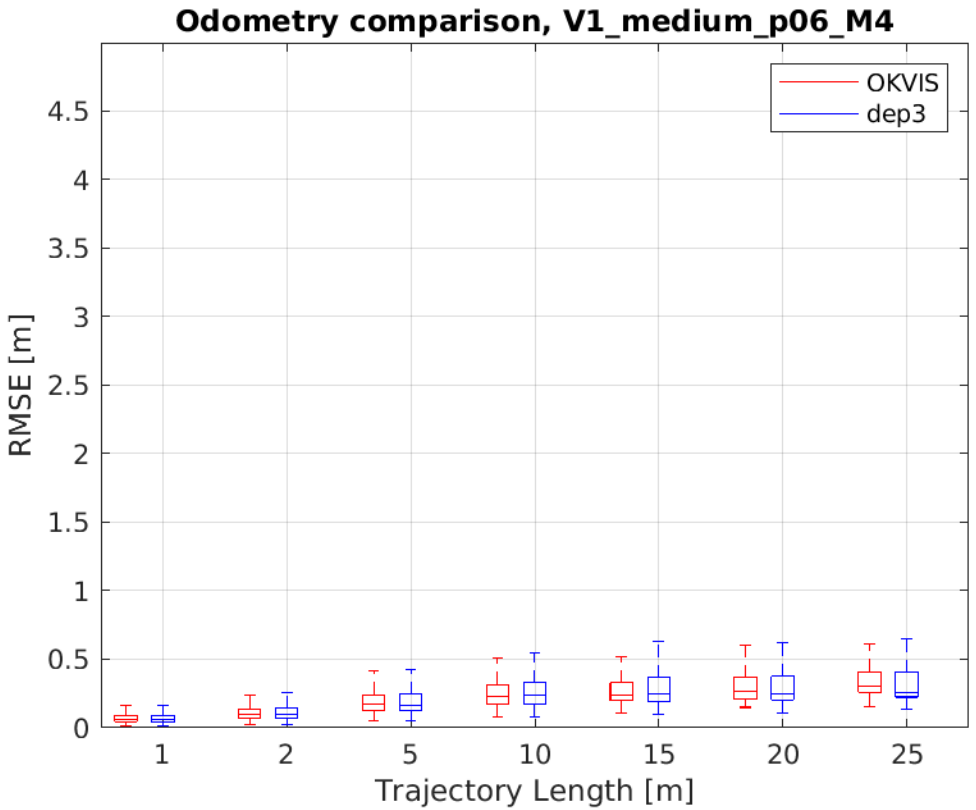
Experiments & Results
VINS-Mono



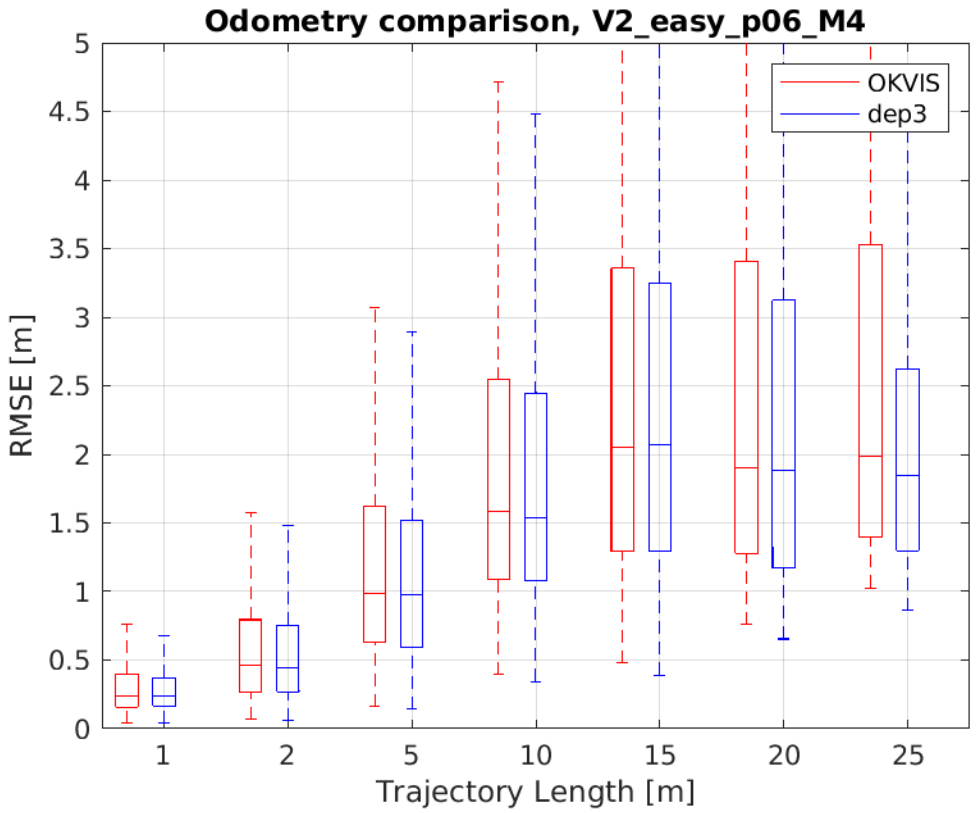


Experiments & Results
OKVIS

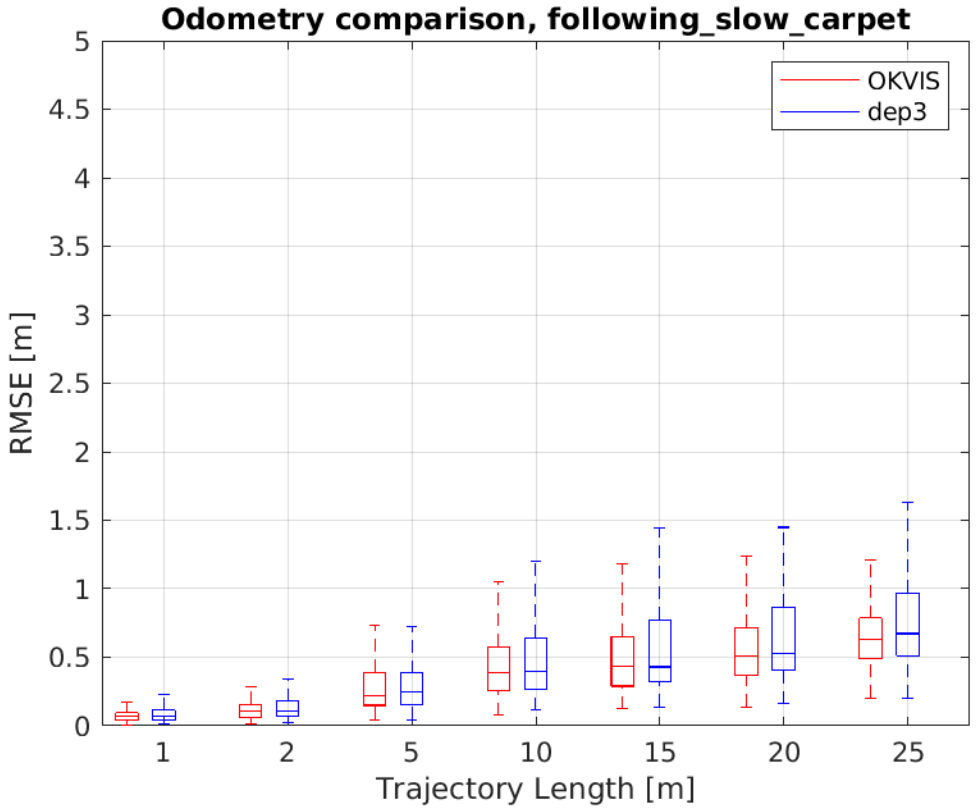


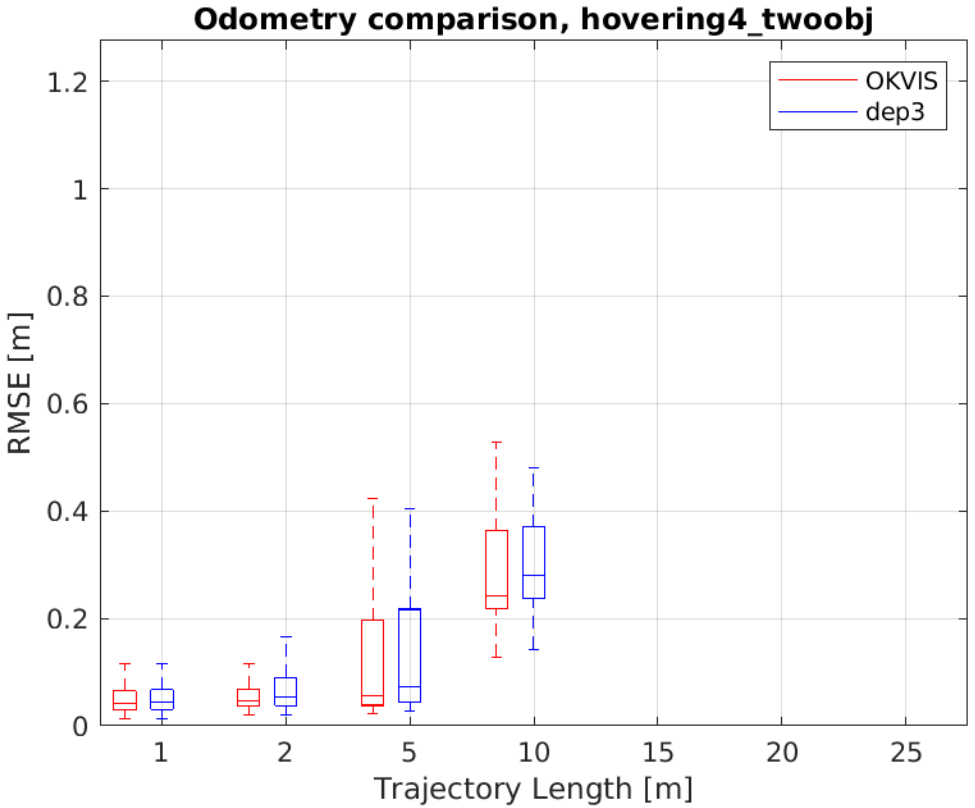


Experiments & Results
OKVIS

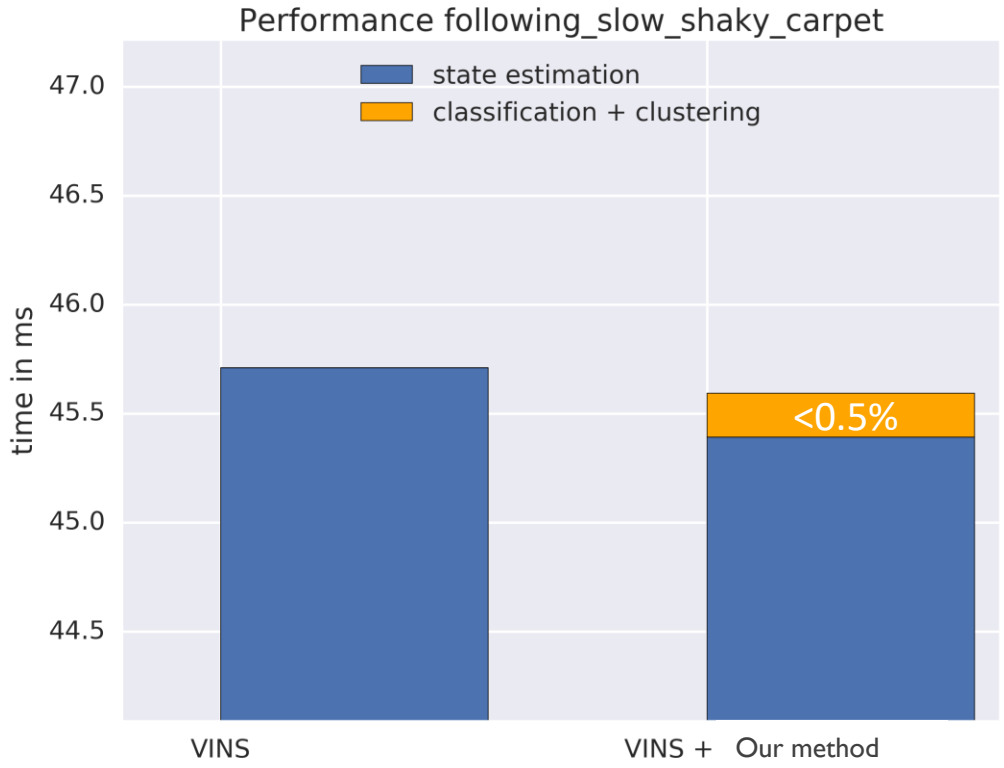


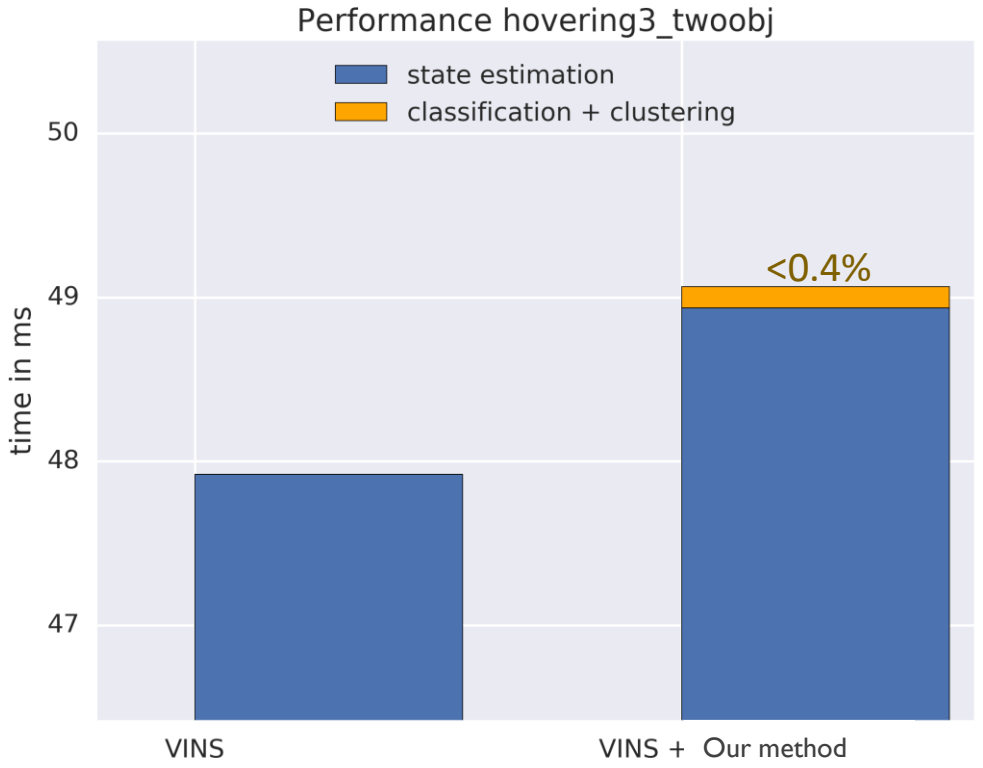
Experiments & Results
OKVIS





Experiments & Results
Benchmarks





Conclusion

This Projects proposes a simple solution to deal with dynamic objects in a SLAM system that…

… also works under high occlusion by dynamic objects

… is computational cheap

… works especially well in a „following scenario“ and with texture-rich objects

There are also other methods to prevent dynamic objects to influence the state estimation, like OKVIS does.

Further Work

- Reprojection Error Threshold
  - Initialization with dynamic objects
  - Adaptive threshold based on IMU
  - Adaptive threshold based on number of features available

- OKVIS / Descriptor Based Feature Matching Systems
  - Robust cluster movement prediction

SLAM for Dynamic Environments

Thank You

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Questions?

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