

Lecture 10.1

Introduction to Visual SLAM

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What is SLAM?

What is SLAM?

- Simultaneous localization and mapping

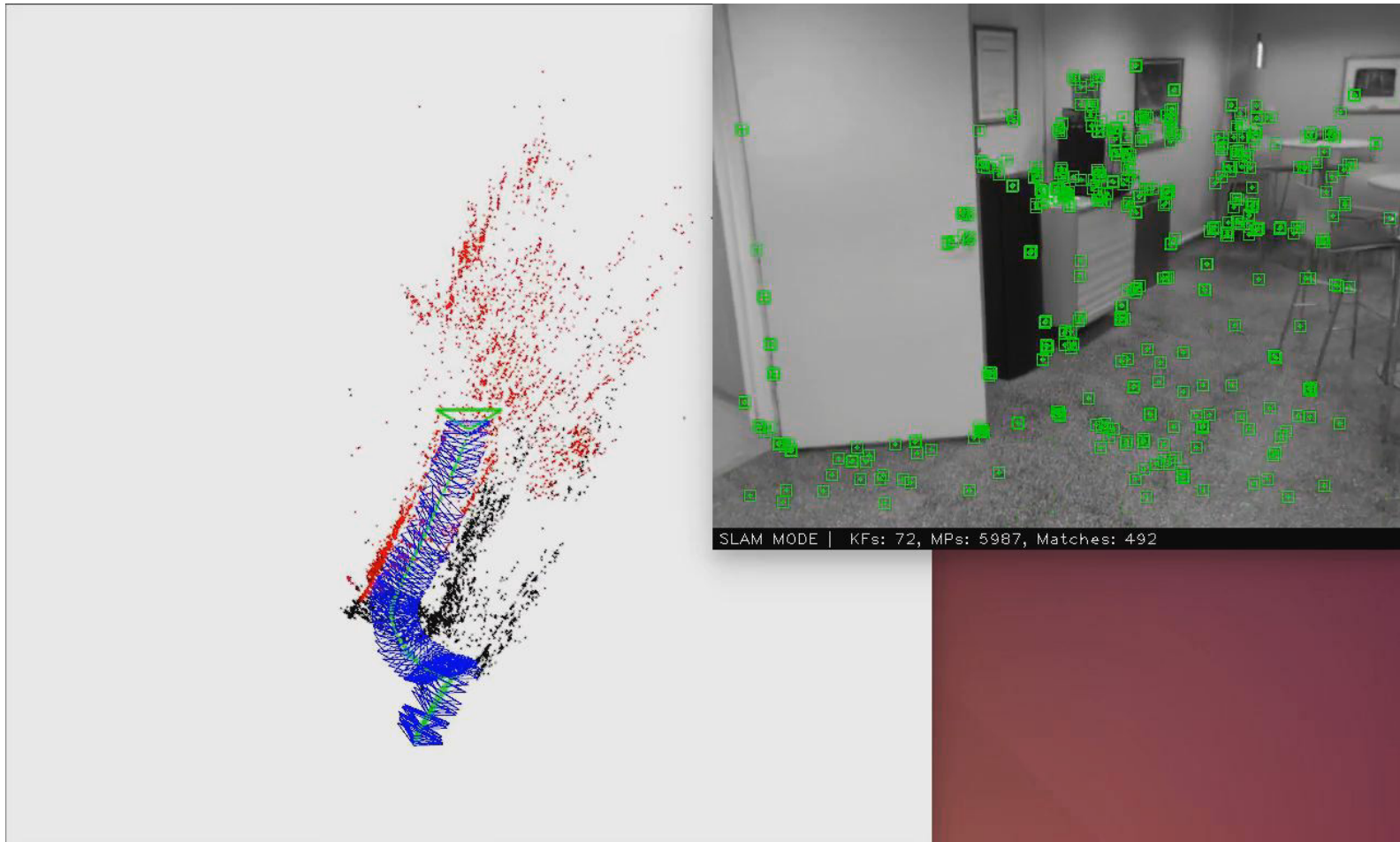
What is SLAM?

- Simultaneous localization and mapping
- Mapping
 - Continuously expanding a map while exploring the environment
- Localization
 - Localization within the map

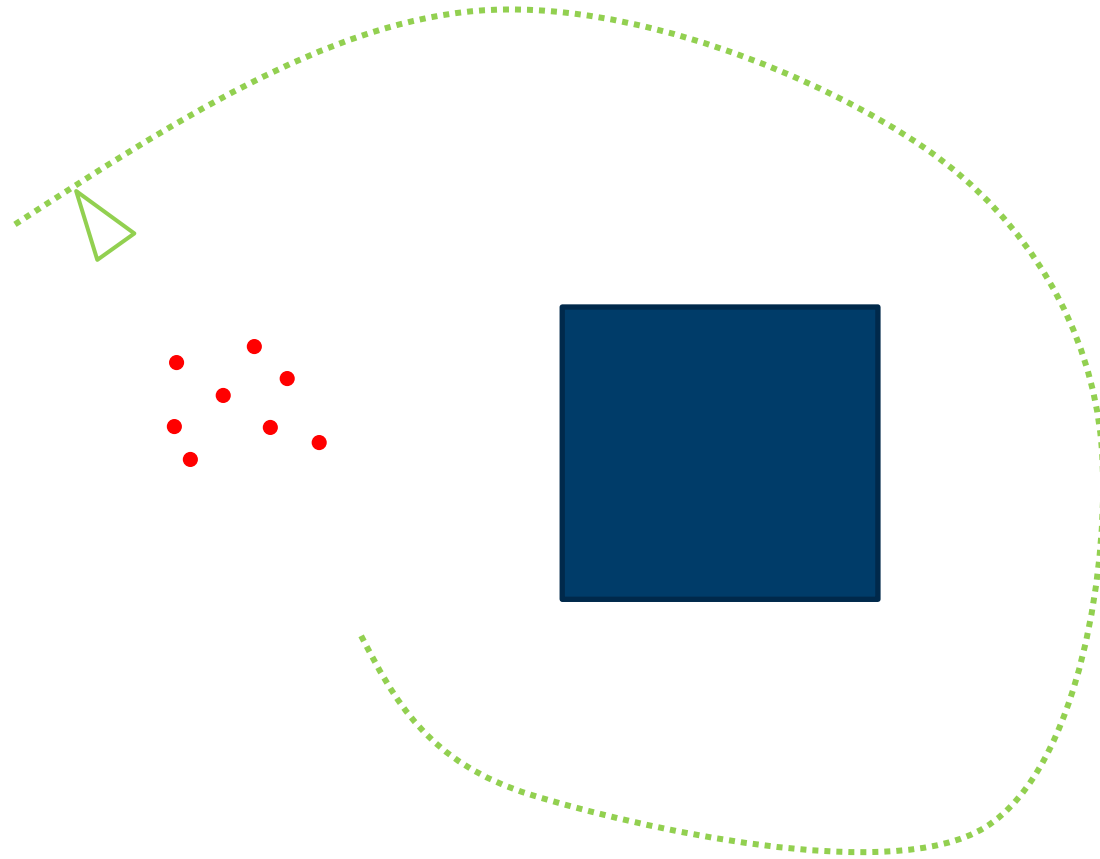
What is Visual SLAM?

- Visual simultaneous localization and mapping
- Mapping
 - Continuously expanding a map while exploring the environment
- Localization (tracking)
 - Localization within the map = tracking the map in image frames

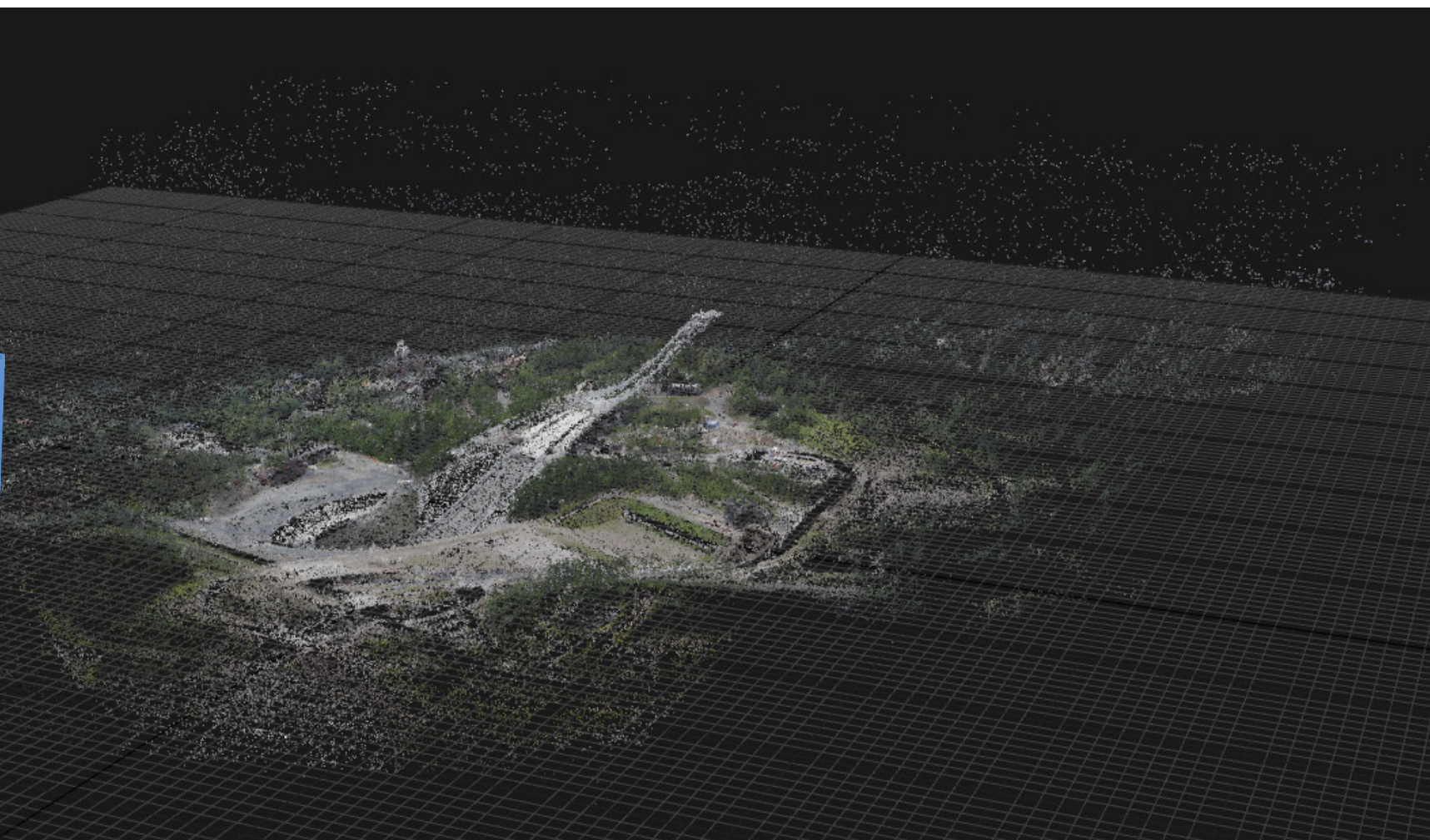
Example



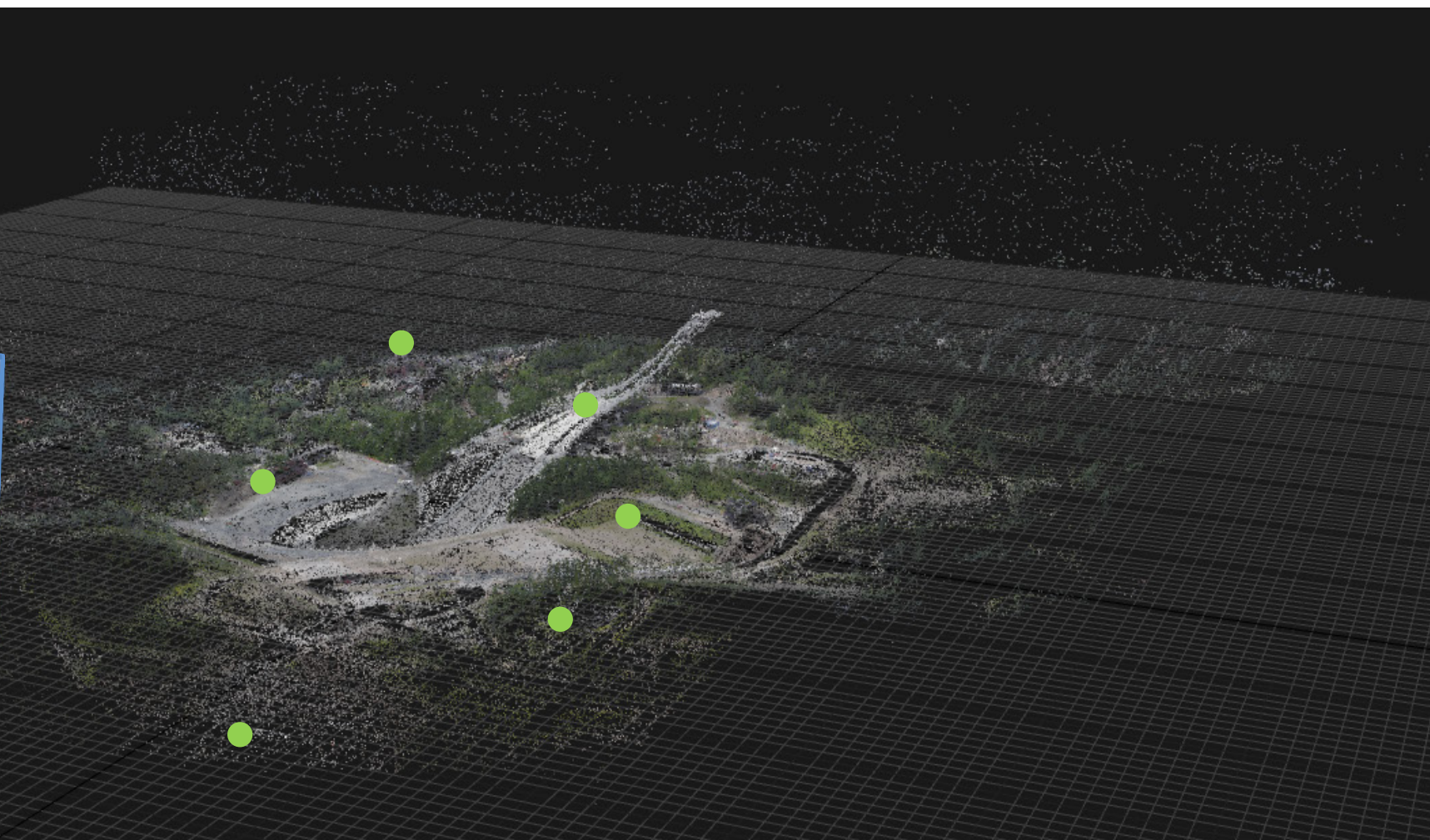
How do we track a map?



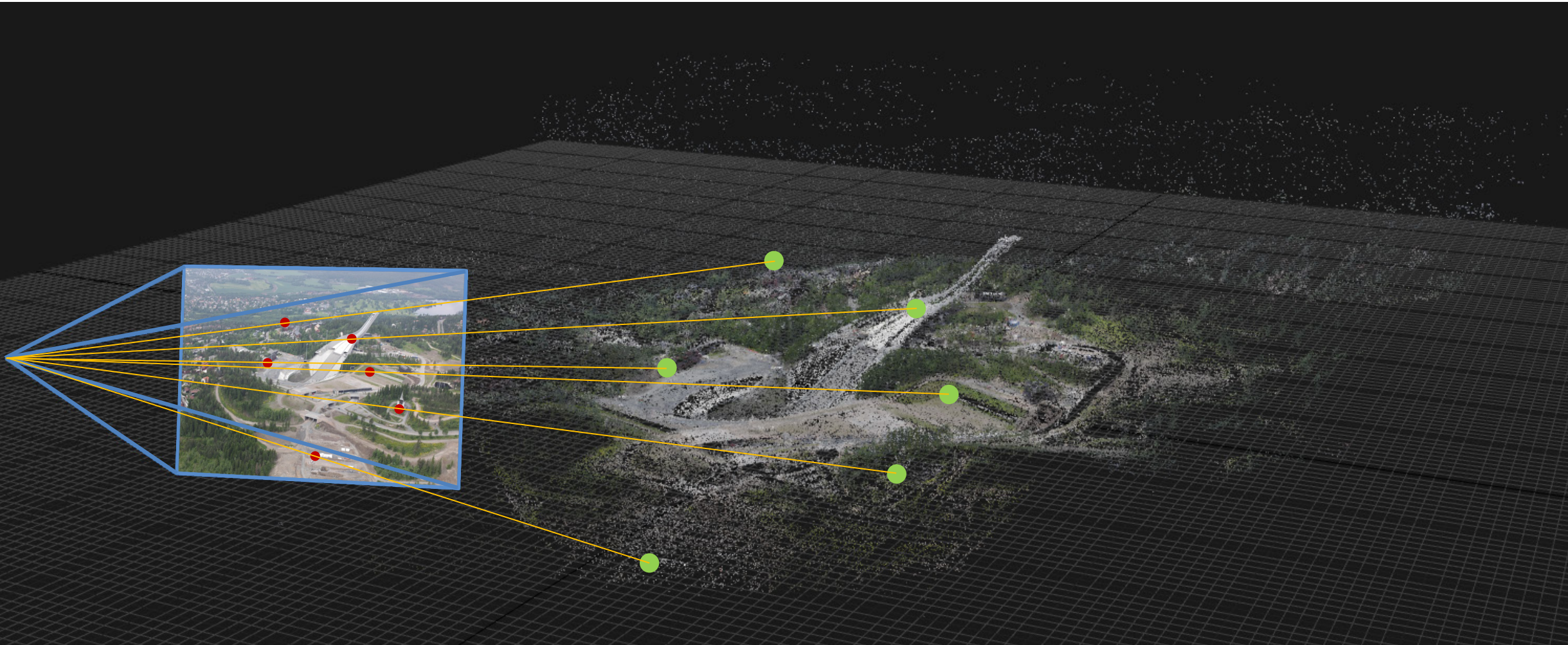
Pose from known 3D map



Pose from known 3D points



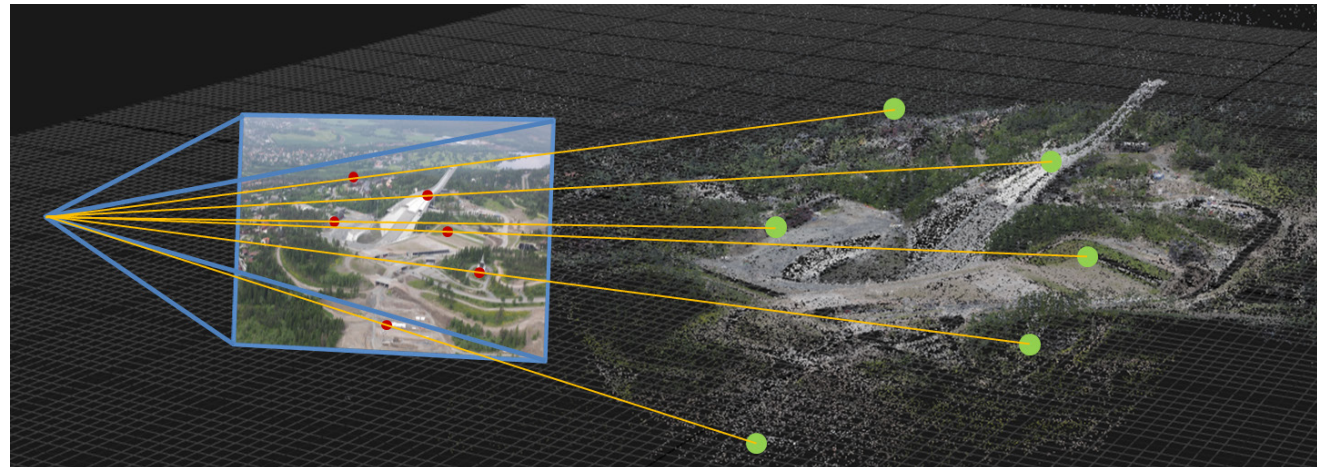
Pose from known 3D points



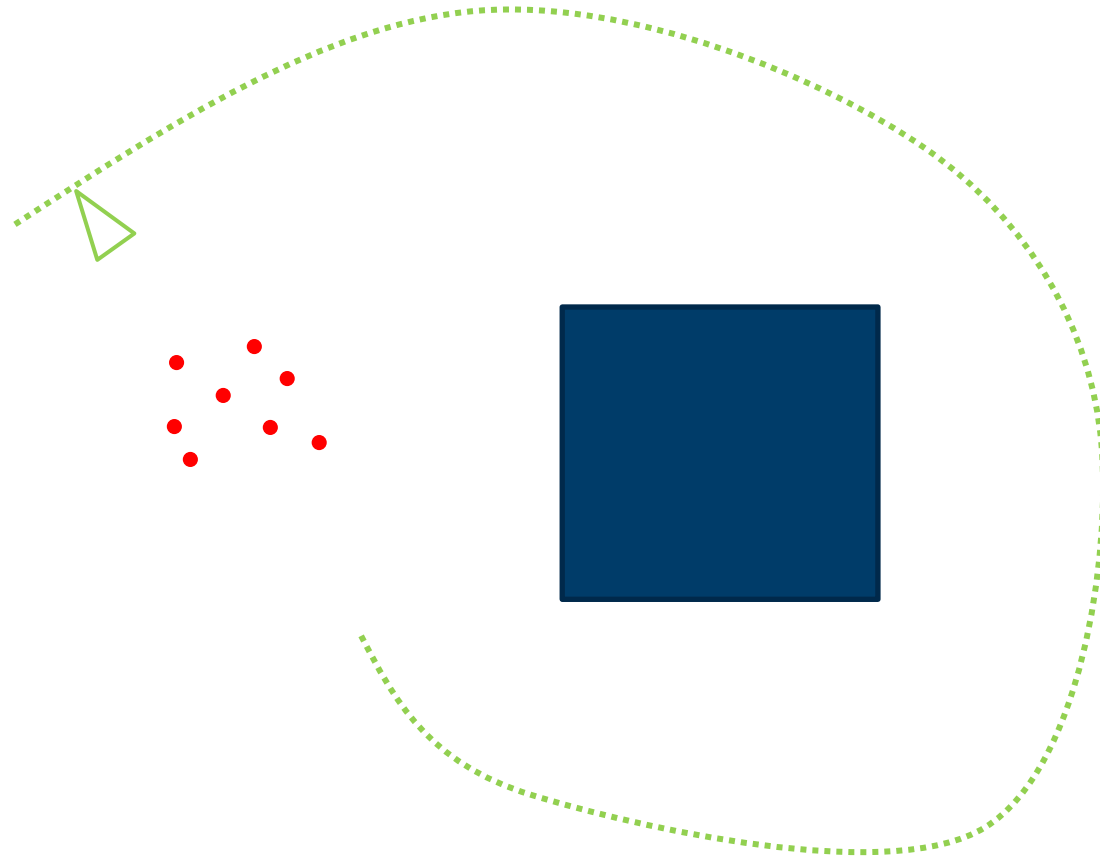
Pose from known 3D points

- Minimize geometric error

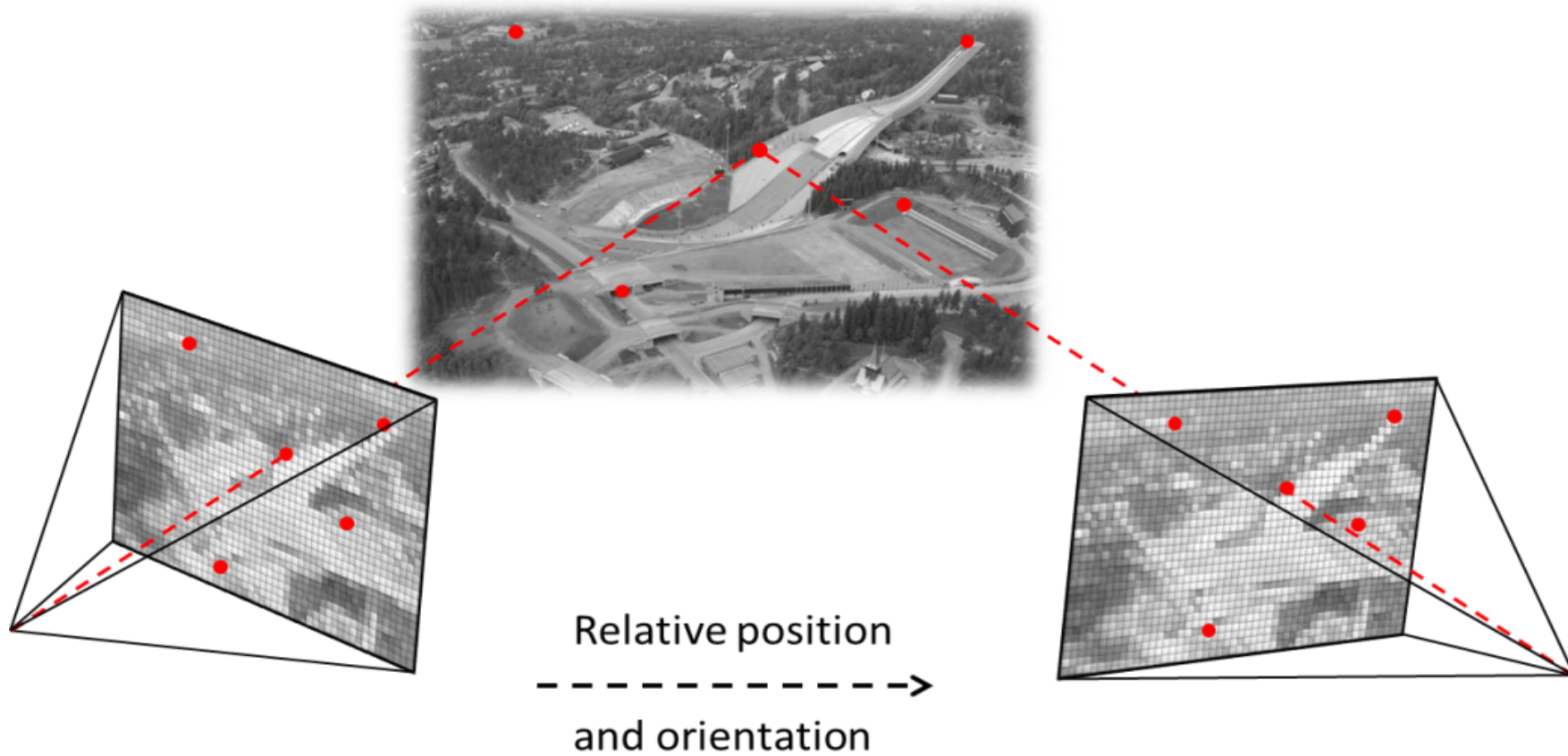
$$\mathbf{T}_{cw}^* = \operatorname{argmin}_{\mathbf{T}_{cw}} \sum_i \left\| \pi(\mathbf{T}_{cw} \tilde{\mathbf{x}}_i^w) - \mathbf{u}_i \right\|^2$$



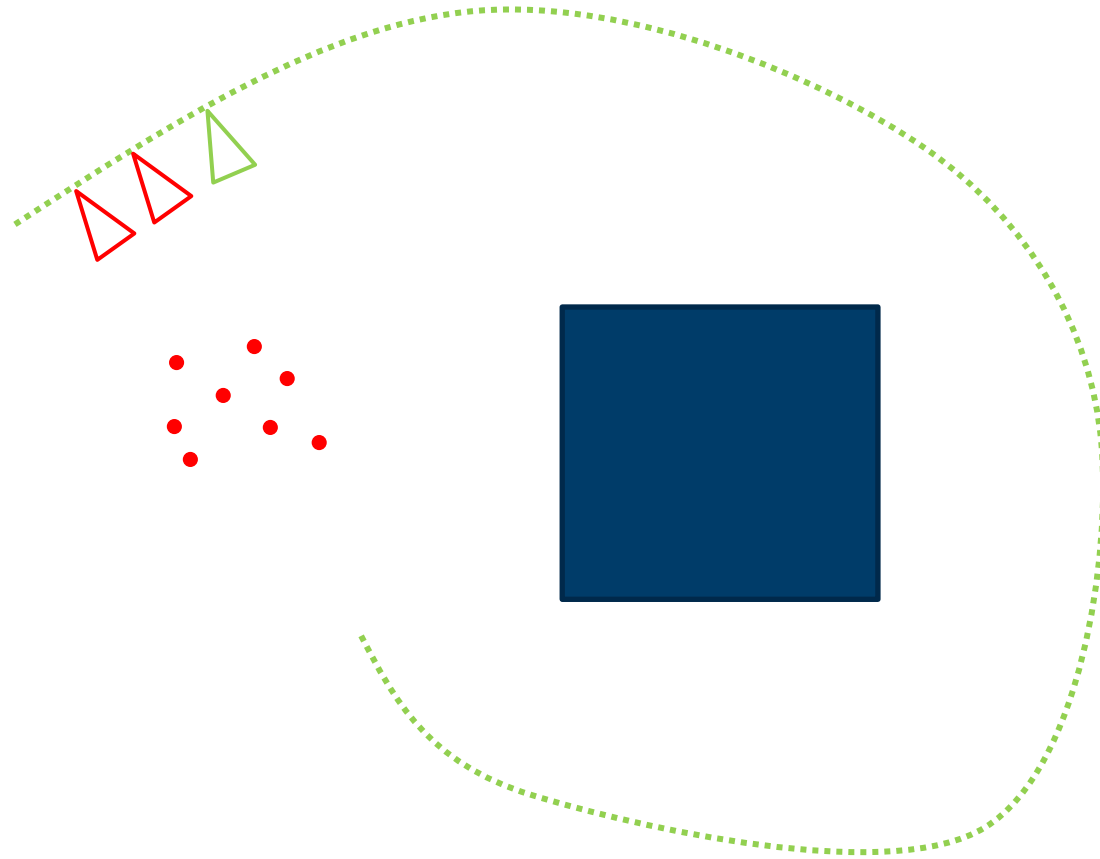
How do we build a map?



Relative pose and 3D from two views

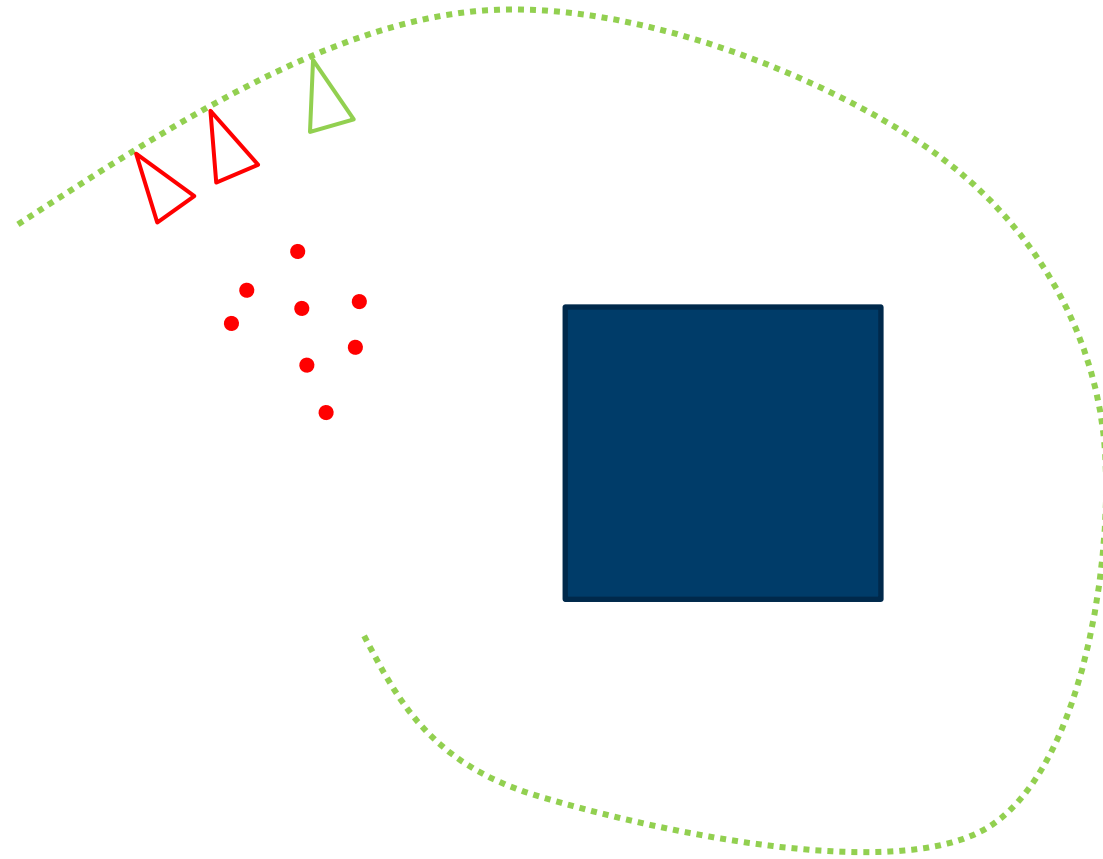


Map initialization and tracking

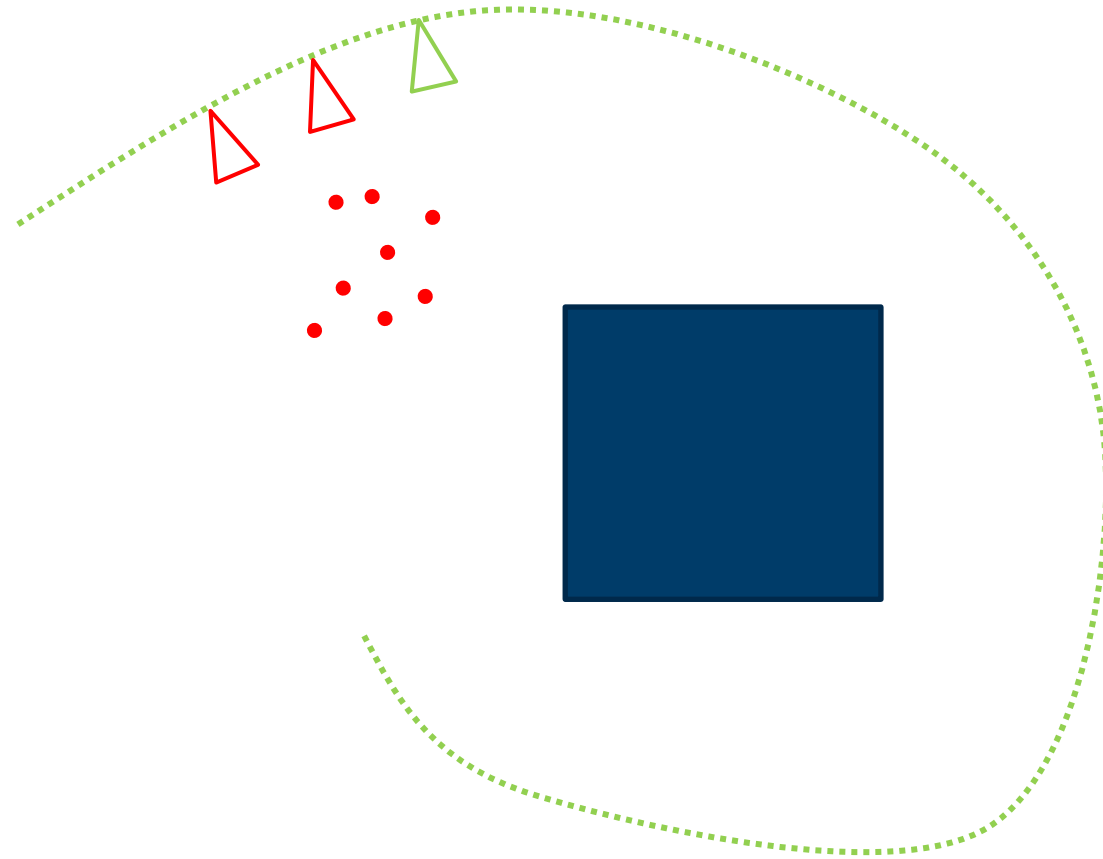


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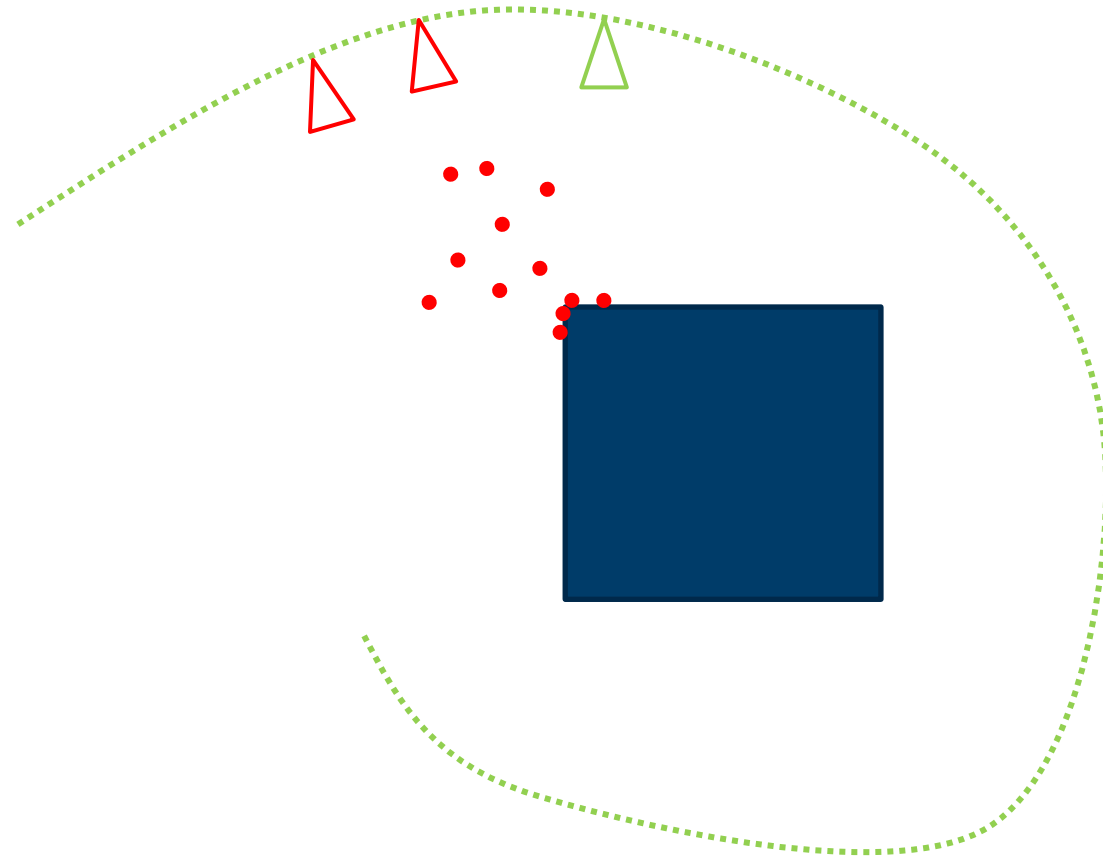
Map reinitialization and tracking



Map reinitialization and tracking

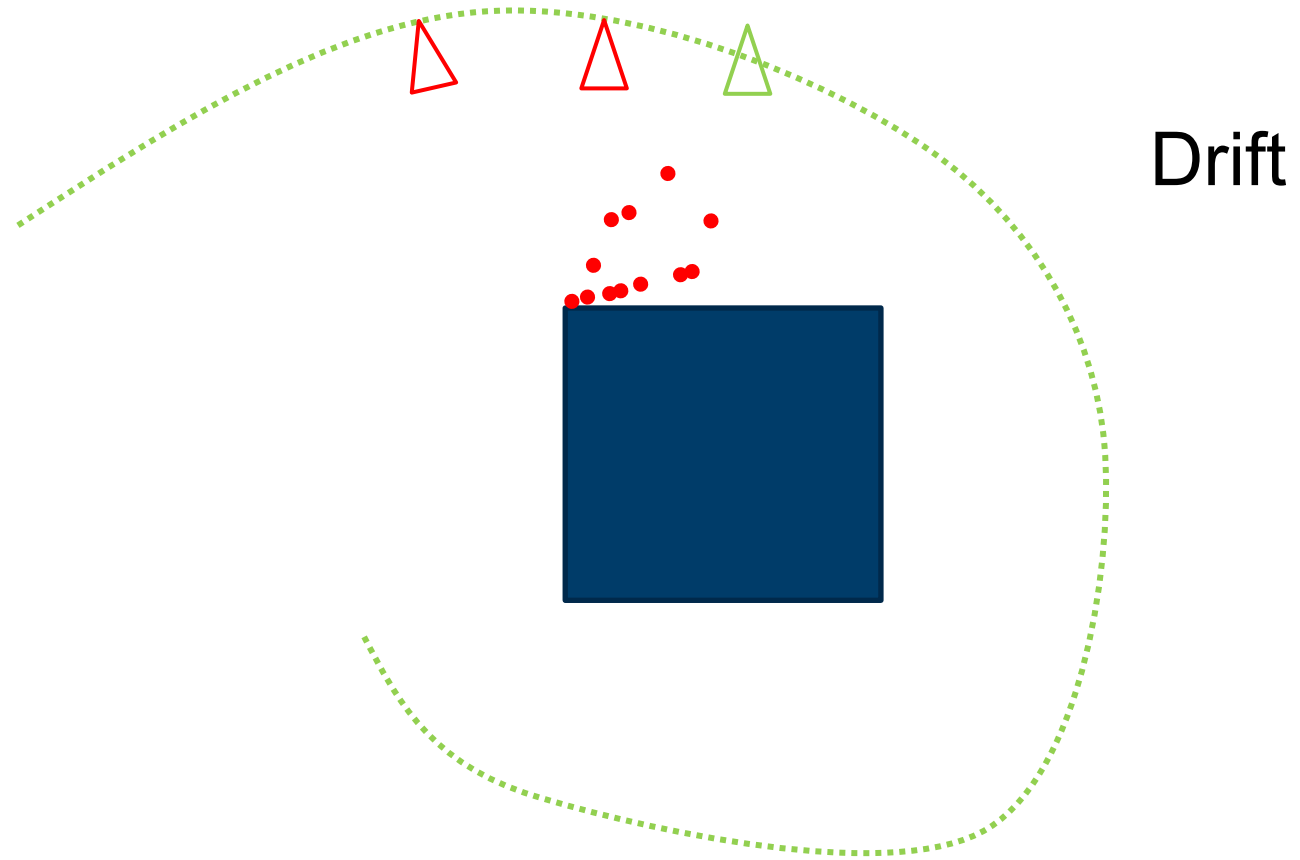


Map reinitialization and tracking



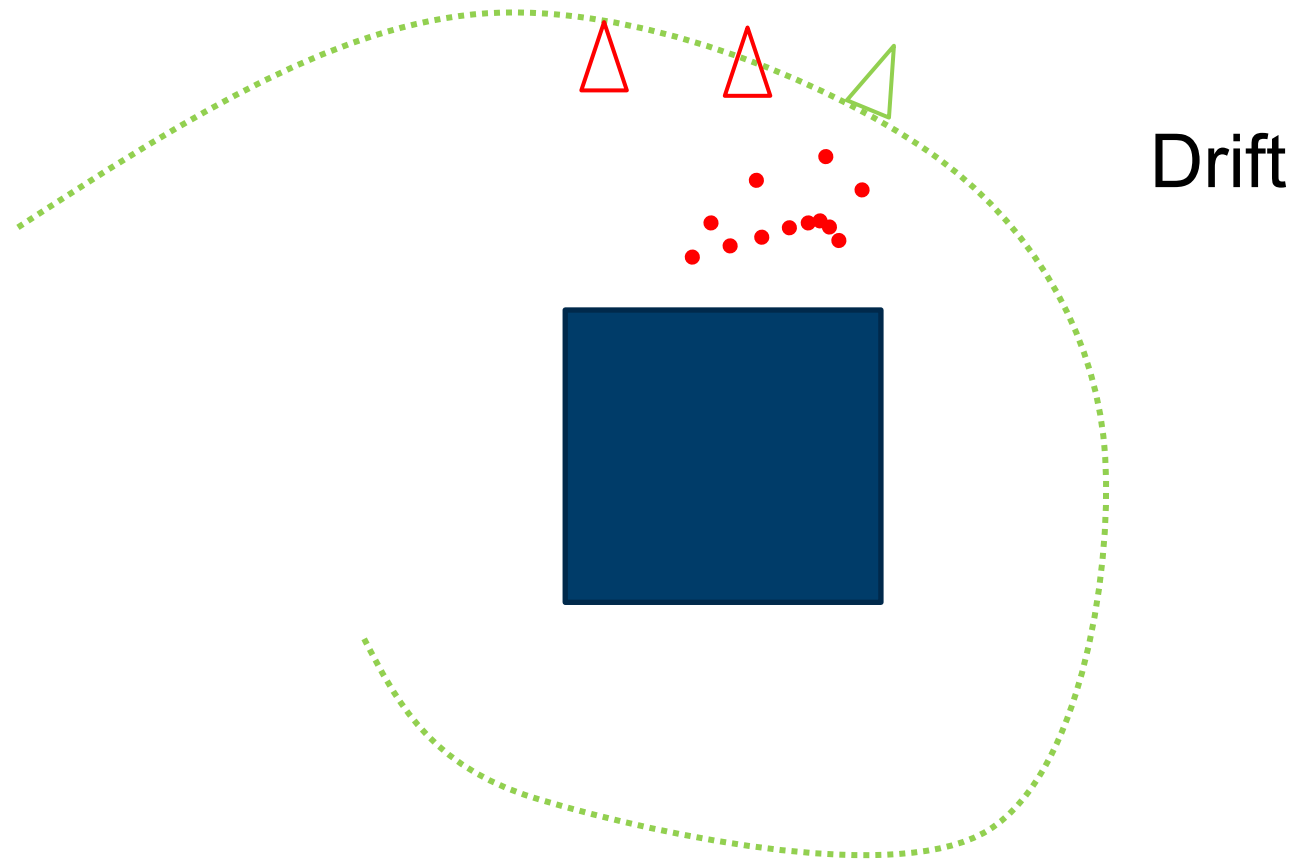
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Map reinitialization and tracking



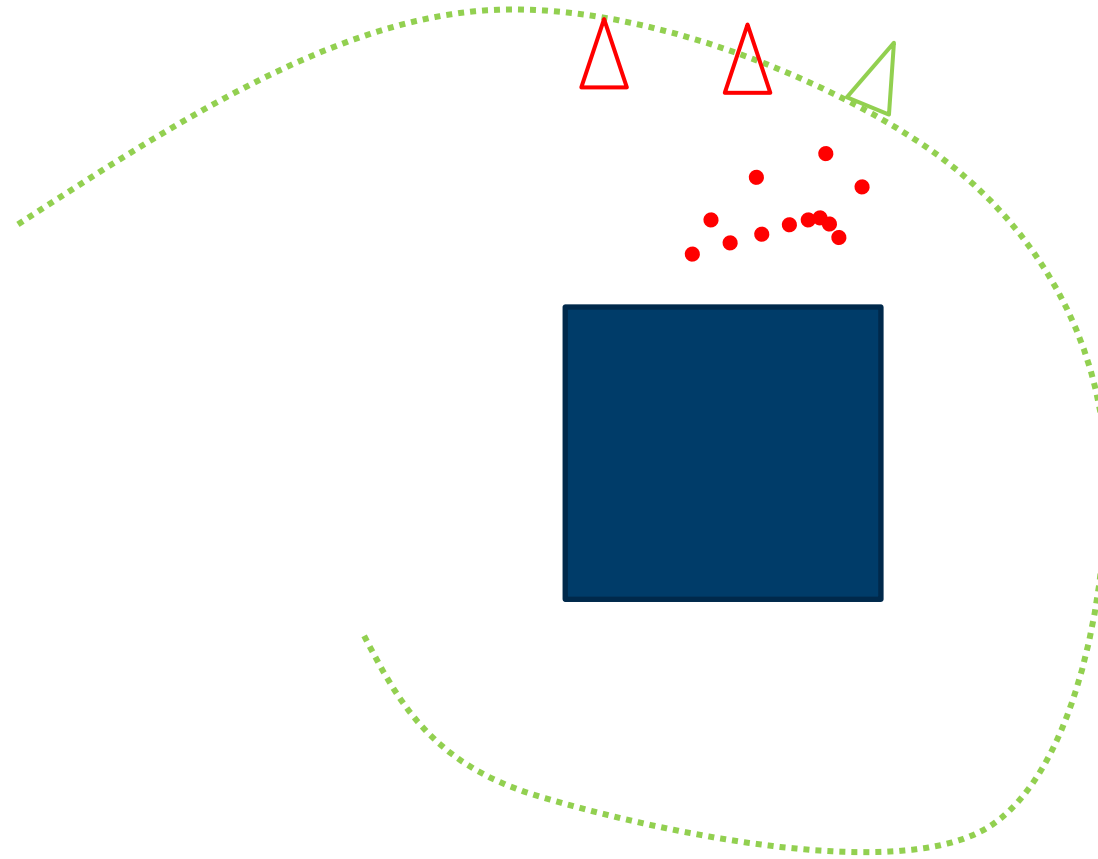
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Map reinitialization and tracking



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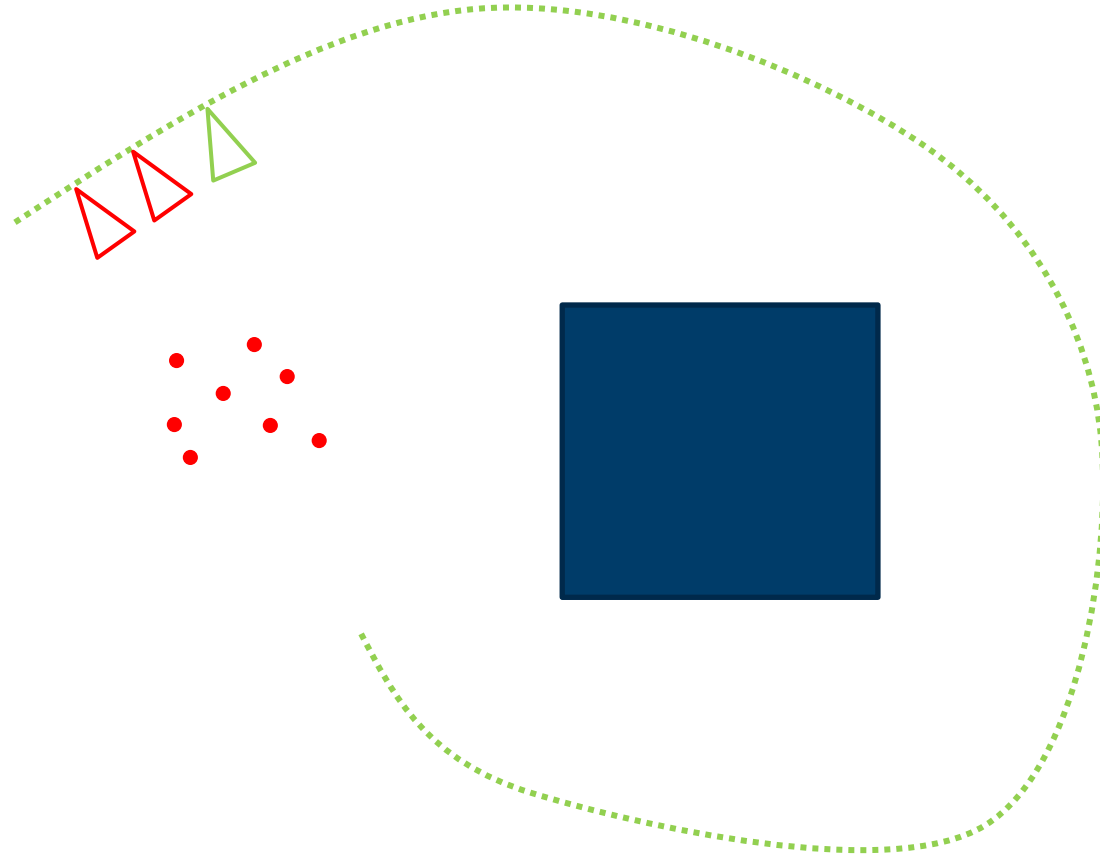
Map reinitialization and tracking



Drift

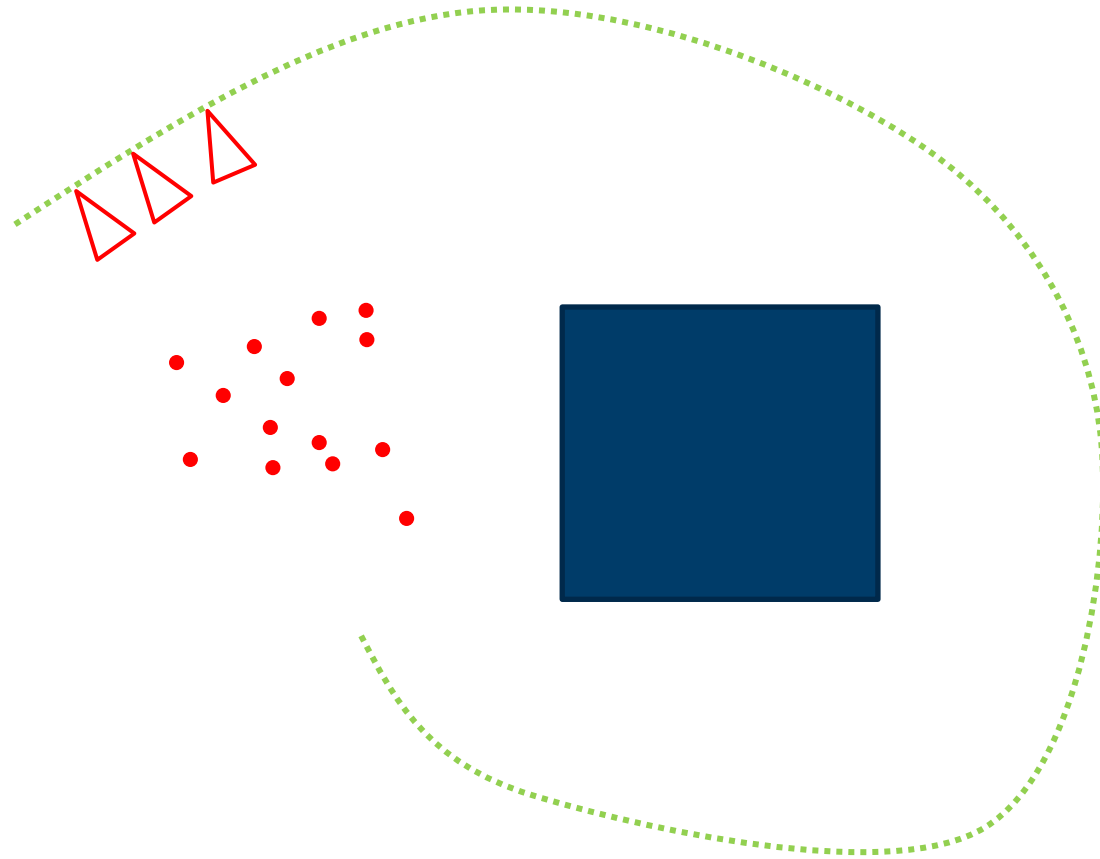
Very naïve
Visual Odometry (VO)

Multi-view mapping



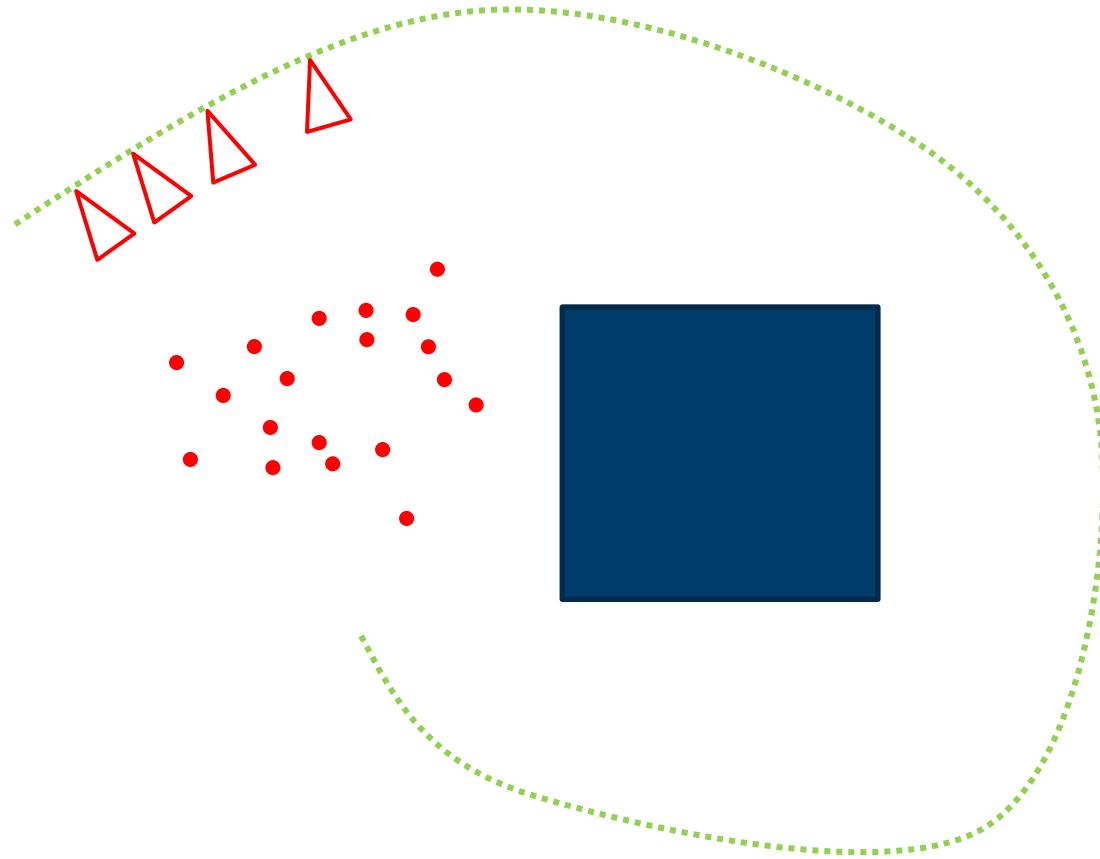
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Multi-view mapping



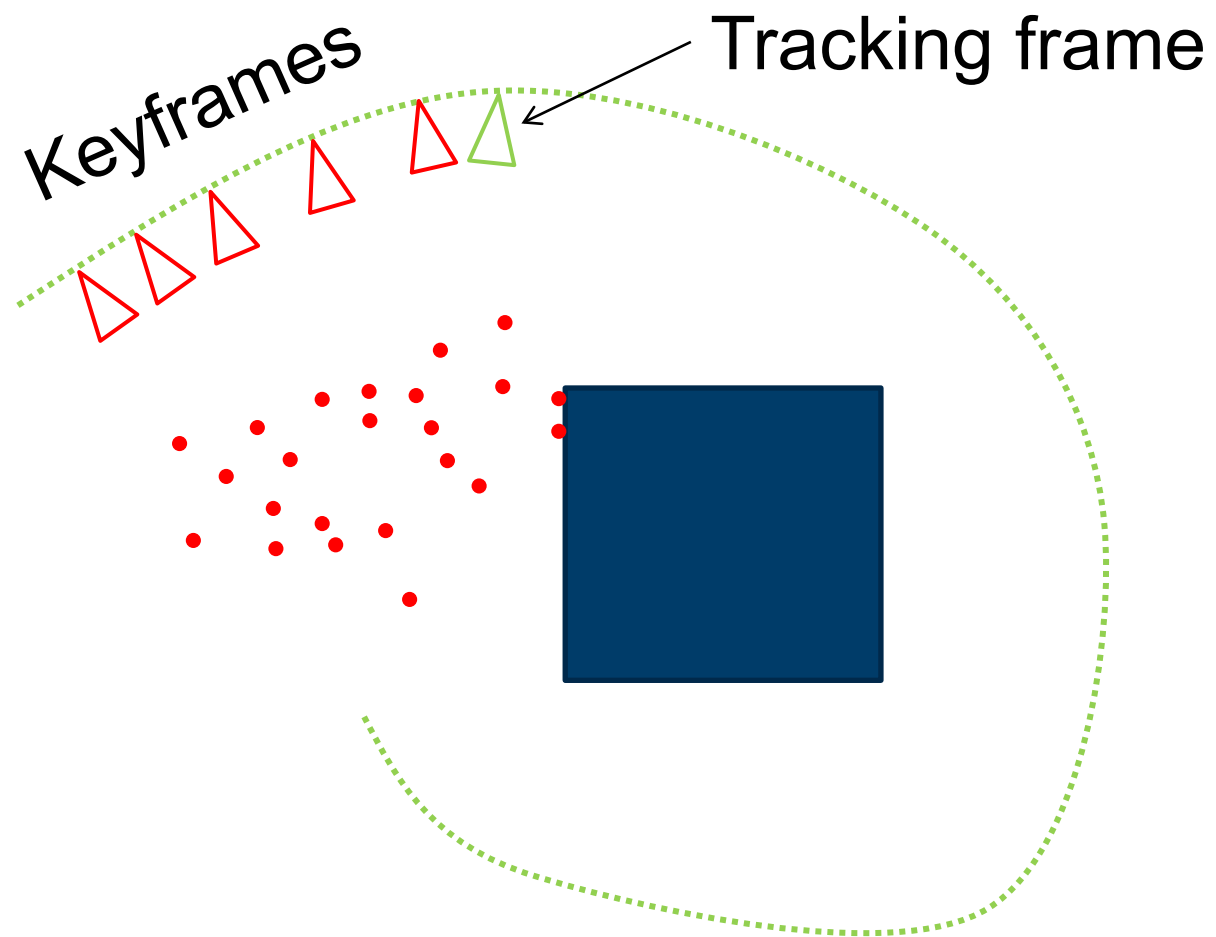
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Multi-view mapping

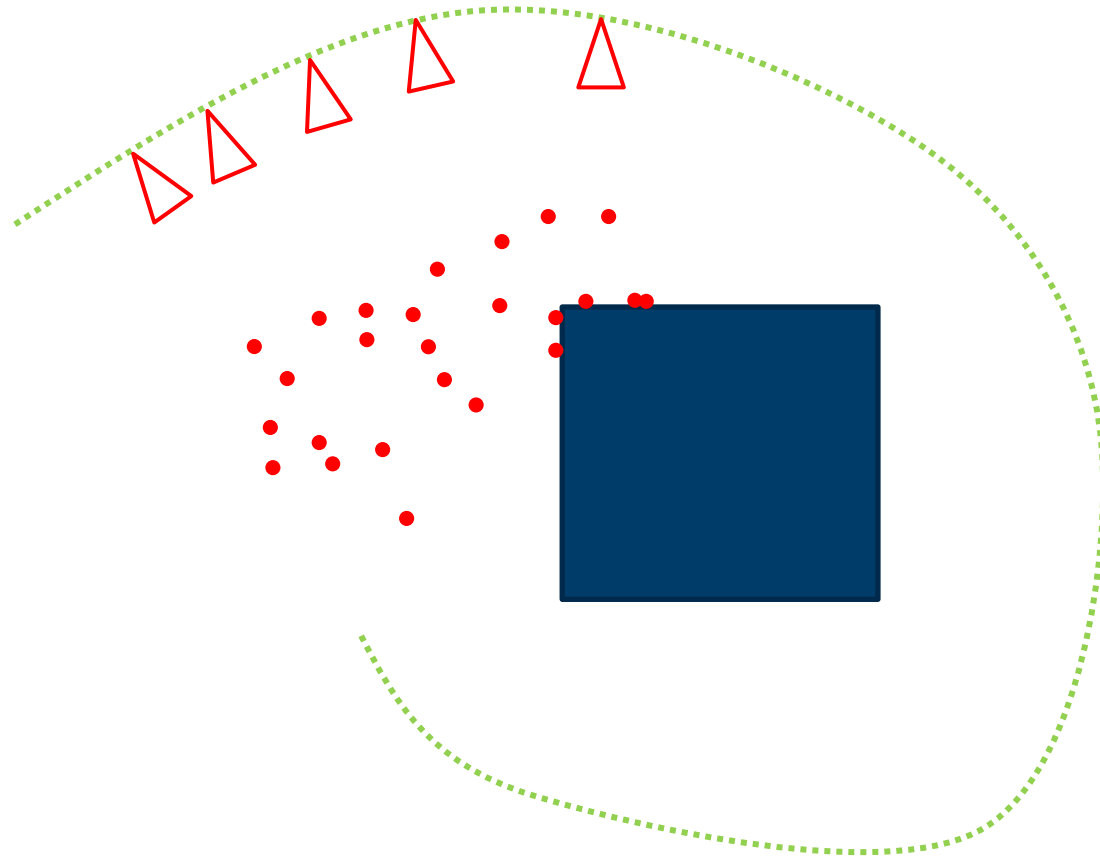


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Multi-view mapping

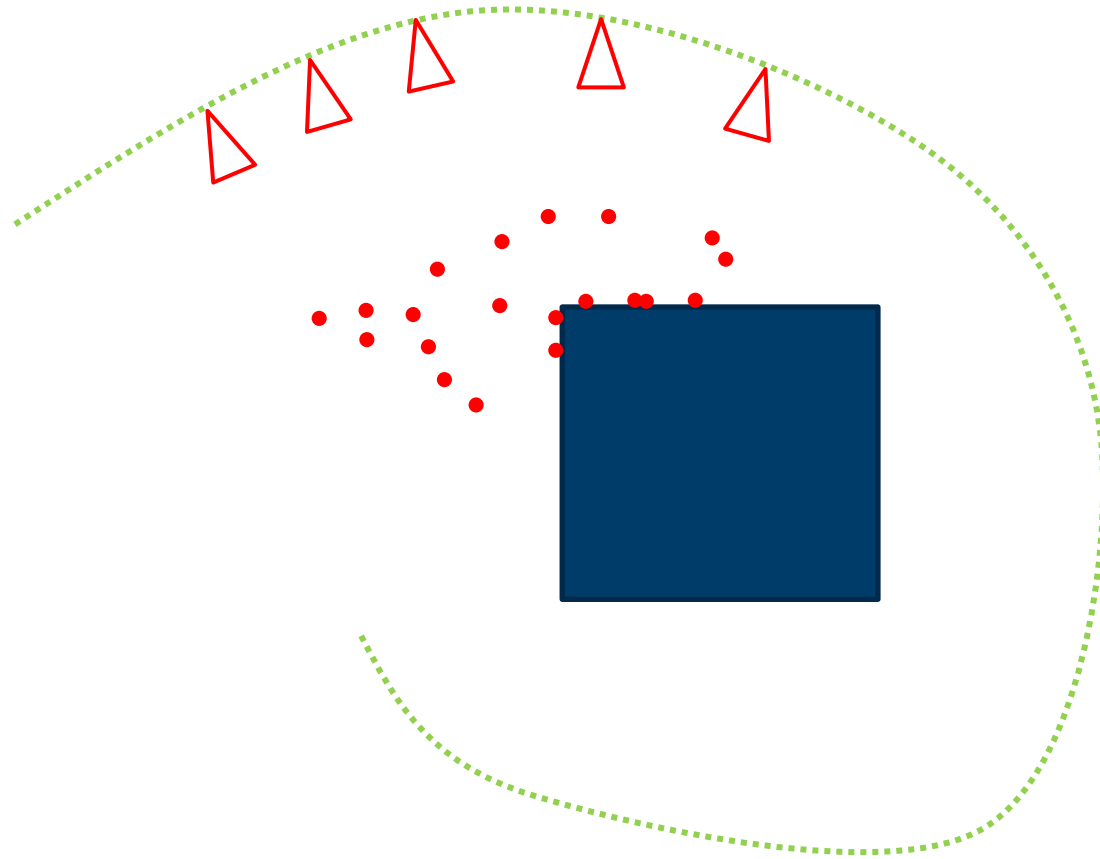


Sliding window mapping



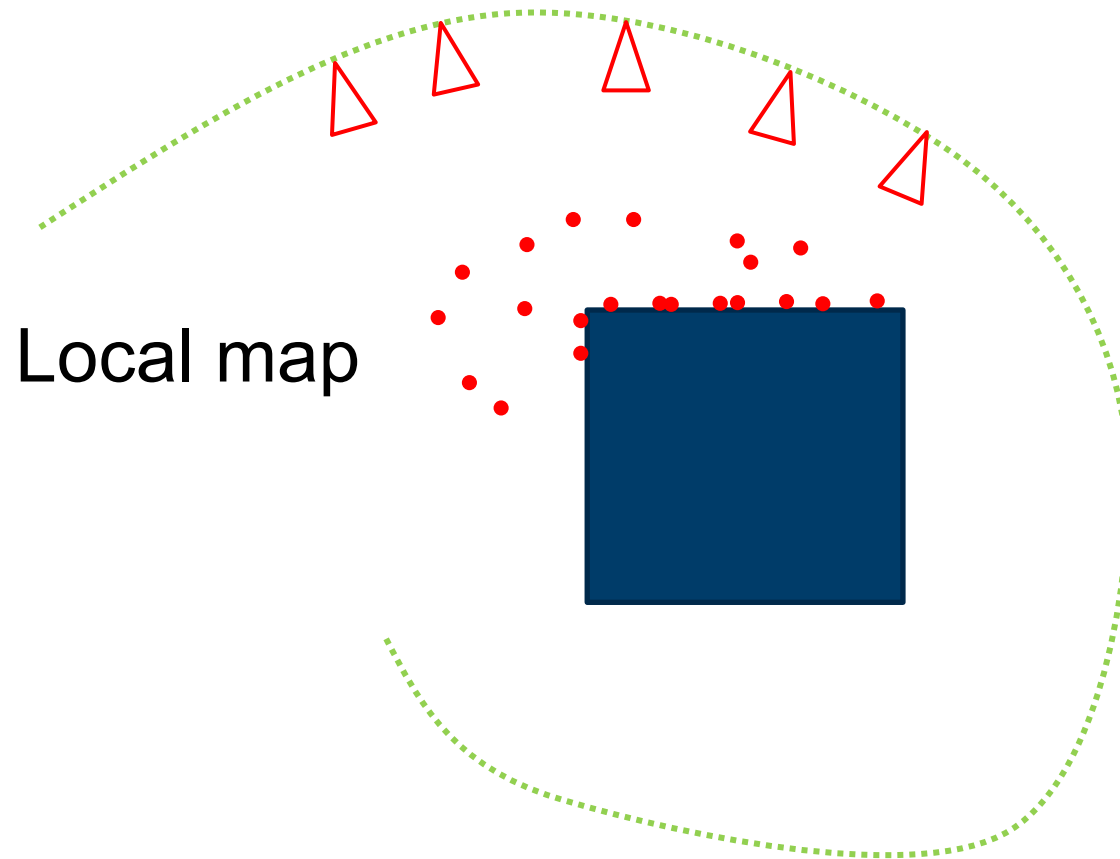
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Sliding window mapping

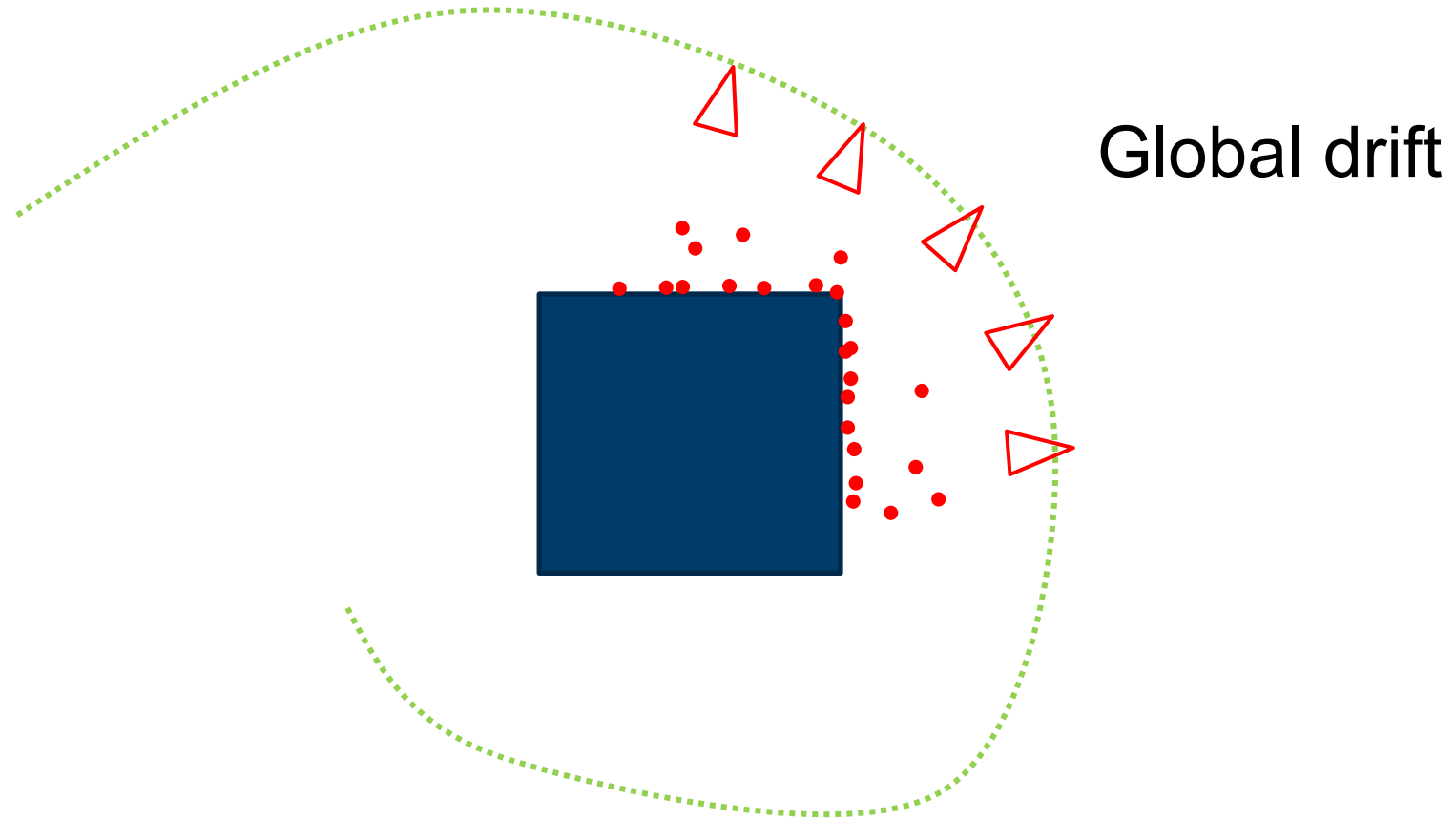


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Sliding window mapping

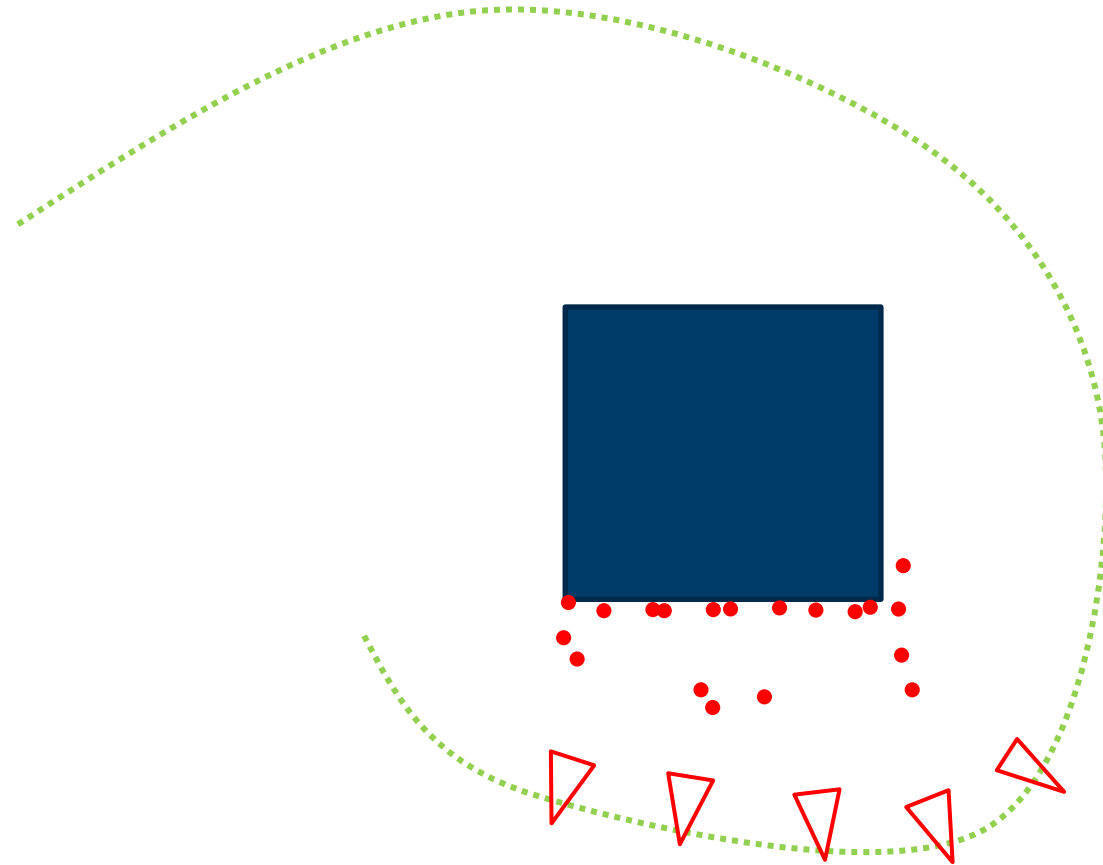


Sliding window mapping



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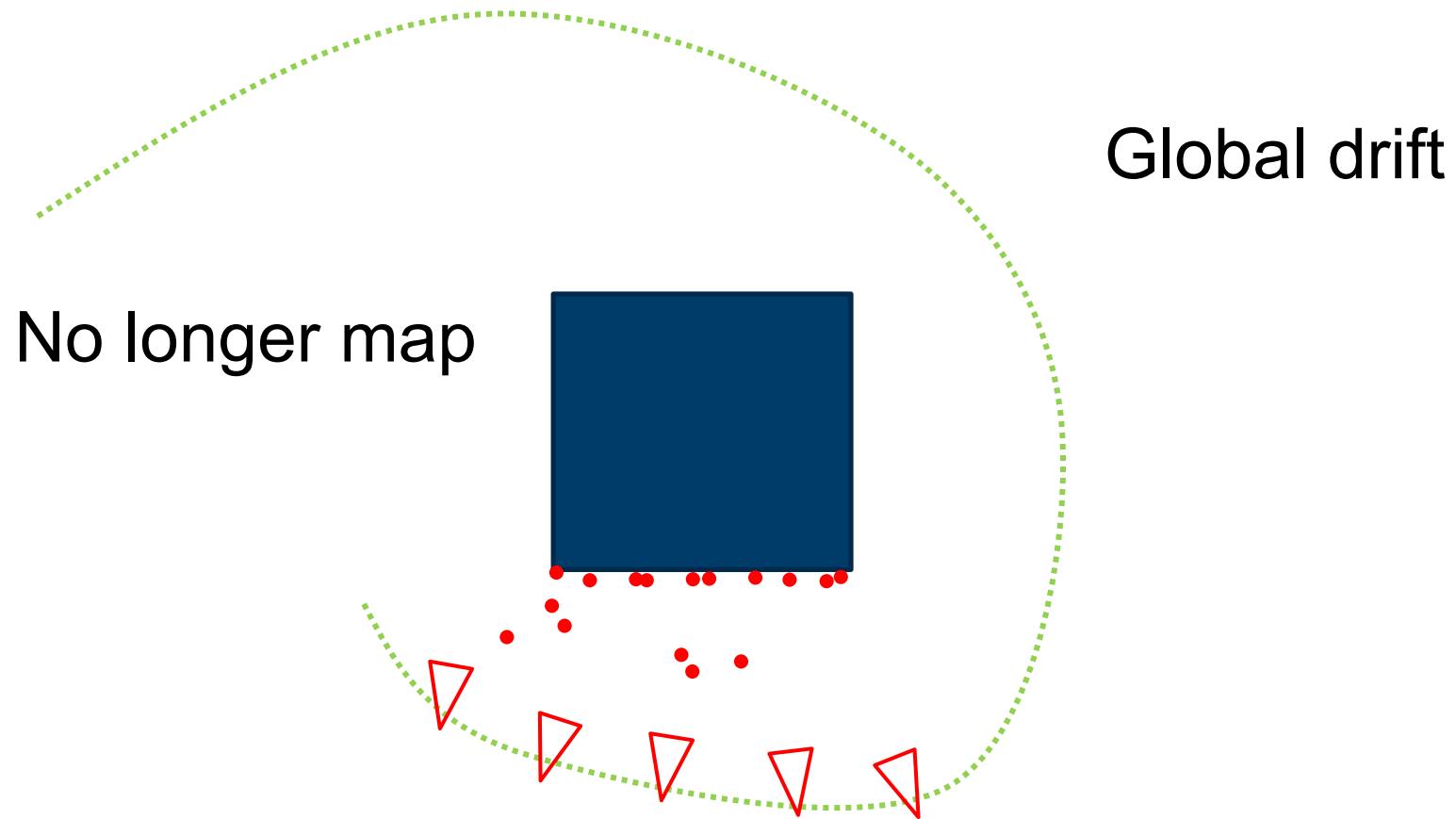
Sliding window mapping



Global drift

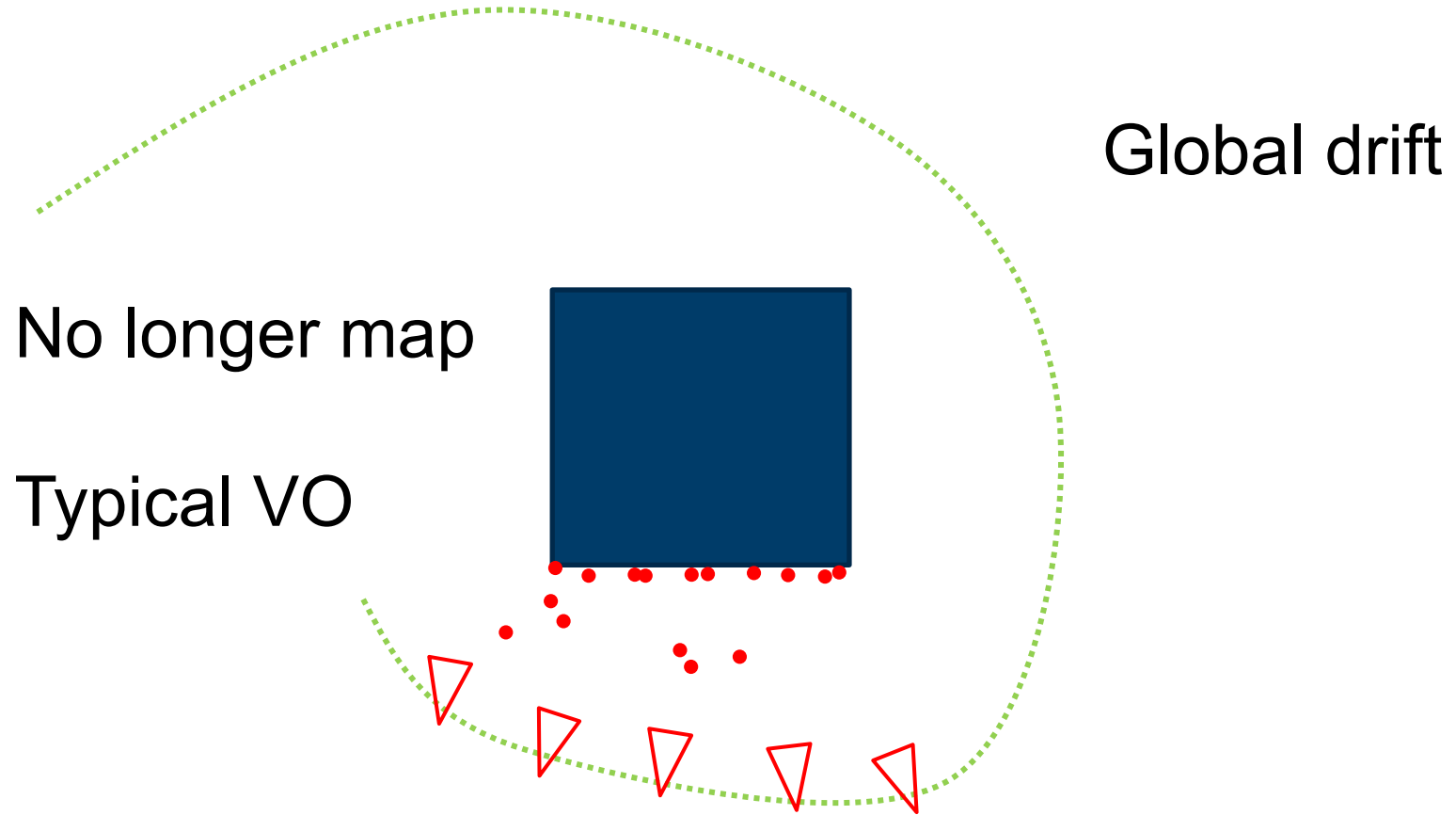
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Sliding window mapping



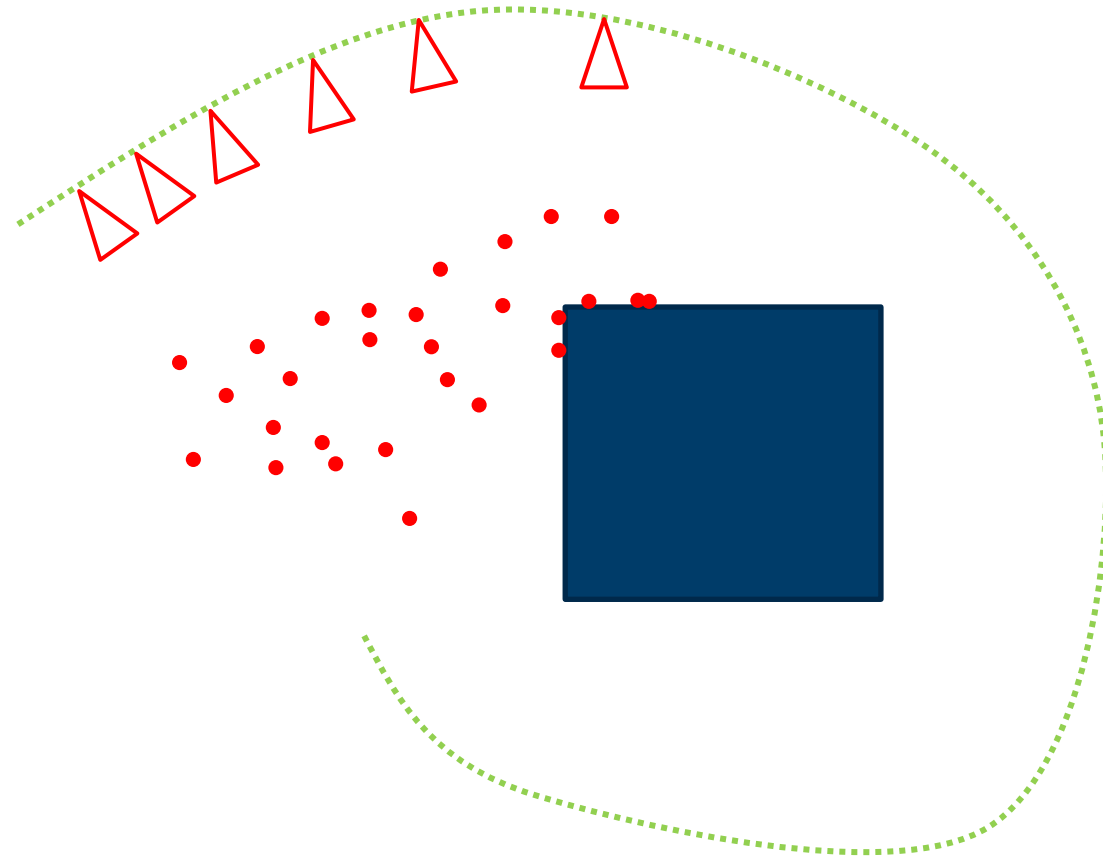
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Sliding window mapping



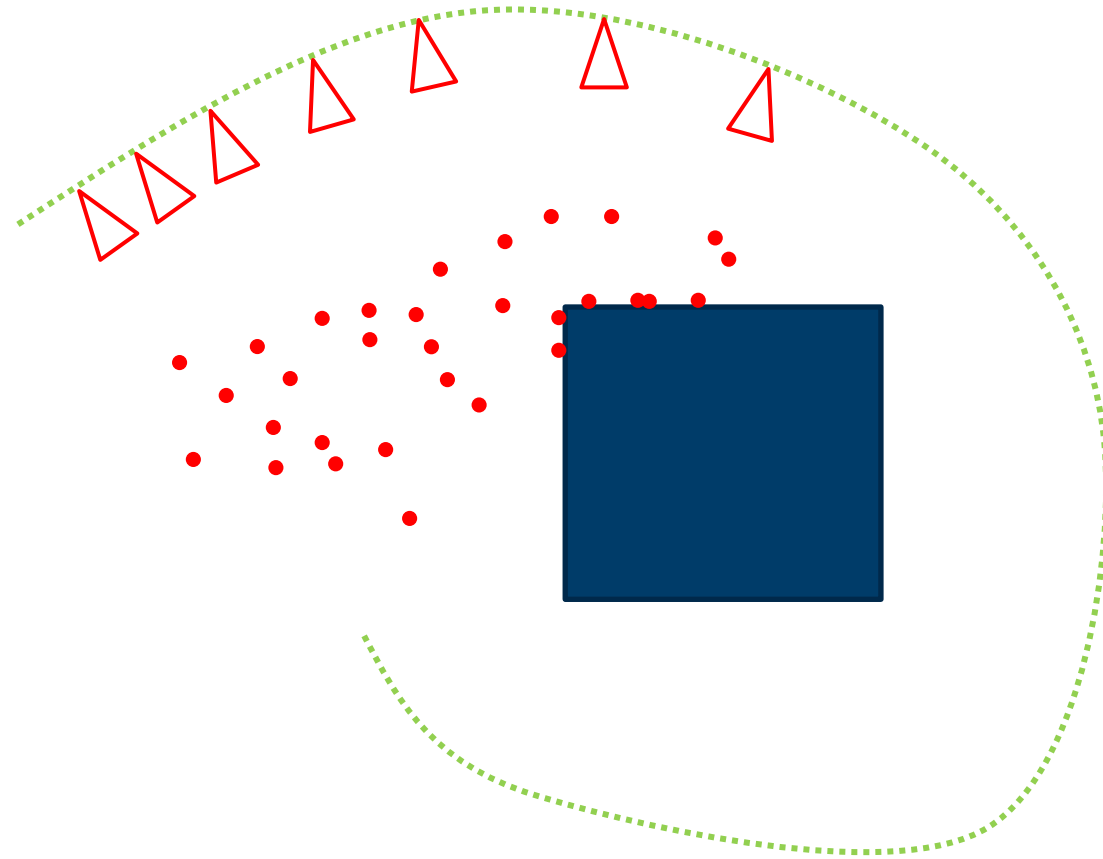
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Monocular Visual SLAM



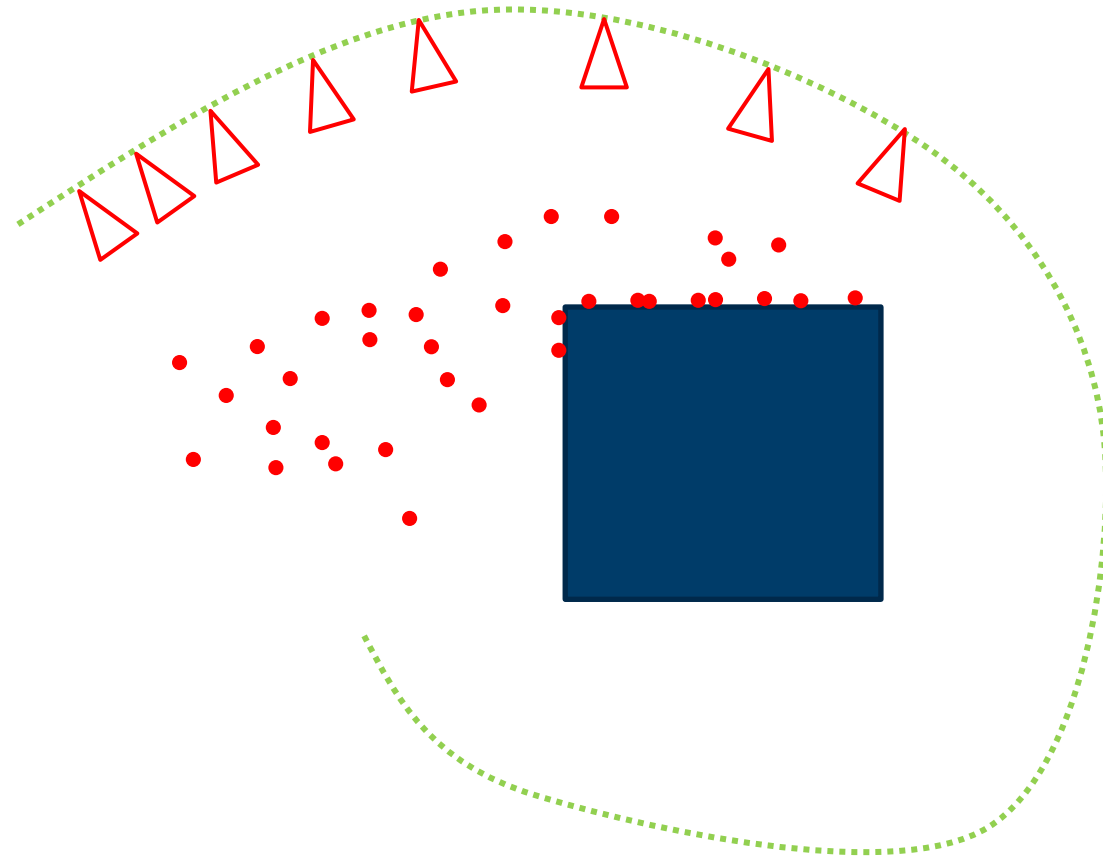
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Monocular Visual SLAM



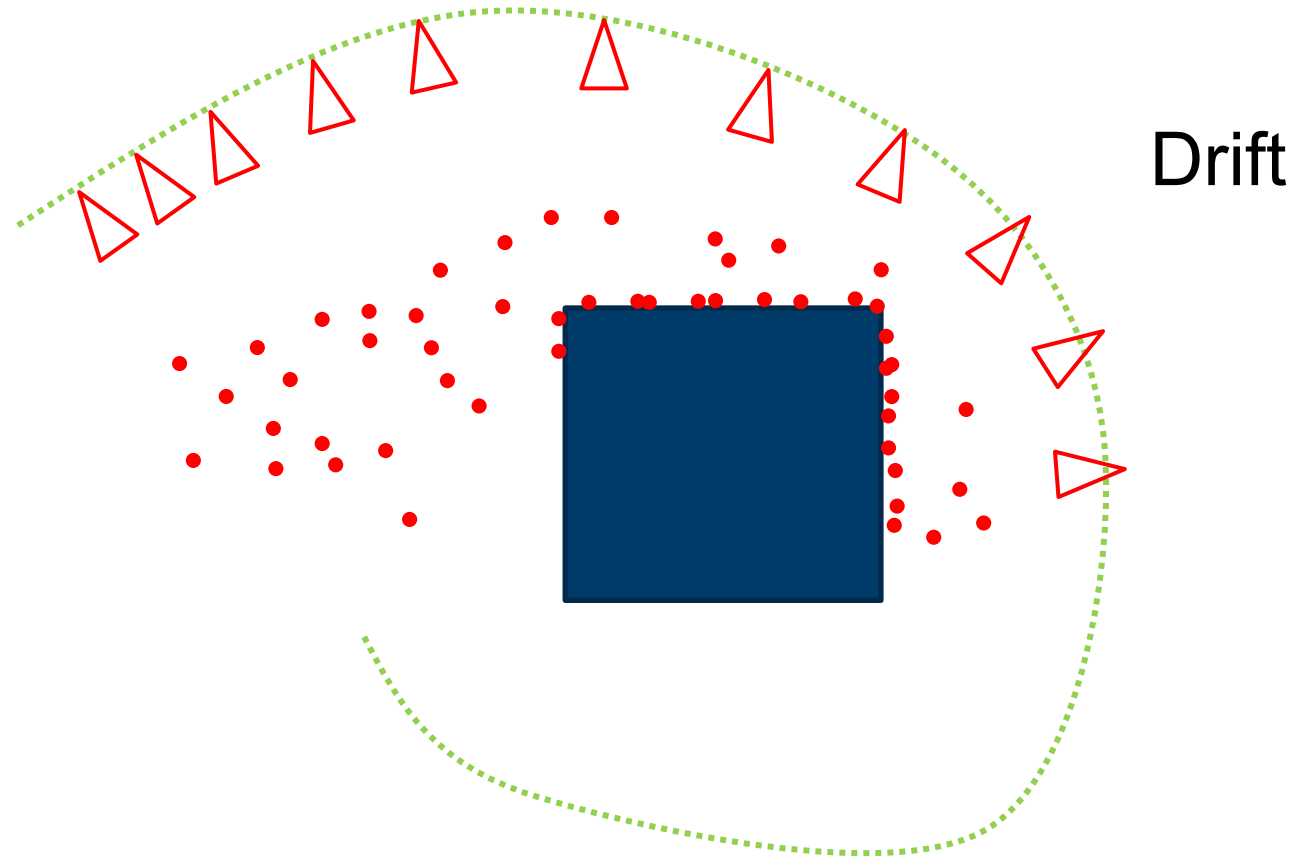
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Monocular Visual SLAM



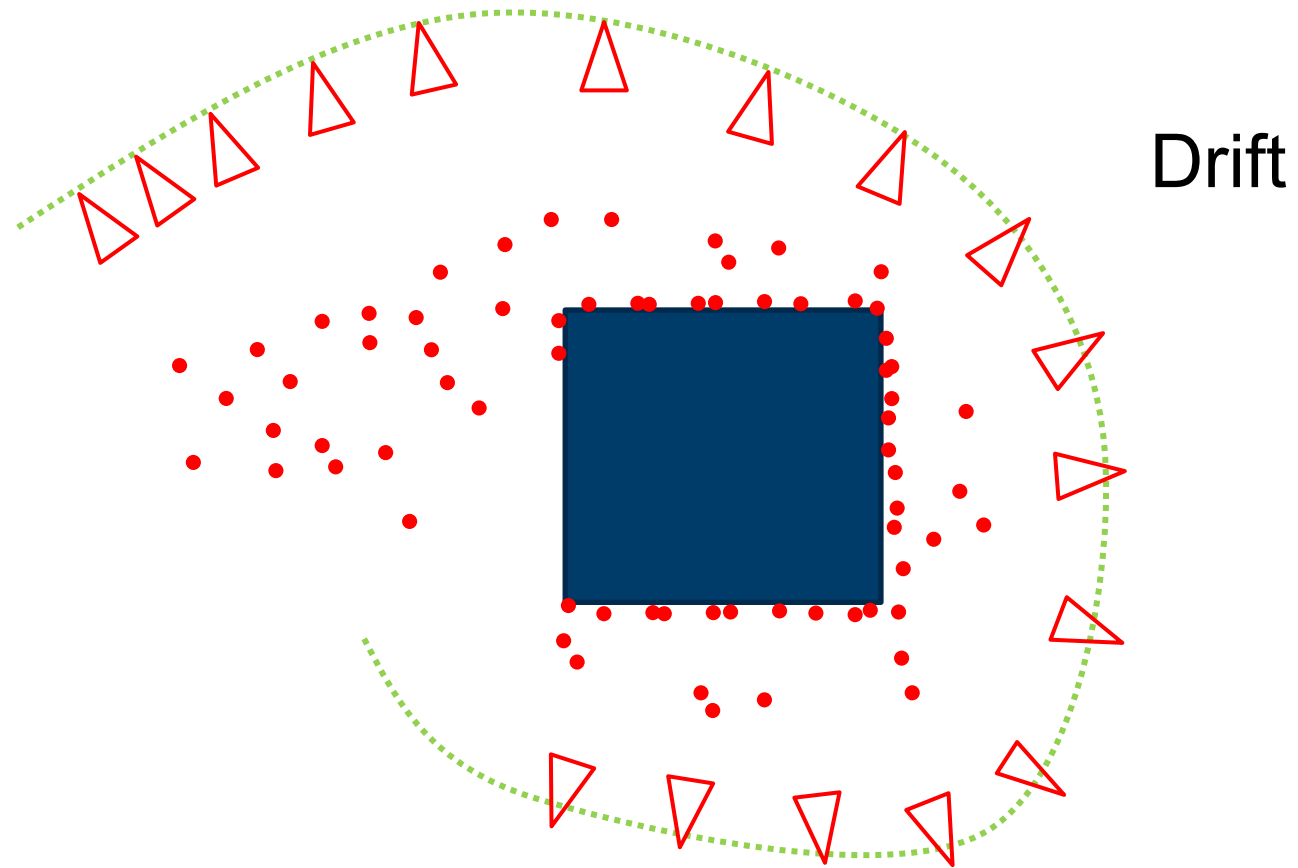
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Monocular Visual SLAM



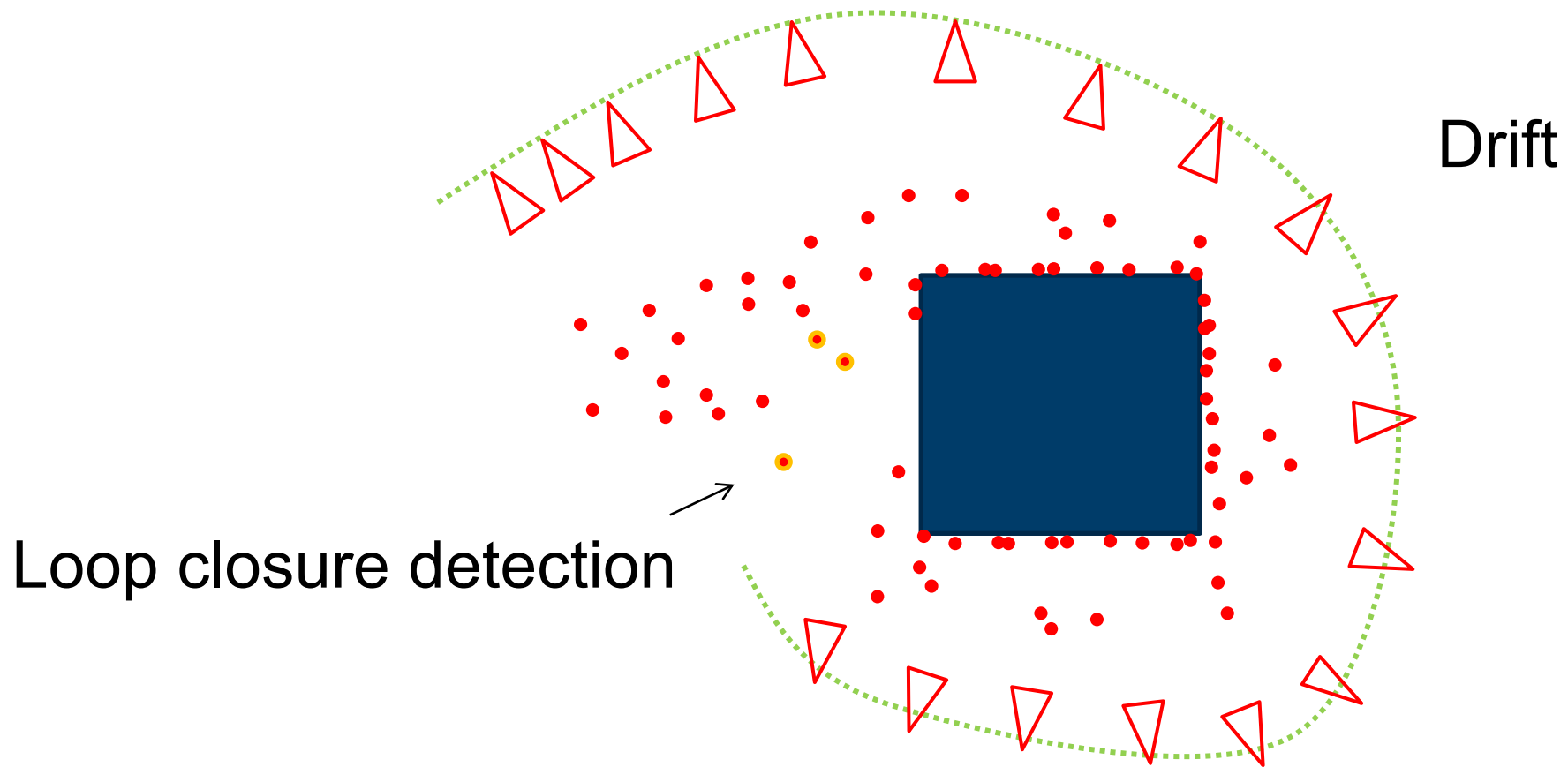
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Monocular Visual SLAM



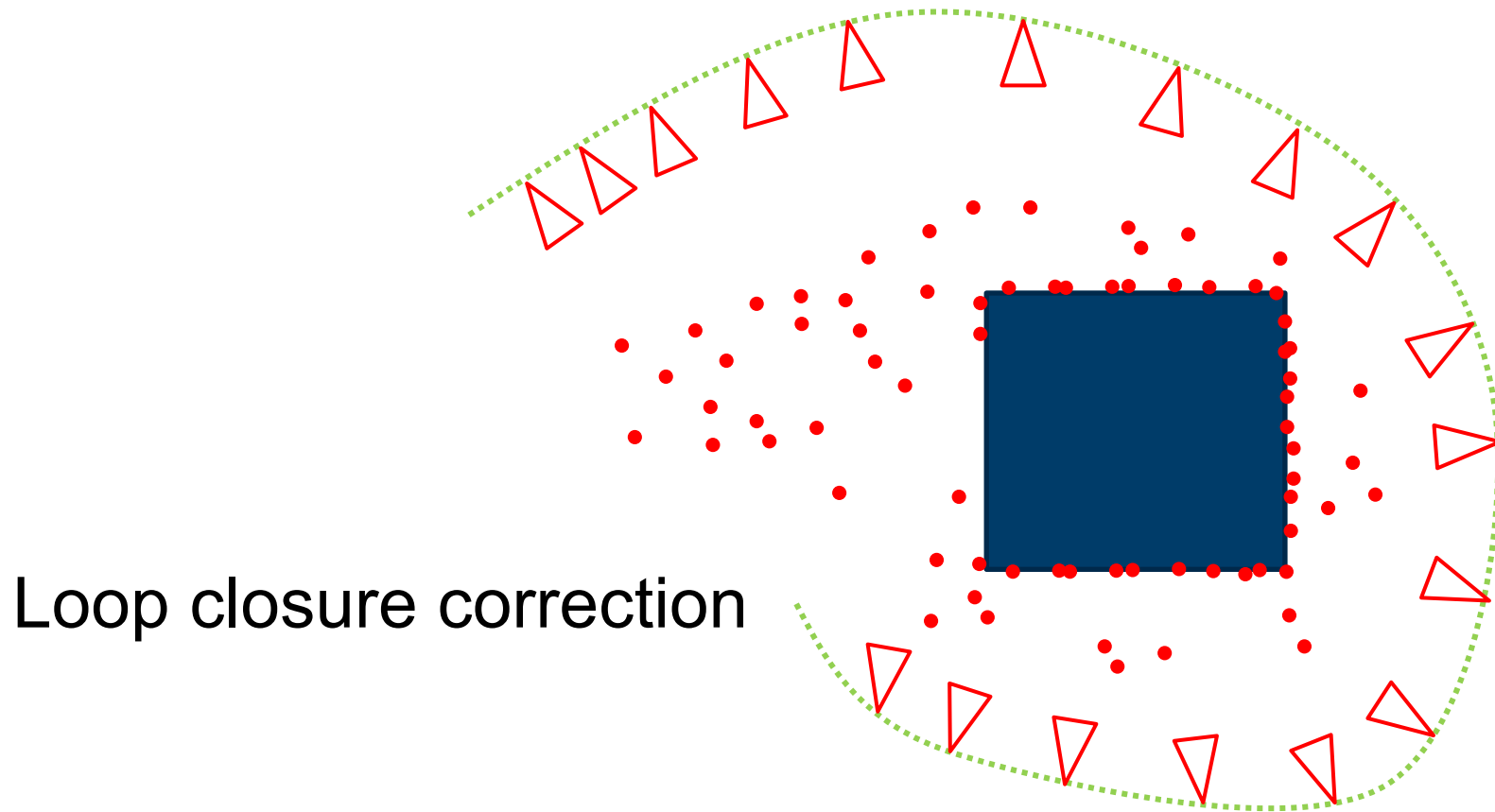
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Monocular Visual SLAM

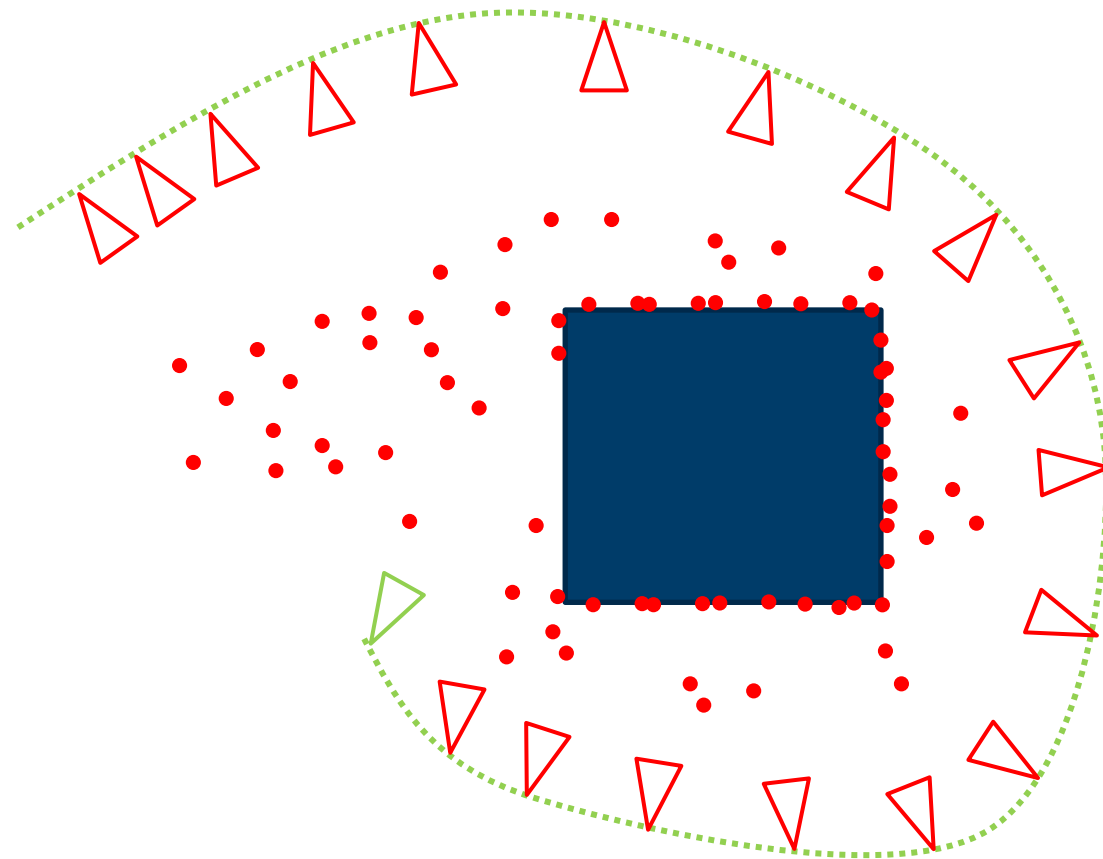


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Monocular Visual SLAM

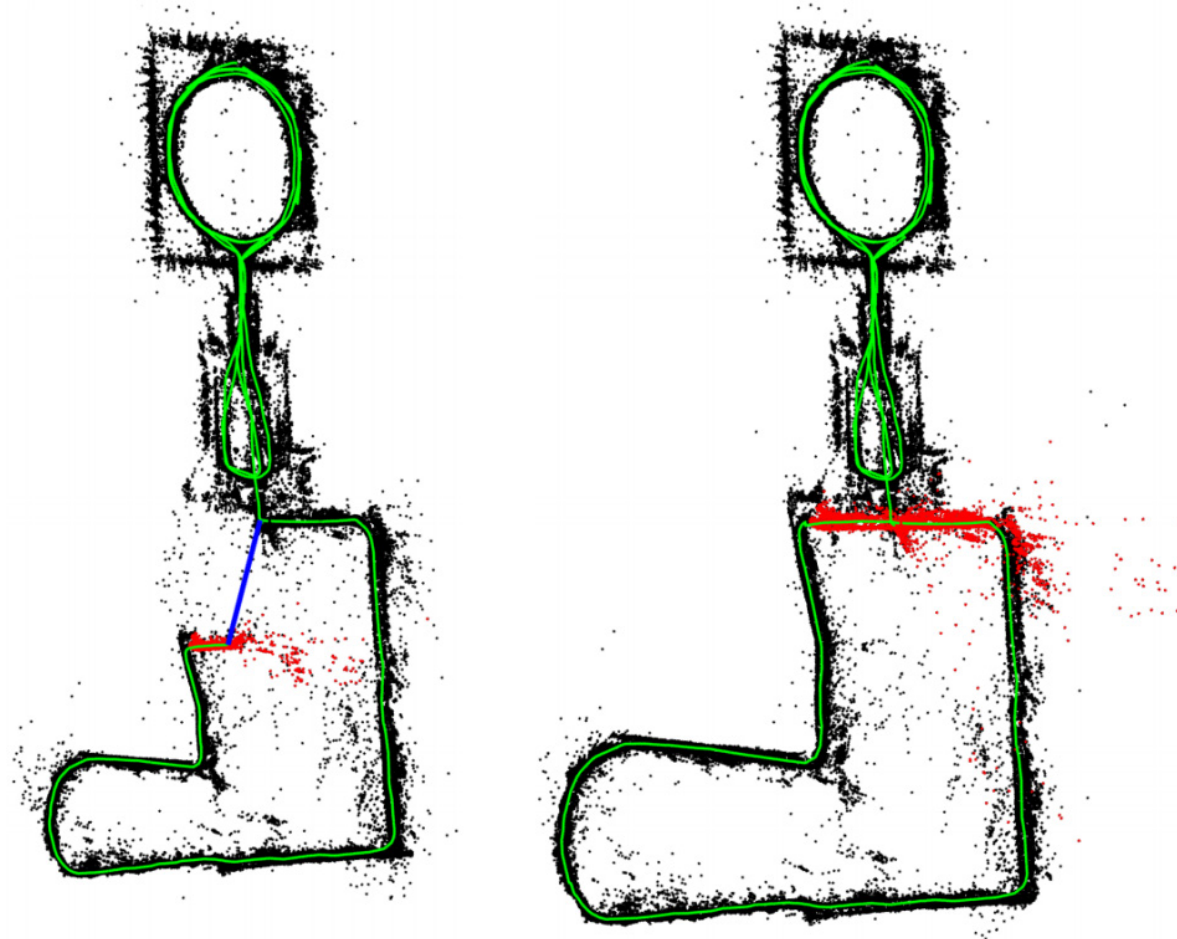


Monocular Visual SLAM



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Visual SLAM vs visual odometry



Mur-Artal, R., Montiel, J. M. M., & Tardos, J. D. (2015). ORB-SLAM: A Versatile and Accurate Monocular SLAM System. *IEEE Transactions on Robotics*, 31(5), 1147–1163

Visual SLAM vs visual odometry

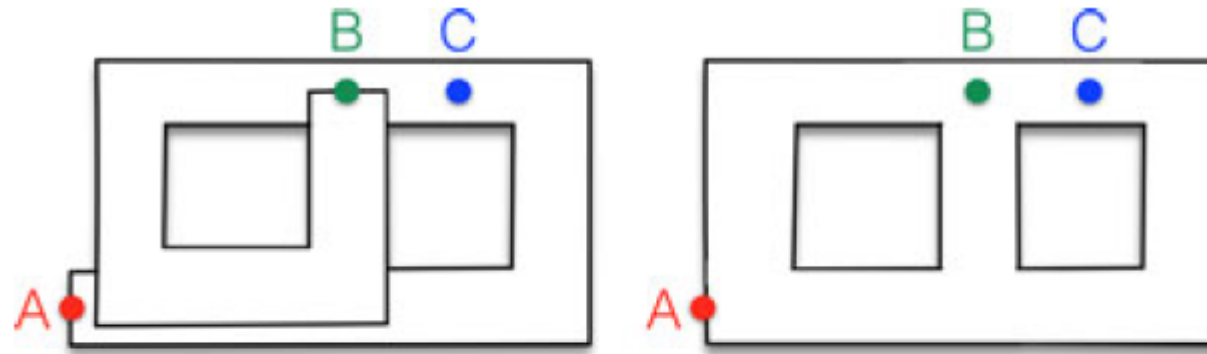
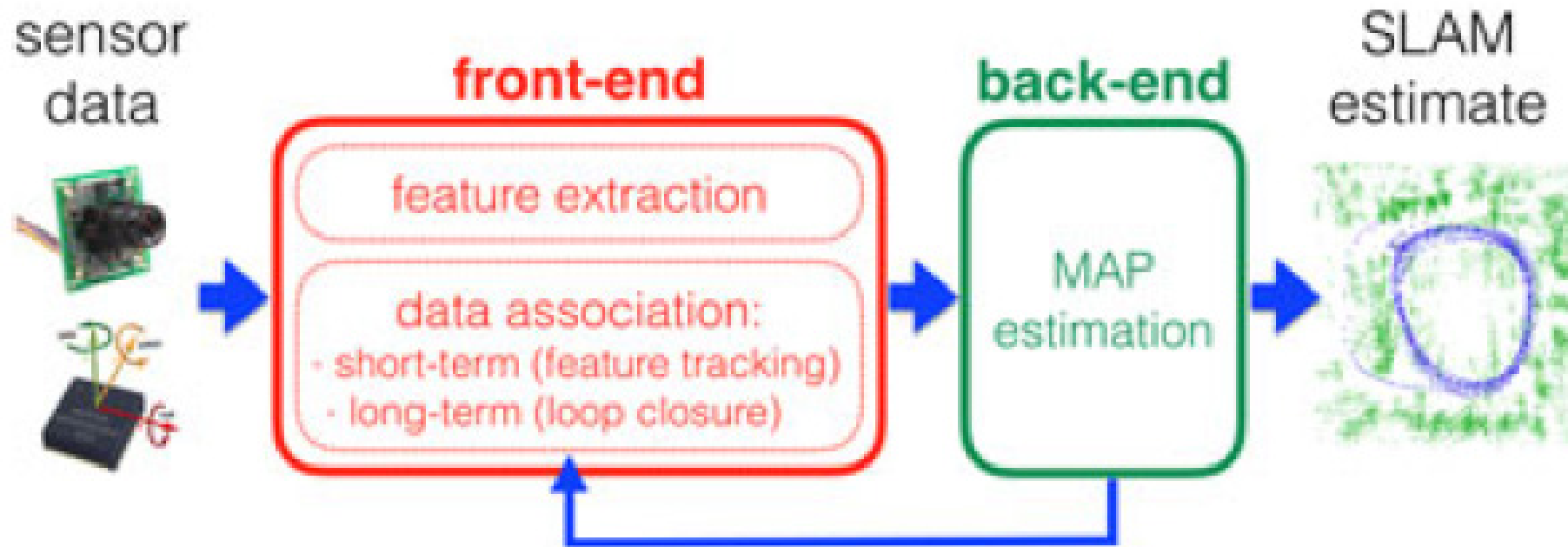


Fig. 1. Left: map built from odometry. The map is homotopic to a long corridor that goes from the starting position A to the final position B. Points that are close in reality (e.g., B and C) may be arbitrarily far in the odometric map. Right: map built from SLAM. By leveraging loop closures, SLAM estimates the actual topology of the environment, and “discovers” shortcuts in the map.

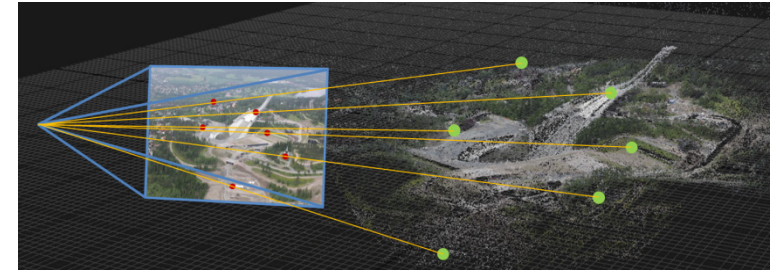
Components of SLAM



Cadena, C., et al. (2016). Past, Present, and Future of Simultaneous Localization and Mapping: Toward the Robust-Perception Age. *IEEE Transactions on Robotics*, 32(6), 1309–1332

Components of VSLAM

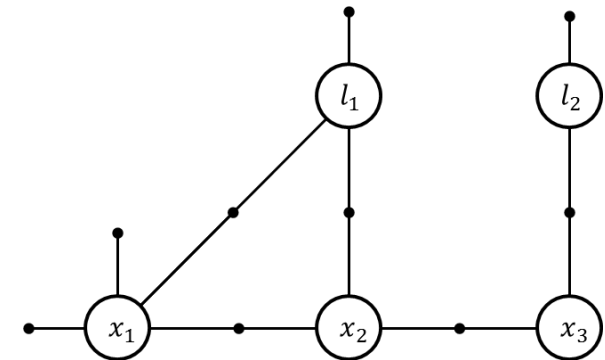
- Short-term tracking
 - Pose estimation given the map
 - Keyframe proposals
- Long-term tracking
 - Visual place recognition
 - Loop closure detection over keyframes
- Mapping
 - Optimizing the map over keyframes
 - Data fusion



(a)



Lowry, S. et al. (2016). Visual Place Recognition: A Survey. IEEE Transactions on Robotics, 32(1), 1–19.



Supplementary material

- “Parallel Tracking and Mapping for Small AR Workspaces”,
Klein and Murray,
In Proc. International Symposium on Mixed and Augmented Reality (ISMAR'07, Nara), 2007
https://www.robots.ox.ac.uk/~vgg/rg/papers/klein_murray_2007_ptam.pdf
- “Past, Present, and Future of Simultaneous Localization And Mapping: Towards the Robust-Perception Age”,
Cadena et al., IEEE Transactions on Robotics 32 (6) pp 1309-1332, 2016
<https://ieeexplore.ieee.org/document/7747236>
- “Visual Place Recognition: A Survey“,
Lowry, S. et al., IEEE Transactions on Robotics, 32 (1), pp 1–19, 2016
<https://ieeexplore.ieee.org/document/7339473>