Final project SssssSLAM

Self–made
Semi-stable

Semantic
Segmentation

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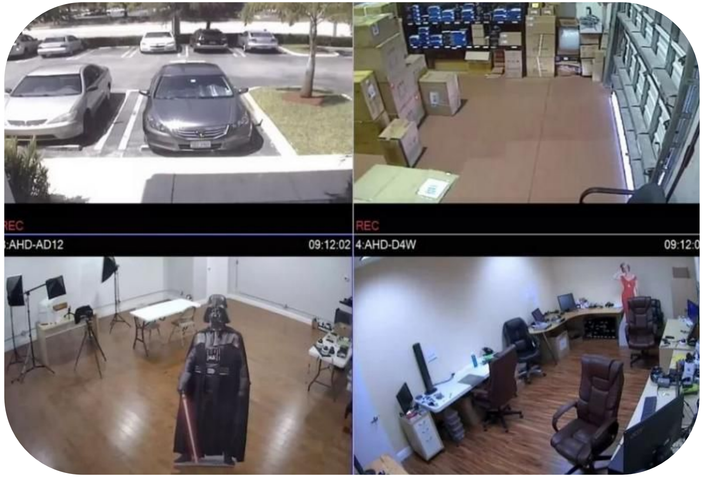
Skolkovo Institute of Science and Technology

Mobile Robotics Laboratory

Problem statement

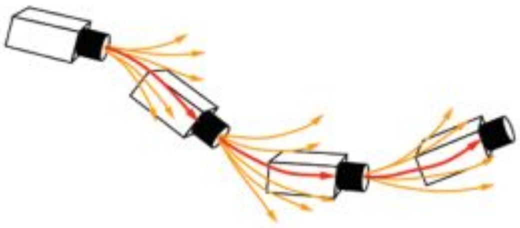
Aim: Monocular camera tracking & mapping

Input: a sequence of images



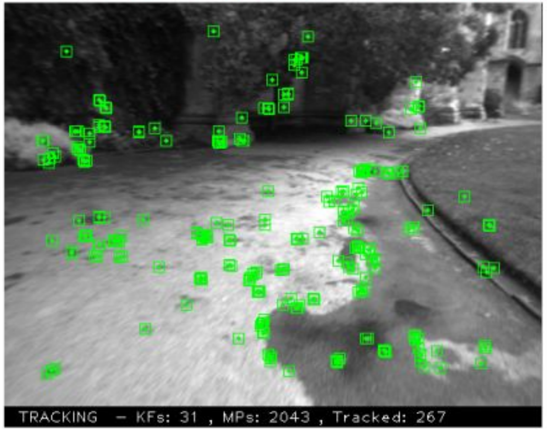
Output: a camera path

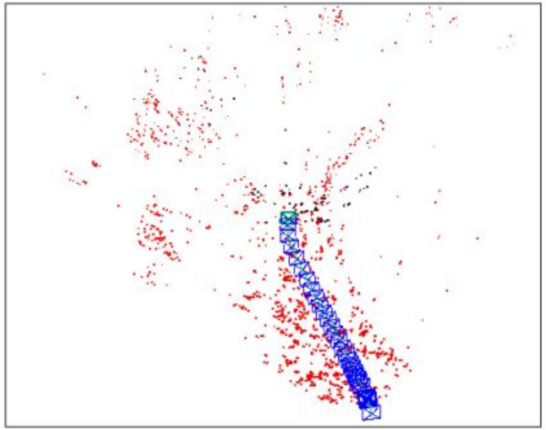
with a feature map of “stable” objects



Overview

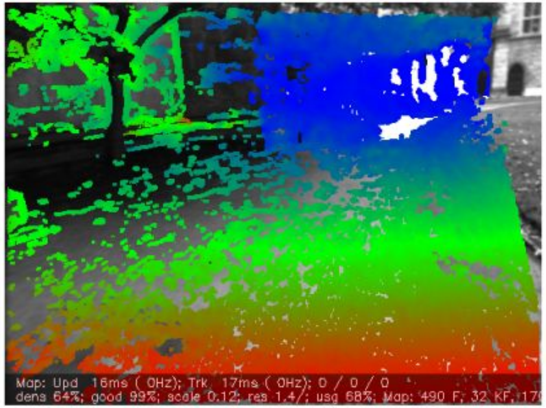
Sparse methods:

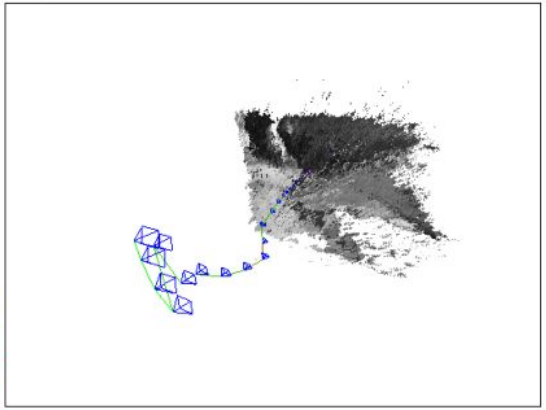




ORB-SLAM

Dense methods:





LSD-SLAM

Chosen method

Bundle Adjustment with ArUco Initialization

- Bundle Adjustment (BA) [1]:
  Map point 3D locations $\mathbf{X}_{w,j} \in \mathbb{R}^3$ and keyframe poses $\mathbf{T}_{iw} \in \mathrm{SE}(3)$, where w stands for the world reference, are optimized minimizing the reprojection error with respect to the matched keypoints $\mathbf{x}_{i,j} \in \mathbb{R}^2$. The error term for the observation of a map point j in a keyframe i is:

$$\mathbf{e}_{i,j} = \mathbf{x}_{i,j} - \pi_i(\mathbf{T}_{iw}, \mathbf{X}_{w,j}) \tag{5}$$

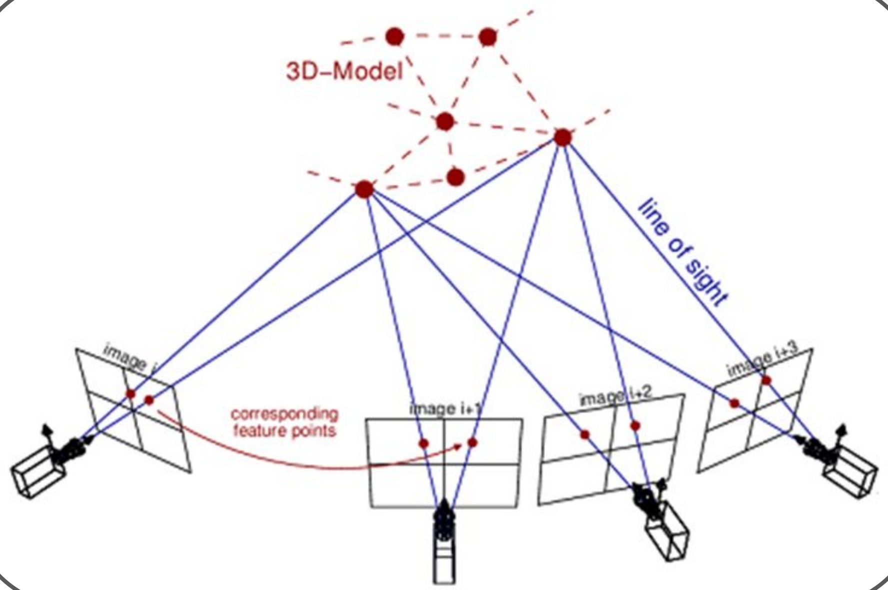
where π_i is the projection function:

$$\pi_i(\mathbf{T}_{iw}, \mathbf{X}_{w,j}) = \begin{bmatrix} f_{i,u}\frac{x_{i,j}}{z_{i,j}} + c_{i,u} \\ f_{i,v}\frac{y_{i,j}}{z_{i,j}} + c_{i,v} \end{bmatrix} \tag{6}$$

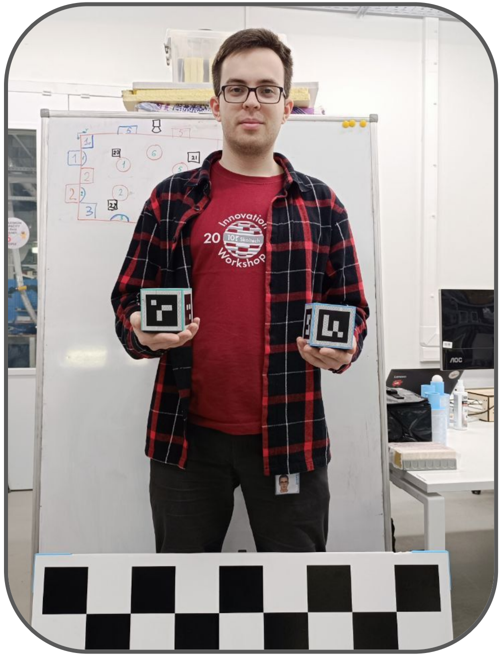
$$\begin{bmatrix} x_{i,j} & y_{i,j} & z_{i,j} \end{bmatrix}^T = \mathbf{R}_{iw}\mathbf{X}_{w,j} + \mathbf{t}_{iw}$$

where $\mathbf{R}_{iw} \in \mathrm{SO}(3)$ and $\mathbf{t}_{iw} \in \mathbb{R}^3$ are respectively the rotation and translation parts of $\mathbf{T}_{iw}$, and $(f_{i,u}, f_{i,v})$ and $(c_{i,u}, c_{i,v})$ are the focal length and principle point associated to camera i. The cost function to be minimized is:

$$C = \sum_{i,j} \rho_h(\mathbf{e}_{i,j}^T \mathbf{\Omega}_{i,j}^{-1} \mathbf{e}_{i,j}) \tag{7}$$



Algorithm of operation



- ✓ **Calibrate** a camera & collect a **dataset**
- ✓ Apply **Semantic Segmentation**
- ✓ **Feature extraction** and description
- ✓ Discard **non-reliable** keypoints
- ✓ **Matching** with Lowe ratio test
- ✓ Apply **ArUco Initialization**
- ✓ **Bundle Adjustment** with various **Loss** functions
- ✓ **Visualization** of camera path and feature map
- ☐ Retrieval of previously observed keypoints
- ☐ **Loop closure** (based on embeddings from NN)

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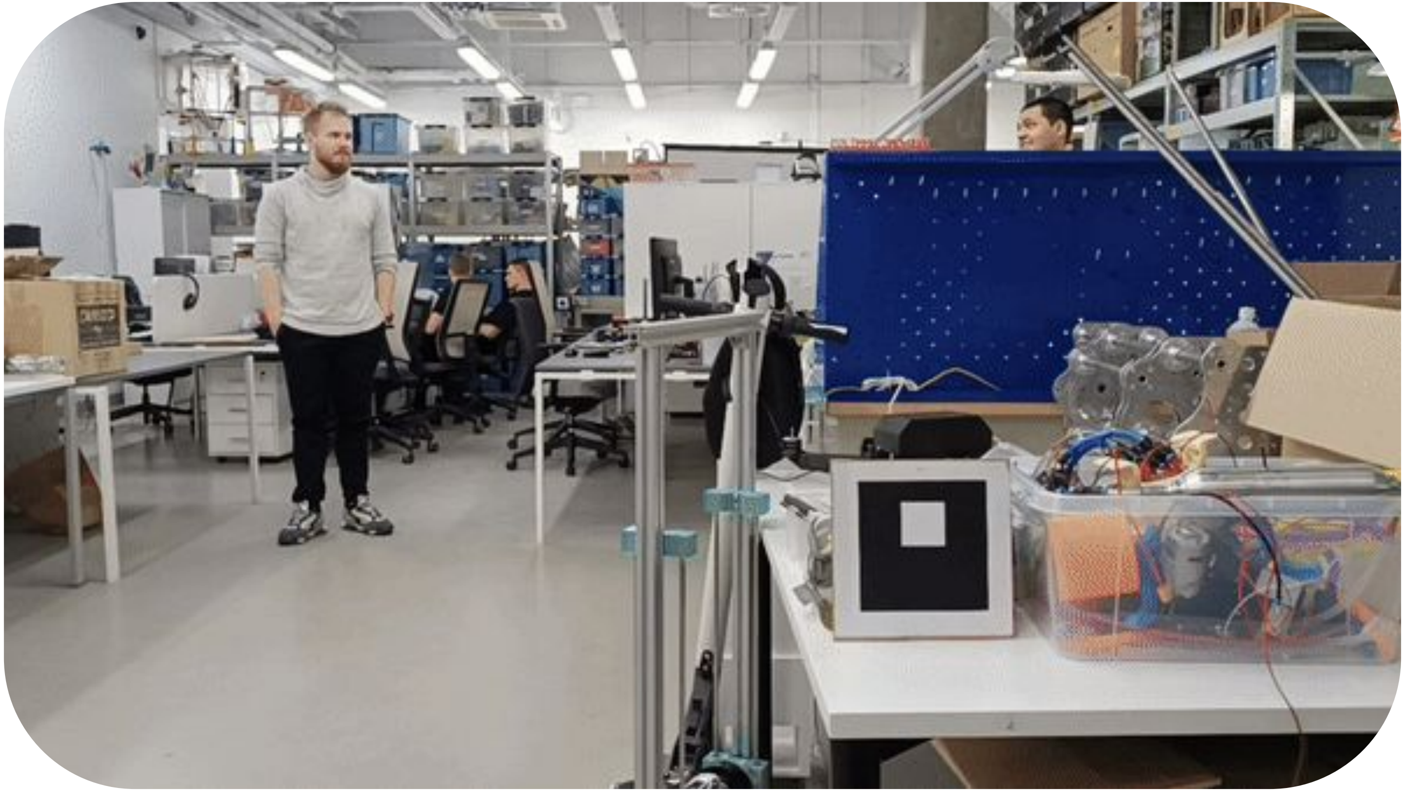
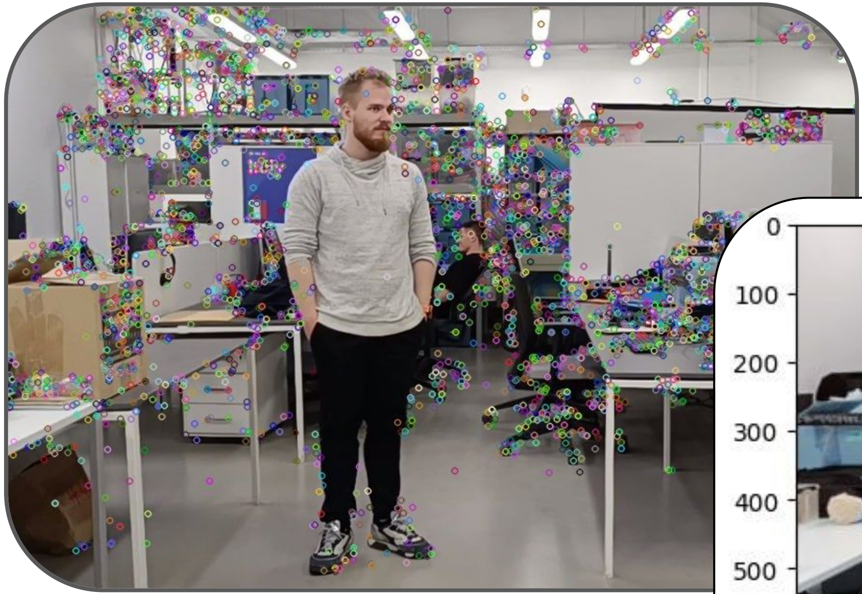
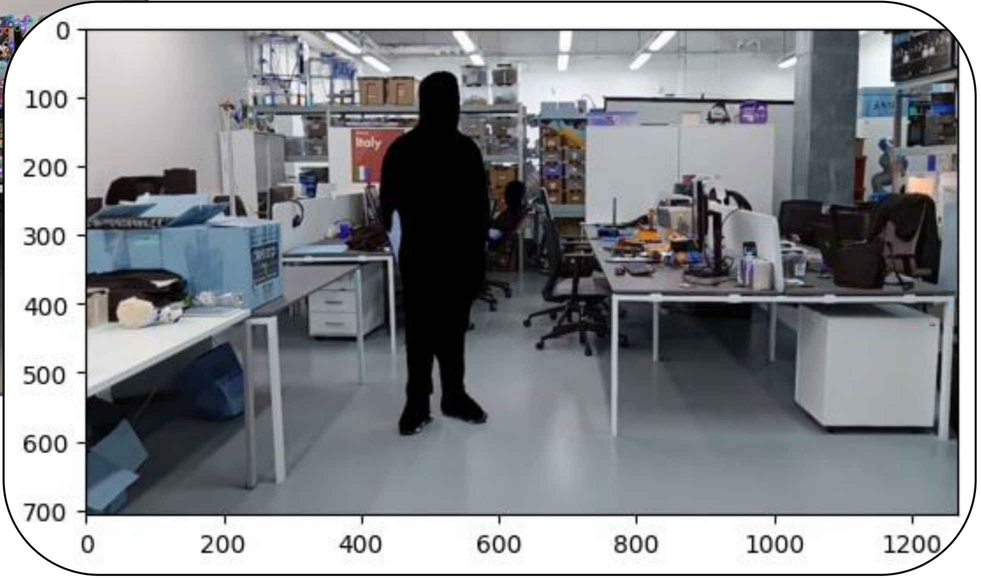
1 step: Collecting dataset



2 step: Semantic Segmentation



ResNet-1



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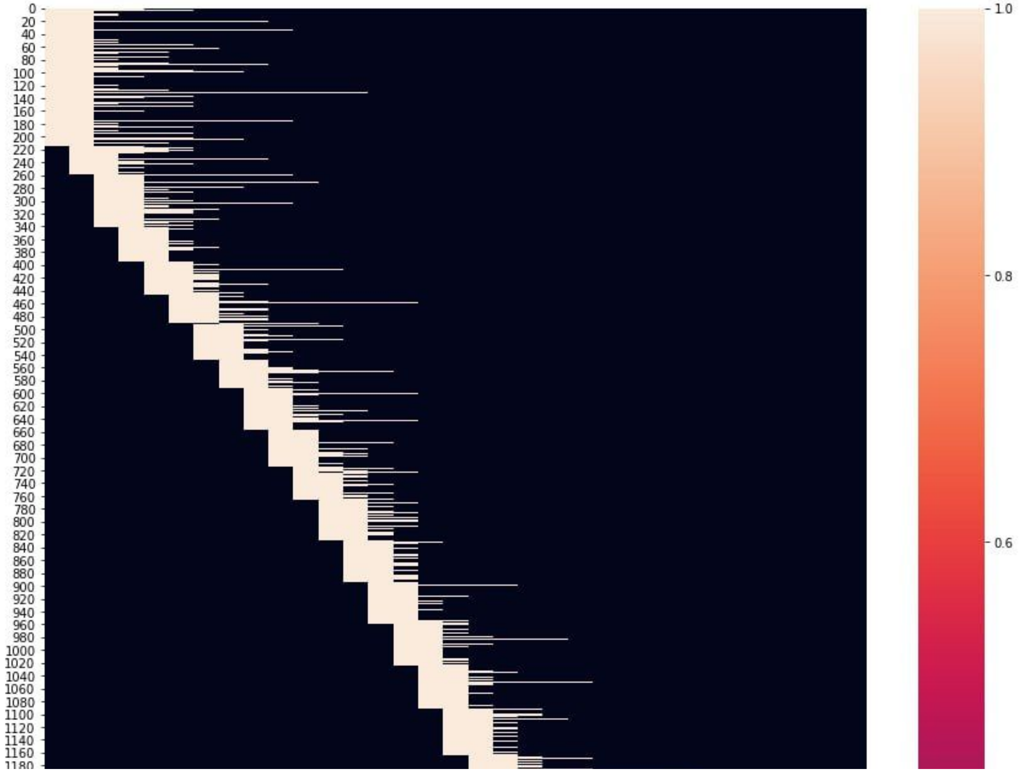
3 step: Feature extraction & Matching (Lowe ratio test)

BEFORE

AFTER

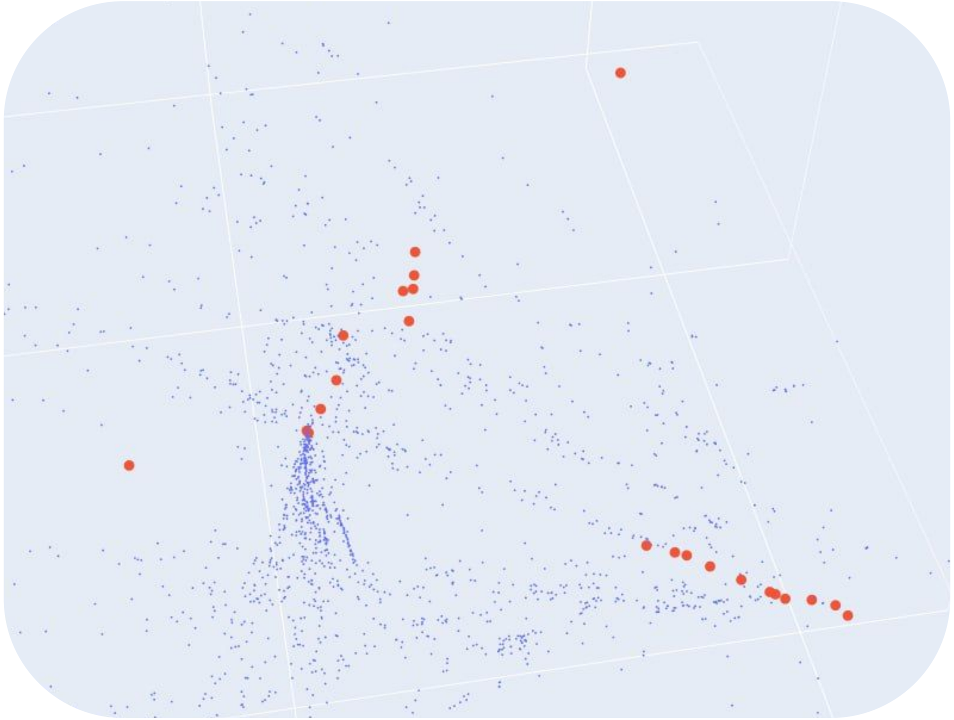
Feature observations in consequent keyframes

Keyframes



Global features

First steps – Lack of initialization



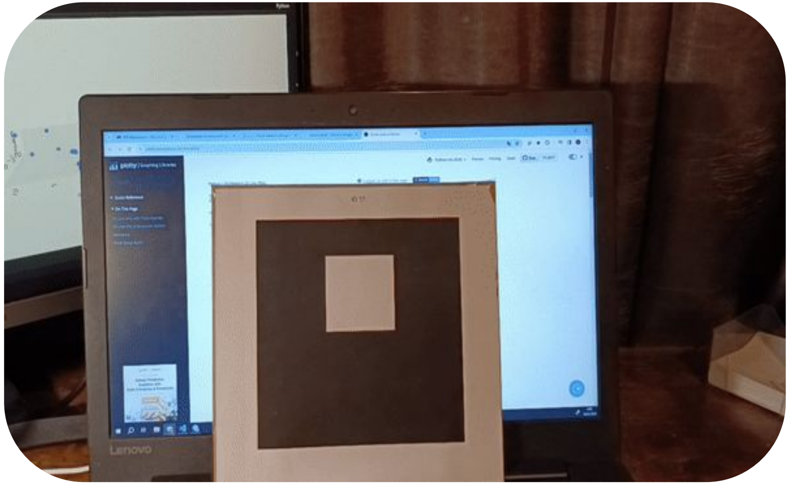
- Camera positions
- Feature positions

Results:

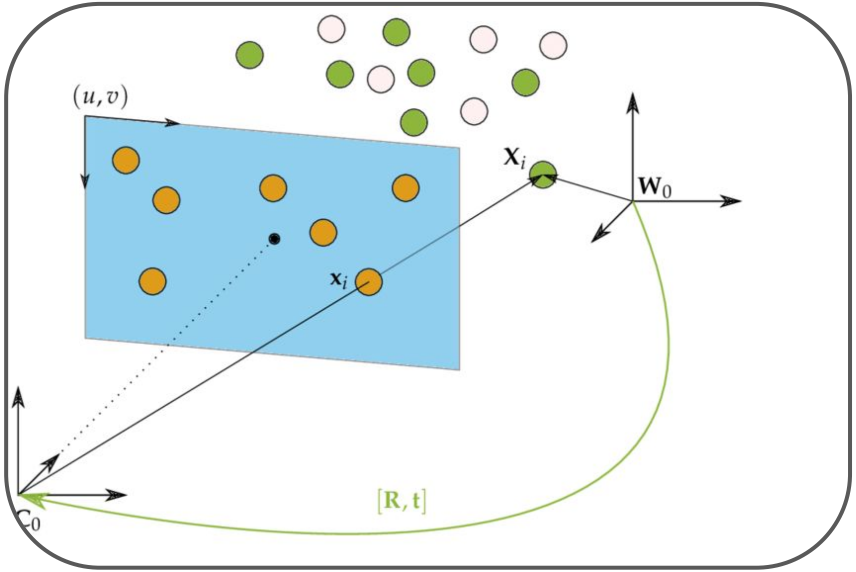
- Camera path is not reliable
- Map is totally uninterpretable
- Non-repeatable
- Scale – ?

4 step: ArUco Initialization

Filtration of outliers



ArUco observations



Perspective-n-Point (PnP)
Pose Computation

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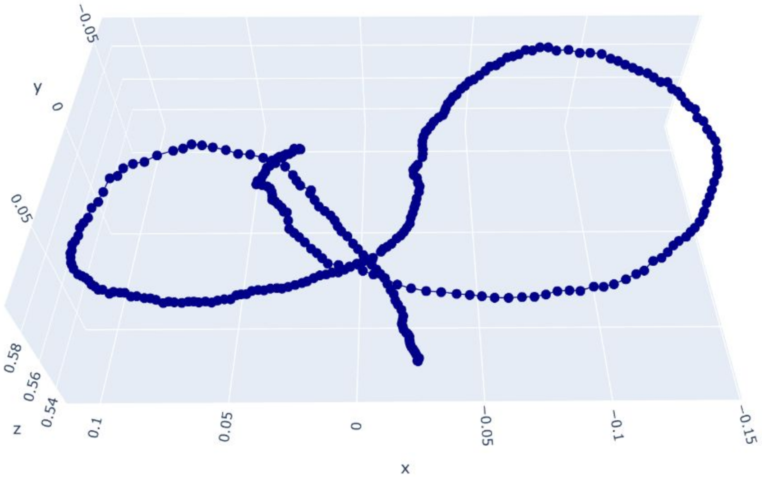
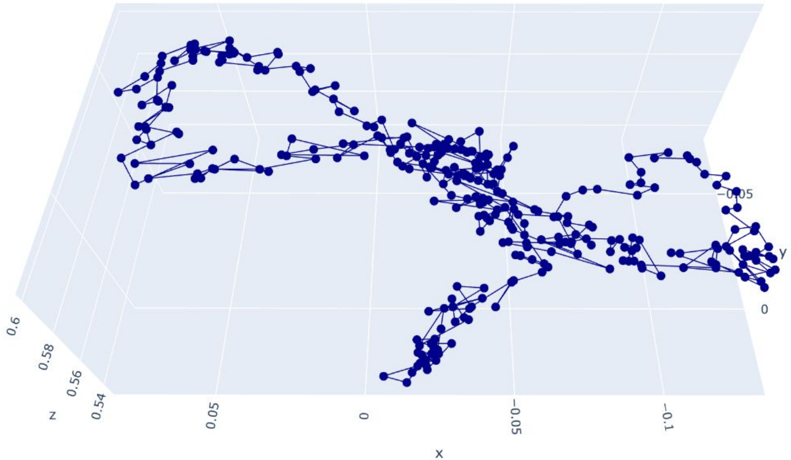
4 step: ArUco Initialization





ArUco position
in camera frame

Camera position
in ArUco frame

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5 step: Graph optimization pipeline

- Graph initialization:

```
mrob.FGraph(mrob.CAUCHY)
```

- Adding ArUco corners as reference points:

```
graph.add_node_landmark_3d(..., mrob.NODE_ANCHOR)
```

- Adding a new camera pose:

```
graph.add_node_pose_3d(mrob.geometry.SE3())
```

- Adding a pose in Aruco frame (if any):

```
graph.add_factor_camera_proj_3d_point(aruco_corners)
graph.add_factor_1pose_3d(mrob.geometry.SE3(pose_wrt_aruco),...)
```

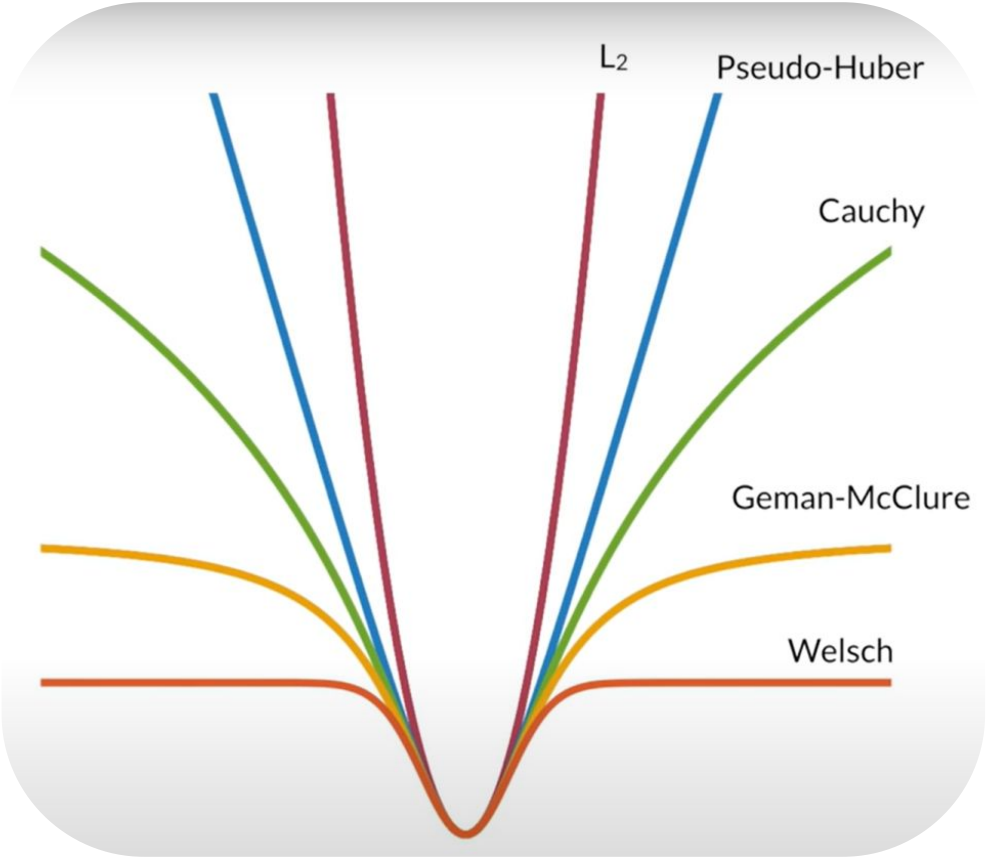
- Dealing with observations:

```
graph.add_node_landmark_3d(last_position + 3*np.random.random((3, 1)))
graph.add_factor_camera_proj_3d_point((u, v),...)
```

- Optimization:

```
graph.solve(method=mrob.LM, maxIters=200)
```

Loss functions



Cauchy

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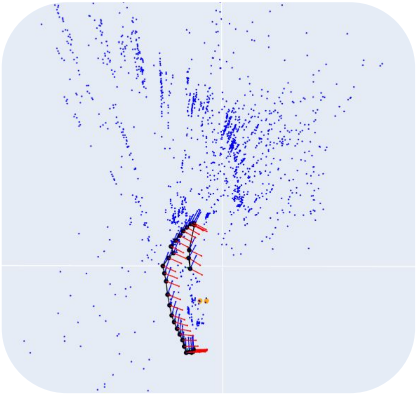
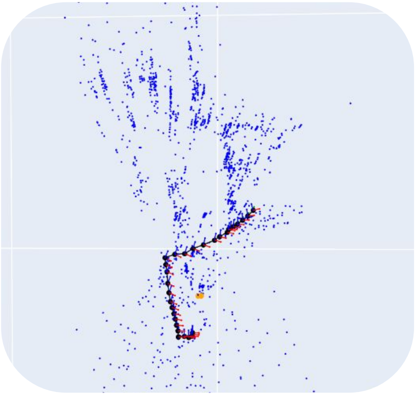
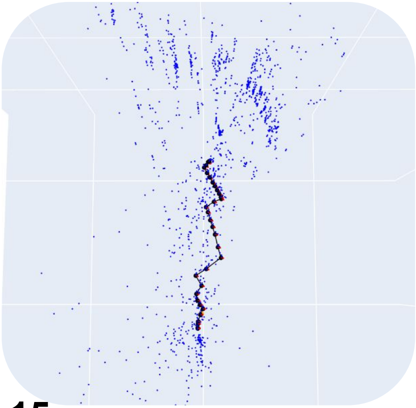
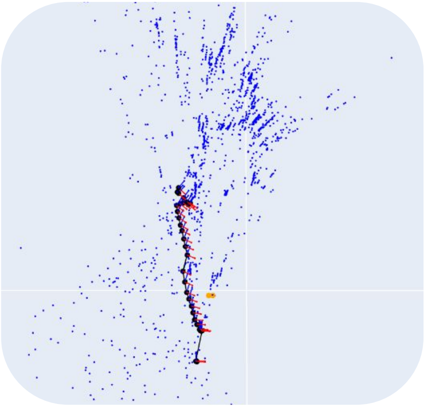
Our results

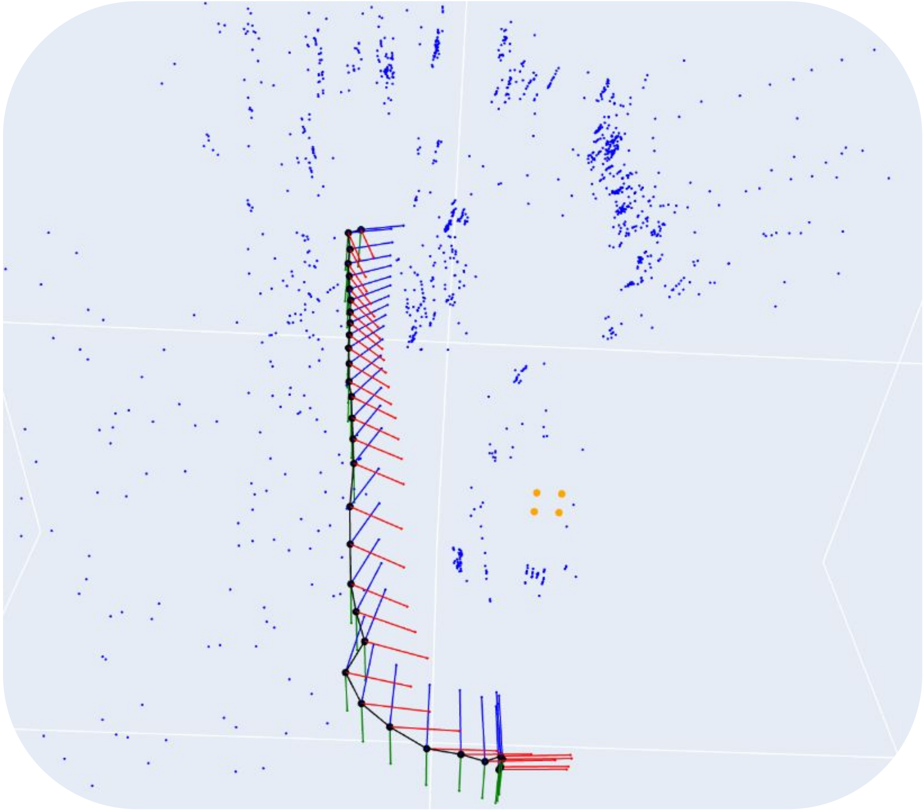








The BEST



Our amazing team

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Daria Chekina

Aikun Bexultanova

Jingtao Xu

Thank you for your attention!

Be HAPPY!!!

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