Module: 3D Vision
Project: 3D recovery of urban scenes (Session 3)

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Goal

3D Reconstruction from two images with known internal parameters

Tasks

- 1. Estimation of the fundamental matrix
  - 1.1 Normalized 8-point algorithm **(3.0)**
  - 1.2 Robust estimation of the fundamental matrix **(2.5)**
  - 1.3 Epipolar lines **(1.0)**
- 2. Triangulation with the DLT method **(2.5)**
- 3. Reconstruction from two views:
  - 3.1 Estimate the image matches **(Provided)**
  - 3.2 Estimate the Fundamental Matrix **(Provided)**
  - 3.3 Estimate the Essential Matrix **(1.0)**
  - 3.4 Estimate the Camera Matrices from the Essential Matrix **(Optional 0.75)**
  - 3.5 3D Visualization **(Optional and provided)**
  - 3.6 Reprojection Error **(Optional 0.25)**

Assignment

- Code is provided in python in a jupyter notebook.
- Auxiliary functions and algorithms are provided on additional modules.
- Deliver before 16h of next Tuesday, January 14.

Deliverables

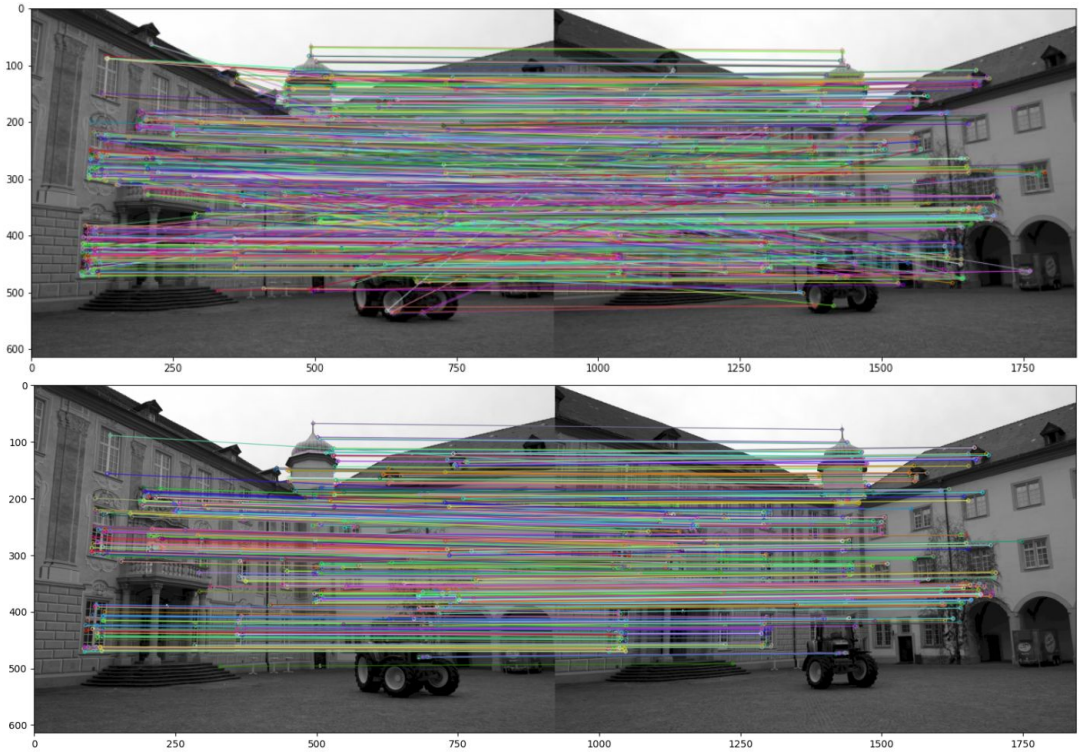
- **Jupyter notebook:** ready to run.
  - Document your code and decisions on markdown.
  - Be clear of what information is assumed/required for each algorithm/operation.
  - Understand the equations do not just reproduce them from the slides.
- **Report:**
  - Short report.
  - In depth analysis.
  - Do not paste code in report. I am interested in analysis and justification.
  - Problems and comments.
  - You can use the notebook as a report **IF, AND ONLY IF,** you format the notebook appropriately.

1. Estimation of the fundamental matrix

1.1 Normalized 8-point algorithm

Check the slides from the lecture!

1. Estimation of the fundamental matrix
1.2 Robust estimation of the fundamental matrix



1. Estimation of the fundamental matrix
1.2 Robust estimation of the fundamental matrix

- Function that robustly estimates F using the previous function and RANSAC (you can use as a basis the provided function in lab 2: 'Ransac_DLT_homography').
  The inliers are obtained with a threshold on the first order approximation of the geometric error: **Sampson distance**,

$$\frac{(x_i'^T F x_i)^2}{(Fx_i)_1^2 + (Fx_i)_2^2 + (F^T x_i')_1^2 + (F^T x_i')_2^2}$$

1. Estimation of the fundamental matrix
1.2 Robust estimation of the fundamental matrix

Geometric distance
(used for determining the inliers in the RANSAC function)

$$d([x_i], [\hat{x}_i])^2 + d([x_i'], [\hat{x}_i'])^2 \text{ s. t. } \hat{x}_i'^T F \hat{x}_i = 0 \ \forall i$$

where the different matchings $x_i \longleftrightarrow x_i'$ are the data,
[.] is the projection operator to Euclidean coordinates.

1. Estimation of the fundamental matrix
1.2 Robust estimation of the fundamental matrix

Geometric distance

A variant is (we use the distance of a point to a line $d(x, l) = |x^T l|/||l||$):

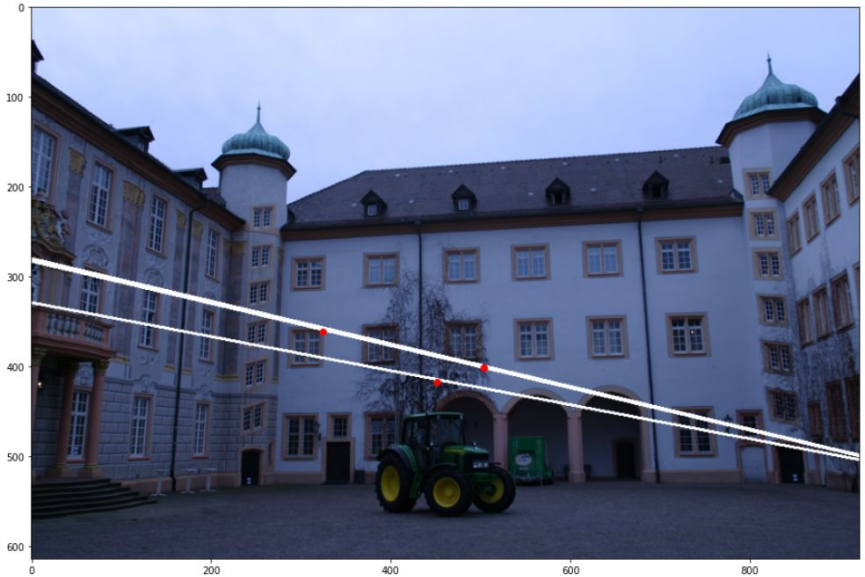
$$d(x_i', Fx_i)^2 + d(x_i, F^T x_i')^2$$

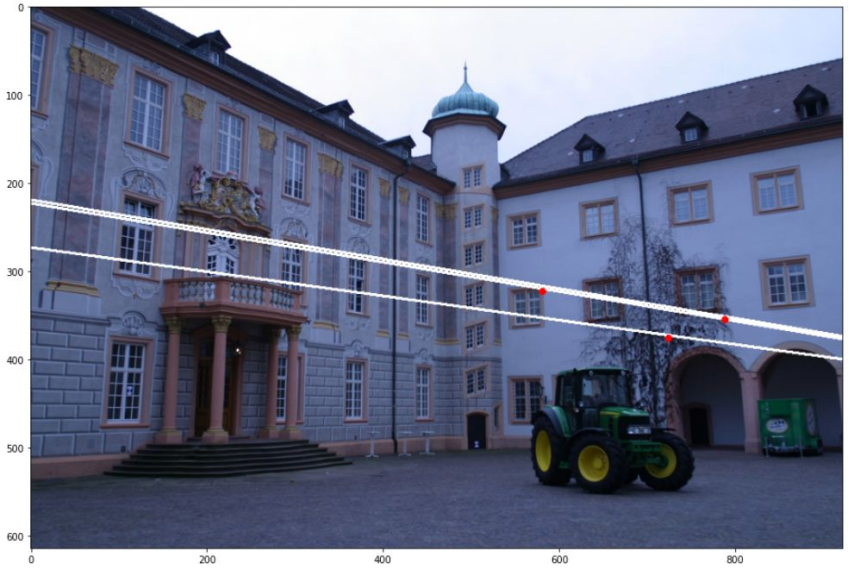
$$= (x_i'^T F x_i)^2 \left(\frac{1}{(Fx_i)_1^2 + (Fx_i)_2^2} + \frac{1}{(F^T x_i')_1^2 + (F^T x_i')_2^2} \right)$$

We will use the **Sampson error**
(1st order approx. of the geometric distance)

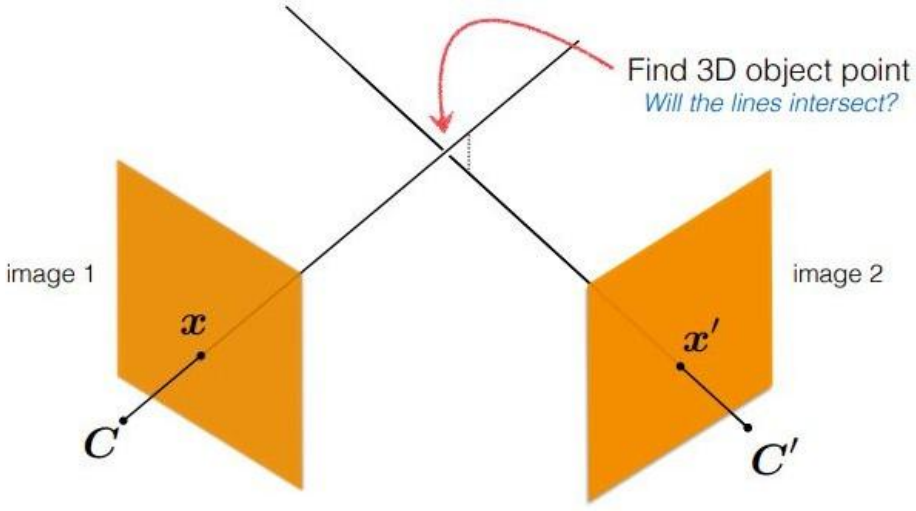
$$\frac{(x_i'^T F x_i)^2}{(Fx_i)_1^2 + (Fx_i)_2^2 + (F^T x_i')_1^2 + (F^T x_i')_2^2}$$

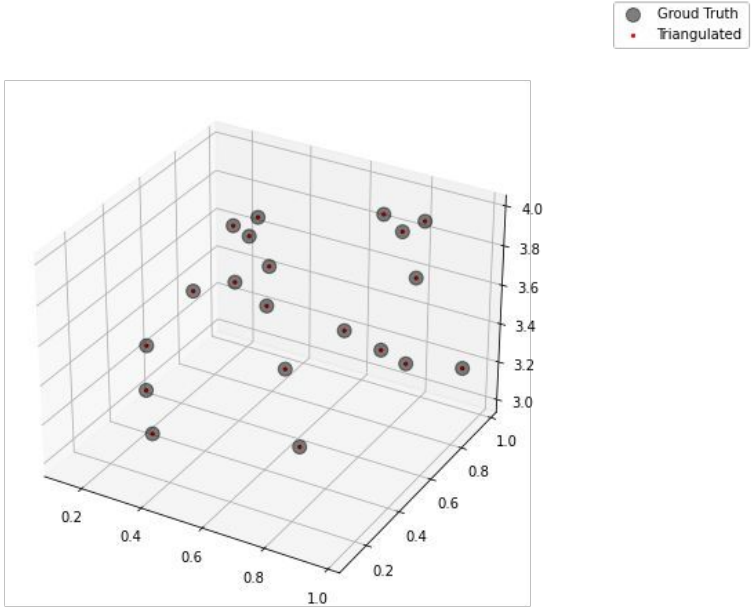
1. Estimation of the fundamental matrix
1.3 Epipolar lines





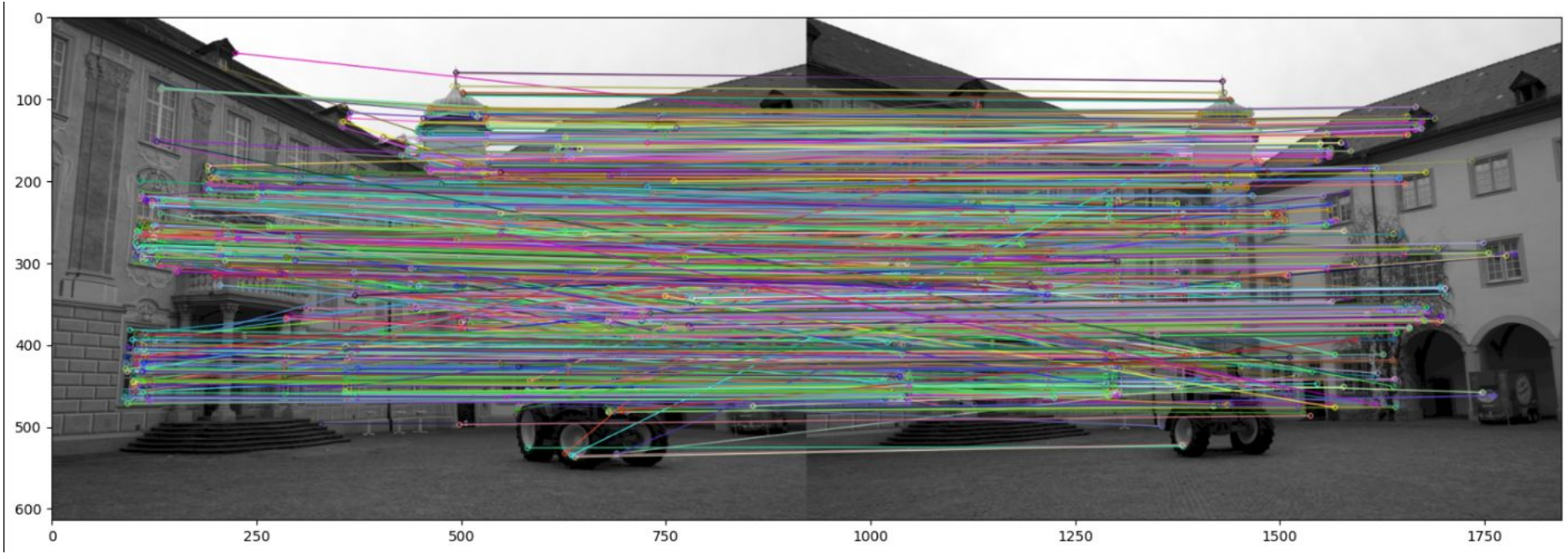
2. Triangulation with the DLT method



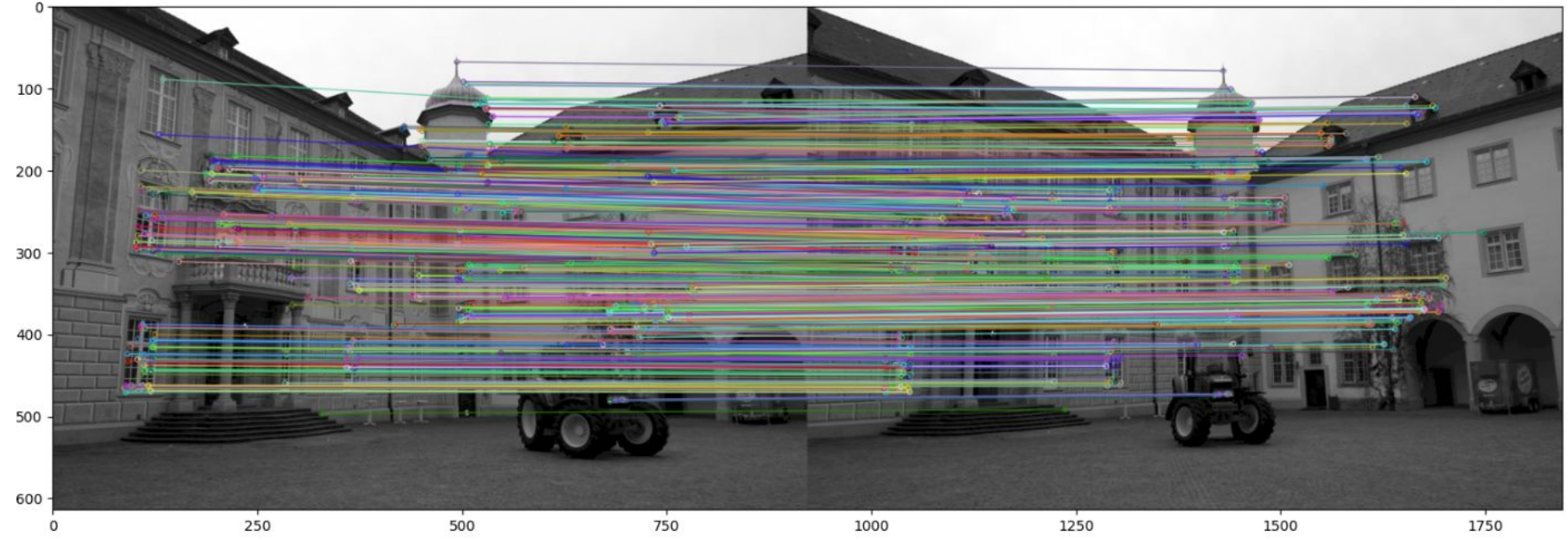


3. Reconstruction from two views

3.1 Estimate the image matches

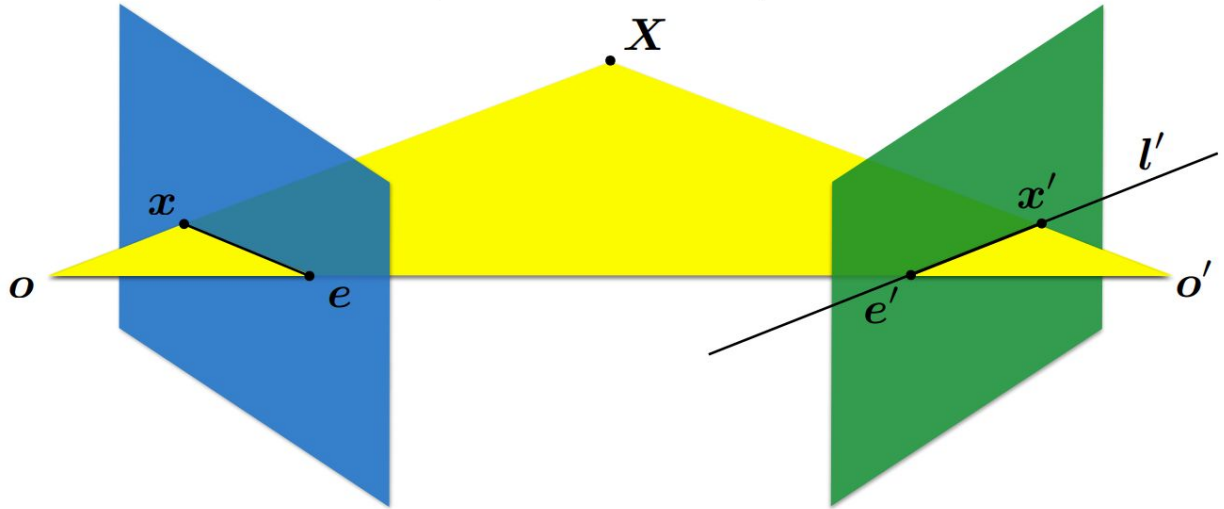


3. Reconstruction from two views
3.2 Estimate the Fundamental Matrix



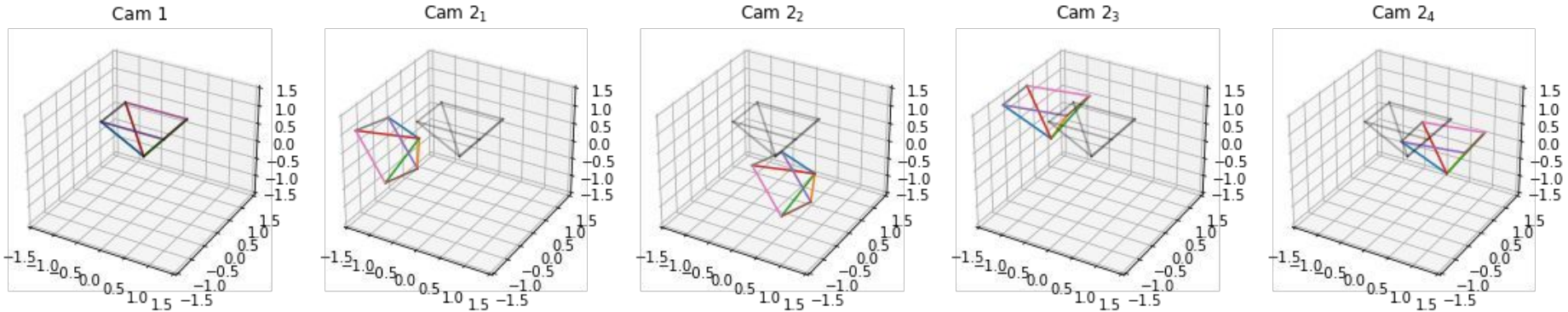
3. Reconstruction from two views
3.3 Estimate the Essential Matrix

$$\mathbf{E}x = l'$$

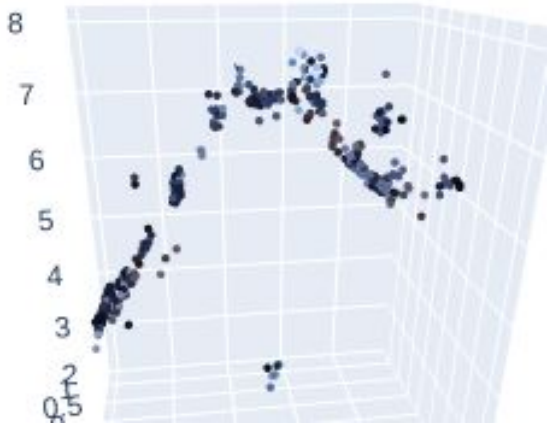


3. Reconstruction from two views

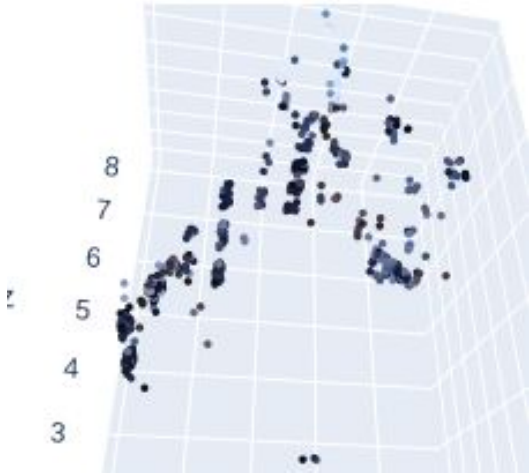
[Optional] 3.4 Estimate the Camera Matrices from the Essential Matrix



3. Reconstruction from two views
[Optional] 3.5 3D Visualization



Top view



Front view

3. Reconstruction from two views
[Optional] 3.5 3D Visualization: Keypoints

3. Reconstruction from two views
[Optional] 3.6 Reprojection error