A2: Triangulation

1. Overview

In this assignment, you will gain hands-on experience in reconstructing 3D geometry from corresponding image points of two images. Specifically, you will practice:

- Basic linear algebra operations;
- Estimating fundamental matrix F from corresponding image points;
- Recovering relative pose (i.e., R and **t**) from the fundamental/essential matrix;
- Determine 3D coordinates of image points using the recovered projection matrices.

2. Methodology

The related theory has been explained in the lecture and is covered in the lecture note (i.e., handout). In this section, mainly the major steps of each algorithm are provided. Please refer to the lecture note and/or the lecture slides for the technical details.

Step #1: Estimate fundamental matrix F from given corresponding image points using the normalized 8-point algorithm **(20%)**

- Normalization – 5%
- Linear solution (based on SVD) – 5%
  - The recovered F is up to scale, please make the last element 1.0
- Constraint enformanct (based on SVD) – 5%
  - Find the closest rank-2 matrix
- Denormalization – 5%

Step #2: Recover relative pose (i.e., R and **t**) from the fundamental matrix **(20%)**

- Find the 4 candidate relative poses (based on SVD) – 10%
- Determine the correct relative pose – 10%
  - determinant(R) = 1.0 (within a tiny threshold due to floating-point precision)
  - **most** (it theory it is 'all' but not in practice due to noise) estimated 3D points are in front of the both cameras (i.e., z values w.r.t. camera is positive)

Step #3: Determine the 3D coordinates for all corresponding image points **(30%)**

- Compute the projection matrix from K, R, and t – 10%
- Compute the 3D point using the linear method (based on SVD) – 10%
- [Optional] Non-linear least-squares refinement of the 3D point computed from the linear method – **10% extra**

- Triangulate all corresponding image points – 10%

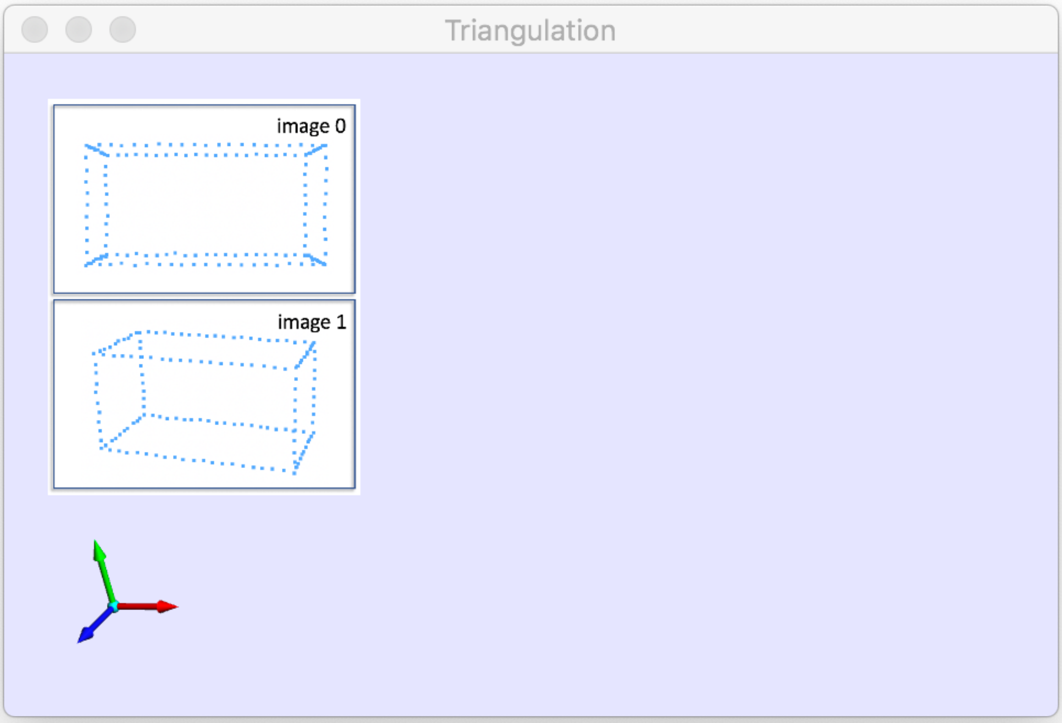
It is strongly advised to **define a function for each sub-task**. This way you have a clean and well-structured implementation, which also makes your testing and debugging easier. Each function can also be reused for some other purposes.

4. Data, code framework, and viewer

The data used in this assignment are 160 pairs of image points from two images. The points from the two images have one-to-one correspondences. All points are stored in homogenous coordinates (i.e., in the form of *x, y, w* and *w* is set to 1.0). Each line has three floating-point numbers representing a single image point. The points of the two images are store separately in the following two files

- /A2_Triangulation_Code/resources/data/image_points_0.xyz
- /A2_Triangulation_Code/resources/data/image_points_1.xyz

Build and run the viewer from the provided source code, the image points will be automatically loaded for you (so you don't need to do anything for file IO). You will see the image points visualized as below:



If you **press the 'space' key, the reconstruction method will be triggered**.

The reconstruction function is named '*triangulation(…)*', located in the file '*triangulation_method.cpp*'. You will need to implement this function to be able to reconstruct 3D points from the corresponding image points. Comments and guidance are provided in the function. Example code is also provided within the function for you to get familiar with the necessary data structures and APIs.

In addition to the interactions (e.g., rotate, translate, zoom in/out) provided by the viewer, you can also

- take a snapshot of the visualization by pressing the ‘s’ key.
  (It is required to include in your report a few snapshots of the reconstructed 3D points from different views).
- save the reconstructed 3D points into a file by pressing both ‘Ctrl’ and 's'.
  (It is required to include the file of your reconstructed 3D points in your submission).

3. Submission (deadline: 23:59, Mar 19)

Your submission should include

(1) The entire source code including the provided code framework and your implementation of the ‘triangulation(…)’ method. Your code should compile and reproduce your result without modification.

(2) A report **(30%)**
- Description of the methodology – 5%
- Demonstration of your result – 5%
- Evaluation of your results (e.g., accuracy, how to improve it) – 5%
- Discussion on how to obtain the camera intrinsic matrix K and the effect of K’s precision on the final reconstruction. You can tune the parameters of K (at lines 145 - 148 in ‘*triangulation.cpp*’) and run the reconstruction multiple times and evaluate the results. – 10%
- A short description of “who did what” – 5%

(3) The file of the reconstructed 3D points (in .xyz format. Pressing ‘Ctrl’ and 's' to save).

Please compress all the above into an archive file and name it in the following format:

GEO1016_Assignment_2_Group_X.zip

where ‘X’ is your group ID, which can be found here:
https://docs.google.com/document/d/1WMPXgWD0_2F9oDSub1K-g6NdRKqIRyWj3sUFDCpfFSk/edit

Enjoy recovering 3D!!!