Please read the instructions carefully before starting this homework.

- Due Date: **April 21, 2022, 12:20 (PM)**.
- Please submit in PDF format to NTU COOL. Late submission may not be accepted.
- Please clearly show each step of your solution; otherwise you might lose some points.
- You may refer to any material you want, including books, slides, and the Internet, etc. However, you must do this homework completely alone. **DO NOT discuss with other people**.
- If you have any questions, please email 3dcv@csie.ntu.edu.tw. Emails sent after 17:00 on April 20th may not be responded to, except for urgent or technical issues.
- Total Points: 105pts.

Problem 1 PoseNet

The problem of camera relocalization is defined as: given a query image, find the 6-DOF camera pose in a known scene.

(a) [5pts] PoseNet is a camera relocalization method that regresses camera position and orientation. What are the advantages and disadvantages of using end-to-end deep learning to estimate caemra pose?

(b) [10pts] The original loss function of PoseNet is a naive end-to-end loss for regressing position $\widehat{x}$ and orientation $\widehat{q}$ with a hyperparameter β. What are the disadvantages of this loss function? How to improve from it?

$$\mathcal{L} = \|x - \widehat{x}\|_2 + \beta \|q - \widehat{q}\|_2$$

Problem 2 Camera Relocalization

[12pts] For the image-based localization using 2D-3D matching in a very large scene, describe the steps to construct a compressed scene representation using the vocabulary tree.

Problem 3 Epipolar Geometry

Epipolar geometry describes the geometric relationship between two camera systems. Assume that the two cameras are centered at C_0 and C_1, and the corresponding image planes are I_1 and I_2, respectively.
[10pts] Question: Show that the determinants of essential matrix and fundamental matrix are zero, i.e. $det(E) = 0$ and $det(F) = 0$.

Problem 4 Camera Model

(a) [6pts] Write down the camera intrinsic matrix and explain the parameters.

(b) [5pts] Which of the following factor does not affect seriously the intrinsic parameters of a camera model? (A) Effective Focal length (B) Offset of optical center (C) Exposure (D) Zoom In.

Problem 5 Homography

[12 pts] Given the camera matrix K, show that the homography H_R that models the camera motion of rotation R and translation t but the distance d of camera and object plane are very far, then $H_R = KRK^{-1}$.

Problem 6 Projection Matrix

(a) [6pts] Determine the minimum number of correspondence n that is needed to estimate camera projection matrix P by DLT method. Explain your answer.

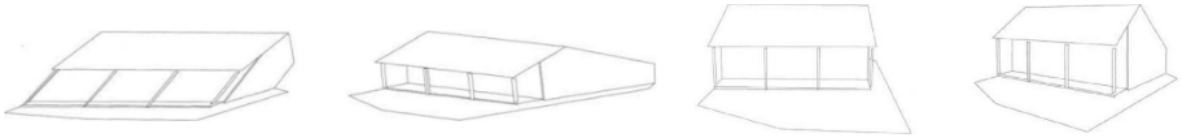
(b) [12pts] After estimating camera projection matrix P, we can get intrinsic matrix K and extrinsic matrix E by RQ decomposition. Given P as below, please decompose the intrinsic matrix K and extrinsic matrix E.

$$P = \begin{bmatrix} 5 & -3 & 3 & 5 \\ 4 & 3 & 2 & 10 \\ 0 & 0 & 1 & 1 \end{bmatrix}$$

Problem 7 Orthographic Camera Model

(a) [5pts] In which of the following scenarios are best suited for using an orthographic camera model? (A) A car passing quickly in front of you (B) Walking around the Taipei 101 (C) An airplane flying at a very high attitude (D) The bike riding side by side with you.

(b) [10pts] We know that there might be more than one solutions when using an affine camera model. To upgrade it to euclidean reconstruction, we can assume further orthographic projection model. Briefly explain why orthographic projection model can achieve euclidean reconstruction.



Affine Reconstruction Euclidean Reconstruction

Problem 8 Triangulation

[12 pts] We can estimate 3D points by 2D correspondence in a calibrated specific camera model by triangulation. But due to noise, we might use some estimations to solve this problem. Write down at least two ways to approach the problem and briefly describe the concepts.