ASSIGNMENT3: FUNDAMENTAL MATRIX ESTIMATION, CAMERA CALIBRATION, TRIANGULATION

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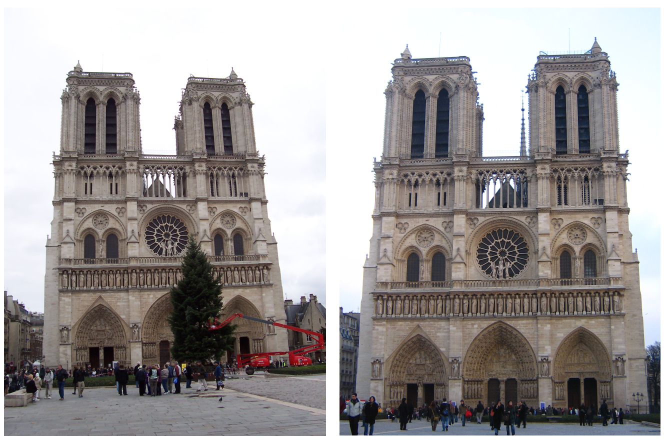
DUE: MONDAY, JUNE 10TH AT 10:00 AM



Images and data files are provided in the zip file. In addition, for this assignment, we will need **VLFeat** in Matlab and **Cyvlfeat** in Python to obtain matching points. Sample codes are provided to help to start your implementation.

The scope of this assignment is to estimate the fundamental matrix of two views using matching points in two views of the same location and, moreover, develop a 3D reconstruction routine. For this, you will apply your code on two different pairs of images.

PART I (30 POINTS): FUNDAMENTAL MATRIX ESTIMATION

The first task is to fit the fundamental matrix, which relates points in one scene to epipolar lines in another. In this part, fit the fundamental matrix or **'library'** pair of images, and report the residual (or mean squared error distance) in pixels between points in both images and the corresponding epipolar lines. A code to visualize the epipolar lines is provided and it must be included in your report.

Recall that the definition of the Fundamental Matrix is:

$$\begin{bmatrix} x & y & 1 \end{bmatrix} \begin{bmatrix} f_{11} & f_{12} & f_{13} \\ f_{21} & f_{22} & f_{23} \\ f_{31} & f_{32} & f_{33} \end{bmatrix} \begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = 0$$

and for two corresponding points, you will get one equation (**check the slides about Eight-point algorithm**) :

$$f_{11}xx' + f_{12}xy' + f_{13}x + f_{21}x'y + f_{22}yy' + f_{23}y + f_{31}x' + f_{32}y' + f_{33} = 0$$

$$\begin{bmatrix} xx' & xy' & x & x'y & yy' & y & x' & y' & 1 \end{bmatrix} \begin{bmatrix} f_{11} \\ f_{12} \\ f_{13} \\ f_{21} \\ f_{22} \\ f_{23} \\ f_{31} \\ f_{32} \\ f_{33} \end{bmatrix} = 0$$

known

unknown

94

Tips: The least squares estimate of F is full rank; however, the fundamental matrix is a rank 2 matrix. As such we must reduce its rank. In order to do this we can decompose F using singular value decomposition into the matrices U ΣV' = F. We can then estimate a rank 2 matrix by setting the smallest singular value in Σ to zero thus generating Σ_2 . The fundamental matrix is then easily calculated as F = U Σ_2 V'.

- **Fundamental Matrix Song :)**
  - https://www.youtube.com/watch?v=DgGV3l82NTk

PART II (40 POINTS): FUNDAMENTAL MATRIX ESTIMATION WITH RANSAC

In this part, use **'NotreDame'** pair images! The second part of this assignment is to fit the fundamental matrix using a potential matching set of points. In real-world applications, it is unlikely to have perfect point correspondence with which to estimate fundamental matrix (like in part I). So you will estimate the fundamental matrix using unreliable point correspondences from SIFT (a code to generate point correspondences is provided). The set of points are generated as follow:

- SIFT descriptors are computed to obtain key-points and their descriptors.
- It selects the best matches based on a threshold resulting in top few hundred pairs of descriptors.

In order to estimate the fundamental matrix from this noisy data, you'll need to use RANSAC in conjunction with your fundamental matrix estimation.

You will iteratively choose some number of point correspondences (8, 9, or some small number), solve for the fundamental matrix using the function you wrote for the part I, and then count the number of inliers. Inliers in this context will be point correspondences that "agree" with the estimated fundamental matrix. In order to count how many inliers a fundamental matrix has, you'll need a distance metric based on the fundamental matrix. (Hint: For a point correspondence (x',x) what properties does the fundamental matrix have?). You'll need to pick a threshold between inlier and outlier and your results are very sensitive to this threshold so explore a range of values. You don't want to be too permissive about what you consider an inlier nor do you want to be too conservative. Return the fundamental matrix with the most inliers

Tips: check RANSAC lecture and recall how the expected number of iterations of RANSAC to find the "right" solution in the presence of outliers. For example, if half of your input correspondences are wrong, then you have a 0.5^8 = 0.39% chance to randomly pick 8 correspondences when estimating the fundamental matrix. Hopefully, that correct fundamental matrix will have more inliers than one created from spurious matches, but to even find it you should probably do thousands of iterations of RANSAC.

PART III (30 POINTS): TRIANGULATION (ALGEBRAIC SOLUTION)

In this part, use **"library and house"** pair images! Use the camera matrices and the point matches for the triangulation, use the algebraic method to triangulate the position of every pair of matching points and given two cameras. Display the matched points in 3D, along with the camera centers, from different points of view. Use equal scaling for all axis in your plots (you can use plot3 in MATLAB and, for Python users, you can make use of the plot3d function provided in the first assignment.)

Tips and Details

- Recall that the camera centers are given by the null spaces of the matrices. They can be found by taking the SVD of the camera matrix and taking the last column of V.
- You do not need the camera centers to solve the triangulation problem. They are used just for the visualization.

Deliverables

1. A report of 500-1500 words with plots and figures. Do not forget to display everything in images (e.i. epipolar lines).
2. Well documented code with the required functionality for each part of the assignment.
3. Upload everything on Eleum