EECS 442 Computer Vision, Fall 2014
Homework 2

Due on **Thursday October 9, 2014 at 11:55pm**
Please submit your assignment on ctools

1 [30 points] Fundamental Matrix

In this question, you will explore some properties of fundamental matrix and derive a minimal parameterization for it.

(a) [**10 points**] Show that two 3×4 camera matrices M and M' can always be reduced to the following canonical forms by an appropriate projective transformation in a 3D space, which is represented by a 4×4 matrix H. Here, we assume $e_3^T(-A'A^{-1}b + b') \neq 0$, where $e_3 = (0, 0, 1)^T$, $M = [A, b]$ and $M' = [A', b']$.
[0 0 1]
Note: You don't have to show the explicit form of H for the proof.
(*Hint: The camera matrix has rank* 3.)

$$\hat{M} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \text{ and } \hat{M}' = \begin{bmatrix} a_{11} & a_{12} & a_{13} & b_1 \\ a_{21} & a_{22} & a_{23} & b_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(b) [**10 points**] Given a 4×4 matrix H representing a projective transformation in a 3D space, prove that the fundamental matrices corresponding to the pairs of camera matrices $(M,\ M')$ and $(MH,\ M'H)$ are the same.

(c) [**10 points**] Using the conclusions from (a) and (b), derive the fundamental matrix F of the camera pair $(M,\ M')$ using a_{11} , a_{12} , a_{13} , a_{21} , a_{22} , a_{23} , b_1 , b_2. Then use the fact that F is only defined up to a scale factor to construct a seven parameter expression for F. (*Hint: The fundamental matrix corresponding to a pair of camera matrices* $M = [I \mid 0]$ *and* $M' = [A \mid b]$ *is equal to* $[b]_\times A$)

Refer to HZ pg. 581 for expansion to notation: $[b]_\times$.

2 [10 points] Epipolar Geometry

Given l and l' are epipolar lines corresponding to points x and x' in two images, and k is any line not passing through the epipole e, then show that l and l' are related by $l' = F[k]_\times l$.

Refer to HZ pg. 581 for expansion to notation: $[k]_\times$.

3 [60 points] Programming Assignment

3.1 Fundamental Matrix

This programming assignment is concerned with the estimation of the fundamental matrix from point correspondences. Implement both the linear least squares version [**20 points**] of the eight-point algorithm and its normalized version [**10 points**] as proposed by Hartley. In both cases, enforce the rank-two constraint for the fundamental matrix via singular value decomposition.

The data for this assignment can be found in the zipped file. The zipped file contains two datasets. For each dataset, you will find the files

pt_2d_1.txt
pt_2d_2.txt
image1.jpg
image2.jpg
pt_3d.txt

The first two of these files contain matching image points (in the following format: number n of points followed by n pairs of floating-point coordinates). The two remaining files are jpeg versions of the images where the points were found. You may use the file *readTextFiles.m* to read in the data from 2D files. You may also choose to write your own function to read files.

You must turn in:

- An algorithmic break-down of the process.
- A copy of your code
- For both methods and both datasets, the average distance between the points and the corresponding epipolar lines for each image, as well as a drawing similar to Figure 10.4 in the PFs book showing the epipolar lines and the feature points for each image pair.

3.2 Stereo Rectification

[**30 points**] Using the same dataset, and the function you wrote for problem 3.1, perform image rectification on the two images. While choosing the matching transform to be applied on the image, make sure the algorithm minimizes the distance error between transformed pixels.

You must turn in:

- An algorithmic break-down of the process
- A copy of your code
- The H transforms for both images
- Error. You may report the distance error between all transformed pixels.