CS 512 Assignment 5

Report

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1. Problem Statement

In this assignment, I implemented 8-point algorithm to compute fundamental matrix and estimate epipolar lines and epipoles.

2. Proposed Solutions

We can reconstruct the epipolar geometry by estimating the fundamental matrix from point correspondences only.

Each correspondence leads to a homogeneous equation of the form:

$$\bar{p}_r^T F \bar{p}_l = 0$$

If we denote

$$F = \begin{bmatrix} f_1 & f_2 & f_3 \\ f_4 & f_5 & f_6 \\ f_7 & f_8 & f_9 \end{bmatrix}$$

We have the vector form

$$\begin{bmatrix} x_1x'_1 & x_1y'_1 & x_1 & y_1x'_1 & y_1y'_1 & y_1 & x'_1 & y'_1 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_Mx'_M & x_My'_M & x_M & y_Mx'_M & y_My'_M & y_M & x'_M & y'_M & 1 \end{bmatrix} \begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \\ f_5 \\ f_6 \\ f_7 \\ f_8 \\ f_9 \end{bmatrix} = \mathbf{0}$$

Find fundamental matrix:

- We can simplify this equation to

  $$Ax = 0$$

  A is a n x 9 matrix and x is a 9 x 1 matrix.

- Then do SVD to A, we got

  $$A = UDV^T$$

  The entries of F are proportional to the components of the last column of V.

- However, we need to ensure the rank of F to be 2, we do an SVD to F

$$F = U_F D_F V_F^T$$

- Set the last diagonal element of D to be 0, denoted as D′

- The corrected estimate of F is

$$F' = U_F D_F' V_F^T$$

Find epipoles:

- For left epipole:
  Left epipole is the right null space of F
- For right epipole:
  Right epipole is the left null space of F (last column of U)

Find epipolar lines:

- Given P_l on the left image, the corresponding right epipolar line is FP_l
- Given P_r on the right image, the corresponding left epipolar line is F^TP_r

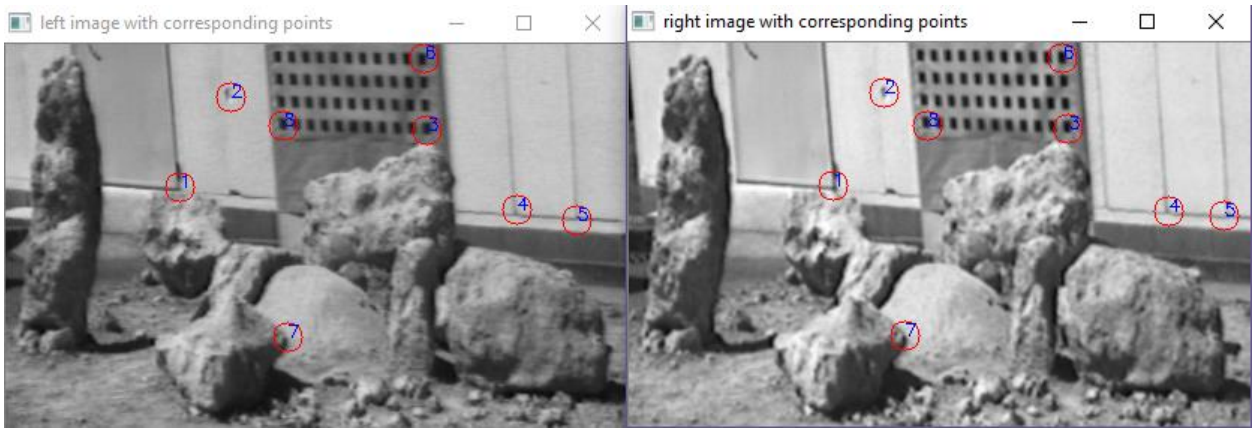
3. Implementation Details

- Run the program by python as5.py left.jpg right.jpg
- The left and right image will be displayed.
- Choose the corresponding point using mouse on two images (Choose 8 pairs of corresponding points) and display them on images
- Compute and display fundamental matrix using the chosen points
- Compute and display epipoles
- Compute and display epipolar lines:
  - Press l (left) to select a point on left image and display the corresponding epipolar line on the right image
  - Press r (right) to select a point on right image and display the corresponding epipolar line on the left image

4. Results and Discussion

Results:

1) Choose the corresponding points on two images



2) Compute and display fundamental matrix and epipoles

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(C:\Users\Li Xu\AppData\Local\conda\conda\envs\my_root) C:\Users\Li Xu\repos\cs512-f17-li-xu\AS5>python as5.py left.jpg
right.jpg
Please choose the 8 pairs of corresponding points on the images

Press any key to compute fundamental matrix and epipoles

F matrix is:
[[ -3.10228280e-06  -2.23899749e-04  -3.27961499e-03]
 [  2.18467667e-04  -3.19613297e-05  -2.01903270e-02]
 [ -6.36869435e-03   2.68136404e-02   9.99999998e-01]]
left epipole is:  [-0.98472972  0.17374666]
right epipole is:  [-0.96614561 -0.25786144]
Press l (left) to choose a point in left image and draw the corresponding epipolar line in the right image

Press r (right) to choose a point in right image and draw the corresponding epipolar line in the left image

Press l (left) to choose a point in left image and draw the corresponding epipolar line in the right image

Press r (right) to choose a point in right image and draw the corresponding epipolar line in the left image

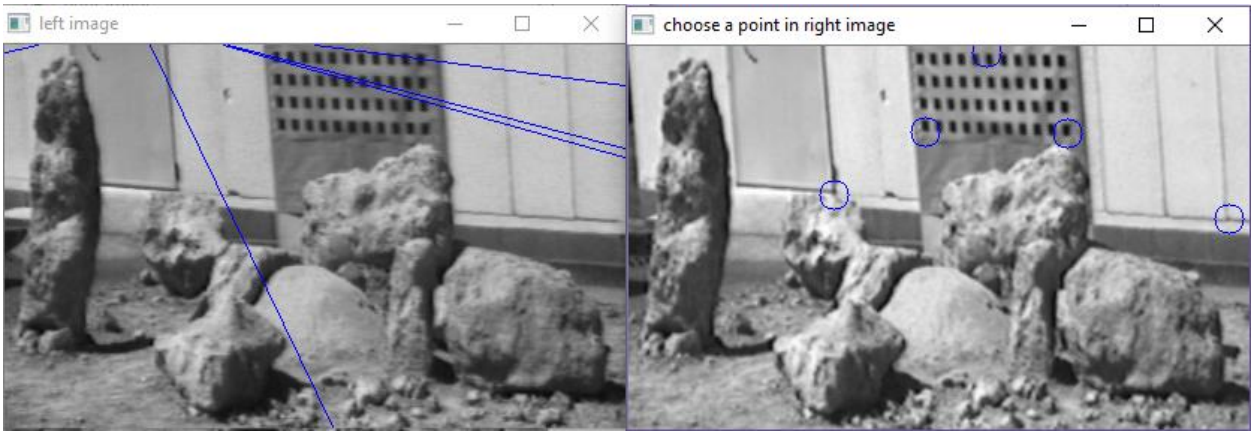
Press l (left) to choose a point in left image and draw the corresponding epipolar line in the right image

Press r (right) to choose a point in right image and draw the corresponding epipolar line in the left image


(C:\Users\Li Xu\AppData\Local\conda\conda\envs\my_root) C:\Users\Li Xu\repos\cs512-f17-li-xu\AS5>
```

3) Select points on left image and display right epipolar lines

4) Select points on right image and display left epipolar lines



Discussions:

1) The more corresponding points we choose, the more accurate the results are.

2) During the testing and debugging my program, I found using mouse to select corresponding points is not that accurate. Instead of using mouse click, in the future, we can use OpenCV feature matching functions to choose corresponding points, e.g. SIFT.

5. Reference

1. Mouse as a Paint-Brush https://docs.opencv.org/3.0-beta/doc/py_tutorials/py_gui/py_mouse_handling/py_mouse_handling.html
2. https://github.com/marktao99/python/blob/master/CVP/samples/sfm.py
3. The 8-point algorithm http://www.cs.cmu.edu/~16385/Slides/12.4_8Point_Algorithm.pdf
4. Epipolar (Stereo) Geometry https://www.cse.unr.edu/~bebis/CS791E/Notes/EpipolarGeonetry.pdf