Computer Vision
Assignment 3

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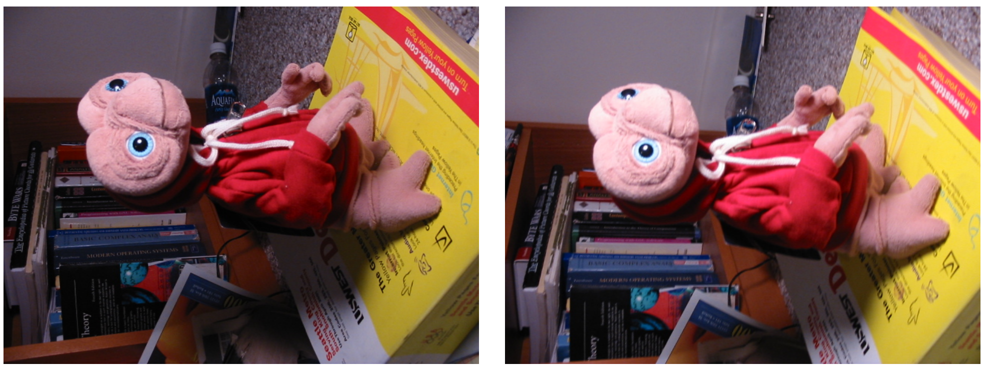
1 Introduction

The focus of this assignment is on *establishing a camera view relationship* between *two images* from *detected and matched point correspondences* from input images, without *user input or calibration*. The view relationship will be given in the form of a 3 x 3 *fundamental matrix*. We limit the scope of this report to only methods based on two views. We inspect our methods on the images shown in Figure 1.



(a) et000.jpg (b) et003.jpg

Figure 1: Two views of a scene used in our experiments.

2 Epipolar Geometry and the Fundamental Matrix

Intuition: A fundamental matrix F is a correlation, a 3x3 matrix, which maps a *point* x in one image of a 3D scene into the corresponding *epipolar line* $l^{'}$ in a second image of the same scene, expressed by $l^{'} = Fx$. Points on the same epipolar line l in the first image maps to the same line $l^{'}$, so F is singular and of rank 2. F has 7 degrees of freedom: 9 entries with 2 degrees of freedom lost because $detF = 0$ and the common scaling of entries is insignificant. The true corresponding point $x^{'}$ in the other image is somewhere on the line $l^{'}$ (consider $x^{'T}l^{'} = x^{'T}Fx = 0$). In this way, the fundamental matrix describes the relationship between the camera views in two images, independently of the scene [refer Figure 2].

3 The Full pipeline

The full pipeline, which is implemented for this report, consists of the phases:

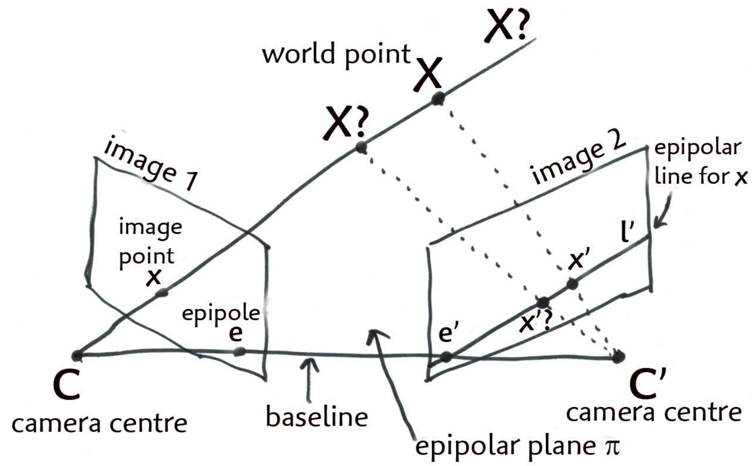


Figure 2: Two images taken of the same 3D scene with two cameras having C and $C^{'}$ as their centres of projection. The baseline joins the two camera centres and intersects the image planes in the epipoles e and $e^{'}$. For the point x in the first image, $l^{'}$ is its corresponding epipolar line. The point $x^{'}$ in the second image corresponding to x in the first image is somewhere on $l^{'}$, depending on the depth in the first image of the world-point X corresponding to x. An epipolar plane π is spanned by the baseline and the image point x.

1. Find interest points using the feature detectors like SURF, SIFT.
2. Obtain match point correspondences by methods like FLANN, BruteForce.
3. Robust estimation of the fundamental matrix by methods like RANSAC.

4 Evaluation of the Implemented Methods

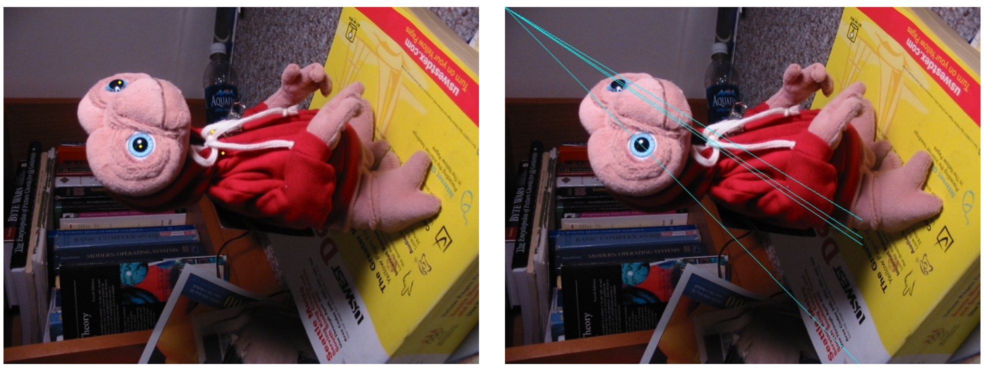
Results of the following three kinds of experiments will be presented.

1. Parallel camera motion without rotation or the camera remaining at the same point.
2. Visually inspecting epipolar lines.
3. The symmetric epipolar distance error measure given by $\frac{\sum_i d(x_i, F^T x_i^{'})^2 + d(x_i^{'}, F x_i)^2}{2*N}$ is relevant to test the achieved accuracy of the fundamental matrix estimates, with respect to the detected point correspondences.

5 Presentation of the Inspection Images

The images for visual inspection by epipolar line correspondences and four randomly selected points, are shown in Figures 3, 4, 5. The estimated fundamental matrix for the figure 4 is

$$F_4 = \begin{bmatrix} 0.000002 & 0.000030 & 0.045887 \\ -0.000026 & -0.000006 & -0.032026 \\ -0.050551 & 0.031372 & 1.000000 \end{bmatrix}$$



(a) points in et000.jpg

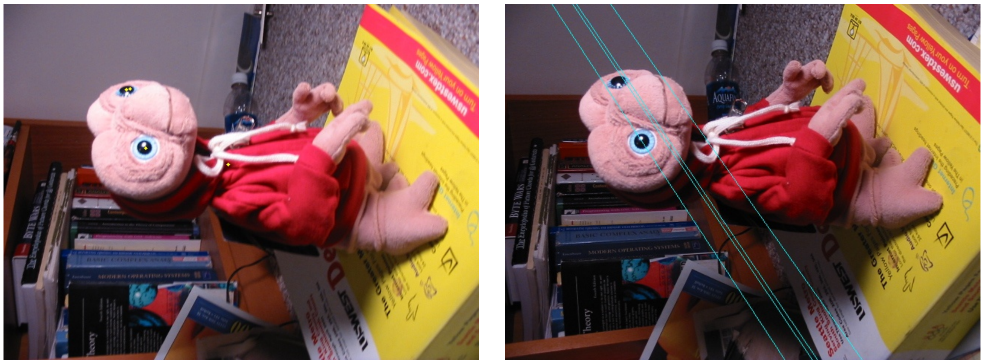
(b) epilines in et000.jpg

Figure 3: When the camera does not move(i.e., both scenes are same), the achieved results look sensible. The symmetric epipolar distance error is 0.000004. The epipole is the origin of the scene itself. All the epilines pass through the epipole(i.e., origin in this case).

6 Varying Feature Detector, Matching and Estimation method

We experimented on various extensions, such as varying the feature detection methods, varying the algorithms used to estimate the fundamental matrix in the individual phases of the pipeline.

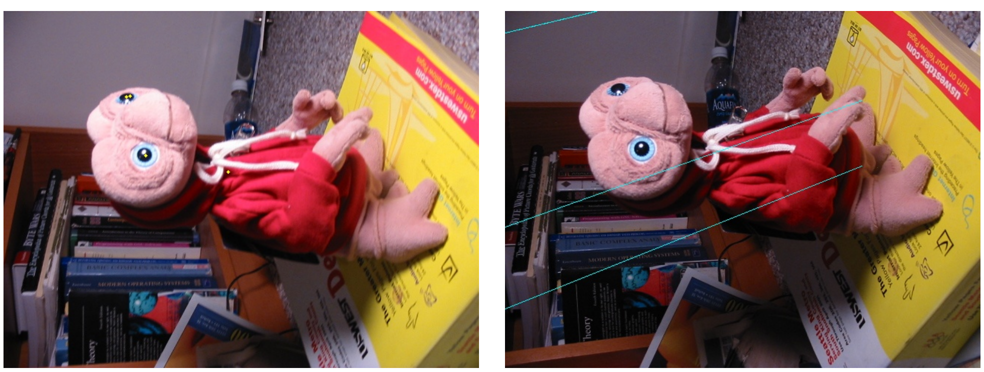
Feature Detector	Error (FLANN)	Error(BruteForce)
SIFT	7.555645	7.532256
SURF	7.618867	7.720477



(a) points in et003.jpg (b) epilines in et000.jpg

Figure 4: Four randomly selected points, shown as circles, and their computed epipolar lines are shown for visual inspection. The epipolar lines here are not entirely accurate. E.g. the right most point on first image is not matched with the epipolar line in the second image. This is likely due to error in estimating F matrix. The symmetric epipolar distance error is 7.618867.

Estimation method	Error(FLANN)
8POINT	61.155902
RANSAC	7.618867
LMEDS	5.757605



(a) points in et003.jpg (b) epilines in et000.jpg

Figure 5: When 8POINT Method is used to estimate the fundamental matrix, the epipolar lines match to unreasonable points. The symmetric epipolar distance error is very high, 61.155902.

7 Conclusions

The matching and estimation methods seem to be quite robust for getting some kind of sensible results, but are not necessarily very accurate. This is justified from the non-zero symmetric epipolar distance errors obtained with our implementations.

A web interface of our implementation to experiment on user given images is available here.