Computer Vision Assignment 4

Student

# 1 Estimating a Camera Matrix Pair and Reconstructing 3D Features

1.1 Problem Description

Estimating camera matrices from an image pair involves determining the relative positions and orientations of the cameras that captured the images. This is done using corresponding feature points between the two images, detected through SIFT (Scale-Invariant Feature Transform) feature matching. The provided 3x3 calibration matrix, which describes the intrinsic parameters of the cameras (such as focal length and optical center), is used to refine the estimation process. By accurately estimating these camera matrices, the 3D structure of the scene can be inferred from the 2D image pair. **Aim**: Estimate the spatial relationship between cameras and reconstruct the 3D coordinates of features.
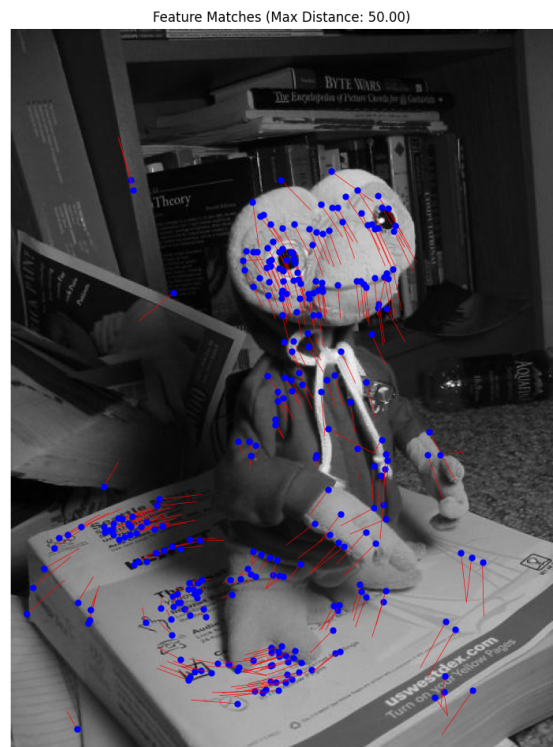
1.2 Part (a): Feature Matches

Description: In the file `q1.py`, in the function `plot_matches`, I visualize feature matches between two images. I first convert the input image to grayscale using OpenCV. Then I filter the matches based on a maximum allowed distance between matched points using a helper function called `filter_matches`. I use a distance of 50. A matplotlib figure is created to display the grayscale image, and for each pair of matched coordinates (x1, y1) and (x2, y2), a red line is drawn between the points, while a blue circle is placed at the first point (x1, y1) for clarity.

Discussion: Justify why a lenient threshold was used to retain incorrect matches. Discuss implications for further steps.
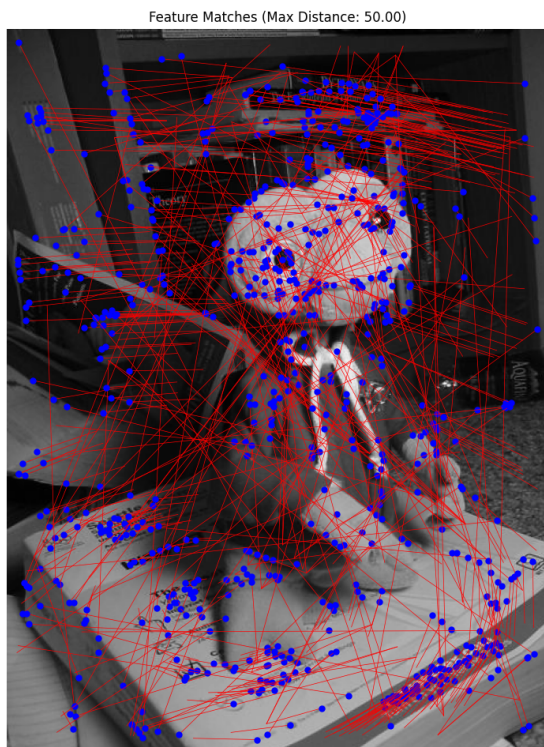
(a) All feature matches.

(b) Feature matches within a maximum distance of 50.

Figure 1: Feature matches displayed on greyscale image.

1.3 Part (b): Estimating the Fundamental Matrix using RANSAC

Description: RANSAC is used to enhance the accuracy by estimating the best fundamental matrix from the noisy data which means defining the inliers. **Results**: Present the final inlier matches after RANSAC, and explain why the fundamental matrix is re-estimated with all inliers.

Figure 2: Inlier matches after RANSAC.

Discussion: Discuss the rationale behind re-estimating the fundamental matrix using all inliers.

1.4 Part (c): Essential Matrix and SVD Decomposition

Description: Explain how the essential matrix is computed from the fundamental matrix and calibration matrix.

Results: Show the singular values of the essential matrix and discuss any discrepancies from the theoretical expectation.

Listing 1: SVD Calculation of the Essential Matrix

```
% Example code for SVD decomposition
```

```
[U, S, V] = svd(E);
disp(diag(S)); % Display the singular values
```

Discussion: Discuss how the SVD algorithm may return orthogonal matrices with undesirable reflections and how the correction was applied.

1.5   Part (d): Determining Camera Matrices

Description: Explain how two camera matrices are determined from the essential matrix.
   Results: Present the two camera matrices.
   Discussion: Briefly discuss how these matrices relate to the camera positions and orientations.

1.6   Part (e): Triangulation and 3D Reconstruction

Description: Describe the triangulation process to determine 3D coordinates of inlier matches.
   Results: Showcase your 3D reconstruction, including the positions of the cameras and the 3D points.
   Discussion: Discuss any challenges with the reconstruction, such as inaccuracies with points far from the cameras.

2   Rectifying an Image Pair

2.1   Problem Description

Describe the process of rectifying an image pair using the camera matrices obtained in the previous section.
   Aim: Align the two images such that matching points have the same vertical coordinates.

2.2   Part (a): Image Rectification

Description: Explain how the camera matrices were used to rectify the images.
   Results: Present the rectified images.
   Discussion: Discuss any challenges encountered during rectification, such as changes to the image coordinate system.

2.3   Part (b): Drawing Epipolar Lines

Description: Explain how epipolar lines were drawn on the rectified images.
   Results: Show images with epipolar lines.
   Discussion: Discuss why epipolar lines should be horizontal in rectified images and any challenges in ensuring alignment.

3   Verifying Solutions on Another Dataset

3.1   Problem Description

Describe how the methods were applied to the "fountain" dataset. Briefly discuss any changes made.

3.2   Results

Present the key results, including fundamental matrix estimation, 3D reconstruction, and rectification.

3.3   Discussion

Briefly discuss how the results differ from the initial dataset and any challenges encountered.