Computer Vision (2018-2019)

ASSIGNMENT 3: FUNDAMENTAL MATRIX ESTIMATION, CAMERA CALIBRATION, TRIANGULATION

June 9, 2019

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Overview

This report summarizes the work done of the third assignment from the Computer Vision Course. The purpose of this assignment was to estimate the fundamental matrix by using two views and considering matching points of the same location as well as to develop a 3D reconstruction from two images. 3 pairs of various images were provided as resources.

This report contains distinct sections, describing each part of the assignment correspondingly. Part 1 presents results from the fundamental matrix estimation based on the provided points. Part 2 discusses estimation of the fundamental matrix with the application of Random Consensus Sample (RANSAC) algorithm and results obtained in 2 different experiments (different parameter values). Finally, part 3 discusses the implementation of matching the points in 3D through triangulation with the use of an algebraic method.

Archive contents

Besides this report, the submitted archive also contains the following files:

1. For part 1:
   - *part1_final.m* is the main MATLAB file for part 1. It loads the images and the matching points, fits the fundamental matrix and visualizes the epipolar lines.
   - *estimate_fundamental_matrix.m* is a function that takes a set of point matches and applies the eight-point algorithm.
2. For part 2:
   - *part2_final.m* is the main MATLAB file for part 2. It loads the images and matches and uses RANSAC to eliminate outliers and find a good fundamental matrix.
   - *ransac_fundamental_matrix.m* takes a set of matches and finds a fundamental matrix (and inliers/outliers) based on RANSAC.
3. For part 3:
   - *part3_final.m* is the main MATLAB file for part 3. It loads the house and library images and matches and performs algebraic triangulation to determine the 3D points.

- *triangulate_points.m* applies the algebraic method to triangulate the 3D positions of a set of matching points.
- *plot_triangulated_points.m* visualizes a set of triangulated points and the corresponding camera positions.

4. Script files that were supplied to us: *draw_epipolar_lines.m*, *find_matching_points.m*, *plot_correspondence.m*

Part 1 (Fundamental Matrix Estimation)

The first part of the assignment included the fundamental matrix estimation with the use of the Eight-point algorithm. This has been performed with respect to the "library" pair of images. The matching point pairs were provided in a file and loaded into the program.

The correspondences between images are visualized in figure 1.

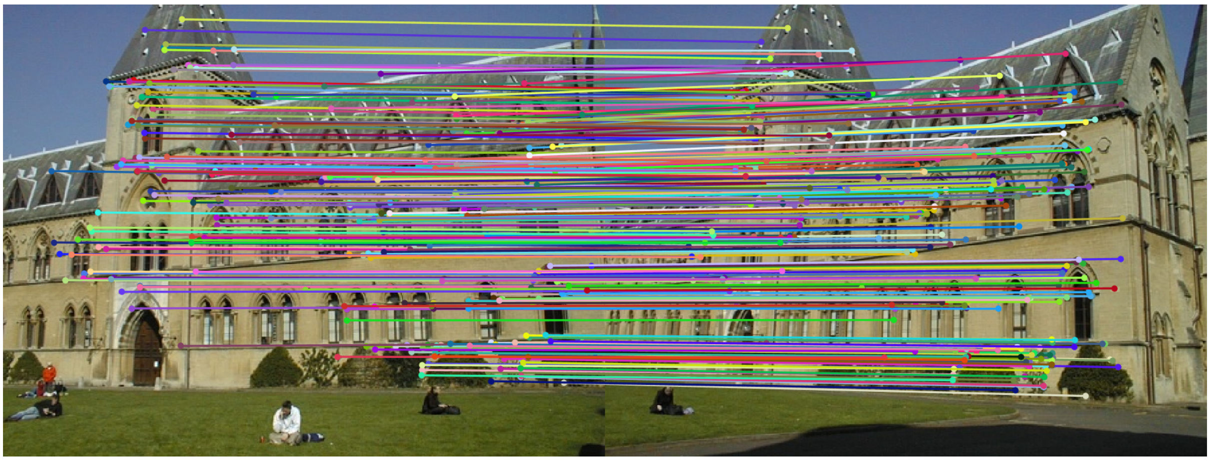

Figure 1: Matching correspondences between the library image pair

Based on the provided matching points, the fundamental matrix was computed. Subsequently, the relevant epipolar lines for one image, corresponding to the points from another, were visualized. The visualizations of epipolar lines for the first and the second image of the library are presented in figure 2.

The mean squared error in pixels between points in both the images and the corresponding epipolar lines was estimated to: 0.0002.

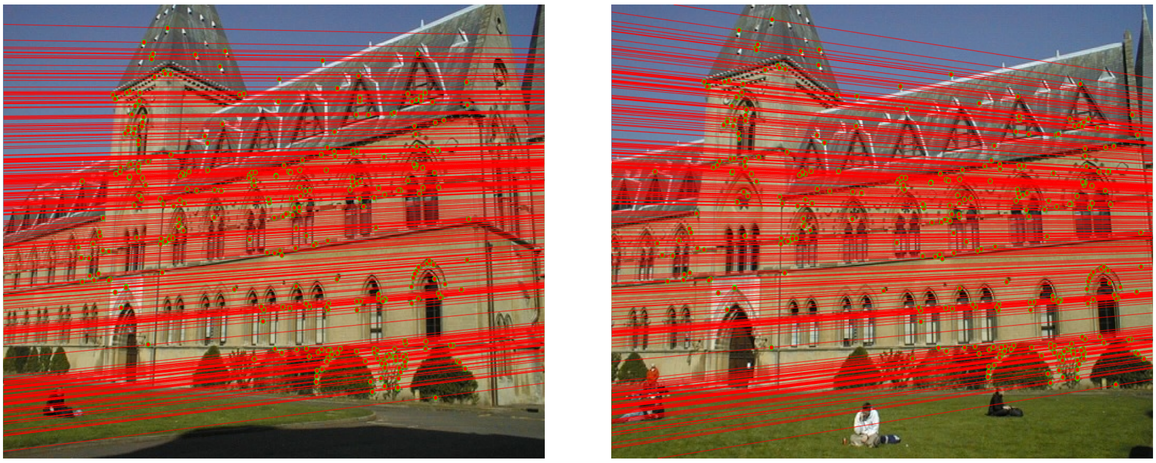

Figure 2: Epipolar lines visualization for the library images

Part 2 (Fundamental Matrix Estimation with RANSAC)

In part 2, we used RANSAC and the eight-point algorithm implemented for part 1 to find good fundamental matrices and to remove outliers from sets of noisy matching points. The following experiments were done on the "NotreDame" images, with 308 points extracted and matched using VLFeat. By tuning the parameters of the fundamental matrix estimation method, we obtained different numbers of inliers/outliers and different results. We experimented with the number of iterations of the RANSAC method, the threshold for inlier/outlier classification and the minimum number of acceptable inliers.

In figure 3 we display the two images with the matches extracted by VLFeat. It is noticeable that there is a large number of outliers: points which were wrongly matched.

Figure 3: Points extracted and matched using VLFeat

Experiment 1

For the first experiment, we ran 1000 iterations of the RANSAC implementation with a threshold of 0.1 and a minimum number of acceptable inliers equal to 150. The method returned a set of 289 inliers with a mean squared residual error of 0.2365. The sets of matching inliers are shown in figure 4.

Figure 4: Set of inliers determined by RANSAC (experiment 1)

It is noticeable that some of the most visible outliers were removed, with a few exceptions. These parameter values were quite conservative and they preserved most of the points. The fundamental matrix that led to this set of inliers was then used to visualize the epipolar lines in figure 5.

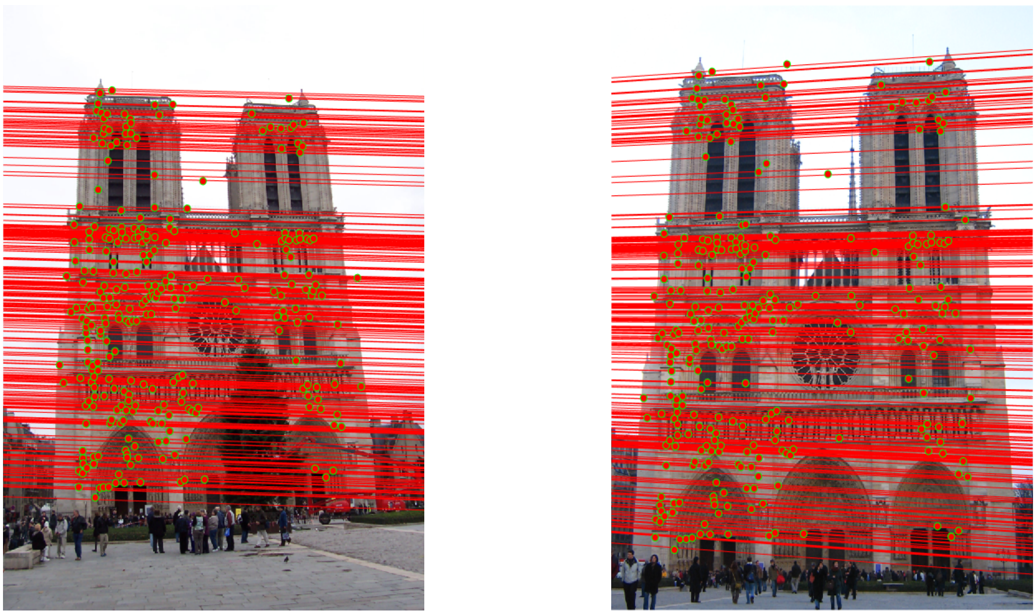

Figure 5: Epipolar lines visualization for the Notre Dame images (experiment 1)

We then attempted to take the entire set of inliers and fit the fundamental matrix again. The result is clearly not good, as seen in the visualization in figure 6. The RANSAC procedure was applied with a too high threshold and still kept some outliers. These outliers then drastically affected the estimation of the new fundamental matrix.

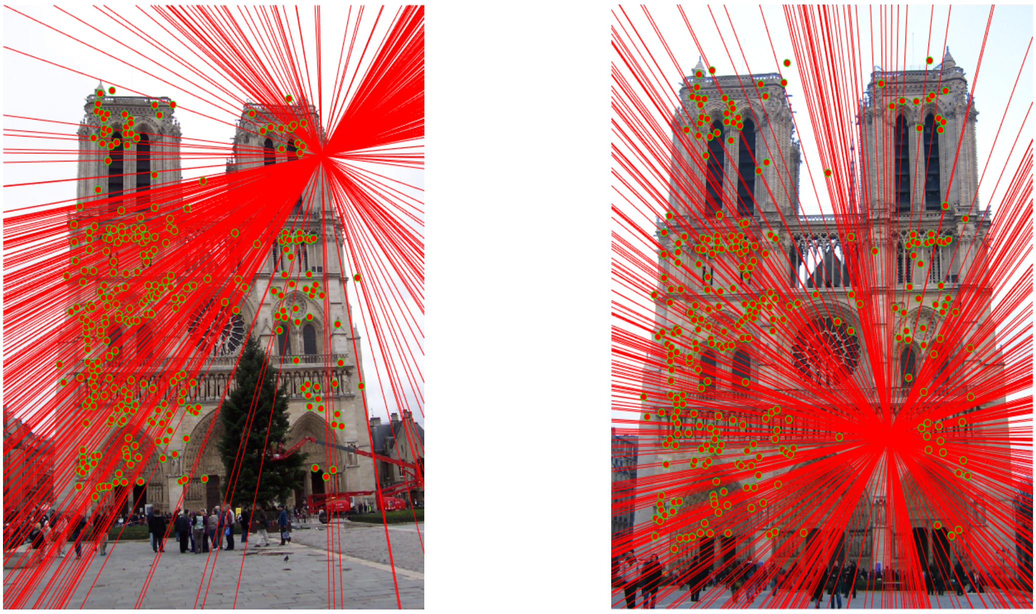

Figure 6: Epipolar lines visualization (after refitting on all inliers) for the Notre Dame images (experiment 1)

Experiment 2

To try to solve the problem illustrated above, for the second experiment we ran 250 iterations of the RANSAC implementation with a threshold of 0.01 and a minimum number of acceptable inliers equal to 100. The method returned a set of 117 inliers with a mean squared residual error of 0.0280. The sets of matching inliers are shown in figure 7.

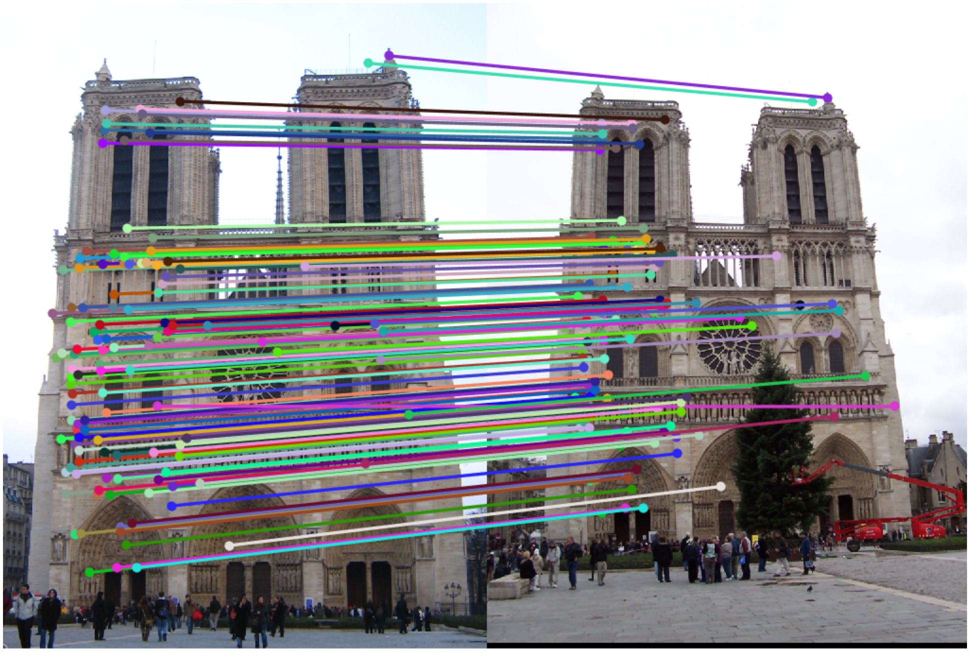

Figure 7: Set of inliers determined by RANSAC (experiment 2)

There are clearly far fewer points left in the set, however now there are no more noticeable outliers. The fundamental matrix that led to this reduced set of inliers was then used to visualize the epipolar lines in figure 8. As the hyperparameters of the method were quite different, the resulting epipolar lines are also different.

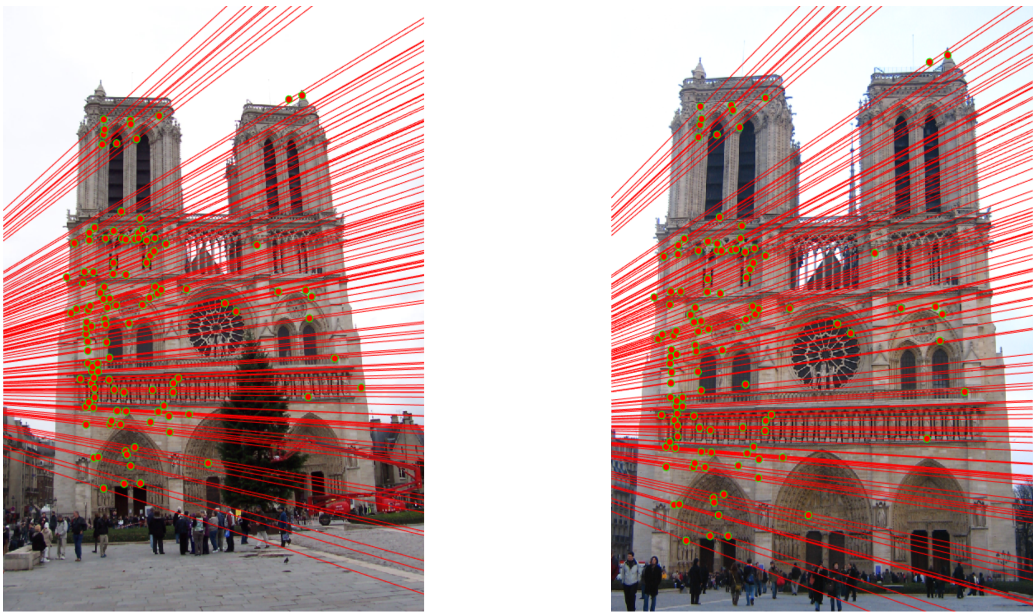

Figure 8: Epipolar lines visualization for the Notre Dame images (experiment 2)

As discussed above, the set of inliers obtained in experiment 2 is much smaller than the one for the first experiment, and seems to have no apparent outliers left. This suggests that refitting the matrix on this set of inliers should produce acceptable results. The result is shown in figure 9, and is consistent with this observation. The fundamental matrix seems to be better now.

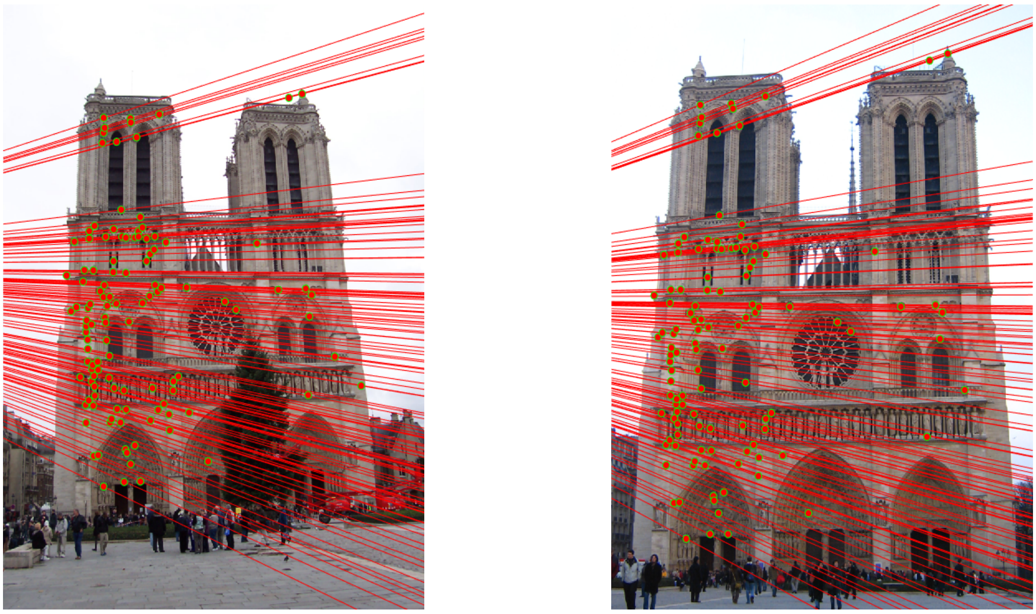

Figure 9: Epipolar lines visualization (after refitting on all inliers) for the Notre Dame images (experiment 2)

Part 3 (Triangulation through the algebraic method)

For the third part we simply built, for each pair of matching points, a homogeneous system based on the camera matrix and the image points. Using SVD we solve these systems to get the values of the triangulated points, then we divide by the fourth component to transform to Euclidean coordinates.

Note that we interchanged the Y and Z axes when creating the scatterplots, in order to "rotate" the resulting plots and have the point clouds more closely aligned with the original images.

House images

Figure 10 shows two different views of the triangulated points (blue) and the camera centres (yellow and red) for the house images.

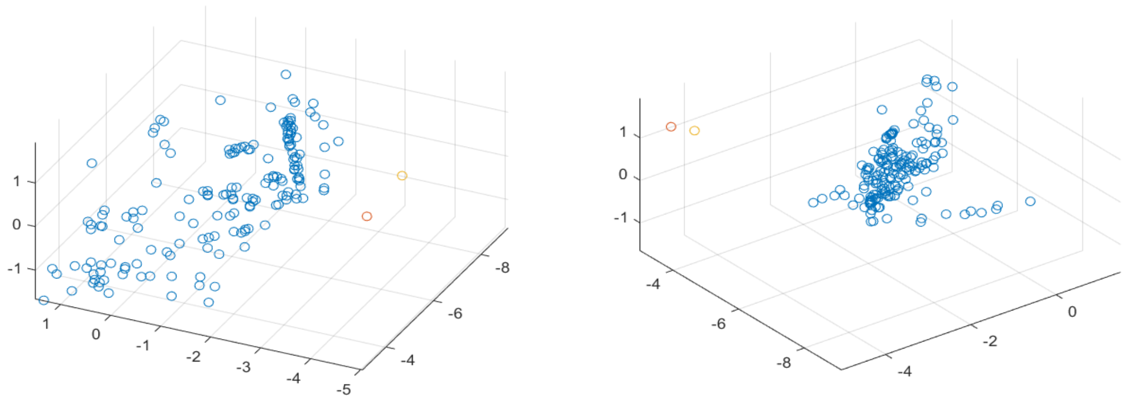

Figure 10: Triangulated points for the house images

In figure 11, we arranged the view in such a way that the correspondence between the triangulated points and the keypoints is more clearly visible. The cluster of 4 points on the house's chimney are visible in the visualization, and from there it's also easy to notice other correspondences between points. This suggests that the triangulation was performed correctly.

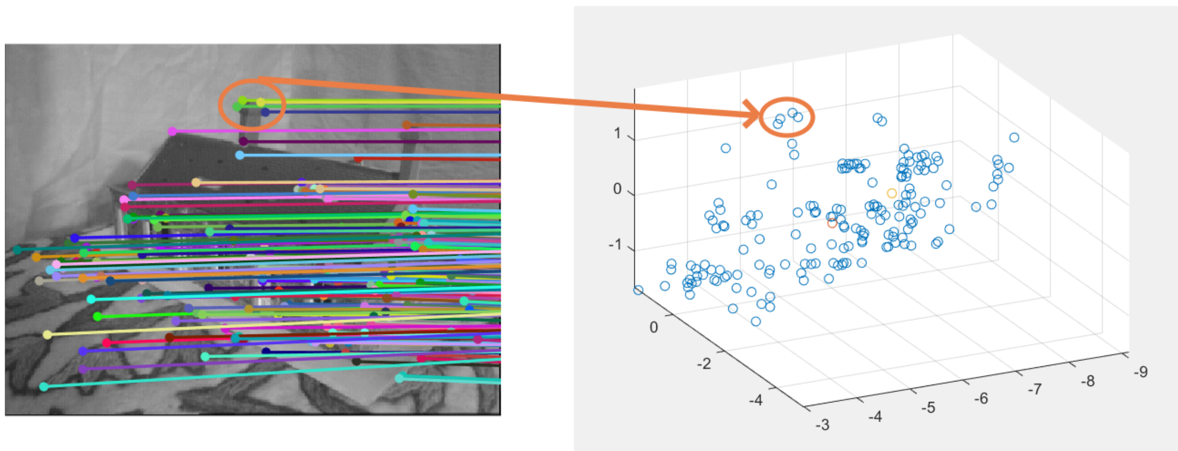

Figure 11: Correspondence between triangulated points and the provided keypoints (for the house images)

Library images

Figure 12 shows two different views of the triangulated points (blue) and the camera centres (yellow and red) for the library images.

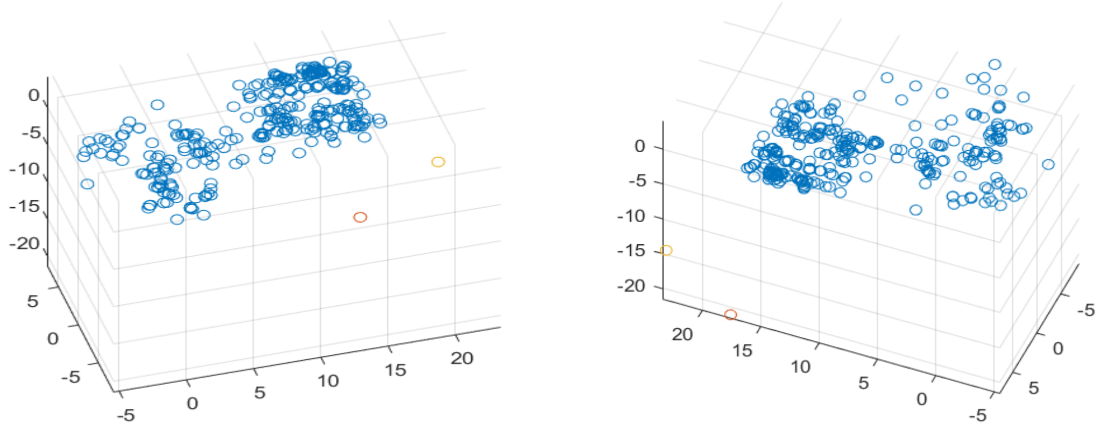

Figure 12: Triangulated points for the library images

A clearer visualization is obtained by rotating the view as shown in figure 13. The cluster of 4 points circled on the left is clearly visible in the original image. From there, it is easy to determine correspondences between other points and see how they map to the original image.

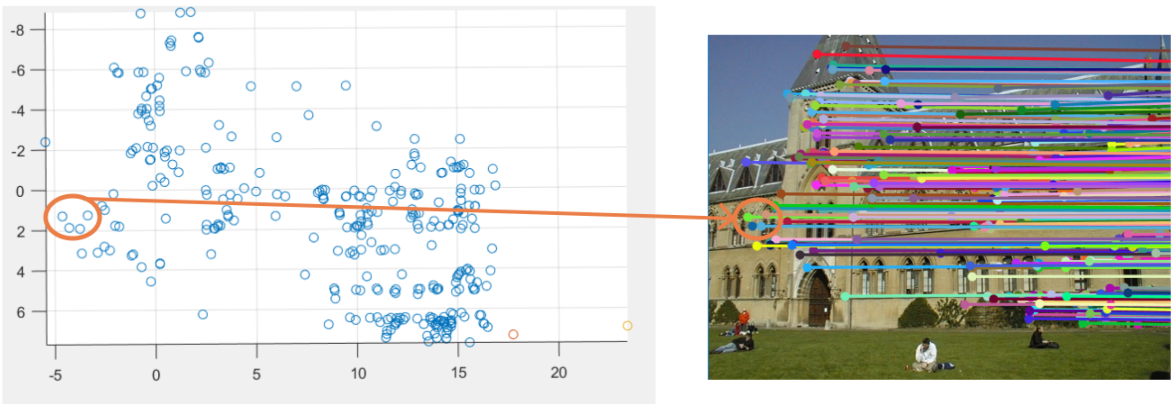

Figure 13: Correspondence between triangulated points and the provided keypoints (for the library images)