Computer Vision

Structure from Motion

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1. Feature extraction and initialization with epipolar geometry

1.1 Implementation

Firstly, image 0 and image 4 are selected as initial image pair. vl_sift is used to extract features and $vl\_ubcmatch$ is used to match features. Then image coordinates of features in two images are converted to homogeneous coordinates. With homogeneous coordinates, 8-point RANSAC is used to get fundamental matrix and inliers. Based on results, inlier, outlier matches and epipolar geometry can be plotted.

1.2 Results and Discussion

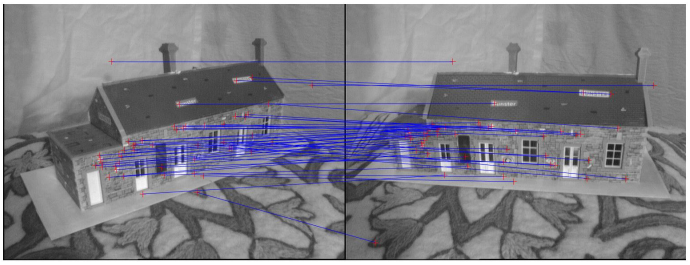


Figure 1: Inlier matches of image 0 and image 4

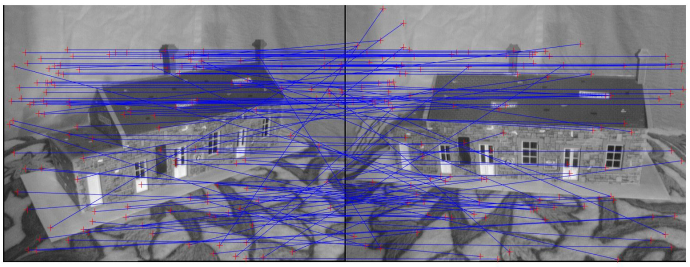
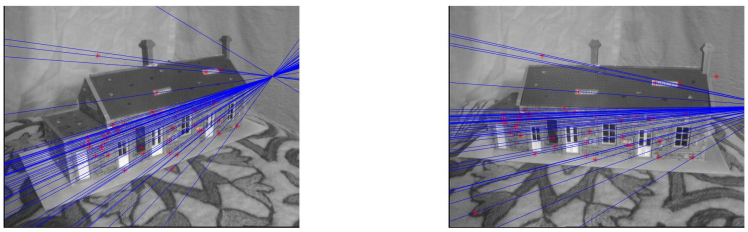


Figure 2: Outlier matches of image 0 and image 4



(a) image 0 (b) image 4

Figure 3: Epipolar geometry of image 0 and image 4

2. Triangulation and adding new views

2.1 Implementation

With fundamental matrix, F and camera intrinsics, K, essential matrix can be computed: $E = K^T F K$. The calibrated coordinates can also be calculated: $x_{calibrated} = K^{-1} x_{inlier\ coordinates}$. To find the camera pose, we can define the first camera pose (image 0) as $[I|0]$ and get camera pose of the second image (image 4) from the decomposition of essential matrix. With two camera poses and related calibrated coordinates, 3D coordinates can be reconstructed.

With similar procedure, three more images (image 1-3) are added: each time, taking image 0 as the first image, new image as the second image to do feature extraction and match. With calibrated image coordinates in new image and corresponding 3D coordinates in image 0, 6-point RANSAC can be used to compute projective matrix of new image. With two camera poses and related calibrated coordinates, new 3D coordinates can be reconstructed.

2.2 Results and Discussion

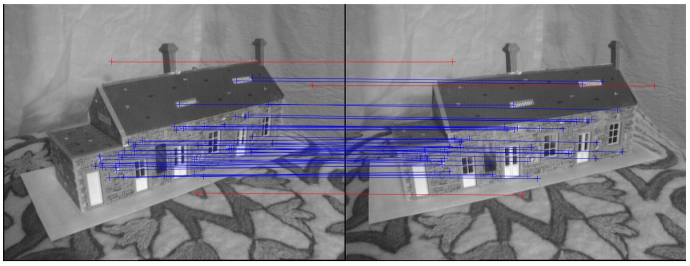


Figure 4: Inlier (blue) and outlier (red) matches of image 0 and image 1

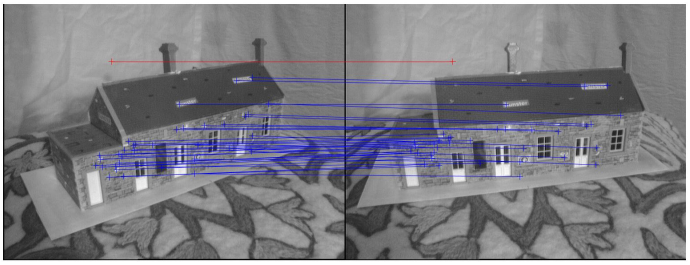


Figure 5: Inlier (blue) and outlier (red) matches of image 0 and image 2

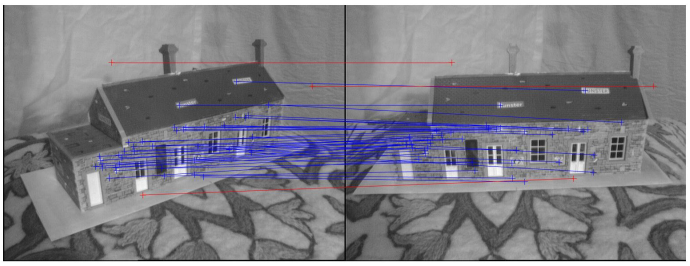


Figure 6: Inlier (blue) and outlier (red) matches of image 0 and image 3

3. Plotting

3.1 Implementation

All reconstructed 3D points and cameras are plotted.

3.2 Results and Discussion

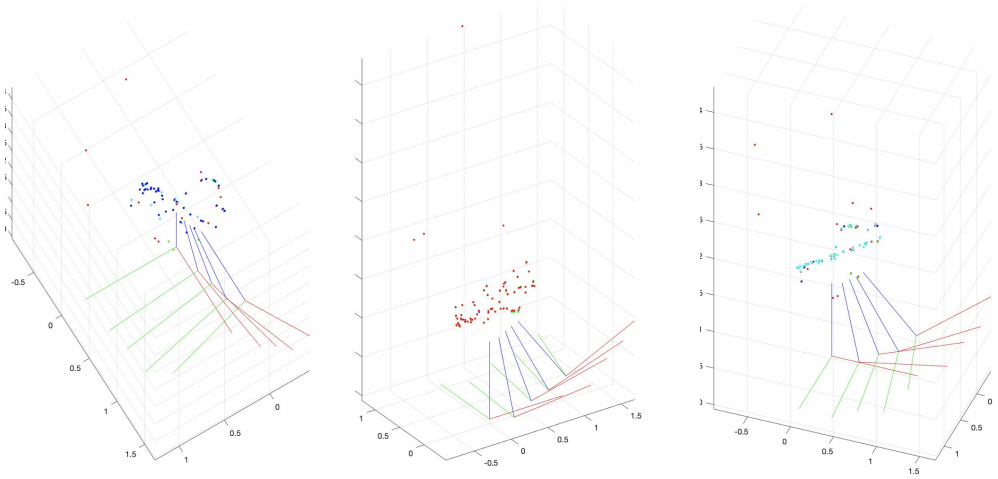


Figure 7: Result of 3D points

In Figure 7, red means points reconstructed from the first image pair, green means from the second pair, blue means from the third pair, cyan means from the fourth pair. When rotating this 3D plot, it is noticeable that points with different colors are overlapped quite well, which means the reconstruction from different image pairs are consistent. If requiring a higher accuracy, bundle adjustment can be considered for further improvement.

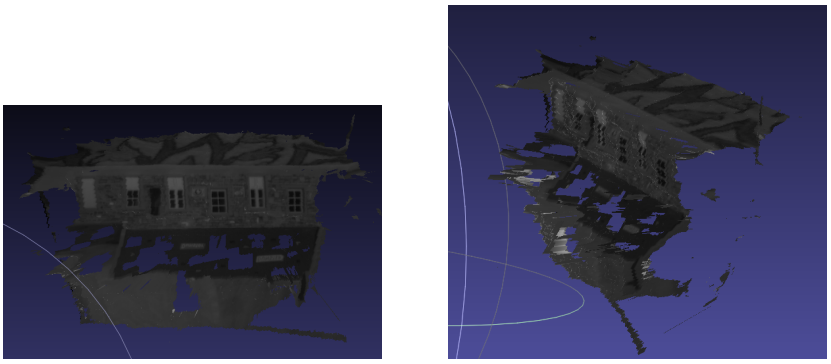
4. Dense Reconstruction

4.1 Implementation

Based on exercise 6 (stereo matching), codes are reused here to build dense reconstruction. Image 2 and image 3 are chosen as left and right images here. At first, two images are rectified based on known camera intrinsics and camera poses. Then a fixed disparity range from -40 to 40 is used for winner-takes-all stereo matching method to get disparity map. Then 3D cloud points can be generated from disparity map and 3D model can be imported in meshlab app to have a look. (as shown in Figure 9)

4.2 Results and Discussion

Figure 8: Result of disparity map



(a) (b)

Figure 9: Result of 3D model