

# Report for BBM418-Assignment-2

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## 1 Summary

This document is a report for BBM-418 Computer Vision Laboratory Assignment-2. An implementation of Panoramic photography technique was done and results are given for this assignment. Sample space consists of images which are parts of a panoramic image. Python was used as programming language and OpenCV was used for processing library. Results show that we were partially able to form panoramic images with some errors and missing parts. Reasons for the errors are discussed in Conclusion section and details of the algorithm is given in the next section.

## 2 Algorithm

For creating the panoramic image a number of different images are combined using their common feature points. To find feature points ORB algorithm is used and to feature points which are closest to each other are considered as match pairs. Step by step the algorithm:

**1) Load all of the images:** Images which will constitute the panoramic image are loaded into the memory as black and white images.

**2) Find feature points and descriptors:** Using an ORB detector feature points and related descriptors in images are found. One problem with this part is to decide what to do with the images which have no feature points. A naive solution is omitting the problematic image. But experimenting with this method showed that, due to the number of images which possesses the said handicap, omitting causes serious deficiency in the resultant panoramic image.

To overcome this problem, instead of ignoring these images, I tried another approach: I cropped some parts of the both images and concatenated them. After this process the algorithm continued as if the images are attached correctly and they formed a meaningful image. Since on the next iteration total number of feature points in the newly created image may be sufficient, this approach gives algorithm a chance to correct some errors. And even if still not enough number of features can not be found in the next iteration, with this method more meaningful panoramic images are created. Empirical results also showed that this approach gives better results than the first approach. Cropping amount is decided by experimenting. 0.2 is selected as cropping ratio.

**3) Match feature points :** After finding feature points It's required to match these points in two images. For this k-nearest neighbors (KNN) algorithm is used. After finding these matches ratio test is applied to eliminate bad matches. But this was not enough since these matches will be used for finding the Homography Matrix. After experimenting with different numbers 15 is selected as the minimum number of matches required.

The same problem mentioned above arises here: What happens if enough number of matches can not be found in image pair? The same solution is preferred in this situation.

**4) Calculate the Homography Matrix:** Using the found matching feature points different Homography Matrices are calculated by applying this given method: <https://math.stackexchange.com/q/2619023>

To find the best suited Homography Matrix RANSAC algorithm is used. The number of iterations and distance threshold in RANSAC algorithm are found by experimenting. 100 gave acceptable results as iteration number and so is 10 as distance threshold.

**5) Combine two images:** At this stage we have feature points and Homography Matrix ready. Now we just need to combine the two images.

To finish this last step as time efficiently as possible I make three assumptions: First one is I assume that the best feature points match correctly. Second and third assumptions are about the spatial features of photos. I assume that angle and distance between the camera and floor are kept constant as the photos are captured. Such that, neither rotation nor up-down translation is needed while attaching the two images.

After making these assumption I follow a simple approach: I take "the best" feature point in image 1, multiply this point with Homography Matrix to find the corresponding point in image 2. Then, I concatenate the two images in such a way that the two points are on the top of each other. I do not rotate nor shift the image in Y direction. Eventhough this approach doesn't always give reliable results It's fast and easy to apply.

### 3 Conclusion

When we compare the ground truth image and the resultant image we see some missing parts the resultant image. Also some parts do not align precisely. The source of errors can be gathered in 4 main groups:

First one is errors due to not being able to find feature points or matches. Also, found match points are not always correct. This happens when the ORB algorithm can not find feature points or enough number of qualified matches. To overcome this problem another algorithm(SIFT, SURF etc.) may be used as replacement.

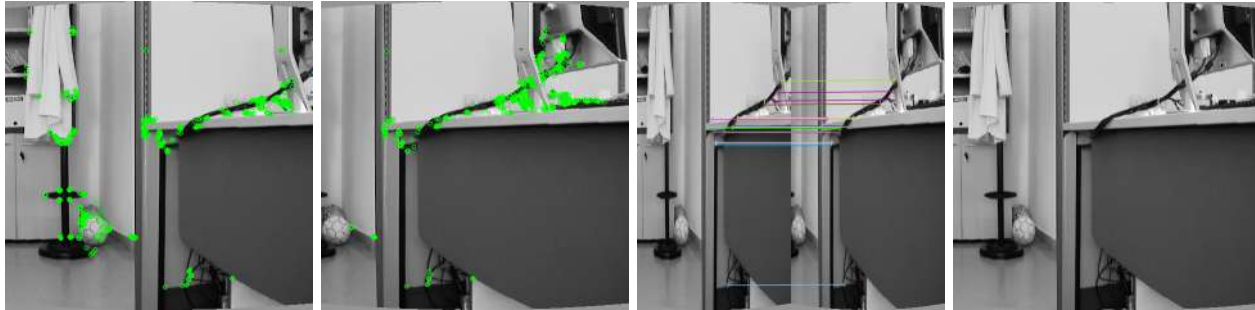
Second one is errors due the miscalculation of Homography Matrix. In spite of the fact that RANSAC algorithm is used for better results there is still error possibility for Homography Matrix.

Third one is my assumptions about the spatial features of photos. Some photos may require rotation and shift. The last one is about the approach I chose for image concatenation. Taking all match pairs and calculating the overlapping amount of images would probably give better results rather than taking just one point and doing the calculation.

### 4 Results

Here are the results for given sample images:

#### 4.1 For sample photos 1

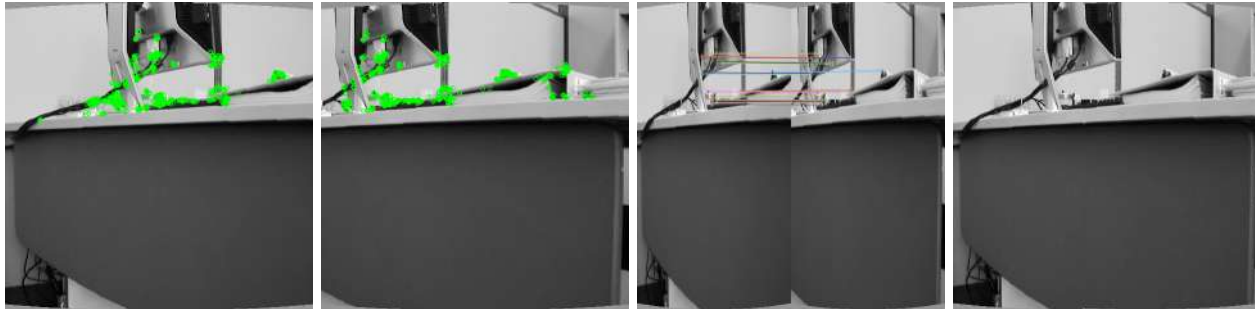


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation

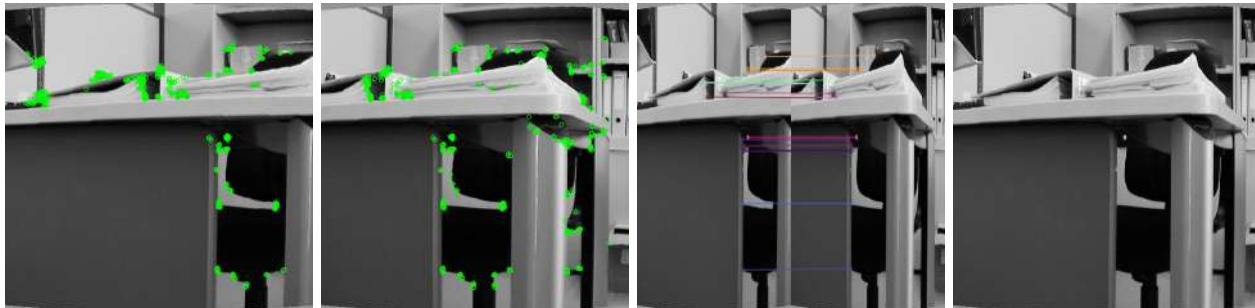


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation

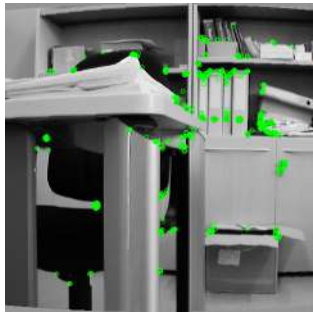


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

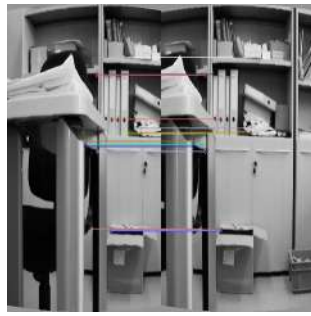
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



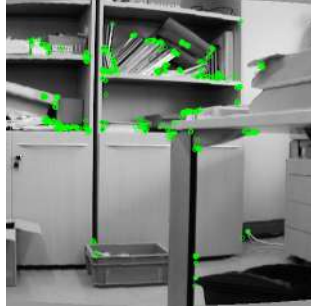
(c) Matched feature points on both images



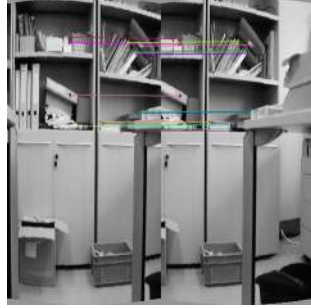
(d) Images after concatenation



(a) Image 1 with feature points



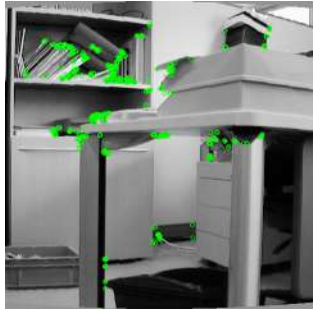
(b) Image 2 with feature points



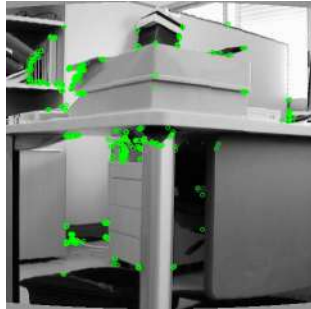
(c) Matched feature points on both images



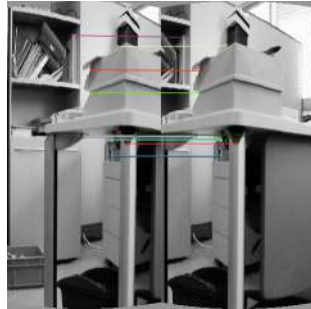
(d) Images after concatenation



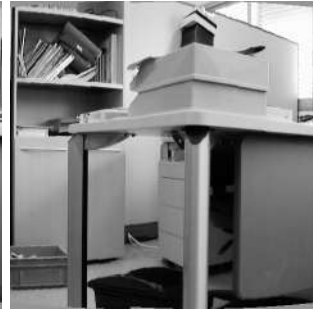
(a) Image 1 with feature points



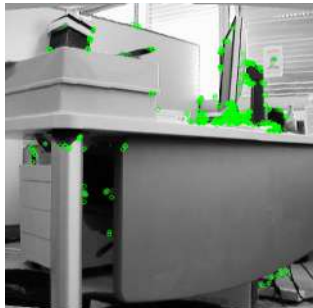
(b) Image 2 with feature points



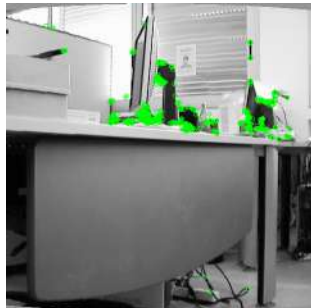
(c) Matched feature points on both images



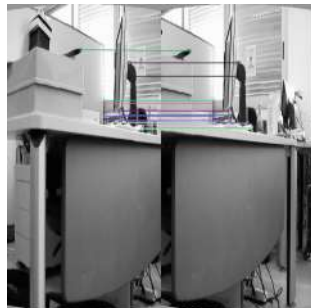
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation

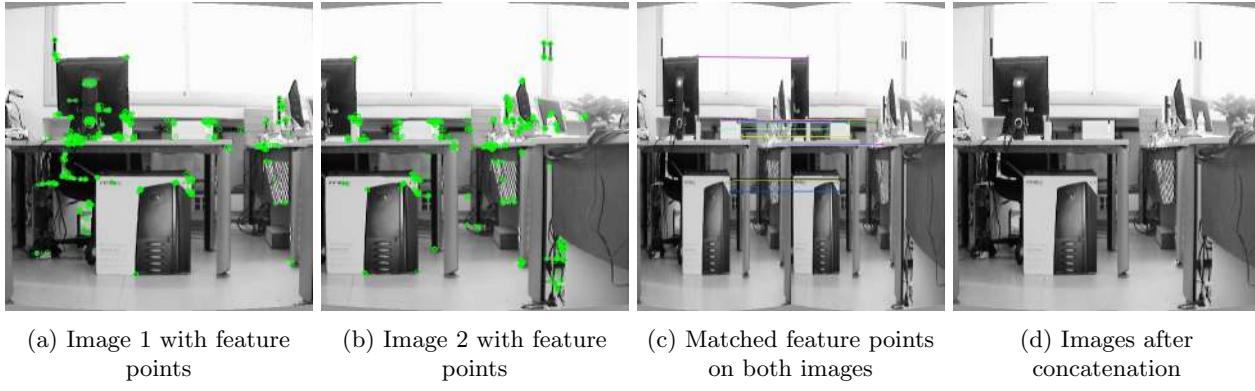
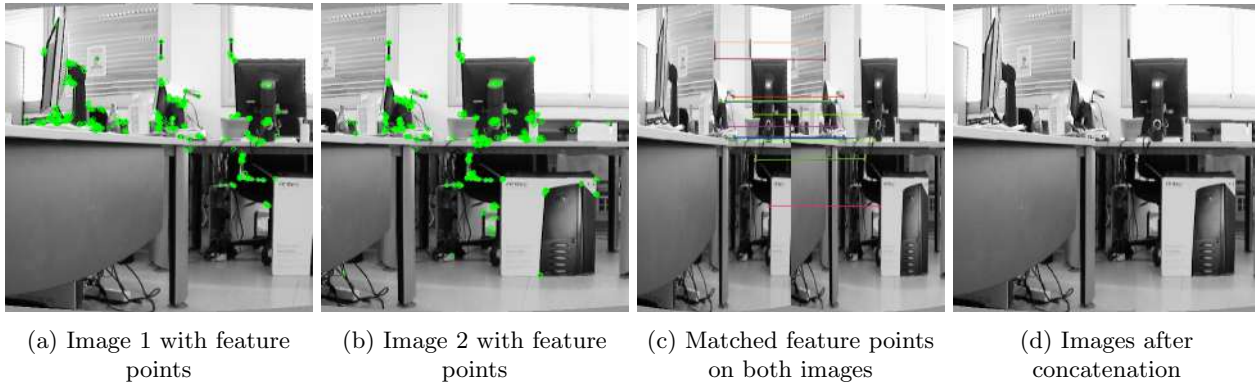
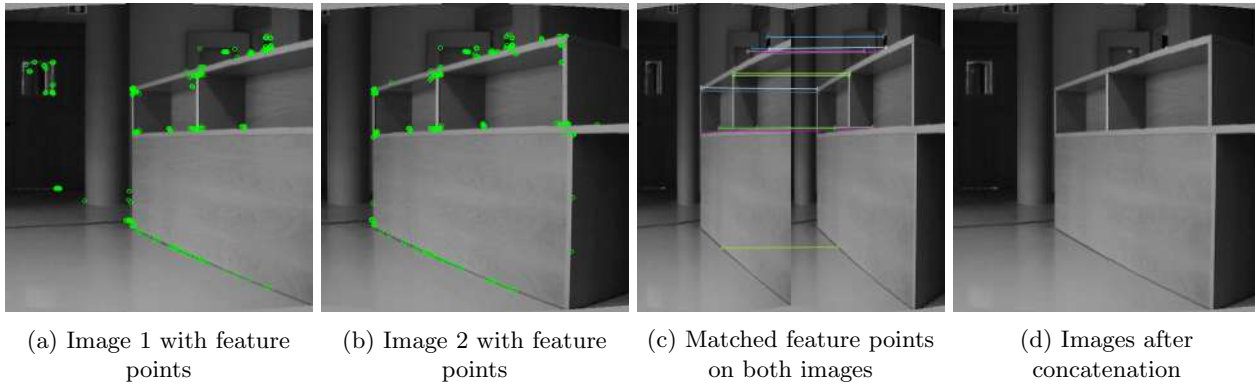


Figure 10: Resultant Panoramic Image

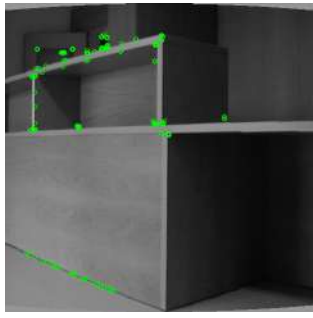


Figure 11: Ground Truth Image

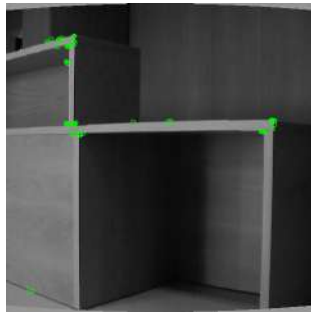
## 4.2 For sample photos 2



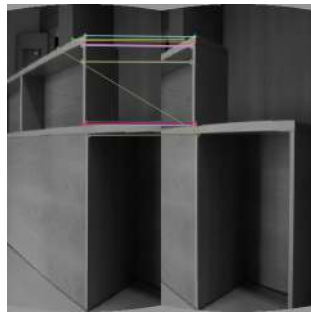




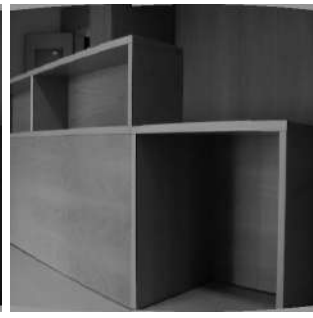
(a) Image 1 with feature points



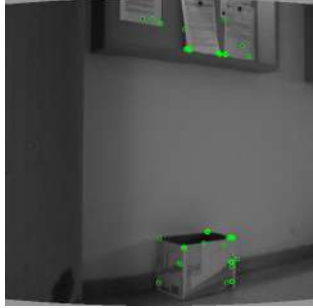
(b) Image 2 with feature points



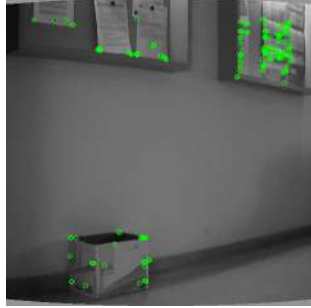
(c) Matched feature points on both images



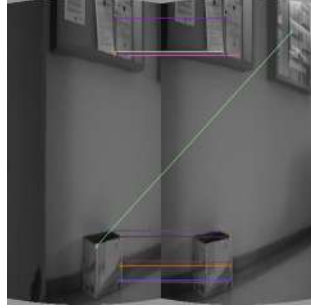
(d) Images after concatenation



(a) Image 1 with feature points



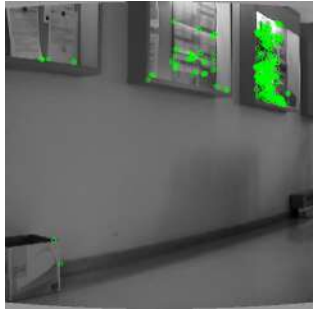
(b) Image 2 with feature points



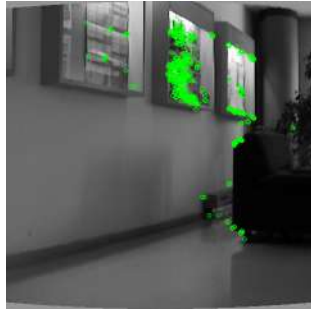
(c) Matched feature points on both images



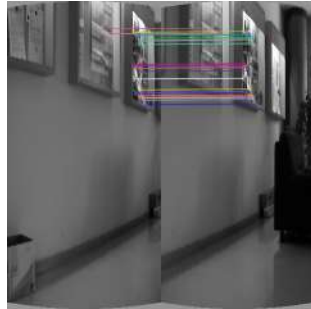
(d) Images after concatenation



(a) Image 1 with feature points



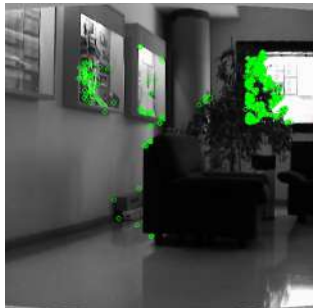
(b) Image 2 with feature points



(c) Matched feature points on both images



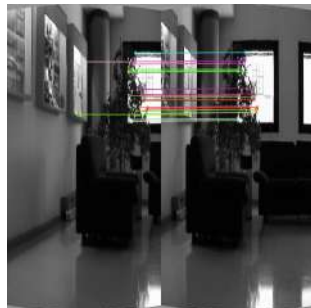
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



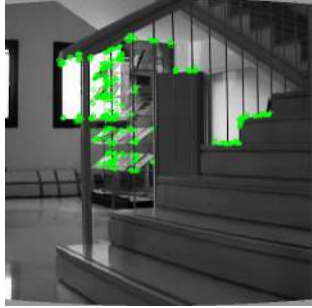
(c) Matched feature points on both images



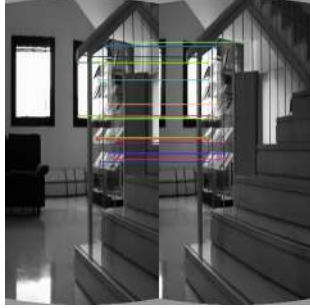
(d) Images after concatenation



(a) Image 1 with feature points



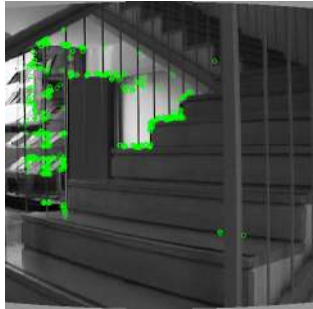
(b) Image 2 with feature points



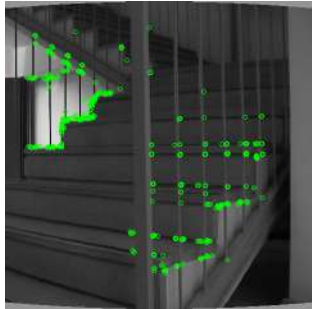
(c) Matched feature points on both images



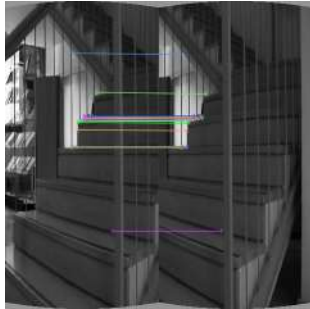
(d) Images after concatenation



(a) Image 1 with feature points



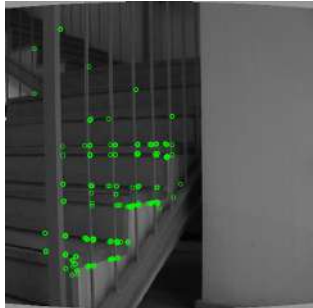
(b) Image 2 with feature points



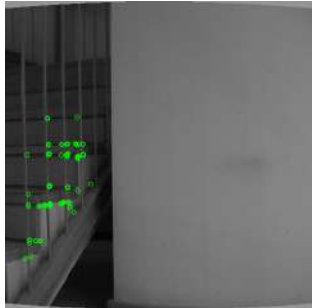
(c) Matched feature points on both images



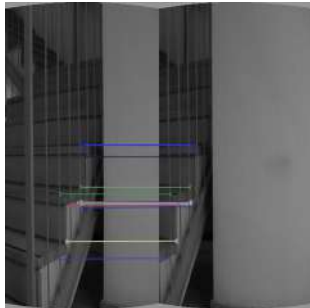
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



Figure 21: Resultant Panoramic Image



Figure 22: Ground Truth Image

### 4.3 For sample photos 3

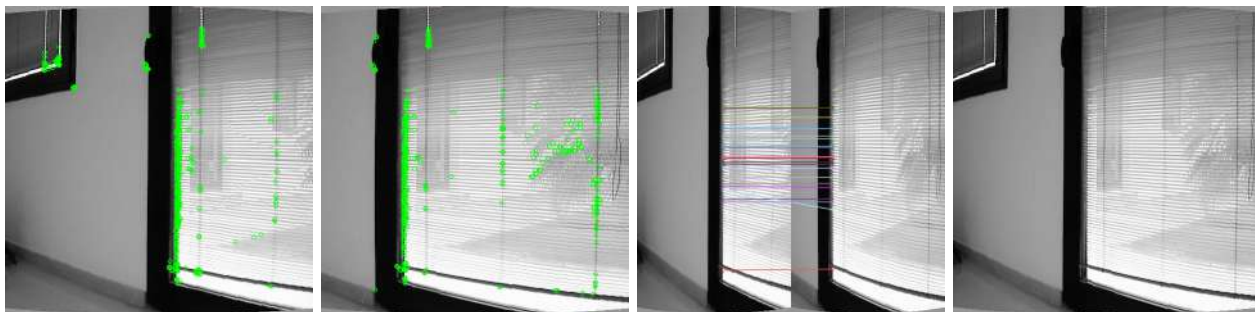


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation



(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation



(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation





(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



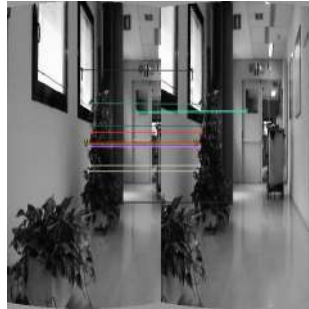
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



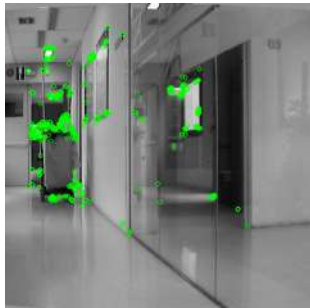
(c) Matched feature points on both images



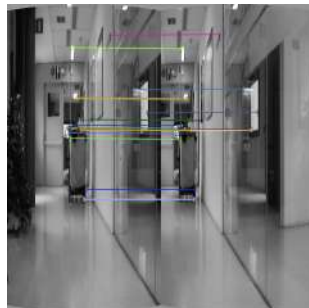
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



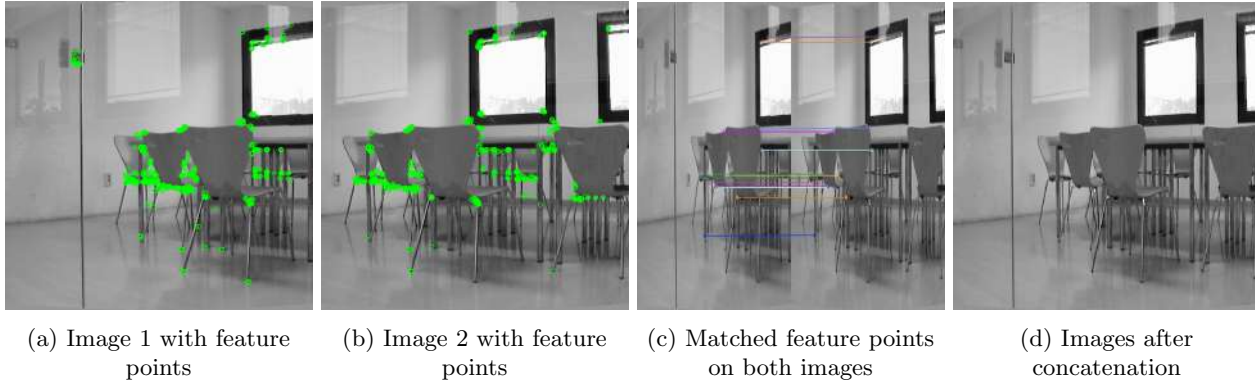
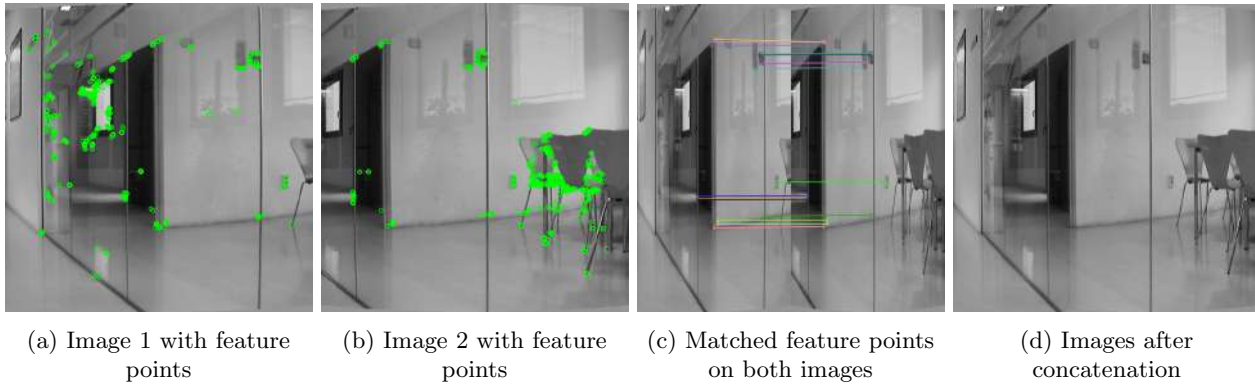
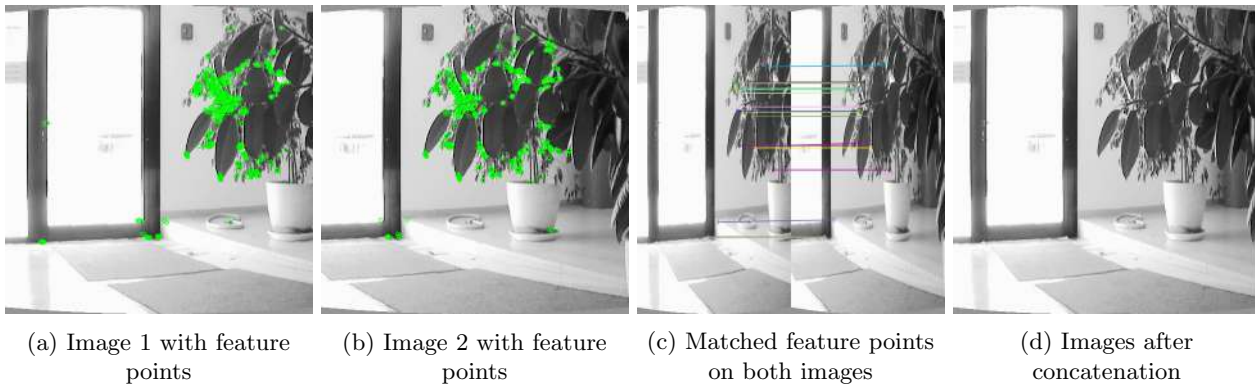


Figure 32: Resultant Panoramic Image



Figure 33: Ground Truth Image

#### 4.4 For sample photos 4

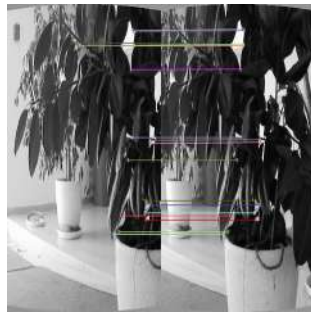




(a) Image 1 with feature points



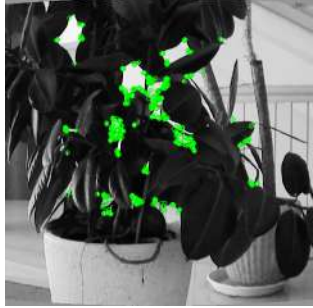
(b) Image 2 with feature points



(c) Matched feature points on both images



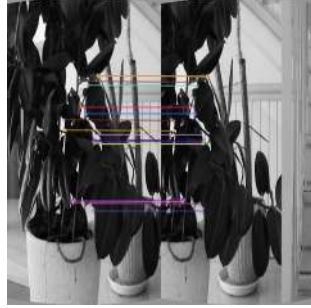
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



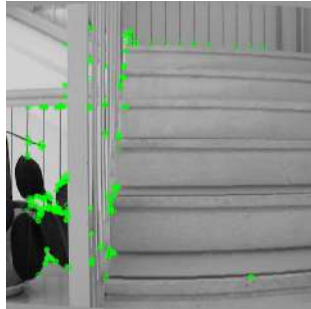
(c) Matched feature points on both images



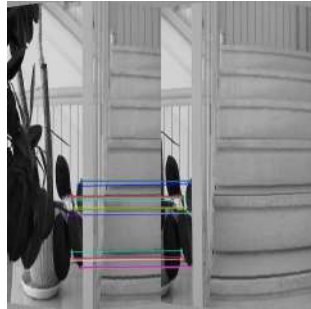
(d) Images after concatenation



(a) Image 1 with feature points



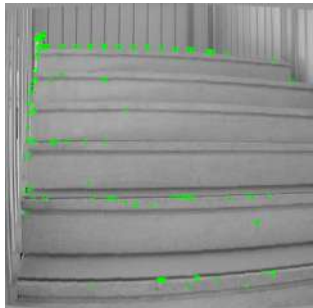
(b) Image 2 with feature points



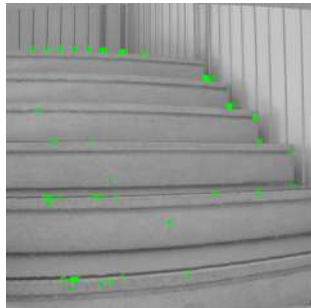
(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



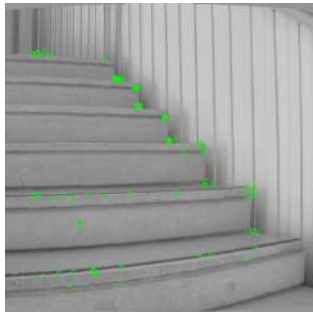
(b) Image 2 with feature points



(c) Matched feature points on both images



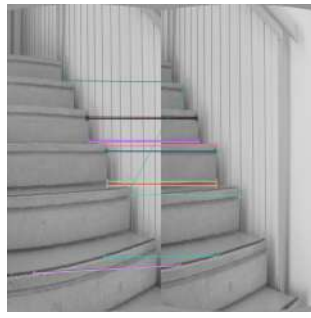
(d) Images after concatenation



(a) Image 1 with feature points



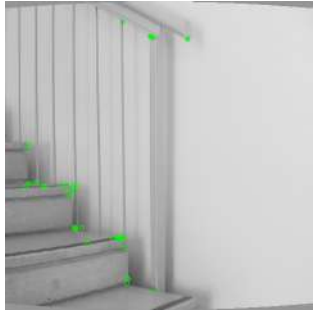
(b) Image 2 with feature points



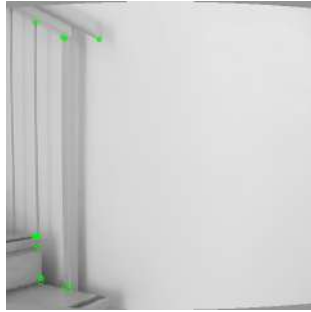
(c) Matched feature points on both images



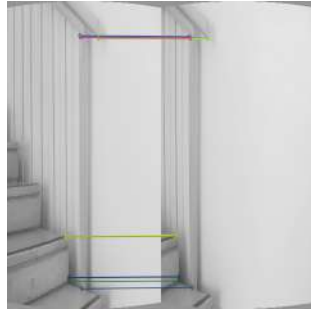
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



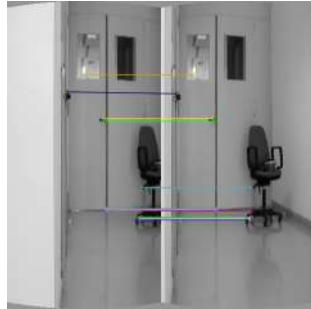
(d) Images after concatenation



(a) Image 1 with feature points



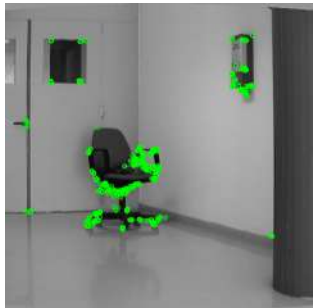
(b) Image 2 with feature points



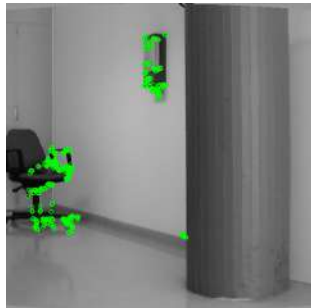
(c) Matched feature points on both images



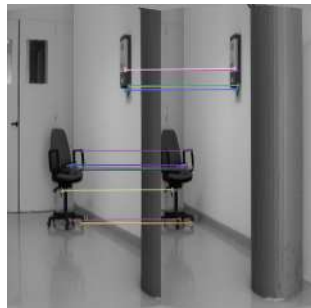
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



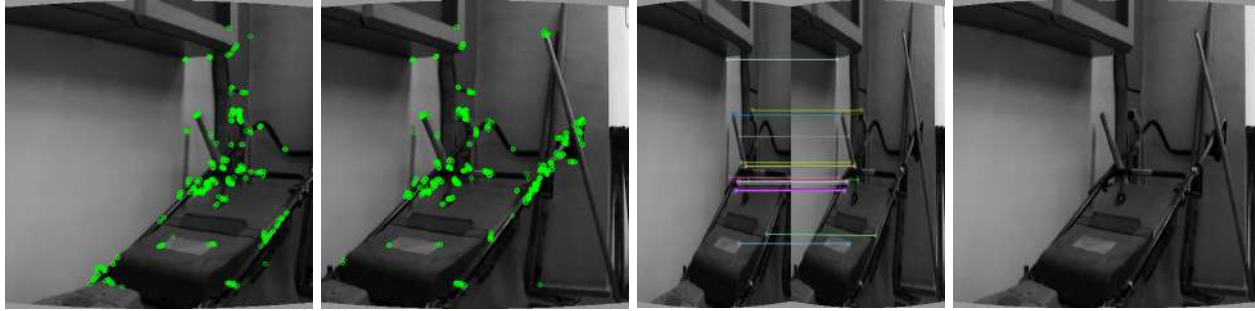


Figure 43: Resultant Panoramic Image



Figure 44: Ground Truth Image

#### 4.5 For sample photos 5

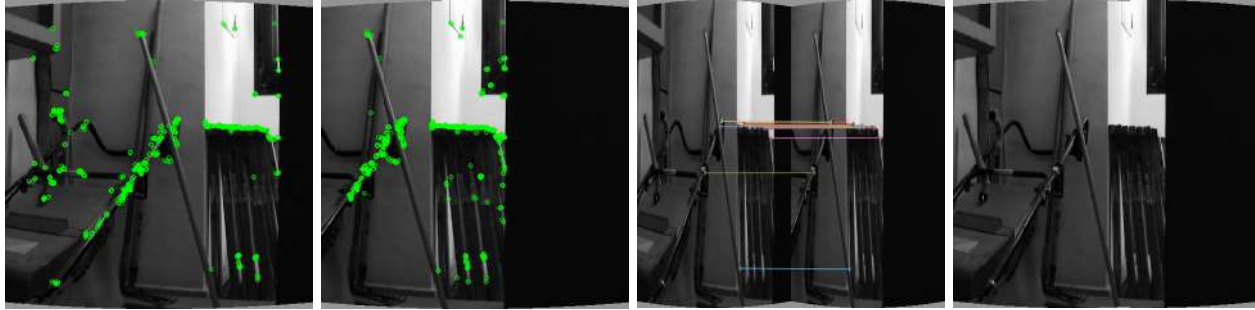


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation

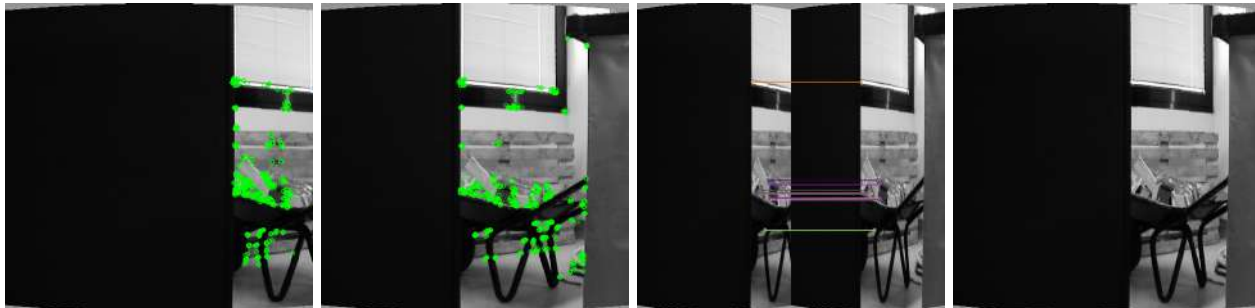


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

(d) Images after concatenation

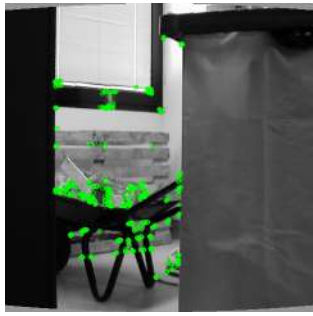


(a) Image 1 with feature points

(b) Image 2 with feature points

(c) Matched feature points on both images

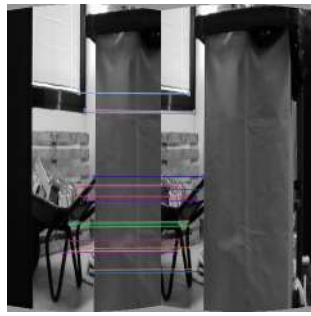
(d) Images after concatenation



(a) Image 1 with feature points



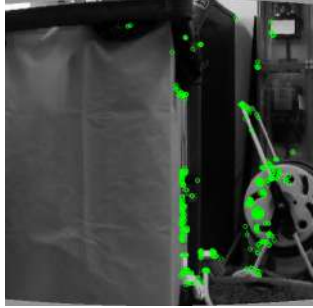
(b) Image 2 with feature points



(c) Matched feature points on both images



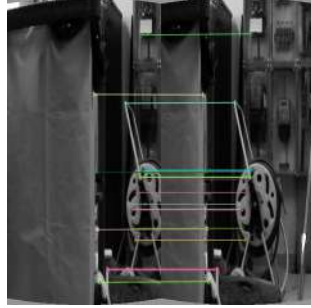
(d) Images after concatenation



(a) Image 1 with feature points



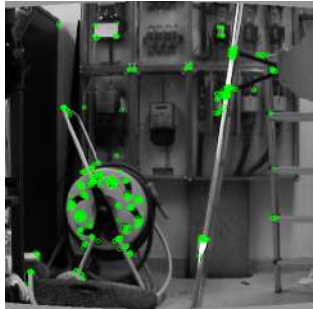
(b) Image 2 with feature points



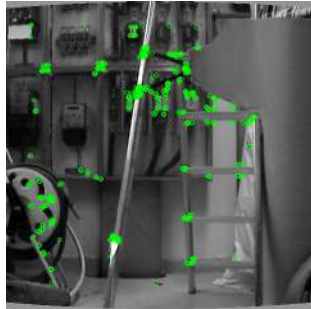
(c) Matched feature points on both images



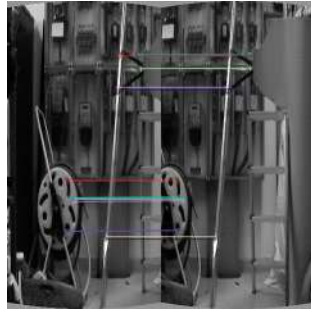
(d) Images after concatenation



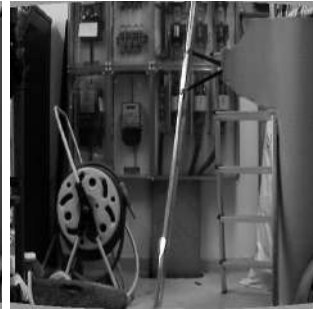
(a) Image 1 with feature points



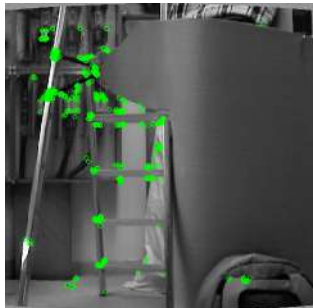
(b) Image 2 with feature points



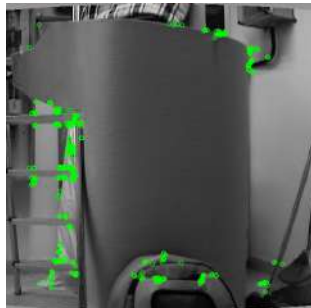
(c) Matched feature points on both images



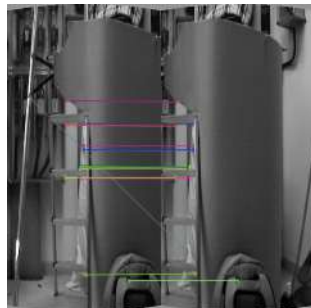
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation

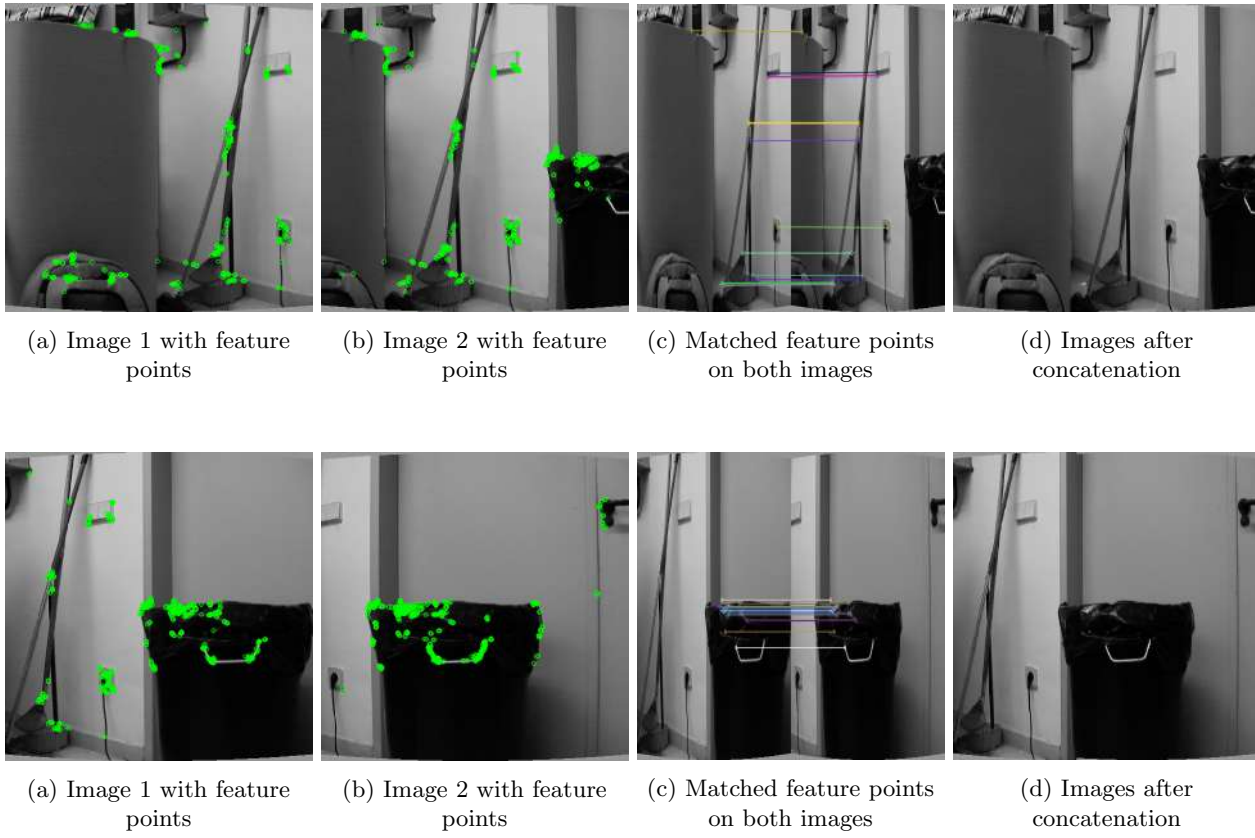
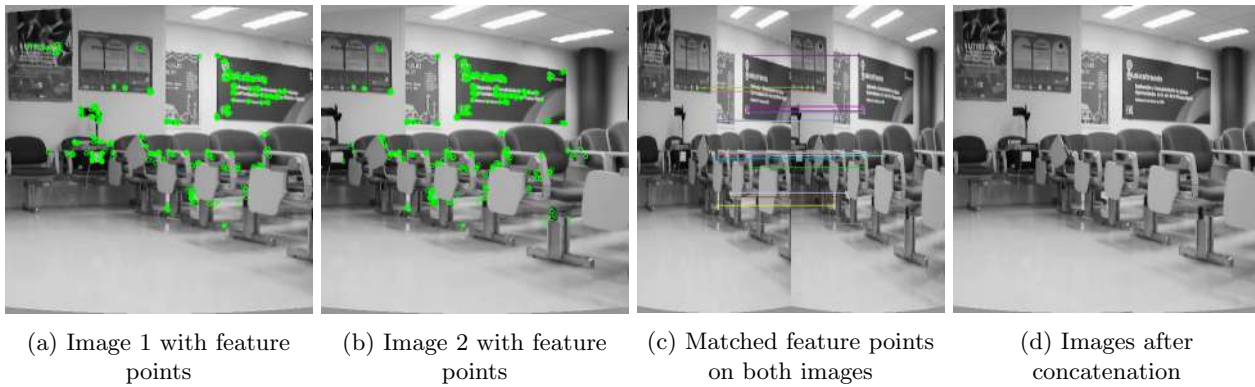


Figure 54: Resultant Panoramic Image



Figure 55: Ground Truth Image

#### 4.6 For sample photos 6







(a) Image 1 with feature points



(b) Image 2 with feature points



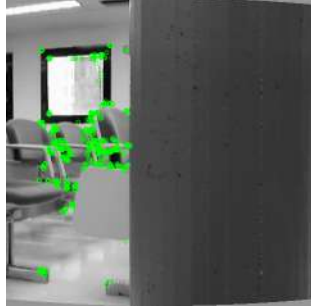
(c) Matched feature points on both images



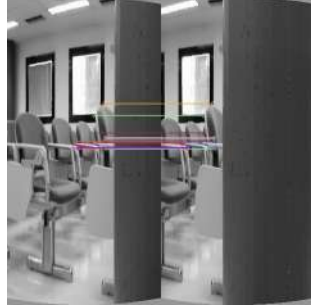
(d) Images after concatenation



(a) Image 1 with feature points



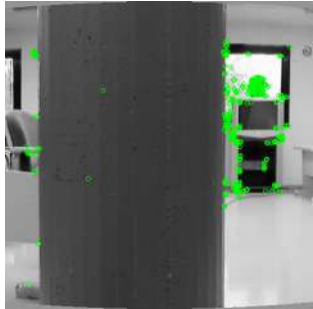
(b) Image 2 with feature points



(c) Matched feature points on both images



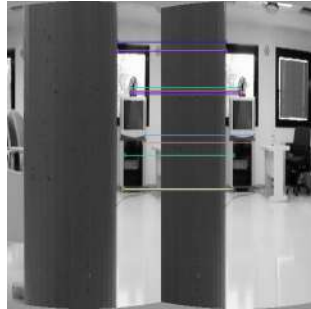
(d) Images after concatenation



(a) Image 1 with feature points



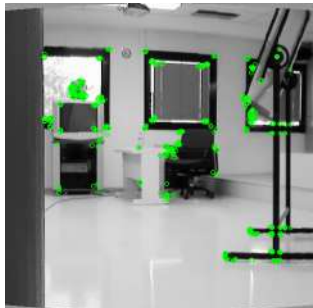
(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



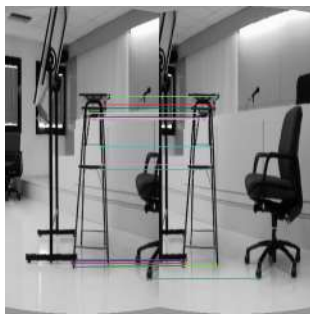
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



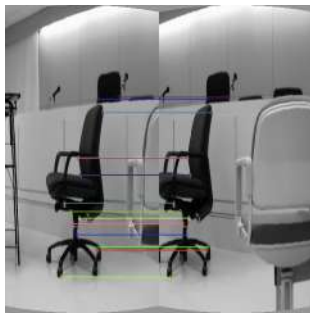
(d) Images after concatenation



(a) Image 1 with feature points



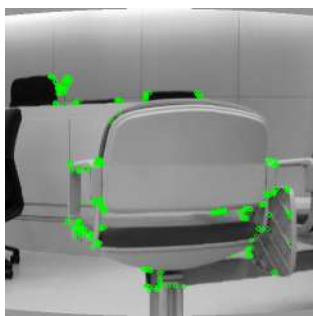
(b) Image 2 with feature points



(c) Matched feature points on both images



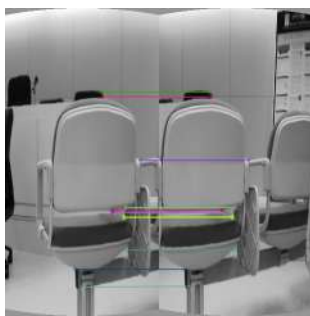
(d) Images after concatenation



(a) Image 1 with feature points



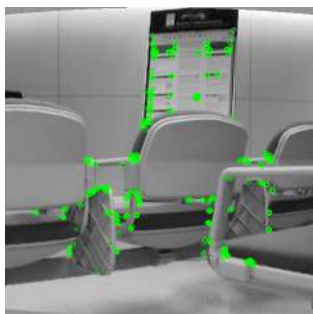
(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation

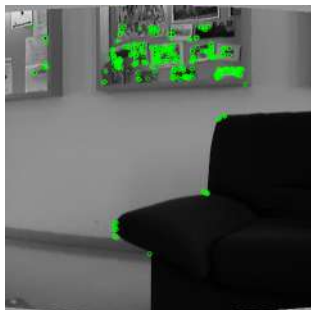


Figure 65: Resultant Panoramic Image



Figure 66: Ground Truth Image

#### 4.7 For sample photos 7



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



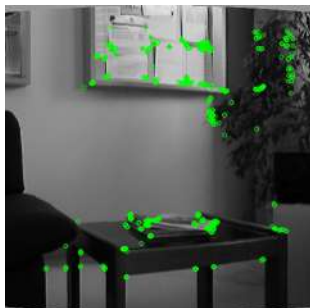
(c) Matched feature points on both images



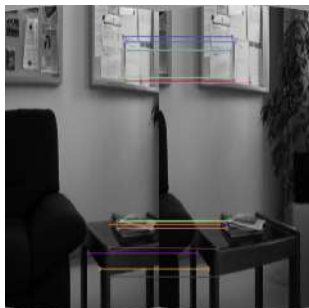
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images

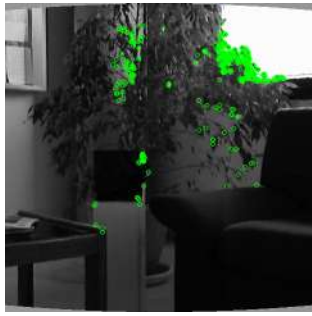


(d) Images after concatenation

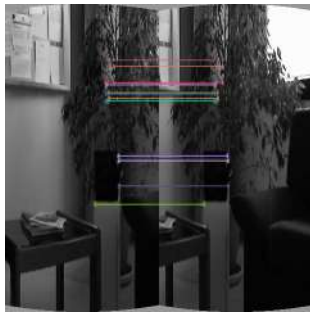




(a) Image 1 with feature points



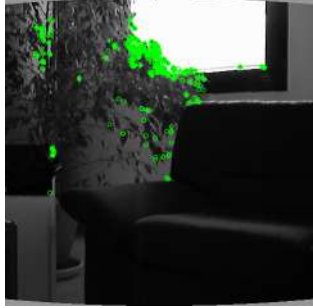
(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



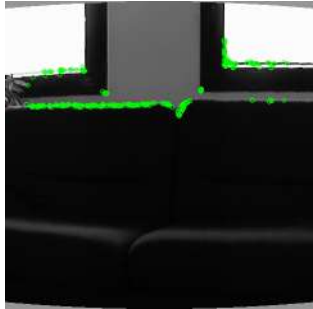
(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



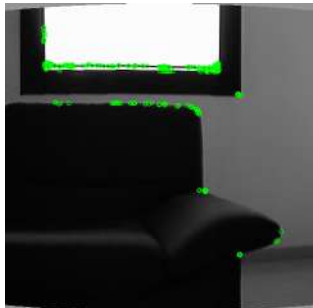
(b) Image 2 with feature points



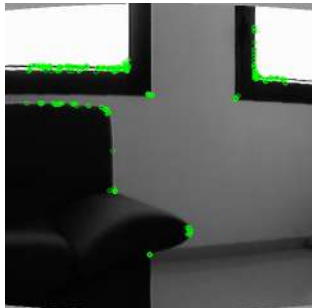
(c) Matched feature points on both images



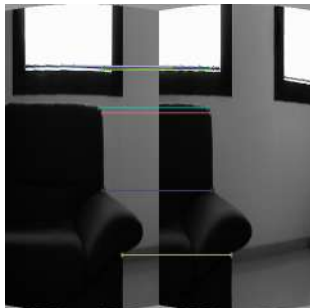
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation

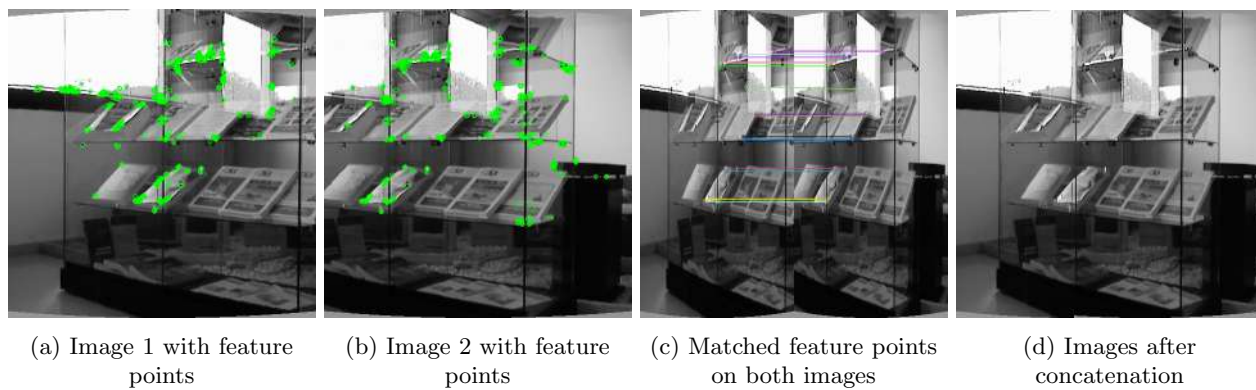
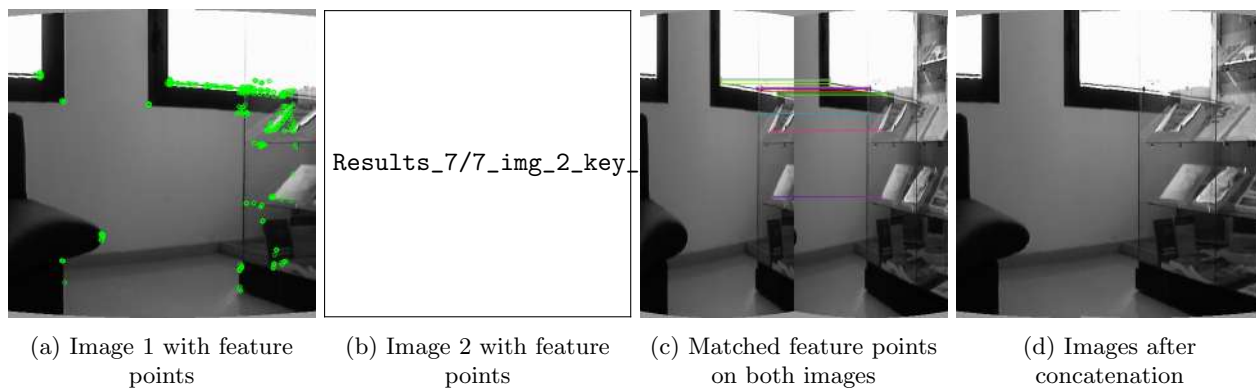
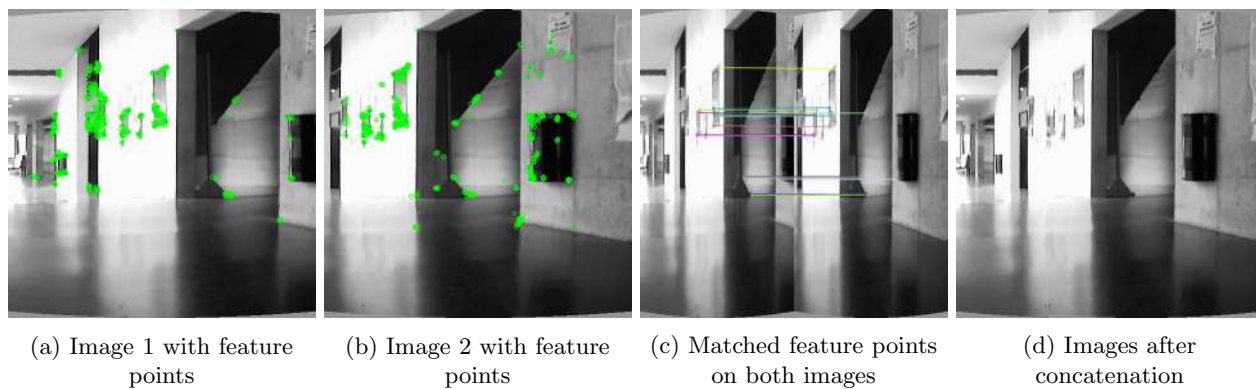


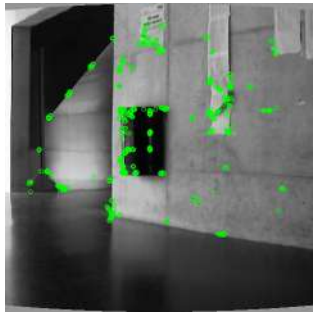
Figure 76: Resultant Panoramic Image



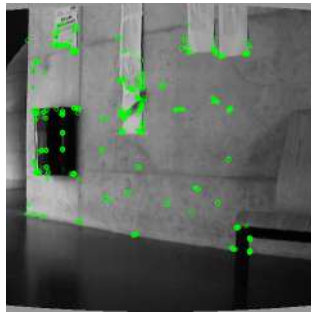
Figure 77: Ground Truth Image

#### 4.8 For sample photos 8

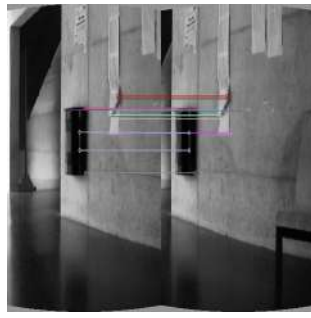




(a) Image 1 with feature points



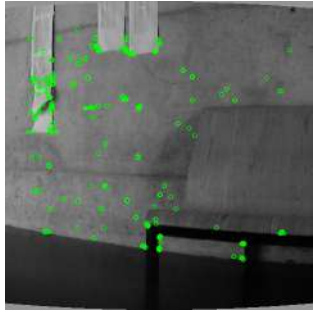
(b) Image 2 with feature points



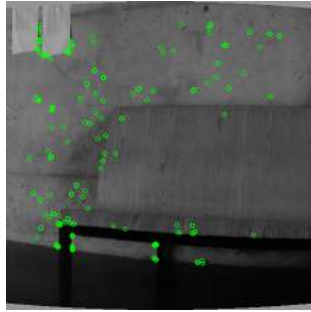
(c) Matched feature points on both images



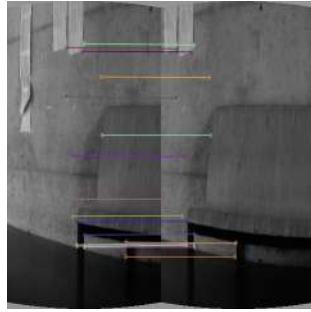
(d) Images after concatenation



(a) Image 1 with feature points



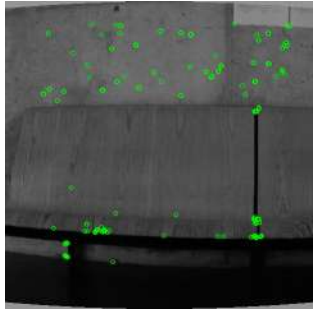
(b) Image 2 with feature points



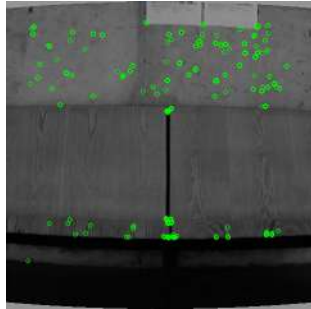
(c) Matched feature points on both images



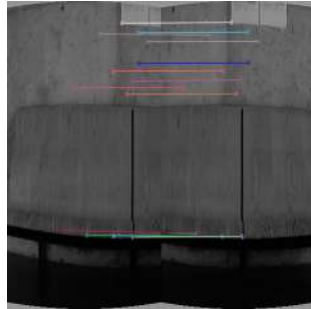
(d) Images after concatenation



(a) Image 1 with feature points



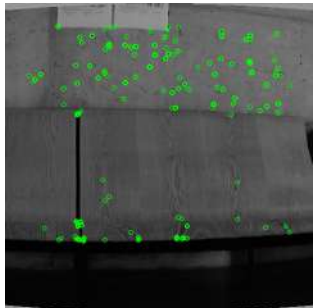
(b) Image 2 with feature points



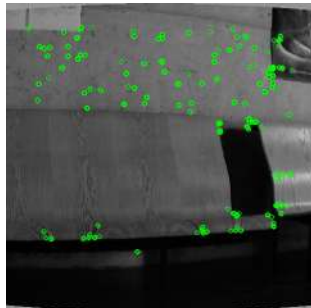
(c) Matched feature points on both images



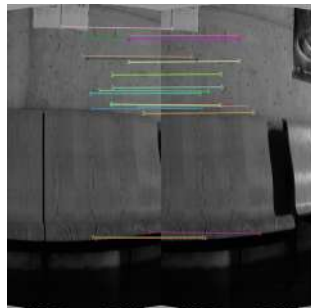
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points

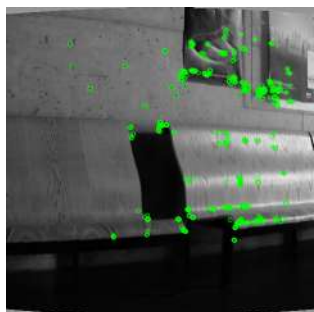


(c) Matched feature points on both images

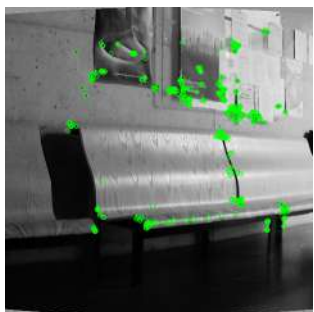


(d) Images after concatenation

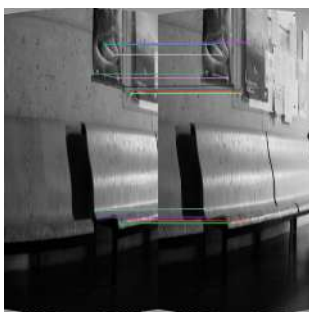




(a) Image 1 with feature points



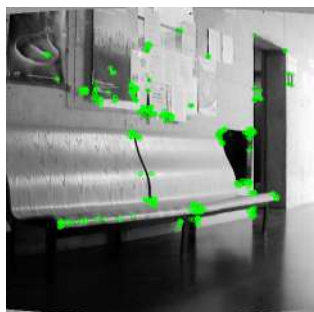
(b) Image 2 with feature points



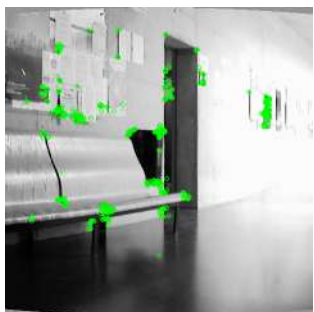
(c) Matched feature points on both images



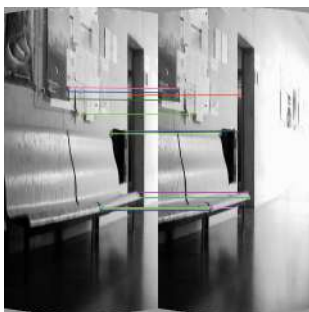
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



Figure 87: Resultant Panoramic Image



Figure 88: Ground Truth Image

#### 4.9 For sample photos 9



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



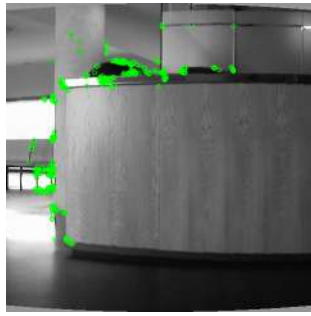
(c) Matched feature points on both images



(d) Images after concatenation



(a) Image 1 with feature points



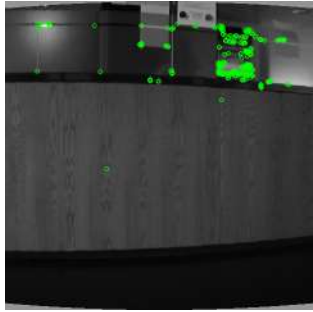
(b) Image 2 with feature points



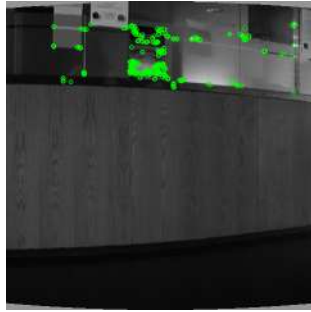
(c) Matched feature points on both images



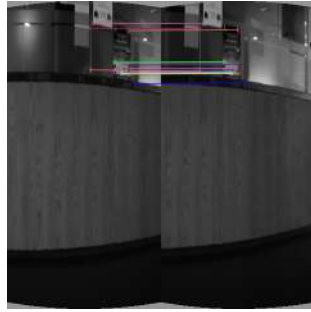
(d) Images after concatenation



(a) Image 1 with feature points



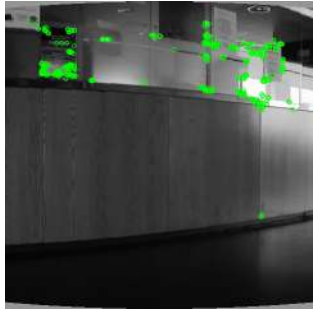
(b) Image 2 with feature points



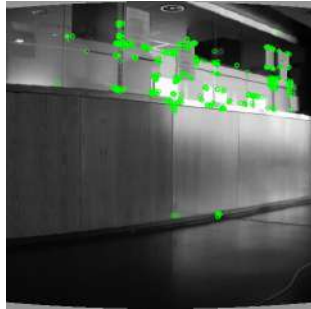
(c) Matched feature points on both images



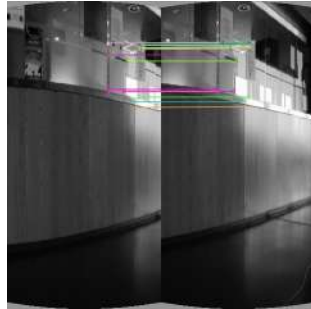
(d) Images after concatenation



(a) Image 1 with feature points



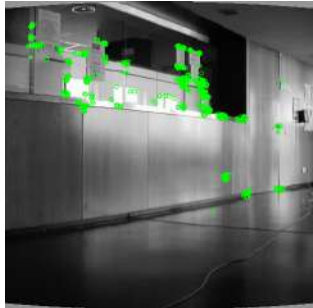
(b) Image 2 with feature points



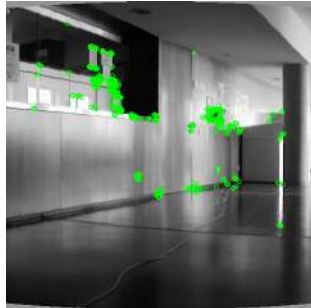
(c) Matched feature points on both images



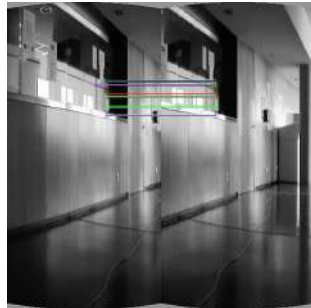
(d) Images after concatenation



(a) Image 1 with feature points



(b) Image 2 with feature points



(c) Matched feature points on both images



(d) Images after concatenation



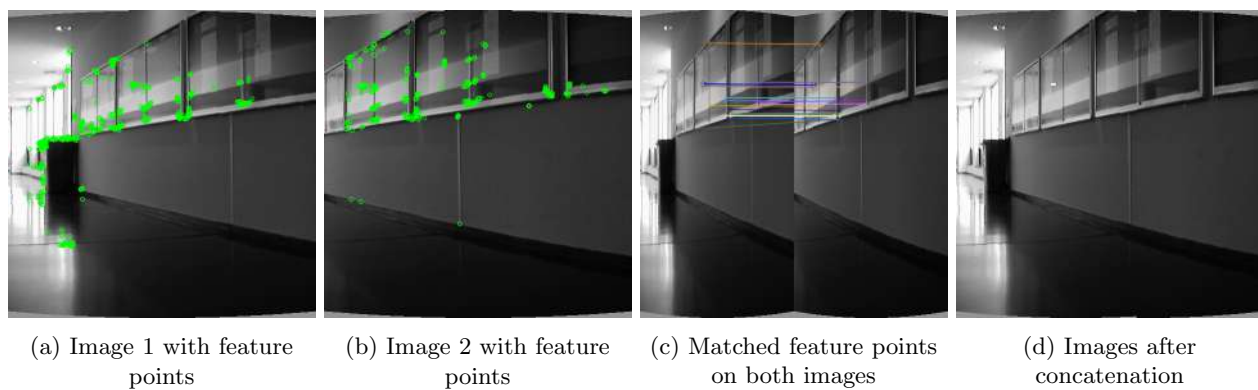
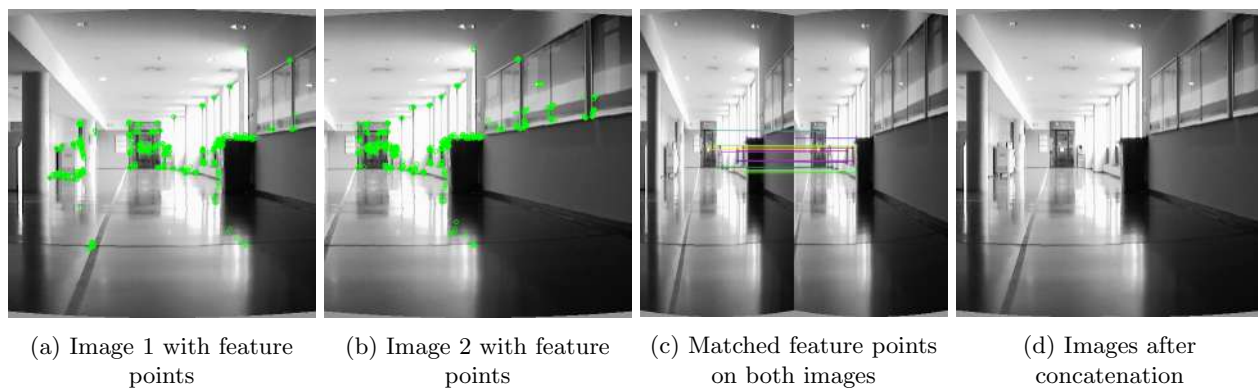
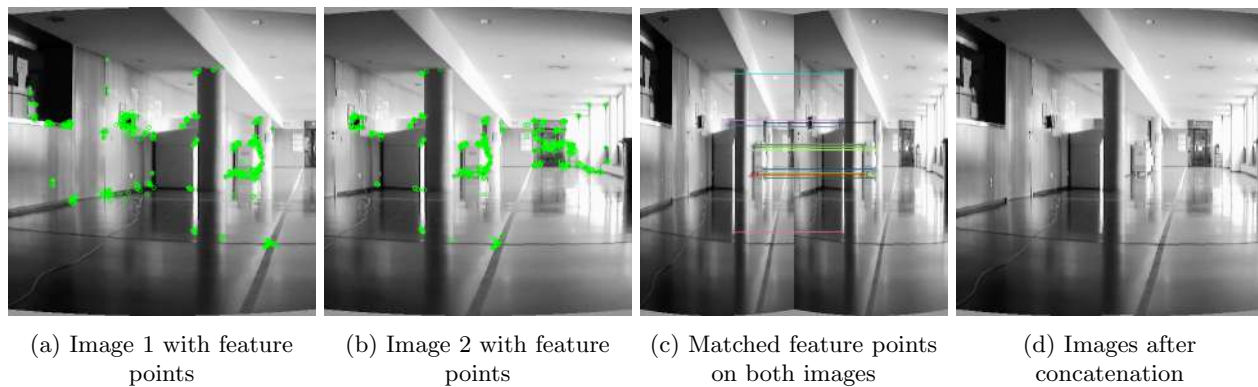


Figure 98: Resultant Panoramic Image



Figure 99: Ground Truth Image