Computer Vision

Assignment 1 - Report

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1 Implementation

Step-1

This implementation[1] starts by finding key points in both images using a technique called Harris corner detection. This technique spots points in images that are likely to be corners or where different features meet.

Step-2

After finding these key points, the method calculates descriptions for those key points using called SIFT. SIFT gives each point a unique description based on its surroundings in the image. It helps to match points between the images later on.

Step-3

To establish correspondences between keypoints in the two images, a brute-force matching approach is utilized. Each point in one image is compared with all points in the other image, and the best matches are selected according to the euclidean norm of the descriptions.

Step-4

Finally, to ensure proper alignment of the two images, a special technique called RANSAC is utilized. In the selection of RANSAC parameters, considering the number of points utilized to estimate the transformation holds significance. Although employing more points, such as 4 or 5, typically results in more accurate transformations, it was discovered that depending on at least 4 points was more reliable. Additionally, adjusting the residual threshold, which measures the difference between observed and estimated values, is essential for finding precise transformations.

2 Experiment

Initial Parameters:
Harris Corner Detection
blockSize = 9
ksize = 7
k = 0.20

[1] https://github.com/muradohi/Image-Stitching/blob/main/Code_ComputerVision.ipynb

Harris Corner Images

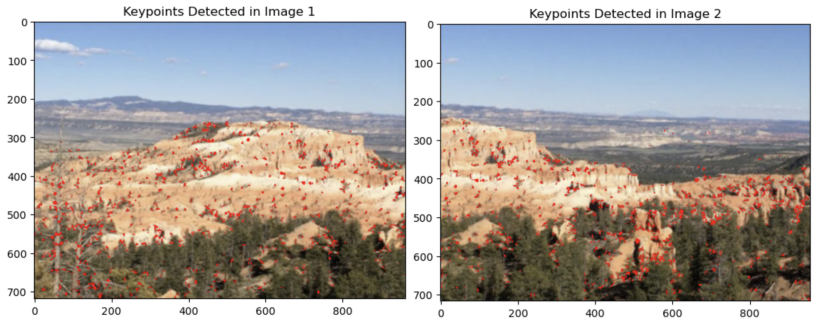

Figure 1: Harris Corner Keypoints

SIFT Descriptor

keyPointDiameter=11
Matching Threshold Ratio = 0.80

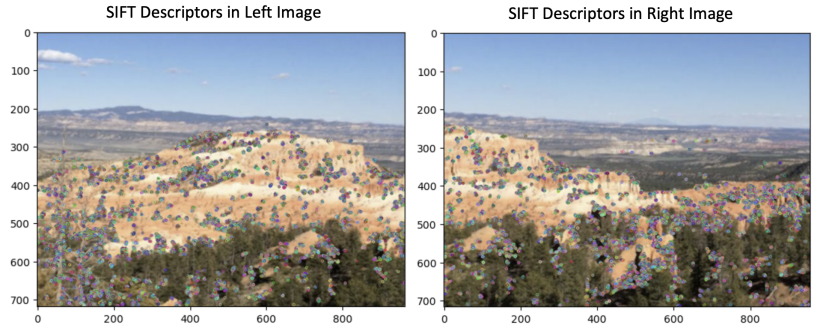

Figure 2: SIFT Descriptor Keypoints

Descriptor Matches

```
Match 1: queryIdx=732, trainIdx=147, distance=53.06599807739258
Match 2: queryIdx=6766, trainIdx=4039, distance=48.90807723999234
Match 3: queryIdx=7991, trainIdx=6536, distance=81.92679595947266
Match 4: queryIdx=8675, trainIdx=7722, distance=132.2308654785156
Match 5: queryIdx=8676, trainIdx=7722, distance=136.62722778320312
Match 6: queryIdx=8741, trainIdx=7722, distance=134.18270874023438
Match 7: queryIdx=8742, trainIdx=7722, distance=132.24220275878906
Match 8: queryIdx=8743, trainIdx=7722, distance=136.95619201660156
Match 9: queryIdx=8744, trainIdx=7722, distance=147.89523315429688
Match 10: queryIdx=8825, trainIdx=7722, distance=145.53694152832031
Match 11: queryIdx=8826, trainIdx=7722, distance=136.97810363769531
Match 12: queryIdx=8827, trainIdx=7722, distance=135.7129364013672
Match 13: queryIdx=8828, trainIdx=7722, distance=140.82968139648438
Match 14: queryIdx=8910, trainIdx=7722, distance=148.46211242675781
Match 15: queryIdx=8911, trainIdx=7722, distance=141.75331115722656
Match 16: queryIdx=10087, trainIdx=9361, distance=90.86803436279297
Match 17: queryIdx=10356, trainIdx=9446, distance=91.21403503417969
Match 18: queryIdx=10357, trainIdx=9446, distance=93.53608703613281
Match 19: queryIdx=12528, trainIdx=11982, distance=70.61869812011719
Match 20: queryIdx=14464, trainIdx=13601, distance=72.70487976074219
Match 21: queryIdx=14494, trainIdx=13601, distance=130.27279663085938
Match 22: queryIdx=14495, trainIdx=13601, distance=65.61249542236328
Match 23: queryIdx=16617, trainIdx=16548, distance=62.153038024902344
```

Figure 3: Descriptors Matches

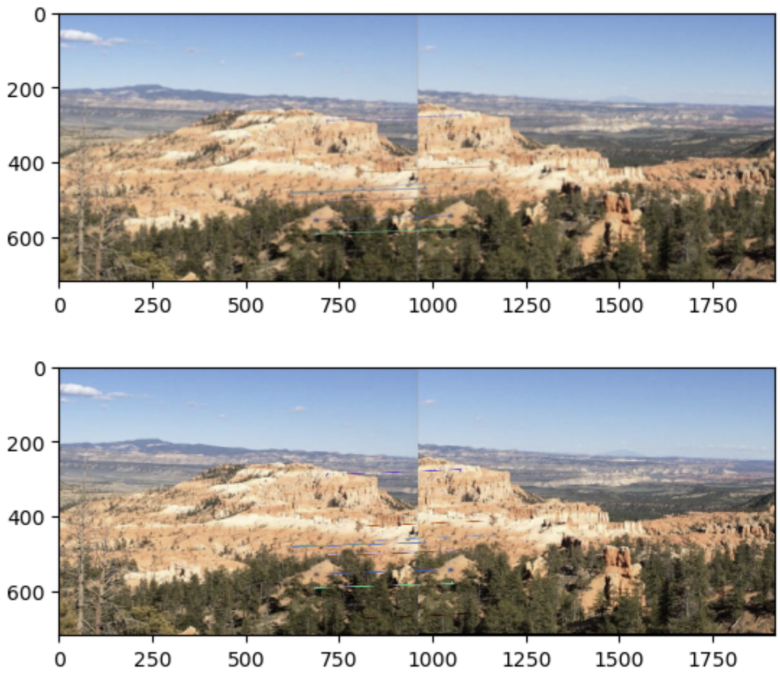

Figure 4: Descriptors Matches

RANSAC
minpoints=4
thresholdresidual=2
iterations=2000

```
RANSAC-own:
M [[ 1.02115442e+00  3.53661869e-02 -6.35249968e+02]
 [-2.26793108e-02  1.02241447e+00 -8.32685706e+00]]
inliers [ 1  2  3  5  6  7  9 10 11 12 14 15 16 17 18 19 21]
Average keypoint distance 1.921091459148842
```

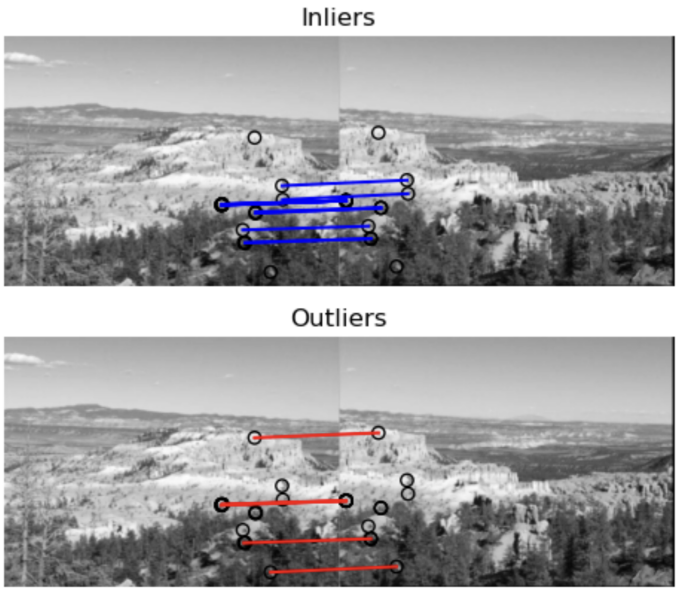

Figure 5: RANSAC Inliers and Outliers

Stitched Image

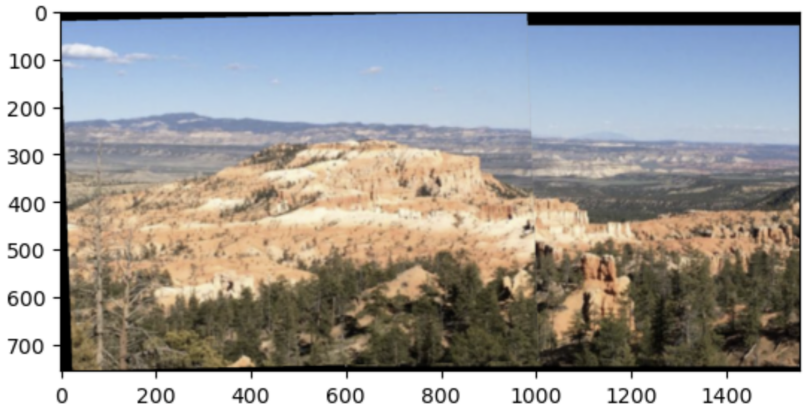

Figure 6: Stitched Image

3 Sensitivity Analysis

3.1 Harris Corner Detection Parameters

Sensitivity factor k
Sensitivity factor k is used to distinguish between corners and edges when detecting features in an image. It's usually set within the range of 0 to 0.2.

When k is small, the algorithm tends to detect sharp corners as features.

Sensitivity factor k:

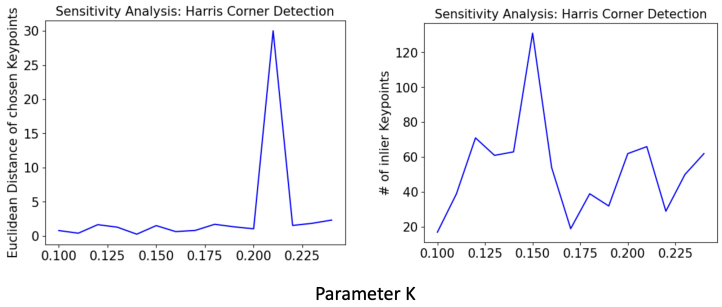

Figure 7: Sensitivity Analysis k

The optimal value for k lies between 0.125 and 0.20. k=0.2 was selected for which the minimal average distance is 1.04. With k=0.15, insufficient keypoints would be found for this test with block sizes.

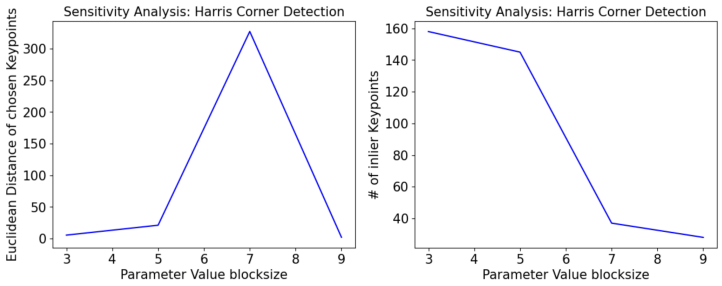

Figure 8: Sensitivity Analysis BlockSize

BlockSize Block sizes of 11 or larger won't provide sufficient keypoints for estimating an affine transformation. The best values found for blocksize were between 7 and 9. So 9 was chosen.

ksize: Aperture parameter The optimal value for ksize was found to be 7

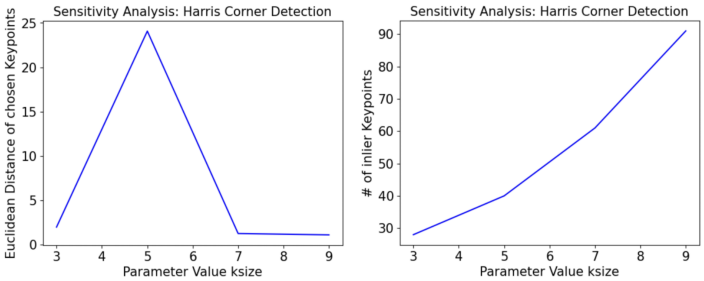

Figure 9: Sensitivity Analysis ksize

as the euclidien distace is very low and the minimal average distance is 1.25.

3.2 SIFT Descriptor Parameters

KeypointDiameter The diameter of keypoints used for SIFT descriptors.

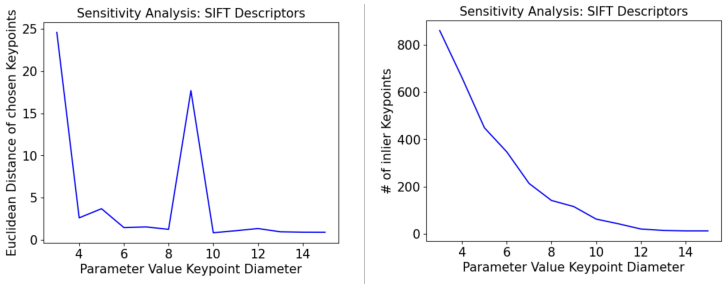

Figure 10: Sensitivity Analysis KeypointDiameter

The best size around the keypoints for the SIFT descriptor was found to be 13.

3.3 Thresholding and RANSAC Parameters

Ratio Residual-threshold is mainly used for determinining inliers and outliers for a transformation.

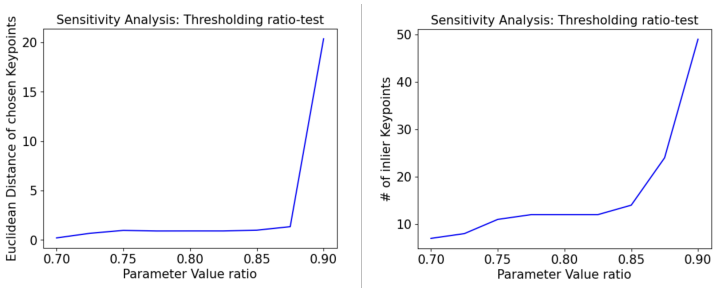

Figure 11: Sensitivity Analysis Ratio

0.85 was taken as the optimal value for the ratio for which the euclidien distance is minimal with more number of inliers.

Residual-threshold
Residual-threshold is mainly used for determinining inliers and outliers for a transformation.

The optimal range for the ratio used in the ratio-test for thresholding was found to be between 1.5 and 2.0.

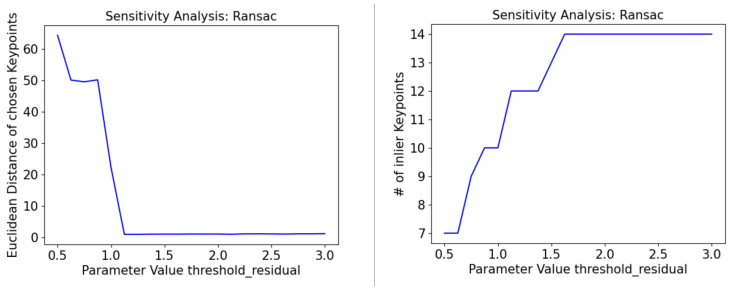

Figure 12: Sensitivity Analysis Residual-threshold

4 Final Result

Parameters Used

Harris Corner Detection

blockSize = 9
ksize = 7
k = 0.20

Harris Corner with Keypoints

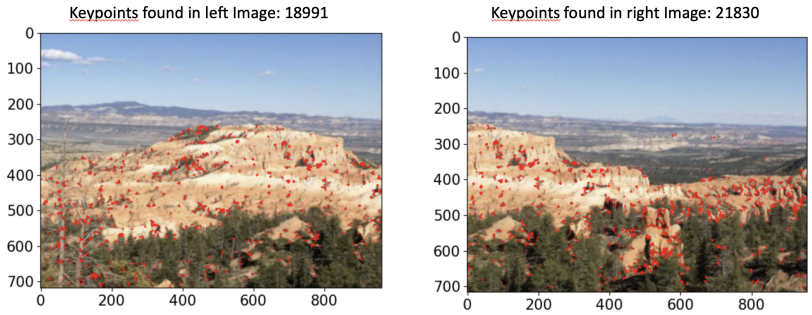

Figure 13: Harris Corner Keypoints

SIFT Descriptor

keyPointDiameter=13
Matching Threshold Ratio = 0.85

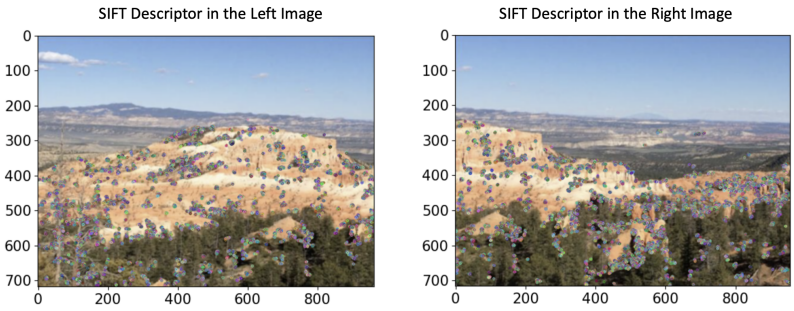

Figure 14: SIFT Descriptor Keypoints

Descriptors Matches

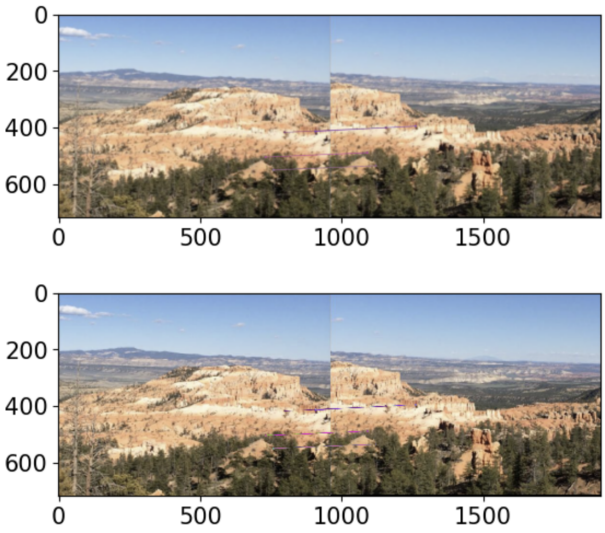

Figure 15: Descriptors Matches

RANSAC
minpoints=4
thresholdresidual=2
iterations=2000

```
Keypoints after Matching/Thresholding: 14
inliers [ 0  1  2  3  4  5  6  7  8  9 10 11 12 13]
Average keypoint distance 0.9864421647966798
```

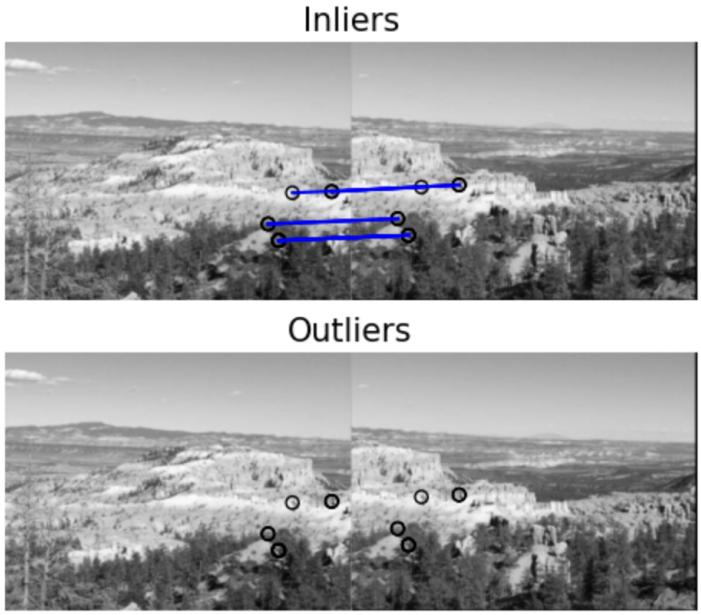

Figure 16: RANSAC Inliers and Outliers

Stitched Image

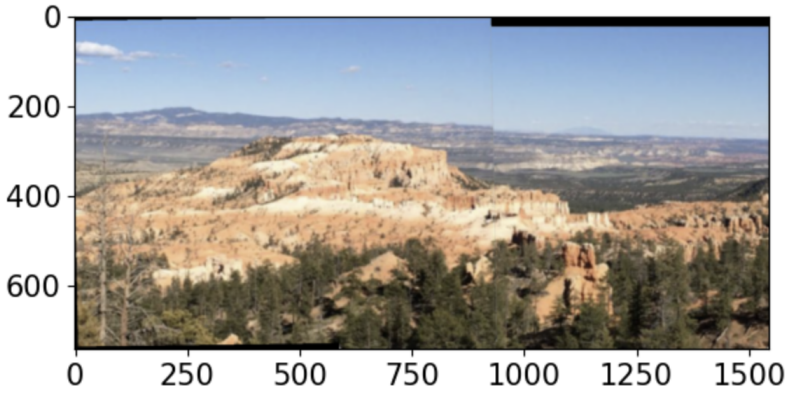

Figure 17: Stitched Image

Test Image
Harris Corner with Keypoints

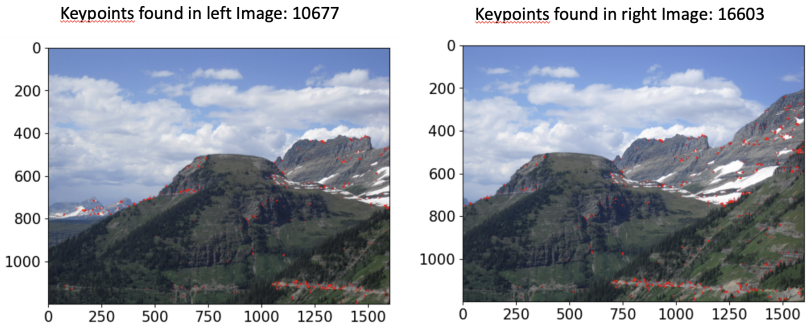

Figure 18: Harris Corner Keypoints

SIFT Descriptor

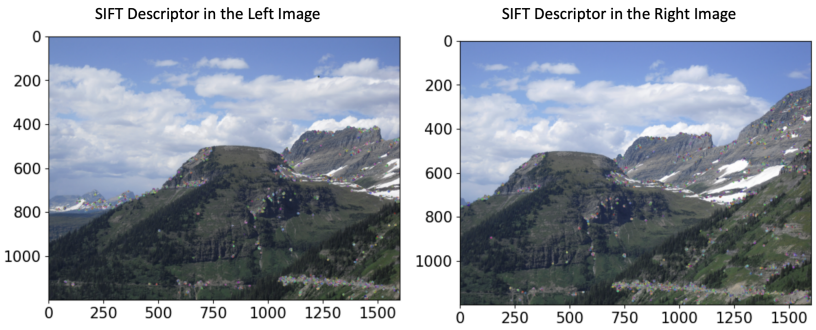

Figure 19: SIFT Descriptor Keypoints

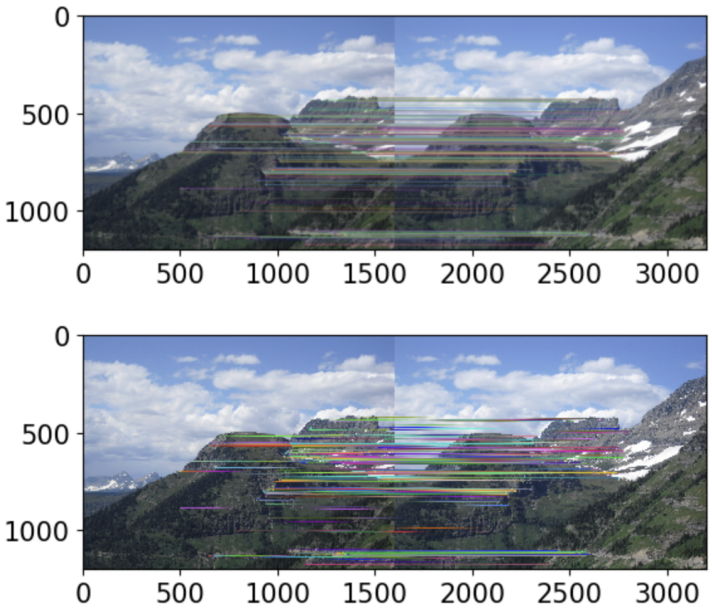

Figure 20: Descriptors Matches

RANSAC

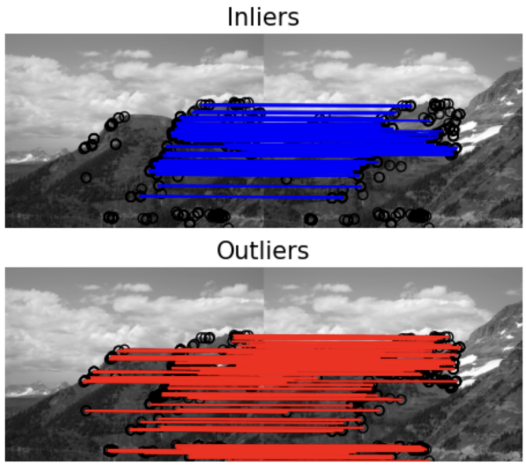

Figure 21: RANSAC Inliers and Outliers

Stitched Image

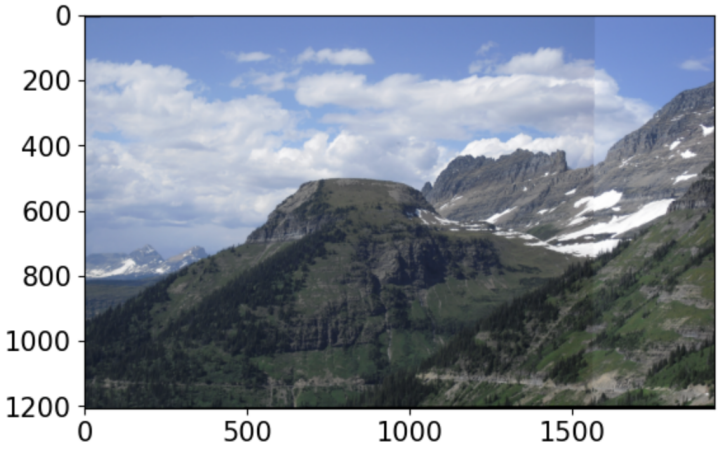

Figure 22: Stitched Image