CSE 573 - Project 2

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Image Stitching

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The goal of this project is to be able to create panoramas given at most three images by determining ordering of the images and then performing image stitching without using standard stitching libraries.

1 Introduction

Image stitching is the process of combining multiple photographic images with overlapping fields of view to produce a segmented panorama or high-resolution image. Any two given images with overlapping fields of view can easily be combined by computing the homography matrix and then warping one image to another by doing a perspective transform of one image to another using the computed homography matrix. The homography matrix can be computed using **RAN**dom **SA**mple **C**onsensus (RANSAC) algorithm.

However, to correctly determine the homography matrix, the order of the images has to be know. No ordering given for the test images. Hence, for ordering the given images, SIFT features are used. The algorithm is discussed in detail in section ordering of images below in 1.

2 Feature extraction using SIFT

To perform the task of stitching, the images should first be ordered and then we need to estimate the homography matrix. However, matching cannot be directly performed on whole image. Hence, Features are extracted from the image using SIFT.

SIFT or **S**cale-**I**nvariant **F**eature **T**ransform is a robust feature detection algorithm used to detect and describe local features in images and is invariant to scale, rotation, intensity and affine changes. It for finding the features in an image. An example of an image with SIFT feature is given below in Figure 1.

Figure 1: A image showing the SIFT features

3 Finding the matches - kNN matcher

Each image consists of a set of features. We need to find the matching features present in both images. This is done by taking the top k points in the feature space from image I' to every point in image I and then the closest point is considered to be a match if it satisfies the ratio test.

4 Finding Homography

A Homography is a transformation matrix of $\mathbb{R}^{3x3}$ that maps the points in one image to the corresponding points in the other image. Given points $p_1 = (x, y)$ and $p_2 = (x', y')$ in homogeneous coordinates, H can be used to convert one to another using

$$H * p_1 = p_2$$

The homography matrix is estimated by using direct linear transformation. Each point can be presented in form of a matrix B of $\mathbb{R}^{2x9}$ and H can be flattened and represented in form of a vector h as given below.

$$B = \begin{bmatrix} x_i & y_i & 1 & 0 & 0 & 0 & -x'_i x_i & -x'_i y_i & -x'_i \\ 0 & 0 & 0 & x_i & y_i & 1 & -y'_i x_i & -y'_i y_i & -y'_i \end{bmatrix}$$

$$h = \begin{bmatrix} h_{00} \\ h_{01} \\ h_{02} \\ h_{10} \\ h_{11} \\ h_{12} \\ h_{20} \\ h_{20} \\ h_{21} \\ h_{22} \end{bmatrix}$$

For n points, there will be $2n$ equations and hence a matrix A with $\mathbb{R}^{2nx9}$ which will be 'n' B matrices stacked vertically.

$$A = \begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -x'_1x_1 & -x'_1y_1 & -x'_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -y'_1x_1 & -y'_1y_1 & -y'_1 \\ & & & & & ... & & & \\ x_n & y_n & 1 & 0 & 0 & 0 & -x'_nx_n & -x'_ny_n & -x'_n \\ 0 & 0 & 0 & x_n & y_n & 1 & -y'_nx_n & -y'_ny_n & -y'_n \end{bmatrix}$$

We have to solve for h such that $Ah = 0$ or minimize $||Ah - 0||^2$. Hence, h will be the eigen vector corresponding to the smallest eigen value of the matrix $A * A^T$.

The vector h has to be converted to a unit vector and reshaped to $\mathbb{R}^{3x3}$ which is the homography matrix H.

5 Getting the best homography using RANSAC

RANSAC is an iterative algorithm which is used to calculate the Homography matrix that warps a given image I to another image I'. The steps in the RANSAC algorithm are given below

1. Sample a small set of matches (at least 4 point pairs) from I and I'
2. Using these point pairs, compute the homography matrix H.
3. Using the homography matrix H convert all the match pairs of I to I' by taking the dot product of H and I.
4. Find the distance between expected and actual point using euclidean distance (or any similar distance measure).
5. Find the number of inliers n_i which lie under the given threshold.
6. If n_i is greater than $n_{i_{best}}$ or 1st iteration, update the $n_{i_{best}}$ and H_best to n_i and H respectively.
7. If n_i equals required inliers (some percentage like 40% of total matches) break loop else continue repeat until number of iterations are complete.

6 Ordering of Images

The images are ordered based on a simple observation. The fact that only three images are given for testing is leveraged and the following observations are used to get the image ordering.

1. Middle image : Will have the most overlapping matches as it has overlapping fields of view with both images on the left and right.
2. Left image : Will have the maximum x-coordinate of the inliers greater than the maximum inlier coordinate of the middle image.
3. Right image : Will have the maximum x-coordinate of the inlier less than the maximum inlier coordinate of the middle image.

Using the found coordinates, the images are re-ordered and then stitched.

7 Warping Images

The images obtained cannot be directly warped with the homogrpahy matrix as they will be cropped or not e displayed properly as shown in Figure 2. The panorama size changes with the homography matrix. Hence, new dimensions of the image is found by multiplying the corners of the image to be warped with the homography matrix H. These new coordinates are then used to form a translation matrix H' which shifts the image to be warped I such that no information is lost. Since matrix multiplication is commutative, the image I is warped using the dot product of H' and H which yields the resultant image as shown in Figure 3.

8 Stitching images

Once the order of the images are known, Stitching can be performed iteratively. First two images can be stitched by computing the homography matrix H using RANSAC followed by warping one image over other. The image resulting from warping can be reused for stitching with the last image which yields the panorama.

The test images used for testing is given in Figure 4.

The result obtained by stitching the images in the test set is given in Figure 5.

9 Bonus points

The photos taken at UB are shown in Figure 6. The output panorama is shown in Figure 7.

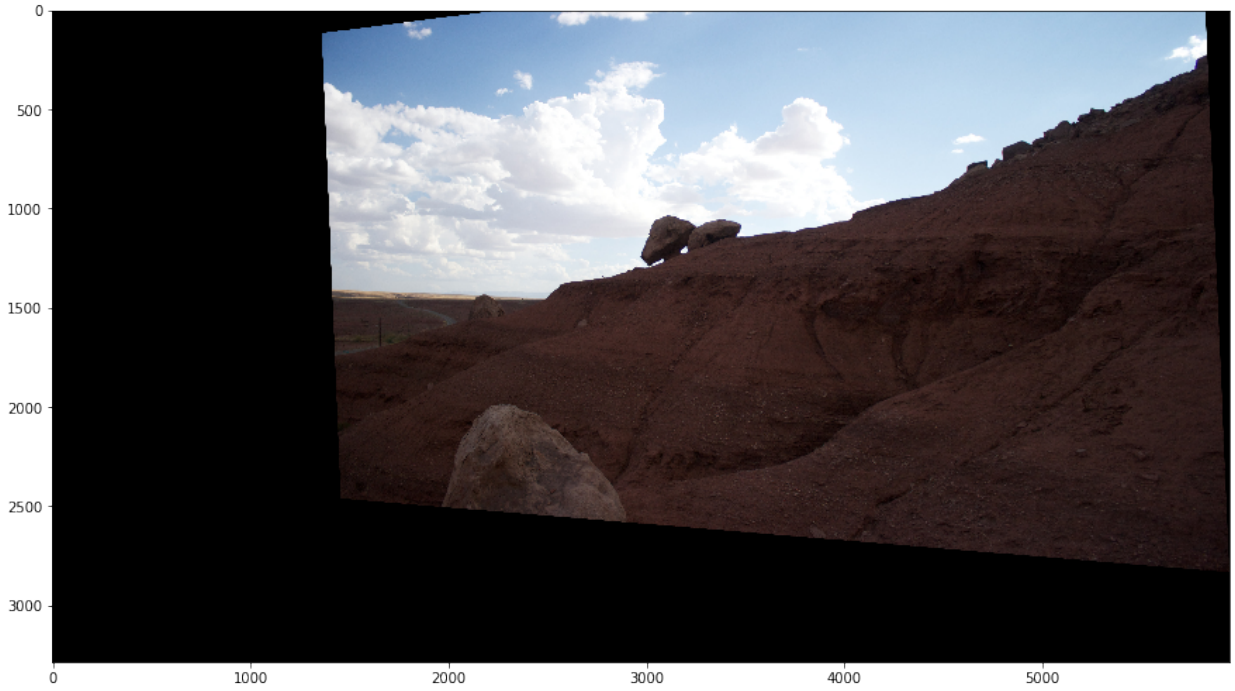

Figure 2: Image cropped due after applying because no correction is applied

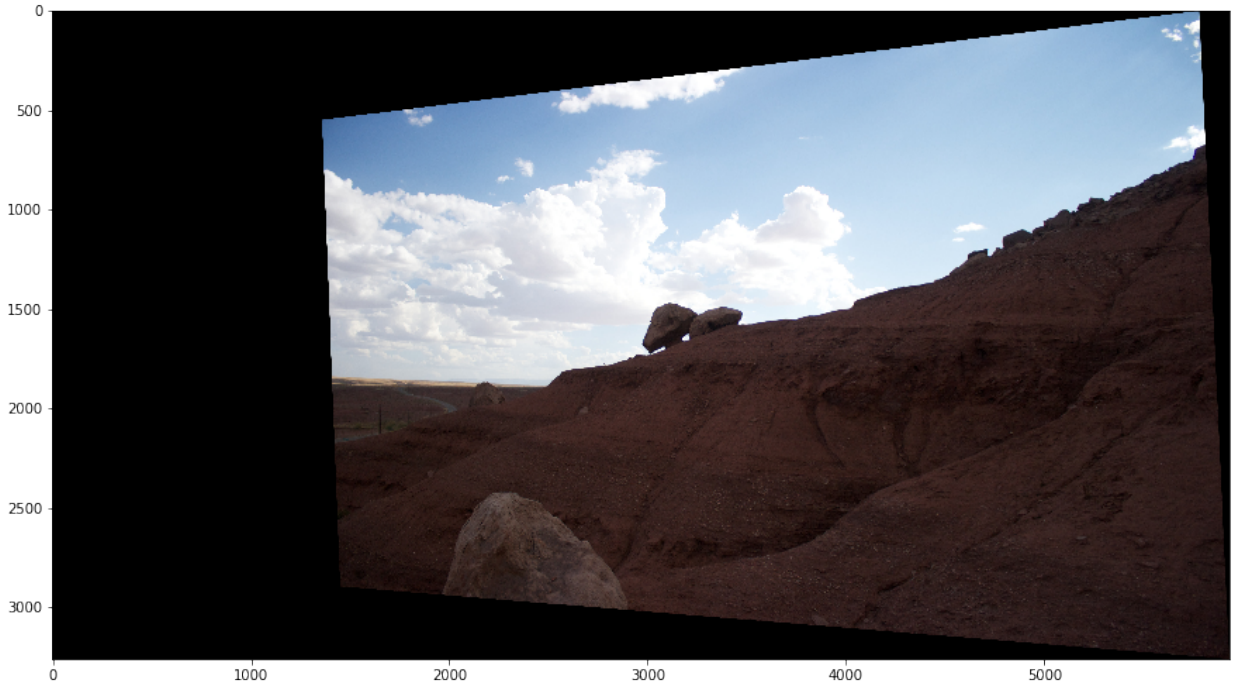

Figure 3: Full Image obtained after using the translation homography. (Y axis shifted)

References

1. Stackoverflow - Warping image - Showing the while image when using open CV warp perspective

Figure 4: Given test set

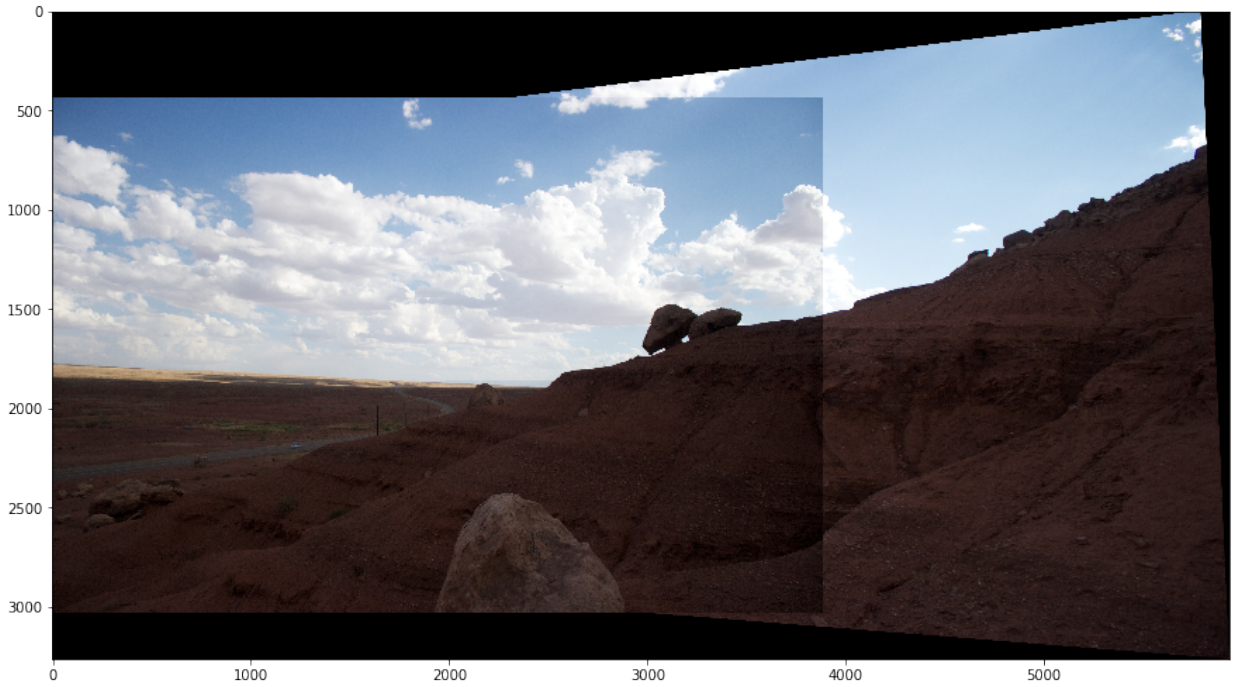

Figure 5: Panorama of the given test image

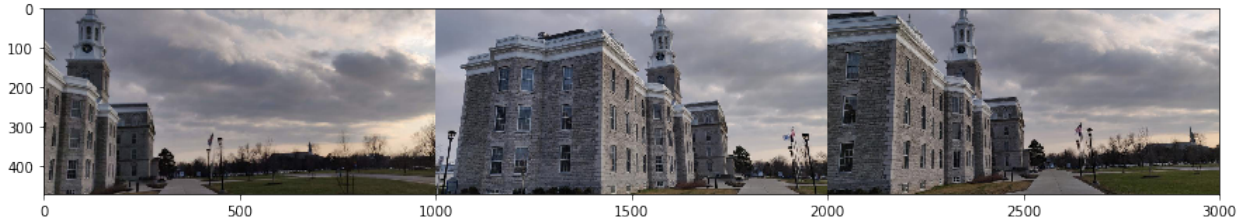

Figure 6: Set of images taken at UB

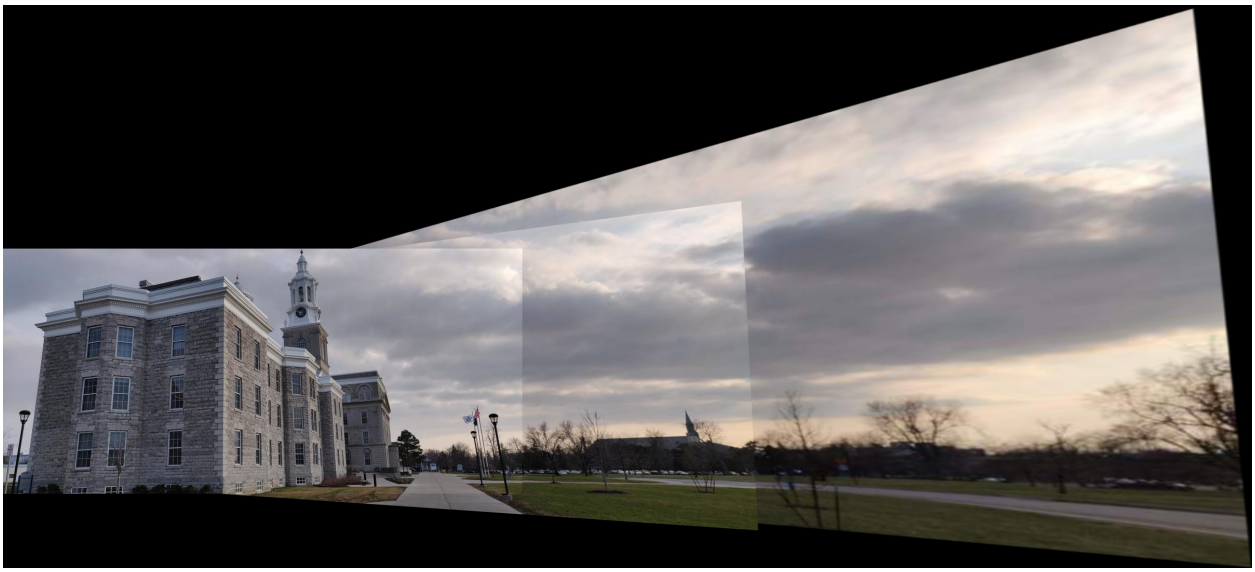

Figure 7: Panorama of the Images taken at UB