Lab 5: Camera Mosaic

-Niket Purohit

Introduction

In this lab, we focus upon learning photomosaicing and Harris corner detections to stitch multiple images in a single frame. By stitching together small, overlapping images, the digital image processing technique known as image mosaic photomosaicing creates one enormous image. To create a smooth and continuous larger image, the technique entails aligning and blending the smaller images. A corner detection operator called the Harris corner detector is used to extract corners and infer characteristics from images.

Camera Calibration

The primary step to this lab is camera calibration. In this we Camera calibration calculates the specifications of a camera's lens and image sensor. These attributes can be used to correct lens distortion, measure an object's size in world units, or locate the camera in the image. Applications like machine vision use these tasks alongside harris corner detection to find and quantify things.

The calibration of camera was done with a 7x9 checkered board with the squares being 30mm by 30mm each.

Here are a few images we used for camera calibration –

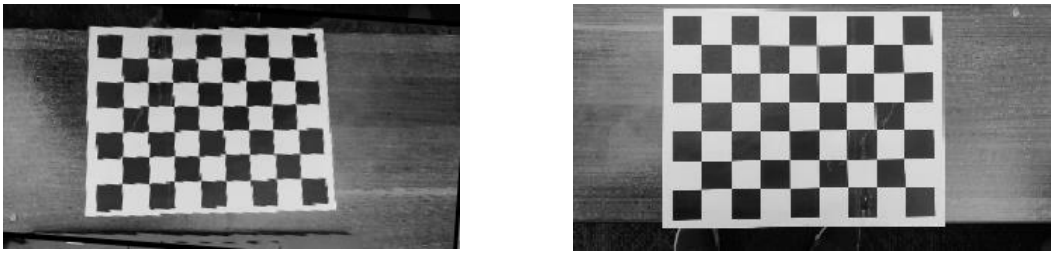

Figure 1: Primary Images for Calibration

The corners are manually removed to determine the inaccuracy. The four extreme corners of each image's rectangular checkerboard pattern must first be properly clicked before the MATLAB Camera Calibration toolbox automatically extracts the grid corners. The calibration took more than a single attempt. Initially my error exceeded 1.2583 which means I need to recalibrate and fix the issue by redoing pixelation. I reduced the pixels to 1600x730. Furthermore, the guidelines suggested that the error should be <1. The standard deviation of the reprojection of the error after reducing the pixels and recalibration was (0.30501 0.33401).

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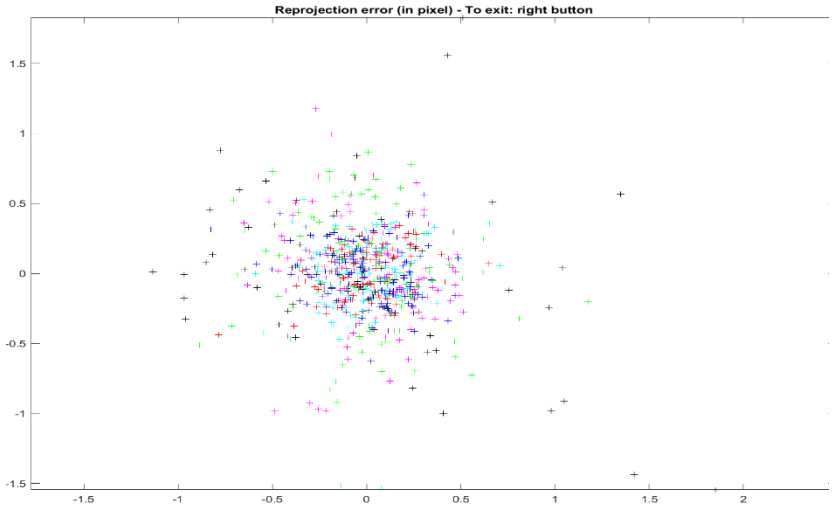

Figure 2:Projection of Error

The camera calibration parameters were self-defined while we found the error by the algorithm. The extrinsic and intrinsic characteristics are used in the calibration procedure to compute the camera matrix. The extrinsic parameters signify a hard transition from the coordinate system of the 3-D world to that of the 3-D camera. The intrinsic parameters show a projective translation from the coordinates of the 3-D camera to the coordinates of the 2-D image.

After optimization, the distortion coefficients are determined and are represented by kc. The tangential distortion is represented by the distortion coefficients p1, p2, and the radial distortion by the distortion coefficients k1, k2, and k3.

Since many contemporary camera lenses are already designed to reduce tangential distortion, their magnitude is lower than radial distortion coefficients. The distortion parameter values are there for several reasons, including the fact that we didn't carefully extract the corners from certain severely deformed photos. Second, when the image is obtained at a very slanting angle, some grid points are blurred due to the depth of field (DOF) of the image, leading to poor corner extraction.

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Calibration parameters after initialization:

Focal Length:          fc = [ 1233.11176   1233.11176 ]
Principal point:       cc = [ 799.50000   364.00000 ]
Skew:             alpha_c = [ 0.00000 ]   => angle of pixel = 90.00000 degrees
Distortion:            kc = [ 0.00000   0.00000   0.00000   0.00000   0.00000 ]

Main calibration optimization procedure - Number of images: 13
Gradient descent iterations: 1...2...3...4...5...6...7...8...9...10...11...12...13...14...15...16...17...18...19...20...21...22...done
Estimation of uncertainties...done


Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 1242.95966   1241.11876 ] +/- [ 9.00486   9.19975 ]
Principal point:       cc = [ 807.62977   367.03141 ] +/- [ 7.90037   6.12553 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000 ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.16654   -0.57067   0.00066   0.00226   0.00000 ] +/- [ 0.02008   0.14405   0.00226   0.00300   0.00000 ]
Pixel error:          err = [  0.30501 0.33401 ]

Note: The numerical errors are approximately three times the standard deviations (for reference).
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Figure 3: Error Parameters

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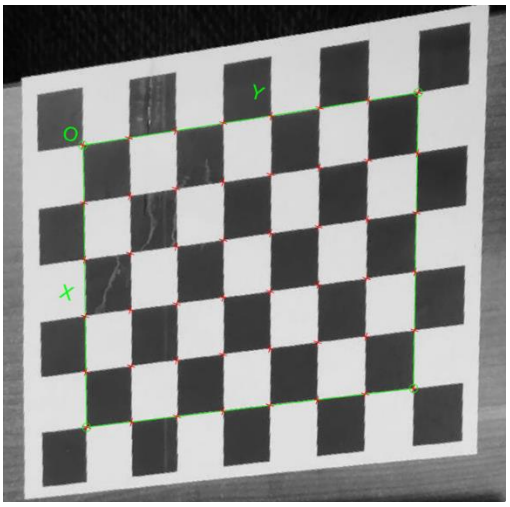

Figure 5: Image before calibration

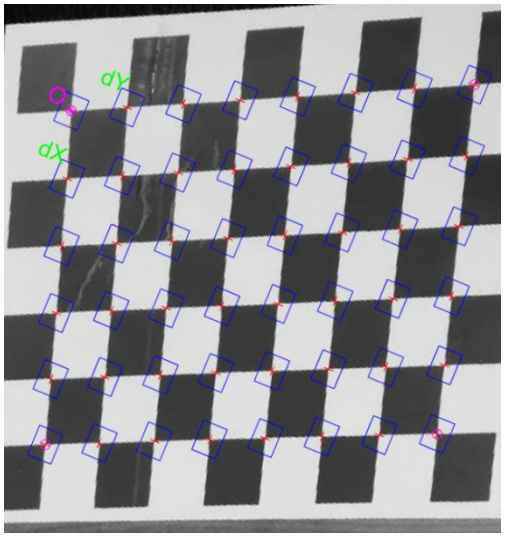

Figure 4:Image after calibration

Latino Students Center mural Mosaic

The images were captured from the Latino student center mural on Forsyth Street.

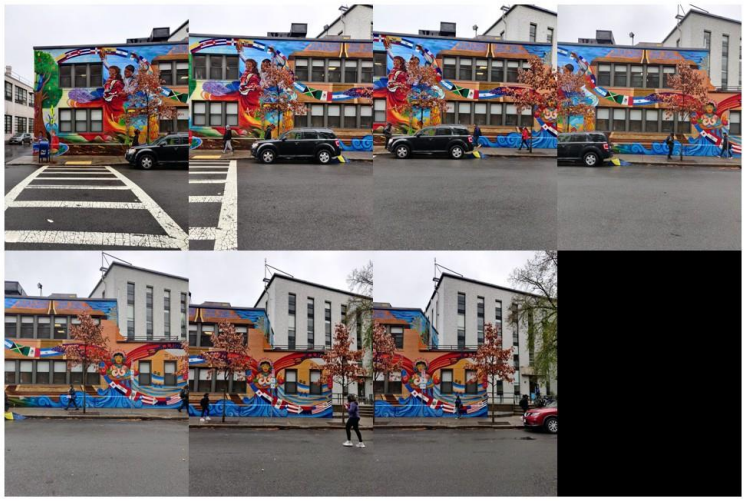

Figure 6: Primary Images of LSC

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These are the undistorted images taken from the phone's camera used to stitch together and form a single picture through MATLAB and harris corner detection. The default settings are those that were utilized to implement these parts. The Harris Corner Detector has 1,000 characteristics and uses a two-row, two-column "tile" technique. The characteristics were evenly spaced out throughout the picture. The distribution of the features across the image using the tile method gave the features a non-maximal suppression effect.

Here we also activated the smoothing filtering in the frequency domain.

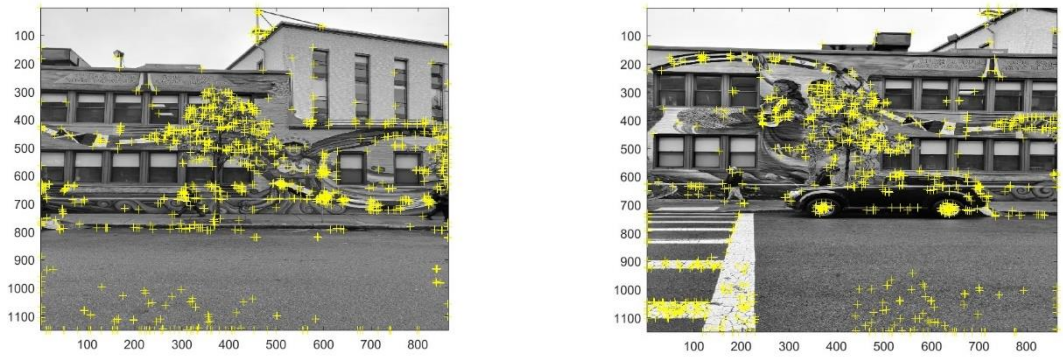

Figure 7: Harris Corner Detection

We see in the final output that final creation of mosaic is successful through stitching and harris corner detection which perfectly detected the corners in the wall and buildings but as we see that near the car the detection fluttered a little. As a result, we may say that the Harris feature detector tries to find corners. Additionally, it aids in the detection of many corners of various building features, like building borders, windows, railings, etc. Because of this, the structure has more elements than the road, crosswalk, and automobile.

Figure 8: LSC Mosaic

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Cinder Wall Mosaic

We used a set of 6 images to form a mosaic of the Cinder wall at Cabot center. As we observe, the patterns on the wall are very uniform and hence we made aa few changes in the harris corner detection. The Harris Corner Detector has 1,800 features and used a two-row, two-column "tile" technique. The distribution of the features over the image using the tile method gave the features a nonmaximal suppression effect.

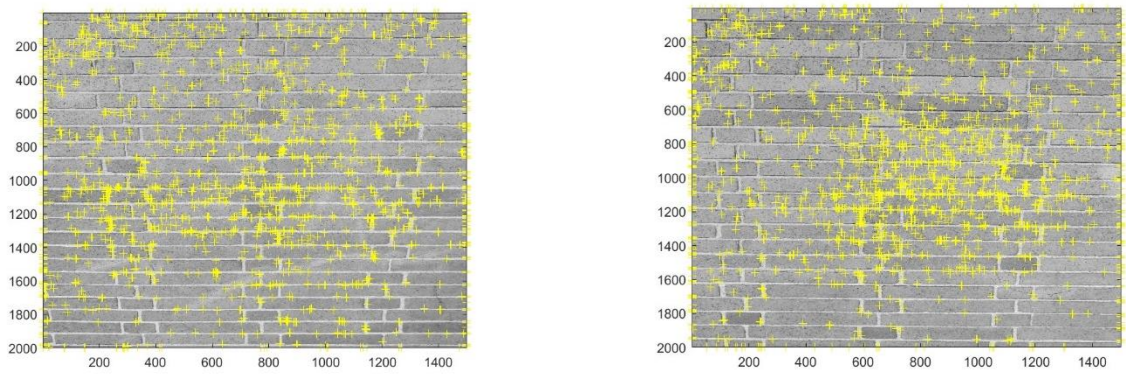

Figure 9:Harris Corner Detection

We observe that the detection of these corners is clearer towards the end of the wall rather than in the center due to numerous distinct corners in the wall. With the increase in the harris corner feature we will see that the stitching is more precise. We see in the final output that the stitching is near to accurate as due to the repetitive patterns we used a lot of harris corner features.

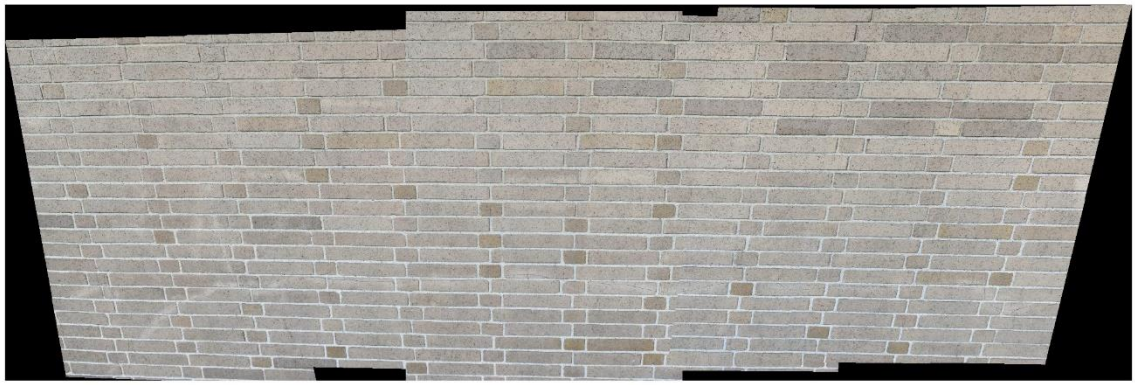

Figure 10: CInder Wall Mosaic

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Ruggles Mural Mosaic (15% overlap)

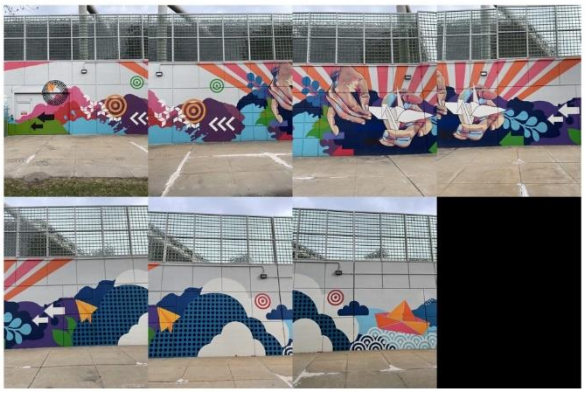

Figure 11:Primary images of Ruggles mural with 15% overlapping

The Ruggles wall just beneath the Ruggles station has a mural wall long enough to perform the experiment with 2 different sets of images of the same mural. The overlapping is of 15% and hence different from the other set which has the overlapping of 50%. The Harris Corner Detector has 1,000 characteristics and uses a two-row, two-column "tile" technique. The characteristics were evenly spaced out throughout the picture. The distribution of the features across the image using the tile method gave the features a non-maximal suppression effect. We can disperse the stitching more evenly by adding more feature points.

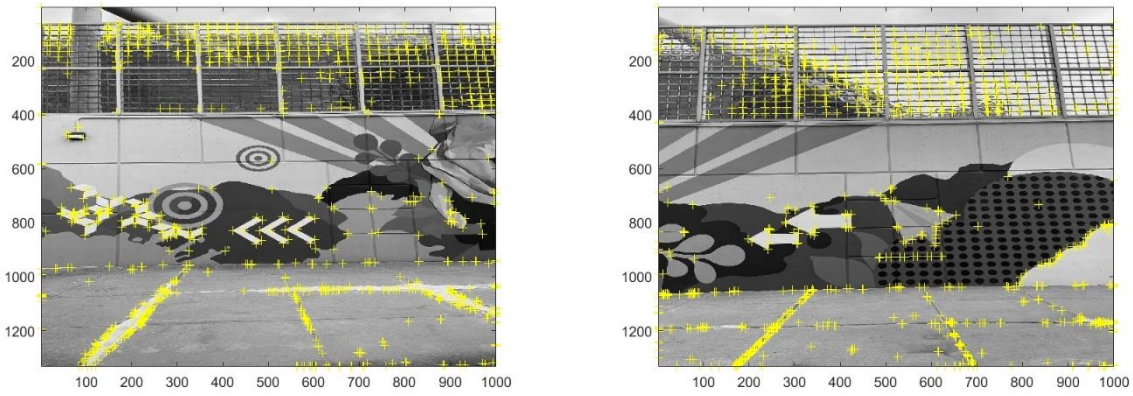

Figure 12:Harris Corner Detection

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We see in the final mosaic image that the stitching is not that good. This is because we used 50% overlapping instead of any higher rate and hence the bad results from the algorithm.

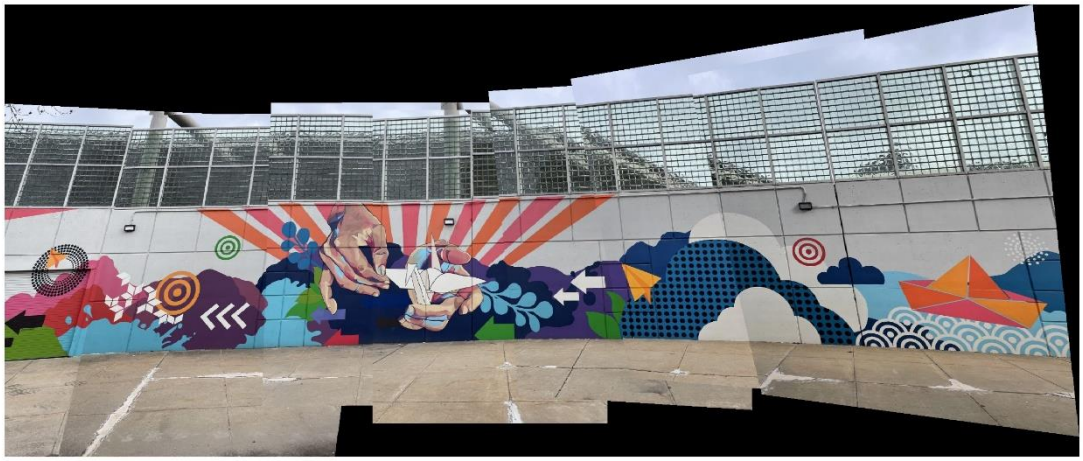

Figure 13: Ruggles Mosaic with 15% overlapping

Ruggles Mural Mosaic (50% overlap)

We use the same default parameters as above but this time we take the images with 50% overlapping to form our mosaic instead of 15%.

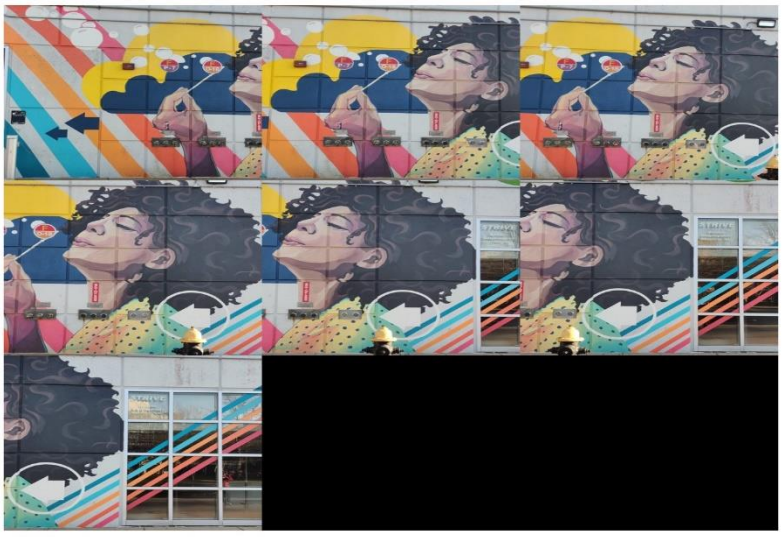

Figure 14:Primary images of Ruggles mural with 50% overlapping

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The Harris Corner Detector has 1,000 characteristics and uses a two-row, two-column "tile" technique. The characteristics were evenly spaced out throughout the picture. The distribution of the features across the image using the tile method gave the features a non-maximal suppression effect. We observe that the clarity of corner detection is somewhat precise with there not being many corners but there are some distortions.

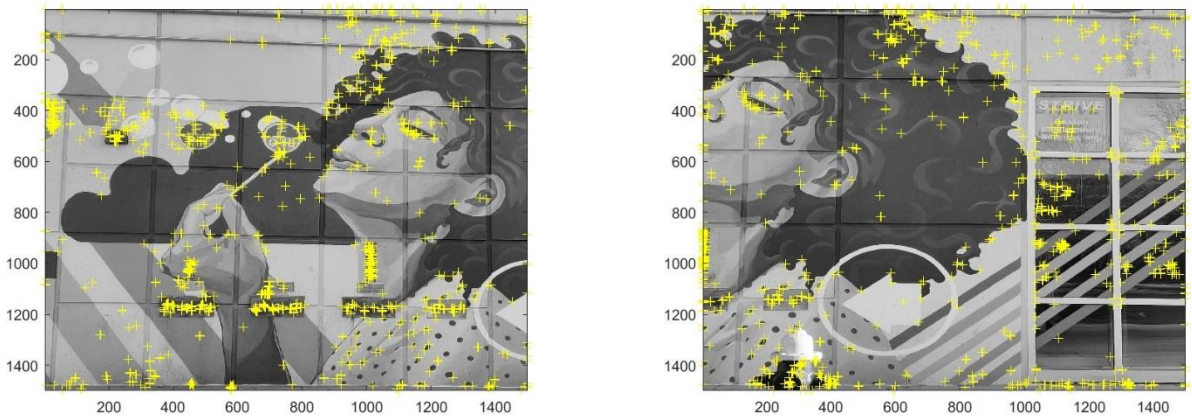

Figure 15:Harris corner detection

In the final stitching, we observe that the mosaic formed by the algorithm is more precise and better formatted than that of the mural with 15% overlapping when using harris corner detector

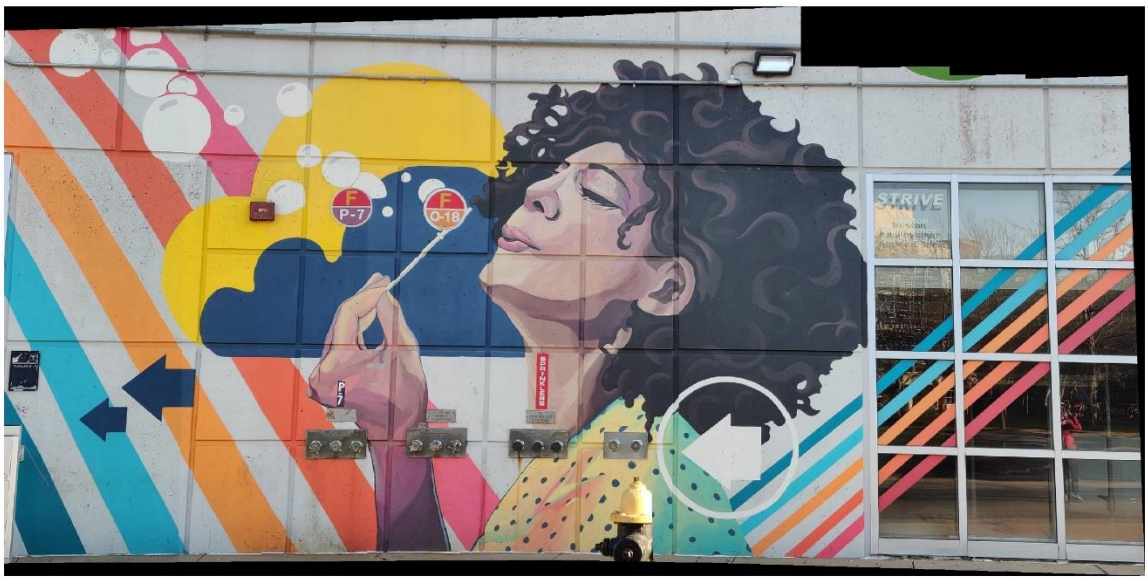

Figure 16: Ruggles Mosaic with 50% overlapping

with 1000 feature. The pattern and overlapping helps in better mosaicking of the image and hence the output is more on point.

Conclusion

In this lab we learnt in-depth about camera calibration and working on photo mosaicking. We learnt that as the growth of technology took place, we did not have to make any calibrations as the modern day cameras are pre-calibrated. We learnt how to use harris corner detection and features through this lab which helped in image stitching and mosaicking. Through the lab we found out that with the same number of harris features used, we get a better output through greater overlapping. Also, in the cinder wall experiment we found out that due to due to the repetitive pattern we had to use much more harris features than in other experiments to help is blend better.