LAB 5

Camera Mosaic

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1. CAMERA CALIBRATION

Camera calibration is the process of determining the relationship between the 3D world coordinates and the 2D image coordinates captured by a camera. This relationship is defined by a set of camera parameters that includes the intrinsic parameters, such as focal length, principal point, and distortion coefficients, as well as the extrinsic parameters, such as rotation and translation, that describe the position and orientation of the camera relative to the 3D world coordinates.

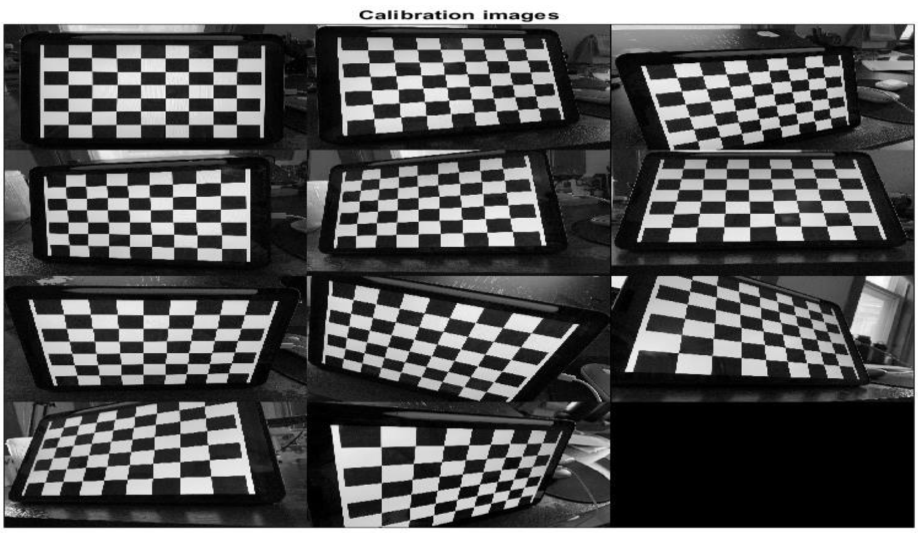
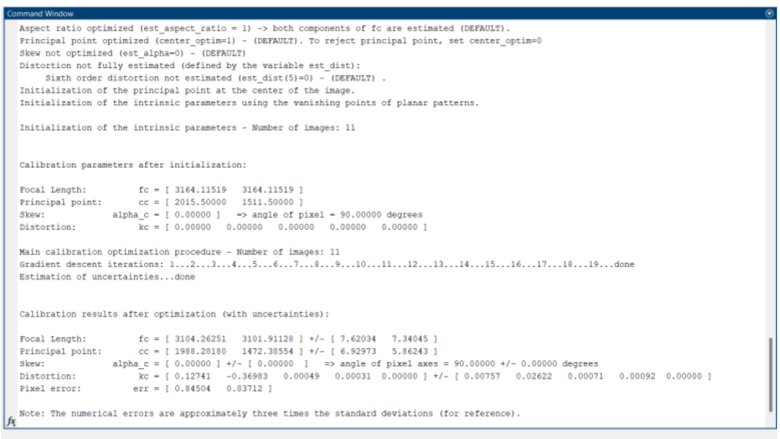


Fig 1 Camera images used for calibration.

In total 11 images of 7x9 checkerboard were taken for calibration. These 11 images were fed to Caltech Camera Calibration Toolbox. The Reprojection error after the first attempt of the calibration came out to be [**0.84504   0.83712**] which is acceptable. Since iPhone cameras are already calibrated the reprojection error is minimum.



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Command Window
Aspect ratio optimized (est_aspect_ratio = 1) -> both components of fc are estimated (DEFAULT).
Principal point optimized (center_optim=1) - (DEFAULT). To reject principal point, set center_optim=0
Skew not optimized (est_alpha=0) - (DEFAULT)
Distortion not fully estimated (defined by the variable est_dist):
     Sixth order distortion not estimated (est_dist(5)=0) - (DEFAULT) .
Initialization of the principal point at the center of the image.
Initialization of the intrinsic parameters using the vanishing points of planar patterns.

Initialization of the intrinsic parameters - Number of images: 11


Calibration parameters after initialization:

Focal Length:          fc = [ 3164.11519   3164.11519 ]
Principal point:       cc = [ 2015.50000   1511.50000 ]
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: 11
Gradient descent iterations: 1...2...3...4...5...6...7...8...9...10...11...12...13...14...15...16...17...18...19...done
Estimation of uncertainties...done


Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 3104.26251   3101.91128 ] +/- [ 7.62034   7.34045 ]
Principal point:       cc = [ 1988.28180   1472.38554 ] +/- [ 6.92973   5.86243 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000  ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.12741   -0.36983   0.00049   0.00031  0.00000 ] +/- [ 0.00757   0.02622   0.00071   0.00092  0.00000 ]
Pixel error:          err = [ 0.84504   0.83712 ]

Note: The numerical errors are approximately three times the standard deviations (for reference).
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Fig 2 Calibration Result

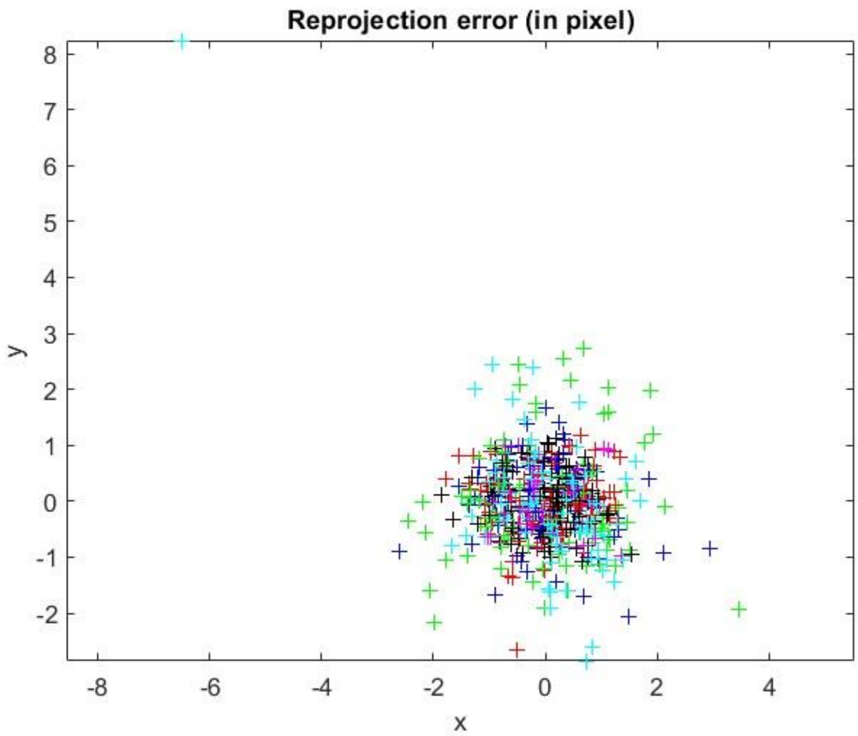

Fig 3 Reprojection error

1.2 CALIBRATION PARAMETERS

Calibration parameters are the set of intrinsic and extrinsic parameters that define the relationship between the 3D world coordinates and the 2D image coordinates captured by a camera. The intrinsic parameters describe the internal characteristics of the camera, including:

- Focal length: the distance between the lens and the image plane, which affects the magnification of the image. **Fc = [3104.26251 3101.91128] +/- [7.62034 7.34045]** after optimization.
- Principal point: the intersection of the optical axis with the image plane, which defines the image centre. **Cc = [1988.28180 1472.38554] +/- [692973 5.86243] after optimization**
- Skew: The skew parameter describes the non-orthogonality between the x and y axes of the image plane. In an ideal camera model, the x and y axes are orthogonal, but in real-world cameras, there can be manufacturing imperfections or mechanical misalignments that introduce a slight skew. This skew can cause a distortion in the shape of objects in the image, making them appear slanted or tilted**. Alpha_c [0.0000]. Angle of pixel = 90.00000 degree** after optimization.
- Lens distortion: the nonlinear distortions introduced by the lens that cause straight lines to appear curved in the image. **Kc = [0.12741 -0.36983 0.00049 0.00031 0.00000] +/- [0.00757 0.02622 0.00071 0.00092 0.00000]** after optimization.

The extrinsic parameters describe the position and orientation of the camera relative to the 3D world coordinates, including:

- Translation vector: the vector that defines the position of the camera in the 3D world coordinates.
- Rotation matrix: the matrix that describes the orientation of the camera relative to the 3D world co-ordinates.

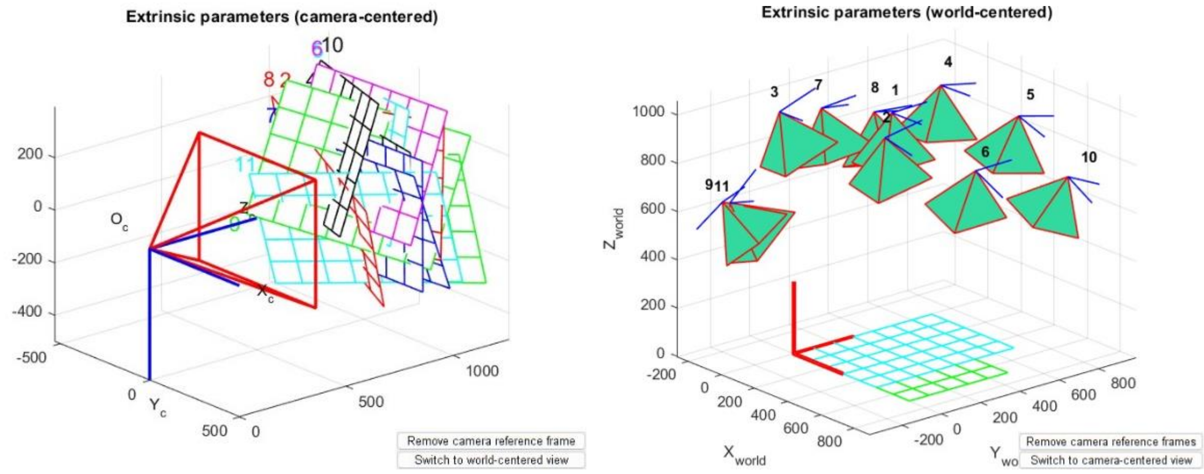

Fig 4 Extrinsic Parameters

Calibration parameters are typically estimated using a calibration process that involves capturing images of a calibration target, analysing the images to extract the corresponding feature points, and then solving for the parameters using mathematical algorithms such as least-squares optimization. Once the calibration parameters are determined, they can be used to convert the 2D image coordinates to 3D world coordinates and vice versa, which is useful for many computer vision tasks such as object tracking, stereo reconstruction, and augmented reality.

Fig 5 Before Calibration (Original Image)

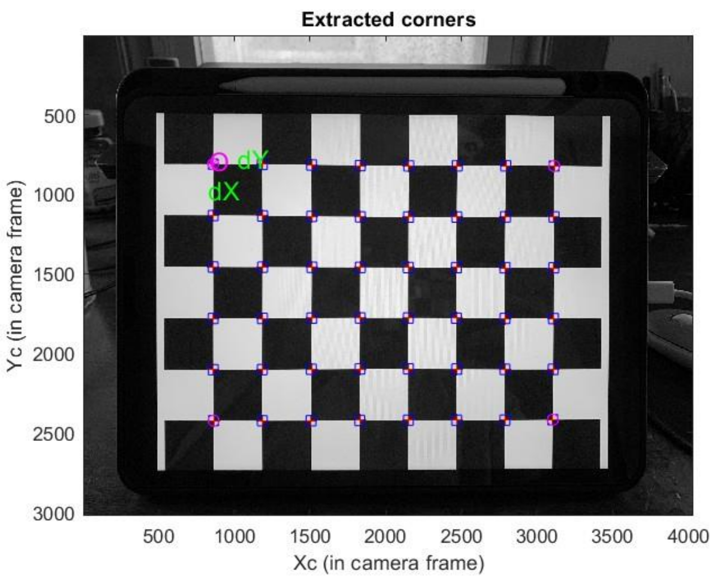

Fig 6 After Calibration with extracted corners

The precision of extracted corner is very high because of minimum pixel error. The photos are taken from iPhone which is already calibrated camera by Apple.

2. Image Mosaicing

Image mosaicing is the process of stitching together multiple images of the same scene to create a larger, panoramic view. The goal of image mosaicing is to seamlessly blend the individual images into a single, wide-angle image that captures more of the scene than any single image could.

Image mosaicing has a wide range of applications, including in photography, surveillance, virtual tours, and robotics. It is a challenging problem in computer vision due to the need to accurately register and blend the images while maintaining a consistent geometry and minimizing visual artifacts.

2.1. Mural images on the Latino Student Centre Building

The pictures were taken on Forsyth Street. Before, the 'Undistort image' feature of the calibration tool could be used to correct for camera distortions, but the subsequent photos produced by the toolbox would only be in black and white.

However, modern smartphone cameras have improved to the point that they already deliver us with undistorted photographs; attempting to undistort an image using the toolbox will just result in the image becoming even more distorted and bending toward the corner.

Fig 7 Latino Student Centre images for Calibration

Total of 7 images where taken which are undistorted since the camera used is highly calibrated.

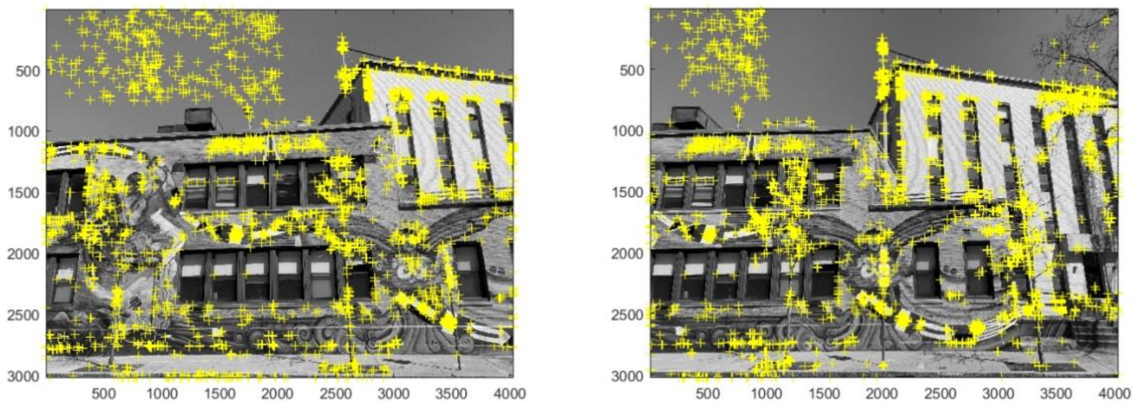

Fig 8 Harris feature detector samples

The Harris Corner Detector was set with 5,000 features, and 'tile' approach of 4 rows and 4 columns. The features were distributed sufficiently across the image. The tile approach distributed the features across the image, which provided a non-maximal suppression effect to the features.

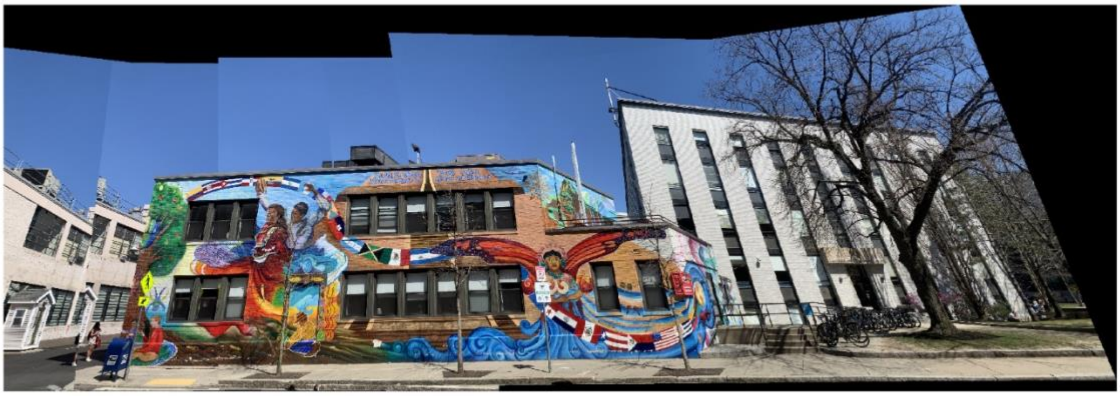

Fig 9 Final LSC Mosaic

From the Fig. 9 it is obvious that the panorama creation is successful, and the images are stitched properly. The final image is best aligned near the buildings. However, some misalignment is present in between first and second image. The main reason for this misalignment can be due lack of features present in sky. Due lack of feature it is difficult to align two images and hence a mismatch can be seen.

2.2. Brick wall behind Shillman hall

A set of 5 images where taken of brick wall behind the Shillman hall. All the images are undistorted.

Fig 10 Brick wall images for calibration

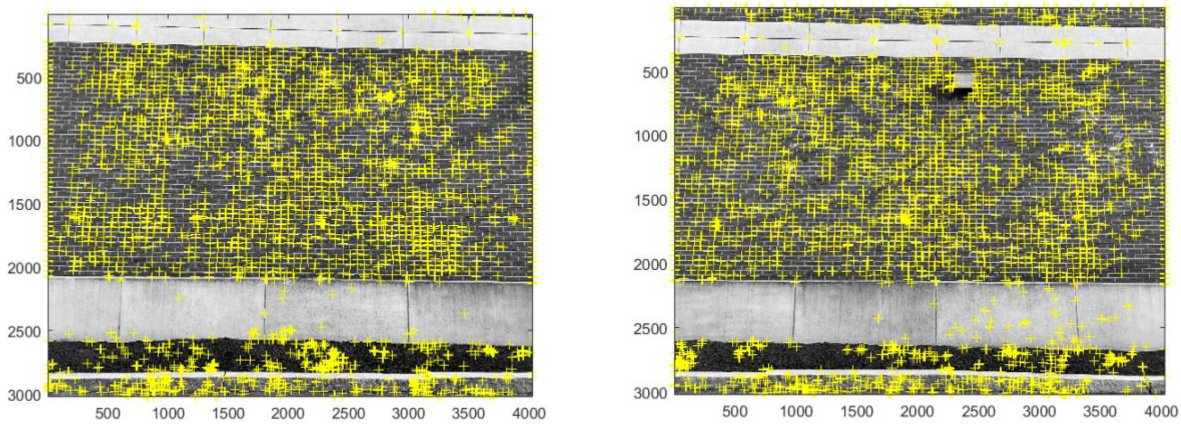

Fig 11 Harris corner detector samples

The Harris Corner Detector was set with 3000 features, and ‘tile’ approach of 4 rows and 4 columns. The tile approach distributed the features across the image, which provided a nonmaximal suppression effect to the features.

Fig 12 Final Brick wall mosaic

Comparing the brick wall performance with LSC mosaic we can say that the alignment in LSC mosaic more precise because it has many features which are not similar hence the algorithm does not get confused and aligns the images almost perfectly. But in case of brick wall mosaic we can see that the alignment is not precise and because it has more similar features and hence the algorithm gets confused while aligning the images.

2.3 Ruggles Mural with 50% Overlapping

A set of 6 photos were captured at Ruggles with 50% overlapping. The parameters used for implementation of these part are the default ones.

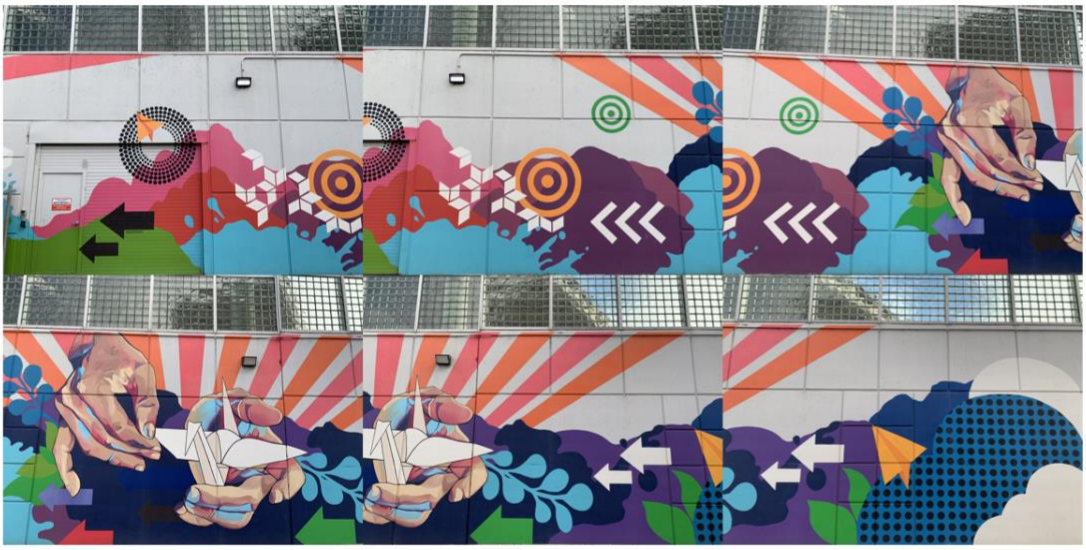

Fig 13 Ruggles Mural 50% Overlapping Images for Calibration

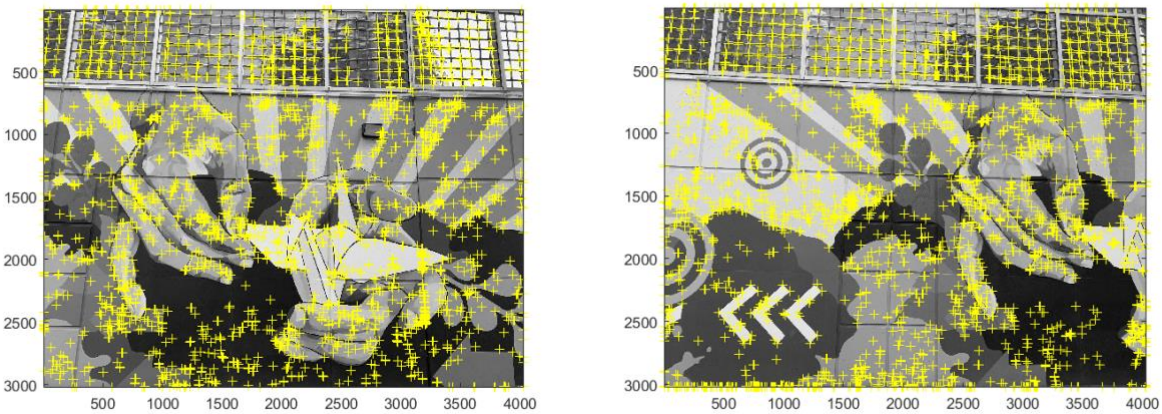

Fig 14 Harris Feature Detector Samples

The Harris Corner Detector was set with 3,000 features, and 'tile' approach of 4 rows and 4 columns. The features were distributed sufficiently across the image. The tile approach distributed the features across the image, which provided a non-maximal suppression effect to the features.

Fig 15 Ruggles Mural 50% Overlapping Panaroma

2.4 Ruggles Mural with 15% Overlapping

A set of 6 photos were captured at Ruggles with 15% overlapping. The parameters used for implementation of these part are the default ones.

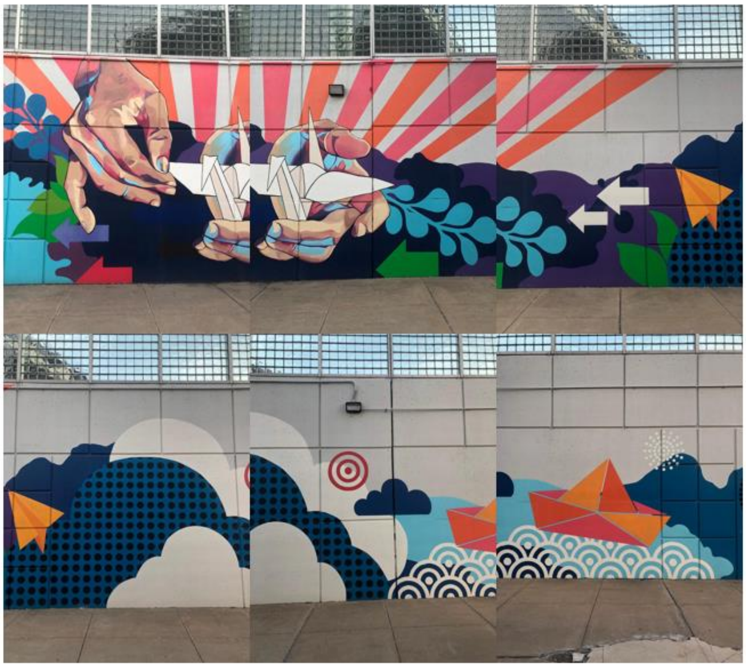

Fig 16 Ruggles Mural 15% Overlapping Images for Calibration

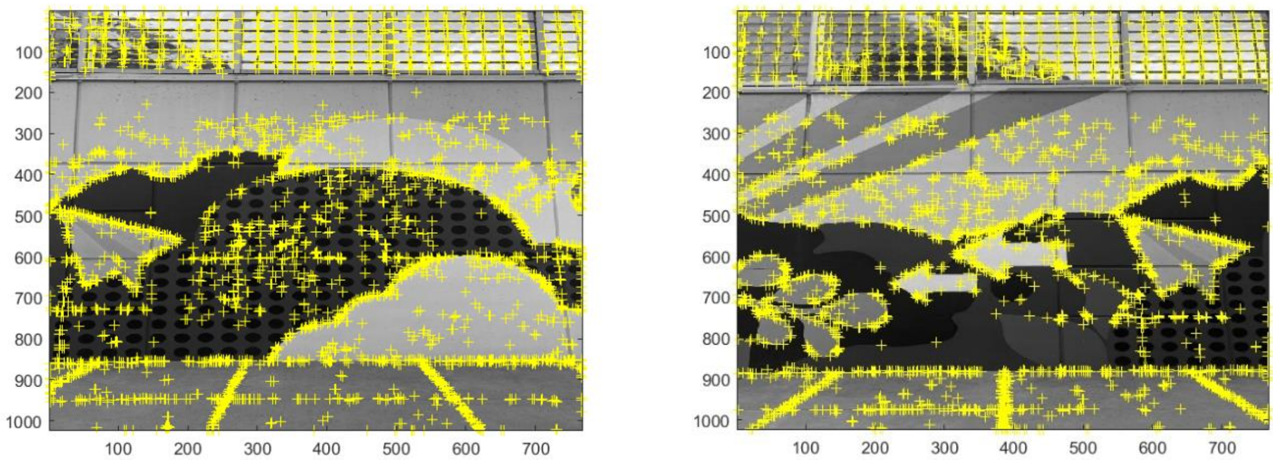

Fig 17 Harris Feature Detector Samples

The Harris Corner Detector was set with 3,000 features, and ‘tile’ approach of 2 rows and 2 columns. The features were distributed sufficiently across the image. The tile approach distributed the features across the image, which provided a non-maximal suppression effect to the features.

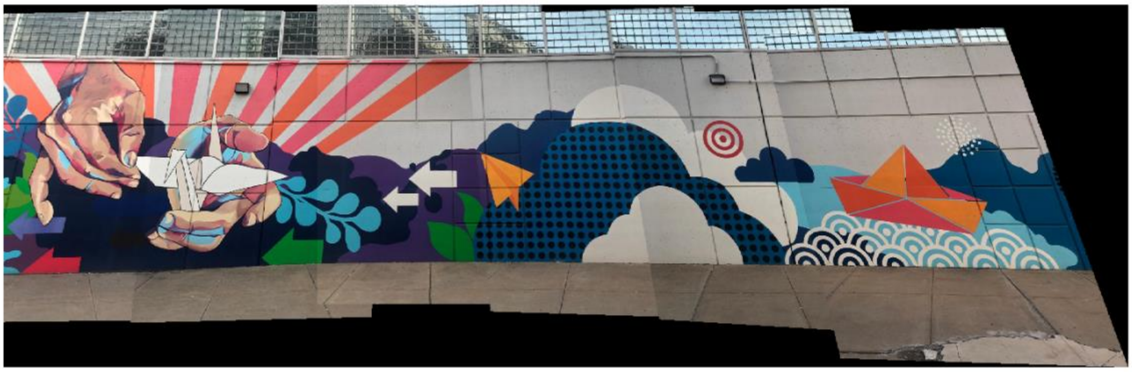

Fig 18 Ruggles Mural 15% Overlapping Panaroma

If we use a Harris Corner Detector with 3000 features, 50% overlapping stitching is substantially better than 15% overlapping stitching. It demonstrates a poor performance of the mosaicking method at 15% overlap. It is challenging to merge the photographs in the right order because numerous feature points are in the upper portion of the image, which is entirely made up of the cage's repetitive square pattern. It is challenging to blend because of the pattern's synchronization.

3. CONCLUSION

In conclusion, this assignment has provided valuable insights on various aspects of image processing, specifically on Harris corner detector and image mosaic algorithms. As a result of this assignment, I have learned how a Harris corner detector operates, how to identify corner features in an image, and the functioning of image mosaic algorithms. Additionally, I have gained practical experience in applying image mosaic algorithms to stitch together a mural photograph. Finally, I am now able to articulate what scenes/images will work well or poorly for image mosaicing. Overall, this assignment has provided me with a comprehensive understanding of these image processing concepts, which will undoubtedly prove useful in my future endeavors.

4. REFERENCES

• https://www.mathworks.com/help/vision/ug/camera-calibration. html

• https://www.mathworks.com/help/vision/ug/feature-based-panoramic-imaghtml

• https://data.caltech.edu/records/jx9cx-fdh55 • https://szeliski.org/Book/