CAMERA MOSAIC

CALIBRATION

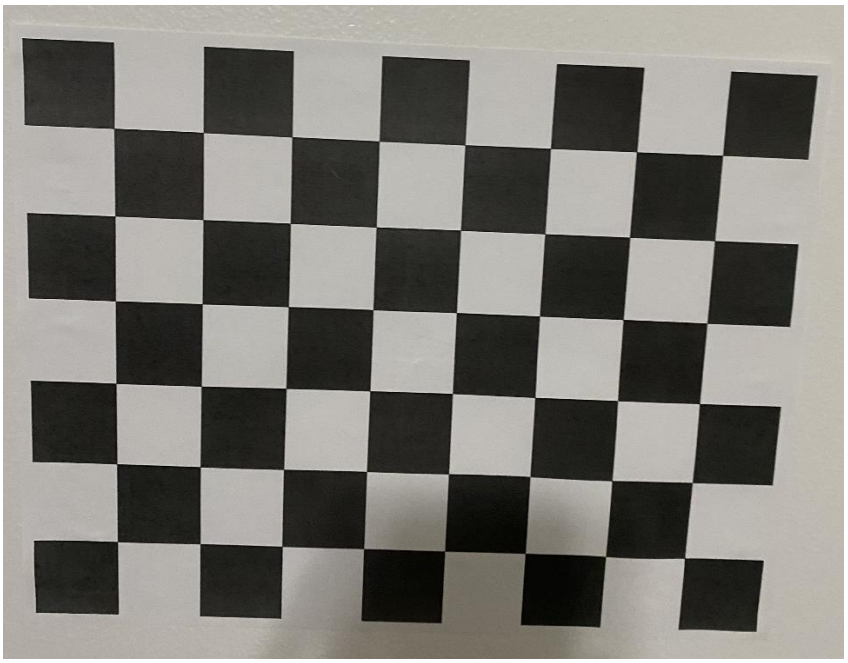

Fig.1 Checkerboard image before calibration

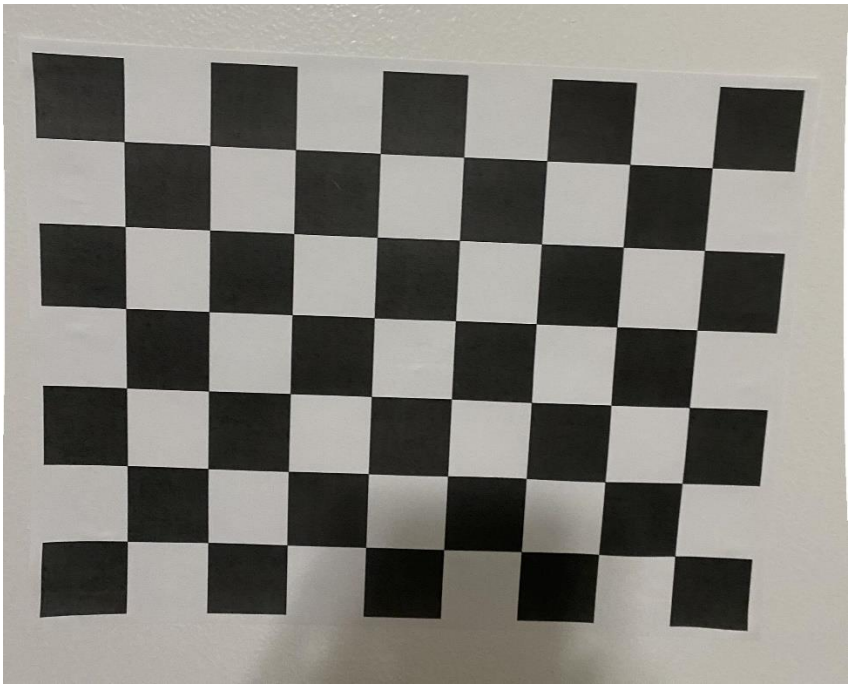

Fig. 2 Checkerboard Image after calibration

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Calibration parameters after initialization:

Focal Length:          fc = [ 3135.54840   3135.54840 ]
Principal point:       cc = [ 1511.50000   2015.50000 ]
Skew:             alpha_c = [ 0.00000 ]   => angle of pixel = 90.00000 degrees
Distortion:            kc = [ 0.00000   0.00000   0.00000   0.00000   0.00000 ]
```

Fig. 3 Calibration Parameters

```
Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 3054.26112   3061.48514 ] +/- [ 11.16243   9.96807 ]
Principal point:       cc = [ 1541.05215   2007.82972 ] +/- [ 9.57233   9.23571 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000  ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.14062   -0.45841   0.00310   0.00126  0.00000 ] +/- [ 0.00951   0.03737   0.00123   0.00130  0.00000 ]
Pixel error:          err = [ 1.02260   0.96880 ]
```

Fig. 4 Reprojection Errors and Uncertainties

LSC MOSAIC

Fig.5 Montage of Images captured at LSC

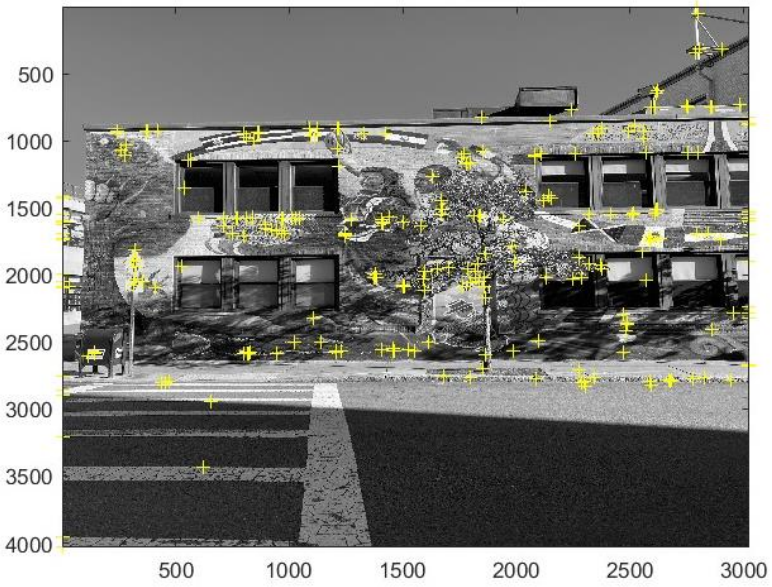


Fig. 6 Harris Corner Detection for Image 2

Fig. 7 Panorama after Stitching of LSC Images

Adjustments needed for stitching LSC Images

The adjustments primarily were seen in the hyper-parameters of the Harris Corner Detection algorithm.

1. Initially, the “tile” parameter in the Harris Corner detection was set as [1 1] with the maximum number of points as 500. This led to the trees in the scene attracting the greatest number of corners, while the rest of the scene was bereft of detected corners. This resulted in a poor stitch.
2. So, the “tile” was increased to [10 10] – creating 100 windows to force the algorithm to search more uniformly. This resulted in better distributed features, which created a good panorama. However, this set of parameters also detected corners at relatively flat regions such as the sky. A higher thresholding was needed.
3. So, the threshold was increased to $2x10^7$, and maximum number of detected points was reduced to 500, which eliminated unnecessary corners. See Figure 6.

Since, the road had no features to match, its stitching is not perfect. However, the building structure is patched.

CINDER WALL MOSAIC

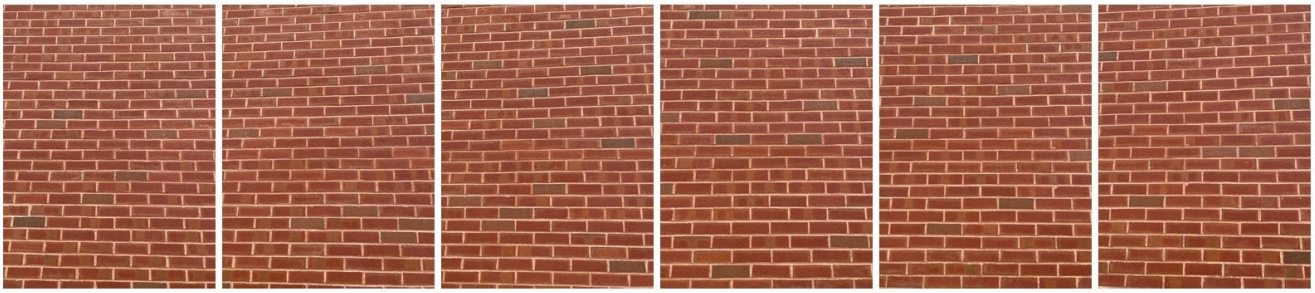


Fig. 8 Montage of Images of a brick wall near Shillman Hall

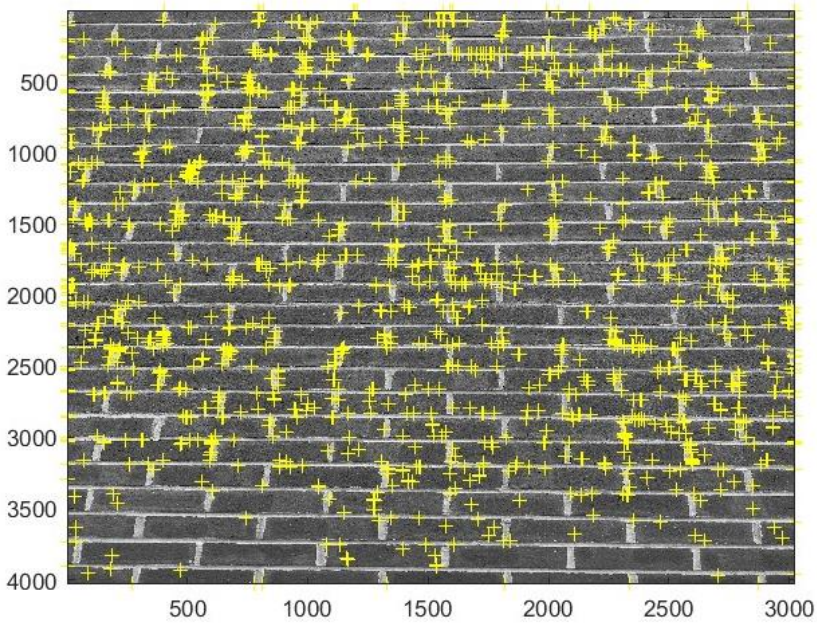
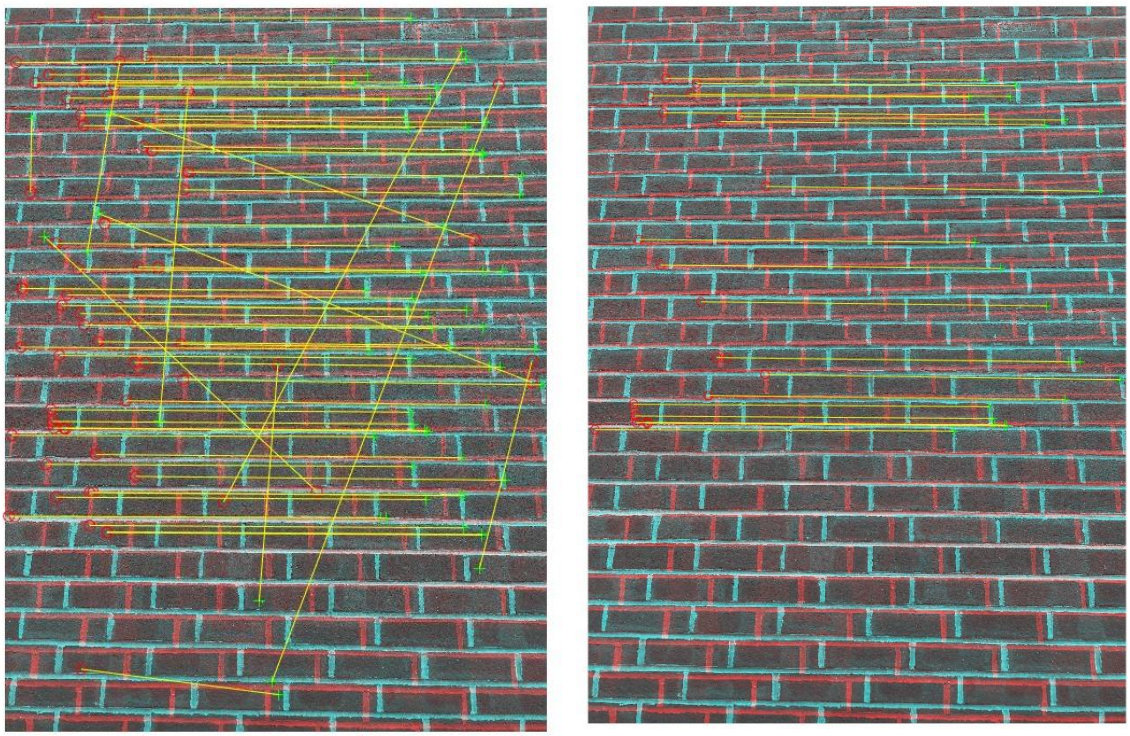


Fig. 9 Harris Corner Detection for Image 1

Fig. 10 Stitching of cinder wall

Comparison of Performance with LSC Mural

1. Setting the "tile" parameter to [1 1], threshold to $2x10^7$ and maximum number of points to 500 yielded a uniform distribution of corners. See Figure 9.
2. The subsequent feature extraction and feature matching also proceeded without any hitch owing to the ample number of corners to draw from, even after setting stringent corner detection parameters including a high threshold value.
3. The reason for this is the absence of outstanding and sharp features such as trees or patterns in the wall.
4. Additionally, the bricks are not completely uniform and a spotted with pores and other such patterns which provided unique features for feature extraction. Even so, there were many false matches. See Figure 11. However, the "estgeotform2d" function successfully weeded out the outliers using MSAC.



(a) (b)

Fig. 11 (a) Feature Matching before Outliers were removed (b) Feature Matching after outlier removal

RUGGLES MOSAIC

Fig. 12 Montage of 15% overlapping images from Ruggles Station

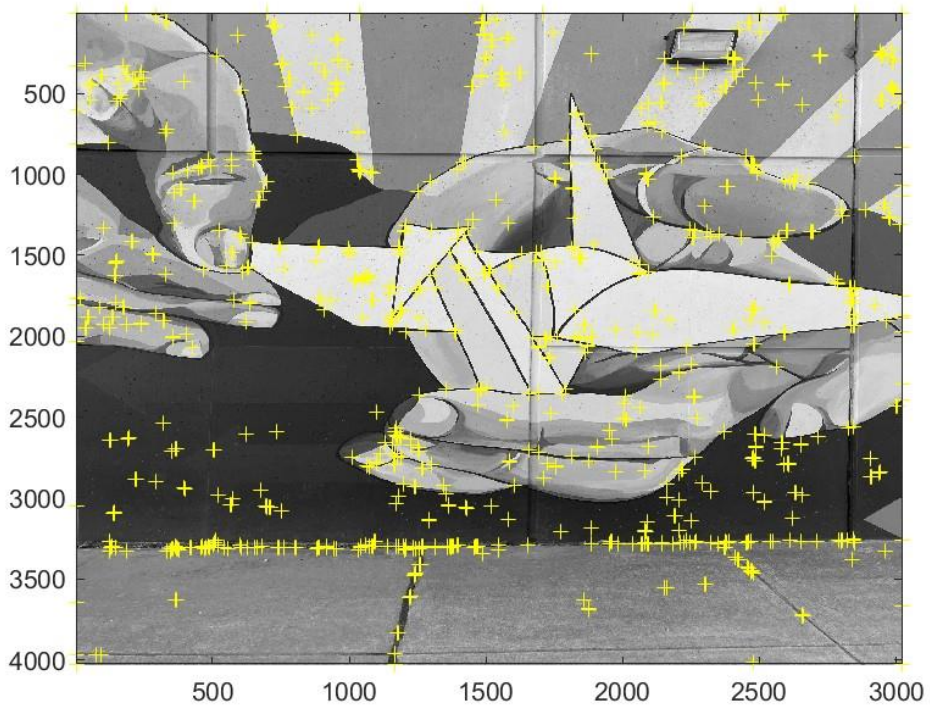


Fig. 13 Harris Corner Detection for Image 4

Fig. 14 Panorama after stitching 15% overlap images

Fig. 15 Montage of 50% overlapping images from Ruggles Station

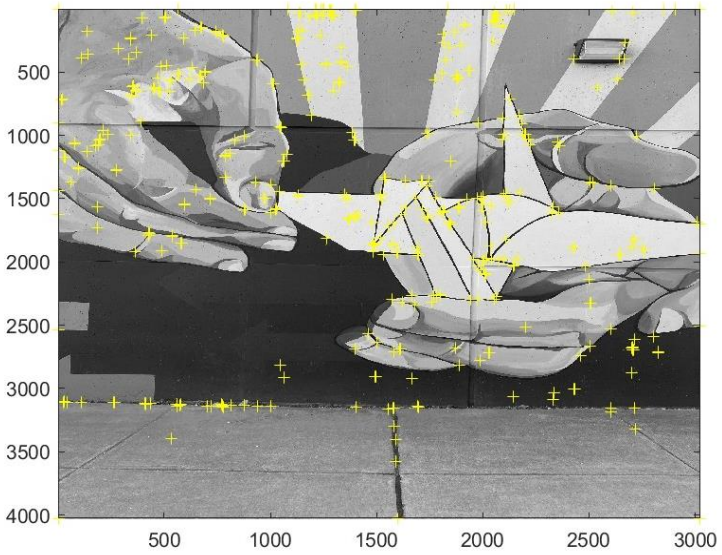


Fig. 16 Harris Corner Detection for Image 4

Fig. 17 Panorama after stitching of 50% overlap images

Performance Comparison with 15% and 50% overlap images

1. The feature extraction and feature matching are tough in this case due to minimal overlap.
2. Projective transformation calculation between successive images needs a minimum of 4 matched features. In the 15% overlap case, this was only achieved after successively decreasing the threshold and increasing the number of tiles and detected points in the Harris Corner Detector.

After these tuning, a stitching was successfully achieved. See Figure 14

50 % overlap images :

1. Feature extraction and feature matching easier due to significant overlap.
2. Even after setting highly restrictive Harris Corner Detector hyperparameters, the “matchFeatures” function was able to find matches which eventually led to a good panorama without many adjustments to the Harris Corner Detector hyperparameters.

Discussion of adjustments/modifications :

The adjustments in this exercise were solely implemented on the Harris Corner Detector. The below table summarizes them for both cases.

The 15% overlap scenario requires a much-relaxed setting of the corner detector to facilitate corner and feature detection and eventual matching. The detector was made to find more number of corners in a more distributed fashion (more tiles) with a smaller threshold.

Harris Parameters	15 % Overlap	50% Overlap
Tile	[10 10]	[1 1]
Threshold	$2x10^6$	$2x10^7$
Number of Points to detect	1000	500

The difference in the number of points is easily apparent in Figures 13 and 16.

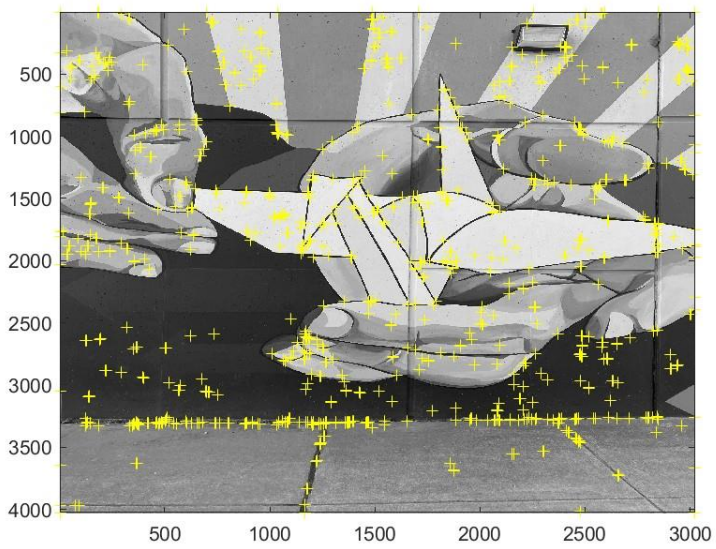


Fig. 13 (reprinted) Harris Corners Image 4 for 15 % overlap. The number of corners detected in this image is nearly twice of the same in the 2nd case.

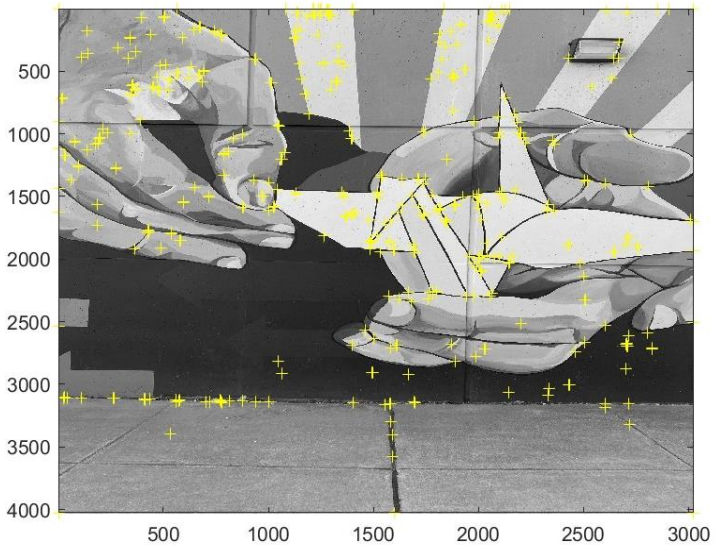


Fig. 16 (reprinted) Harris Corners Image 4 for 50 % overlap

Additional adjustments that can be made (not implemented) :

1. For the 15% overlap case, the Harris Detector can be tuned to execute only in the overlapping regions of images. This can be done if the feature matching fails later.
2. The “matchFeatures” function in Matlab has a parameter “MatchThreshold”. The threshold represents a percent of the distance from a perfect match. Setting a higher value for it represents a looser condition for feature matching.