EECE: 5554 Robot Sensing and Navigation

Lab 5: Camera Mosaic

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Chessboard camera calibration

Size of calibration images: 4032x3024

Chessboard dimensions: 9x7

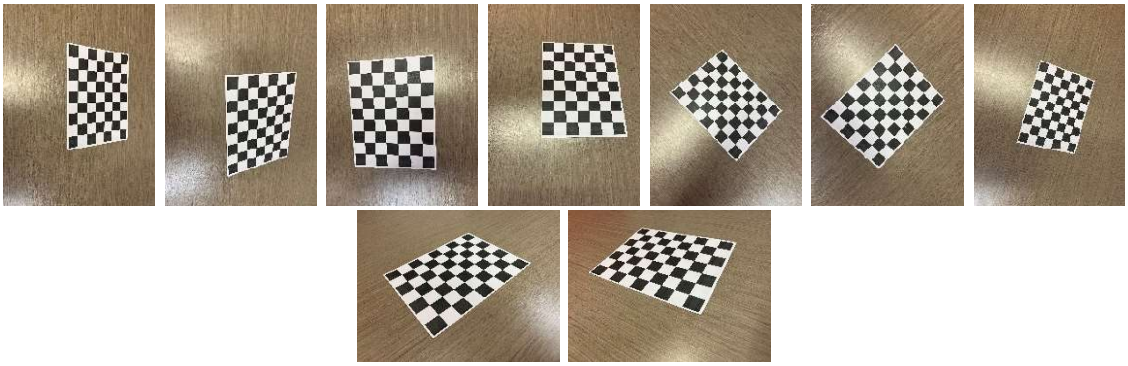

Fig.1 Calibration images captured on my phone.

I have captured 20 images in total, but I have picked a few to show how and in what orientation I captured the images.

1. Reprojection Pixel Error:

1.1 Calibration Parameter:

1.1.1 Extracting Grid Corners

The images used in the calibration process were renamed according to the syntax and proper extension of the Toolbox.

In this step, we manually select the four corners of the grid on the chessboard to help the tool identify the corner automatically. An example is shown in Fig. 2.

1.1.2 Calibration

The calibration was performed as explained in the toolbox's example page and the reprojection error was seen as shown below in Fig. 3.

The extrinsic parameters were obtained using the ***"show extrinsic"*** option in the tool. The 3D plot of the parameters is shown in Fig. 4 & 5.

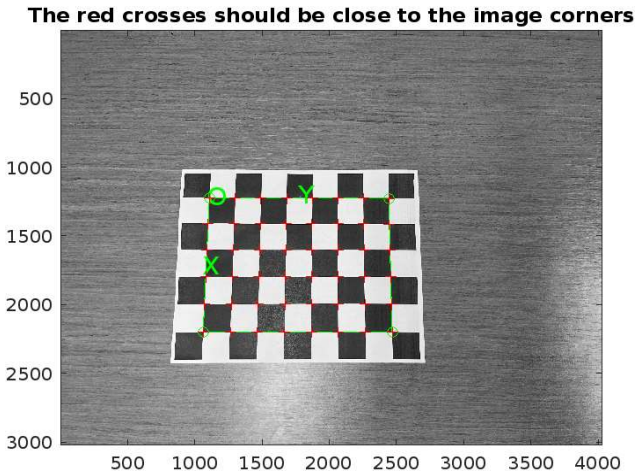

Fig. 2 Example of the corner extraction from one of the chessboard calibration images.

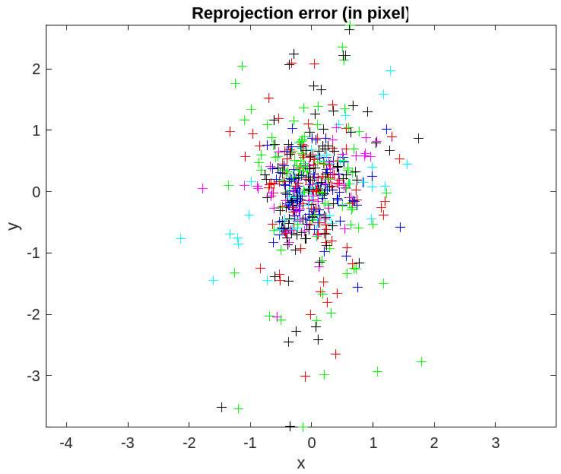

Fig. 3 Reprojection pixel error after initial optimization.

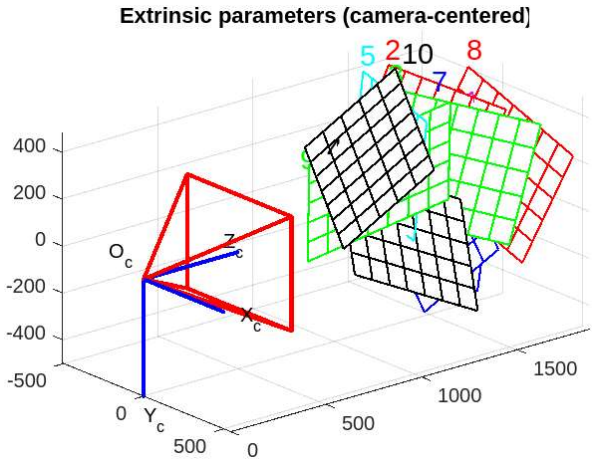

Fig. 4 Relative position of the grid with respect to the camera.

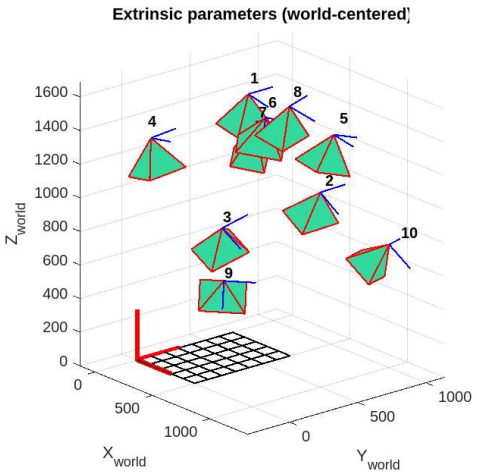

Fig. 5 Extrinsic parameters in world-centred view. The orientation and the position of the camera are denoted by the green pyramid.

There was no necessity for a second calibration as the reprojection pixel error didn't exceed 1. The pixel error was [0.54676 0.89660]. Calibration results after initial optimization are shown in Fig. 6.

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


Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 3093.31033   3097.63004 ] +/- [ 18.24432   18.26900 ]
Principal point:       cc = [ 2000.88609   1496.27269 ] +/- [ 12.98090   13.31667 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000  ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.17814   -0.70986   -0.00572   -0.00114  0.00000 ] +/- [ 0.01804   0.10907   0.00151   0.00175  0.00000 ]
Pixel error:          err = [ 0.54676   0.89660 ]

Note: The numerical errors are approximately three times the standard deviations (for reference).
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Fig. 6 Calibration results after initial optimization.

1.2 Before and after calibration.

Based on the calibration results we proceed to undistort the images. Fig. 7 shows the difference between images before and after distortion. Slight changes can be seen in the background of the chessboard but nothing with the chessboard. The reason for this might be because of our phones which will automatically filter out unnecessary distortions.

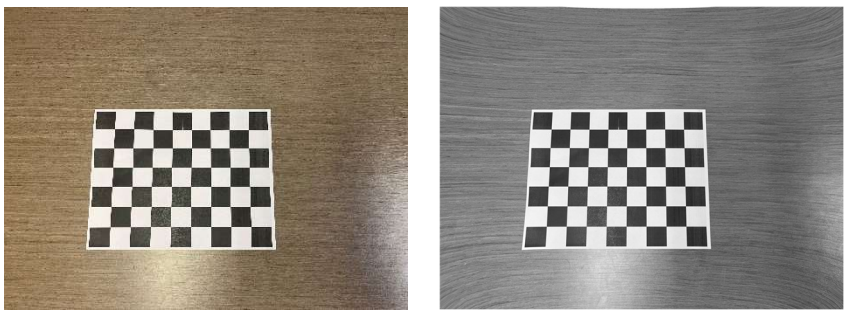

Fig. 7 Left: Before undistortion; Right: After undistortion

2. LSC Mosaic

2.1 LSC Image Set

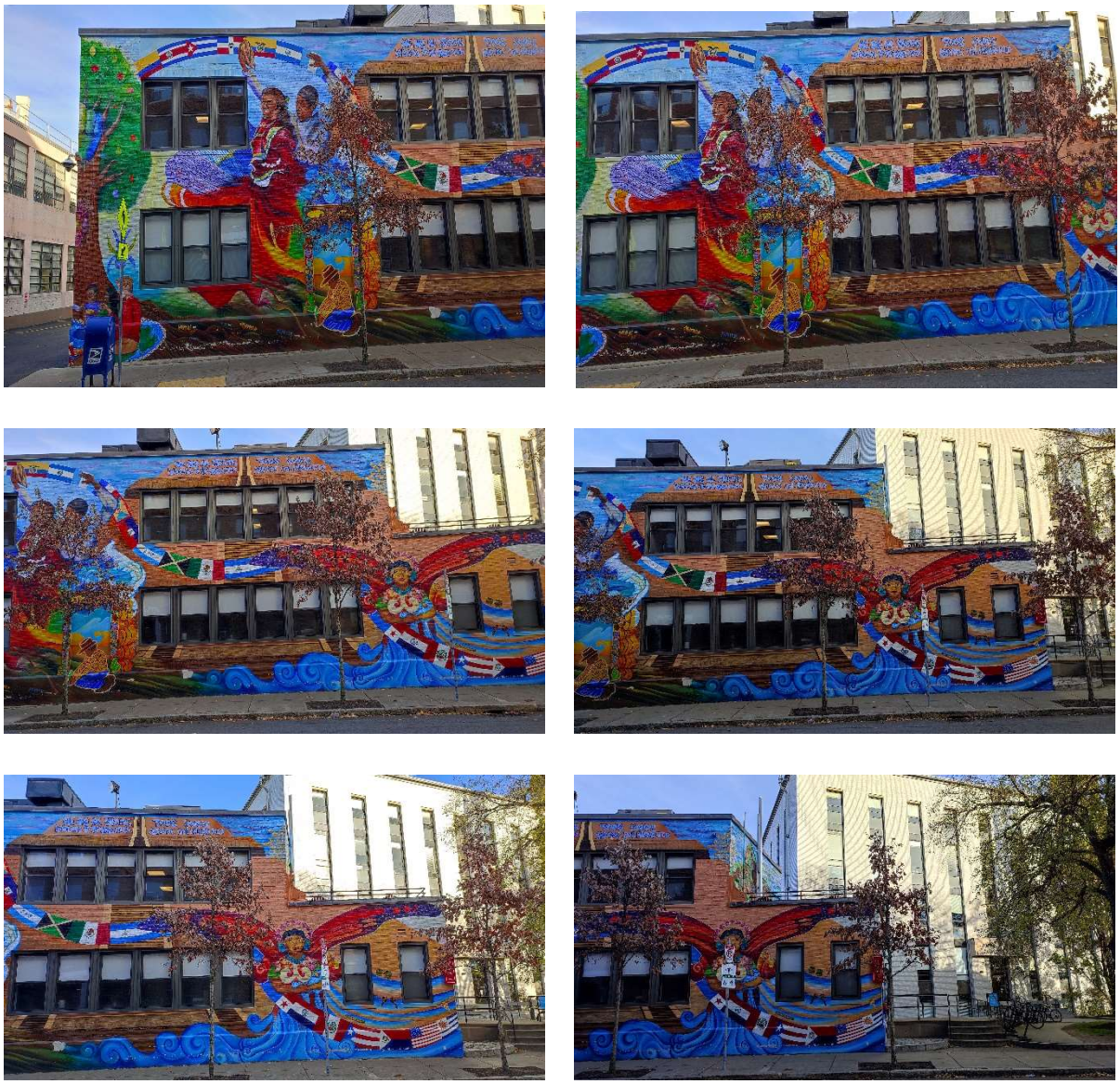

Fig. 8 Image set of the mural at LSC.

2.2 Distribution of Harris corners across the LSU dataset.

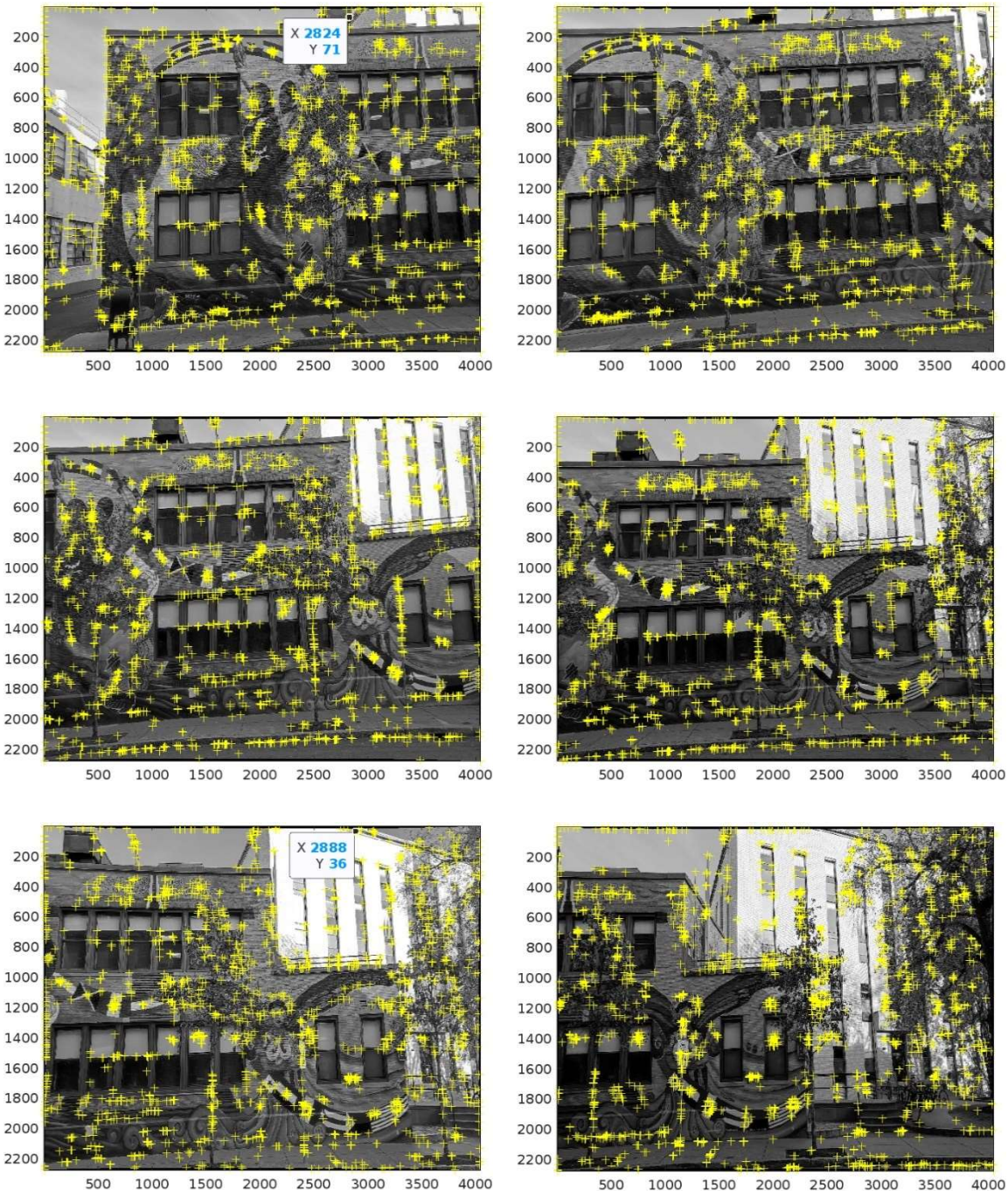

Fig. 9 Distribution of Harris corners across the LSU image dataset after applying the parameters in the harris.m file.

2.3 LSU mosaic

Fig. 10 Final output after panoramic stitching of all the images in the LSU dataset.

2.4 Discussion on the output

- All the images in the dataset were converted into grayscale and then the calibration result was used to undistort the images.
- Using the Harris corner feature detector, the feature points in the undistorted images were selected.
- Few parameters in the harris.m were adjusted to obtain the accurate results as seen above in Fig. 10.
- The parameters changed in harris.m file are:

  param.N = 2000
  param.hsize = 5
  param.tile = [10 10]

3. Brick wall mosaic

3.1 Brick wall image set

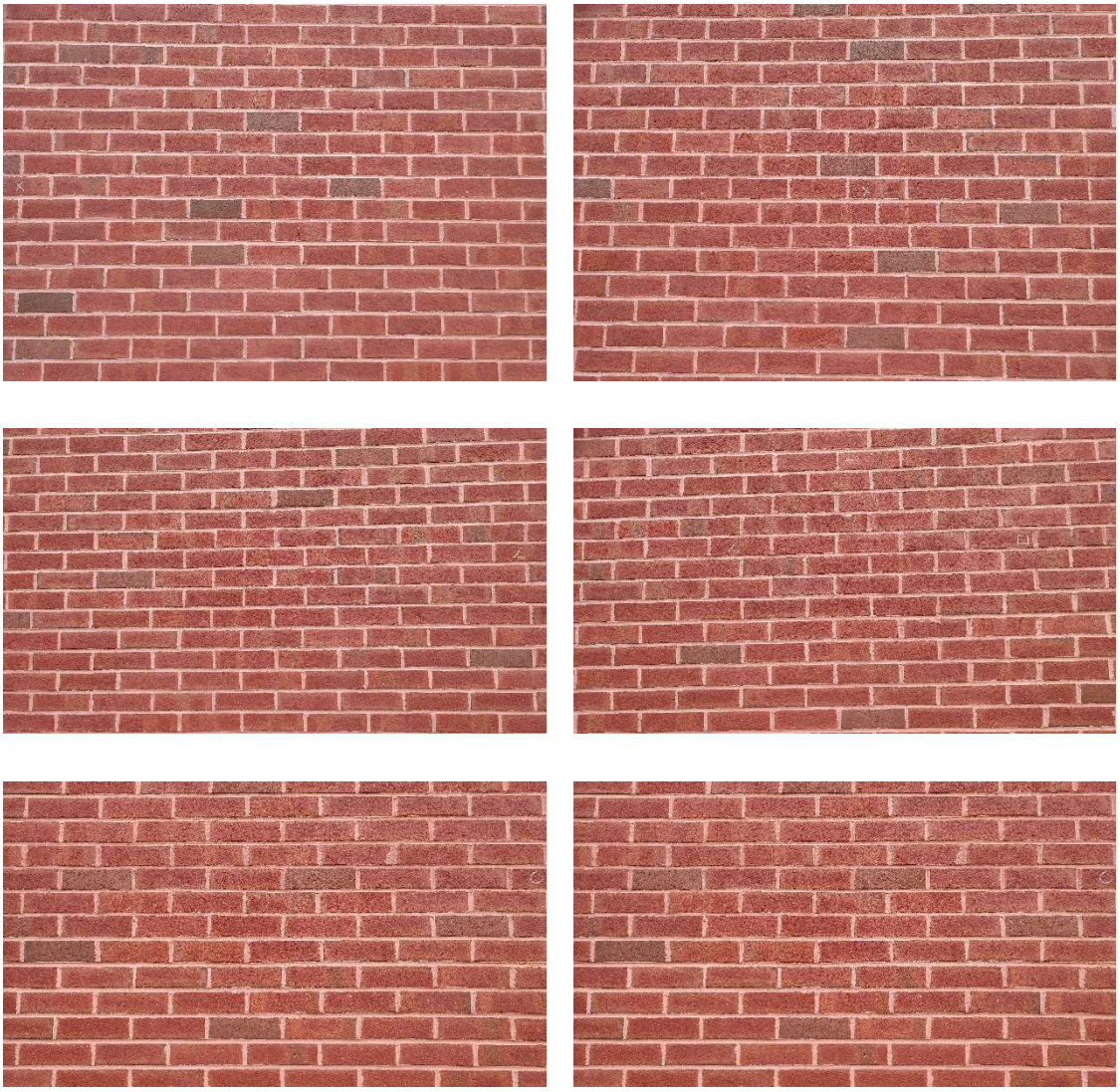

Fig. 11 This is an image of a brick wall and is arranged in the order of how it was clicked.

3.2 Distribution of Harris corners

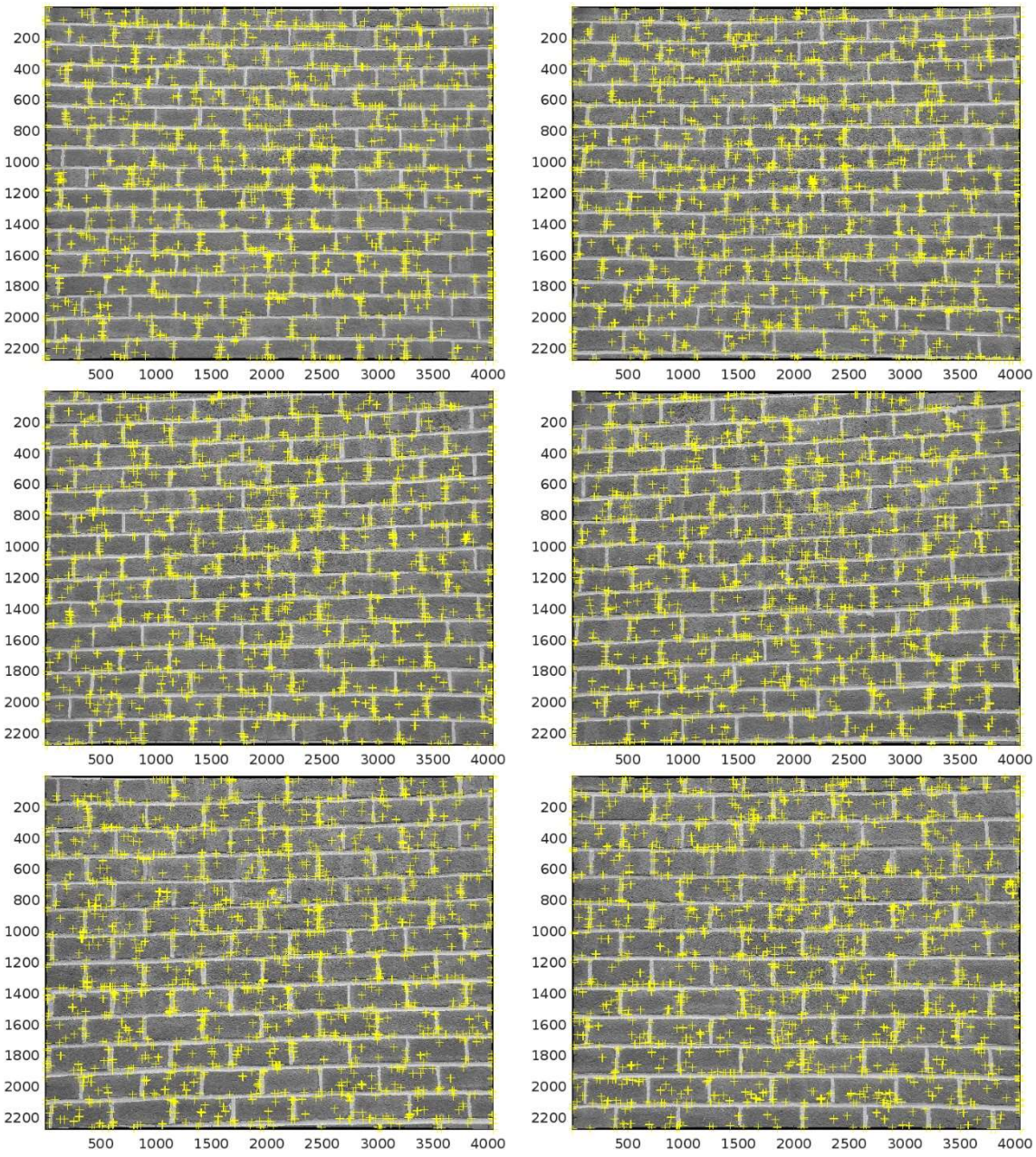

Fig. 12 Distribution of Harris corner across brick wall image set after adjusting the parameters in the harris.m file.

3.3 Brick wall mosaic

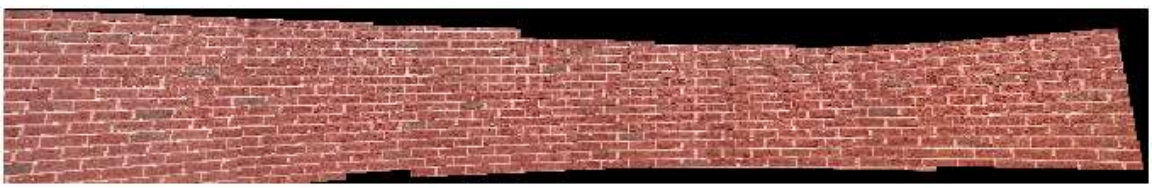

Fig. 13 Brick wall mosaic after performing panoramic stitching.

3.4 Discussion on the output

- The same parameters that were used for LSU are used in this brick mosaic as well. But the output is not the same as seen in the LSU image but the difference is very less compared to LSU.
- The row and columns of the bricks were not matched properly with the nearby image. The reason for this is because of the same texture and high similarity between the images.
- The algorithm suffers because there aren't any distinguishing features as seen in the LSU image set, every image is alike.

4. Random mosaic

4.1 Image set with 15% overlap

Location: Ruggles station

Fig. 14 These images were captured with less than 15% overlap between each image.

4.2 Image set with 50% overlap

Location: Ruggles station

Fig. 15 These images were captured with about 50% overlap between each image.

4.3 Distribution of Harris corners with 15% overlap

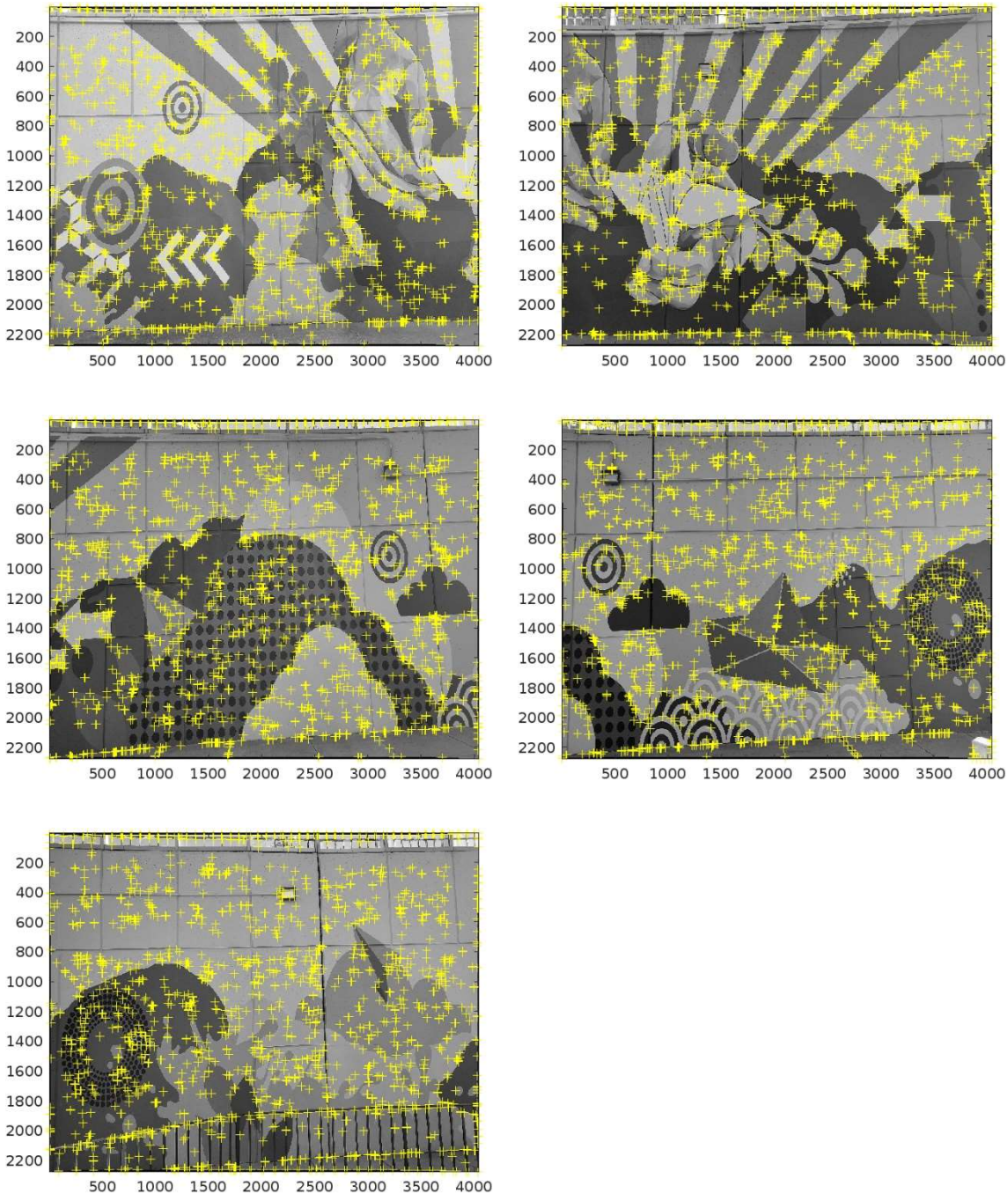

Fig. 16 Distribution of Harris corners across the 15% overlap images after applying the parameters in the harris.m file.

4.4 Distribution of Harris corners with 50% overlap

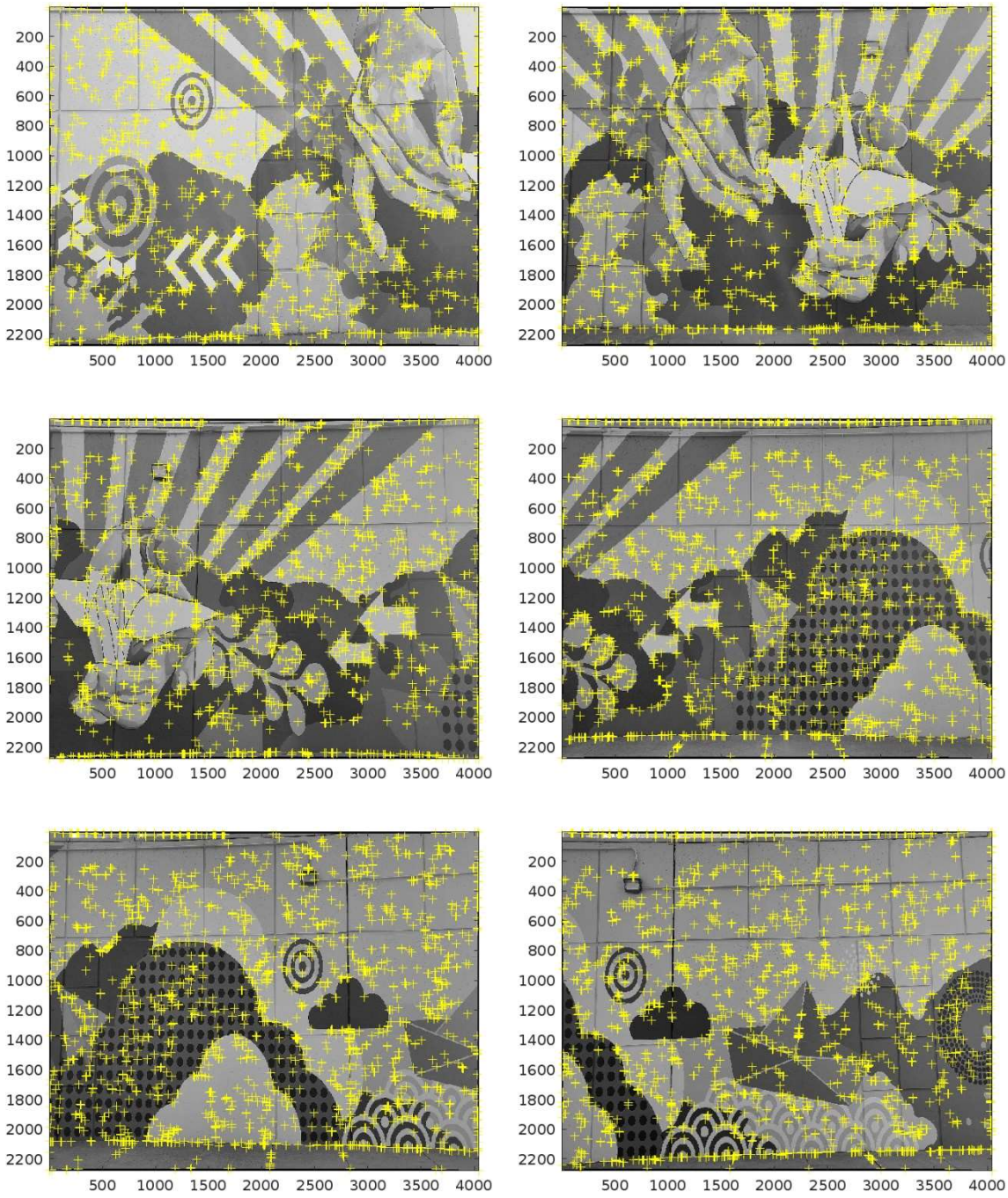

Fig. 17 Distribution of Harris corners across the 50% overlap images after applying the parameters in the harris.m file.

4.5 Final mosaic – 15% overlap

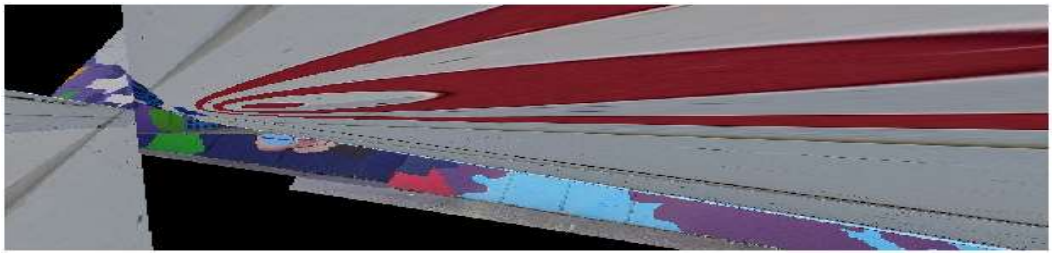

Fig. 18 Final mosaic from Ruggles with 15% overlap.

4.6 Final mosaic – 50% overlap

Fig. 19 Final mosaic from Ruggles with 50% overlap.

4.7 Discussion on the output

4.7.1 15% overlap vs 50% overlap

- Fig. 18 is the final output after adjusting the values in harris corner filter for the set of images with an overlap of less than 15%
- Fig. 19 is the final output of stitched images with about 50% overlap between each image.
- The image set with 15% overlap is poorly stitched when compared with 50% overlap images.
- The reason for the 15% overlap images performing badly is because of the low number of features was seen.

4.7.2 Description of any adjustments made

After adjustments to the parameters of the harris filter mainly the maximum number of interest points and the tile size, we were able to get the best image when using the maximum interest points as 4500 and the tile size as [30 30] pixels.

References

1. J.-Y. Bouguet, “Camera calibration toolbox for matlab,” May 2022.
2. C. Harris, M. Stephens et al., “A combined corner and edge detector,” in Alvey vision conference, vol. 15, no. 50. Manchester, UK, 1988, pp. 10–5244.