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RSN LAB 5 - Camera Mosaic

Camera Calibration

A set of 20 images of a checkerboard clicked from different perspectives is used for camera calibration. The set of images used for calibration is shown in Fig.1

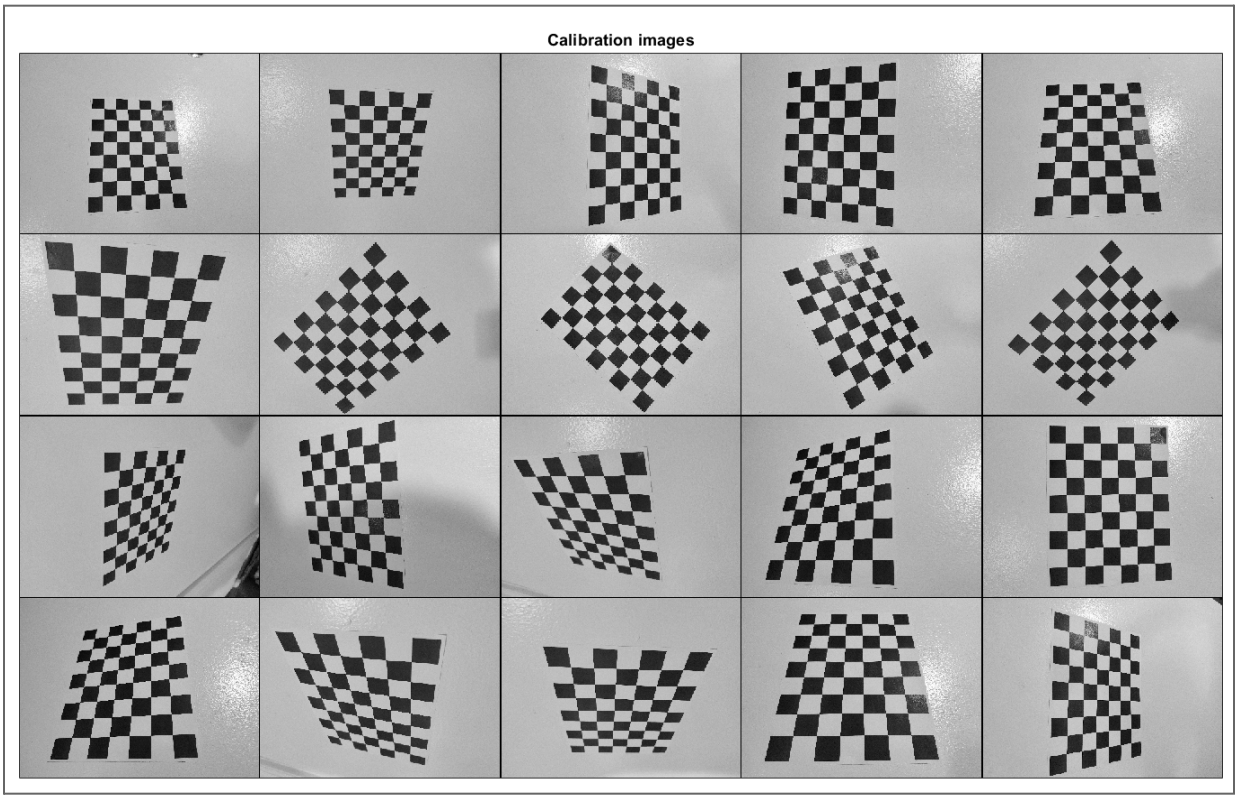

Fig. 1: Checkerboard images for camera calibration

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Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 3078.83095   3071.66188 ] +/- [ 5.50808   5.99437 ]
Principal point:       cc = [ 1993.56037   1481.80596 ] +/- [ 5.72633   6.31689 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000  ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.12672   -0.46302   0.00192   0.00055  0.00000 ] +/- [ 0.00810   0.03601   0.00084   0.00080  0.00000 ]
Pixel error:          err = [ 0.80784   0.80234 ]

Note: The numerical errors are approximately three times the standard deviations (for reference).
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Fig. 2: Intrinsic parameters estomated after calibration

The images used for calibration have the dimensions 4000 x 3000. Considering the large size of the images, a pixel error of [0.80784 0.08234] seems reasonable. A plot of reprojection errors for all of the images is shown in Fig. 3

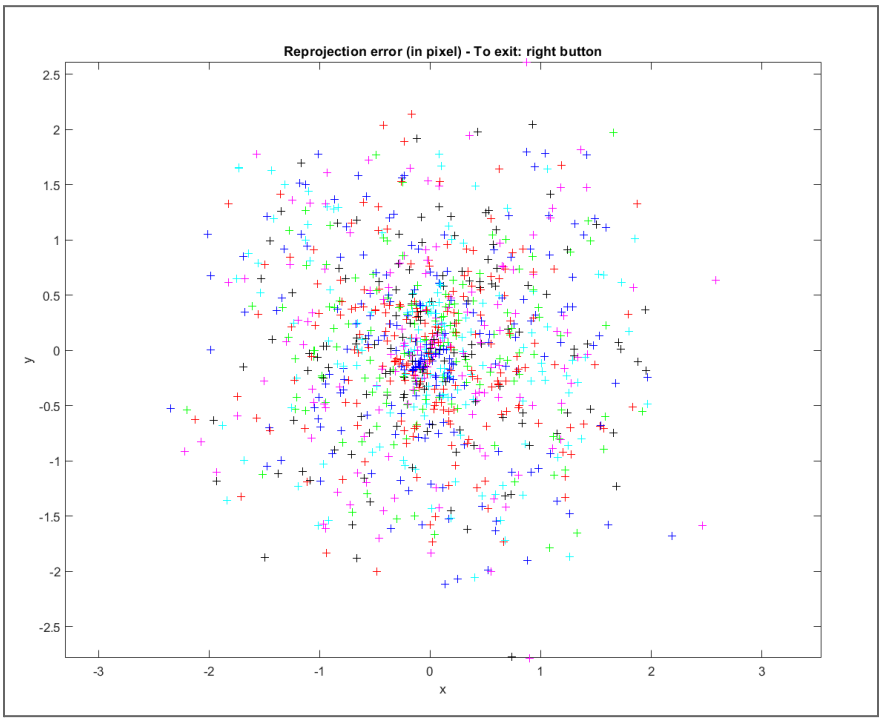

Fig. 3: Reprojection error for all calibration images

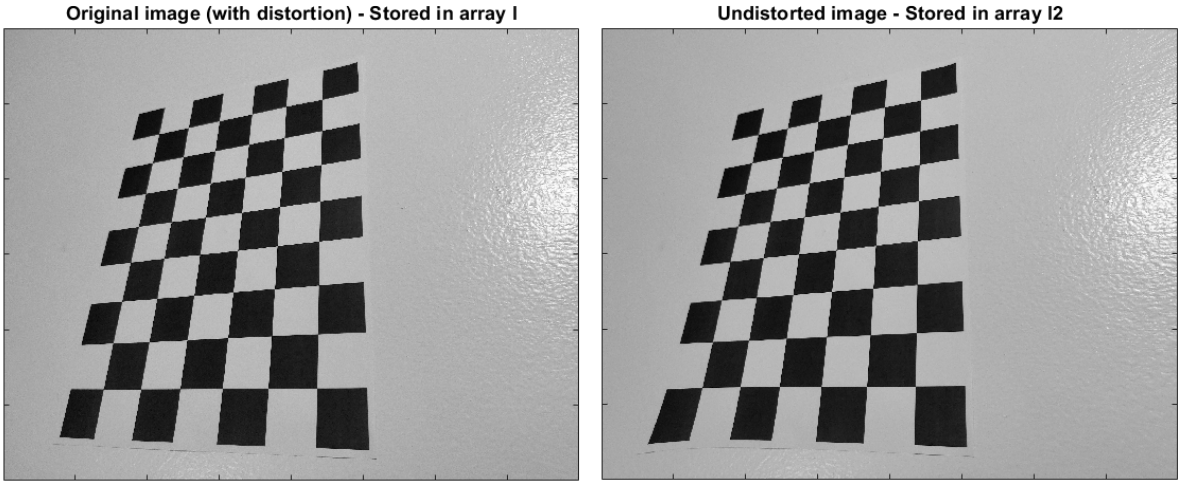

Fig. 4: Image of checkerboard before and after calibration

After calibrating (undistorting) the image, it can be seen that the calibrated image is warped around the edge. The reason for this could be that the image clicked from the camera is already calibrated, and hence applying the calibration again on the image would actually cause the warping.

Mural on Latino Student Centre

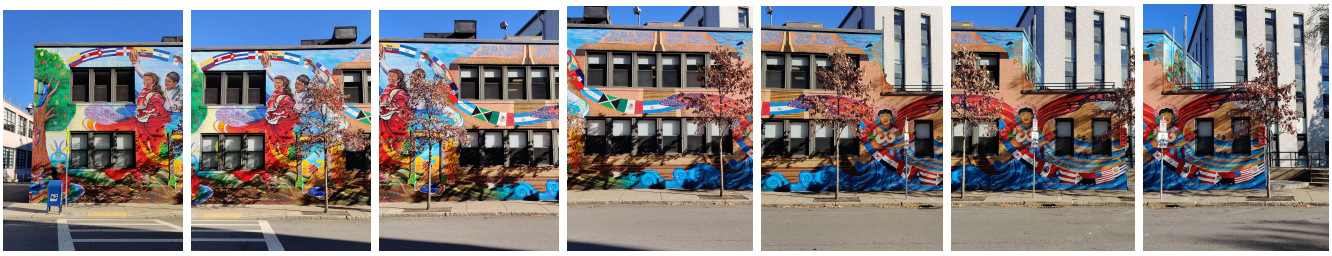

Fig. 5: LSC mural images (the first image is the right-most image)

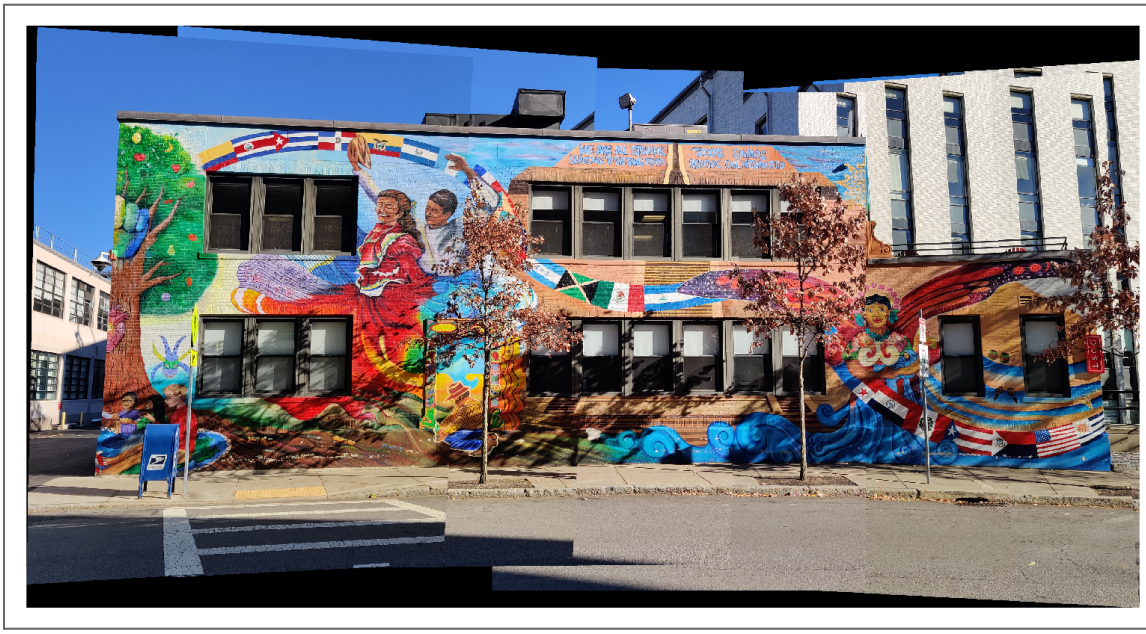

Fig. 6: Stitched LSC mural

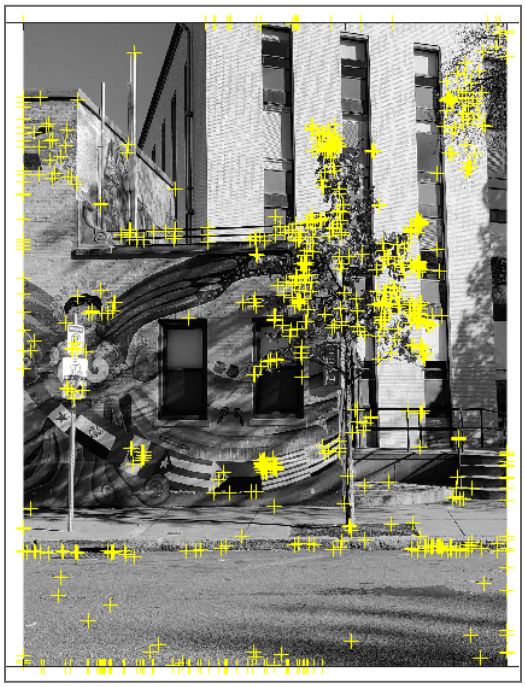

Fig. 7: Harris corner detection on the first image

Description of Harris detector used for LSC

Fig. 7 shows the output of the harris detector function. The detected corners are marked by a cross. It is apparent from the image that the tree in front of the mural createsa a lot of 'corners' with a very high value of **R (measure of corner response)**. If the image is not processed regionally, then all of the detected corners would be concentrated on the tree.

Secondly, we also don't want unnecessary features to be detected on the road in front of the mural, or in the sky which can hamper the feature matching. In order to tackle these problems, the following adjustments are made:

1. In the harris corner detection function, the **tile size is set to [5 5]**. This parameter divides the image into 25 sections and separately runs the harris detection algorithm on each of these sections. **This step ensures that the features are not concentrated on the trees, and are distributed throughout the image**.

2. The max number of corners detected are set to 1200. So in each of the 25 sections of the image, the maximum points that can be detected are 48 (1200/25)

3. The **threshold for R is set to 5000000**. This threshold is determined empirically after examining the corner response of the image. This threshold helps to eliminate points detected in the sky or on the road, or basically any points which may not be 'strong' corners.

Cinder Block Mosaic

Initial images with harris corners

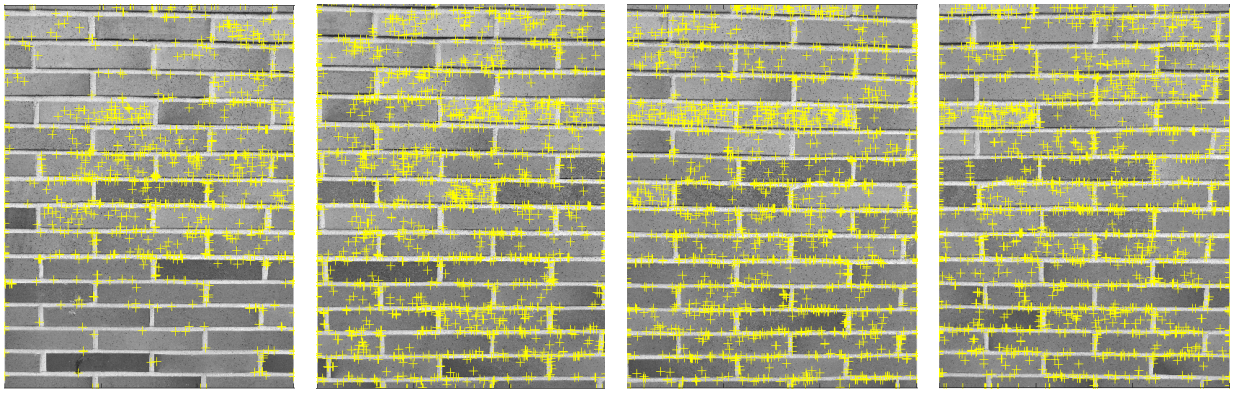

Fig. 8: Harris corner detection on initial cinder block images

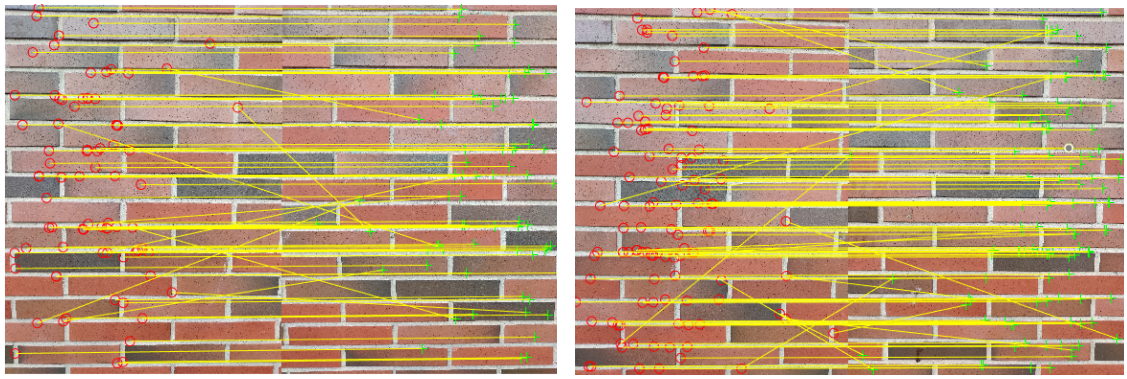

Fig. 9: Matched features for cinder block before outlier elimination

Fig. 10: Matched features for cinder block after outlier elimination

It is observed in the cinder block images that **there are no unique features across the wall**. In an ideal scenario, the harris detector should only detect the corners and sharp edges of the cinder block. On the contrary, the detected corners are seen to be fairly spread across the image. The reason for this is that the surface of the cinder block image is not smooth. **The cinder block has textured surface which if zoomed in will seem like a corner which leads to detection of corners on the surface of the cinder block**. This effect is shown in fig 11.

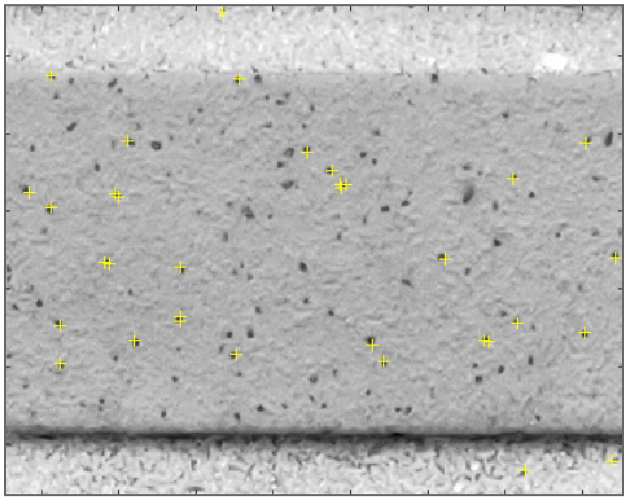

Fig. 11: Corners detected on the surface of the cinder block due to the texture

Fig 9 shows the matched features in two consecutive images before rejection of outliers. **It is evident that there are many features which are matched incorrectly due to the similar nature of the features**. Fig. 10 shows the matched features after the rejection of outliers. The function 'estgeotform2d' was able to find some pairs of features that are unique. These unique features are not necessarily the corners of the cinder block, but also include the features on the surface of the block as discussed earlier.

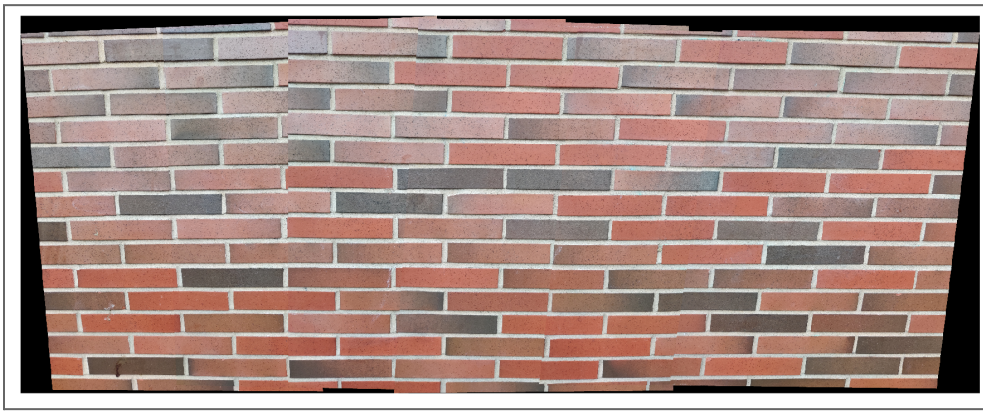

Fig. 12: Stitched image of cinder blocks

Performance of cinder block image compared to LSC

- The LSC mural had a large number of unique features which could be easily mapped in the consecutive pairs of images, while the cinder block has no unique features, leading to a worse result of stitched image as compared to LSC mural.

- In order to stitch the cinder block image, the threshold for R (measure of corner response) had to be brought down to 2000000 in order to increase the number of points detected by harris function. The tile size used for cinder block images had to be increased to spread out the detection of features across the image.

Ruggles Mural (Third Mural)

Images with 50% overlap

Fig. 13: Set of 50% overlapped images

Fig. 14: Stitched image of 50% overlapping mural

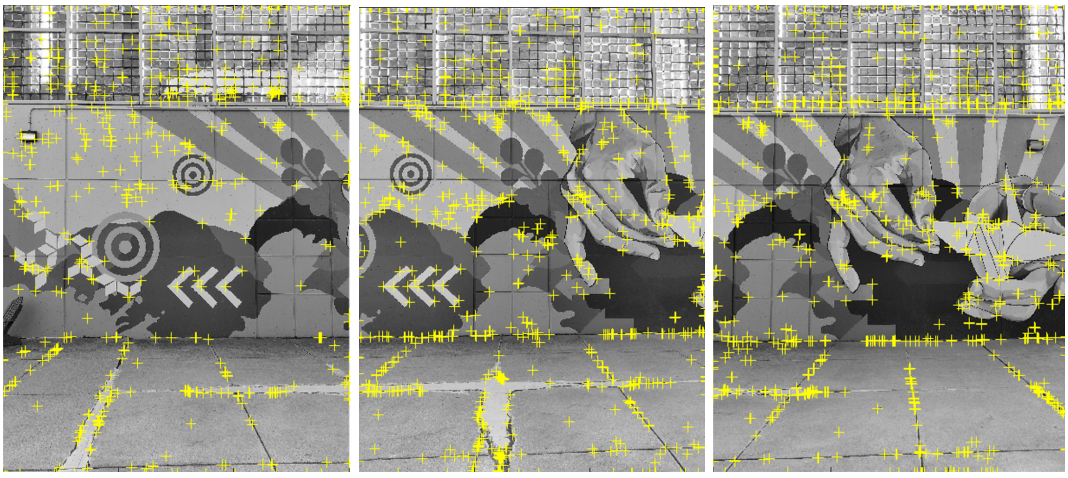

Fig. 15: Detection of harris features in the 50% overlap images

Images with 15% overlap

Fig. 16: Stitched image of 15% overlapping mural

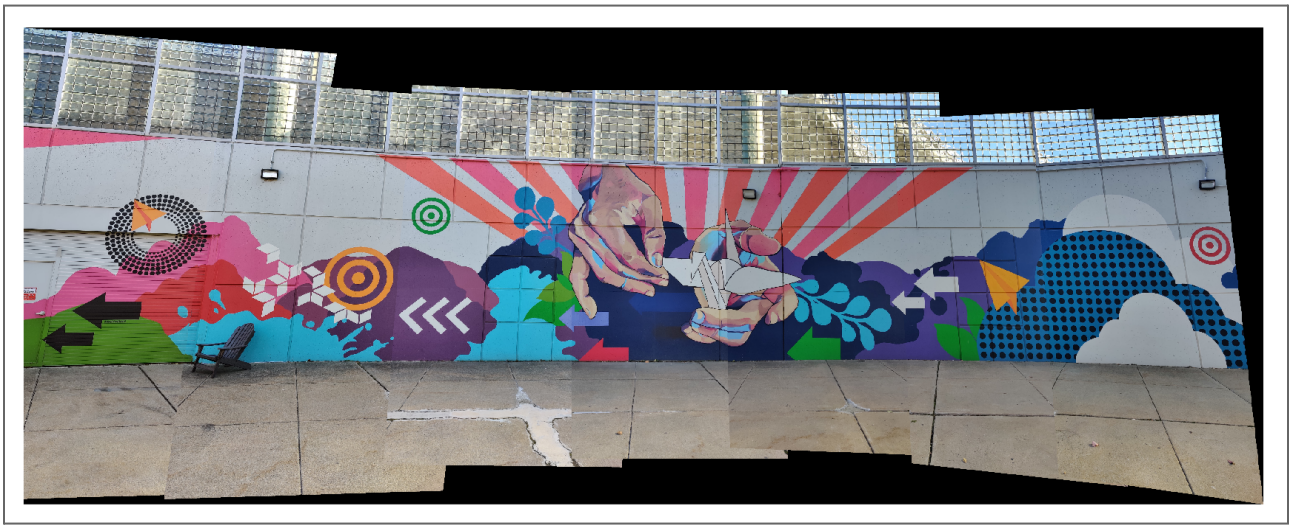

Fig. 17: Stitched image of 15% overlapping mural

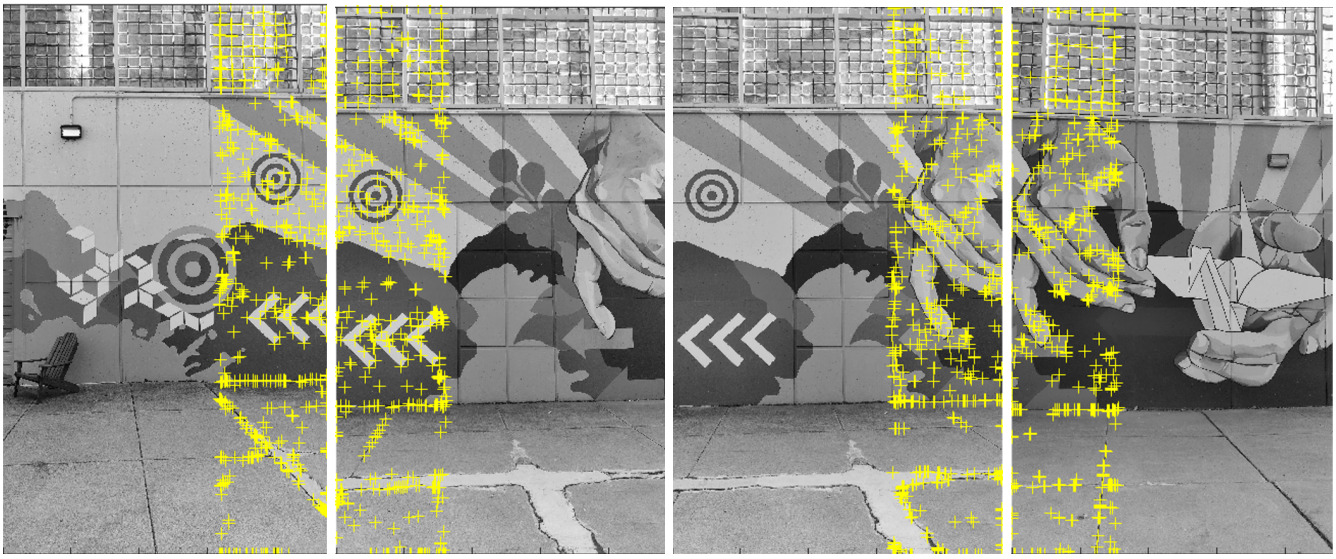

Fig. 18: Detection of harris features in the 15% overlap images (features detected according to the masking algorithm)

Performance of 50% vs 15% overlapping images

- It is evident that in the images with 50% overlap, there are a lot of unique overlapping features in consecutive pairs of images. This leads to a robust estimation of geometric transformation between the images, and a good final result.

- In images with 15% overlap very few strong and unique features exist, because of which the estimation of geometric transformations between images can fail in some cases when the matched points are less in number.

Adjustment in 50% and 15% images for best results

- In images with 50% overlap, we need to identify only the strong features and reject redundant or unnecessary points. In order to achieve this, the threshold for R is set to 5000000.

- To spread out the features a bit, a tile size of [8 8] is applied, with a total of 1000 points. This means that the figure is divided into 64 parts with maximum of 16 points per section.

- Initial attempts were made to stitch the 15% overlapping images by running the harris corner function over the entire image, which resulted in poorly stitched images due to false detections in features, and less matched features.

- To overcome this, a mask was used which will try to find features in the last 33% and the first 33% of consecutive images (as shown in fig. 18).

- This algorithm worked surprisingly well along with the threshold R set to 0 (in order to detect the weakest of the overlapping features) and the tile size as [10 10] to maximize the spread of the detected points.