

EECE5554 – ROBOTIC SENSING AND NAVIGATION

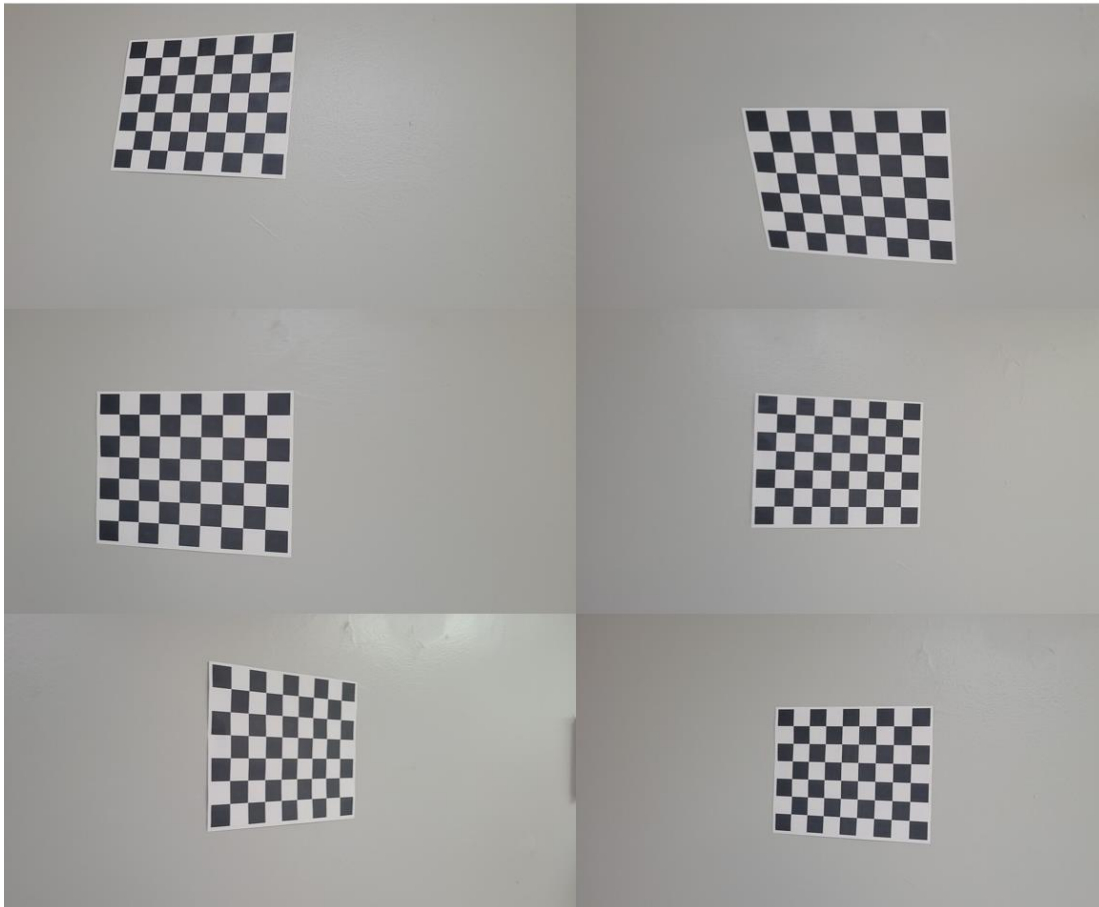
LAB -5 REPORT

BASIL REJI

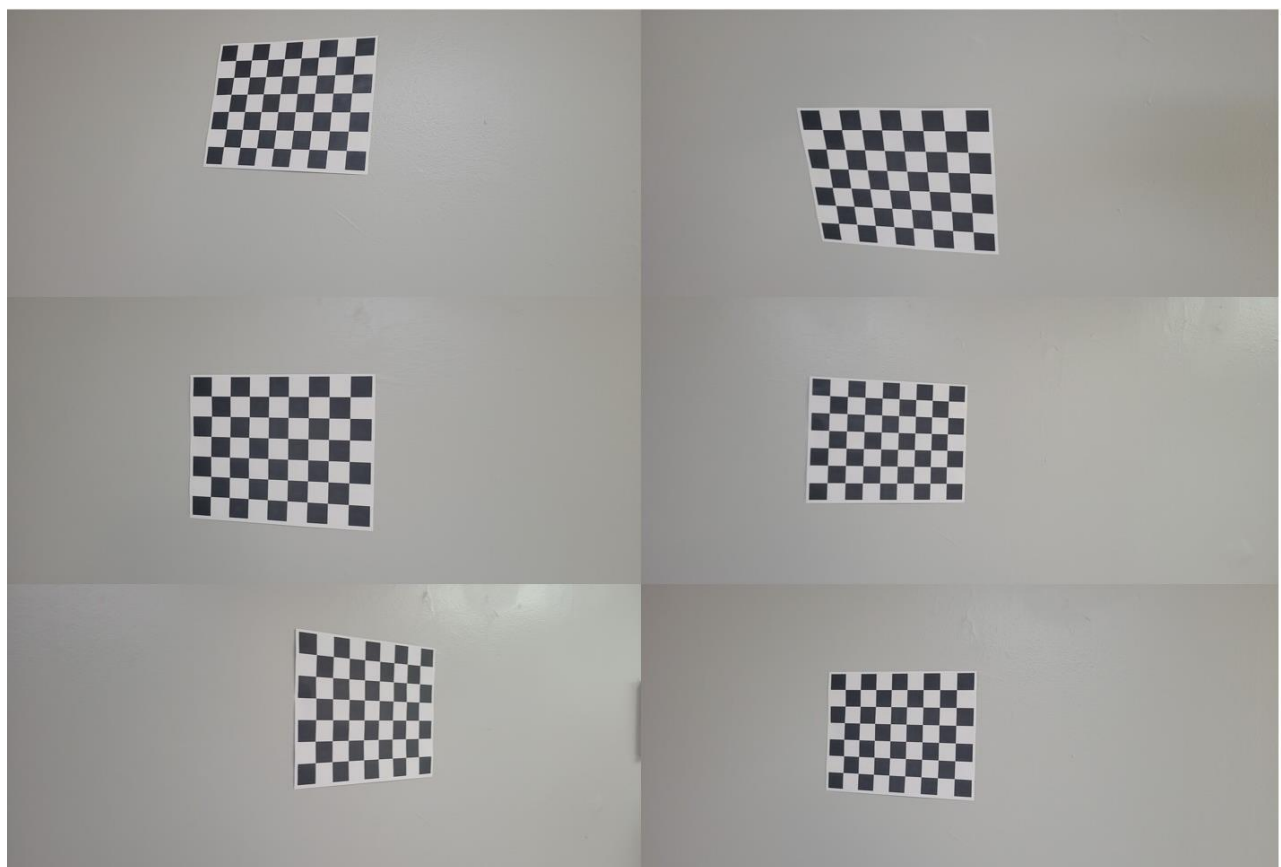
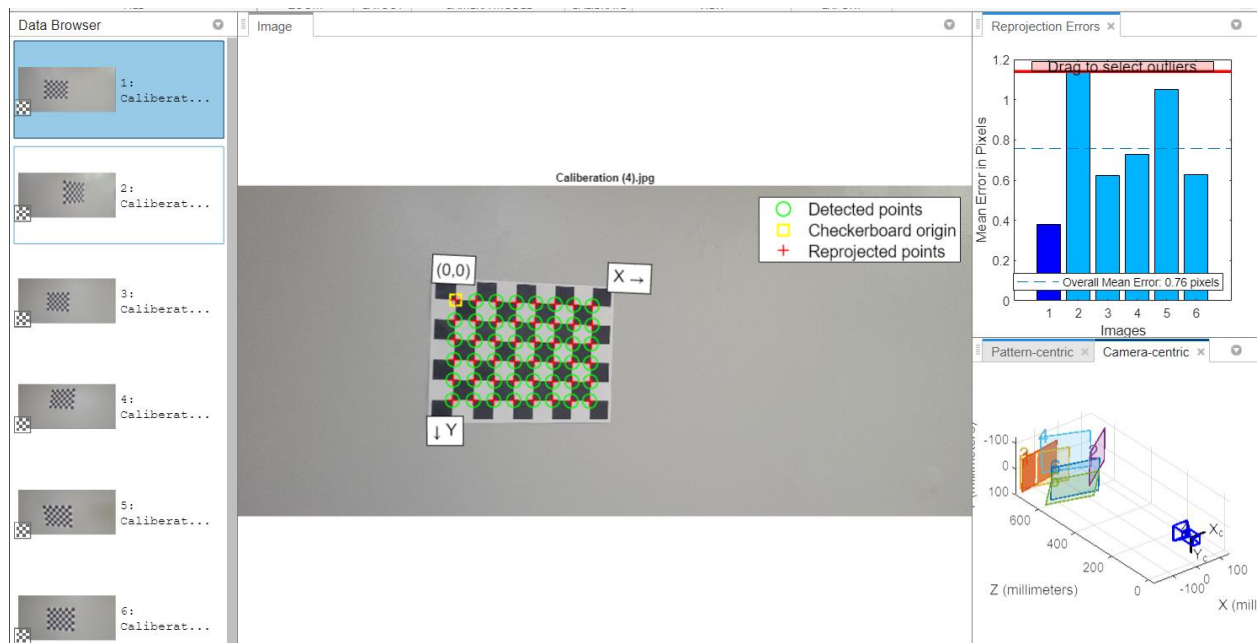
For Lab 5, The photos were taken from Samsung Galaxy S21 model phone.

Camera Calibration

The camera calibration of Samsung galaxy S21 phone camera was done by the following method. First the printout of a calibration pattern in an A4 sized paper was taken and was stuck in a plane surface. Then the photo of the same from various angles were taken and was calibrated using corner detection method using MATLAB. Camera calibration is the process of estimating parameters of the camera by finding a special calibration pattern. The parameters include camera intrinsics, distortion coefficients, and camera extrinsics



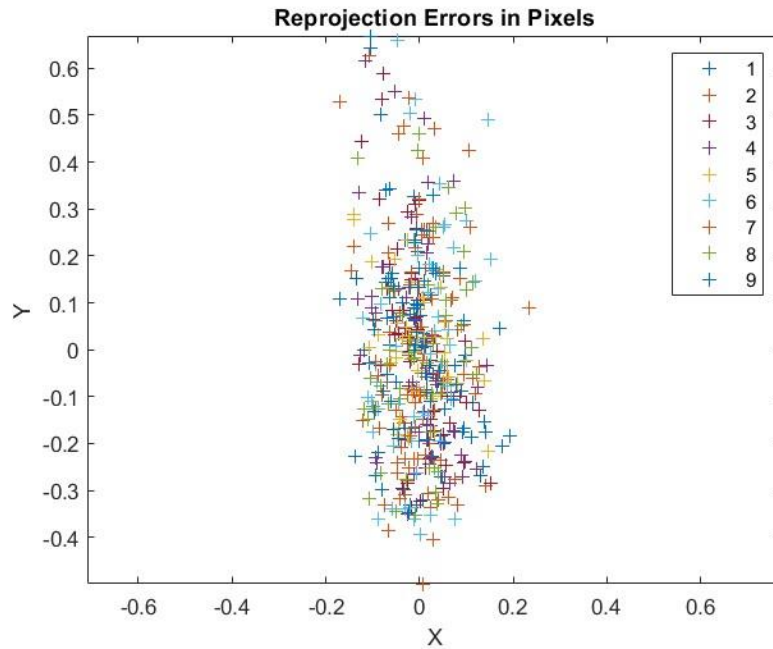
Images used for camera calibration in mosaic



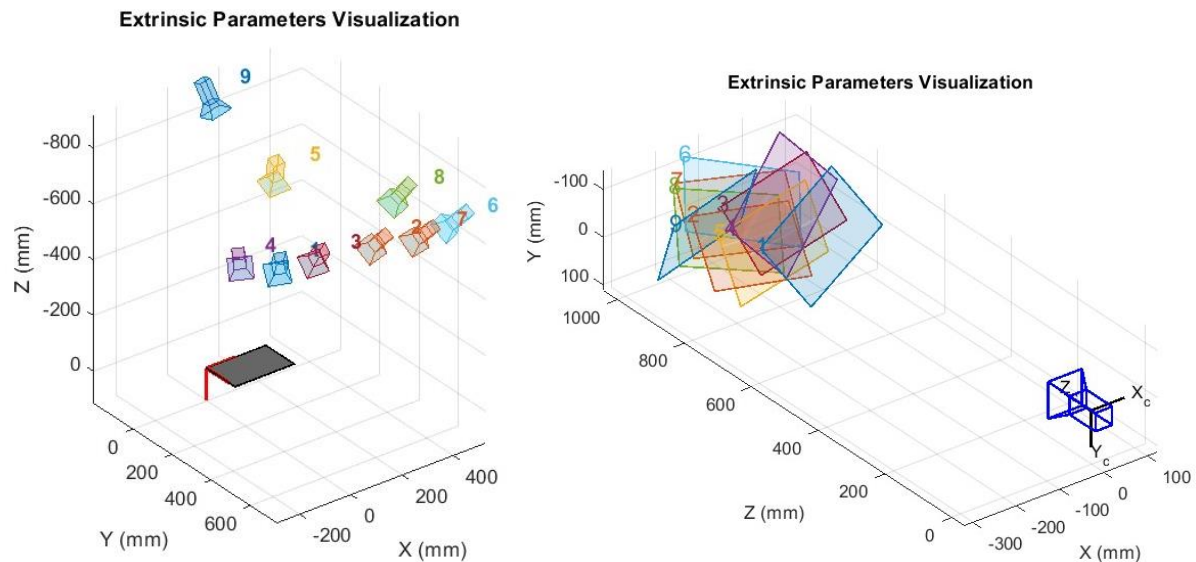
Images After Calibration

The reprojection error of the calibrated images was plotted using MATLAB. It was found that there was considerable reprojection error but was concentrated within a margin of ± 3 pixels. Since this error was

acceptable for image stitching using Harris Corner detection, I decided to proceed with the camera. The reprojection error could have been improved by having more iterations of calibration. Another reason for the higher error is because all Samsung galaxy phone cameras have an automatic multi-frame processing using with an Artificially Intelligent Image Signal Processor (ISP). This helps in calibration and prevent distortion of images and helps in beautifying the image. Hence, applying further calibration would cause errors.



The extrinsic parameters are given below



Estimation errors represent the uncertainty of each estimated parameter.

The estimation errors were found through MATLAB and is given below.

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Standard Errors of Estimated Camera Parameters
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Intrinsics
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Focal length (pixels): [ 714.1886 +/- 3.3219    710.3786 +/- 4.0579 ]
Principal point (pixels): [ 563.6480 +/- 5.3967    355.7251 +/- 3.3036 ]
Radial distortion: [ -0.3536 +/- 0.0091    0.1730 +/- 0.0488 ]

Extrinsics
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Rotation vectors:
[ -0.6096 +/- 0.0054    -0.1789 +/- 0.0073    -0.3835 +/- 0.0024 ]
[ -0.7283 +/- 0.0050    -0.0996 +/- 0.0072     0.1964 +/- 0.0027 ]
[ -0.6722 +/- 0.0051    -0.1444 +/- 0.0074    -0.1329 +/- 0.0026 ]
[ -0.5836 +/- 0.0056    -0.2901 +/- 0.0074    -0.5622 +/- 0.0025 ]
[ -0.3157 +/- 0.0065    -0.1441 +/- 0.0075    -0.1067 +/- 0.0011 ]
[ -0.7581 +/- 0.0052     0.1947 +/- 0.0072     0.4324 +/- 0.0030 ]
[ -0.7515 +/- 0.0051     0.0767 +/- 0.0072     0.2070 +/- 0.0029 ]
[ -0.6223 +/- 0.0053     0.0231 +/- 0.0073     0.3663 +/- 0.0024 ]
[  0.3443 +/- 0.0063    -0.2226 +/- 0.0073    -0.0437 +/- 0.0014 ]

Translation vectors (mm):
[ -146.0516 +/- 6.0391    -26.8684 +/- 3.7318    797.9027 +/- 3.9002 ]
[ -209.4357 +/- 6.9637    -59.4563 +/- 4.3578    921.8198 +/- 4.6295 ]
[ -129.3823 +/- 7.0907    -44.1028 +/- 4.3751    937.6832 +/- 4.4913 ]
[ -151.0048 +/- 6.6905    -27.3251 +/- 4.1339    884.2789 +/- 4.3925 ]
[ -174.9499 +/- 6.7056    -24.3498 +/- 4.1606    886.4961 +/- 4.6686 ]
[ -134.3095 +/- 7.8887    -103.4979 +/- 4.8925    1042.4554 +/- 4.8184 ]
[ -173.9845 +/- 7.6891    -73.1689 +/- 4.7812    1017.2386 +/- 4.8126 ]
[ -202.9446 +/- 7.4327    -87.9089 +/- 4.6482    983.6958 +/- 4.9072 ]
[ -319.8860 +/- 6.3213   -119.8897 +/- 4.0922    829.4582 +/- 4.9591 ]

fx >>
```

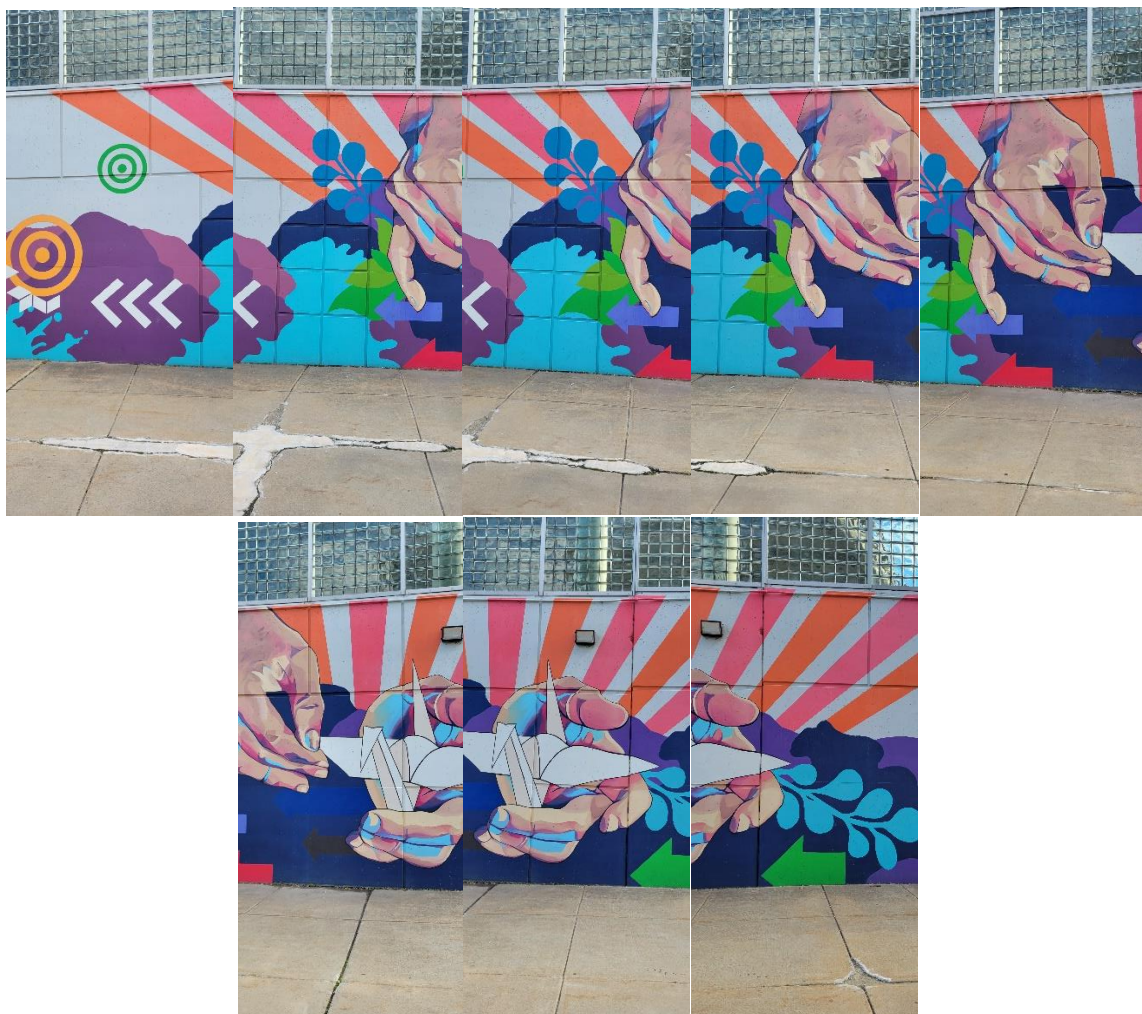
Data Collection

3 sets of data were collected with the Samsung Galaxy S21 phone Camera

a) Photos of Latina Student Center with 50 percent Overlap



b) Graffiti in front of Ruggles Station with both 50 percent and 15 percent overlap
i- 15 percent overlap



ii- 50 percent overlap

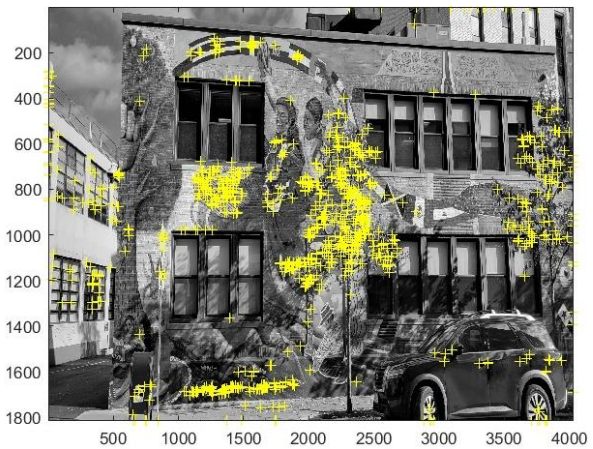
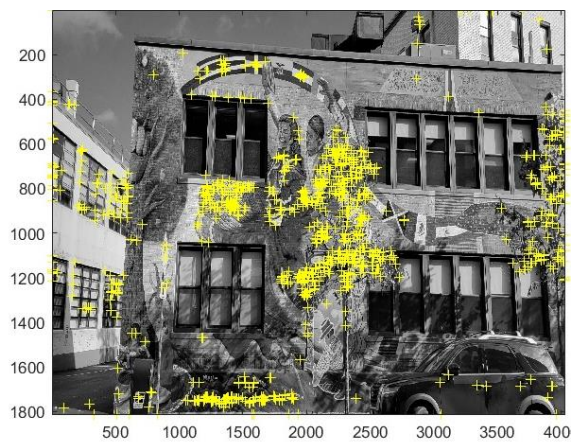
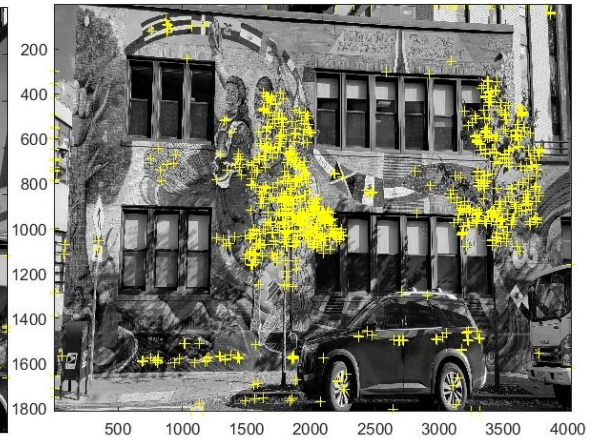
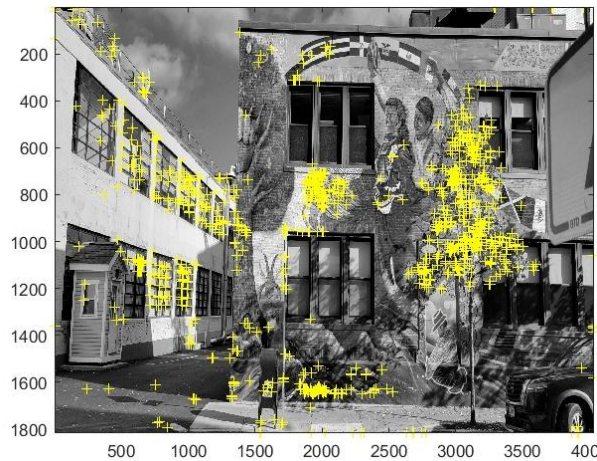


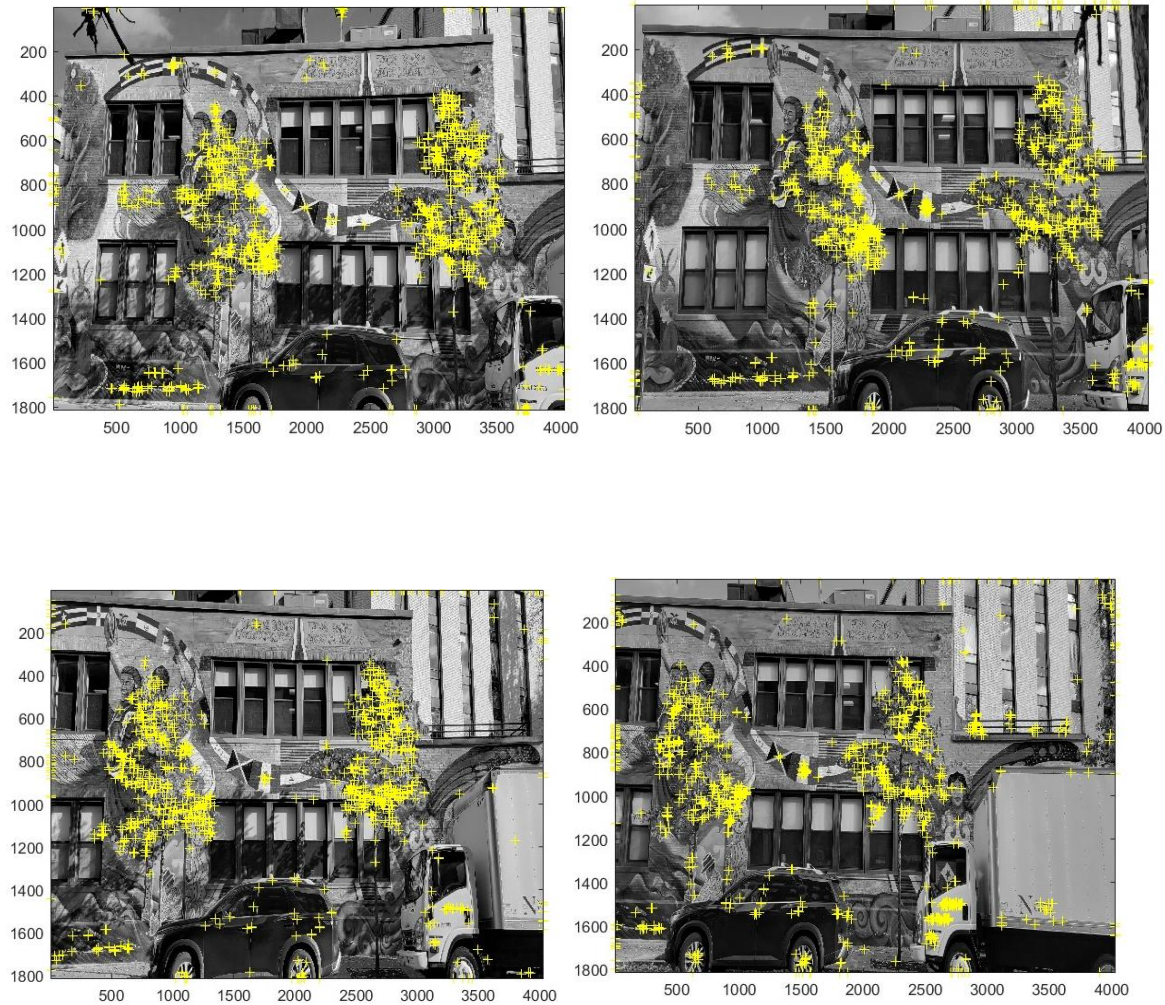
c) Photos of a brick wall with design in between of Curry Student Center and Snell Library



Harris Corner Detection for Photo Mosaicing

1. Latina Student Center





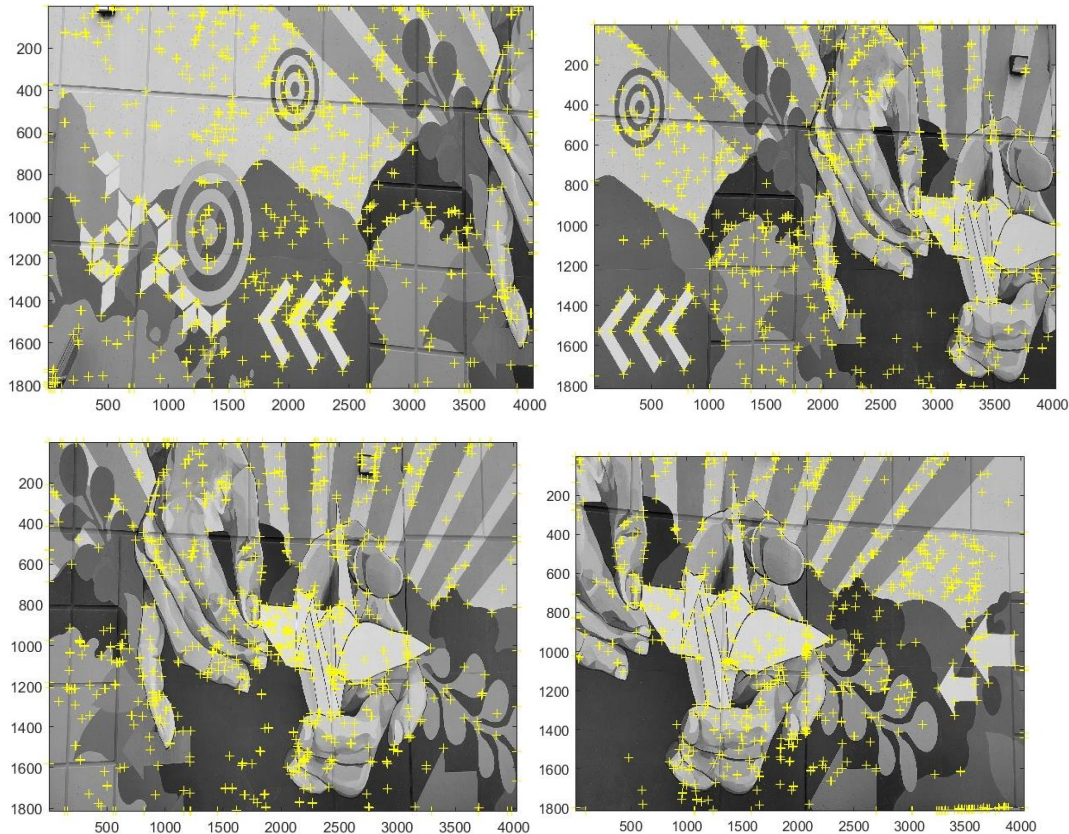
The pictures of Latina Student center were taken with 50 percent overlap and applied the Harris corner detection algorithm to the pictures to obtain a stitched image. The yellow scatter points denote the common overlap corner detect points obtained by the algorithm from the input images. The algorithm then stitched the images together to form a final mosaic. Here we can see that the detect point clusters are more in the graffiti in the building and hence the final stitch of the building is more accurate compared to the sky and the adjacent buildings where the corner detect points were substantially less.

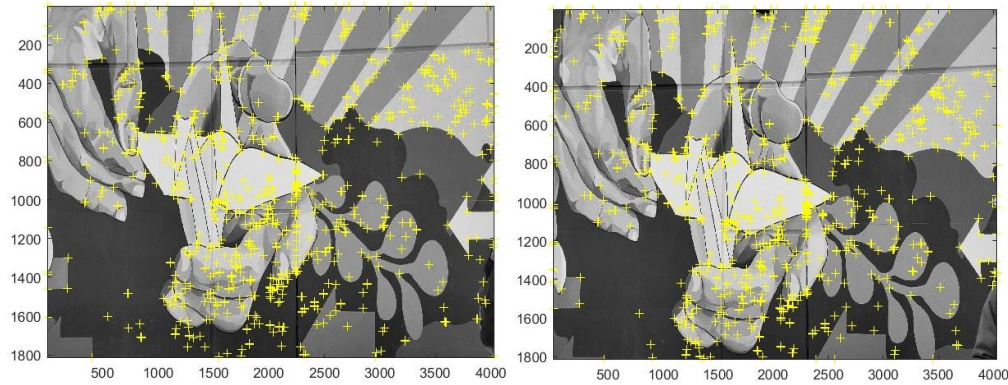


In the stitched image, we can see that the images are mosaiced very close to the original scene, but the images are not actually aligned perfectly at the levels they were supposed to be aligned. Some pictures are aligned with bricks that were actually lower than them in the original image. Also, it can be seen that all the images except the first and last images have aligned with each other at approximately the mid-section areas signifying that the stitching has taken place near the 50% mark.

2. Ruggles Grafitti

a) 50 percent overlap





The photos of graffiti in ruggles station was taken with 50 percent overlap. Here we can see that there are lots of detection points distributed evenly in the overlapping area. Hence the algorithm gets a more accurate stitched image when the Harris corner detection program was run with the images as input.

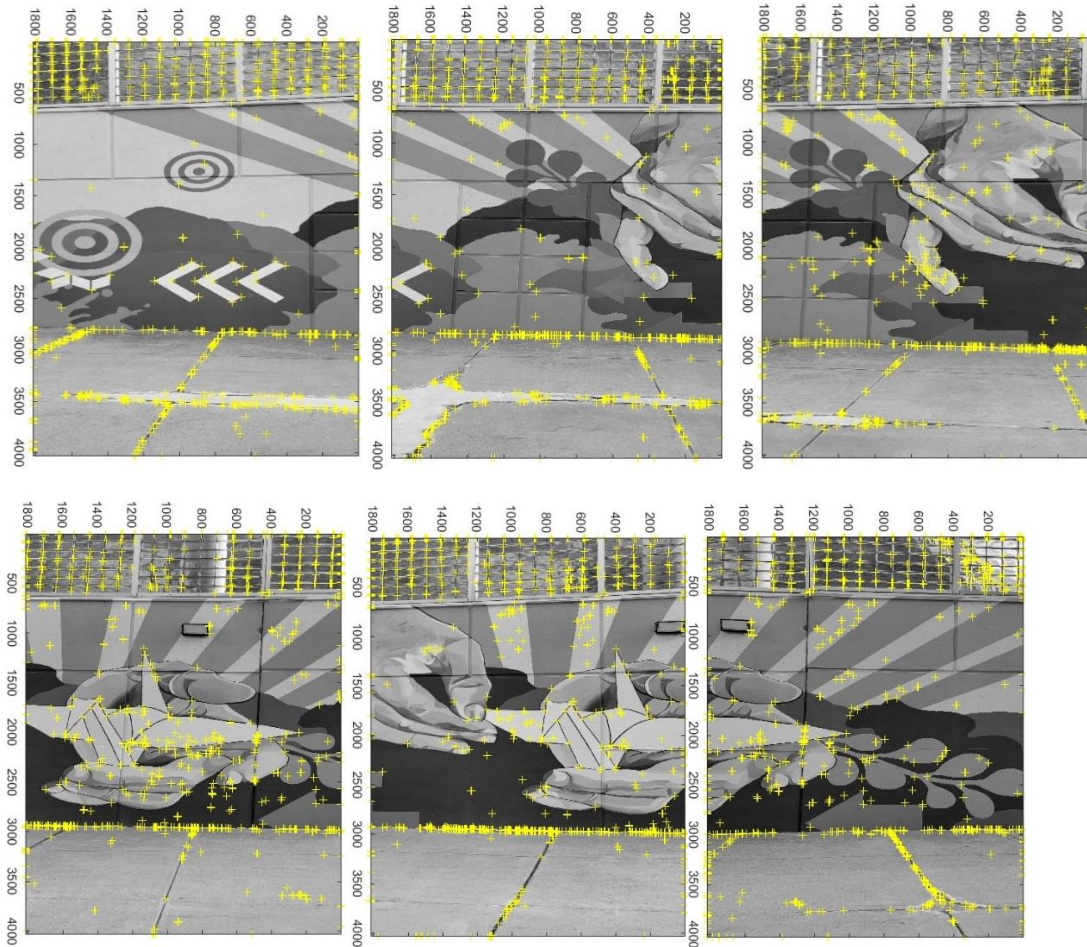


We can see that the final stitched image is very accurate but still has a slight offset in the orientation.

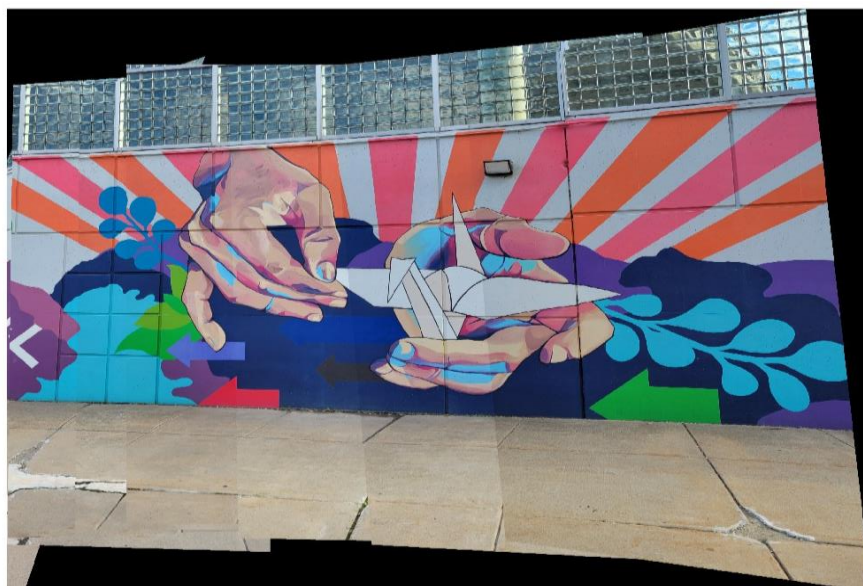
b) 15 percent Overlap

The photos of the same mosaic with 15 percent overlap was taken in front Ruggles station.

It was found that the images were flipped by the algorithm 90 degrees in order to find the Harris corners and stitch the images. Therefore the outputs are also flipped. We can notice this by the rotation of x and y axes in the figures.



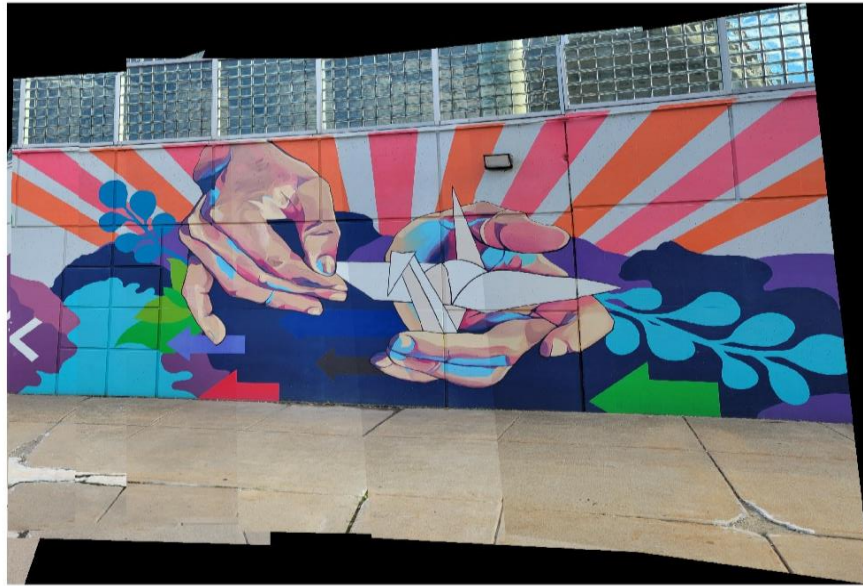
We can notice that even though the overlap is only 15 percent, the algorithm has done a great job of finding the corners and stitch the images together with great accuracy but there is still a greater offset compared to the 50 percent overlap.



15 % overlap vs 50 % overlap comparison



50 percent overlap



15 percent overlap

From these images, we can clearly see that the Harris corner detection works better with higher concentration of overlapping between images. The offsets and the stitching orientation differences are clear when the overlap is just 15 percent but when there is over 50 percent overlap, the images are stitched with a much higher accuracy.

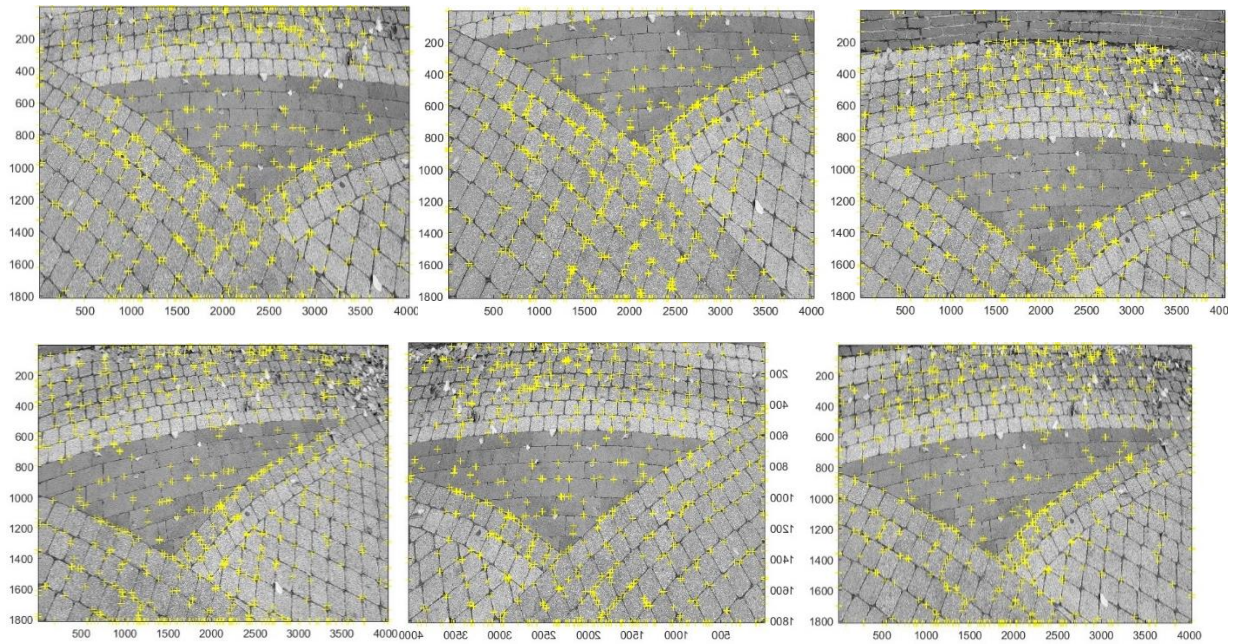
When two adjacent images have low percentage of overlap, two things could happen:

1. Mismatched Harris corner
2. Mismatched corner contribute more weight in transformation calculation

This can be rectified using the following methods:

1. Changing the distribution of points over the image as [5 5] which makes the points spread over the image rather than concentrating at 1 point
2. Changing the number of corner points to 8000 to increase corner points
3. Changing the threshold of the system to 500000 which increases the quality of corner features resulting in a good panorama

3. Brick Wall



The images of the brick wall on the floor between Curry Student Center and Snell Library were taken and Harris corner detection was applied.



We can see that the stitched image was well stitched in the center but the corners of the stitched image showed significant offset compared to the graffiti mosaics. The algorithm was unable to identify the actual corners of the final image and hence that area is blacked out. Even still, the stitched image is fairly accurate.