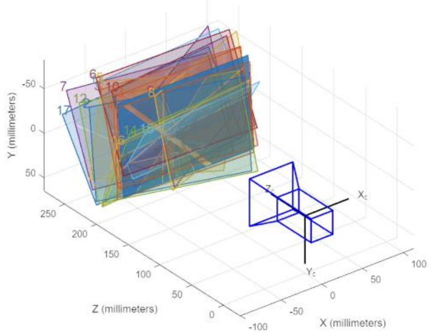
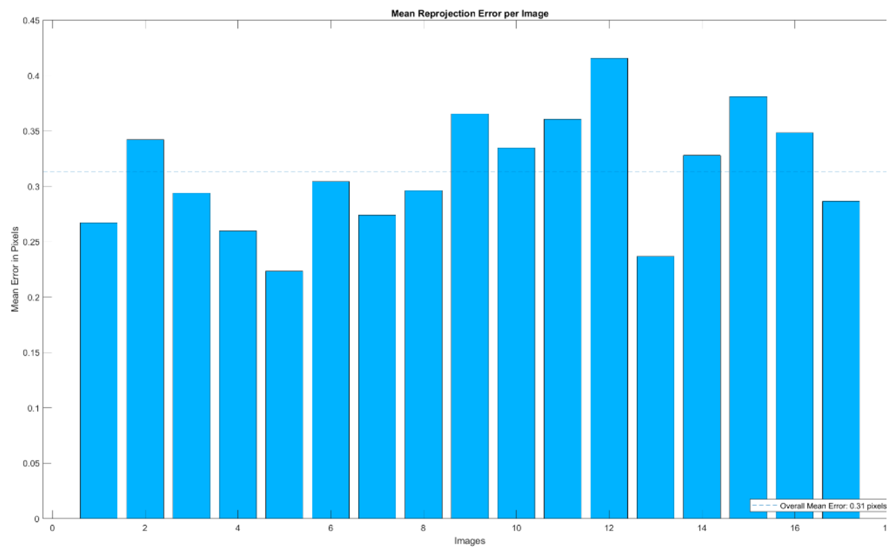
Robot Sensing and Navigation: LAB 5 Report

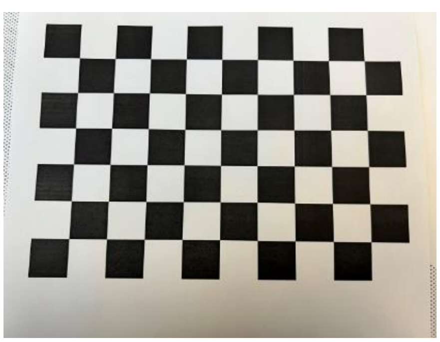
Camera calibration is the process of determining the intrinsic and extrinsic parameters of a camera, which are essential for accurately measuring and interpreting the image captured by the camera. Intrinsic parameters refer to the internal characteristics of the camera, such as focal length and lens distortion, while extrinsic parameters describe the camera's position and orientation in the 3D world. By calibrating a camera, we can correct for distortion and other errors, allowing us to accurately measure the size, distance, and position of objects in an image. Camera calibration is a crucial step in many computer vision applications, such as object recognition, stereo vision, and augmented reality. For the following assessment, a 10 * 7 checkerboard with square size of 20 mm was used to calibrate the camera. I used both camera calibration toolbox and computer vision toolbox to code calibration. A total of 17 images were used, the mean re-projection error was around **0.31 pixels**. Extrinsic parameters have translation and rotation vectors.

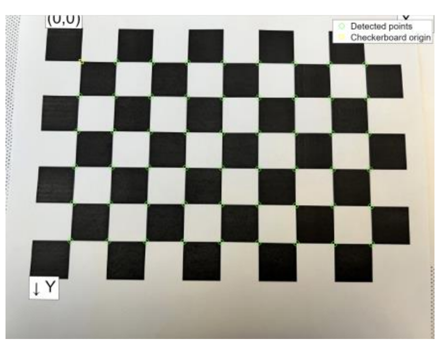
```
  cameraIntrinsics with properties:

             FocalLength: [503.8259 501.8289]
          PrincipalPoint: [323.7829 241.5499]
               ImageSize: [480 640]
        RadialDistortion: [0.1112 -0.3096]
    TangentialDistortion: [0 0]
                    Skew: 0
                       K: [3×3 double]
```





Undistortion: It is the process of removing or correcting the distortion in an image caused by the lens of a camera. Lens distortion can cause image distortion, such as radial or tangential distortion, where straight lines appear curved or objects near the edges of the image appear distorted. To undistort an image, the camera's intrinsic parameters, such as the focal length and distortion coefficients, are used to model the distortion and apply corrections to the image. This process can improve the accuracy of measurements and the overall quality of computer vision applications that rely on undistorted images.





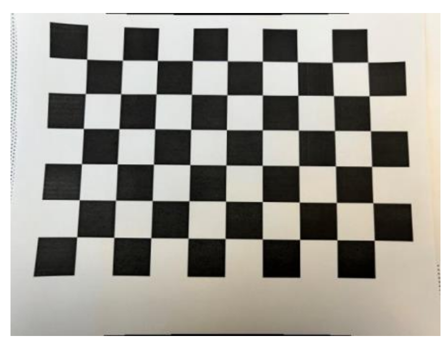


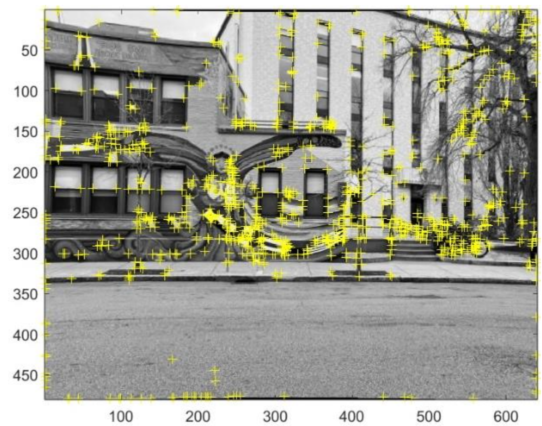
Fig: Normal Image

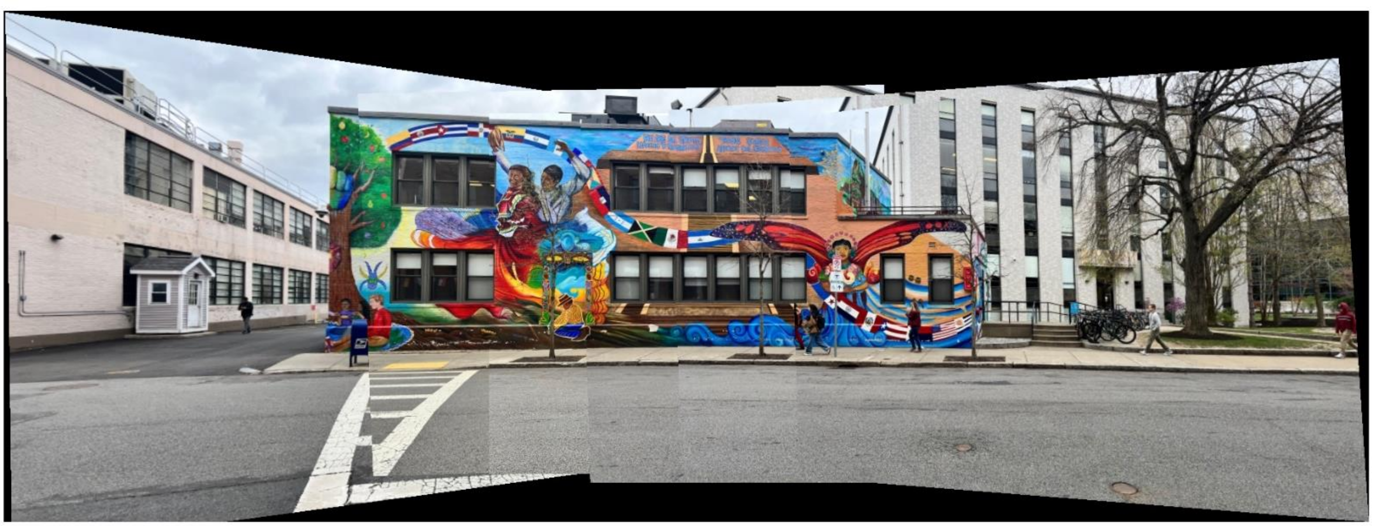
Fig: Corner Detection

Fig: Undistorted Image

- **LSC Murial:**

In an effort to capture the full view of the Latino Student Center, six images were taken from various angles. These images were then undistorted using camera parameters, although this step may not have been necessary as normal images produce better result than undistorting images as new cameras have post processing already. Utilizing 1000 points as features and a 2 * 2 tile, a high-quality panorama was generated. However, due to the second image being taken at an angle, the crosswalk below was not in line with the rest of the building. The majority of the lines at the bottom and middle of the building aligned well, but the top did not form a straight enough line as some images did not entirely cover the roof. Despite this issue, the resulting panorama provides an impressive view of the Latino Student Center. Distorted and undistorted panorama result and rest of the Harris corner images are available in the git.



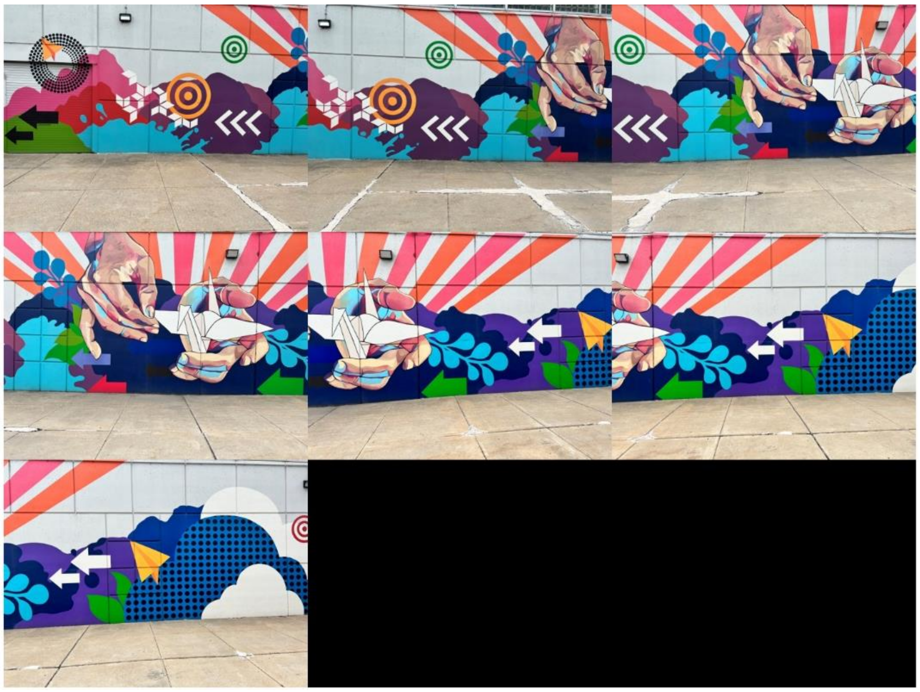


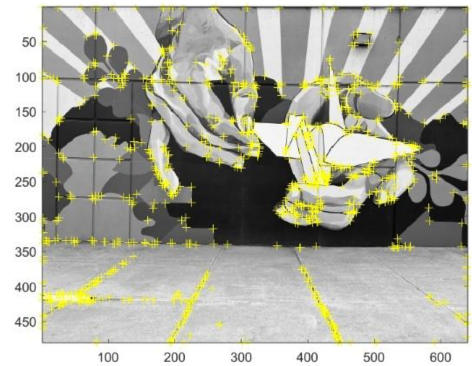
To generate a panorama, a 2D descriptor was utilized, which may have caused some distortion in the resulting image. However, the Harris file provided proved to be more effective than the original harris corner. This is because the Harris file has the ability to calculate the eigenvalues of the gradient matrix directly, rather than relying on the corner response function as initially proposed by Harris. By using this improved method, a higher quality panorama was produced with less distortion.

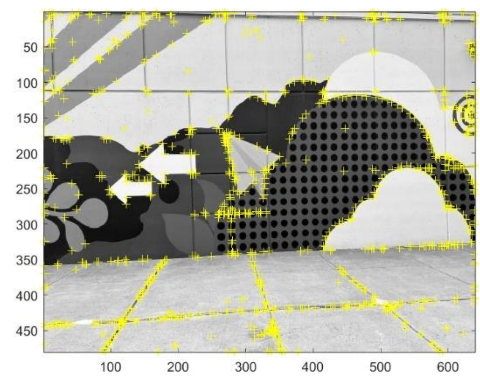
❖ **Ruggles Mosaic:**

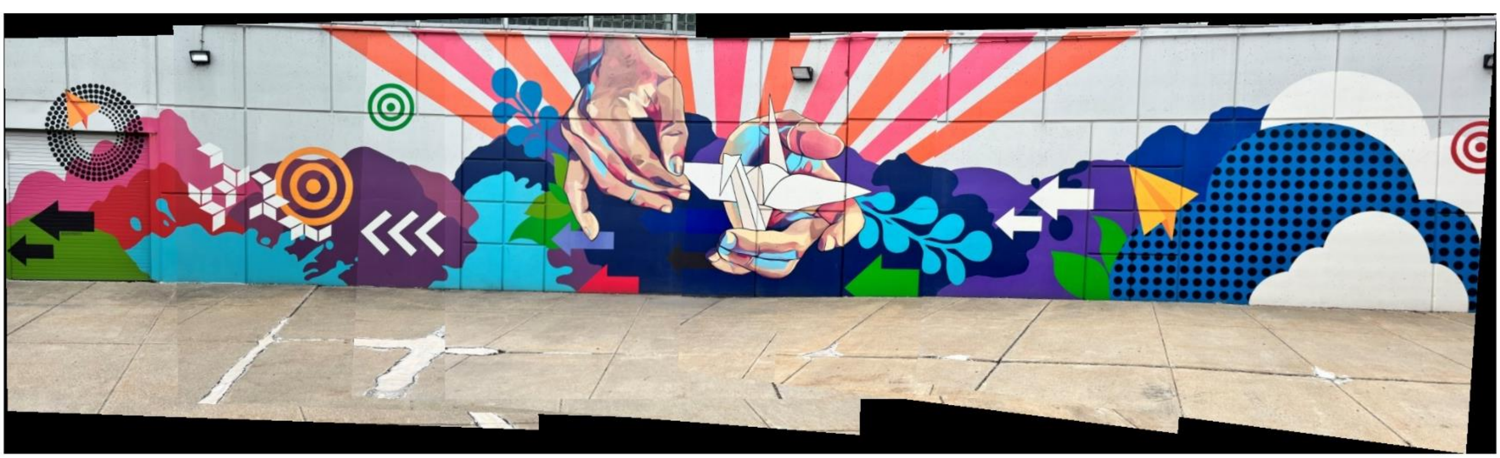
- **50% overlap**:

To create a comprehensive representation of the Ruggles mural, a meticulous approach was taken in capturing the scene. A set of seven images was utilized, and each image was processed using 1000 point features and a 2x2 tile layout to ensure a high level of detail and resolution. A 50% overlapping angle was employed during the capture process, enabling maximum coverage of the mural.





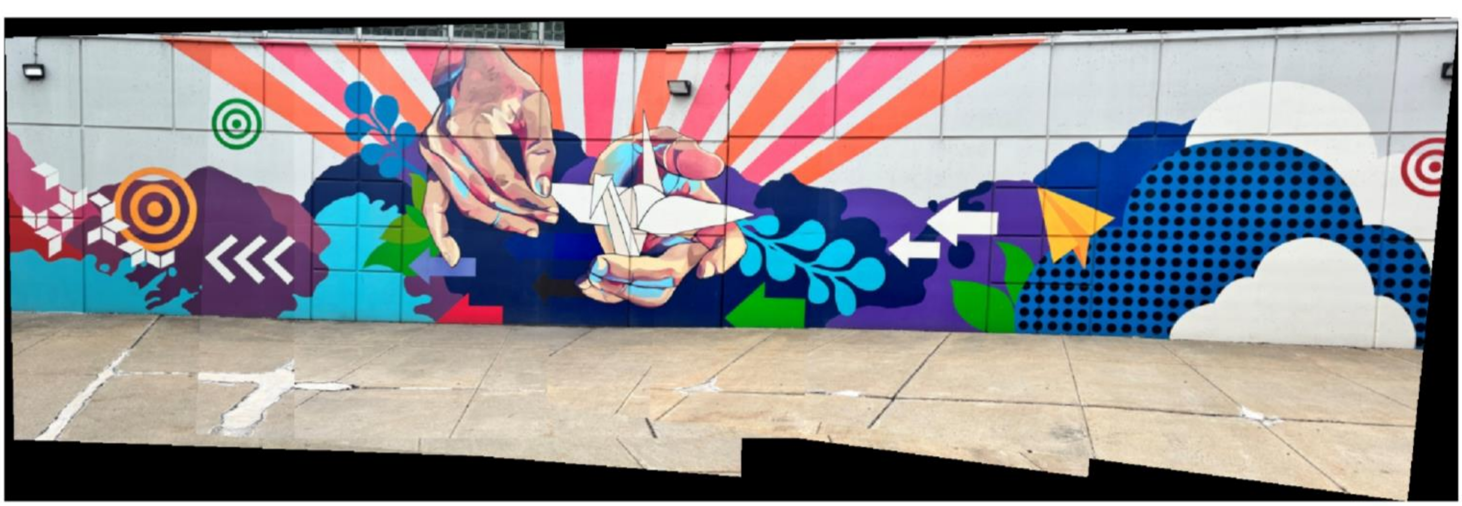




Almost all lines match each other, the bottom of all picture is at a different tilt, so below the first tile, there will be distortions.

- **15% overlap:**

A methodical approach was taken to capture the intricate details of the Ruggles mural, utilizing a set of seven images processed with 1000 point features and a 2x2 tile layout. The images were captured with a 15% overlapping angle, resulting in comprehensive coverage of the scene. The resulting panorama was a visually striking image that showcased the beauty of the mural in stunning detail. The strategy of employing a 15% overlapping angle in the capture process proved to be effective in creating a seamless and coherent panoramic image.



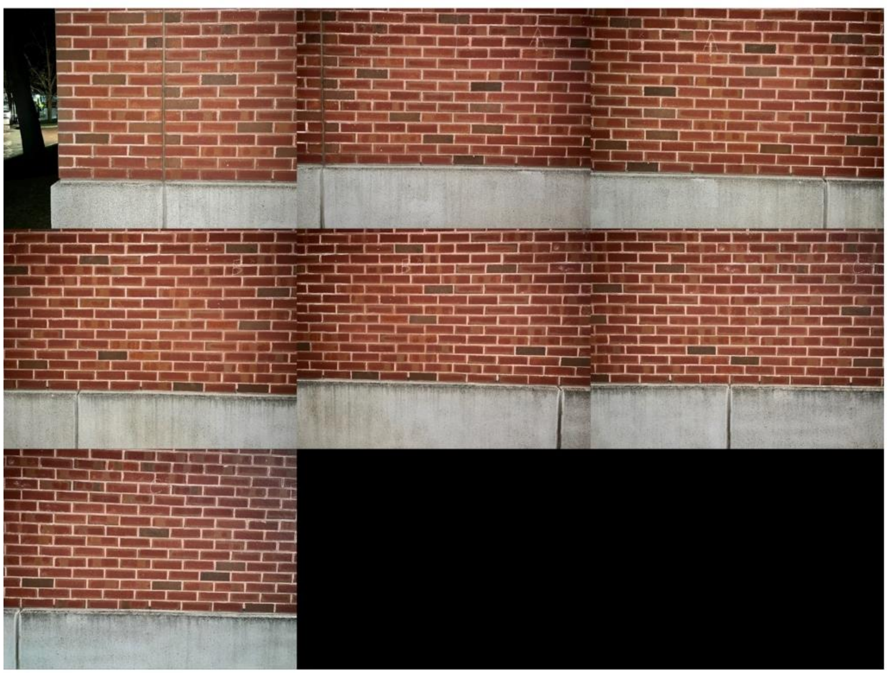
Comparison: In general, using images with a higher overlap percentage, such as 50%, may result in a more accurate and seamless stitching process. This is because the additional overlap provides more information to work with, resulting in a better blending of the images and a higher quality panorama.

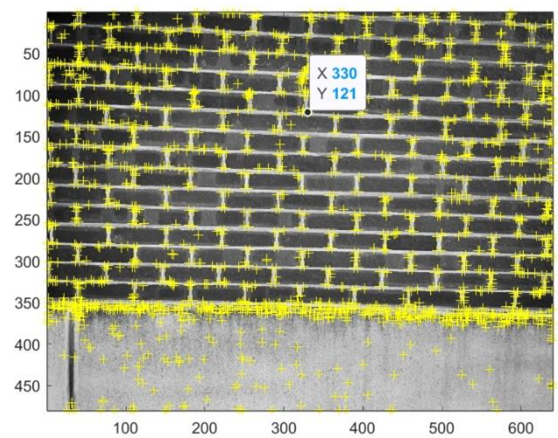
However, using images with a lower overlap percentage, such as 15%, can be effective in capturing a larger scene with fewer images. Additionally, the lower overlap can provide a more significant field of view and can be less time-consuming to capture.

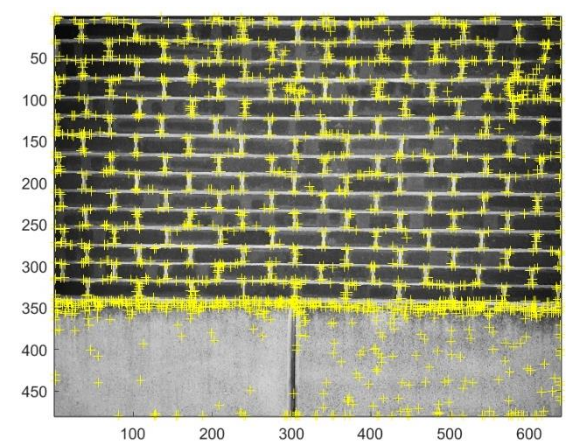
For the above, I got a better result with 15% overlapping image as the mosaic was longer than most, also I used few images in 15% overlapping image and it produced a better result.

- **Cinder Wall:**

To create a high-quality panorama of a Cinder wall, a set of seven images were utilized with an overlap percentage ranging from 40% to 50%. The Harris corner detection algorithm was employed, resulting in well-distributed corner points throughout the images. Given the repetitive nature of the wall pattern, 2000 points were selected as features for the panorama creation. This approach resulted in a significant increase in feature points, which had a positive impact on the final image alignment. While the panorama creation was successful with 1000 points, using 2000 points resulted in an even more precise and accurate image stitching process. Overall, the successful stitching of the images with 2000 feature points and the well-aligned panorama image is a testament to the efficacy of the approach taken in capturing the Cinder wall.







With more feature points, cinder wall gives the same result as LSC/ mosaic, but it also affects the performance. Symmetry is always difficult to distinguish.

Conclusion: In conclusion, camera calibration is a crucial step in obtaining accurate and high-quality images for image stitching. Utilizing feature detection algorithms, such as Harris corners, can aid in the creation of well-aligned panoramas with precise image stitching. The number of feature points utilized during the stitching process, as well as the overlap percentage of the images, play a critical role in the final output. By optimizing these parameters and selecting appropriate techniques, successful image stitching can be achieved, resulting in visually striking panoramic images with high detail and resolution

Reference: https://www.mathworks.com/help/vision/ug/feature-based-panoramic-image-stitching.html?searchHighlight=panorama&s_tid=doc_srchtitle