LAB 5: Camera Mosaic

Robotics: Sensing and Navigation

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Abstract

This document contains the results and discussion from using a Harris corner detection algorithm and the Caltech Camera Calibration toolbox in order to make stitch together photosets and make panoramas of the Latino Student Center, a brick wall, and the mural on the steps beside Behrakis,

Introduction

Within the realm of image processing and computer vision, the Harris corner detector is a useful algorithm used to identify unique features within images. By calculating the intensity gradient of the pixels within the image and assigning a likelihood of a corner being present at a pixel, the Harris corner detector is able to discern distinct visual components of a photo. These features can then be analyzed in such a way to discern valuable information from the image. In the instance of object recognition, the pattern of unique features an object presents within a photo can be used to have a robot identify and track it. Additionally, in the instance of panoramas, the pattern of shared corners between two images can be used to determine how they should be stitched together in order to make one larger, comprehensive image. This second application is used within this lab to explore the Harris corner detector.

Procedure

Before taking any photos for the purpose of constructing a panorama, a MATLAB example of feature based panoramic image stitching was used to understand the process of image stitching. Additionally, the Caltech Camera Calibration toolbox was downloaded and used to calibrate the iPhone X camera that would be used to take photos. From here, a calibration pattern was printed out, photos were taken of it from multiple angles, these were then uploaded to the calibration toolbox where the corners of the images were extracted and, using said extraction, calibration parameters were derived. After this, the MATLAB feature recognition script was edited to enable the use of a Harris feature detector. Upon editing this program, panoramic photos were taken of the Latino Students Center (LSC), a brick wall, and the Behrakis steps mural (with both 15% and 50% image overlapping). Care was taken to prevent any rotation of the camera while capturing the images. These mosaic photos were then uploaded to the Harris feature recognition MATLAB script where, upon appropriately editing the parameters of the Harris detector function, panoramas were constructed. The results of both this calibration and these panoramas can be seen in the Results section.

Results

As mentioned, multiple photos were taken for the Caltech Camera Calibration toolbox. These images can be seen in Figure 1 below.

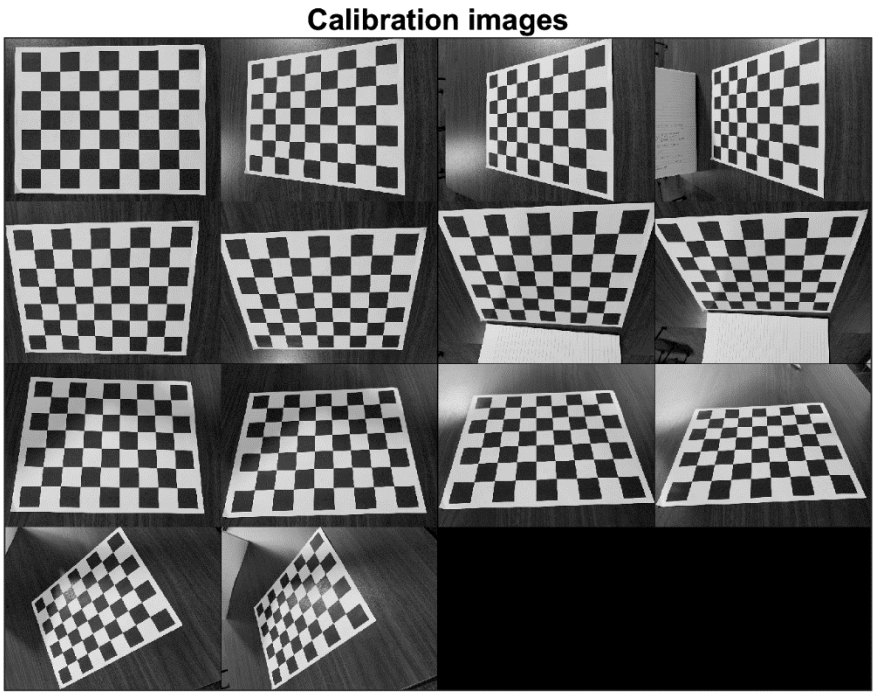

Figure 1: Calibration Photoset

Extracting the corners from each of the photos shown in Figure 1 enabled the generation of calibration parameters for the iPhone X camera. The output in the command line of these calibration parameters can be seen below in Figure 2.

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Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 3112.86420   3110.47326 ] +/- [ 11.29984   12.02313 ]
Principal point:       cc = [ 2007.79600   1492.78090 ] +/- [ 11.66303   9.63261 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000  ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.15575   -0.47872   0.00113   -0.00344  0.00000 ] +/- [ 0.01474   0.05285   0.00119   0.00135  0.00000
Pixel error:          err = [ 1.66382   1.60846 ]
```

Figure 2: Calibration Parameters

As can be seen in Figure 2, the pixel error was approximately 1.6-1.7. Since the camera of the iPhone X takes 4K pixel images, this error could be considered small enough to consider the corner extraction to be successful and for the calibration to proceed. In addition to the calibration parameters, a plot of the reprojection pixel error was outputted and is shown in Figure 3 below.

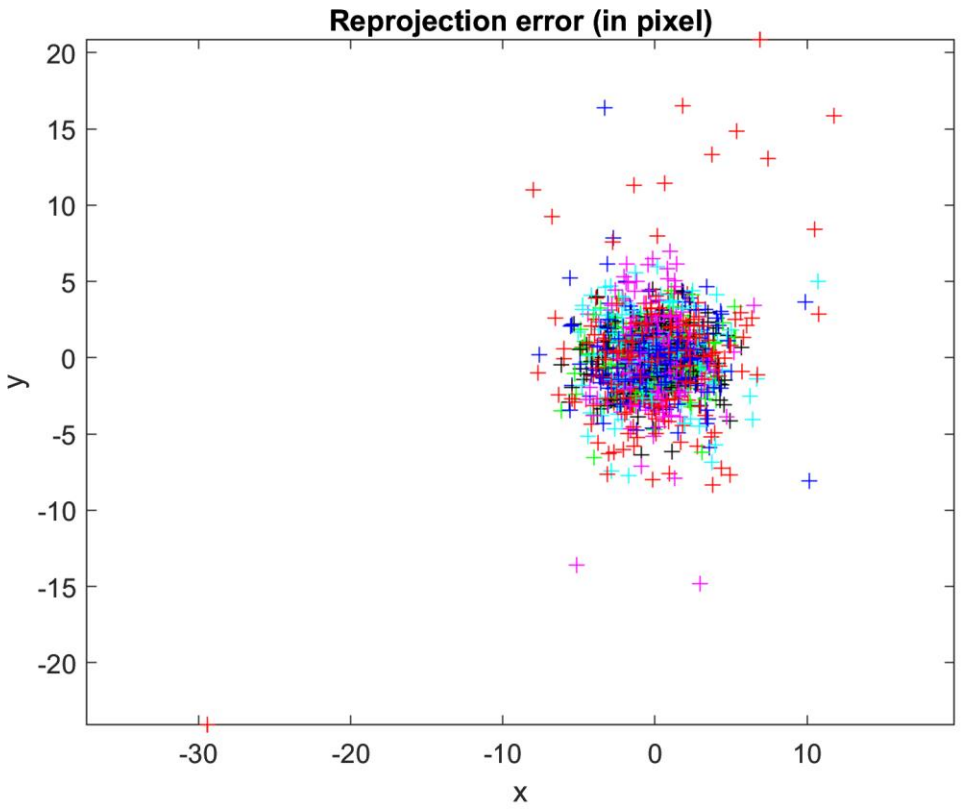


Figure 3: Reprojection Error

Despite a successful corner extraction process, it was found upon attempting to calibrate the camera according to the determined parameters that the calibration was erroneous. This can be seen in the before and after calibration images shown in Figure 4 below.

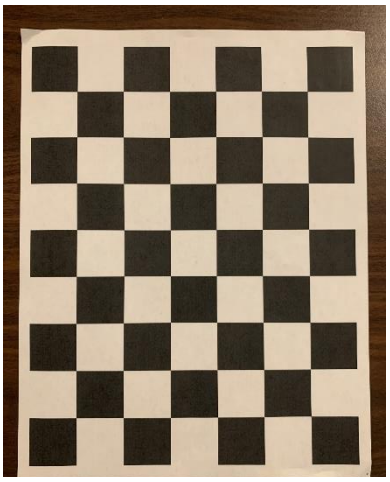


Figure 4a: Before Calibration

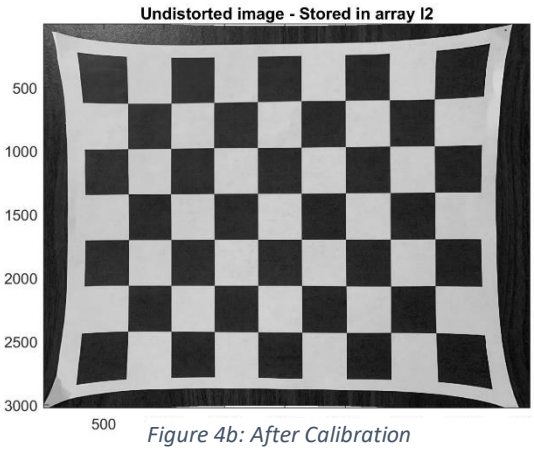


Figure 4b: After Calibration

AIt is evident when comparing the before image of Figure 4a to the after image of Figure 4b that the calibration erroneously distorts straight edges into curves. This faulty calibration can be attributed to the dated nature of the Caltech Camera Calibration toolbox and the fact that most current cameras (including the one used to take photos in this lab) already calibrate the images. These factors result in the calibration instead introducing distortion rather than eliminating it.

The images used to construct the LSC panorama can be seen in Figure 5 below.

Figure 5: LSC Photoset

By specifying the Harris corner detector function to detect 3000 corners and to divide the detection of these corners evenly across the quadrants of each image using the 'tile' input, the following distributions of Harris corners across the LSC photo set was created and shown in Figure 6 below.

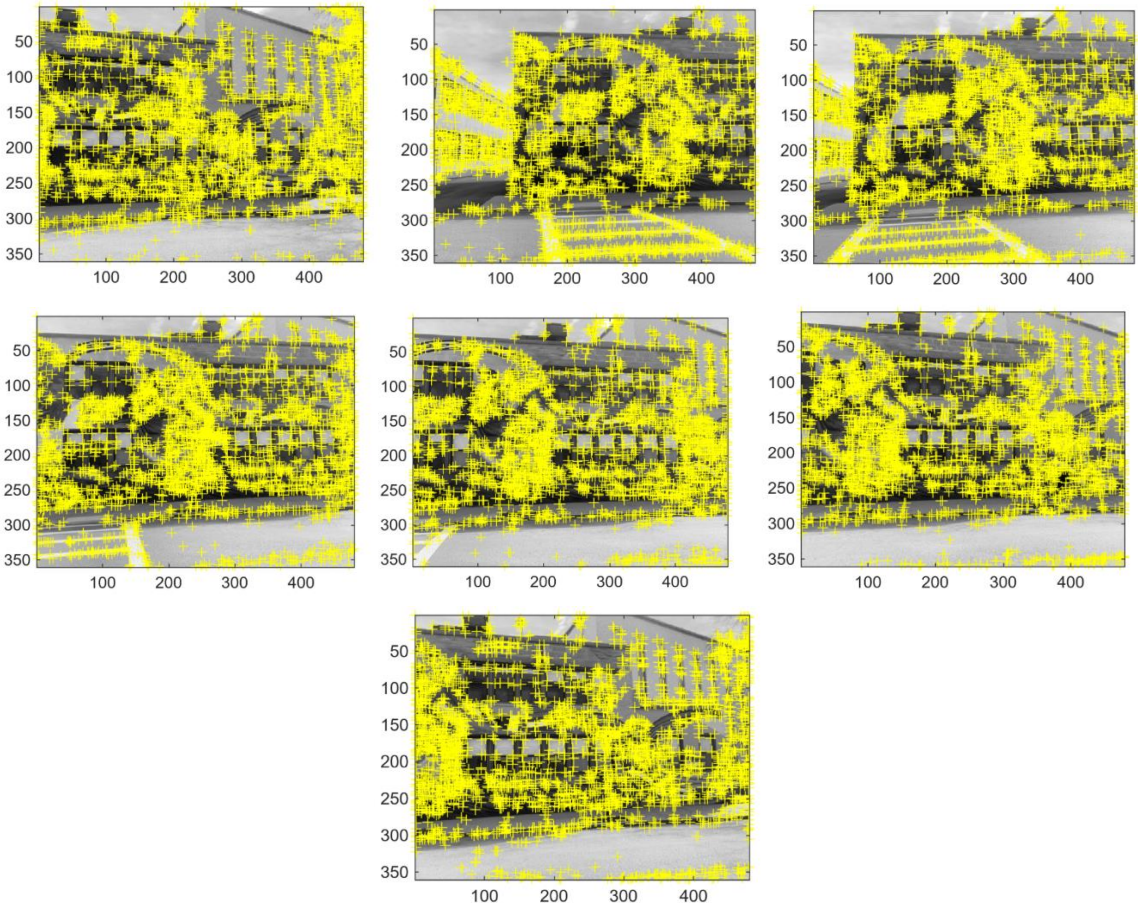


Figure 6: LSC Harris Corners Photoset

Using the shared detected corners across these images, the images could be stitched to create an LSC panorama. This panorama can be seen in Figure 7 below.

Figure 7: LSC Panorama

As discussed previously, the Harris detector needed to be specified to detect 3000 corners spread evenly between a 2x2 grid within the image to construct the panorama. However, additional steps to enable this process was to specify that the function, estgeotform2d, for estimating the transformation images do so in an 'affine' method as opposed to a 'projection' method and to resize the image down to a 360x480 image. These improved the detection of corners and the final panorama quality in appearance.

Additionally, the photo set of images used to create a panorama of a brick wall can be seen in Figure 8 below.

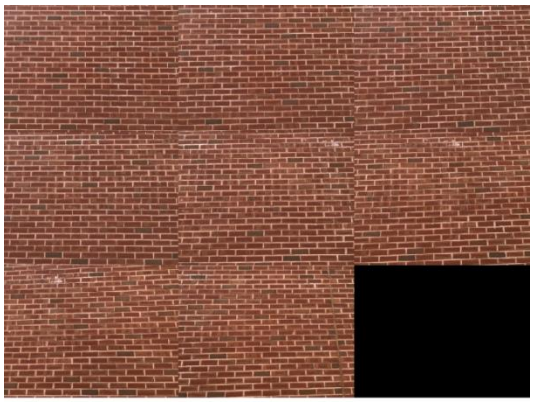
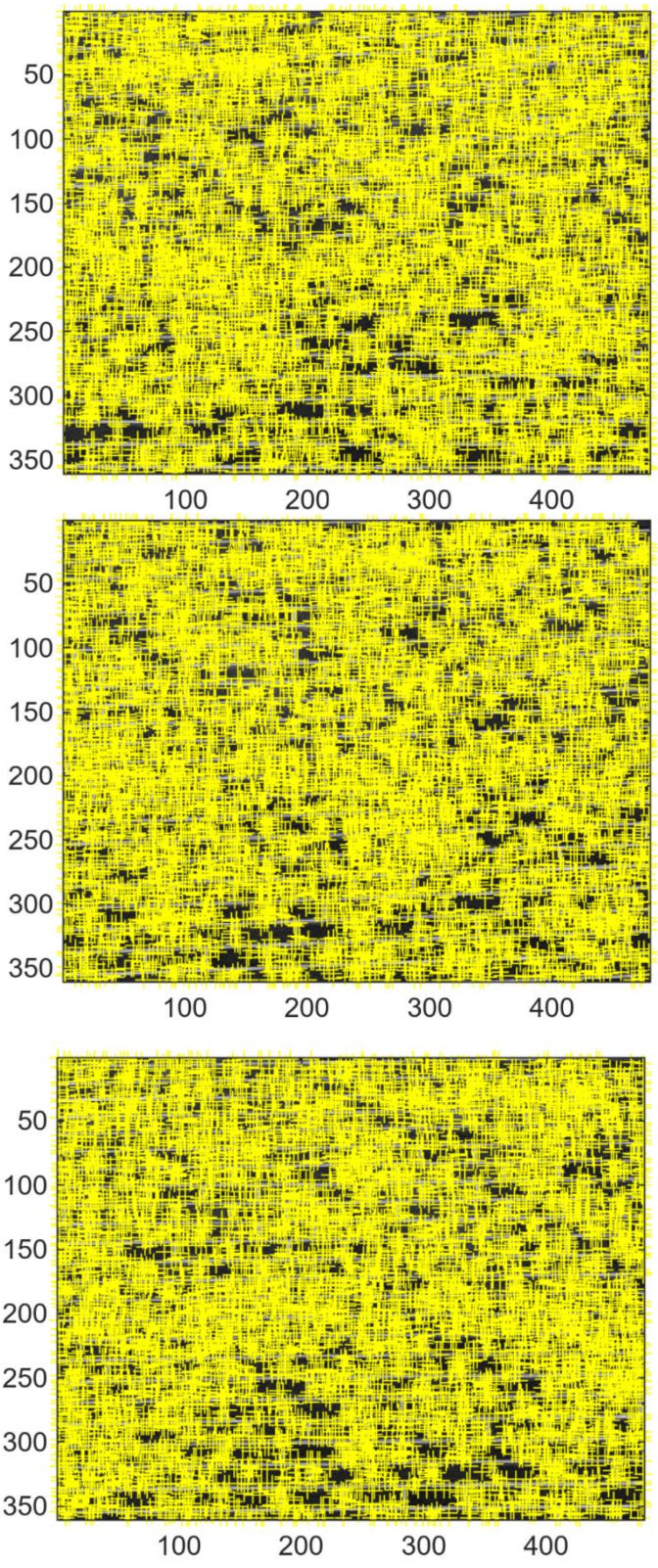


Figure 8: Brick Wall Photoset

The results of the Harris corner detection script can be seen in Figure 9 below.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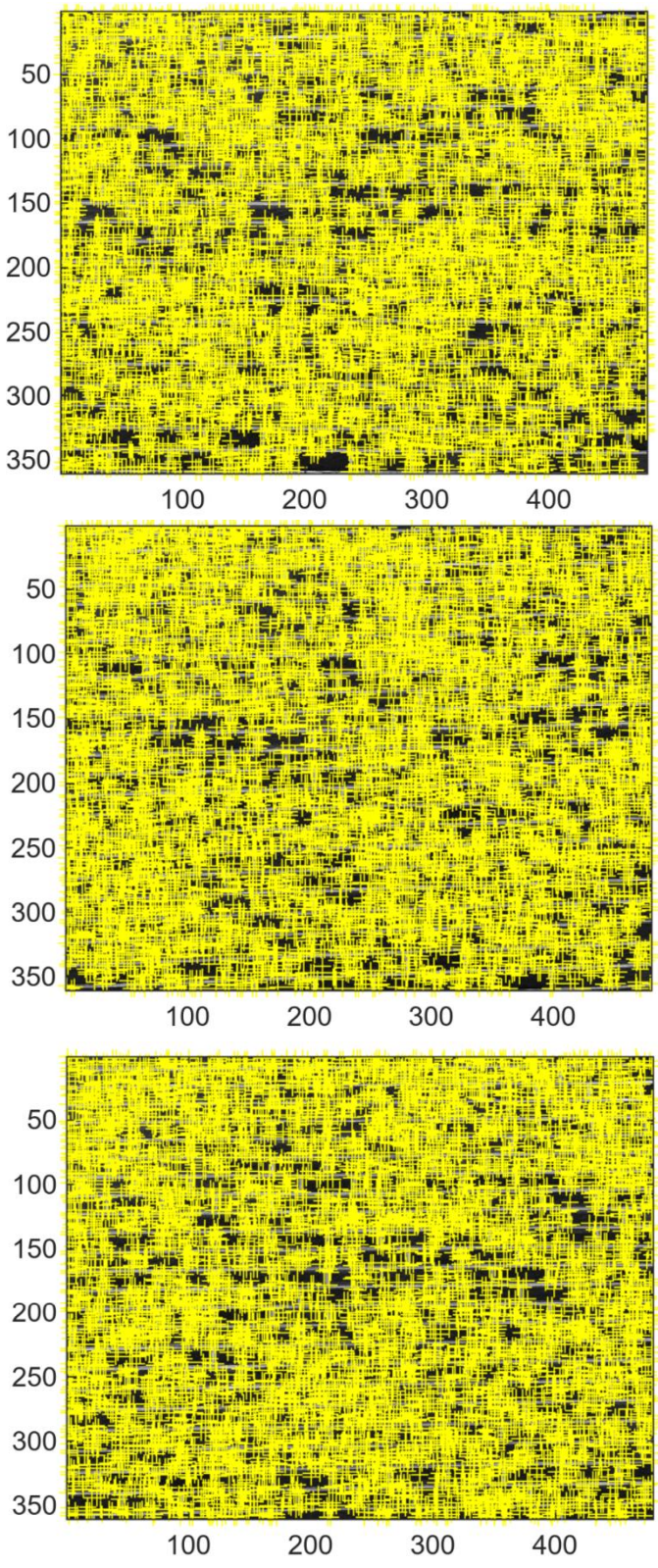
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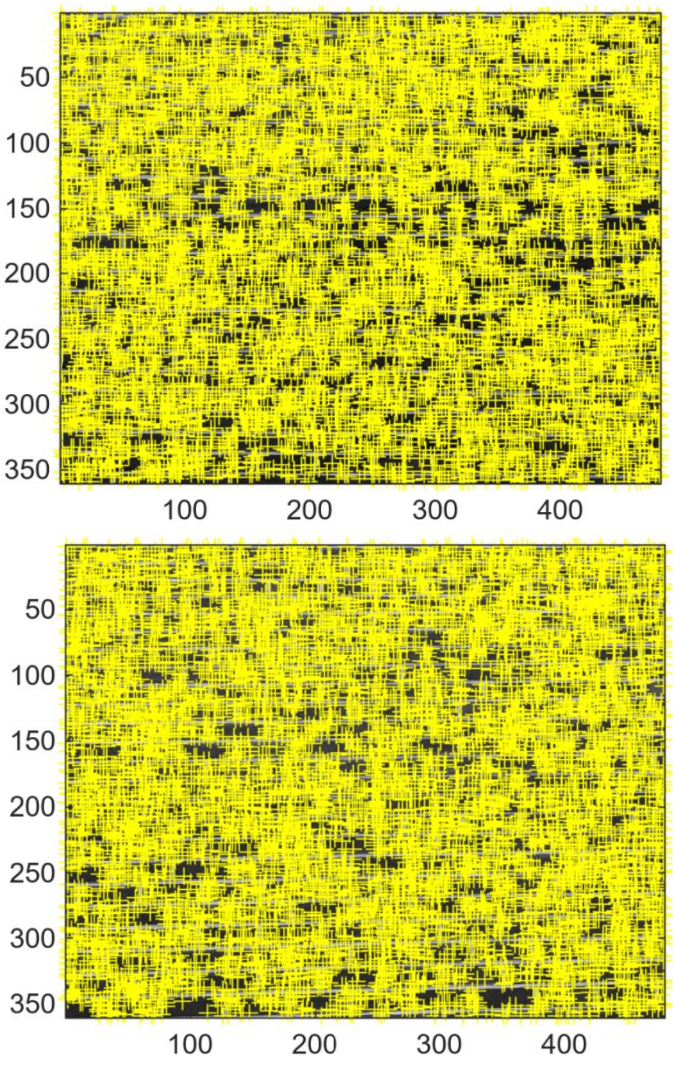


Figure 9: Brick Wall Harris Corners Photoset

The final panorama constructed from these images can be seen in Figure 10 below.

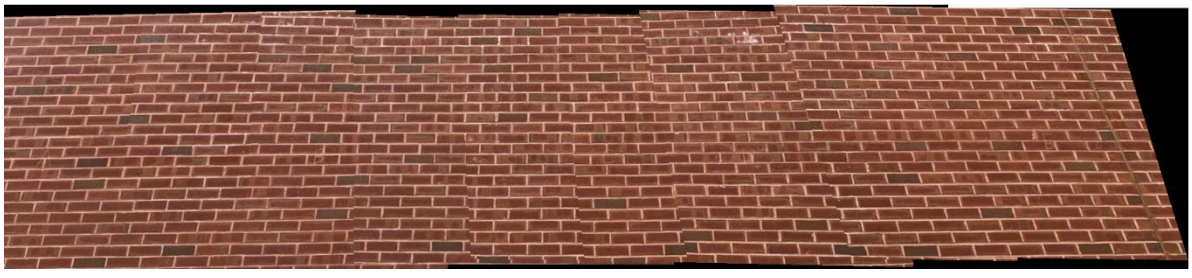
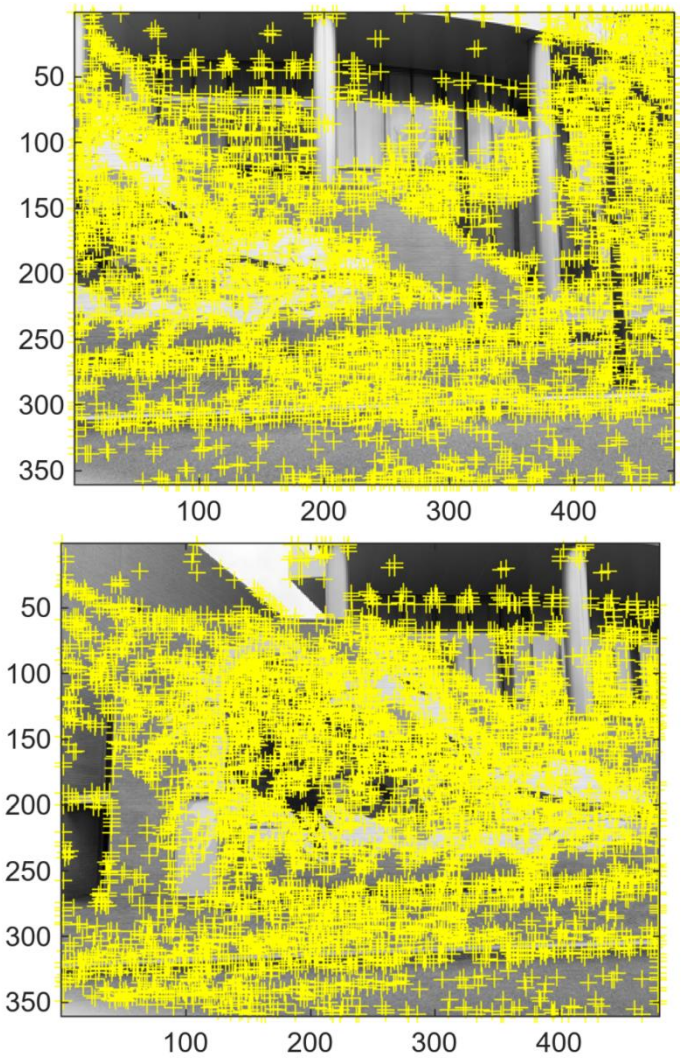


Figure 10: Brick Wall Panorama

This panorama is sufficiently good given the circumstances. However, there is apparent misalignment between some images. This is the case in spite of more than doubling the number

of corners the Harris detector was instructed to generate, going from 3000 corners in the LSC photoset to 7000 corners here. This makes sense. The repetitious nature of the pattern of bricks of the wall provide few unique features for the detector to find as significant and thereby appropriately line up the photos. While there may be a contrast between the bricks and the mortar between them, these straight lines still do not provide great changes in intensity that would enable a proper corner matching process. Hence, the panorama is not of great quality compared to the building of the Latino Student Center in Figure 7 which provides far better unique features.

The third mural of on the steps of the Behrakis building had two panormas constructed of it, one with 15% image overlap and the other with 50% image overlap. Their Harris detector image results can be seen in Figures 11 and 12 respectively below.



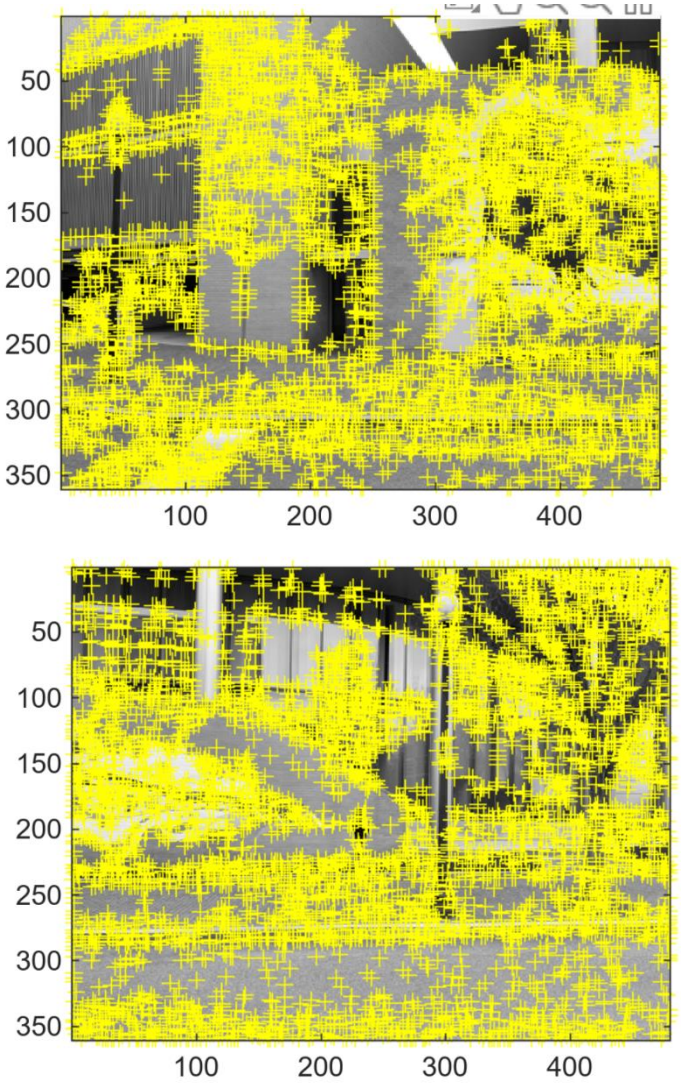
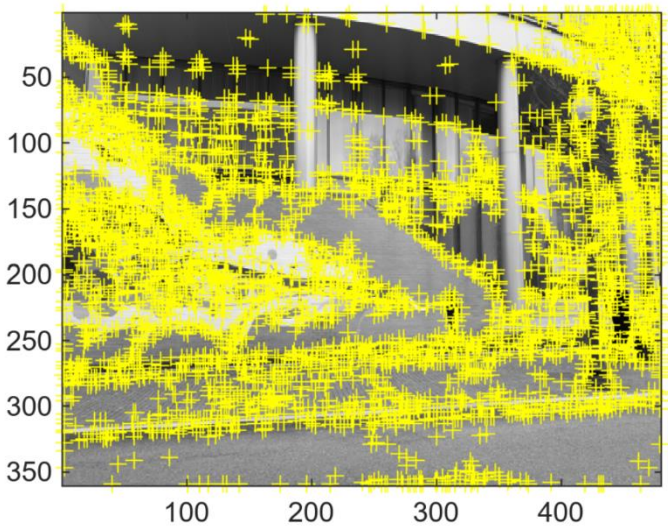


Figure 11: Third Mural 15% Overlap Harris Corners Photoset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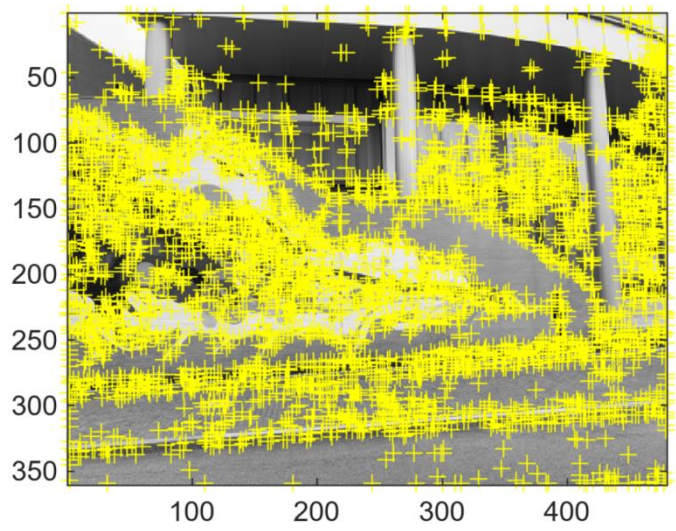
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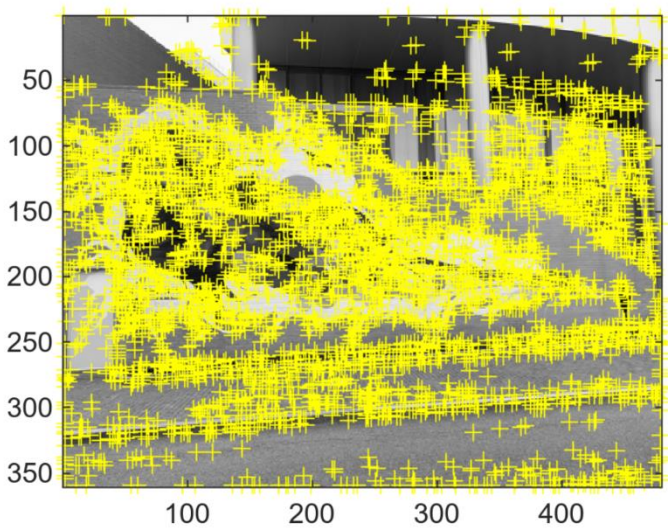
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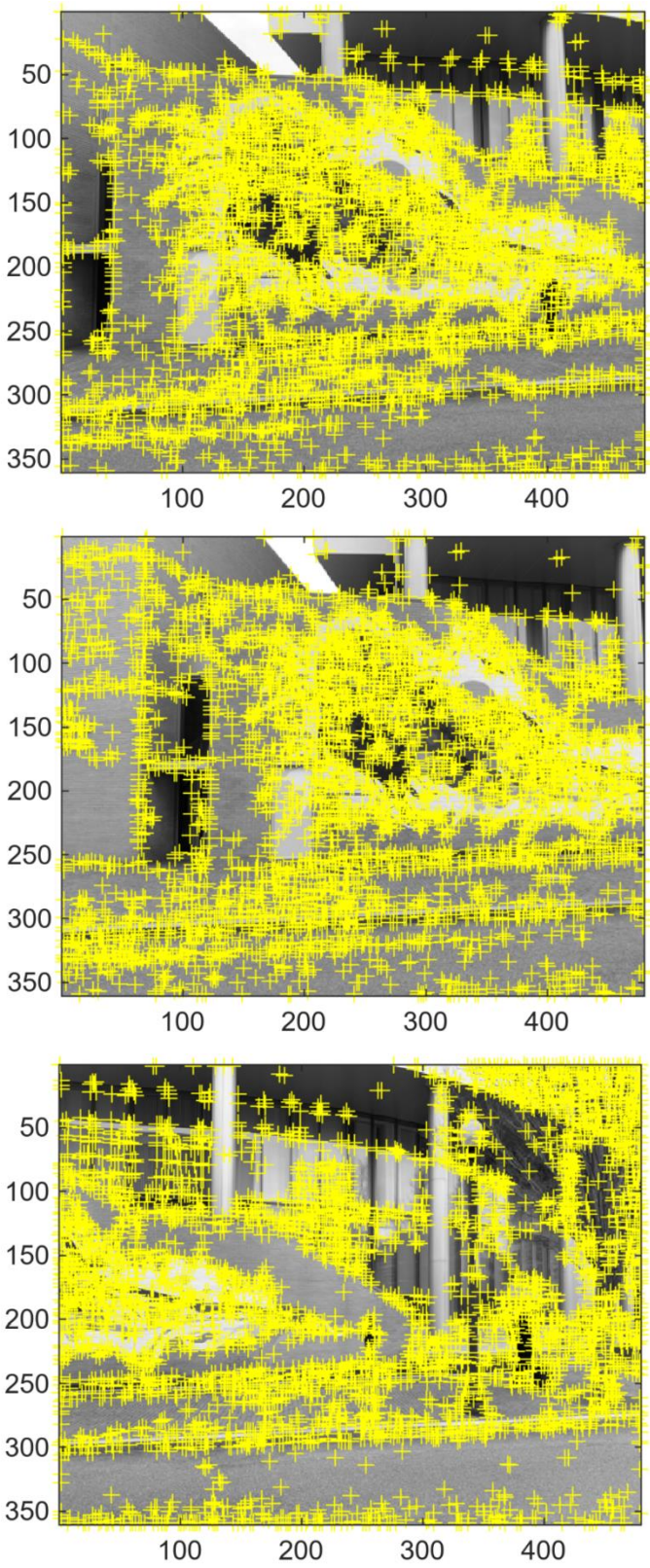

Figure 12: Third Mural 50% Overlap Harris Corners Photoset

The panoramas generated from the 15% overlap and 50% overlap can be seen in Figures 13 and 14 respectively below.

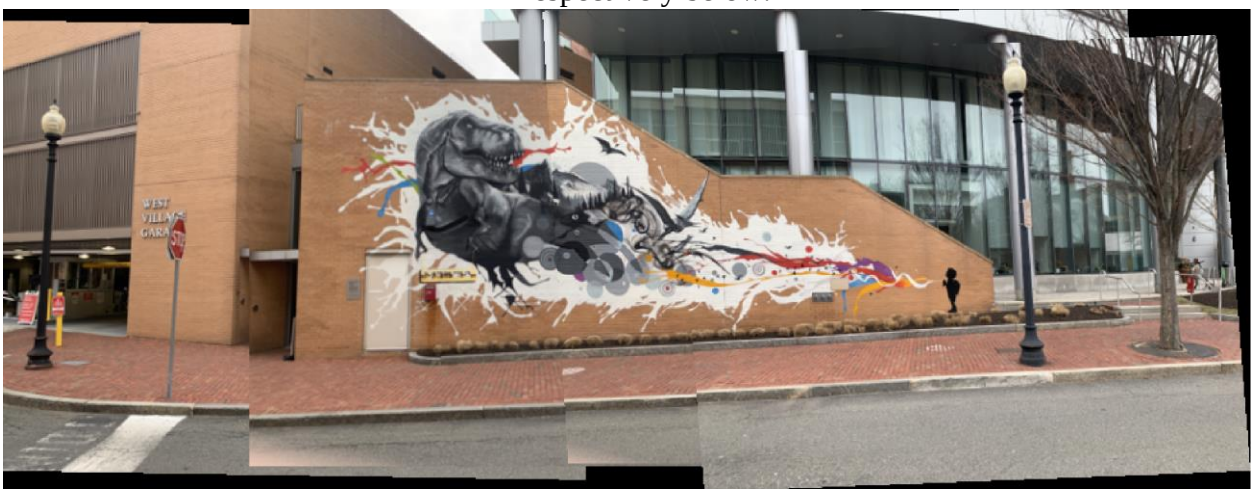

Figure 13: Third Mural 15% Overlap Panorama

Figure 14: Third Mural 50% Overlap Panorama

As can be seen between Figures 13 and 14, the 50% overlap does appear to perform better. There is less misalignment in the mural itself and better alignment amongst straight edges that have fewer unique corners for the 50% overlapped image. This makes sense as, with less overlap between there are fewer unique corners that can be shared in order to appropriately match up and align the photos into a panorama. Consequently, it was necessary to increase the number of corners detected from 4000 corners for the 50% overlap mural (increased from the LSC panorama because those photos had even greater overlap) to 5000 corners for the 15% overlap. Note, though, this increase is not as great as that between the LSC panorama and the brick wall

panorama as, even in the case of a smaller area of overlap, said overlap still contained unique features that the brick wall panorama did not.

Discussion

From making these panoramas, it can be concluded that the number of unique features a Harris detector is able to pick up and then compare between images makes for a better final panorama. Images made up of repeating simple patters, such as the brick wall's squares and straight lines, do not provide much variation in intensity and unique features and consequently will either have a poor panorama outcome or require a drastically increased number of detected corners. Additionally, decreasing the amount of overlap between images can adversely affect the stitching process as there is less area for finding unique features and thereby fewer features to compare between images in order to appropriately stitch them. This is seen in the case of the third mural panoramas. It should be noted though that presence of unique features for corner detection bears greater relevance than overlapping area, as evidenced by the great increase in number of corners needed to be detected for the brick mural in comparison to going from a 50% to 15% overlap for the third mural.