**Introduction**

In this lab, we focus upon learning photomosaicing and Harris corner detections to stitch multiple images in a single frame. By stitching together small, overlapping images, the digital image processing technique known as image mosaic photomosaicing creates one enormous image. To create a smooth and continuous larger image, the technique entails aligning and blending the smaller images. A corner detection operator called the Harris corner detector is used to extract corners and infer characteristics from images.

**Camera Calibration**

The primary step to this lab is camera calibration. In this we Camera calibration calculates the specifications of a camera's lens and image sensor. These attributes can be used to correct lens distortion, measure an object's size in world units, or locate the camera in the image. Applications like machine vision use these tasks alongside harris corner detection to find and quantify things.

The calibration of camera was done with a 7x9 checkered board with the squares being 30mm by 30mm each.

A picture containing text, white, black, checker

Description automatically generatedHere are a few images we used for camera calibration –

Figure : Primary Images for Calibration

A black and white checkered surface

Description automatically generated with low confidence

The corners are manually removed to determine the inaccuracy. The four extreme corners of each image's rectangular checkerboard pattern must first be properly clicked before the MATLAB Camera Calibration toolbox automatically extracts the grid corners. The calibration took more than a single attempt. Initially my error exceeded 1.2583 which means I need to recalibrate and fix the issue by redoing pixelation. I reduced the pixels to 1600x730. Furthermore, the guidelines suggested that the error should be <1. The standard deviation of the reprojection of the error after reducing the pixels and recalibration was (0.30501 0.33401).

Chart, scatter chart

Description automatically generated

Figure :Projection of Error

The camera calibration parameters were self-defined while we found the error by the algorithm. The extrinsic and intrinsic characteristics are used in the calibration procedure to compute the camera matrix. The extrinsic parameters signify a hard transition from the coordinate system of the 3-D world to that of the 3-D camera. The intrinsic parameters show a projective translation from the coordinates of the 3-D camera to the coordinates of the 2-D image.

After optimization, the distortion coefficients are determined and are represented by kc. The tangential distortion is represented by the distortion coefficients p1, p2, and the radial distortion by the distortion coefficients k1, k2, and k3.

Text

Description automatically generatedSince many contemporary camera lenses are already designed to reduce tangential distortion, their magnitude is lower than radial distortion coefficients. The distortion parameter values are there for several reasons, including the fact that we didn't carefully extract the corners from certain severely deformed photos. Second, when the image is obtained at a very slanting angle, some grid points are blurred due to the depth of field (DOF) of the image, leading to poor corner extraction.

Figure : Error Parameters

A picture containing floor

Description automatically generatedA picture containing text

Description automatically generated

Figure :Image after calibration

Figure : Image before calibration

**Latino Students Center mural Mosaic**

A picture containing text

Description automatically generatedThe images were captured from the Latino student center mural on Forsyth Street.

Figure : Primary Images of LSC

These are the undistorted images taken from the phone’s camera used to stitch together and form a single picture through MATLAB and harris corner detection. The default settings are those that were utilized to implement these parts. The Harris Corner Detector has 1,000 characteristics and uses a two-row, two-column "tile" technique. The characteristics were evenly spaced out throughout the picture. The distribution of the features across the image using the tile method gave the features a non-maximal suppression effect.

A black car parked in front of a house

Description automatically generated with low confidenceA picture containing text, truck, screenshot

Description automatically generated Here we also activated the smoothing filtering in the frequency domain.

Figure : Harris Corner Detection

A picture containing text, road

Description automatically generatedWe see in the final output that final creation of mosaic is successful through stitching and harris corner detection which perfectly detected the corners in the wall and buildings but as we see that near the car the detection fluttered a little. As a result, we may say that the Harris feature detector tries to find corners. Additionally, it aids in the detection of many corners of various building features, like building borders, windows, railings, etc. Because of this, the structure has more elements than the road, crosswalk, and automobile.

Figure : LSC Mosaic

**Cinder Wall Mosaic**

A picture containing chart

Description automatically generatedChart

Description automatically generatedWe used a set of 6 images to form a mosaic of the Cinder wall at Cabot center. As we observe, the patterns on the wall are very uniform and hence we made aa few changes in the harris corner detection. The Harris Corner Detector has 1,800 features and used a two-row, two-column "tile" technique. The distribution of the features over the image using the tile method gave the features a nonmaximal suppression effect.

Figure :Harris Corner Detection

A black and white photo of a brick wall

Description automatically generated with low confidenceWe observe that the detection of these corners is clearer towards the end of the wall rather than in the center due to numerous distinct corners in the wall. With the increase in the harris corner feature we will see that the stitching is more precise. We see in the final output that the stitching is near to accurate as due to the repetitive patterns we used a lot of harris corner features.

Figure : CInder Wall Mosaic

**A picture containing text, cage

Description automatically generatedRuggles Mural Mosaic (15% overlap)**

Figure :Primary images of Ruggles mural with 15% overlapping

A picture containing diagram

Description automatically generatedDiagram

Description automatically generatedThe Ruggles wall just beneath the Ruggles station has a mural wall long enough to perform the experiment with 2 different sets of images of the same mural. The overlapping is of 15% and hence different from the other set which has the overlapping of 50%. The Harris Corner Detector has 1,000 characteristics and uses a two-row, two-column "tile" technique. The characteristics were evenly spaced out throughout the picture. The distribution of the features across the image using the tile method gave the features a non-maximal suppression effect. We can disperse the stitching more evenly by adding more feature points.

Figure :Harris Corner Detection

A picture containing graphical user interface

Description automatically generatedWe see in the final mosaic image that the stitching is not that good. This is because we used 50% overlapping instead of any higher rate and hence the bad results from the algorithm.

Figure : Ruggles Mosaic with 15% overlapping

**Ruggles Mural Mosaic (50% overlap)**

Application

Description automatically generatedWe use the same default parameters as above but this time we take the images with 50% overlapping to form our mosaic instead of 15%.

Figure :Primary images of Ruggles mural with 50% overlapping

Map

Description automatically generatedMap

Description automatically generatedThe Harris Corner Detector has 1,000 characteristics and uses a two-row, two-column "tile" technique. The characteristics were evenly spaced out throughout the picture. The distribution of the features across the image using the tile method gave the features a non-maximal suppression effect. We observe that the clarity of corner detection is somewhat precise with there not being many corners but there are some distortions.

Figure :Harris corner detection

Application

Description automatically generated with medium confidenceIn the final stitching, we observe that the mosaic formed by the algorithm is more precise and better formatted than that of the mural with 15% overlapping when using harris corner detector with 1000 feature. The pattern and overlapping helps in better mosaicking of the image and hence the output is more on point.

Figure : Ruggles Mosaic with 50% overlapping

**Conclusion**

In this lab we learnt in-depth about camera calibration and working on photo mosaicking. We learnt that as the growth of technology took place, we did not have to make any calibrations as the modern day cameras are pre-calibrated. We learnt how to use harris corner detection and features through this lab which helped in image stitching and mosaicking. Through the lab we found out that with the same number of harris features used, we get a better output through greater overlapping. Also, in the cinder wall experiment we found out that due to due to the repetitive pattern we had to use much more harris features than in other experiments to help is blend better.