EECE5554 – Robot Sensing and Navigation

Lab-5

Introduction:

In this lab we will look at the role and use of calibrated cameras for simple photo mosaicing. We will be using your camera phone for all the imaging associated with this Lab.

Camera Calibration:

Camera Calibration is used to estimate the parameters of a lens and image sensor of an image or video camera. We employ these parameters to rectify the lens distortion, measure the size of an object in world units, or determine the location of the camera. Calibration images were taken of a 7x9 checkerboard with 30mm x 30mm squares each. I have taken 10 images of checker box for calibration that are fed into Caltech Camera Calibration Toolbox.

To Ascertain the error, the corners are manually extracted. After clicking on the four extreme corners of the rectangular checkerboards pattern of each image, the grid corners are automatically extracted by the MATLAB Camera Calibration toolbox.

Fig 1: Corner Selection for Error Calculation

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Use focal provided
Estimated focal: 681.4801 pixels
Guess for distortion factor kc ([]=0): -0.3
Satisfied with distortion? ([]=no, other=yes) 1
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Fig 2: Error Calculation

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Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 910.48539   930.47175 ] +/- [ 29.45452   28.18601 ]
Principal point:       cc = [ 545.05706   497.93195 ] +/- [ 28.60753   24.76542 ]
Skew:             alpha_c = [ 0.00000 ] +/- [ 0.00000  ]   => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:            kc = [ 0.06879   -0.37171   0.01792   0.01170  0.00000 ] +/- [ 0.09129   0.24090   0.00721   0.01093  0.00000 ]
Pixel error:          err = [ 4.33578   3.29261 ]

Note: The numerical errors are approximately three times the standard deviations (for reference).
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Fig 3: Calibration Results

We could see from Fig 3 that the standard deviation of the reprojection error is [4.33578,3.29261]. Further the reprojection error is plotted in the form of colour-coded crosses. The spread of the re-projection error is shown in Fig 4. We could also see that there is a circular pattern formed which is due to the excitation of every axis of the calibration images and capturing of different angles.

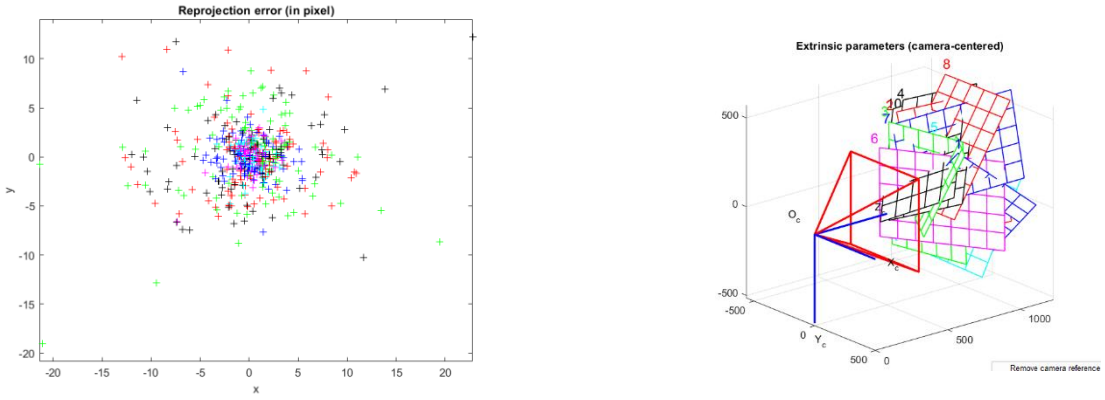

Fig 4 : Plot of data

Calibration Parameters:

The calibration algorithm used to calculate the camera matrix employs the extrinsic and intrinsic parameters. The extrinsic parameters represent a rigid transformation from world co-ordinate system to the 3-d camera co-ordinate system. The intrinsic parameters represent a projective transformation from the 3-D camera co-ordinates to 2-D image co-ordinates.

The intrinsic matrix, K is defined as

$$\mathbf{K} = \begin{vmatrix} f_x & s & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{vmatrix}$$

Where,

fc is Focal length in pixels

s is Skew coefficient

cc = Principal point in pixels

We can notice from Fig 2 that the value of fc is [910.48539 930.47175] +/- [29.45452 28.18601] and the value of cc is [545.05706 497.93195] +/- [28.60753 24.76542].

Image Mosiacing:

1. Murals on Latino Student Center

The images for this analysis were captured at the latino student center on the Forsyth street. About 7 images were taken and used for the analysis. The images are original as they are undistorted ones. The parameters are set to default for implementation and the harris corner detector is set to 1000. Further a tile approach of 2 rows and 2 columns is used. The usage of tile approach distributes the features across the image that would provide a non maximal suppression effect to the features.

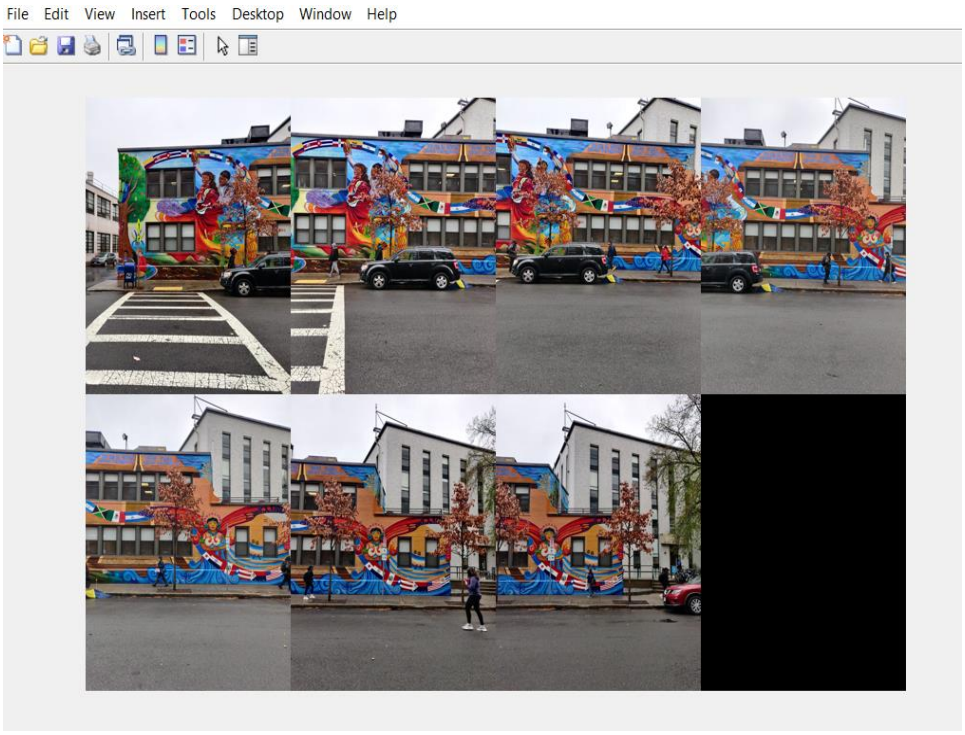

Fig 5: Images used for analysis

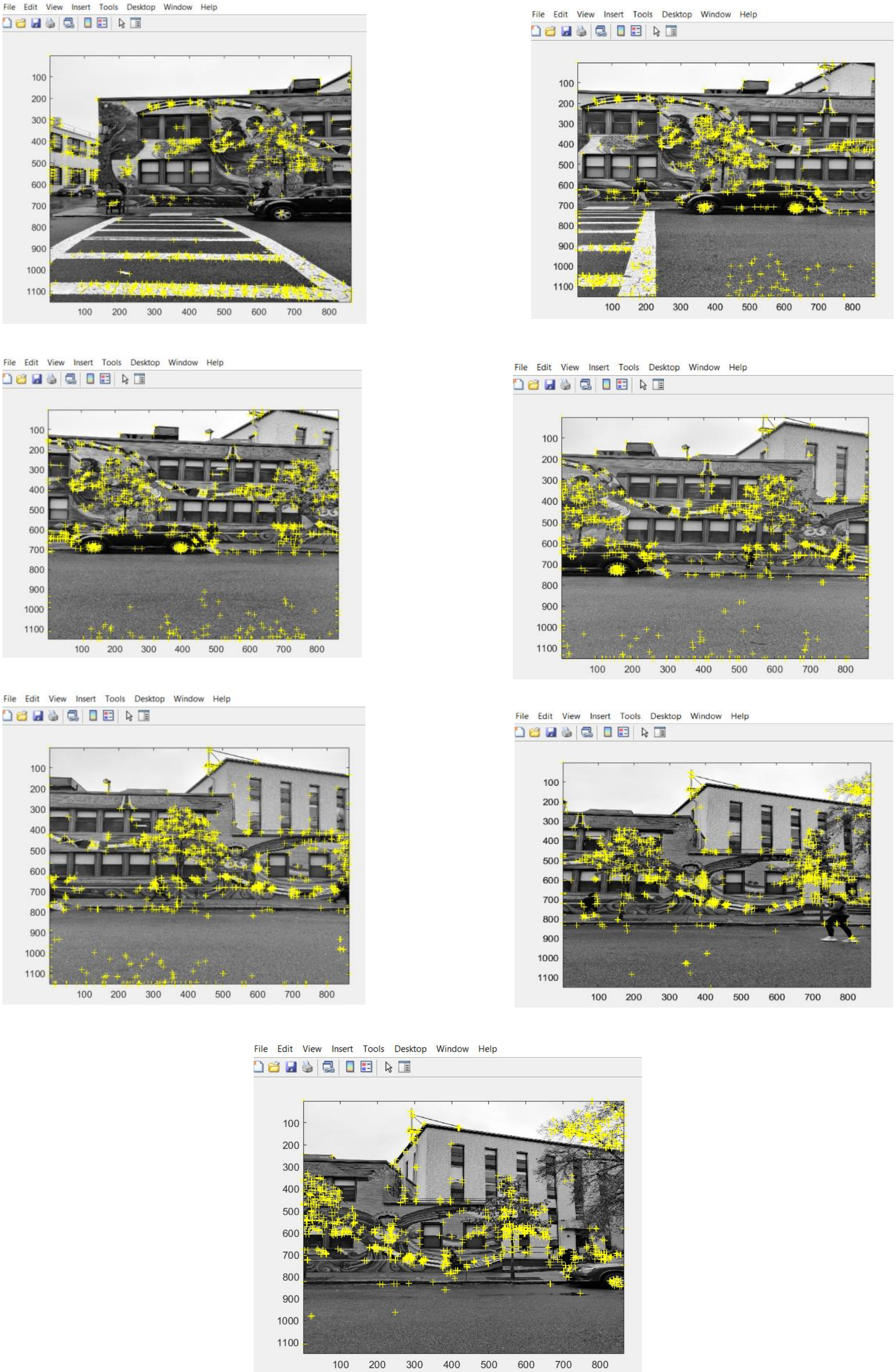

Fig : Harris Corner Images

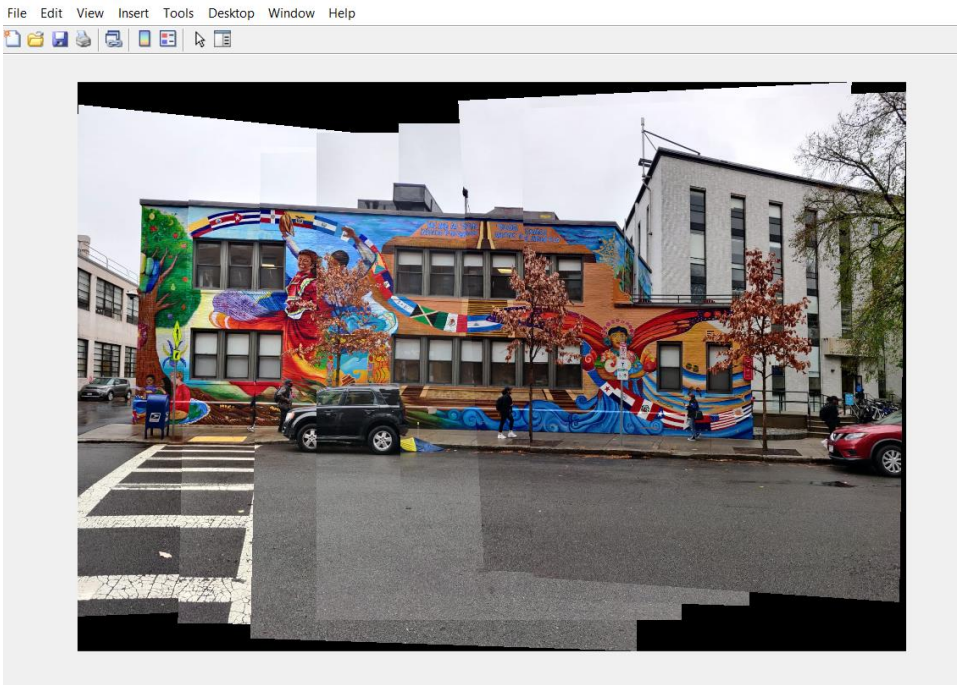

Fig : Panoramic Image

2. Murals on Ruggles (50% overlap)

The images for this analysis were captured in Ruggles. About 8 images were taken with about 50% overlap and used for the analysis. The images are original as they are undistorted ones. The parameters are set to default for implementation and the harris corner detector is set to 1000. Further a tile approach of 2 rows and 2 columns is used. The usage of tile approach distributes the features across the image that would provide a non maximal suppression effect to the features.

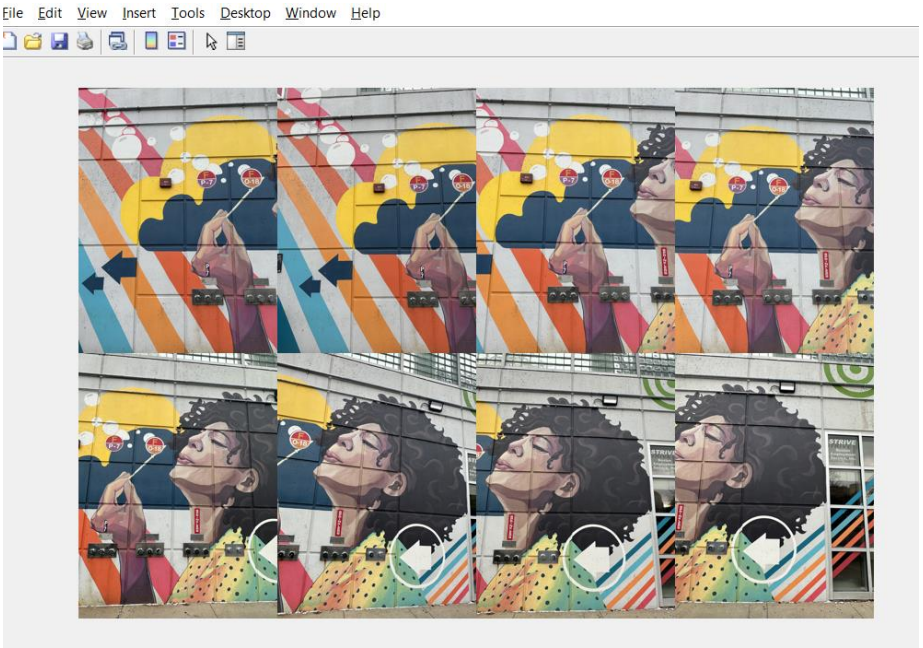

Fig : Images used for analysis

Fig : Harris Corner Images

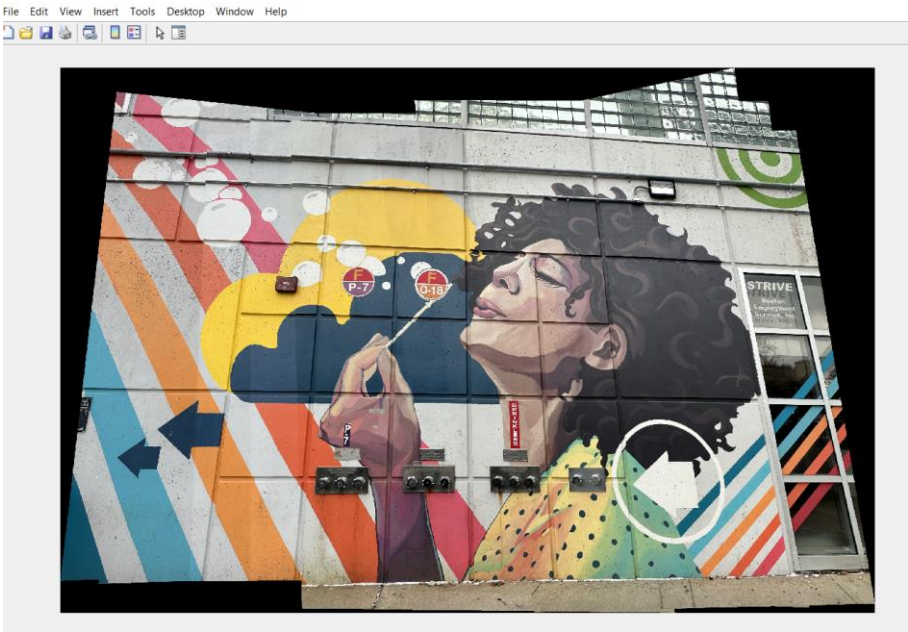

Fig : Panoramic Image

3. Murals on Ruggles (15% overlap)

The images for this analysis were captured in Ruggles. About 8 images were taken with about 15% overlap and used for the analysis. The images are original as they are undistorted ones. The parameters are set to default for implementation and the harris corner detector is set to 1000. Further a tile approach of 2 rows and 2 columns is used. The usage of tile approach distributes the features across the image that would provide a non maximal suppression effect to the features.

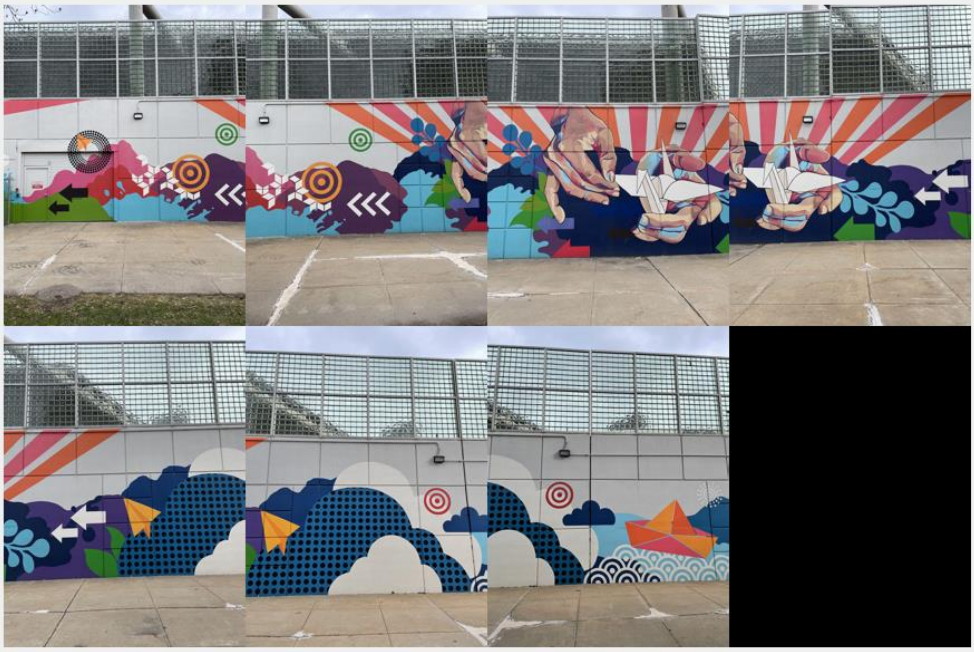

Fig : Images used for Analysis

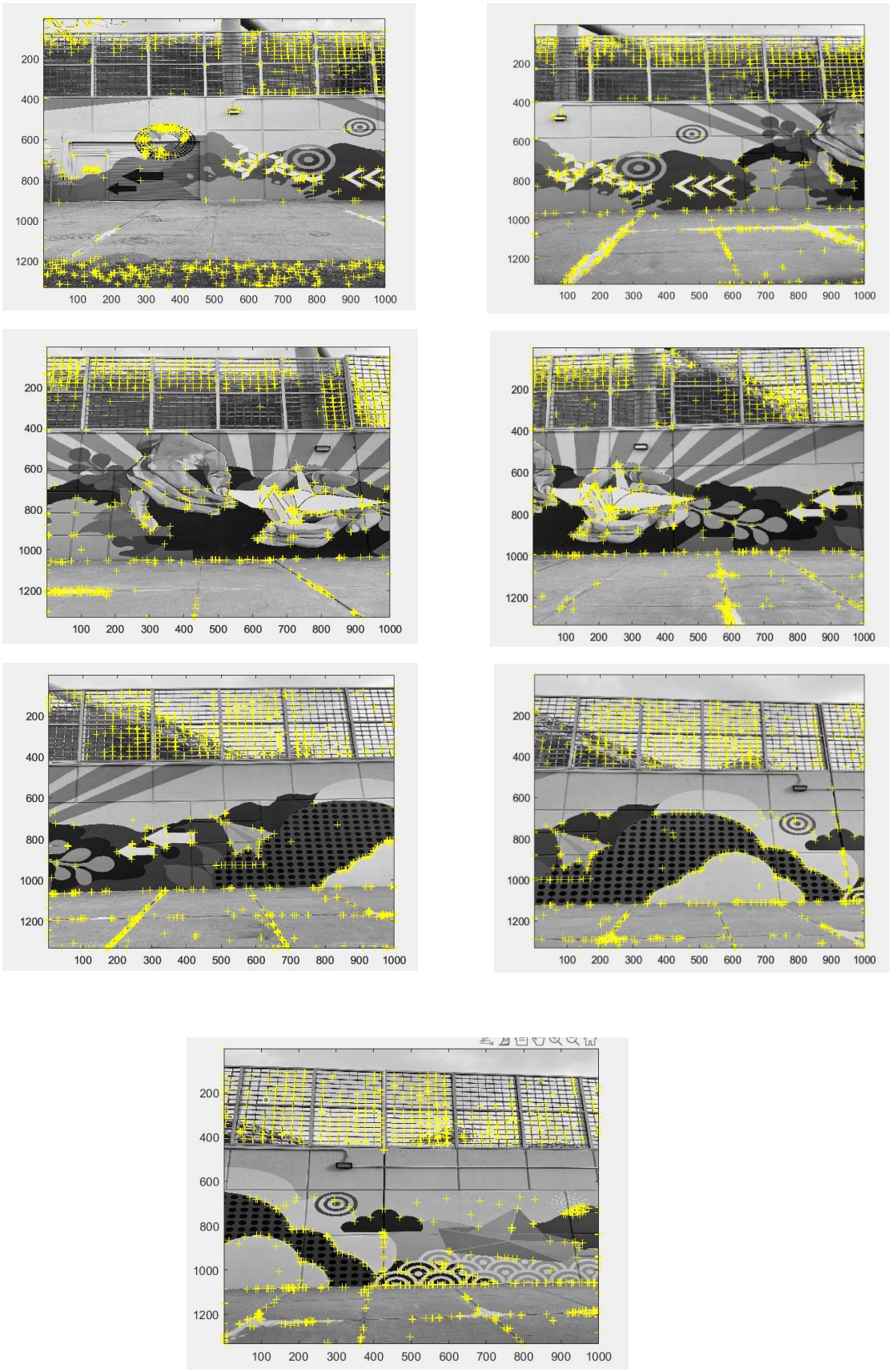

Fig : Harrison Corner Image

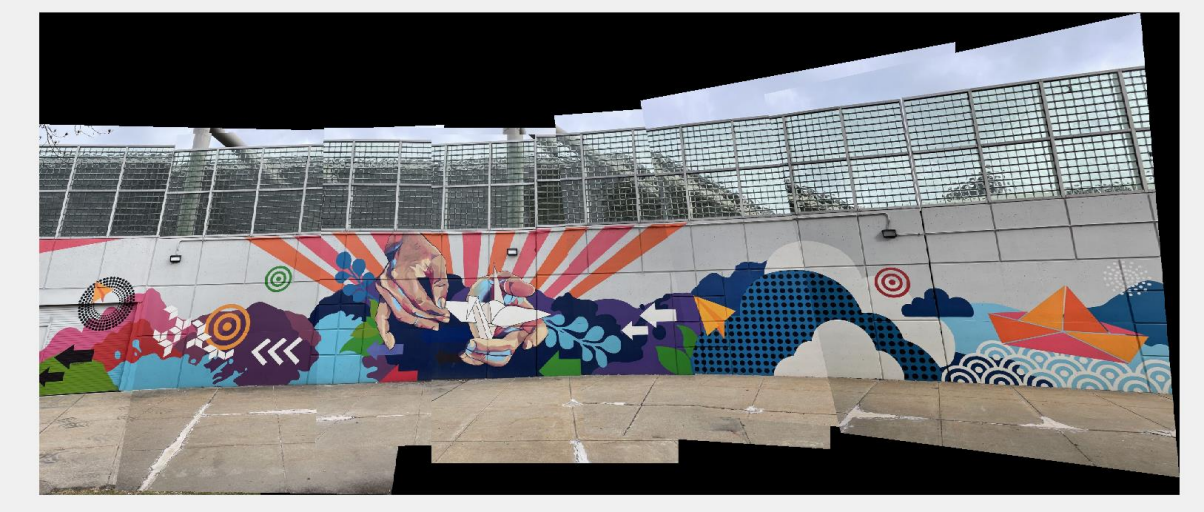

Fig : Panoramic Image

4. Cider Wall

The images for this analysis were in Northeastern University. About 6 images were taken and used for the analysis. The images are original as they are undistorted ones. The parameters are set to default for implementation and the harris corner detector is set to 1500. Further a tile approach of 2 rows and 2 columns is used. The usage of tile approach distributes the features across the image that would provide a non maximal suppression effect to the features.

Fig : Images used for Analysis

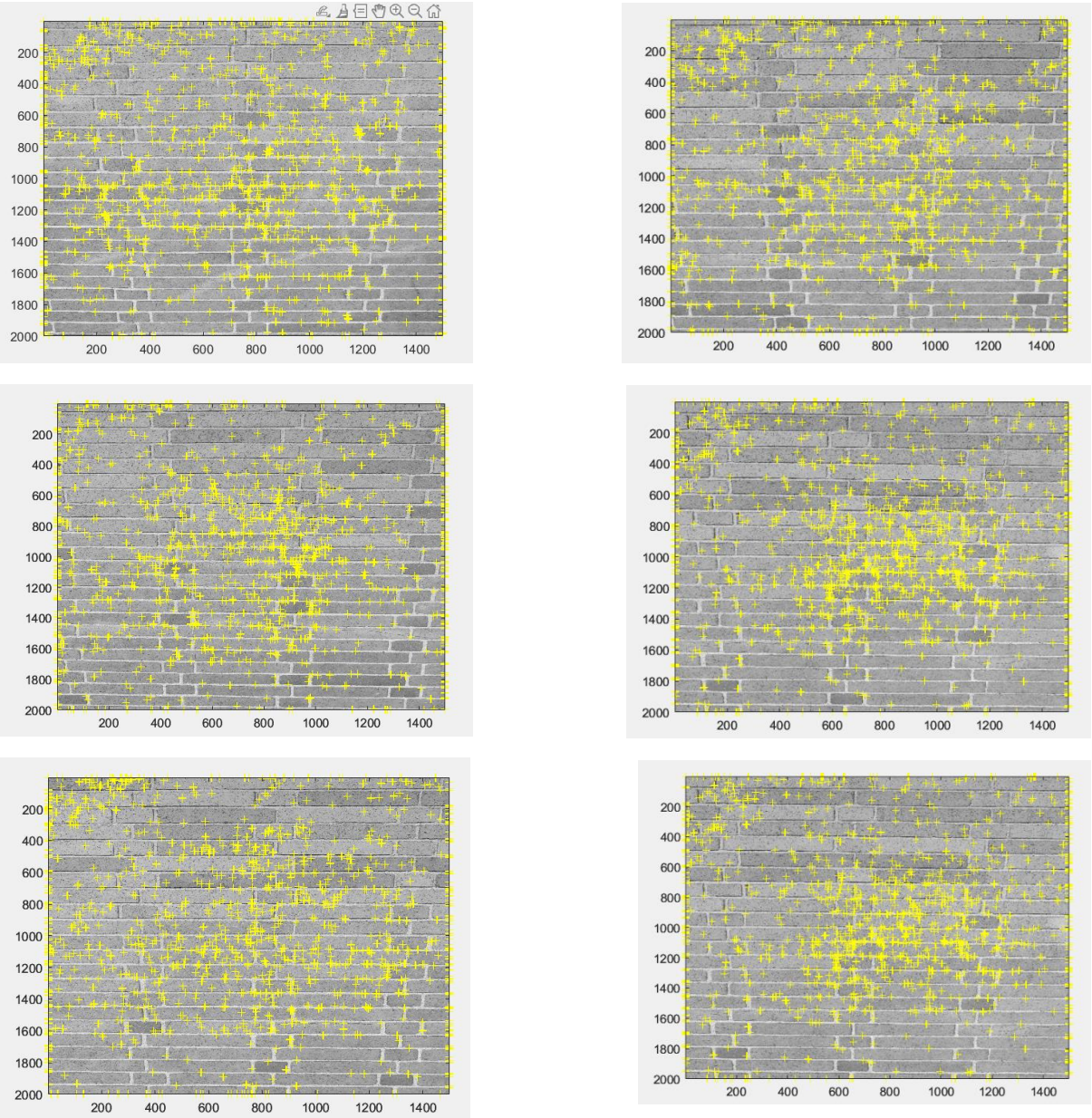

Fig : Harrison Corner Image

Fig : Panoramic Image