

# Lab4 Report

## 1. Camera Calibration

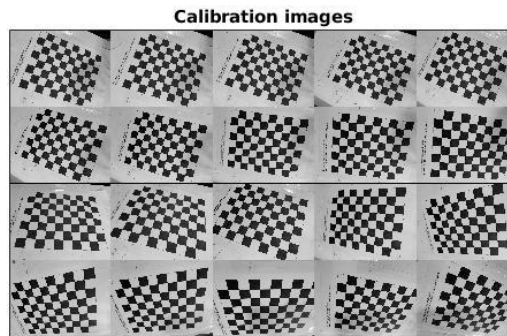
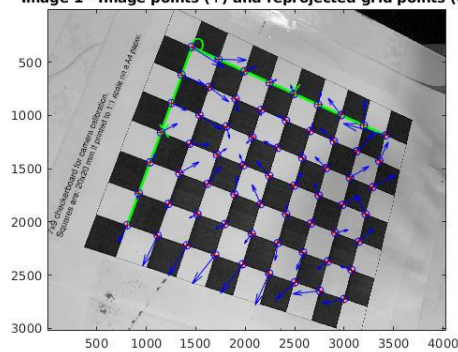


Figure 1: Checker board photos taken by iPhoneXS

Image 1 - Image points (+) and reprojected grid points (o)



Reprojection error (in pixel)

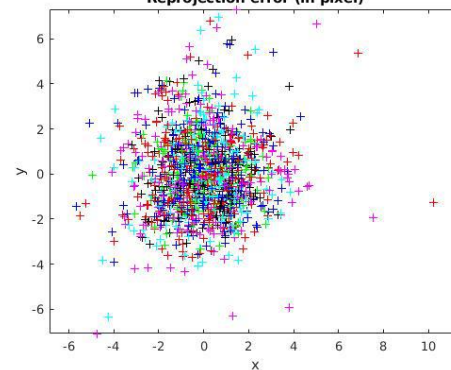
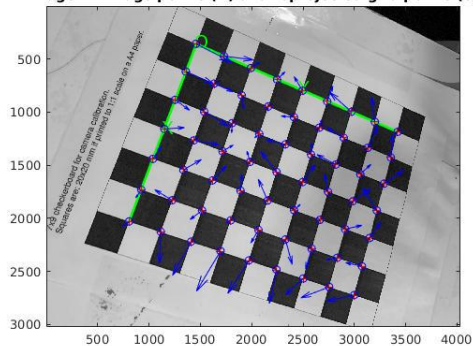


Figure 2: Re-projection error after first calibration

Image 1 - Image points (+) and reprojected grid points (o)



Reprojection error (in pixel)

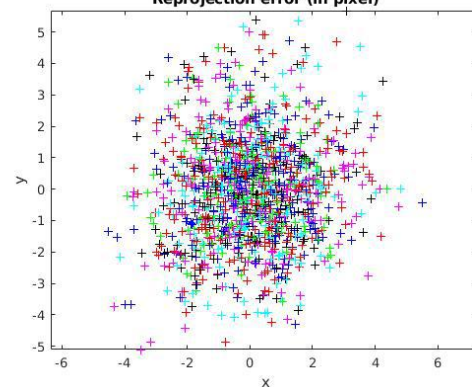


Figure 3: Re-projection error after Recomp.corners and Re-calibration

Calibration results after optimization (with uncertainties):

```
Focal Length:      fc = [ 3093.26007   3109.21673 ] +/- [ 10.89459   11.35837 ]
Principal point:   cc = [ 2016.45916   1498.99190 ] +/- [ 7.41318    6.31625 ]
Skew:              alpha_c = [ 0.00000 ] +/- [ 0.00000 ] => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:        kc = [ 0.11410   -0.30991   -0.00041   -0.00076   0.00000 ] +/- [ 0.00805   0.02473   0.00072   0.00091   0.00000 ]
Pixel error:       err = [ 1.54318   1.71926 ]
```

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

Figure 4: First calibration results

Calibration results after optimization (with uncertainties):

```
Focal Length:      fc = [ 3091.07138   3106.98313 ] +/- [ 10.72141   11.17745 ]
Principal point:   cc = [ 2013.88823   1497.43253 ] +/- [ 7.25876    6.19396 ]
Skew:              alpha_c = [ 0.00000 ] +/- [ 0.00000 ] => angle of pixel axes = 90.00000 +/- 0.00000 degrees
Distortion:        kc = [ 0.11622   -0.31847   -0.00057   -0.00101   0.00000 ] +/- [ 0.00789   0.02422   0.00071   0.00089   0.00000 ]
Pixel error:       err = [ 1.51709   1.69492 ]
```

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

Figure 5: Re-calibration results

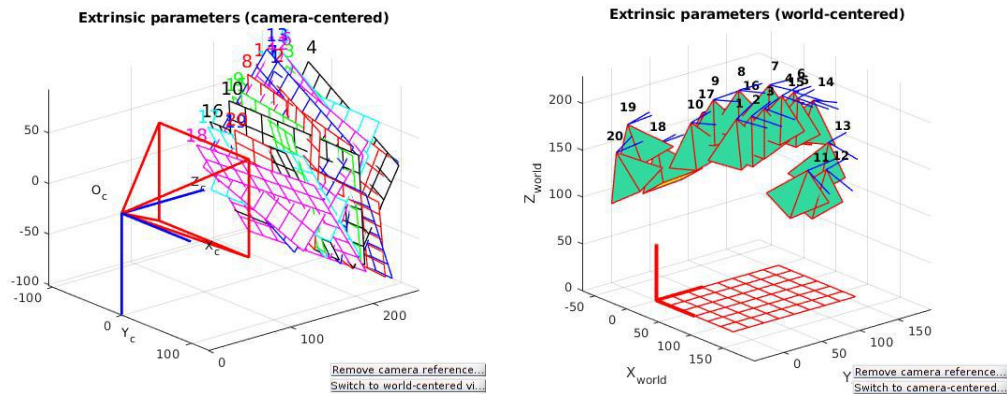


Figure 6: Extrinsic parameters

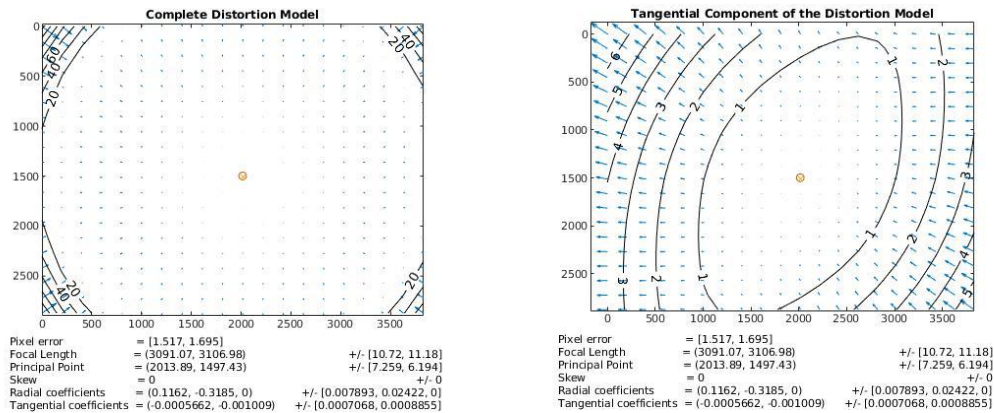


Figure 7: Visualize distortions

## Conclusion:

As we see in Figure 4 and Figure 5, after Recomp.corners process, pixel error became a little bit smaller, which is [1.51709 1.69492]. However, this error is still larger than the what it suggests to be in the calibration example. I think the reason is the new generation of iPhone has done some preprocess with its images to tune the intrinsic parameters of its cameras and undistort the image. This preprocess might have conflicts with the calibration process and magnify the pixel error.

## 2. Camera photos undistortion

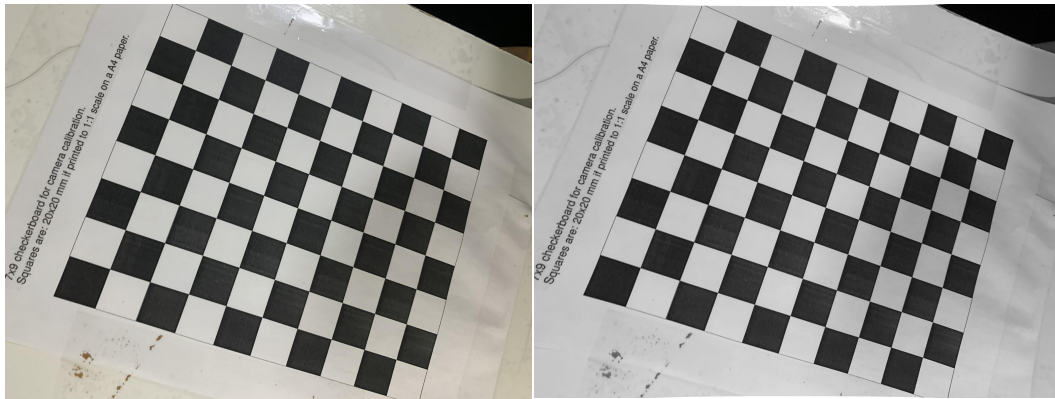


Figure 8: Original photo(left) and Rectified photo(right)



Figure 9: Original Latino photo(left) and Rectified Latino photo(right)

### Conclusion:

As we see in Figure 8 and Figure 9, after Undistort Image process, rectified photos have more distortion than original photos taken by iPhoneXS. Therefore, the preprocess done by new iPhone should be incompatible with the calibration process we used. So I will use original photos for later manipulation in Lab4.

## 3. Latino Panoramic Image Stitching

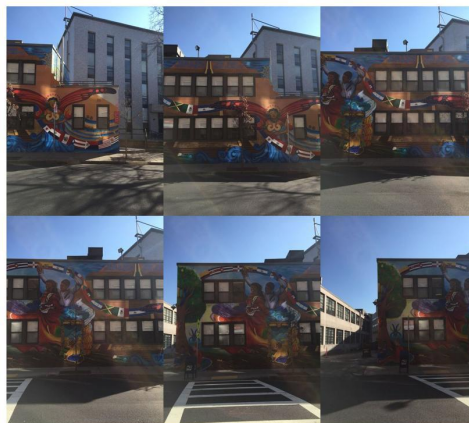


Figure 10: Original Latino photos thumbnail



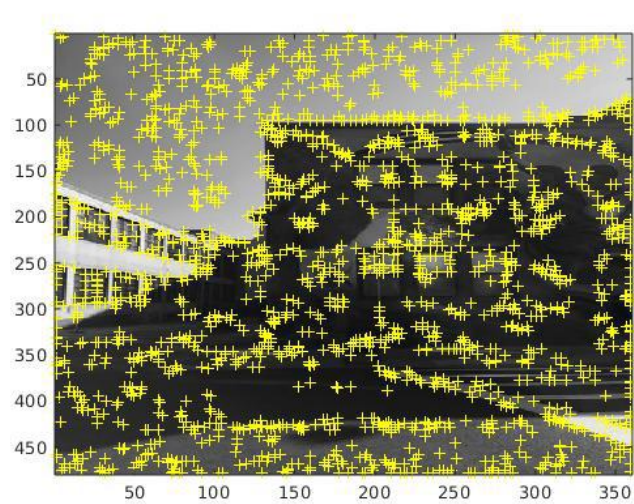


Figure 11: Harris feature extraction



Figure 12: Latino photos Panorama



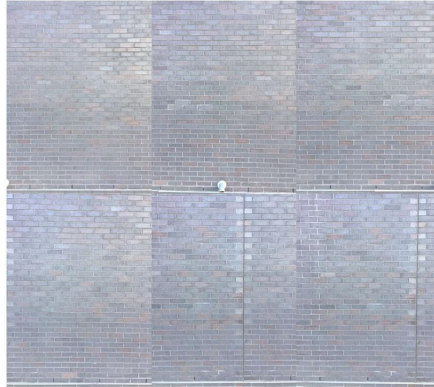
```
centers =
      0      0  1.0000
-149.8332 -57.4306 1.0000
-268.1663 -44.0938 1.0000
-337.0514 -41.0550 1.0000
-452.0244 -60.2549 1.0000
-556.8890 -51.8616 1.0000
```

Figure 13: Estimate the position(left) and transform matrix(right)

**Conclusion:**

As we see in Figure 12, in this panorama, the Graffiti wall is concatenated smoothly but objects in the front view as well as the background are distorted. I think when we concatenated these photos, we matched features in the images with “projective” algorithm, which might lead to unexpected distortion for the area far away from the focus.

#### 4. Cinder Wall Panorama with 50% overlapping



*Figure 14: Original Mosaicing photos thumbnail*



*Figure 15: Mosaic photos Panorama*

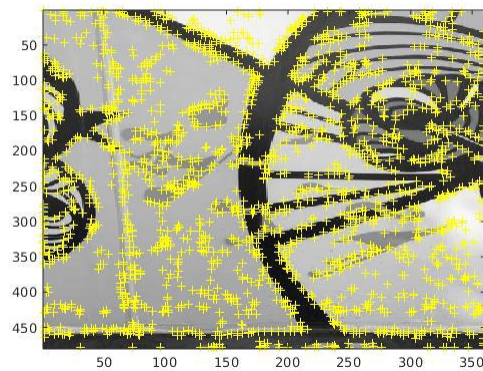
#### **Conclusion:**

Due to a lack of features in these cinder walls, we had fewer features to match, which led to some distortion in the panorama.

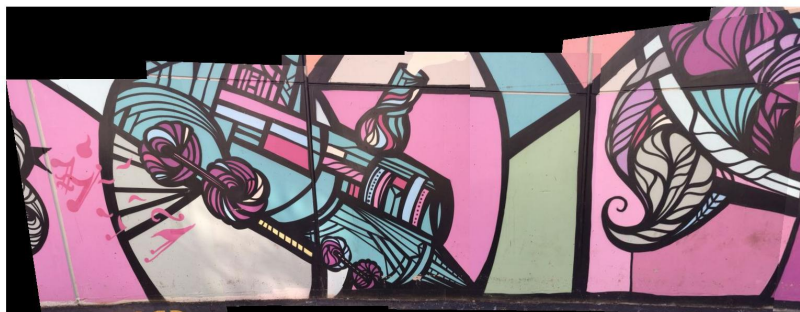
## 5. Graffiti 15% overlapping Image Stitching



*Figure 16: Original Graffiti photos thumbnail*



*Figure 17: Harris feature extraction*



*Figure 18: Graffiti photos Panorama*

**Conclusion:**

Again, panorama has some distortions due to a lack of features. These images have only 15% overlap, similar features are few and tends to mis-estimating the transform matrix.