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Report Exercise 2

For more information on the implementations see the commented m-files sent with this report

2.1: Normalization

First the I computed the mean of all points to get the centroid.

Then I subtracted the centroid from the points, so that the points are now around the origin.

Then I computed their root-mean-squared-distance and divided it by $\sqrt{2}$ respectively $\sqrt{3}$.

Then I assembled the normalization matrices from the above computed values, and computed with them the normalized points.

2.2: Direct Linear Transform

First I normalized the points as above, then I assembled the matrix A from the normalized points, with a singular value decomposition I got the values of P. After that I denormalized P and computed the decomposition of P. And finally compute the error of the reprojected points.

As one can see on the image below, the the reprojected points(blue stars) in the region of the original ones(red circles).

For the unnormalized points the result is quite similar, so I don't show an extra image here, as the error is in the same magnitude as with normalized points. The change can only be seen in the Matrix P, which is totally different. It may also give a good results because the points are quite evenly distributed.

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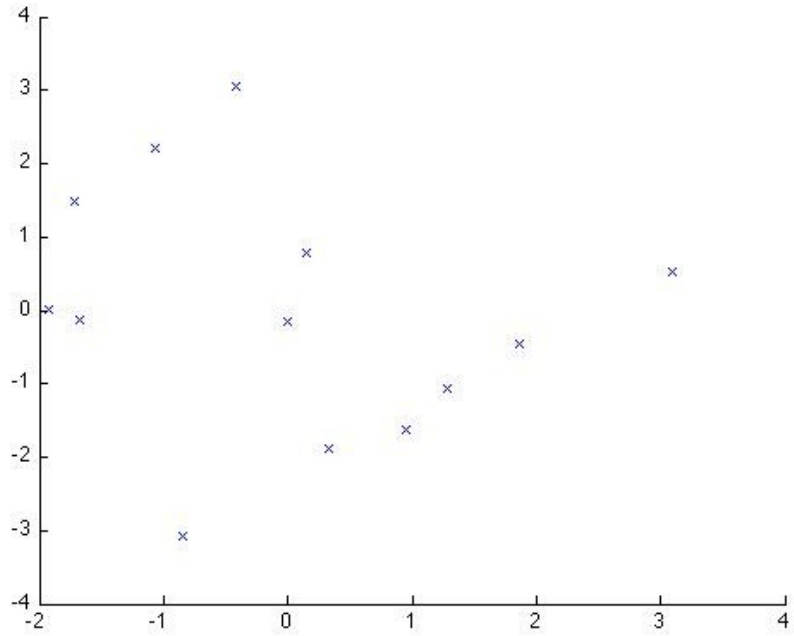
The distribution of the errors of the reprojected points:



I would say that it's in a reasonable region considering the accuracy of clicking a point in an image.

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2.3: Gold Standard Algorithm

The first steps are the same as in the above DLT algorithm but then I compute with fminsearch the matrix P that minimizes the error of the reprojection and constrains the skew to zero and α_x to α_y.

Below is again the visualization of the reprojected points(blue stars) relative to the original ones(red circles). Visually there's no difference between the above algorithm and this one. However to my astonishment the error is a bit bigger than before but the skew is a bit smaller and α_x and α_y are now within 1% of each other.

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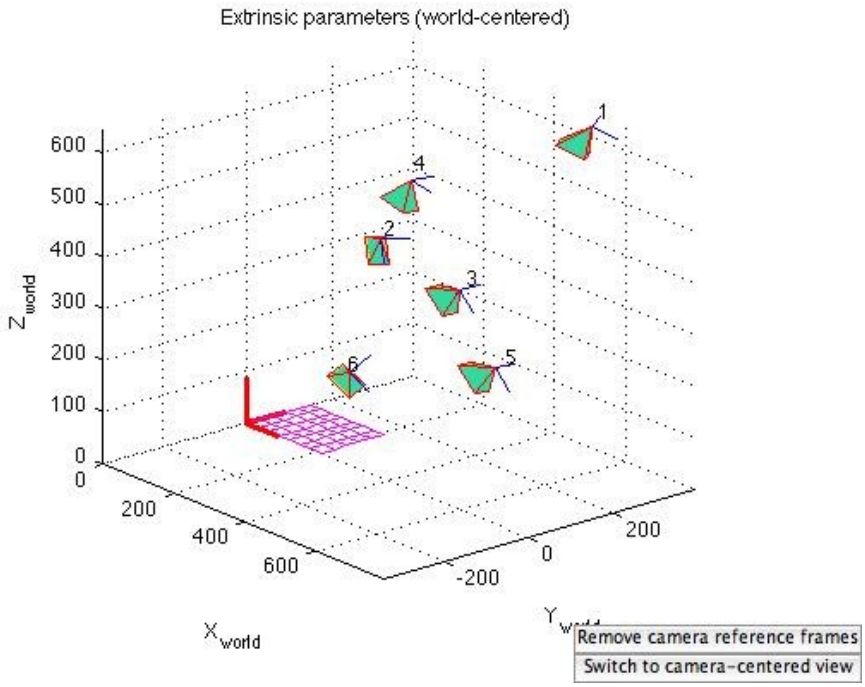
2.4: Bouget's Calibration Toolbox

I've made 6 Images from different angles of the calibration pattern, found at the end of the document. The calibration is quite easy to run, at gives more accurate results than with the algorithms above, but I don't know if the accuracy comes from the better sampling of the points, or of a more accurate algorithm, probably it's a bit of both.

The following Images show the output/results of the calibration toolbox.

Positions of the camera:



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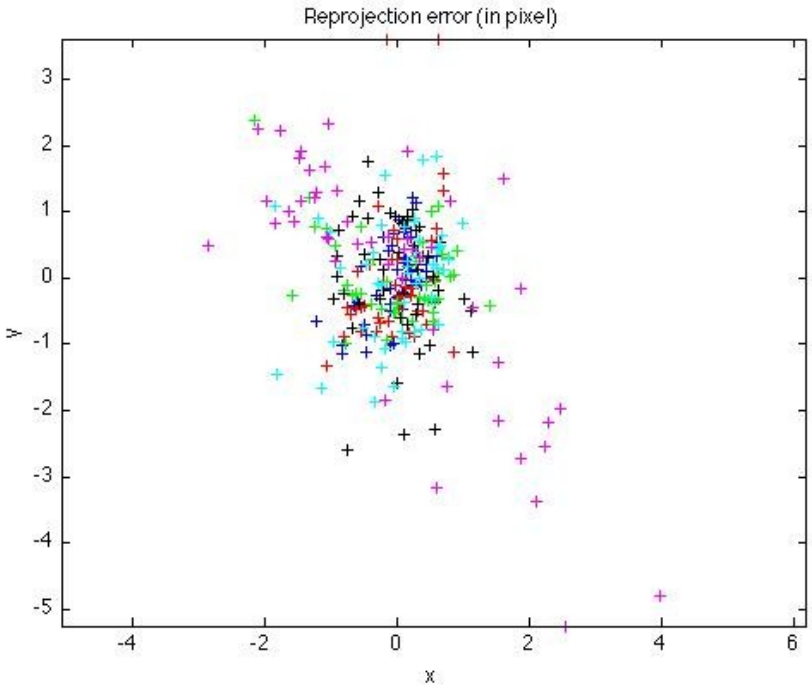
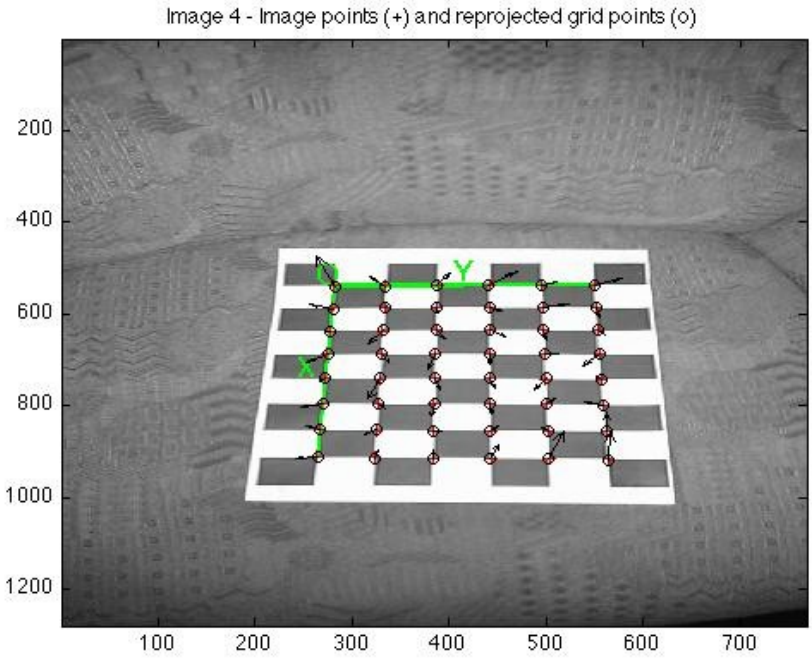
Error of the reprojected points



Actually this is in the same magnitude as the error in the DLT algorithm.

One of the images with the input points and the reprojected grid points



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Finally if you look at the skew, with this toolbox it is zero, while it has some non-zero value in the above algorithms.

And here the results/output of the calibration of this toolbox:

Calibration parameters after initialization:

Focal Length: fc = [1245.12560 1245.12560]

Principal point: cc = [383.50000 639.50000]

Skew: alpha_c = [0.00000] => angle of pixel = 90.00000 degrees

Distortion: kc = [0.00000 0.00000 0.00000 0.00000 0.00000]

Main calibration optimization procedure - Number of images: 6

Gradient descent iterations:
1...2...3...4...5...6...7...8...9...10...11...12...13...14...15...16...17...18...19...20...21...22...23...24...25...26...27...28...29...30...done

Estimation of uncertainties...done

Calibration results after optimization (with uncertainties):

Focal Length: fc = [1155.72663 1243.23646] ± [67.85582 55.80935]

Principal point: cc = [306.82144 984.65525] ± [28.92055 89.01650]

Skew: alpha_c = [0.00000] ± [0.00000] => angle of pixel axes = 90.00000 ± 0.00000 degrees

Distortion: kc = [-0.22268 0.42162 0.03472 0.00105 0.00000] ± [0.11507 0.32867 0.02333 0.01003 0.00000]

Pixel error: err = [0.79865 1.05353]

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