Camera Calibration Toolbox for Matlab

Single Camera

1. Download the toolbox from: http://www.vision.caltech.edu/bouguetj/calib_doc/.
2. Run Matlab and add the location of the folder **TOOLBOX_calib** to the main Matlab path.
3. Run **calib_gui_normal** to bring up the GUI window (Figure 1).

Fig 1. GUI for single camera calibration.

4. Capture images of the calibration pattern (Figure 2). Name these images with the same prefix and use consecutive numbers as suffix.

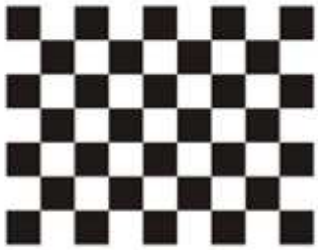

Fig 2. Camera calibration pattern.

5. Select “Image names” from the GUI. Key in the prefix for the calibration images and select the image format. All the calibration images will be displayed (Figure 3) once this is done.

```
Basename camera calibration images (without number nor suffix): left
Image format: ([]='r'='ras', 'b'='bmp', 't'='tif', 'p'='pgm', 'j'='jpg', 'm'='ppm')
```

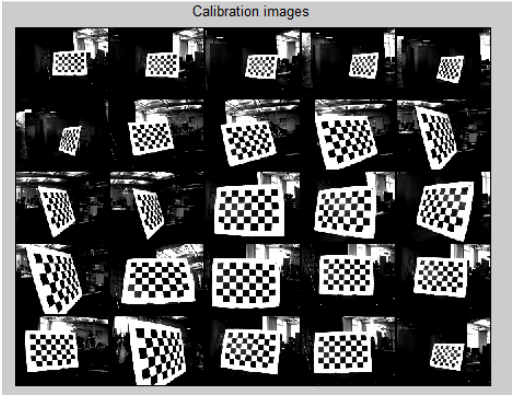

Fig 3. Display of all the calibration images.

6. Next, click on “Extract grid corners” from the **calib_gui_normal** GUI**.**
    a. Enter the number of images to process.
    b. Enter the window size for corner finder.
    c. Enter choice for automatic or manual square counting.

```
Extraction of the grid corners on the images
Number(s) of image(s) to process ([] = all images) =
Window size for corner finder (wintx and winty):
wintx ([] = 5) =
winty ([] = 5) =
Window size = 11x11
Do you want to use the automatic square counting mechanism (0=[]=default)
  or do you always want to enter the number of squares manually (1,other)? 1
```

7. Click on the 4 corners of the calibration pattern starting from the top left corner and proceed clockwise.

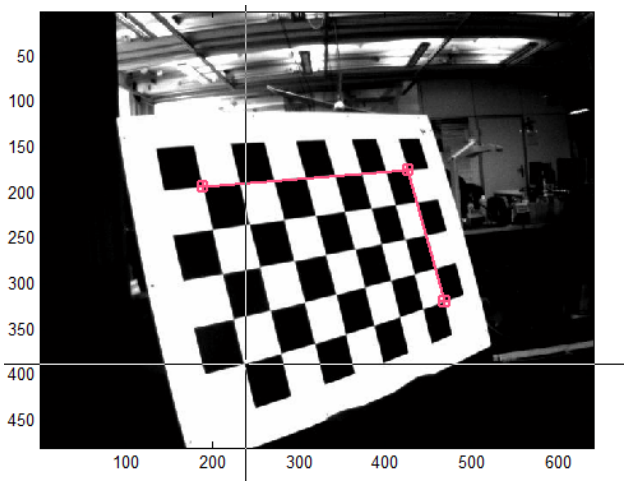

Fig 4. Select corners from top left and clockwise.

8. Enter the number of squares in the x and y directions and enter the size of each square.

```
Number of squares along the X direction ([]=10) = 4
Number of squares along the Y direction ([]=10) = 7
Size dX of each square along the X direction ([]=100mm) = 120
Size dY of each square along the Y direction ([]=100mm) = 120
```

9. Repeat steps 7 and 8 for all the other calibration images.
10. Click on “Calibration” from the **calib_gui_normal** GUI to finish the calibration process.
11. Click “save” from the **calib_gui_normal** GUI to save the calibration results. The calibration results are saved as “calib_data.mat” by default.
12. Figure 5 shows the calibration results which consist of the Focal length, Principal Point, Skew and Distortion of the camera.

```
Calibration parameters after initialization:

Focal Length:          fc = [ 641.07546   641.07546 ]
Principal point:       cc = [ 319.50000   239.50000 ]
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: 3
Gradient descent iterations: 1...2...3...4...5...6...7...8...9...10...11...12...13...14...15...16...17...18...19...20...done
Estimation of uncertainties...done


Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 644.52404   646.87252 ] ± [ 3.48794   2.94252 ]
Principal point:       cc = [ 276.74367   240.53286 ] ± [ 5.63944   4.32649 ]
Skew:             alpha_c = [ 0.00000 ] ± [ 0.00000 ]   => angle of pixel axes = 90.00000 ± 0.00000 degrees
Distortion:            kc = [ -0.43965   0.17665   -0.00114   0.00173   0.00000 ] ± [ 0.03413   0.28614   0.00180   0.00157   0.00000 ]
Pixel error:          err = [ 0.11138   0.08363 ]

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

Fig 5. Calibration results for a single camera.

Stereo Camera

1. Do single camera calibration for both the left camera and save the calibration results as “Calib_Results_left.mat”.
2. Repeat the process for the right camera and rename the calibration results as “Calib_Results_right.mat”.
3. Enter **stereo_gui** in the workspace to bring up the stereo calibration GUI.

Fig 6. GUI for stereo camera calibration.

4. Select “Load left and right calibration files” and enter the calibration filenames for both the left and right cameras. Enter to finish the calibration process.
5. Figure 7 shows the calibration results for a stereo camera which consist of the calibration results for the left and right cameras respectively, and the rotation and translation vectors of the right camera center with respect to the left camera center.
6. Click “save” from the **stereo_gui** GUI to save the calibration results. The calibration results are saved as “Calib_Results_stereo.mat” by default.

```
Stereo calibration parameters after loading the individual calibration files:


Intrinsic parameters of left camera:

Focal Length:          fc_left = [ 644.58454   646.47538 ] ± [ 1.42427   1.24167 ]
Principal point:       cc_left = [ 265.35324   240.98509 ] ± [ 2.68981   2.08519 ]
Skew:             alpha_c_left = [ 0.00000 ] ± [ 0.00000  ]   => angle of pixel axes = 90.00000 ± 0.00000 degrees
Distortion:            kc_left = [ -0.45282   0.31984   -0.00152   0.00292  0.00000 ] ± [ 0.01160   0.07552   0.00078   0.00074  0.00000 ]


Intrinsic parameters of right camera:

Focal Length:          fc_right = [ 652.59491   654.68539 ] ± [ 1.45002   1.26031 ]
Principal point:       cc_right = [ 361.58485   208.27569 ] ± [ 2.74992   2.11303 ]
Skew:             alpha_c_right = [ 0.00000 ] ± [ 0.00000  ]   => angle of pixel axes = 90.00000 ± 0.00000 degrees
Distortion:            kc_right = [ -0.46709   0.41341   -0.00245   0.00278  0.00000 ] ± [ 0.01344   0.10882   0.00080   0.00070  0.00000 ]


Extrinsic parameters (position of right camera wrt left camera):

Rotation vector:             om = [ -0.00050   -0.00306  -0.00162 ]
Translation vector:           T = [ -48.57317   -0.40727  -0.23240 ]
```

Fig 7. Calibration results for a stereo camera.

Reference

1. http://www.vision.caltech.edu/bouguetj/calib_doc/