UMassAmherst

Camera Calibration

Using Matlab & OpenCV to Remove
Camera System Distortion

Links

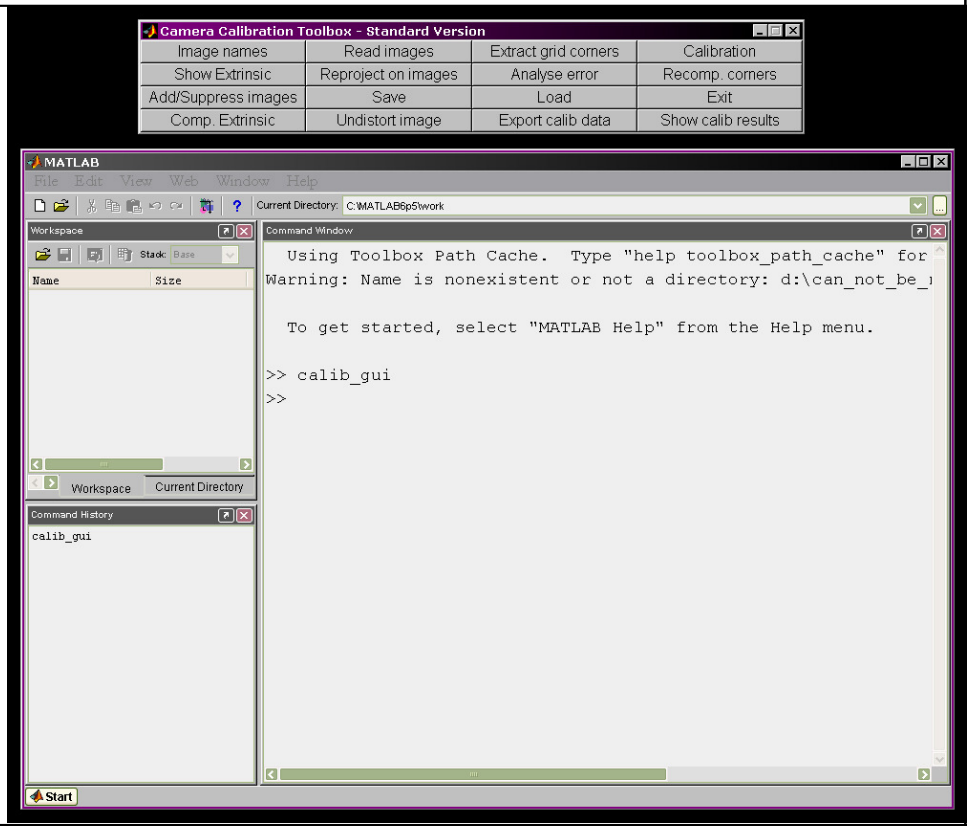
- The Matlab Camera Calibration Toolbox (main site)
  - http://www.vision.caltech.edu/bouguetj/calib_doc/
- Toolbox Download
  - http://www.vision.caltech.edu/bouguetj/calib_doc/download/index.html
- Most Useful Tutorial
  - http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/example.html
- Other Useful Toolbox Links
  - List of all Function in Toolbox
    http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/functions.html
  - Calibration Parameters
    http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/functions.html
- Open Source Computer Vision Toolbox
  - Open Source Computer Vision Library (OpenCV): C/C++; Win32, Linux
    http://sourceforge.net/projects/opencvlibrary/
  - Using OpenCV with Visual Studio
    http://opencvlibrary.sourceforge.net/VisualC++

Calibration Step 1

- Install the toolbox and add the path
- Start Matlab
- Type `calib_gui`
- Use unix like commands (ls and cd) to navigate to the dir with the calibration images
- Click 'Read images'

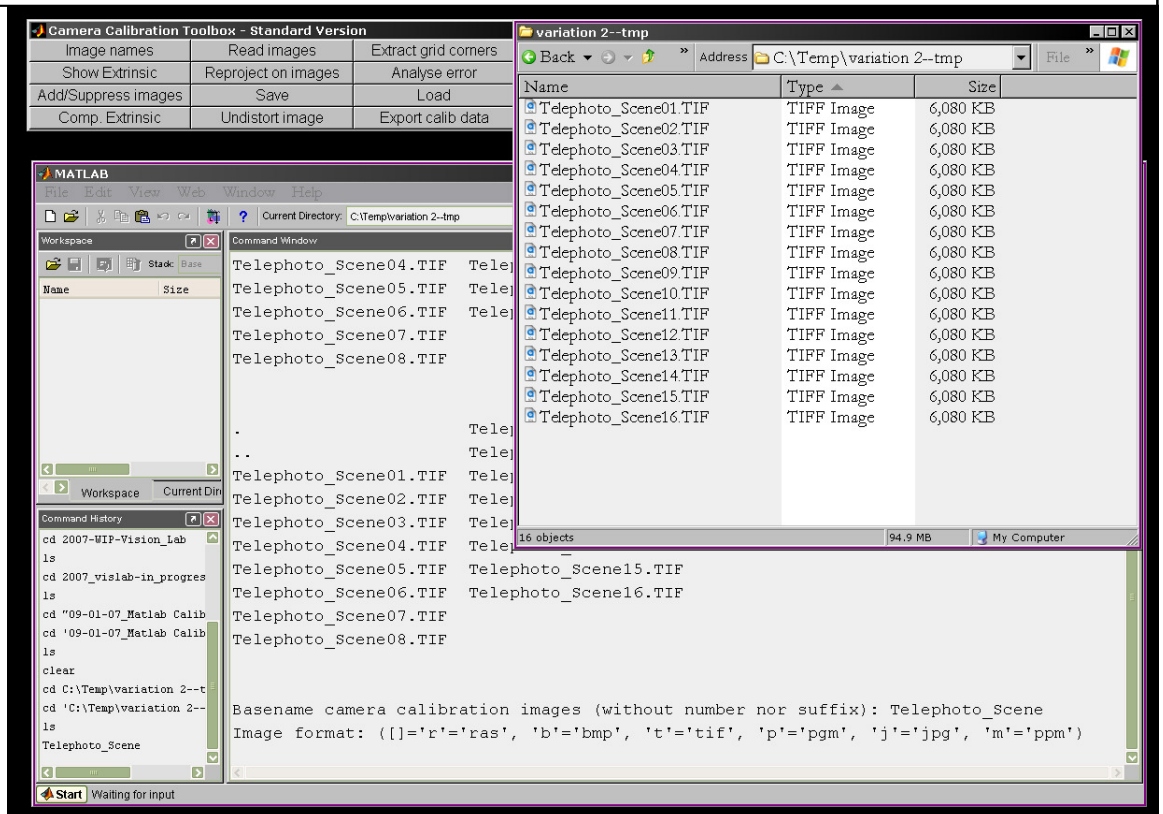
- NOTE: the images will be converted to a single channel using a formula found in:
  - ima_read_calib.m
  - line 74
- The formula they use to convert to one channel:

```
Ii =
0.299*Ii(:,:,1) +
0.5870*Ii(:,:,2) +
0.114*Ii(:,:,3);
```

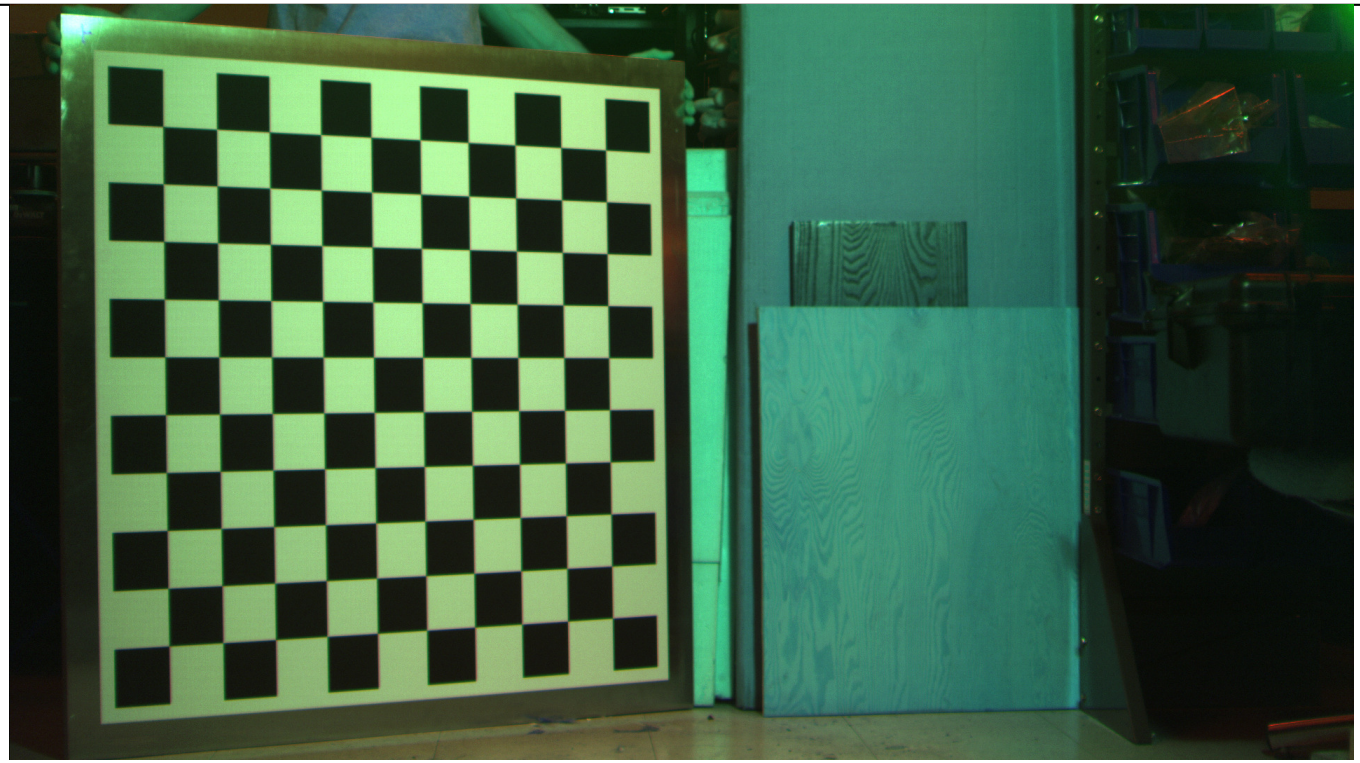


Select Calibration Images

- All calibration images need a common name prefix and a number scheme
  - Telephoto_Scene
  - 00 to 99
- Renaming all images is tedious, use of unix commands and scripting helpful, something (mv *.TIF prefix"ij".TIF)

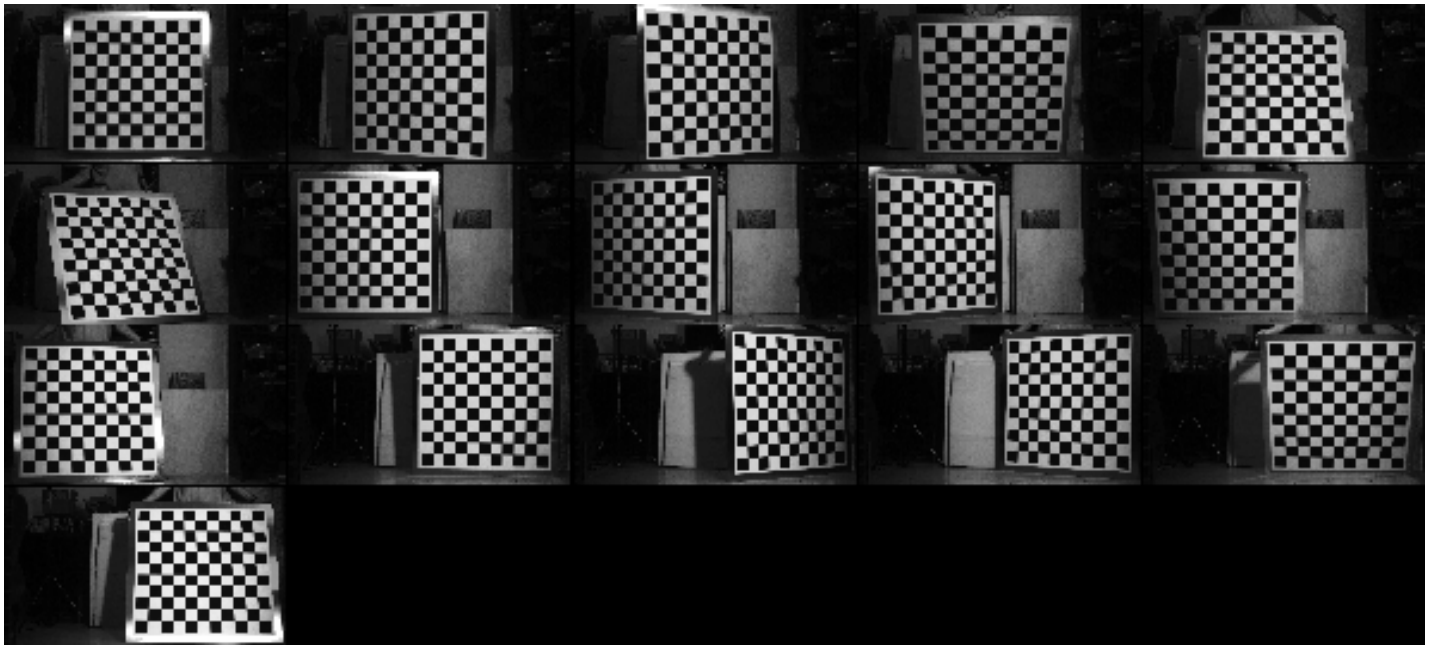


Example Calibration Image



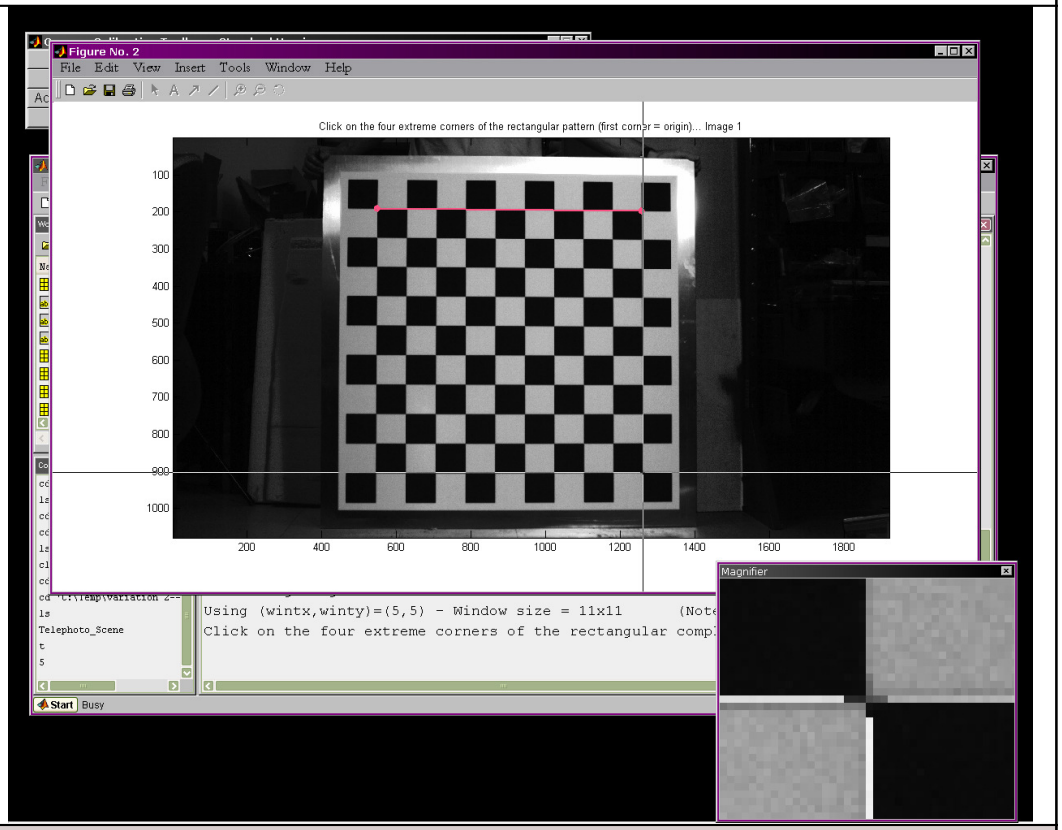
- Image taken in CIR, shown in RGB

Preview Read Images



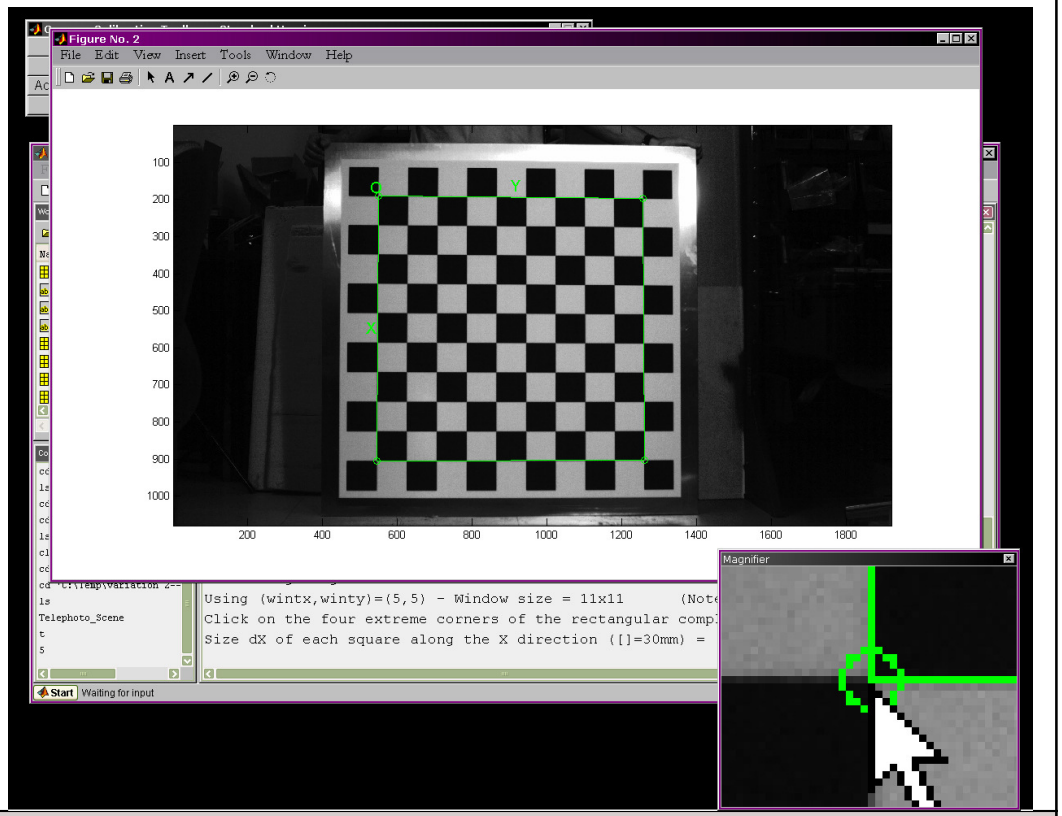
Extracting Grid Corners

- When starting this part of the process, the program will ask for
  - Window size
  - This is for corner detection
  - A smaller window is more accurate, but maybe require "better eyes"
- The zoomed in view is through windows magnifier.
- Most Linux GUI based distributions have a similar utility
- Notice the red line
  - Line is drawn connecting the last two points you selected



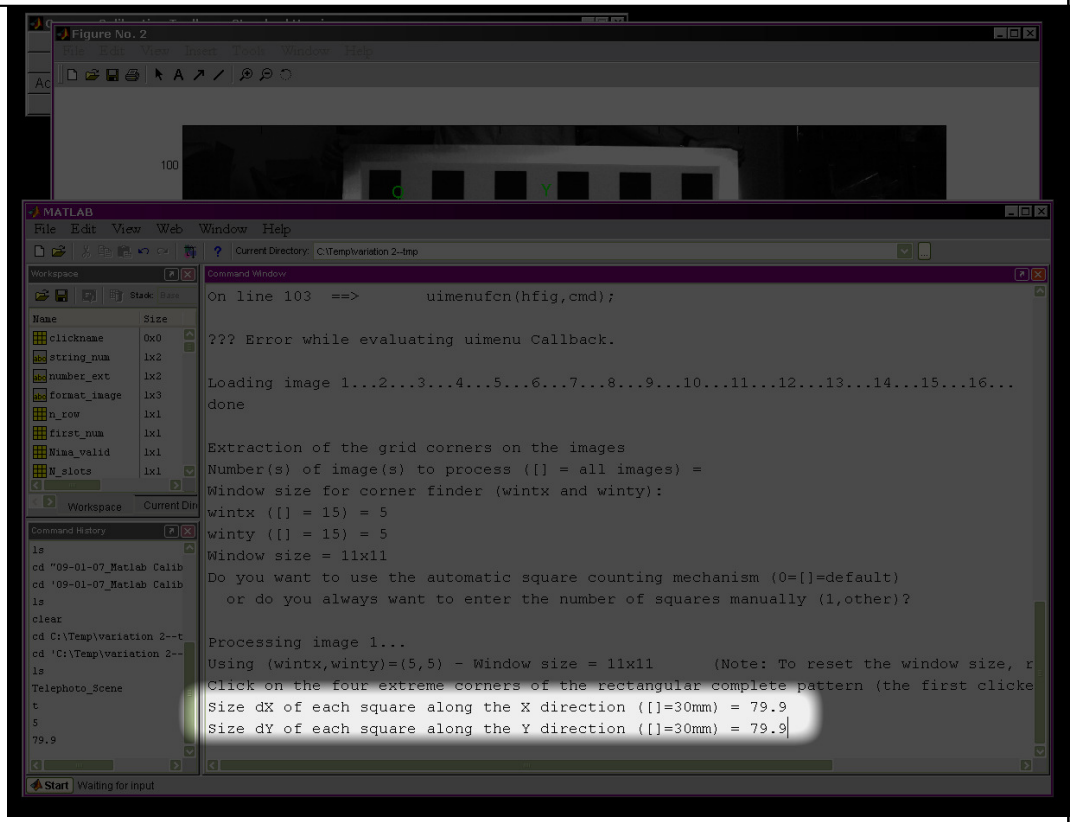
Picking Last Corner

- After picking last corner, green square is drawn
- Extracting grid corners from the first image is a special case
  - After picking the last corner, the program will ask you to supply measurements of the grid squares.

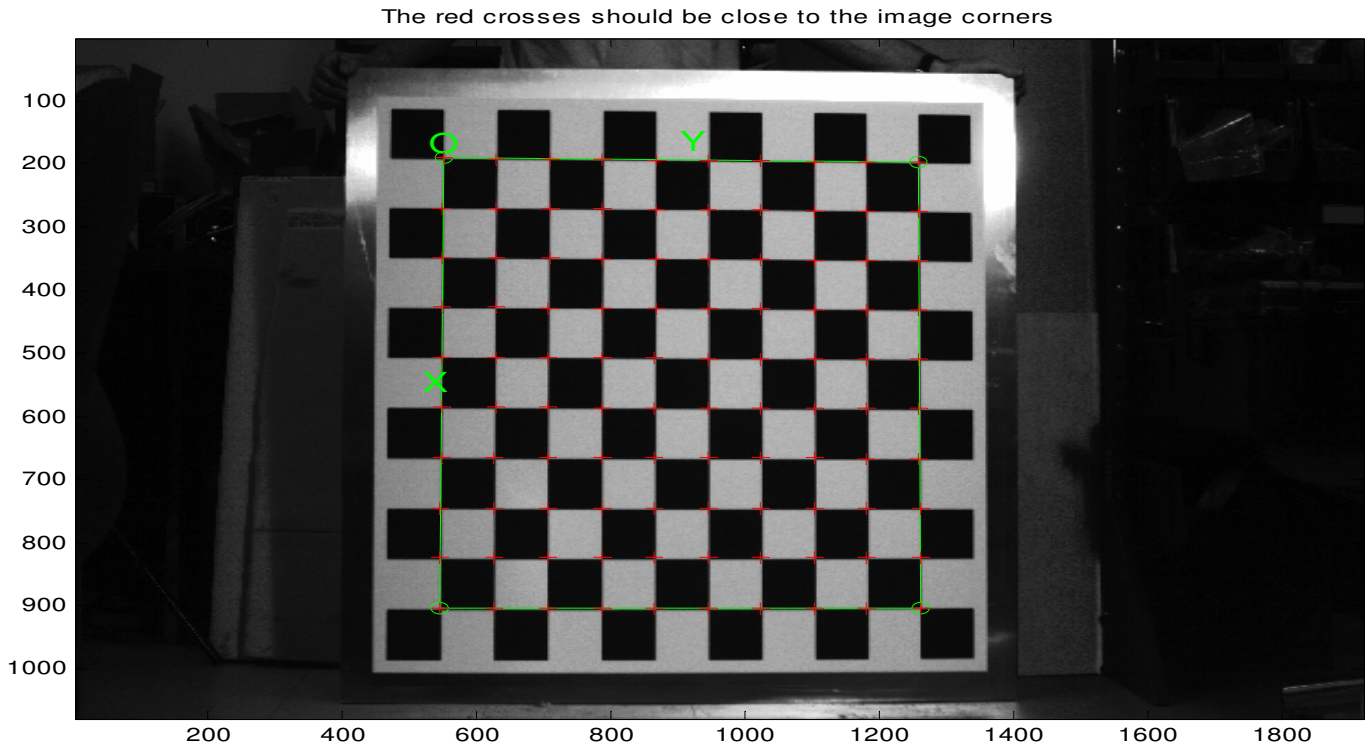


First Corner Extraction

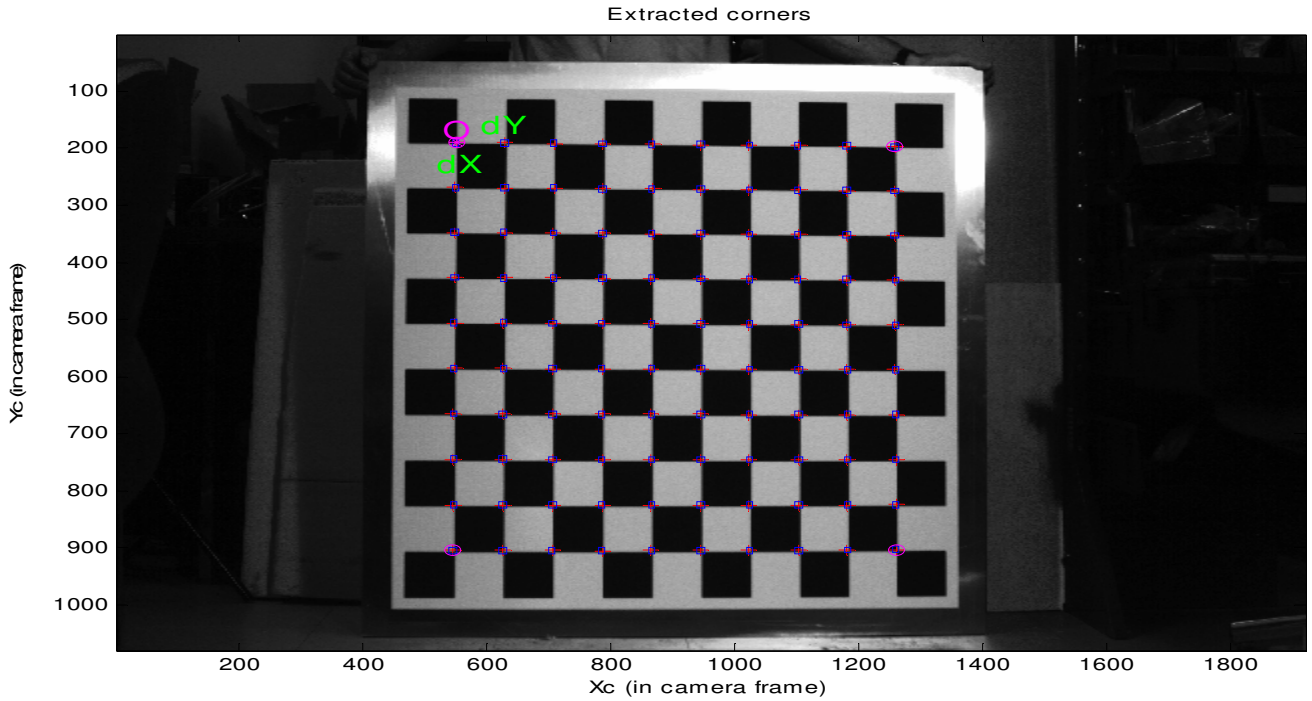
- Oddly, the program does not ask for measurements until after the first corner extraction
- Our most accurate measurement found the grid squares to be 79.9mm^2



Verify Corner Extraction



Grid Points Extracted



Run Calibration

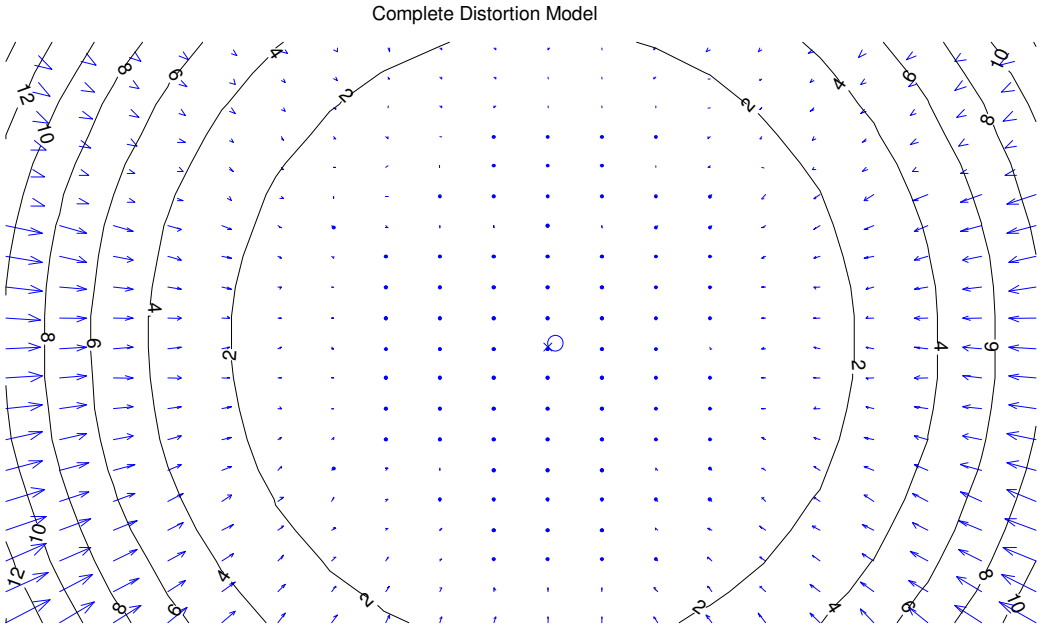
- After extracting the corners from every image, click 'Calibration'
- The system will carry out a number of iterations of the gradient descent method and will converge if the corners are found accurately

```
Calibration results after optimization (with uncertainties):

Focal Length:          fc = [ 3513.44159   3510.48363 ]  ± [ 4.16406   4.17913 ]
Principal point:       cc = [ 974.00660   532.29039 ]  ± [ 4.53338   4.50995 ]
Skew:             alpha_c = [ 0.00000 ]  ± [ 0.00000  ]
                          => angle of pixel axes = 90.00000  ± 0.00000 degrees
Distortion:            kc = [ -0.14662   0.06462   -0.00020   -0.00088  0.00000 ]
                          ± [ 0.00606   0.08436   0.00028   0.00028  0.00000 ]
Pixel error:          err = [ 0.10706   0.11851 ]

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

- Values in units of pixels

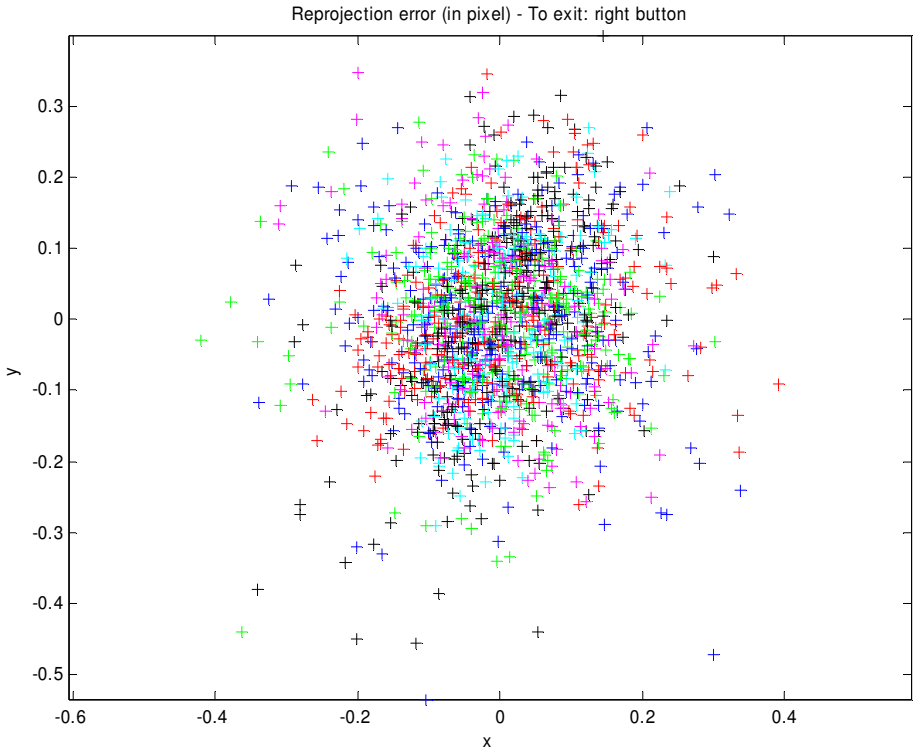
See Distortion model

- This command is not in the GUI menu
- `visualize_distortions`



Find Errors

- From the GUI menu select 'Analyse Errors'
  - `They spelled it wrong?`
- Click on outliers to see which image and corner they are coming from
- To fix
  - remove that image from the calibration
  - pick the corners for that image manually by pixel value
  - consider different calibration images
- Also, for more accurate results in general
  - Optimal calibration images
  - Number of images
  - Where the grid resides in the image (WRT the distortion)

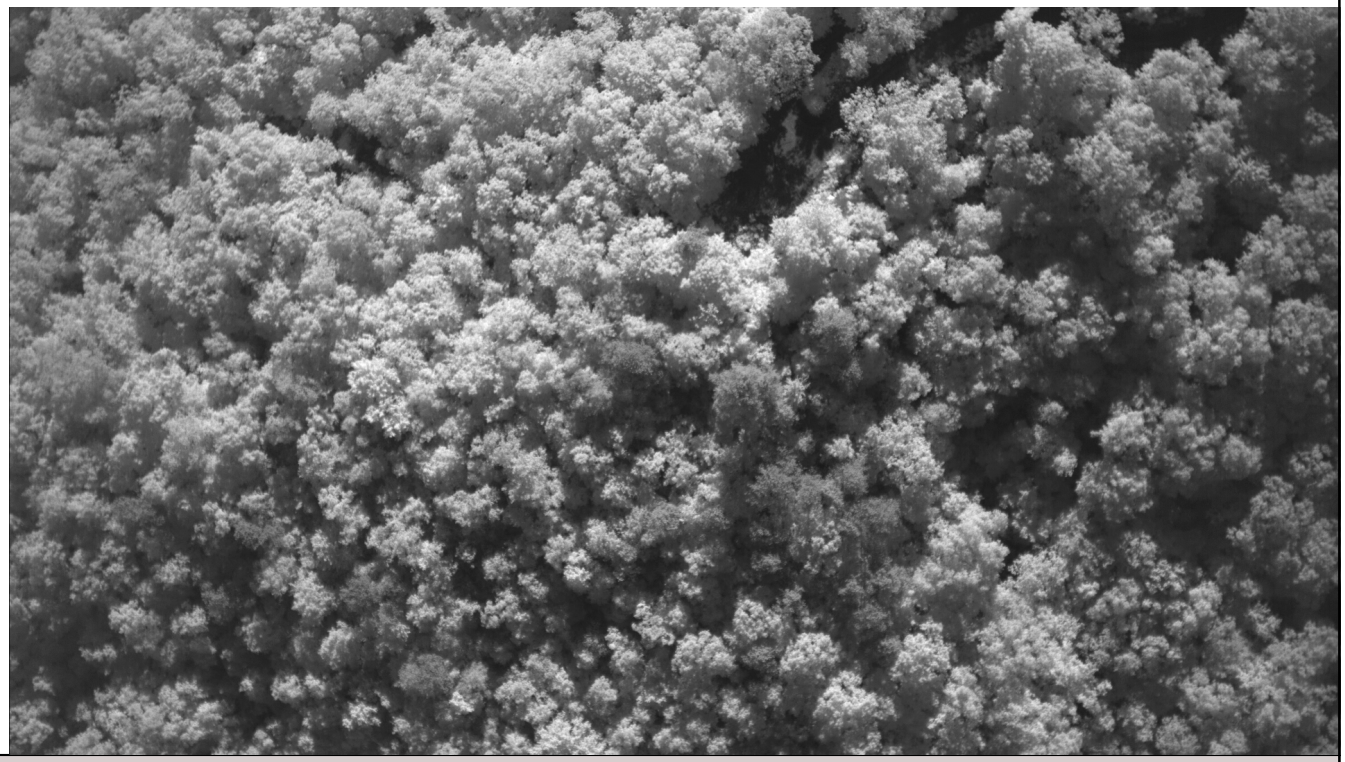


Undistort

- Once the calibration is found to be satisfactory
  - Click 'Undistort Image'
    - Can undistort all calibration images or any image of choice
- OpenCV has the same undistort function
  - Uses the same parameters and units
  - Allows different interpolation models to be used

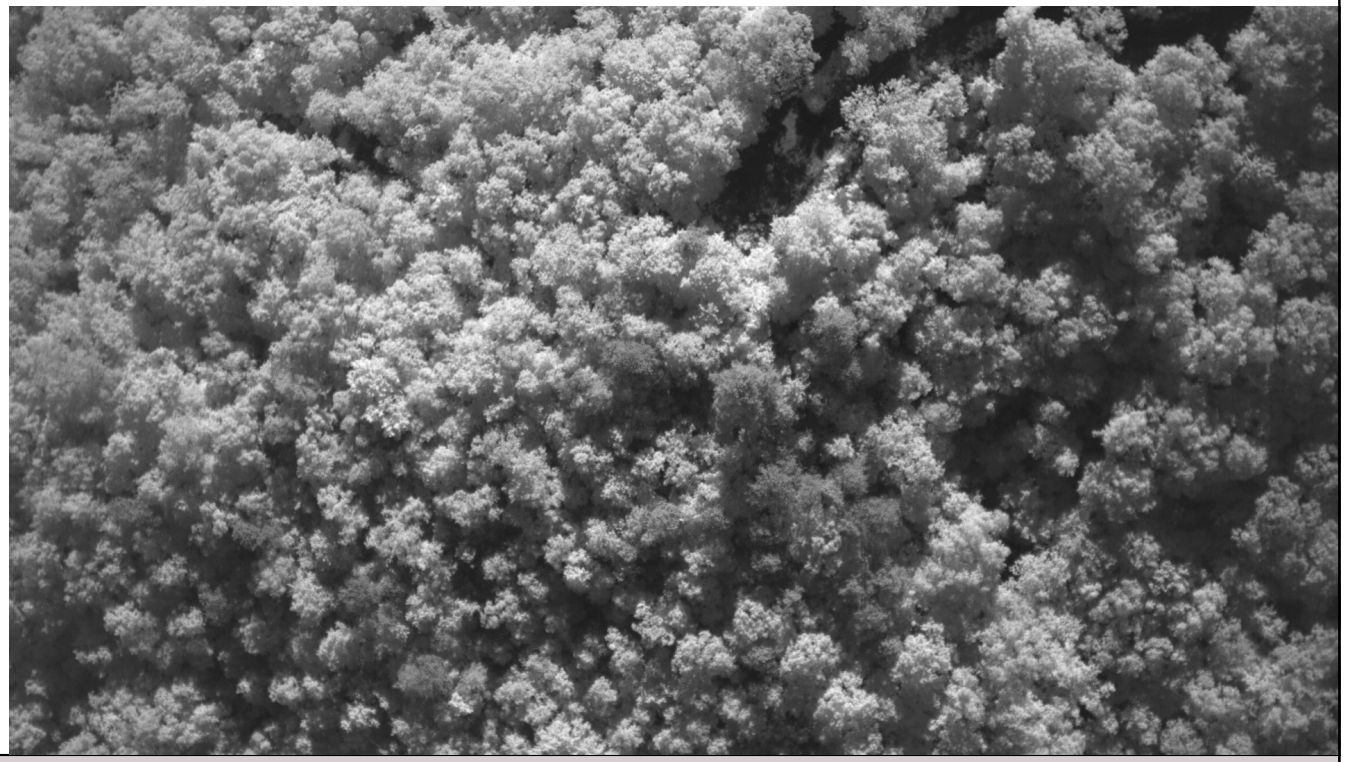
Undistort Example - Before

- This is only the red channel



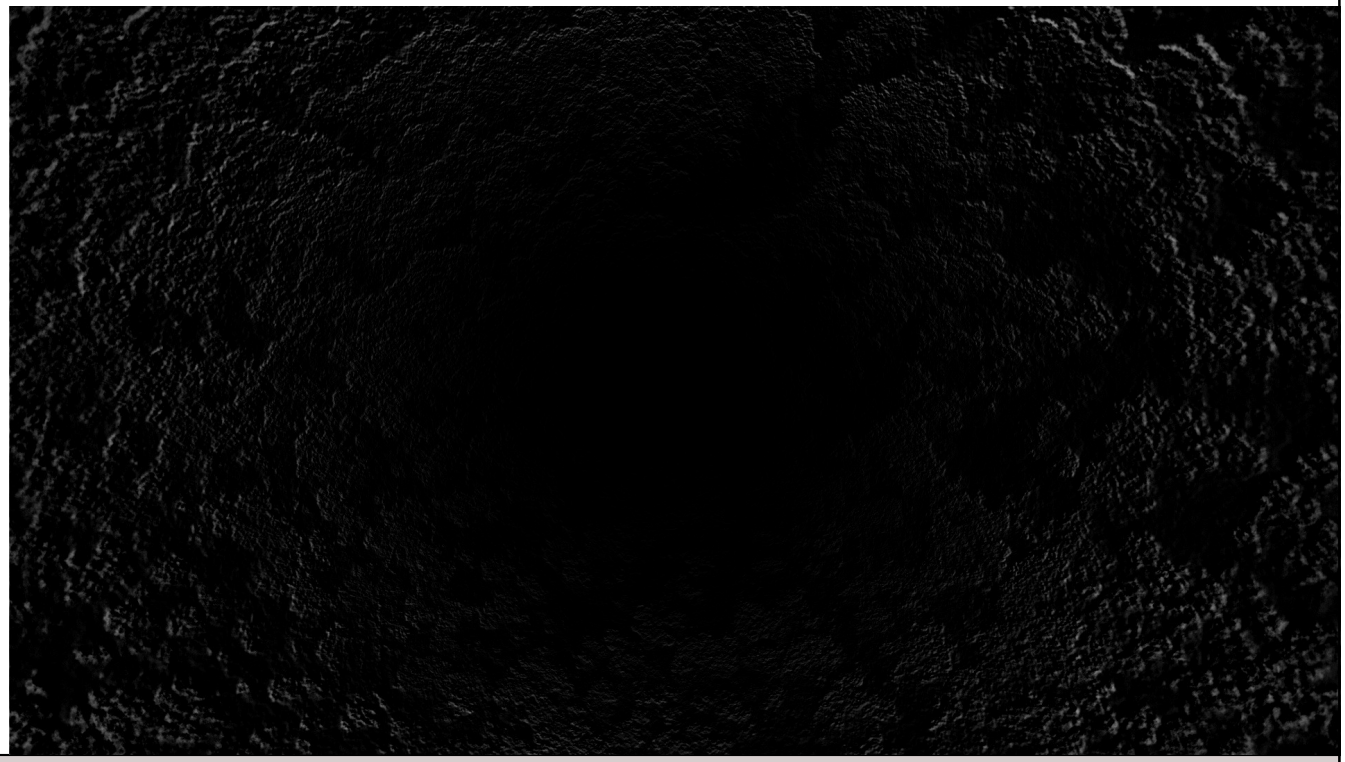
Undistort Example - After

- This is only the red channel



Undistort – See What it Did

- Subtract one image form the other (matrix subtraction)



Comparing

- Undistored minus distorted with distortion model overlaid