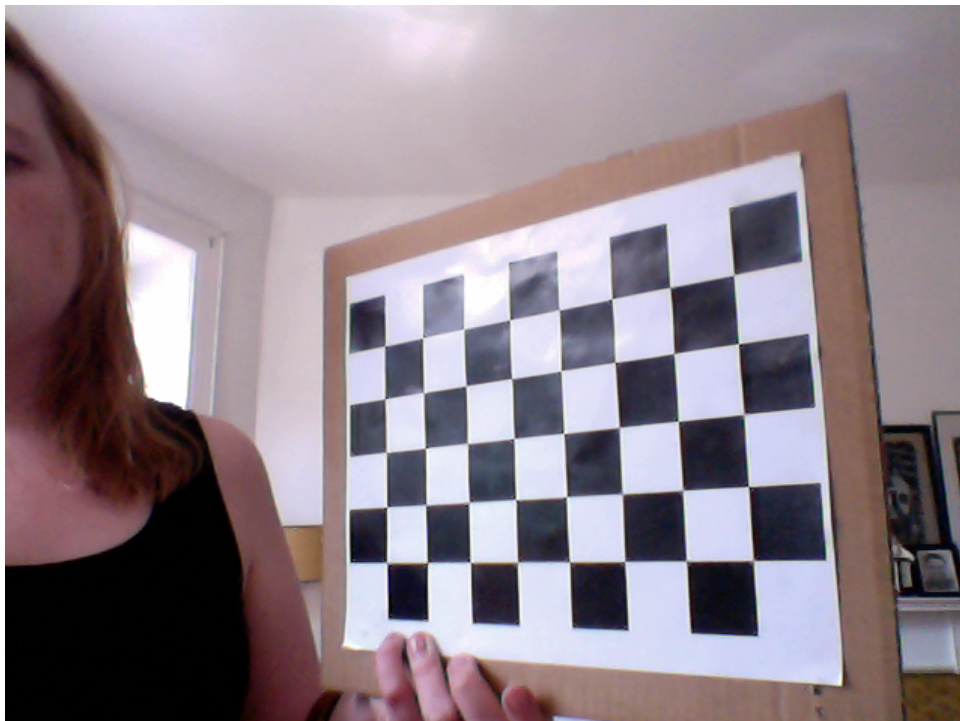


## HOW TO: Calibrate a Camera

### Overview:

Camera calibration is a simple and easy process that is often used in a number of computer vision tasks like undistortion, object position estimation, and 3D reconstruction. The calibration process determines lens properties like the amount of barrel and pin-cushion distortion, the camera's focal length, and the lens's principal point (the point where the aperture, or pin hole, is aligned to the sensor pixels of the camera). The calibration process creates a matrix that helps to relate the x,y pixel position in an image to 3D coordinates in the world. Camera calibration creates two files that store parameters about the lens and sensor configuration of a camera. Calibration must be done for every new camera lens pair or whenever a camera lens is changed on a sensor. For fixed lens camera, like webcams, if calibration is done properly it only needs to be done once.

### Calibration Rig Setup:



**Figure 1: The completed calibration rig**

To do calibration we will need to do create a simple calibration rig like the one in Figure 1. This will involve a little bit of work. You will need:

1. A standard 8.5x11 piece of printer paper
2. A printer
3. A piece of cardboard larger than the paper ~11 x13
4. Tape (double sided works great!)
5. A ruler (metric please!)



In the directory SimpleCV/tools/ open and print the file Grid5x8.png using your favorite image editing software. The only caveat is that image should be really big and almost fill the page, but not so big that there is not about a 2.5cm/1in border around the checker board. Now take your slightly larger piece of cardboard and tape the checker board image to the cardboard. We use the cardboard because it is **very very** important that the checker board image stays completely flat during calibration. The calibration routines assumes that the distance between points on the board stay constant, and if we wiggle the bend this paper this assumption does not hold. Now measure, very carefully, the size of one black square on the grid and record this value. For an 8.5x11 piece of paper each checker board square should be about 3cm on a side. If it is different than this you will need to modify /SimpleCV/tools/Calibrate.py such that when the method `cam.calibrate(imgList, grid_sz=XXX)` where XXX is your grid square size in meters. It is worth noting that the calibration unit will be in whatever unit you use for this value. So if you use inches for this value, the output of all calibration files will be in inches. Ingenuitas recommends you pretend you are NASA and do everything in meters.

## Calibration

We are now ready to perform calibration. We are going to give the camera about three dozen good images of the checkerboard in all sorts of positions. To do a good calibration we need the checkerboard to cover every part of the camera in at least a few images and we also need to capture images of the checker board very far away from the camera, and at off angles to the camera.

To run the calibration application we go type the following in the command line

```
> cd /SimpleCV/tools
>python Calibrate.py
```

That will run the calibration application. To view the output of the application open up your favorite web browser, and in the URL bar type the following

localhost:8080

You should see the output of your camera! If the checkerboard is visible SimpleCV will overlay a rainbow grid over the checkerboard. Now arrange the windows so you can see both the command line application and the browser windows. The calibration application has three keyboard controls:

- Space Bar – Grab a frame
- c – Calibrate
- q – Quit



We are going to grab about 35 frames and then calibrate the camera. To grab a frame we press space, to calibrate we press 'c', to exit the application press 'q'. A good recipe to follow for calibration is the following:

- Ten images where the checkerboard is parallel to the camera and almost fills the image
- Ten images where the checkerboard is parallel to the camera and far away, so that it occupies about  $1/6^{\text{th}}$  of the screen. Take at least one image near each of the corners and near the center of the image.
- Five images where the checkerboard occupies most of the screen but is at a 45 degree angle with the screen along the long axis of the board.
- Five images like the above but the checkerboard is rotate 45 degrees about the short axis of the board.
- Five images where the image is rotate about 45 degrees along both axes

The figures below give a few good examples of calibration images and what the calibration grid should look like.

