Note: This tutorial assumes that you have completed the previous tutorials: ROS Tutorials (/ROS/Tutorials).

Please ask about problems and questions regarding this tutorial on answers.ros.org (http://answers.ros.org). Don't forget to include in your question the link to this page, the versions of your OS & ROS, and also add appropriate tags.

How to Calibrate a Stereo Camera

Description: This tutorial cover using the camera_calibration (/camera_calibration)'s `cameracalibrator.py` node to calibrate a stereo camera with a left and right image over ROS.

Keywords: stereo, camera, calibration

Tutorial Level: BEGINNER

Contents

1. Before Starting

Make sure that you have the following:

- a large checkerboard (8x6) (/camera_calibration/Tutorials/StereoCalibration?action=AttachFile&do=view&target=check-108.pdf) or checkerboard (7x6) (/camera_calibration/Tutorials/StereoCalibration?action=AttachFile&do=view&target=check_7x6_108mm.pdf) with known dimensions. This tutorial uses a 8x6 checkerboard with 108mm squares
- a well lit 5m x 5m area clear of obstructions and check board patterns
- a stereo camera publishing left and right images over ROS (if you want to use two independent cameras as a stereo camera, you must make sure the images have identical time stamps)

NOTE: Checkerboard size refers to the number of internal corner, as described in the OpenCV documentation (i.e. the 8x6 checkerboard contains 9x7 squares)

2. Compiling

Start by getting the dependencies and compiling the driver.

```
$ rosdep install camera_calibration
$ rosmake camera_calibration
```

3. Camera Publishing

Make sure that your stereo camera is publishing left and right images over ROS. Let's list the topics to check that the images are published:

```
$ rostopic list
```

This will show you all the topics published, check to see that there is a left and right `image_raw` topic:

```
/my_stereo/left/camera_info
/my_stereo/left/image_raw
/my_stereo/right/camera_info
/my_stereo/right/image_raw
/my_stereo_both/parameter_descriptions
/my_stereo_both/parameter_updates
/my_stereo_l/parameter_descriptions
/my_stereo_l/parameter_updates
/my_stereo_r/parameter_descriptions
```

4. Start the Calibration

To start the calibration you will need to load the image topics that will be calibrated:

```
$ rosrun camera_calibration cameracalibrator.py --approximate 0.1 --size 8x6 --square 0.108 right:=/my_stereo/right/image_raw left:=/my_stereo/left/image_raw right_camera:=/my_stereo/right left_camera:=/my_stereo/left
```

The **--approximate** option allows the camera calibrator to work with images that do not have the exact same timestamp. Currently it is set to 0.1 seconds. In this case, as long as the timestamp difference is less than 0.1 seconds, the calibrator will run with no problem.

This will open up the calibration window which will highlight the checkerboard, you will not see any images in the calibration window until a checkerboard is present:

4.1 Dual Checkerboards

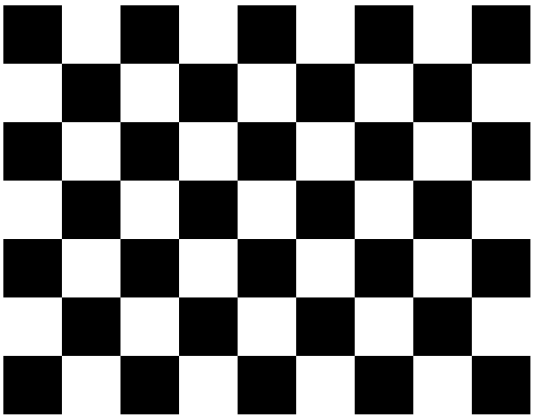
New in D

Starting in Diamondback, you will be able to use multiple size checkerboards to calibrate a camera.

To use multiple checkerboards, give multiple `--size` and `--square` options for additional boards. Make sure the boards have different dimensions, so the calibration system can tell them apart.

5. Holding the Checkerboard

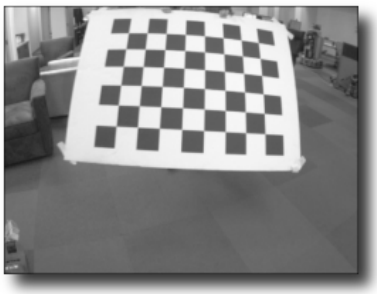
Make sure that you hold the checkerboard horizontally (more checkers horizontally than vertically).

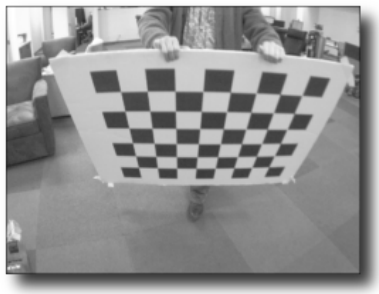


6. Moving the Checkerboard

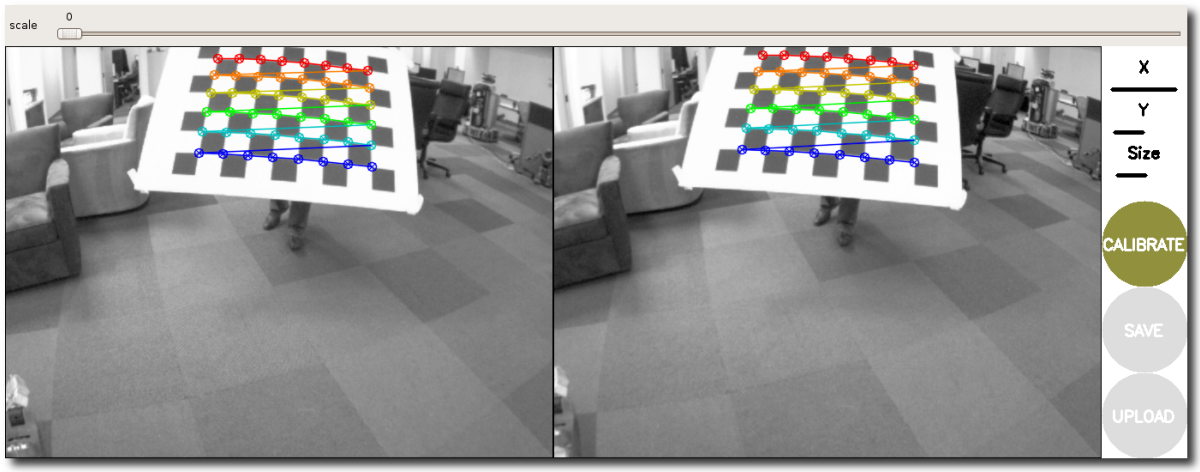
In order to get a good calibration you will need to move the checkerboard around in the camera frame such that:

- the checkerboard is detected at the left and right edges of the field of view (X calibration)
- the checkerboard is detected at the top and bottom edges of the field of view (Y calibration)
- the checkerboard is detected at various angles to the camera ("Skew")
- the checkerboard fills the entire field of view (Size calibration)
- checkerboard tilted to the left, right, top and bottom (X,Y, and Size calibration)



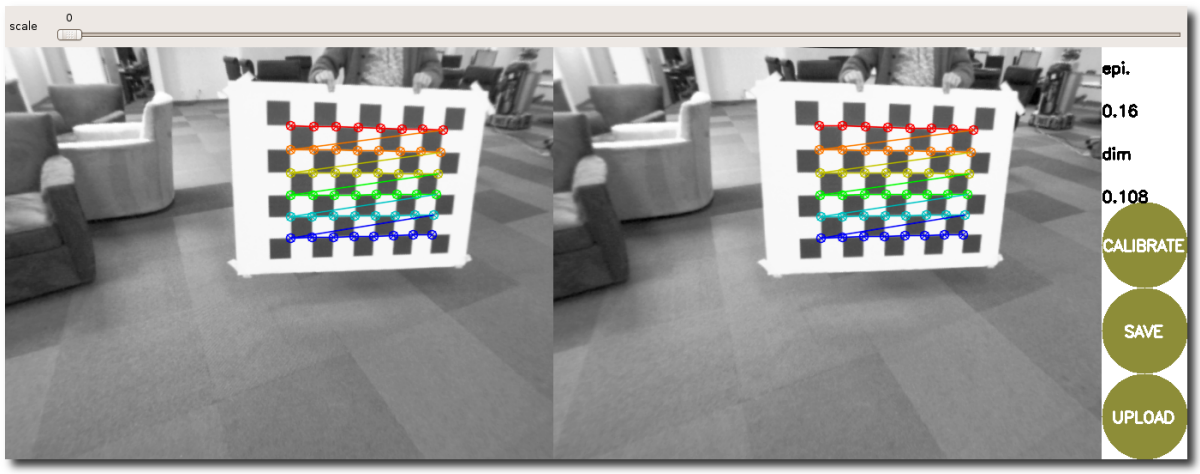


As you move the checkerboard around you will see three bars on the calibration sidebar increase in length. When the **CALIBRATE** button lights, you have enough data for calibration and can click **CALIBRATE** to see the results.



7. Calibration Results

After the calibration is complete you will see the calibration results in the terminal and the calibrated image in the calibration window:



The sidebar will show the measured accuracy and dimensions of the checkerboard square, in the above case the checkerboard square was 111mm with an accuracy of 0.31 pixels.

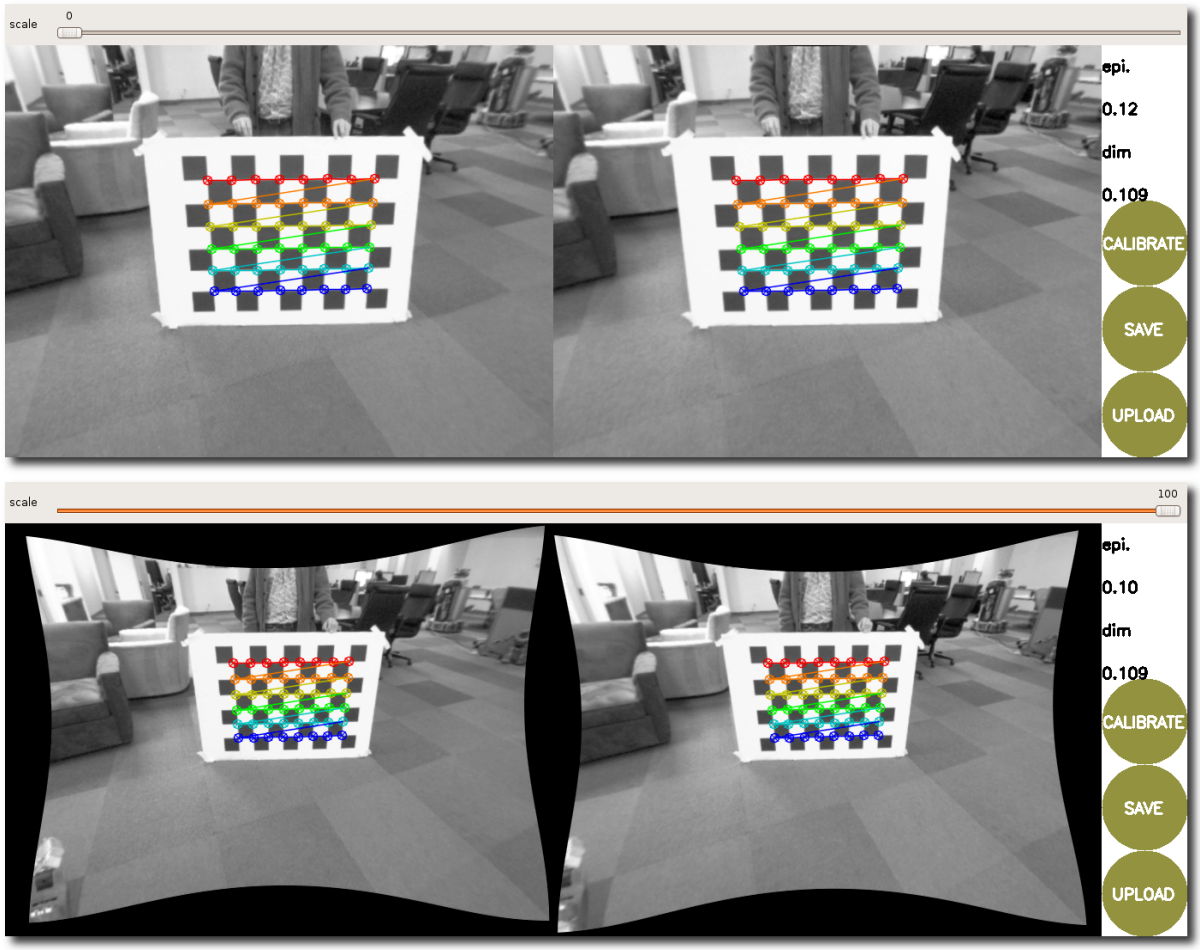
A successful calibration will result in real-world straight edges appearing straight in the corrected image.

A failed calibration usually results in blank or unrecognizable images, or images that do not preserve straight edges.

Typically, an epipolar error below 0.25 pixel is considered acceptable, and below 0.1 excellent.

You can also use the slider at the top of the calibration window to change the size of the rectified image, as shown below. A scale of 0.0 means that the image is sized so that all pixels in the rectified image are valid. The rectified image has no border, but some pixels from the original image are discarded. A scale of 1.0 means that all pixels in the original image are visible, but the rectified image has black borders where there are no input pixels in the original image.

The recommended value for the slider is 0.0.



For more details on the stereo camera model - including interpretation of these results - see http://opencv.willowgarage.com/documentation/python/camera_calibration_and_3d_reconstruction.html (http://opencv.willowgarage.com/documentation/python/camera_calibration_and_3d_reconstruction.html) and image_geometry (/image_geometry).

```
Left:
D =  [-0.31420196940339423, 0.091934927292188981, 0.0012952332628749881, -0.00
16196264582460102]
K =  [425.19601412158482, 0.0, 308.29689772295882, 0.0, 426.02702697756899, 22
3.53789948448997, 0.0, 0.0, 1.0]
R =  [0.99783514664821127, 0.013543024537547797, 0.064355315242164368, -0.0136
44479706482148, 0.99990626305523833, 0.0011372231303031885, -0.064333881330776
027, -0.0020128560018237928, 0.99792640015365552]
P =  [308.02438413775218, 0.0, 270.8484992980957, 0.0, 0.0, 308.0243841377521
8, 226.91282844543457, 0.0, 0.0, 0.0, 1.0, 0.0]

Right:
D =  [-0.30550530964404188, 0.082701072309439266, 0.001966752019596593, -0.001
6409796174513081]
K =  [425.18741896821433, 0.0, 323.8787136811938, 0.0, 426.46867413824884, 22
6.19589833365407, 0.0, 0.0, 1.0]
R =  [0.99769116642055589, 0.011418153515469445, 0.066947458627553177, -0.0113
12576360776634, 0.99993409783500409, -0.0019559148698406695, -0.06696537958133
5679, 0.0011940507500265176, 0.99775458514623427]
P =  [308.02438413775218, 0.0, 270.8484992980957, -28.144333365644293, 0.0, 30
8.02438413775218, 226.91282844543457, 0.0, 0.0, 0.0, 1.0, 0.0]
# oST version 5.0 parameters


[image]

width
640

height
480

[narrow_stereo/left]

camera matrix
425.196014 0.000000 308.296898
0.000000 426.027027 223.537899
0.000000 0.000000 1.000000

distortion
-0.314202 0.091935 0.001295 -0.001620 0.0000

rectification
0.997835 0.013543 0.064355
-0.013644 0.999906 0.001137
-0.064334 -0.002013 0.997926

projection
308.024384 0.000000 270.848499 0.000000
0.000000 308.024384 226.912828 0.000000
```

```
0.000000 0.000000 1.000000 0.000000


# oST version 5.0 parameters


[image]

width
640

height
480

[narrow_stereo/right]

camera matrix
425.187419 0.000000 323.878714
0.000000 426.468674 226.195898
0.000000 0.000000 1.000000

distortion
-0.305505 0.082701 0.001967 -0.001641 0.0000

rectification
0.997691 0.011418 0.066947
-0.011313 0.999934 -0.001956
-0.066965 0.001194 0.997755

projection
308.024384 0.000000 270.848499 -28.144333
0.000000 308.024384 226.912828 0.000000
0.000000 0.000000 1.000000 0.000000
```

If you are satisfied with the calibration, click **COMMIT** (on the pictures above this is button has an old name **UPLOAD**) to send the calibration parameters to the camera for permanent storage.

If you want to save the calibration parameters and images used in calibration, click **SAVE**. Everything will be made available in the compressed folder /tmp/calibrationdata.tar.gz.

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