# CS485/685 Computer Vision

# Spring 2011 – Dr. George Bebis

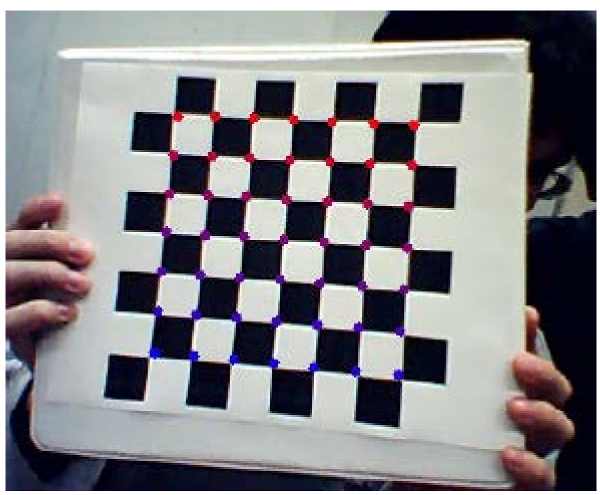
# Programming Assignment 6 (Extra Credit)

# Due Date: 5/13/2011

In this assignment, you will use OpenCV's ***cvCalibrateCamera2*** camera calibration function to compute the extrinsic and intrinsic camera parameters. Note that the calibration method implemented in OpenCV is based on Zhang's method [1]. This method is slightly different from the method discussed in class; however, the main ideas are the same. The calibration object used by this method is planar and requires at least two images from different viewpoints for calibration. It would be useful to take a look of Zhang's paper before working on the assignment.

## Data

The images to be used in your calibration experiments (i.e., 11 images of the same chessboard taken with the same camera at different angles) can be downloaded from the course's webpage. To find the corners in each image, use OpenCV's function ***cvFindChessboardCorners.*** To draw the corners found on each image, use OpenCV's function **cvDrawChessboardCorners**. The figure below shows an example.



## Establishing 2D/3D Correspondences

Since there is no restriction on how we choose the World Reference Frame, to make things easier, choose its origin at one of the corners of the chessboard, the X and Y axes parallel to the squares of the board, and the Z axis perpendicular to the chessboard plane. To create the set of corresponding 3D points, choose (0,0,0) as the coordinates of the top left corner and increment by 1 (i.e., the size of each grid is 1 inch × 1 inch) in the x and y directions. Since we have seven such points horizontally and vertically (i.e., the corners on the inside of the chessboard), the 3D coordinates of the corners will be of the form (m,n,0) where 0<=m<7, and 0<=n<7. Please, note that although the Z coordinate is 0 for all the points of the chessboard in the World Reference Frame, ***cvCalibrateCamera2*** expects the coordinates of the points as 3D points.

## Experiments and Comparisons

Compute the calibration parameters using the 11 chessboard images provided and evaluate your results using the projection and verification tests described below. For each image, choose 80% of the points randomly (i.e., set A) for calibration and the rest 20% of the points (i.e., set B) for verification (see below). Include the parameters computed in your report.

***Projection test:*** using the computed camera parameters for each image, project the world points in set A on the image plane. Suppose that (*r*, *c*) are the projected coordinates and $(\hat{r}, \hat{c})$ are the actual coordinates (i.e., found by ***cvFindChessboardCorners***); the projection error can be computed as follows:

$$Error = \sqrt{(r - \hat{r})^2 + (c - \hat{c})^2}$$

You should report the projection error per image (i.e., by summing the projection errors over all the points in set A) and the average projection error (i.e., by averaging the projection errors over all the images).

***Verification test:*** To verify the results of calibration, you will need to apply the projection test for the points in set B (i.e., points **NOT** used for calibration). You should report the verification error per image (i.e., by summing the verification errors over all the points in set B) and the average verification error (i.e., by averaging the verification errors over all the images).

# Graduate Students Only

Typically, camera calibration results depend on the number of images used for calibration. Repeat the above experiments using (i) the first 4 images, and (ii) the first 8 images. Compare your results with those obtained using all 11 images. What conclusions can you make?

## What to turn in

Turn in a brief report including a print-out of your source code. Your report should include the following: **(1)** methodology (i.e., explanation of the methods used), **(2)** description of the experiments, **(3)** results (i.e., include graphic output of your results), **(4)** explanation of results (i.e., justify your results), and **(5)** a brief summary of what you have learned. Organize your report nicely, label all sections and figures.

[1] Z. Zhang. "A flexible new technique for camera calibration", **IEEE Transactions on Pattern Analysis and Machine Intelligence**, vol. 22, no. 11, pp. 1330-1334, 2000.