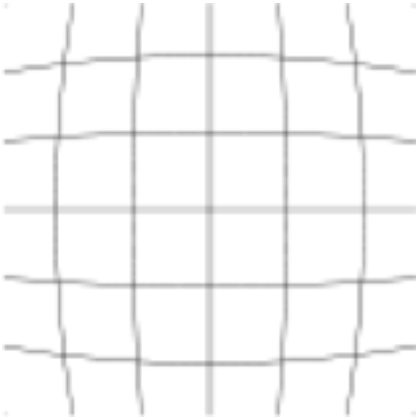
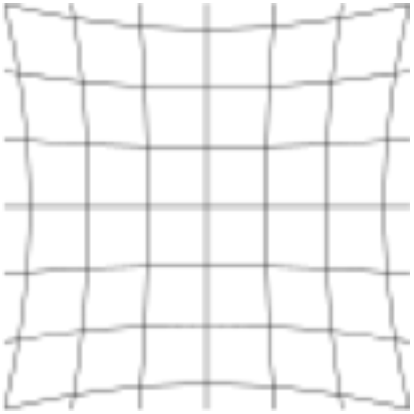
In CS4243_L03_Camera_Basics, we learned

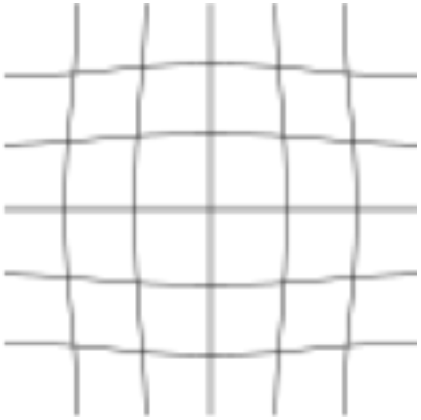
Lens Distortions



Barrel Distortion
(eg. Fisheye lens)



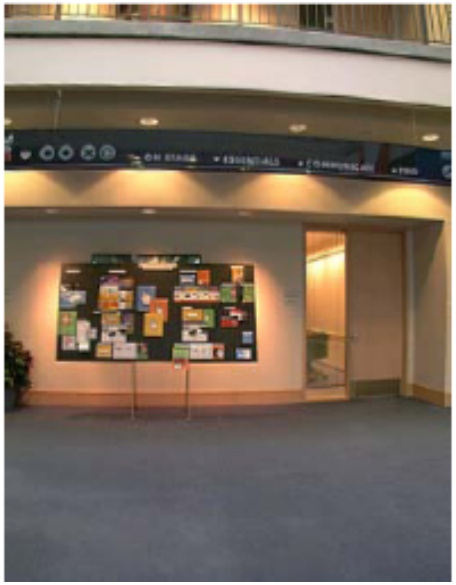
Pincushion Distortion
(eg. Telephoto lens)



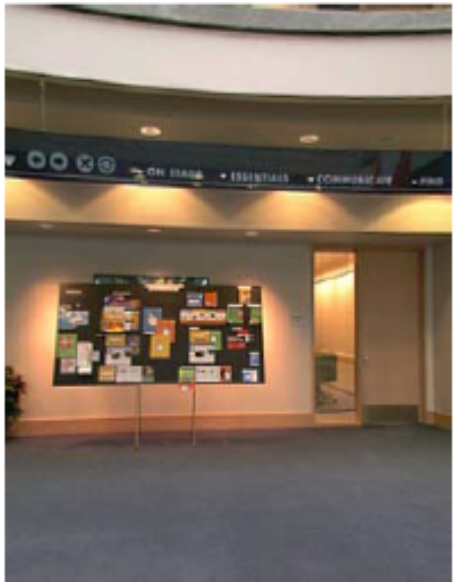
Mustache Distortion
(eg. Large range zooms 18-200mm)

Lens Distortion

- straight lines become curves



barrel



pin-cushion

- Radial distortion can be modelled as

$$x_d = x\,(1 + \kappa_1 r^2 + \kappa_2 r^4 + \kappa_3 r^6)$$
$$y_d = y\,(1 + \kappa_1 r^2 + \kappa_2 r^4 + \kappa_3 r^6)$$

distorted coordinates

undistorted coordinates

distortion parameters

with $r^2 = x^2 + y^2$

- Actual image coords

$$x_a = f_x\, x_d + c_x$$
$$y_a = f_y\, y_d + c_y$$

1. In the course project, the videos given to you had not been corrected for radial distortion.

2. We had however given you the undistorted values in Annotation.zip in IVLE.

3. Use the undistorted values in Annotation.zip to compute the 3D trajectory of the ping pong ball.

4. If you have successfully done the ball tracking, please also reconstruct the 3D trajectory using your distorted values and compare the results with what you get in step 3 above.

We had used OpenCV to do the distortion correction

The following process is used to correct the radial distortions.

$$x = \frac{u - c_x}{f_x}$$
$$y = \frac{v - c_y}{f_y}$$

$$r^2 = x^2 + y^2$$
$$x' = x(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) + 2p_1 xy + p_2(r^2 + 2x^2)$$
$$y' = y(1 + k_1 r^2 + k_2 r^4 + k_3 r^6) + p_1(r^2 + 2y^2) + 2p_2 xy$$

$$u' = x' f_x + c_x$$
$$v' = y' f_y + c_y$$

, where:

- (u, v) is the image coordinate in the rectified image.
- (u', v') is the coordinate of the same point in the original image.
- $A = \begin{pmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix}$ is the camera calibration matrix.

- $\begin{pmatrix} k_1 & k_2 & p_1 & p_2 & k_3 \end{pmatrix}$ are the distortion coefficients.

The following are the intrinsic parameters (i.e. camera resolution, camera calibration matrices and distortion coefficients) of the 3 cameras:

Camera 1:

Camera resolution: 1920 1080

Camera calibration matrix:

$$\begin{pmatrix} 870.14531487461625 & 0 & 949.42001822880479 \\ 0 & 870.14531487461625 & 487.20049852775117 \\ 0 & 0 & 1 \end{pmatrix}$$

Distortion coefficients:

$$\begin{pmatrix} -0.27130810574978376 & 0.123534923968889 29 & 0 & 0 & -0.03413951969097 1919 \end{pmatrix}$$

Camera 2:

Camera resolution: 1920 1080

Camera calibration matrix:

$$\begin{pmatrix} 893.34367240024267 & 0 & 949.96816131377727 \\ 0 & 893.34367240024267 & 546.79562177577259 \\ 0 & 0 & 1 \end{pmatrix}$$

Distortion coefficients:

$$\begin{pmatrix} -0.28161923440814401 & 0.13207856151552402 & 0 & 0 & -0.03995513022494438 \end{pmatrix}$$

Camera 3:

Camera resolution: 1920 1080

Camera calibration matrix:

$$\begin{pmatrix} 872.90852997159800 & 0 & 944.45161471037636 \\ 0 & 872.90852997159800 & 564.47334036925656 \\ 0 & 0 & 1 \end{pmatrix}$$

Distortion coefficients:

$$\begin{pmatrix} -0.29393100306875553 & 0.20417834932193116 & 0 & 0 & -0.10715409751739460 \end{pmatrix}$$

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frame,x,y,undistort_x,undistort_y
0,,,,
1,,,,
2,555,314,526.492588,301.481624
3,570,310,544.195114,297.948346
4,591,306,568.710890,294.731662
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