Overview : Camera Calibration :- Shree Nayar → First Principles of CV → Youtube
Lineas Camera Model

One of the key problems in Computer Vision is recovering the 3 dimensional structure of a scene from its images. Image to full metric reconstruction requires 2 things:-

1) Position & Orientation of the camera w.r.t. world co-ordinate frame → external parameters.
2) How the camera maps the perspective projection points in the world onto its image plane. → Internal parameters such as focal length.

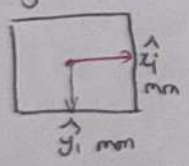
Determining Determining the external & internal parameters of the camera is what is referred to as camera calibration.

Method to find a camera's internal & external parameters.

1) We need a model → Linear Camera Model
   Single matrix called Projection Matrix.
2) Camera Calibration
3) Extracting Intrinsic & Extrinsic Matrices.
4) Example Application: Simple Stereo.

Intrinsic Matrix $K = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}$

f_x, f_y → focal length in pixels in x & y direction.
c_x, c_y → Image Center in Pixels (principal pt)
0s & 1 → Homogenous co-ordinates
↳ Miolith video → Youtube



$u = m_x f \frac{x_c}{z_c} + c_x \qquad v = m_y f \frac{y_c}{z_c} + c_y$

$m_x = \frac{\text{image width (px)}}{\text{sensor width (mm)}} \qquad m_y = \frac{\text{image height (px)}}{\text{sensor height (mm)}}$

Camera = iPhone 16 Pro Max, focal length in mm → 6.9mm, Image Resolution ⇒ 5712 x 4284 px Aperture = f/1.78

24 MP iPhone sensor size → 9.6mm x 7.2mm

$f_x = f m_x$ & $f_y = f m_y$ i.e. focal length in pixels. → Linear Camera Model → YT

$\therefore f_x = \frac{6.9}{9.6} \times 5712 = 0.71875 \times 5712 = 4108$ pixels

$f_y = \left(\frac{6.9}{9.6}\right) \times 4284 = 0.958 \times 4284 = 4107$ pixels

$c_x = \frac{\text{image\_width}}{2} = \frac{5712}{2} = 2856 \qquad c_y = \frac{\text{image\_height}}{2} = \frac{4284}{2} = 2142$

$\therefore$ Theoretical Calculated $K = \begin{bmatrix} 4108 & 0 & 2856 \\ 0 & 4107 & 2142 \\ 0 & 0 & 1 \end{bmatrix}$ $\therefore$ Practical K Observed $= \begin{bmatrix} 3.9808 & 0 & 2.7854 \\ 0 & 3.9744 & 2.14038 \\ 0 & 0 & 1 \end{bmatrix}$

Add a Caption

Look Up **American Wirehair**

Wednesday • Jun 18, 2025 • 3:48 PM Adjust

IMG_0837

Apple iPhone 16 Pro Max HEIF

Fusion Camera — 24 mm ƒ1.78

24 MP • 4284 × 5712 • 3.2 MB STANDARD

ISO800	24mm	0ev	ƒ1.78	1/33s

Add a location...

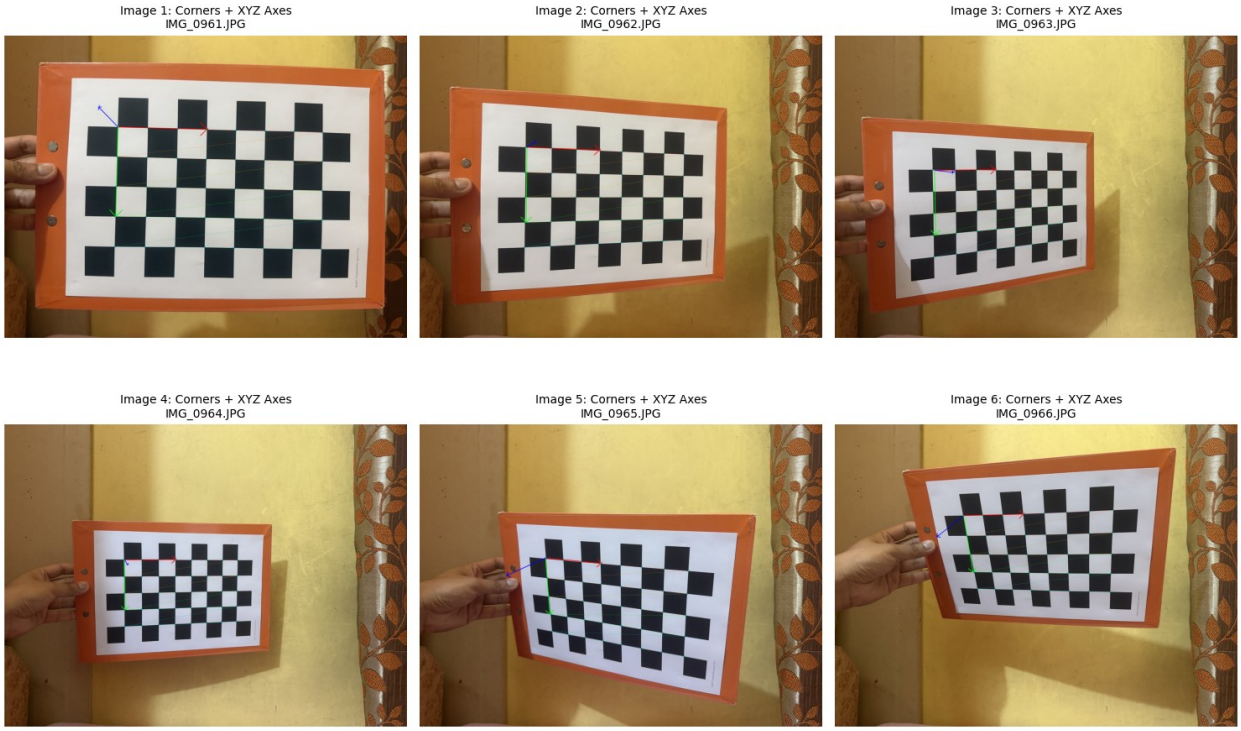
```
import numpy as np
import cv2
import glob
import os
import matplotlib.pyplot as plt
%matplotlib inline

# Chessboard parameters
chessboard_size = (8, 5)
square_size = 3.0  # Square 3.0 cm

# Prepare object points
objp = np.zeros((chessboard_size[0] * chessboard_size[1], 3),
np.float32)
objp[:, :2] = np.mgrid[0:chessboard_size[0],
0:chessboard_size[1]].T.reshape(-1, 2)
objp *= square_size

# Arrays to store object points and image points
objpoints = []
imgpoints = []

# Image loading
image_path = r'C:\Users\vikra\Downloads\Iphone_Images\newdata\*.jpg'
images = glob.glob(image_path)
print(f"Found {len(images)} image(s).")

plt.figure(figsize=(15, 10))

for idx, fname in enumerate(images):
    print(f"\n[{idx + 1}/{len(images)}] Processing:
{os.path.basename(fname)}")

    img = cv2.imread(fname)
    if img is None:
        print(" ✗ Could not read image.")
        continue

    gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)

    # Detection flags
    flags = cv2.CALIB_CB_ADAPTIVE_THRESH +
cv2.CALIB_CB_NORMALIZE_IMAGE


    try:
        ret, corners = cv2.findChessboardCornersSB(gray,
chessboard_size, flags)
    except:
        ret, corners = cv2.findChessboardCorners(gray,
```

```
chessboard_size, flags)

    if ret:
        print(" ✓ Chessboard detected.")

        objpoints.append(objp)

        # Corner refinement
        corners2 = cv2.cornerSubPix(
            gray, corners, (11, 11), (-1, -1),
            (cv2.TERM_CRITERIA_EPS + cv2.TERM_CRITERIA_MAX_ITER, 30,
0.001)
        )
        imgpoints.append(corners2)

        # Draw corners on image
        img_display = img.copy()
        cv2.drawChessboardCorners(img_display, chessboard_size,
corners2, ret)


        if len(objpoints) >= 1:
            h, w = gray.shape[:2]
            camera_matrix_est = np.array([[w, 0, w/2],
                                          [0, w, h/2],
                                          [0, 0, 1]], dtype=np.float32)
            dist_coeffs_est = np.zeros((4,1))

            # Define 3D points for coordinate axes (in chessboard
coordinate system)
            axis_points = np.float32([[0,0,0], [3,0,0], [0,3,0],
[0,0,-3]]).reshape(-1,3) * square_size

            # Find pose of the chessboard
            success, rvec, tvec = cv2.solvePnP(objp, corners2,
camera_matrix_est, dist_coeffs_est)

            if success:
                # Project 3D axis points to image plane
                axis_img_pts, _ = cv2.projectPoints(axis_points, rvec,
tvec, camera_matrix_est, dist_coeffs_est)
                axis_img_pts = np.int32(axis_img_pts).reshape(-1,2)

                # Draw coordinate axes
                origin = tuple(axis_img_pts[0])
                x_axis = tuple(axis_img_pts[1])
                y_axis = tuple(axis_img_pts[2])
                z_axis = tuple(axis_img_pts[3])
```

```
                # Draw axes
                cv2.arrowedLine(img_display, origin, x_axis,
(0,0,255), 8)  # X-axis: Red
                cv2.arrowedLine(img_display, origin, y_axis,
(0,255,0), 8)  # Y-axis: Green
                cv2.arrowedLine(img_display, origin, z_axis,
(255,0,0), 8)  # Z-axis: Blue


                cv2.putText(img_display, 'X', x_axis,
cv2.FONT_HERSHEY_SIMPLEX, 1, (0,0,255), 3)
                cv2.putText(img_display, 'Y', y_axis,
cv2.FONT_HERSHEY_SIMPLEX, 1, (0,255,0), 3)
                cv2.putText(img_display, 'Z', z_axis,
cv2.FONT_HERSHEY_SIMPLEX, 1, (255,0,0), 3)

        # Enhance corner visibility
        for corner in corners2:
            center = tuple(corner.ravel().astype(int))
            cv2.circle(img_display, center, 8, (255,255,0), -1)  #
Yellow filled circles
            cv2.circle(img_display, center, 10, (0,0,0), 2)     #
Black outline

        # Convert BGR to RGB
        img_display_rgb = cv2.cvtColor(img_display, cv2.COLOR_BGR2RGB)


        plt.subplot(2, 3, (idx % 6) + 1)
        plt.imshow(img_display_rgb)
        plt.title(f'Image {idx+1}: Corners + XYZ Axes\
n{os.path.basename(fname)}', fontsize=10)
        plt.axis('off')

        # Show plot every 6 images
        if (idx + 1) % 6 == 0 or idx == len(images) - 1:
            plt.tight_layout()
            plt.show()
            if idx < len(images) - 1:
                plt.figure(figsize=(15, 10))
    else:
        print("  Chessboard NOT detected.")

# === Calibration ===
if len(objpoints) >= 3:
    ret, mtx, dist, rvecs, tvecs = cv2.calibrateCamera(
        objpoints, imgpoints, gray.shape[::-1], None, None
    )
```

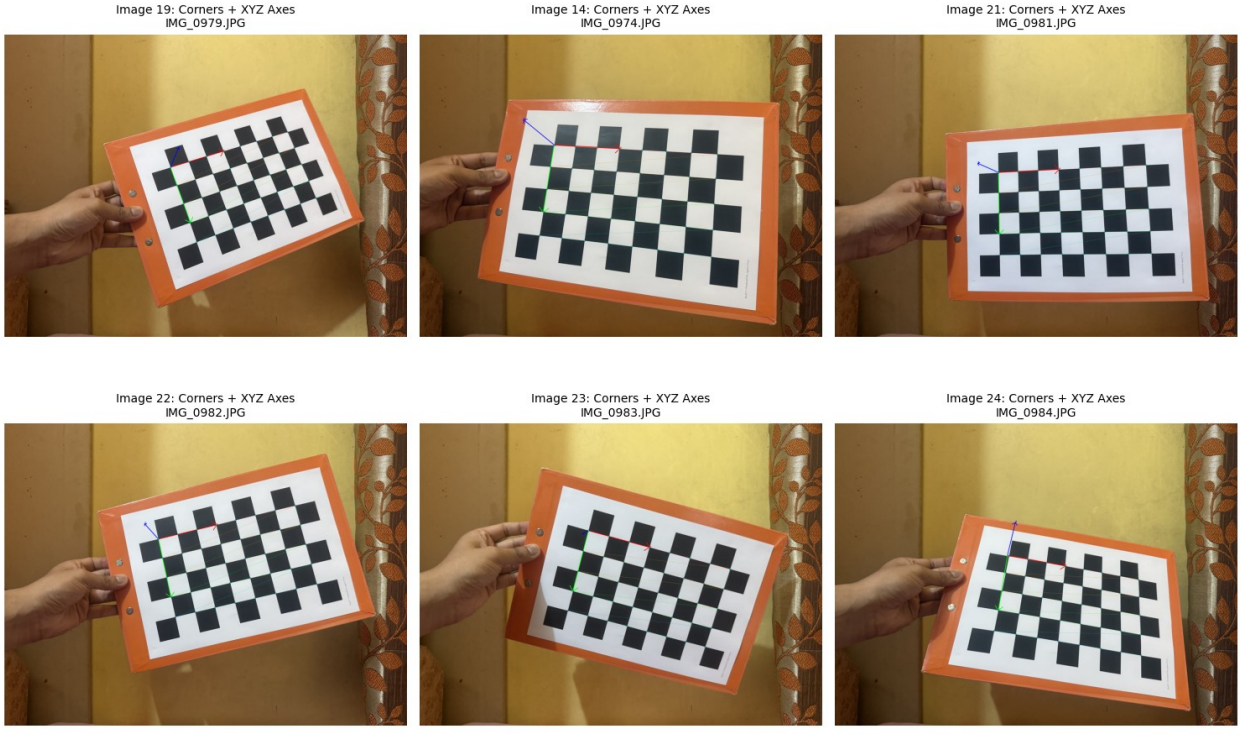
```
    print("\n Calibration complete!")
    print("Camera Matrix:\n", mtx)
    print("Distortion Coefficients:\n", dist)

    # Save calibration data
    np.savez('iphone_calibration_data.npz', mtx=mtx, dist=dist,
rvecs=rvecs, tvecs=tvecs)
    print("Calibration data saved as 'iphone_calibration_data.npz'")

    # Display calibration results
    print(f"\nCalibration Results:")
    print(f"- Used {len(objpoints)} images for calibration")
    print(f"- Reprojection error: {ret:.4f} pixels")

else:
    print(f"\n Not enough valid images to calibrate. Found
{len(objpoints)} valid images, need at least 3.")
```

```
Found 26 image(s).

[1/26] Processing: IMG_0961.JPG
 ✓ Chessboard detected.

[2/26] Processing: IMG_0962.JPG
 ✓ Chessboard detected.

[3/26] Processing: IMG_0963.JPG
 ✓ Chessboard detected.

[4/26] Processing: IMG_0964.JPG
 ✓ Chessboard detected.

[5/26] Processing: IMG_0965.JPG
 ✓ Chessboard detected.

[6/26] Processing: IMG_0966.JPG
 ✓ Chessboard detected.
```




```
[7/26] Processing: IMG_0967.JPG
 ✗ Chessboard NOT detected.

[8/26] Processing: IMG_0968.JPG
 ✓ Chessboard detected.

[9/26] Processing: IMG_0969.JPG
 ✓ Chessboard detected.

[10/26] Processing: IMG_0970.JPG
 ✓ Chessboard detected.

[11/26] Processing: IMG_0971.JPG
 ✓ Chessboard detected.

[12/26] Processing: IMG_0972.JPG
 ✗ Chessboard NOT detected.

[13/26] Processing: IMG_0973.JPG
 ✓ Chessboard detected.

[14/26] Processing: IMG_0974.JPG
 ✓ Chessboard detected.

[15/26] Processing: IMG_0975.JPG
 ✓ Chessboard detected.
```

```
[16/26] Processing: IMG_0976.JPG
 ✓ Chessboard detected.

[17/26] Processing: IMG_0977.JPG
 ✗ Chessboard NOT detected.

[18/26] Processing: IMG_0978.JPG
 ✗ Chessboard NOT detected.

[19/26] Processing: IMG_0979.JPG
 ✓ Chessboard detected.

[20/26] Processing: IMG_0980.JPG
 ✗ Chessboard NOT detected.

[21/26] Processing: IMG_0981.JPG
 ✓ Chessboard detected.

[22/26] Processing: IMG_0982.JPG
 ✓ Chessboard detected.

[23/26] Processing: IMG_0983.JPG
 ✓ Chessboard detected.

[24/26] Processing: IMG_0984.JPG
 ✓ Chessboard detected.
```



```
[25/26] Processing: IMG_0985.JPG
 ✓ Chessboard detected.

[26/26] Processing: IMG_0986.JPG
 ✓ Chessboard detected.
```


```
✓ Calibration complete!
Camera Matrix:
 [[3.96468132e+03 0.00000000e+00 2.79612355e+03]
 [0.00000000e+00 3.95918955e+03 2.15585899e+03]
 [0.00000000e+00 0.00000000e+00 1.00000000e+00]]
Distortion Coefficients:
 [[ 0.12295367 -0.19094559  0.00111336 -0.00547174 -0.65125816]]
Calibration data saved as 'iphone_calibration_data.npz'

Calibration Results:
- Used 21 images for calibration
- Reprojection error: 1.5126 pixels
```