NOTE: This document was developed in conjunction with the code that was attached. I tried to type out most equations but the extrinsic calculations were easier done within the code alone so I outputted the results from running the code with the following image. I included the image in case you would like to test the code out yourself and see how 'well' it calibrates the iPhone 15 Plus camera. Also, I would like to add that I did use the OpenCV library in my code but it was solely for image loading, processing, checkerboard detection, corner refinement, and visualization of the detection. I did not use OpenCV to calculate any of the extrinsics but I might add onto it to see how much the manual calibration differs from the OpenCV calibration functions.

ANSWERS IN RED

1. Collect Camera Specifications for iPhone 15 Plus Main Camera

Parameter	**Value**
Sensor Dimensions [1]	**8.0 mm x 6.0 mm**
Image Resolution [1]	**6000 x 4000 pixels**
Focal Length [2]	**26 mm**
Pixel Size [1]	**1.0 micrometer**

2. Convert focal length to pixels
    a. f_x = (focalLength / sensorWidth) * imageResolutionWidth = 19500 pixels
    b. f_y = (focalLength/ sensorHeight) * imageResolutionHeight = 17333.33 pixels

3. Assume principal point is at image center
    a. c_x = imageResolutionWidth / 2 = 3000 pixels
    b. c_y = imageResolutionHeight / 2 = 2000 pixels

4. Assume skew is 0 for square pixels
    a. skewAngle = 0

5. **Intrinsic Matrix**
    a. **K =** $\begin{pmatrix} f_x & s & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} 19500 & 0 & 3000 \\ 0 & 17333 & 2000 \\ 0 & 0 & 1 \end{pmatrix}$

6. Compute Extrinsic Parameters (R,t)
    a. Using a checkerboard and known world coordinates
        i. Checkboard consists of 10x7 inner corners with 25 mm squares
        ii. World coordinates are defined in millimeters, with the checkerboard alight to the XY plane (Z = 0)
    b. Compute Homography Matrix (H)

i. H maps the 3D world points to the 2D image points
ii. Using SVD (Singular Value Decomposition), solve for H

c. Extracting Rotation and Translation from H
   i. The first two columns of H correspond to R1 and R2, the first two columns of R. The third column of R is equated by taking the cross product of R1 and R2 to make sure R is a orthonormal basis.
   ii. The third column of H is t, the translation vector

d. Rotation Matrix R

i. **R =** $\begin{pmatrix} 0.9869 & 0.0393 & -0.1623 \\ 0.0046 & 0.9652 & 0.2617 \\ 0.1669 & -0.2587 & 0.9514 \end{pmatrix}$

e. Translation vector T

i. **T =** $\begin{pmatrix} -0.1375 \\ -0.0735 \\ 1.0 \end{pmatrix}$

f. The iPhone was position approximately 12 inches away from the checkerboard and was aligned to be parallel to the checkerboard (or at least attempted). The results of the translation vector states that the camera was 1 meter away from the checkerboard which is obviously untrue so this calibration was not the best.

[1] https://www.dpreview.com/articles/2668153890/apple-s-iphone-15-and-15-pro-imaging-tech-examined

[2] https://www.apple.com/iphone-15/specs/