CG2 Ex. 3

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1st Image

Image Acquisition

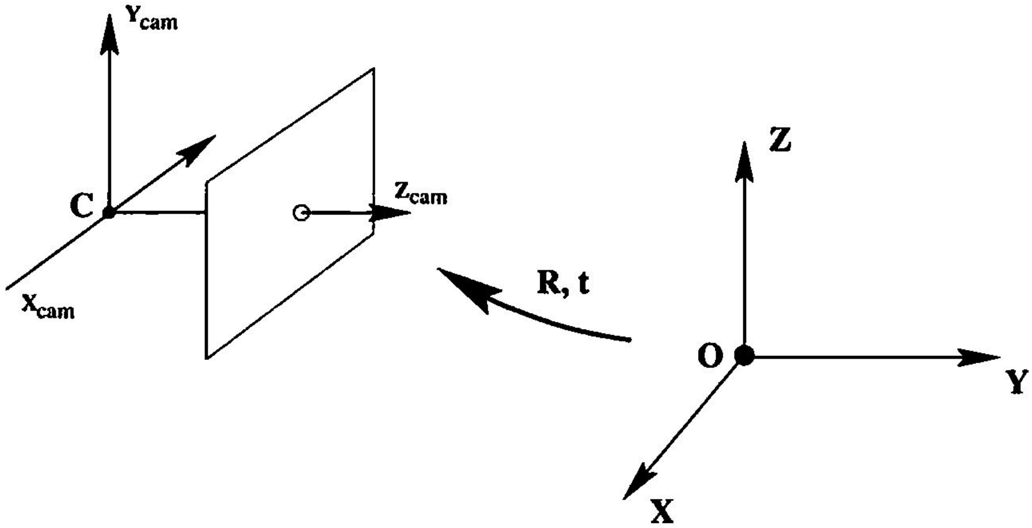

Figure 1: Coordinates for the 3D object space and the 2D sensor space

Phone	Motorola Moto G9 Play
k_x^{-1}	0.8µm/px
Camera Resolution	48MP
Image Resolution	4000 x 3000 px (12MP)
Focal length	4.71mm

Table 1: Moto G9 camera specifications

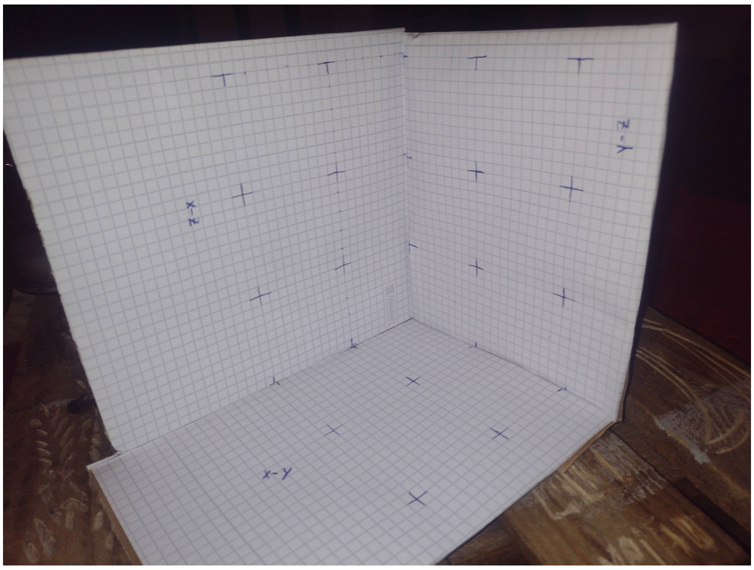

Figure 2: Image captured with Motorola G9 Play

Parameter Intuition

Aspect ratio

The aspect ratio is given by $\frac{\alpha_y}{\alpha_x} = 0.993047$. This can be considered as quadratic pixels, which coincides with most commercially available CCD sensors.

Principal distance α_x

Table 1 shows the specifications of image 2. Note that although the Camera resolution is rated at 48MP, the actual image resolution is only 12MP due to the software's decision to aggregate the 48MP image into so called "Quad Pixels", effectively halving the per pixel count per unit length factor k_x. In slide 11 of lecture 8: The Camera Model we can obtain the equation that relates the principal distance α_x in pixel to the principal distance c in physical units of length. Taking into account the doubling of k_x just mentioned, we obtain:

$$\alpha_x = \frac{1}{2} c k_x = 0.5 * 0.00471m * 1250000 \frac{px}{m} = 2943.75px \tag{1}$$

Which agrees well with the principal value in pixel obtained through our calibration program.

Principal point x_0, y_0

Denotes the 2D coordinates of the principal point in pixels, which is the intersection of the optical

Skew s

The skew angle is given by $arctan(\frac{s}{\alpha_x}) = 92.7864°$ - meaning no significant skewing in the pixels. As [3] points out, unless the photograph was taken from another photograph in a skewed fashion, the s value should be always 0, or 90° if measured in degrees. The value is a bit higher than the one of the second image, which might be caused by the walls of the object not being exactly perpendicular to each other.

Rotation angles ω, ϕ, κ

- $\omega = 115.826$
- $\phi = -36.7402$
- $\kappa = -161.699$

These correspond respectively to the yaw, pitch, and roll rotation angles needed to rotate the world coordinate frame into the camera coordinate frame as shown in figure 1.

C

$[20.4772, 21.6331, 16.6323]^T cm$
The vector C corresponds to the translation vector, also called t, needed to translate from the origin O of the world coordinate system to the projection center C of the camera, as shown in figure 1

Measurement uncertainty

Causes of uncertainty are the imprecise construction of the calibration object itself, as the different sides of grid paper are not precisely aligned, which contributes to a constant uncertainty of about $0.5cm$. Furthermore, the sides of the object are not precisely oriented at 90 degree angles from one another, so an uncertainty proportional to the distance to the origin arises. Finally this method does not correct barreling artifacts from the camera itself, which depending on the smartphone camera model can be quite significant.

2nd Image

Phone	iPhone 7
k_x	$819.672 \frac{px}{mm}$
Camera Resolution	12MP
Image Resolution	1574 x 2100 px (3MP)
Focal length	4 mm

Table 2: iPhone camera specifications

The values were obtained and calculated from [1]

Image Acquisition

Especially the points on the plane XZ are most probably prone to errors. They were measured and placed with a folding rule and may not preserve the exact same distances as the different segments of the shelves. Furthermore, the wooden planks on the floor may also not be even and it cannot be guaranteed that the shelves are located at a perfect 90 degree angle from each other. We expect the measurements to have between 0.5 and 1cm of deviation. [2]

Figure 3: Image captured with iPhone 7

Parameter Intuition

Aspect ratio

The aspect ratio is given by $\frac{\alpha_y}{\alpha_x} = 0.987345$. This can be considered as quadratic pixels, which coincides with most commercially available CCD sensors.

Principal distance α_x

$\alpha_x = 2925.77[pixels]$ - perpendicular distance in pixels between projection center of principal plane and image plane. From the values of table 2 we obtain:

$$\alpha_x = ck_x = 4.0mm * 819.672\frac{px}{mm} \approx 3200px \tag{2}$$

This estimate is not as accurate as the last one but still in rough agreement.

Principal point (x_0, y_0)

$(x_0, y_0) = (1567.45, 1779.69)^T px$ Denotes the 2D coordinates of the principal point in pixels, which is the intersection of the optical

Our values correspond approximately with the displacement from the corner of the image to its center.

Skew s

The skew angle is given by $arctan(\frac{s}{\alpha_x}) = 90.02°$ - meaning no significant skewing in the pixels. As [3] points out, unless the photograph was taken from another photograph in a skewed fashion, the s value should be always 0, or 90° if measured in degrees.

Angles ω, ϕ, κ

- ω : 142.646
- ϕ : -43.7827
- $\kappa = -27.836$

These correspond respectively to the yaw, pitch, and roll rotation angles needed to rotate the world coordinate frame into the camera coordinate frame as shown in figure 1.

C

External position: $(166.33, 136.977, 147.945)^T cm$. Position of the camera with respect to the origin of the defined 3D space coordinate system. Note how the values here are bigger than the ones in the first image, which coincides with them being taken at a further distance from the origin of the object space coordinate system.

Measurement uncertainty

Depends on:
Inaccurate correspondence of points between image and the calibration object.
Inaccurate measurement of ground points, inaccurate construction of calibration object.
Augmenting the total number of homologous points could also improve the accuracy of the measurements up to a certain point, by reducing the uncertainty when selecting the pixel coordinates.

References

[1] In: `https://www.anandtech.com/show/10685/the-iphone-7-and-iphone-7-plus-review/6`.

[2] In: `https://www.cse.usf.edu/~r1k/MachineVisionBook/MachineVision.files/MachineVision_Chapter12`

[3] Richard Hartley and Andrew Zisserman. Multiple View Geometry in Computer Vision. 2nd ed. USA: Cambridge University Press, 2003, p. 164. ISBN: 0521540518.