# CSE 573: Homework Assignment 2

**Name: Sokhey, Harshdeep , UB#50247213**

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# 1 Solution 1

## 1.1 Part 1

Parameter Results from In-Class Activity:

| | |
|---|---|
| Focal Length | [1587.639 1587.240] +- [9.630 10.525] |
| Camera Matrix | [1587.639 0 616.073; 0 1581.240 803.718; 0 0 1] |
| Principal Point | [616.073 803.718] +- [ 0.56784 0.839920 0.003043 0.002302] |
| Square Size | 30.0(mm) |
| Distortion | [0.164960 -0.966937 -0.002024 0.006058] +- [0.056784 0.839920 0.003043 0.002302] |

The five intrinsic camera parameters are:

1. Focal Length
2. Aspect ratio
3. Angle between the optical axes
4. Center of Projection

## 1.2 Part 2

The real cameras deviate from the pinhole model in 3 ways:

1. **Intersection of the principal point**, results from the image rays intersecting at a point. In the case of the pinhole camera, the rays must intersect at the pinhole. For real cameras, the rays may not actually intersect but the region of convergence is so insignificant that it can be treated as a point.

2. **Lens Distortion**, is the *curving effect* seen in real lenses when straight lines are projected through them on the image plane. We can categorize them as : Radial Lens Distortion, Barrel Distortion, Pincushion Distortion.

3. **Deviation from the true plane**, resulting from the distortion of the film plane due to the uneven surface (also known as film flop). This distortion is not seen in digital cameras with perfectly flat image arrays.

### 1.3 Part 3

The uncalibrated images can also be used to estimate the intrinsic camera parameters. In case of architectural images, straight lines could be used to estimate the radial lens distortion along with using a set of parallel lines. Vanishing points of orthogonal set of parallel lines could also be useful for determining intrinsic camera parameters. The paper mentions using the triangle method for determining camera center, center of projection and the focal length. Camera information may also be extracted using structure recovery process for architectural structures that have been damaged or modified using the vanishing point technique.

## 2 Solution 2

### 2.1 Part 1

Using the relation

$$X_c = rX_w - c, \tag{1}$$

where $X_c$ is the camera co-ordinate, $X_w$ is the world co-ordinate, $r$ is the rotation, $c$ is the linear transformation.

$$X_c = +1(Y - 0) \tag{2}$$

$$Y_c = +1(Z + -50) \tag{3}$$

$$Z_c = +1(X + 100) \tag{4}$$

From equation(2-4), we get,

$$\begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & -50 \\ 1 & 0 & 0 & 100 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

### 2.2 Part 2

The given equation can be achieved by using the representation in a Camera Model Pipeline by converting world-coordinates to the pixel coordinates via camera and image plane coordinates.
**Proof:**
Using equation (2-4), we have transformed the world co-ordinates to camera co-ordinates. Converting camera co-ordinates to the Image Plane Co-ordinates, we get:

$$x_i = f\frac{X_c}{Z_c} \tag{5}$$

$$y_i = f\frac{Y_c}{Z_c} \tag{6}$$

where $x_i, y_i$ are the co-ordinates in the Image Plane and $f$ is the focal length.

In matrix form, we can represent equation(5-6) as :

$$\begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix}$$

Converting Image Plane Co-ordinates to Pixel Co-ordinates, we get:

$$u = K_u + u_0 \tag{7}$$

$$v = K_v + v_0 \tag{8}$$

, where $u_0, v_0$ the point of intersection between the optical axis and CCD array with $k_u$ pixels per unit length and $k_v$ pixels per unit length. In matrix form, we can represent equation(5-6) as :

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} K_u & 0 & u_0 \\ 0 & K_v & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}$$

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} K_u & 0 & u_0 \\ 0 & K_v & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} K_u f & 0 & u_0 & 0 \\ 0 & K_v f & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix}$$

□

### 2.3 Part 3

Using the results from 2.2, for $f = 20$, we can say:

$$\begin{bmatrix} sx \\ sy \\ s \end{bmatrix} = \begin{bmatrix} 20 & 0 & 0 & 0 \\ 0 & 20 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix}$$

Given CCD array size = 500x500 , CCD array focal length= 10x10, ($u_0$,$v_0$)= (200,200), we get values for $K_u, K_v, u, v$ as :

$$|K_u| = |K_v| = \frac{500}{10} = 50 \tag{9}$$

Since, $u$ and $v$ are in the opposite directions, we get $K_u = K_v = -50$.

$$u = K_u x + u_0, v = K_v y + v_0 \tag{10}$$

$$\Rightarrow u = -50x + 200, v = -50y + 200 \tag{11}$$

Applying equation(11) in the above matrix, we get,

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} -50 & 0 & 200 \\ 0 & -50 & 200 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} sx \\ sy \\ s \end{bmatrix}$$

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} -50 & 0 & 200 \\ 0 & -50 & 200 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 20 & 0 & 0 & 0 \\ 0 & 20 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & -50 \\ 1 & 0 & 0 & 100 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Solving the above matrix, we get:

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} 200 & -1000 & 0 & 20000 \\ 200 & 0 & -1000 & 70000 \\ 1 & 0 & 0 & 100 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

In equation form, it can be written as :

$$su = 200X - 1000Y + 20000 \tag{12}$$

$$sv = 200X - 1000Z + 70000 \tag{13}$$

$$s = X + 100 \tag{14}$$

### 2.4 Part 4

The *Ames Room Illusion* is an optical illusion based on a distorted room called Ames Room, named after its inventor. The room appears an ordinary room when viewed from the front , however, the back wall is angled to create a trapezoidal top view of the room. Additionally, the ceiling and the floor are also inclined. Thus, a person standing in one corner appears to be larger with respect to the room, to the observer. The same person will appear smaller when standing on the opposite corner, thus creating the illusion. The room is viewed through a pinhole, thus removing any sense of depth when viewing through both eyes. This is often termed as "Loss of Normal Perspective".

## 3 Solution 3

### 3.1 Part 1

Gamma Correction gives the relationship between a pixel's numerical value and its luminance. It controls the overall brightness of an image. It also allows to reproduce colors in an image as captured by a digital camera. This ensures that objects captured by a camera appear the same as seen by out eye.

### 3.2 Part 2

*De-mosaicing Bayer filter* uses a pattern of alternating rows of red and green filters with a row of blue and green filters. The pixels are uneven in number, with more of green pixels, since the human eye has different levels of sensitivity to the three colors. The *Simple Interpolation* algorithm copies an adjacent pixel of the same color channel. We also use *bilinear interpolation* method by computing the red value of a non-red pixel by averaging 2 or 4 adjacent red pixels. The same technique is used for the other colors as well.

### 3.3 Part 3

In a Linear color space, the numerical intensity values vary linearly to their perceived intensity. It means that doubling the numerical value, doubles the intensity. Also, we can add and multiple colors to achieve expected results. RGB is not linear color space.

**Results after removing the BGR2LAB conversion:**