COMPUTER LAB 3: INFERENCE

Ethelbert Uzodinma (S3886026)
Viljami Linna (S4169921)

Department of Artificial Intelligence
University of Groningen

ABSTRACT

2D & 3D Inference refers to a set of procedures carried out on an image to determine the orientation *i.e* the direction viewing an image from a perspective of two or more parallel 3D lines intersecting with the endpoints of this lines.

Index Terms— 2D/3D Inference, camera calibration, vanishing point, singular value decomposition, 3D scene analysis, perspective projection, computer vision.

1. INTRODUCTION

The Image Data provided for this exercises is compressed in a zipped folder named: **inference.zip**. Using this Image file, our task is to determine the orientation of a set of two or more parallel 3D lines from a perspective image of these lines.

2. METHOD

For the practical we first download the file "inference.zip" into the work directory of MatLab.
Then enter the following command in the command window:

```
unzip inference.zip

cd inference
```

The image contained in the `inference` folder for this experiment includes:

`rectangle.tif`, `par_line.m`, `scanpoints.m`, `savescanpoints.m`.

The `tif` image contains a number of concentric rectangles with parallel sides(refer to Figure 1).As a result of the convergence of the parallel lines of the horizontal and vertical vertices of the rectangle a vanishing point is formed.

The size of the image was `480 x 640` pixels. As shown below in Figure 1
First we use:
`imread('rectangle.tiff')` to read the image.
Next, we obtain the

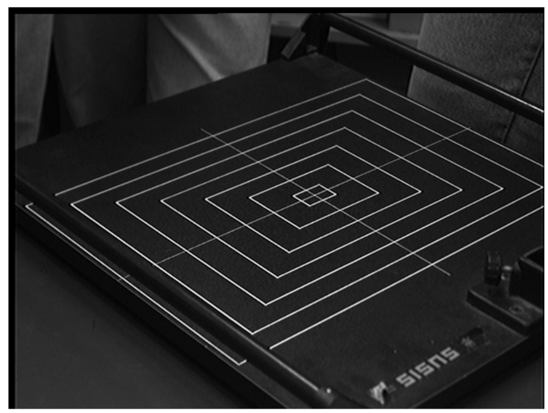

Fig. 1: A image showing rectangular image with two sets of parallel lines

2.1. Exercise 1

In this exercise we show how the camera constant f cam be obtained from the perspective projection of a rectangle, and from this, the direction vectors of the sides of the rectangles and normal of the planar patch containing the rectangles.

In camera-centered coodrdinate system(ccc), a point (x, y, z) in 3D space can be projected to the projection plane (u, v) such that:

$$u = fx/z, \quad v = fy/z, \quad z > f \tag{1}$$

where f is camera distance from image plane(see Figure 2).

Let $p_1 = (u_1, v_1), p_2 = (u_2, v_2), p_3 = (u_3, v_3), p_4 = (u_4, v_4)$ be a rectangle corner points in the projection plane in clockwise order.

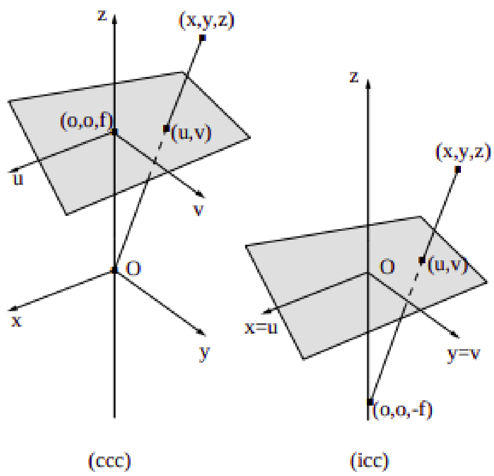

Fig. 2: Camera-centered(ccc) vs image-centered(icc) coordinate system.

Define rectangle side vectors s_1, s_2, s_1, s_1 such that:

$$\begin{aligned} s_1 &= (u_2 - u_1, v_2 - v_1) \\ s_2 &= (u_3 - u_4, v_3 - v_4) \\ s_3 &= (u_2 - u_3, v_2 - v_3) \\ s_4 &= (u_4 - u_1, v_4 - v_1). \end{aligned} \tag{2}$$

Set unit vectors $s_{13D}, s_{23D}, s_{33D}, s_{43D}$ respectively being parallel to the rectangle side vectors in 3D space.

We know that unit vectors in rectangle opposite sides are parallel. Hence:

$$s_{13D} || s_{23D}, \quad s_{33D} || s_{43D} \tag{3}$$

For the two parallel lines in 3D space, the vanishing point $p_\infty = (u_\infty, v_\infty)$ can be found in the intersection point of the projection lines.

Define equation of the projection line l_n through point p_n parallel to s_n:

$$l_n = p_n + \mu_n s_n, \quad s_n \in R \tag{4}$$

where μ_n is scaling factor.

The intersection point i_{n1n2} of the lines l_{n1}, l_{n2} can be found by solving the following equation:

$$p_{n1} + \mu_{n1} s_{n1} = p_{n2} + \mu_{n2} s_{n2}. \tag{5}$$

Equation can be solved by separating u and v, which leads to equation pair with two unknown variables μ_{n1} and μ_{n2}.

Now, two vanishing points $p_{\infty 1}(u_{\infty 1}, v_{\infty 1})$ and $p_{\infty 2}(u_{\infty 2}, v_{\infty 2})$ can be found in the intersection points of the lines l_1, l_2, l_3, l_4 which touch on sides of the square projection on the image plane.

Vanishing points of all 3D lines which lie in parallel planes all lie on a line L_∞ in the image plane called the vanishing line. Since vectors s_1, s_2, s_3 and s_4 all lie in the parallel planes, we can write the following equation for the vanishing line:

$$L_\infty = p_1 + \mu_\infty (p_{\infty 2} - p_{\infty 1}), \quad \mu_\infty \in R \tag{6}$$

Parameterized form of the Equation 6:

$$L_\infty(u,v) : \begin{cases} u = u_{\infty 1} + \mu_\infty (u_{\infty 2} - u_{\infty 1}) \\ v = v_{\infty 1} + \mu_\infty (v_{\infty 2} - v_{\infty 1}) \end{cases} , \mu_\infty \in R \tag{7}$$

On the other hand we can determine:

$$L_\infty = \left\{ \begin{bmatrix} u \\ v \end{bmatrix} : Au + Bv + Cf = 0 \right\} \tag{8}$$

By giving different values to μ_∞, we use Equation 7 to obtain at least four (u, v) value pairs. We substitute these value pairs to Equation 8 and hence get a group of four equations. Now, we solve this equation group and determine the camera constant f.

Now define direction vector d of the 3D line which projection on image plane is l such that:

$$d = \begin{bmatrix} \omega_i \\ \omega_j \\ \omega_z \end{bmatrix}, \quad |d| = 1 \tag{9}$$

After f determined, we can obtain the direction vector of two parallel 3D lines using the following formula:

$$\begin{bmatrix} \omega_i \\ \omega_j \\ \omega_z \end{bmatrix} = \frac{1}{\sqrt{u_\infty^2 + v_\infty^2 + f^2}} \cdot \begin{bmatrix} u_\infty \\ v_\infty \\ f \end{bmatrix} \tag{10}$$

2.2. Exercise 2

Here we use the the convergence of 3 parallel lines in the image both in the vertical and horizontal sides of the rectangle to determine the vanishing points.
First we read the image using

```
I = imread('rectangle.tif');
```

the variable `I` is then parsed as input to the

```
[x,y] = scanpoints(I);
```

After selecting at least 3 vertical parallel lines (see Figure 3), then repeat with:

```
[x2,y2] = scanpoints(I);
```

after selecting at least 3 horizontal parallel lines(see Figure 4).

Then both variables x and y with the values are parsed and saved in `par_lines1.dat`
Similarly, the variables x2 and y2 with the values are parsed and saved in `par_lines2.dat`

using the routine,

`savescanpoints('par_lines.dat, x, y')`
The vector values of the vertical lines saved in `par_lines.dat`
is show below:

x
78.120818 243.068773 292.247212 89.611524 131.652416 246.042751 308.901487 124.109665 185.184015 248.421933 321.392193 156
cell8

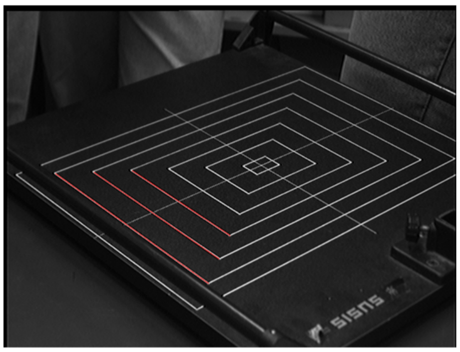

Fig. 3: The parallel vertical sides of the rectangle .

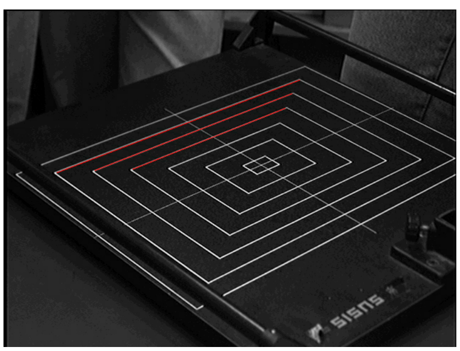

Fig. 4: The parallel horizontal sides of the rectangle .

2.3. Exercise 3

2.4. Exercise 4

3. CONCLUSION

4. REFERENCES