Homework 2: Estimating height from a single image

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***Abstract*—In this homework, we estimate the height of the door at A.V.Williams building from a single perspective image. First, points are manually chosen from the image to find the vanishing points and the vanishing line. Then we use cross ratio to calculate the height of the door.**

I. Compute the vanishing point

First, two pairs of parallel lines are chosen from the image for computing the vanishing points. As a line is determined by two points. Points from the four corners of the facade and the four coners of the door are manually selected for two pairs of parallel lines. Coordinates of the points can be easily obtained and recorded by using the cursor in the figure. The points selected are shown in the Table.II

No.	Points from the image	(x,y)	line (l)
1	upper left corner of the facade	$(53, 211)$	l_1
2	upper left corner of the door	$(100, 254)$	l_1
3	upper right corner of the facade	$(712, 181)$	l_2
4	upper right corner of the door	$(673, 229)$	l_2
5	lower left corner of the facade	$(58, 714)$	l_3
6	lower left corner of the door	$(127, 682)$	l_3
7	lower right corner of the facade	$(717, 713)$	l_4
8	lower right corner of the door	$(657, 685)$	l_4

TABLE I: Points selection for computing the vanishing point

A. The vanishing point and the horizon

As a line can be defined by an equation $y = ax + b$, so with any two points(x_1, y_1) and (x_2, y_2), we can obtain the parameters a and b the describes the line by

$$a = \frac{y_2 - y_1}{x_2 - x_1} \tag{1}$$

$$b = y_1 - ax_1 \tag{2}$$

Using Eq.1 and Eq.2, we can obtain the function for the 2 pairs of lines which are parallel in the scene. Since any set of parallel lines on the plane define a vanishing point, we can obtain two vanishing points by computing the intersect of each pair of the lines (l_1, l_2 and l_3, l_4). Say we have $l_1 = a_1x + b1$ and $l_2 = a_2x + b_2$, the x coordinate of the intersect is $x = \frac{b_2 - b_1}{a_1 - a_2}$ by applying the x coordinate in the line equation $y = ax + b$, we can get the corresponding y coordinate. Since we are using a single perspective image, the four parallel lines in the image all converge to a single vanishing point. Therotically, the two vanishing points that we calculated should be at the same position. Considering the error caused by manually selected points, the coordinates of the vanishing point V_1 is taken as the mean value of the coordinates of the two vanishing points that we calculated.

No.	Points from the image	(x,y)	line (l)
1	ground point 1	$(54, 721)$	$l_{ground1}$
2	ground point 2	$(716, 722)$	$l_{ground1}$
3	lower left corner of the door	$(127, 682)$	$l_{ground2}$
4	lower right corner of the door	$(657, 685)$	$l_{ground2}$

TABLE II: Points selection for computing V_2

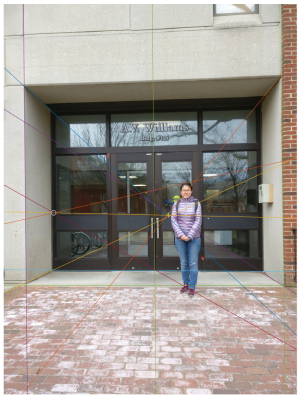

Fig. 1: Vanishing point and vanishing line

In order to find the horizon, we need another vanishing point V_2, which can be obtained by calculating the intersect of two lines on the ground ($l_{ground1}$ and $l_{ground2}$). Again, points that describe the two parallel lines one the ground are manually selected. These two lines converges slower than the previous lines, but still we can find the intersect, i.e. V_2 outside the image. With V_1 and V_2 acquired, the horizon is simply the line passing throught these two vanishing points and we can draw the horizontal vanishing line as shown in Fig. 1 . The vanishing point V_1 is shown as the yellow asterisk (V_2 is out of the image).

B. The vanishing point in the Z axis

The vanishing point in the Z axis is computed by using parallel lines in the facade. The points used for getting the parameters of the parallel lines l_5 and l_6 are point 1 and point 3, point 5 and point 7. With the lines equation obtained, we can then calculated the intersect use a similar method in part A and it turns out that the vanishing point in the Z axis, $V_z$is at infinity since the facade is almost parallel to the camera.

Fig. 2: Height from image

II. Compute the height

A. Height of the door

As the horizon is acquired, now by intersecting the horizon with the line that connects the foot point and the door's bottom, we can get a vanishing point V (shown as the white circle in the left of the image). Now we apply cross ratio to compute the height of the door. In order to do that, we need to get the intersect of the line that passes through point V and the head point of the people and the z axis of the door (green line). Now, set the vanishing point V and the bottom point of the door as reference points, the hight of the door in pixels is denoted as h_D and the height from the intersect to the bottom point of the door is denoted as h'. The corresponding distance from the intersect and the top point of the door to V_z is denoted as h'_∞ and h_∞. Then, by applying cross ration, we have

$$\frac{h_D}{h'}\frac{h'_\infty}{h_\infty} = \frac{H_D}{H}\frac{H'_\infty}{H_\infty} \tag{3}$$

where H_D is the height of door that we want to estimate, H is the height of the reference person(me), H'_∞ is the distance from the head point to infinity in the Z axis and H_∞ is the distance from the top of the door to infinity. Since the fraction of the infinity can be taken as one, we can obtain the height of the door, H_D in reality as

$$H_D = H\frac{h_D}{h'} \tag{4}$$

B. Height of the camera

Noticing that the height of the camera should be the height of the vanishing point. Then in the image plane, the fraction of the height of the vanishing point in pixels and the height of the door in pixels should be proportional to the fraction of their real height, i.e. the following equation is satisfied

$$\frac{height_{V1}}{h_D} = \frac{height_{camera}}{H_D} \tag{5}$$

so that we can obatin the height of the camera from the estimated height of the door.

III. Result and analysis

The estimated height of the door is 2501mm and the estimated height of the camer is 1151mm by using the method declared in the previous section. Though the ground truth is not known, according to common sense that the height of the door should be in the range of 2000mm to 3000mm, thus the accuracy of our estimation should be above 0.8. By analysing the steps taken in the estimation, the error is mainly caused by the manual selection of the points that are used for solving the vanishing points and the vanishing line.

1) The first two vanishing points obtained from the four parallel lines passing through the four corners should be a single point and here we take the mean of the two.
2) V_2 might not be accurate enough.

References

[1] *Single View Metrology*.Retrieved March 15, 2017, from http://cis.upenn.edu/čis580/Spring2017/Lectures/cis580-08-singleViewMetrology2.pdf