ME491(B)
Homework 2 - Single View Metrology

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Contents

1 Introduction

It is possible to compute 3D affine measurements from a single perspective image. This technique is called Single View Metrology [2]. In this homework, the technique of single view metrology will be used to compute the height of a man. The procedure will be described first, before presenting the results.

2 Procedure

To be able to apply single view metrology on an image, the image must have been otained by perspective projection and contain three orthogonal sets of parallel lines. The handed out image meets these requirements and is shown in fig. 1.

Figure 1: Image handed out for homework. The goal is to compute the height of the man.

In order to compare the height of different objects, the ground plane will be used as the reference plane.The first step is therefore to compute the horizon in the image. That is, the vanishing line of the ground plane. This vanishing line is the intersection of a horizontal plane through the camera with the image plane. A useful property the of horizon is that objects above the camera will be projected over this vanishing line, while objects below the camera will be projected under the line. This property can be exploited.

To compute the horizon, two vanishing points are required. The two points can be computed using two orthogonal sets of parallel lines that are parallel to the reference plane. The sets of parallel lines are shown in fig. 2. By defining

Figure 2: Three orthogonal sets of parallel lines, yellow, blue and red, used to compute three vanishing points.

two arbitrary points, $\mathbf{p}_i$ and $\mathbf{q}_i$, on each line $\mathbf{l}_i$, the following formula from projective geometry can be used to calculate the coefficients for each line

$$\mathbf{l}_i = \mathbf{p}_i \times \mathbf{q}_i, \quad i = 1, 2, .., 6 \tag{1}$$

Note that each point is given as a homogeneous coordinate. Then, each vanishing point is located where the lines in each set intersect. Exploiting the point and line duality from projective geometry, the intersection between two lines, $\mathbf{l}_a$ and $\mathbf{l}_b$, is given by

$$\mathbf{v} = \mathbf{l}_a \times \mathbf{l}_b \tag{2}$$

A formula for computing a vanishing point is therefore obtained by combining eq. (1) and eq. (2). As an example, the left vanishing point, $\mathbf{v}_x$, is given by

$$\mathbf{v}_x = (\mathbf{p_2} \times \mathbf{q_2}) \times (\mathbf{p_4} \times \mathbf{q_4}) \tag{3}$$

Ultimately, the horizon is a line between the left vanishing point, $\mathbf{v}_x$, and the right vanishing point $\mathbf{v}_y$. The horizon is represented as a white line in fig. 3.

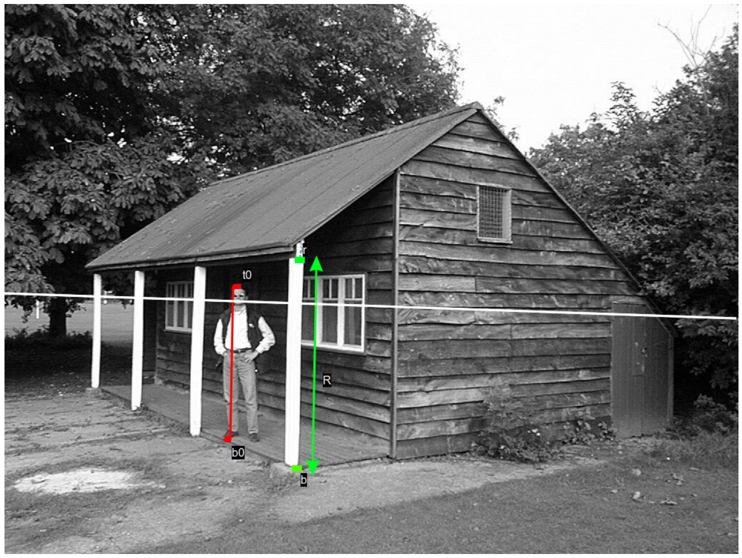

Figure 3: Image containing different reference points. The white line represents the horizon. The reference height R is 201 cm.

Another concept needed in order to compute the height of the man is cross-ratio. The concept is used to determine a ratio of distances between planes in the world. The ratio of distances between the ground plane and the top of the reference object and the ground plane and the man's head can thus be found. If the height of the reference object is given, the man's height can be explicitly calculated.

In fig. 4, the definition of cross-ratio is used in the scene, where four collinear points are chosen along a reference direction. In this case, the reference direction is in the Z-direction pointing upwards from the ground plane. Further, the three points **B**, **R** and **T** all have a corresponding projection on the image plane. The point at infinity in the scene will, according to projective geometry, project onto a vanishing point along the reference direction. This vanishing point can be obtained from the set of parallel lines pointing downwards and colored red in fig. 2.

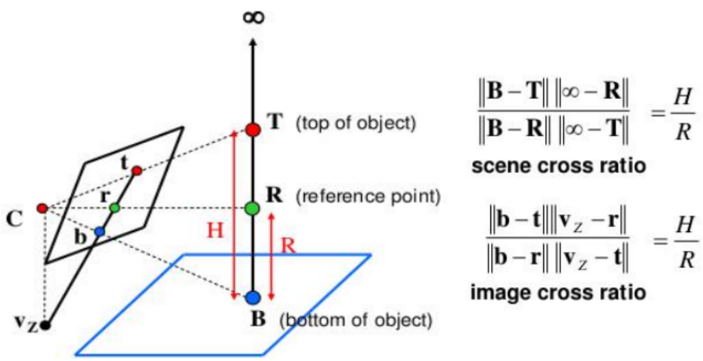

Figure 4: Illustration of cross-ratio determining a ratio of distances between planes in the world.

As marked in fig. 3, the points **b** and **r** can be directly found by inspecting the image. The process of computing **t** is shown in fig. 5. By fixing the point $\mathbf{b_0}$ at the man's feet, a line can be constructed between this point and **b**. This line will be parallel to the ground plane, and therefore intersect the horizon. The point $\mathbf{t_0}$ can now be defined. It is desired to compute the height of the man, so the point is chosen at the top of the man's head. A line between the intersection at the horizon and the chosen point $\mathbf{t_0}$ can then be computed. The intersection between this line and the reference object corresponds to the point **t**. By knowing all the necessary point, the image cross ratio formula in fig. 5 can now be used to calculate the ratio of distance.

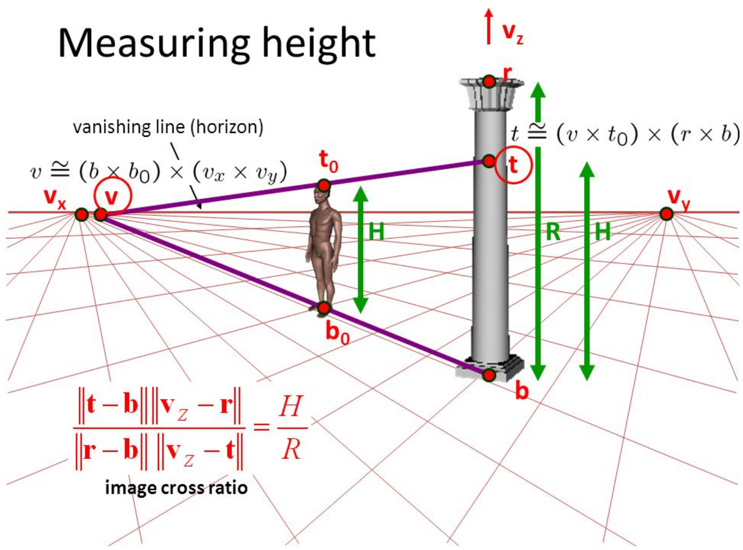

Figure 5: Illustration on how to calculate **t**.

After the ratio of distance between the reference object and the height of the man has been calculated, the height of the man is obtained by multiplying the ratio with the height of the reference object.

3 Result

The height of the man was computed to be 177,62 cm. The real height of the man is 180 cm [2]. However, the man is leaning on his right leg making him slightly shorter. Regardless, the computed result is not optimal.

One reason leading to an erroneous result is uncertainty in definition of points in the image. All the points and lines in the image has been manually defined and their coordinates manually read. Further, the computations of the vanishing points are also sub-optimal. Instead of basing the computations on only two lines, it is better to use several lines and then apply a least-square method to find the optimal intersection between the lines [1].

References

[1] Bob Collins, ed. *Re: vanishing points*. URL: `http://www.cs.cmu.edu/~ph/869/www/notes/vanishing.txt` (visited on 04/06/2020).

[2] A. Criminisi, I. Reid, and A. Zisserman. *Single View Metrology*.