AFFINE 3D MEASUREMENT FROM VANISHING LINE AND POINT

Student ID: A0283551A

February 2024

Introduction

In this assignment the goal was to estimate the height of a car park given a single image, and a reference height of another object(a car) in the image. The procedure follows that of chapter 8.7 in Hartley and Zisserman 2003, and is outlined bellow

1. Detect lines in image (Use Canny to find edges, and Hough Transform to filter out lines).
2. Find two intersection points of the non-vertical lines(We use RANSAC to find unique points)
3. Construct a line through these - the line at infinity for the ground plane.
4. Find an intersection point for the vertical lines.
5. Use the four co-linear points given by the two target points, the intersection point of the vertical lines and the transferred point of the top of the reference to the target, to establish the ratio between the reference and target height.

Some of these points are briefly described bellow

Line Detection

The first sub-problem is to find lines in the image that hopefully lie on (or are parallel to) the groud plane and the vertical plane respectively. We use the Canny operator and the Hough transform for this.

Intersection points

Intersection points of lines can as known be found by using the cross product. The issue is that we have many more intersection points than we need(2). RANSAC is employed to solve this. Firstly pairwise intersections of all the lines are computed. Given N lines there are

$$\sum_{i=1}^{N}\sum_{j=i+1}^{N} 1 = \frac{N(N-1)}{2}$$

unique pairs of lines, ignoring the reflexive pairs (l_i, l_i), and thus at most this many intersection points. Secondly, we compute a binary support matrix encoding whether or not line i is close enough to a point j to be considered intersecting it. The distance from a point $\mathbf{X}$ to a line $\mathbf{l}$ (in homogeneous representation) is given by

$$\frac{|\mathbf{X}^\top \mathbf{l}|}{\sqrt{\mathbf{l}^\top \Omega_\infty^* \mathbf{l}}}$$

Where $\Omega_\infty^* = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$ is the dual conic to the circular points at infinity. This matrix is subsequently used to chose two(one in the case for the vertical intersection point) distinct sets of lines(non-overlapping) that support two different points.

Geometrical Considerations and obtaining the target height

Since parallel world lines all intersect the (imaged) line at infinity at the same point, we can find the point on the target object in the image, with equal height as the reference object in the world scene. This is done by finding the intersection point from the intersection of the straight line between the bottoms (or tops) of the reference and target objects, and the line at infinity previously obtained. Drawing a line from the top of the reference object to this object creates an intersection with the target object. Now we have four co linear points of the bottom and top of the target object, the above mentioned intersection and the vertical vanishing points denoted by $b, t, \tilde{t}, v$ respectively.

If we now let the height of the target and reference be denoted by h, q respectively, we have the following relationship:

$$\frac{h}{q} = \frac{\|b - t\|(\|b - v\| - \|b - \tilde{t}\|)}{\|b - t\|(\|b - v\| - \|b - t\|)}$$

Where the distance is taken in image coordinates.