Vanishing points detection using Thales's theorem

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Abstract

A method for the obtaining of the vanishing point in images that they present perspective projection is shown. The method of Thales's circle (TCM) is utilized, which is based on Thales's theorem; This technical supposes some advantages in relation to another one largely utilized, like the based in spherical geometry [1], [5], [6], since a priori information on the focal length of the camera is not needed. The method assumes than the straight lines that come to a point toward the vanishing point, right now have been extracted adequately from the image. Several test cases with images of the inside of a building that present certain regularity in his structure are presented in order to try the efficacy of the method.

1. Introduction

The vanishing points detection in images has taken importance in various tasks of artificial vision such as: camera calibration, images rectification and the navigation of autonomous vehicles, etc. Several approaches exist to detect vanishing points, one of the most used is the proposed by [1], which raises the use of a Gaussian sphere, others more they use a bayesian model [4]. In our case the method of the Thales's circle (TCM) due to his simplicity and robustness in comparison with the mentioned techniques was used. The present work is divided in three parts, first the Canny's algorithm [7] is applied to the image to extract the edges that compose it; the second step consists in straight lines detection with certain tilt angle by means of Hough transform [7]. Finally TCM method is applied to calculate the vanishing point, on the basis of the straight lines extracted in the previous processes.

2. Perspective projection

The perspective projection is used to represent 3D objects in a 2D projection plane, in such a way that the parallel lines of the object that not be parallel to the projection plane, project in convergent lines. The point where the projected lines come to a point, names him vanishing point (see figure 1). On the basis of this we can classify the perspective projections with one, two and three vanishing points.

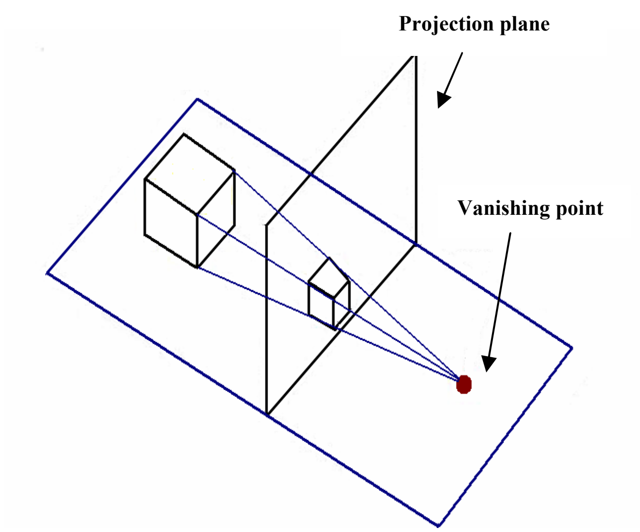


Figure 1. Perspective projection

3. Straight lines detection

Once the edges are extracted by means of the Canny's algorithm, the Hough transform is used to find the straight lines that are present at the image. The Hough transform involves finding the pixels of coordinates (x_i, y_i) that can belong to a straight line using the equation 1:

$$\rho = x\ cos\theta + y\ sen\theta \qquad (1)$$

Where ρ represents the magnitude of the tangent to the straight line as from the origin, and θ the angle of this tangent. A space of parameters composed by ρ and θ (see figure 2) is used, where each cell is voted if some pixel belongs to the equation of the straight line formed by ρ and θ. Finally we look for the most voted cells.

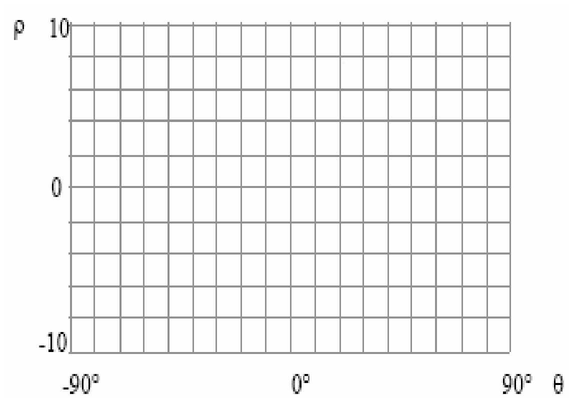


Figura 2. Space of parameters

In this stage we omitted horizontal and verticals lines that may present itself in the image since they lack of interest to locate the vanishing point. Likewise we were established that a straight line with a significant size will have to be formed to the less for 100 pixels of the image (votes) to be considerate.

4. Vanishing point determination

TCM [3] approach consists in a geometric method to determine of robust way vanishing points. Given a set of segments *S*, each segment determines a straight line *g*. One point $L= (x_L, y_L)$ looks for which represents the closer distance between the straight line and one arbitrary point $A= (x_A, x_A)$.

All points *L* form a circle (Thales's circle); by Thales's theorem the angle formed between the points *A*, *L* and *Q* form a right angle. If we calculated the center $M=(x_M,y_M)$, is possible to determine the coordinates of the vanishing point $Q=(x_Q,y_Q)$, (see figure 3).

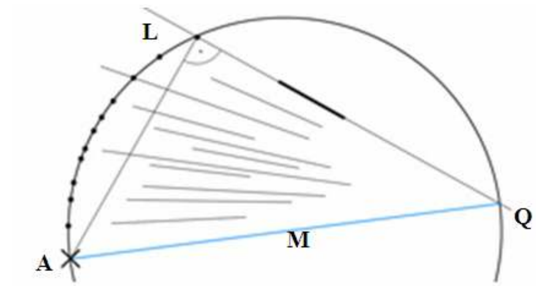


Figure 3. Thales's circle, vanishing point Q, arbitrary point A and points L of the circumference

4.1 Calculation of the center (M) of the circumference

In order to find each point *L,* it is obtained the equation of the straight line $(y=mx + b)$ formed by each segment *S*, as well as the equation of the tangent to this same straight line that passes through point *A*. Once obtained these two equations the system is solved by means of the equalization method, and the values of *x* and *y* that represent the coordinates where the two straight lines are intercepted are calculated.

Given three points P_1, P_2, and P_3 of a circumference is possible to find the center of same [2], (see figure 4).

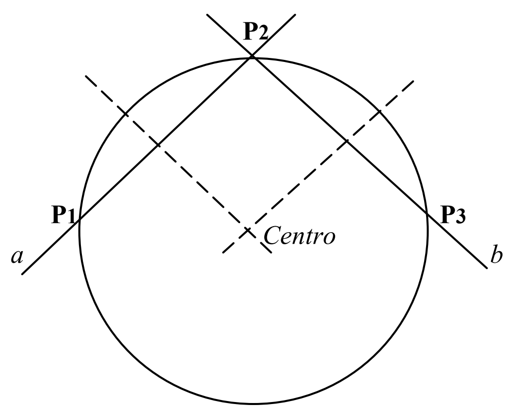


Figure 4. Circumference center determination

The equations of the perpendicular bisectors of the straight lines P_1P_2, and P_2P_3 are given by:

$$y'_a = -\frac{1}{m_a}\left(x - \frac{x_1 + x_2}{2}\right) + \frac{y_1 + y_2}{2} \qquad (2)$$
$$y'_b = -\frac{1}{m_b}\left(x - \frac{x_2 + x_3}{2}\right) + \frac{y_2 + y_3}{2}.$$

Where m_a and m_b represent the slope of the two straight lines respectively. The coordinated x of the point of intersection (center of the circumference) of the perpendicular bisectors is calculates with the equation:

$$x = \frac{m_a m_b (y_1 - y_3) + m_b(x_1 + x_2) - m_a(x_2 + x_3)}{2(m_b - m_a)}. \qquad (3)$$

The value of the coordinate y is obtained substituting x in anyone of the equations of the perpendicular bisectors.

4.2 Calculation of the vanishing point (Q)

The vanishing point is calculated utilizing the coordinates of the center.

$$x_Q = 2x_M - x_A,$$
$$y_Q = 2y_M - y_A.$$

5. Experiments

The test cases come from scenes in surroundings of interiors. It is important to obtain images with good illumination, to guarantee the effectiveness of the detection of edges and lines. Images in gray scale are used.

Figure 5. Original images

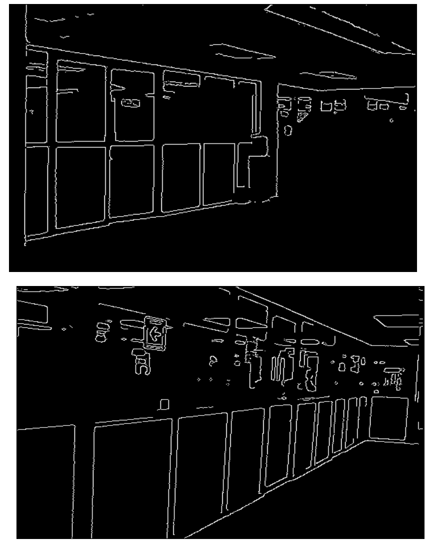
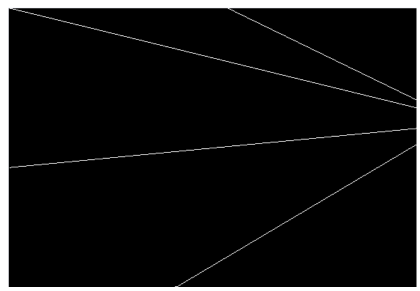
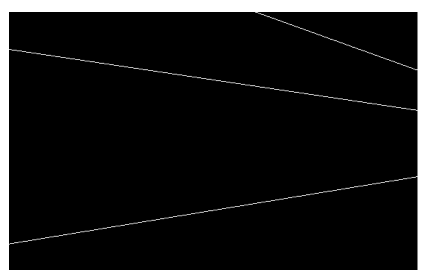


Figure 6. Images segmented with Canny



VP = (699.22, 183.36)



VP = (547.61, 233.21)

Figure 7. Application of Hough transform and detection of the vanishing point

6. Conclusions

In the present work algorithms for the edges extraction, straight line detection, as well as a geometric method to find the vanishing point in images with perspective projection was implemented. The utilized approach (TCM) is simple and robust, in comparison with other works, likewise it has the advantage of not requiring a priori information on the images acquisition. However, it is important emphasize that the success of this algorithm, depends to a large extent on the previous processes (images acquisition, edges segmentation and location of straight lines), therefore is important to count on images taken in suitable conditions, as well as to count on effective algorithms of segmentation.

6. References

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