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Application of gradient-based edge detectors to determine vanishing points in monoscopic images: Comparative study☆,☆☆

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ABSTRACT

The detection of vanishing points in a monoscopic image is a first step to the extraction of 3D data. This article shows a partition of the image space in order to determine the type of perspective which is present, thereby allowing the determination of the vanishing point associated with each of the axes of the special reference system (X, Y, Z). Additionally, the Thales' second theorem allows us to determine the position of the vanishing points of the image and to automatize the process. An algorithm has been used with the data provided by the selected edge detector (Prewitt, Roberts, Sobel, Frei-Chen, Kirsch, Robinson 3 levels, Robinson 5 levels and Frei-Chen directional), which provides the location of the vanishing points contained on the image plane. The comparative study includes two variables: the number of vanishing points and the image resolution. The results show that in general the Prewitt's edge detector provides the best results, both positional and statistical. Increasing the image resolution improves the results, although the results obtained for a resolution of 640 × 480 pixels and another of 1024 × 768 pixels are very similar.

1. Introduction

A monoscopic image is a two-dimensional representation of a three-dimensional scene, obtained as the projection of this scene from one point of vision, giving a perspective. However, in order to use three-dimensional modeling techniques, it is necessary to obtain three-dimensional information from these images by applying photogrammetric or dimensional perspective analysis.

When the projection of a three-dimensional scene is made on a plane, the parallel lines converge in a single point called vanishing point. The knowledge of this point is key to carrying out qualitative and/or quantitative analysis of the monoscopic image. From a qualitative point of view, vanishing points can be used to group common lines in contiguous images in order to combine them, and from a quantitative point of view, vanishing points can be used for three objectives: to obtain dimensions using perspective dimensional analysis, for three-dimensional reconstruction or for the auto-calibration of the camera.

Therefore, it is necessary to define a reliable methodology for the detection of vanishing points, which is the objective of this research.

1.1. Background

Models, which use a single image, need the position of the vanishing points. However, it is not always easy to determine their position accurately, quickly and reliably using computational techniques. Some of the methods developed in the last decades and their most important characteristics are shown below.

Barnard [1] proposed a method to obtain vanishing points and vanishing lines using the orientation of parallel lines and planes, such that these orientations represent a Gaussian sphere with a radius of value 1, centered on the optical center of the camera. This method has the advantage of being a finite or closed space, whereas the gradient space is infinite or open; this may present problems when using a computer since it has a finite memory space. In addition, the sphere has the same symmetry as the central projection, that is, it is symmetrical with respect to the camera's perspective (the focal point of the lens), and therefore it is necessary to know the focal length of the camera.

Magee and Aggarwal [2] propose a computationally low-cost algorithm to determine vanishing points from the extraction of the line segments of an image. The algorithm is applied to the image in order to obtain the line segments, using the following sequence: determination of the image gradient using Kirsch's operator, suppression of the non-maximum values of the results obtained, and search for the lines, applying Hough transform to these results. The vanishing points are obtained using the Gaussian sphere with a radius of value 1. The advantage of this method is that it is not necessary to know the camera's focal length, and also that it does not use any accumulator space on the

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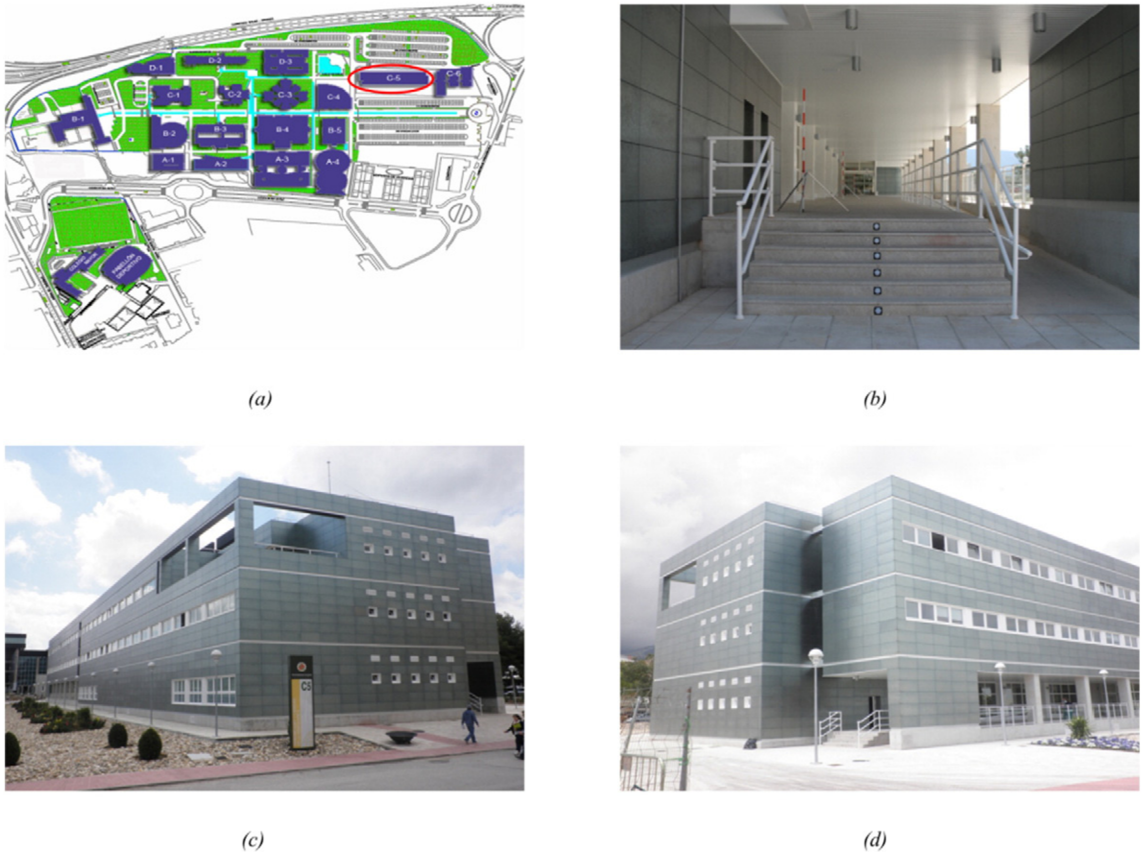

Fig. 1. (a) Map of Las Lagunillas Campus of the University of Jaen and location of Building C5 (www.ujaen.es). (b) Image of the south facade: perspective with one vanishing point. (c) Image of the north and east facades: perspective with two vanishing points. (d) Image of the south and east facades: perspective with two vanishing points.

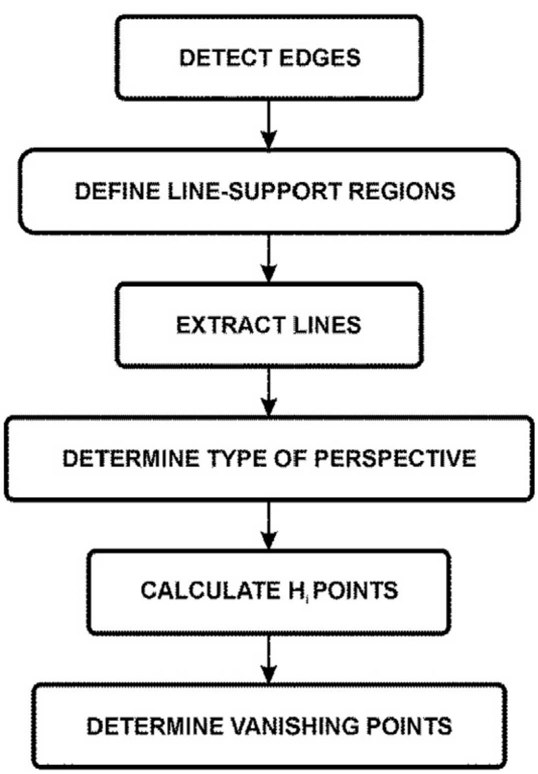

Fig. 2. Flow diagram of the algorithm.

Gaussian sphere; rather, the measurements are taken directly on the sphere.

Collins and Weiss [3] propose the calculation of the vanishing points as a statistical estimation problem on the sphere with a radius of 1. A unitary vector can be represented as a point on the sphere and those which share the same plane tend to be grouped on a large circle. Given that vanishing points can be characterized as an estimation of the true polar axis of the large circle taken from a point sample with size *n*, the determination of the vanishing point is obtained by studying its statistical distribution.

Brillault-O'Mahony [4] presents a new formulation of the accumulator space for the determination of vanishing points which allows their detection whatever their location on the image plane. He defines a transformation between the image plane and the accumulator space which maintains the expected uncertainty as a constant value; this accumulator space is isotropic and finite.

Palmer and Tai [5] use Hough's transformation in order to extract the segments of the line, as this is a robust method to detect segments of straight lines. The algorithm developed preserves accuracy while maintaining a low level of processing. The location of the vanishing point is carried out using an accumulator space on the Gaussian sphere and incorporates a statistical test in order to take into account the effects of noise and errors in parameters. The result is an algorithm which locates vanishing points accurately and efficiently.

Straforini et al. [6] propose a method for extracting lines which has lineal computational complexity and a high degree of accuracy. The lineal complexity is due to the introduction of a polar space which allows the selection of segments which converge on the same point before the calculation of the vanishing point. These characteristics allow this