METHOD OF STRAIGHT LINE DETECTOR ON THE CONTOUR IMAGE

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https://doi.org/10.5281/zenodo.7859327

Abstract. *In this paper described method of straight line detector on the contour image. Presented the result of summing over all straight lines is a two-dimensional function depending on angle and distance. The resulting function does not carry information about the location of the segments on the line, it only says that it exists, therefore, in addition to the described operations, it will be necessary to implement the segment localization algorithm on the line.*

Keywords: *method of straight, line detector, contour image.*

The first stage involves the selection of contours. At the second stage, the brightness of the points is summed along a straight line, which is specified by the angle and length.

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The advantages of the conversion include the high reliability of detection of straight lines. Contour line breaks along a straight line have little effect on the algorithm.

The disadvantages include the need to carry out the operation of finding contours, searching for areas of intersection of the trajectories of individual points in a multidimensional space of parameters, and the need for additional algorithms to localize segments on the found straight lines.

Angle detectors one of the first algorithms was suggested by Bedet [1-5]. It determines the positions of the corners by the maxima of the Hessian determinant from the image brightness function:

$$\mathrm{H} = I_{xx}I_{yy} + I_{xy}^2 \tag{1}$$

This method works well with angles of 90. And since the method uses the second derivatives of the brightness function, the result is heavily influenced by noise. In turn, Forstner [11] proposed an angle detector using only the first derivatives of the brightness function and defined the angles as local maxima:

$$F(x,y) = \frac{\bar{I}_x^2 \cdot \bar{I}_y^2 - \left(\overline{I_x \cdot I_y}\right)^2}{\bar{I}_x^2 + \bar{I}_y^2}, \tag{2}$$

where the dashes above the variables denote the average value in some area of the point (x,y).

The disadvantage of angle detectors using luminance gradient components is that the determination of the gradient components themselves is based on differential masks, models of horizontal and vertical contrast differences. They don't work well at corners, because the mask assumes that the contrast gradient can be extended in a straight line to infinity.

Circle Detectors An obvious way to find circles in an image is to trace the curvature of contour lines. Ali Aidari Rad et al. proposed an algorithm for quickly finding circles in an image [10] using the opposite directionality of a pair of gradient vectors lying at opposite ends of a circle, as well as the fact that their bases lie on a straight line parallel to them [6-8]. The method is faster than the Hook method for finding circles and is more resistant to salt and pepper noise (noise in the form of random white and black dots).

Pattern search methods allow you to detect some geometric primitives in the image. The detection process is fast in speed, but the primitive matching algorithm can be very computationally complex, because it is necessary to take into account the relative position of the primitives in the image with the object in the image being searched.

Thus, deterministic methods perceive an object with practically unchanged properties in a video sequence, methods are based on the detection of graphic primitives: a point, a line, a circle ... The methods are computationally complex, they are very popular nowadays due to their detection quality.

Optical flow search methods

Optical flow search methods are based on the calculation of the direction of the characteristic areas of the image. In these methods, the detection process is divided into two stages: the calculation of the vector velocity field and the determination of the object's displacement.

Lucas–Kanade method The Lucas–Kanade method is a local method for calculating the optical flow, which has linear computational complexity . The main equation of the optical flow contains two unknowns and cannot be uniquely resolved. The Lucas–Kanade method circumvents the ambiguity by using information about neighboring pixels at each point.

The method is based on the assumption that the value of the optical flow is the same in the local neighbourhood of each pixel. Consider a pixel p, then, according to the Lucas–Kanade method, the optical flow should be the same for all pixels located in the window centered at the point p. Namely, the optical flow vector (V_x, V_y) at a point $p$is determined by the formula:

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} \sum_i \omega_i I_x(q_i)^2 & \sum_i \omega_i I_x(q_i) I_y(q_i) \\ \sum_i \omega_i I_x(q_i) I_y(q_i) & \sum_i \omega_i I_y(q_i)^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum_i \omega_i I_x(q_i) I_t(q_i) \\ -\sum_i \omega_i I_y(q_i) I_t(q_i) \end{bmatrix}., \tag{3}$$

where $q_1, q_2, \ldots, q_n$are the pixels inside the window, $I_x(q_i)$, $I_y(q_i)$, $I_t(q_i)$are the partial derivatives of the image $I$with respect to coordinates $x, y$and time $t$calculated at the point q_i, $\omega_i$is the weight assigned to the pixel q_i.As weights , the normal distribution of the distance between $\omega_i$and $p$is usually used q_i[10].

The Lucas–Kanade method is purely local and cannot determine the direction of pixel movement within homogeneous regions. Some images may give a degenerate matrix A, for which the inverse matrix cannot be found, so it is impossible to determine the bias for such images. To date, the Lucas–Kanade method has many modifications. In the Tomasi -Kanade method, displacement is considered to be movement and is calculated by iteratively solving the constructed system of linear equations. The Shi- Tomasi -Kanade method takes into account affine distortions. The Jean- Favaro - Soatto method takes into account affine changes in illumination.

Methods for finding singular points

The algorithm of the methods for finding singular points can be divided into two stages: detection of singular points, comparison of singular points. Feature descriptors are used to match detected features. The singularity descriptor is a vector of numerical characteristics of the neighborhood of the singularity $D(x) = [f_1(w(x))\ldots f_n(w(x))]$, where $w(x)$is some neighborhood of the point x, and $f(w_1, w_2)$is a measure used to compare the neighborhoods of the singular points. In feature matching, it is the feature descriptors that are compared to make decisions about whether features match or not.

Harris-Laplace method The Harris-Laplace method finds singular points in an image. The classical Harris-Laplace method is not resistant to scaling of objects in the image; the method does not find singular points when the scale is greatly changed. Let us describe the Harris–Laplace method, which takes into account the scaling of objects in the image. 1. First, it is necessary to calculate the values of the scale-adapted Harris function for the scales $\sigma_n = \xi^n \cdot \sigma_0$

$$H(x,\sigma_1,\sigma_D) = det(\mu(x,\sigma_1,\sigma_D)) + 0.04 \cdot trace^2\big(\mu(x,\sigma_1,\sigma_D)\big), \qquad (4)$$

where $\mu(x,\sigma_1,\sigma_D) = g(\sigma_1) \cdot \begin{bmatrix} L^2_{x,norm}(x,\sigma_D) & L_{xy,norm}(x,\sigma_D) \\ L_{x,norm}(x,\sigma_D) & L^2_{xy,norm}(x,\sigma_D) \end{bmatrix}$, $\sigma_1 = \sigma_n, \sigma_D = s\sigma_1, s = 0.7$.

2. The number of layers and the value of the scale step ξ should be chosen depending on how large the scale change between two images can be.

3. For each scale level, find the local maxima of the calculated Harris function, these are the singular points for a given image scale. Usually enough points are obtained in this way and some of them can be discarded. For example, you can discard all points for which the value of the Harris function does not exceed some value H_{thr}, because maxima with a small value of the Harris function are less stable.

4. For each singularity found in this way, establish whether the maximum of the function $LoG(x,\sigma_n) = |L_{xx,norm}(x,\sigma_n) + L_{yy,norm}(x,\sigma_n)|$with respect to the variable is reached in it n, i.e. $LoG(x,\sigma_{n-1}) < LoG(x,\sigma_n), LoG(x,\sigma_{n-1}) < LoG(x,\sigma_n)$. If the local maximum is not reached, or the value of the function does not exceed the threshold LoG_{thr}, then the point is discarded.

5. All remaining points are features of the image, each point is associated with the scale σ_n on which it was detected [9].

Invariant handle to rescaling

When using the scale - space feature detector, scale invariance is very easy to achieve. To do this, before calculating the descriptor, it is sufficient to carry out normalization in accordance with the local scale of the feature, for example, if the scale 2 is associated with the feature, then the neighborhood of the feature should be scaled with a factor of 0.5, etc. If the descriptor consists of expressions that use exclusively normalized derivatives, then it is not necessary to scale the neighborhood. It suffices to calculate the values of the derivatives for the value of the scale σ, which is associated with the singularity.

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