Optik 124 (2013) 1692–1695

Contents lists available at SciVerse ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

A positioning method for the feature points of a target board image adopting singular value decomposition

Guan Xu [a,b], Xiaotao Li [b,*], Jian Su [a], Guangdong Tian [a], Libin Zhang [a]

[a] Department of Vehicle Application Engineering, Traffic and Transportation College, Nanling Campus, Jilin University, Renmin Street 5988#, Changchun, Jilin 130025, PR China
[b] Mechanical Science and Engineering College, Nanling Campus, Jilin University, Renmin Street 5988#, Changchun, Jilin 130025, PR China

ARTICLE INFO

Article history:
Received 29 January 2012
Accepted 11 May 2012

Keywords:
Feature points
Singular value decomposition
Vision inspection
Target board image

ABSTRACT

This paper presents a positioning method to extract the feature points employing the singular value decomposition for a target board image as an example. In order to discriminate the feature points from the noises existing in the image, the image matrix is factorized into three matrices. The geometrical implication of the three matrices is interpreted by three transformations which are rotation, scaling, and another rotation. The singular values in the diagonal of the scaling matrix are arranged in descending order, which stands for the significance sequence of the image features. The smaller singular values are corresponding to the noises while the greater ones are considered as primary features. Therefore the new singular values matrix is defined by the modified original scaling matrix in which the smaller singular values are removed by a cutting point. The smoothing image is reconstructed by the two original rotation matrices and the new singular values matrix with the same arrangement. The latter detection procedure of the feature points adopts the Harris corner detection method to evaluate the singular value decomposition filter. The experiments are performed on the target images with the noise densities of 0.005, 0.01 and 0.02 respectively. Comparing with the traditional approach, the feature points on the target which are considered as the primary features are preserved by the filter. Moreover, the noises vanish in the images because they are unimportant details. The experiments prove that the outlined method has the potential to feature points positioning as well as appropriateness for the manufacture engineering and mechanical inspection.

1. Introduction

Feature point or corner point, which is defined by the strong variable point of gray scale in the image or the large curvature point of the boundary curve in the image, remains an active research area with solutions applicable in many domains including human–computer interaction, vision-based measurement, motion capture, parts manufacturing, targets tracking, etc. [1–5]. The chess-board target which consists of squares arranged in two alternating colors is often conducted to demonstrate the positioning information of an object. In the optical research fields, many studies such as camera calibration or correction of lens distortion, assisted by the positioning method for the feature points of a target, are driven to measure the shapes or dimensions of objects by a laser scan system or a camera-based optical system [6–8]. As the crossing points of two neighbor squares which are colored black and white preserve intense grayscale variation, they are described the feature points in this research. Therefore it is important to extract the feature points accurately to understand and analyze of the image [9,10].

Some researchers have been absorbed in the subject of positioning the feature points and put forward a number of algorithms in accordance with respective characteristics of their images. The extraction researches of the feature points are divided in two types: the method employing the object contour information and the method taking advantage of the grayscale variation. The former algorithm is more complicated, and the results depend on the processes of region segmentation and contour extraction, such as Tsai CH algorithm, Rosenfeld A algorithm, Freeman H algorithm and Xiao JL algorithm [11–14]. The latter one to detect the feature corners utilizes the way of distinguishing the grayscale changes in the neighborhood of pixel points, which avoids the complex process of the contour extraction, such as LoG, SUSAN, SIFT and Harris algorithm [15,16,2,17–20]. Considering the methods above, Harris algorithm

* Corresponding author. Tel.: +86 431 85095506/13604306373; fax: +86 431 85095506.
E-mail address: lixiaotao@jlu.edu.cn (X.T. Li).

0030-4026/$ – see front matter © 2012 Elsevier GmbH. All rights reserved.
http://dx.doi.org/10.1016/j.ijleo.2012.08.020

which just adopts the first-order derivative in the calculation of image data and has good robustness for image rotation and brightness-changing is recognized as a better method for corner detection. However, the noises often influence the feature point detection and lead to the erroneous judgment of confusing noises and right feature points. To separate the noises from the right corners, in this paper a filter adopting singular value decomposition (SVD) is chosen to improve the Harris positioning method for the feature points of a target board image. The filter method aims at providing a recognition approach or decision method to detect and position the feature points precisely and efficiently.

2. Feature points positioning method

2.1. SVD soothing method

Image noise is a random variation of brightness information and is usually an aspect of electronic noise. It is produced by the sensor and circuitry of a scanner or a digital camera. Salt and pepper noise which is analyzed in this research is a form of noise typically seen on images. It represents itself as randomly occurring white and black pixels. This type of noise is caused by analog-to-digital converter errors, bit errors in transmission, etc. [21,22]. The theorem of singular value decomposition (SVD) is adopted to smooth the image and preserve the effective feature details. An image gray scale matrix M which employs singular value decomposition method is factorized by [23–25]

$$M = U \sum V^* \tag{1}$$

where M is an $m \times n$ real matrix and composed of the image grayscale values in x and y directions, U is an $m \times m$ unitary matrix, $\sum$ is an $m \times n$ rectangular diagonal matrix with nonnegative real numbers on the diagonal and expressed by

$$\sum = \begin{bmatrix} \sigma_1 & & & & 0 & \cdots & 0 \\ & \cdots & & & & & \\ & & \sigma_p & & & & \\ & & & 0 & & & \\ & & & & \cdots & & \\ & & & & 0 & \cdots & 0 \end{bmatrix}_{m\times n} \quad (\sigma_1 \geq \sigma_2 \geq \cdots \geq \sigma_r > \sigma_p > 0, \quad m \leq n)$$

V^* is an $n \times n$ real unitary matrix. The diagonal entries σ_i ($i = 1, 2, \ldots, p$) of $\sum$ are known as the singular values of M. A common convention is to list the singular values in descending order. In this case, the diagonal matrix $\sum$ is uniquely determined by M.

In geometrical meaning, $\sum$ is considered to be a scaling matrix, and U, V^* are regarded as rotation matrices. M is viewed as a series of three typical geometrical transformations: firstly, a rotation by matrix U, then, a scaling by matrix $\sum$, and finally, another rotation by matrix V^*. The singular values of the matrix $\sum$ are interpreted as the semiaxes of an n-axes ellipsoid in an n-dimensional Euclidean space with the semiaxes length of singular values σ_i ($i = 1, 2, \ldots, p$) A geometrical example of scaling matrix $\sum$ with three singular values σ_1, σ_2 and σ_3 is illustrated in Fig. 1 by a three-dimensional ellipsoid with three semiaxes. With respect to the geometric content of the SVD theorem, the concerned feature scales of an image represented by matrix M are thus characterized by the singular values. The primary features are conserved in the large singular values; furthermore, the insignificant information such as noises is preserved by the smaller singular values. In the research, we set a cutting point σ_r ($r < p$), where r is an experimental value. All of the singular values smaller than σ_r are given by zero to filer the noise in the experiments. In this way, the image is reconstructed by

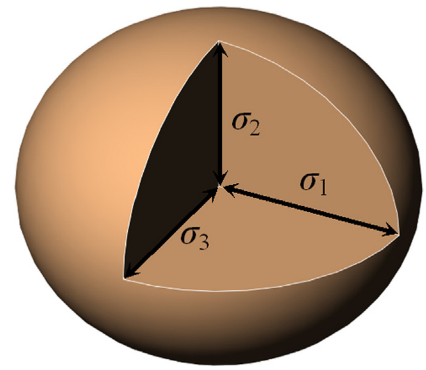

Fig. 1. Geometrical meaning of the singular values σ_1, σ_2 and σ_3 of a three-dimensional scaling matrix.

$$M' = U \sum{}' V^* \tag{2}$$

where M' is a smoothing $m \times n$ real image matrix, $\sum'$ is an $m \times n$ rectangular diagonal matrix defined by

$$\sum{}' = \begin{bmatrix} \sigma_1 & & & & 0 & \cdots & 0 \\ & \cdots & & & & & \\ & & \sigma_r & & & & \\ & & & 0 & & & \\ & & & & \cdots & & \\ & & & & 0 & \cdots & 0 \end{bmatrix}_{m\times n} \quad (\sigma 1 \geq \sigma 2 \geq \cdots \geq \sigma_r > \sigma_p > 0, \ m \leq n).$$

2.2. Corner points detection method

The feature points are extracted by the Harris corner detection in a target board image. As the gradient of grayscale is discontinuous in the corner point, the detection of the corners is performed by calculating the following matrix A [19].

$$A = G(u, v, \sigma) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \tag{3}$$

where I_x and I_y are the grayscale gradients along with the direction of x and y in image, respectively. For calculating I_x and I_y, the two vectors $[-2\,-1\,0\,1\,2]$ and $[-2\,-1\,0\,1\,2]^T$ are adopted to multiply all the elements in the image grayscale matrix in x and y directions, individually. $G(u, v, \sigma) = (1/2\pi\sigma^2)e^{(-(u^2+v^2)/2\sigma^2)}$ is the Gaussian function, where $u = v = 7$ and the standard deviation σ is 2.

Harris corner is defined as the points to satisfy the follow conditions:

$$R = \det A - k(trace(A))^2 > T \tag{4}$$

where the value of k is determined empirically and reported as feasible in the literature values in the range 0.04–0.15. T is equal to $0.01R_{\max}$ where $R_{\max}$ is the largest value in the elements of set R.

3. Experiment results and discussion

The proposed positioning method has been realized in Matlab language on a Celeron 1.73 GHz computer with 2 GB memory. The image resolution is 800 × 600 pixels.