A Comparison on the Image Normalizations for Image Information Estimation

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Abstract**:** In this paper, we propose the estimation method for the image affine information for computer vision. The first estimation method is given based on the XYS image normalization and the second estimation method is based on the image normalization by Pei and Lin. The XYS normalization method turns out to have better performance than the method by Pei and Lin. In addition, we show that rotation and aspect ratio information can be obtained using the central moments of both the original image and the sensed image. Finally, we propose the modified version of the normalization method so that we may control the size of the image**.**

Keywords: Image affine information, information estimation, XYS image normalization

1. INTRODUCTION

The invariant property has made important role in the field of pattern recognition from the sixties. The invariant property has the characteristic of the same geometrical pattern irrespective of the appropriate transformation[7]. The fundamental difficulty to recognize the pattern is to see the same pattern as the different pattern according to the view point. To obtain the invariant, we use the normalization, Fourier descriptor, Zernike moment and the Legendre moment.

In this paper, using the small number of features in the original image, we estimate the geometrical information of the sensed image. The sensed image is defined as the transformed image with the original image by the affine transformation matrix or the specified transformation matrix such as the rotation or the aspect ratio change[1,2]. At first, we show that the rotation and the aspect ratio change are obtained by the central moments of the original and the sensed image. Secondly, we obtain the affine information of the sensed image from the normalization methods such as the XYS and the method by Pei and Lin[8]. Finally, we propose the modified version of the normalization method so that we may control the size of the image.

2. THE IMAGE NORMALIZATION

To obtain the normalized image, the homogeneous affine transformation matrix has important a role. Let μ_{pq} denote the central moments of the digital image $f(x,y)$ of size $M \times N$ where

$$\mu_{pq} = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1}(x-\bar{x})^p (y-\bar{y})^q f(x,y) \qquad (1)$$

$$\bar{x} = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} x f(x,y)}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)} \qquad (2)$$

$$\bar{y} = \frac{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} y f(x,y)}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)} \qquad (3)$$

2.1 The XYS based image normalization

We can decompose the homogeneous affine transformation matrix into an $x-$ shearing, $y-$ shearing and an anisotropic scaling matrix,
i.e.

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} \alpha & 0 \\ 0 & \delta \end{bmatrix}\begin{bmatrix} 1 & 0 \\ \gamma & 1 \end{bmatrix}\begin{bmatrix} 1 & \beta \\ 0 & 1 \end{bmatrix} \qquad (4)$$

with $\alpha, \beta, \gamma, \delta \in C$. In this case, some works in [4] and [5] use the constraints i.e

$$\mu_{31} = 0, \mu_{13} = 0, \mu_{20} = 1, \mu_{02} = 1. \qquad (5)$$

2.2 The image normalization by Pei and Lin[8]

The image normalization we used is given by Pei and Lin [8]. At first, we obtain the covariance matrix

$$\begin{bmatrix} \mu_{20} & \mu_{11} \\ \mu_{11} & \mu_{02} \end{bmatrix} \qquad (6)$$

From the covariance we calculate the eigenvalues λ_1 λ_2 and the first eigenvector $[e_{1x}, e_{1y}]^t$ of the covariance matrix. We may select the constant c such that the normalized image has the size of 512 × 512. Now we obtain the compact image using the transformation matrix A of the image coordinate

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} \frac{c}{\sqrt{\lambda_1}} & 0 \\ 0 & \frac{c}{\sqrt{\lambda_2}} \end{bmatrix} \begin{bmatrix} e_{1x} & e_{1y} \\ -e_{1y} & e_{1x} \end{bmatrix} \quad (7)$$

Let $\mu_{30}, \mu_{21}, \mu_{12}, \mu_{03}$ be the central moments of the original image, and $\mu'_{30}, \mu'_{21}, \mu'_{12}, \mu'_{03}$ be the central moments of the compact image. Then, we get:

$$\begin{aligned}
\mu'_{30} &= a_{11}^3\mu_{30} + 3a_{11}^2 a_{12}\mu_{12} + 3a_{11}a_{12}^2\mu_{21} + a_{12}^3\mu_{03} \\
\mu'_{21} &= a_{11}^2 a_{21}\mu_{30} + (a_{11}^2 a_{22} + 2a_{11}a_{12}a_{21})\mu_{21} \\
&\quad + (2a_{11}a_{12}a_{22} + a_{12}^2 a_{21})\mu_{12} + a_{12}^2 a_{22}\mu_{03} \\
\mu'_{12} &= a_{11}a_{21}^2\mu_{30} + (a_{21}^2 a_{12} + 2a_{11}a_{21}a_{22})\mu_{21} \\
&\quad + (2a_{12}a_{21}a_{22} + a_{22}^2 a_{21})\mu_{12} + a_{12}^2 a_{22}^2\mu_{03} \\
\mu'_{03} &= a_{21}^3\mu_{30} + 3a_{21}^2 a_{22}\mu_{21} + 3a_{21}a_{22}^2\mu_{12} + a_{22}^3\mu_{03}.
\end{aligned} \quad (8)$$

We find the angle α such that

$$\tan\alpha = -\frac{\mu'_{12} + \mu'_{30}}{\mu'_{03} + \mu'_{21}} \quad (9)$$

If $\mu'_{03} + \mu'_{21} < 0$, then $\alpha = \alpha + \pi$.
Finally, the normalized image can be obtained from the original image by the transformation:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} \frac{c}{\sqrt{\lambda_1}} & 0 \\ 0 & \frac{c}{\sqrt{\lambda_2}} \end{bmatrix} \begin{bmatrix} e_{1x} & e_{1y} \\ -e_{1y} & e_{1x} \end{bmatrix} \quad (10)$$

We choose c such that the normalized image may be the size of the original image. We mention that there exist other normalization methods[3,6] not explained in this paper.

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3. THE ASPECT RATIO CHANGE ESTIMATION

We may solve the aspect ratio change information using the two central moments. Before we solve the aspect ratio problem, we are in a position to present a lemma.

Lemma 1[7]: Assume that $f(x_s, y_s)$ is an affine transformed image from $f(x,y)$ by the homogeneous affine transformation matrix

$$\begin{bmatrix} x_s \\ y_s \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}, \quad (11)$$

and μ and μ' denote the central moments of the original and the transformed image, respectively. Then we have the following relationship:

$$\mu'_{pq} = b \sum_{i=0}^{p} \sum_{j=0}^{q} \binom{p}{i} \binom{q}{j} a_{11}^i a_{12}^{p-i} a_{21}^j a_{22}^{q-j} \mu_{i+j,p+q-i-j} \quad (12)$$

where $b = | a_{11}a_{22} - a_{21}a_{12} |$.

Now, we solve the aspect ratio problem. Suppose that an image $f(x,y)$ with the image coordinate $(x,y)^t$ exists. Then the other image $f(x_s, y_s)$ is defined in the image coordinate

$$\begin{pmatrix} x_s \\ y_s \end{pmatrix} = A_s \begin{pmatrix} x \\ y \end{pmatrix} \equiv \begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix}. \quad (13)$$

Let μ_{10} and μ_{01} be the central moments from $f(x,y)$ and $\mu_{10}{}^s$ and $\mu_{01}{}^s$ be the central moments from $f(x_s, y_s)$. Lemma 1 leads to

$$\mu_{10}^s = a^2 b \mu_{10}, \quad \mu_{01}^s = a\ b^2 \mu_{01}. \quad (14)$$

Solving for a and b, we obtain

$$a = \sqrt[3]{\frac{\mu_{01}\mu_{10}^{s2}}{\mu_{01}^s \mu_{10}^2}}, \quad b = \sqrt[3]{\frac{\mu_{10}\mu_{01}^{s2}}{\mu_{10}^s \mu_{01}^2}} \quad (15)$$

4. THE ROTATION INFORMATION ESTIMATION

Now, we solve the rotation estimation problem. Suppose that an image $f(x,y)$ with the image coordinate $(x,y)^t$ exists. Then the other image $f(x_s, y_s)$ is defined in the image coordinate

$$\begin{pmatrix} x_s \\ y_s \end{pmatrix} = A_s \begin{pmatrix} x \\ y \end{pmatrix} \equiv \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{pmatrix} x \\ y \end{pmatrix}. \quad (16)$$

Let μ_{10} and μ_{01} be the central moments from $f(x,y)$ and $\mu_{10}{}^s$ and $\mu_{01}{}^s$ be the central moments from $f(x_s, y_s)$. Lemma 1 leads to

$$\mu_{10}^s = \cos\theta\mu_{10} + \sin\theta\mu_{01}, \quad \mu_{01}^s = -\sin\theta\mu_{10} + \cos\theta\mu_{01} \quad (17)$$

Solving for $\cos\theta$ and $\sin\theta$, we obtain

$$\cos\theta = \frac{\mu'_{10}\mu_{10} + \mu'_{01}\mu_{01}}{\mu_{10}^2 + \mu_{01}^2}, \quad \sin\theta = \frac{\mu'_{10}\mu_{01} - \mu'_{01}\mu_{10}}{\mu_{10}^2 + \mu_{01}^2} \quad (18)$$

5. The relationship between the image size and the normalization

We present the modified XYS normalization method

$$\mu_{31} = \mu_{31} = 0, \mu_{20} = \mu_{02} = c. \quad (19)$$

Using the iterative method [5,9], we obtain the minimum norm solution β^*, γ^* for the simultaneous equation $\mu_{31}^{xy} = \mu_{13}^{xy} = 0$. By Lemma 1, we obtain two equations $\mu_{20} = \alpha^3 \delta \mu_{20}^{xy}$, $\mu_{02} = \alpha\ \delta^3 \mu_{02}^{xy}$. Combining the results with the constraints $\mu_{20} = \mu_{02} = c$ give us

$$\alpha^* = \sqrt[8]{\frac{\mu_{02}^{xy} c^2}{\mu_{20}^{xy3}}}, \qquad \delta^* = \sqrt[8]{\frac{\mu_{20}^{xy} c^2}{\mu_{20}^{xy3}}} \tag{20}$$

If we want to control the size of the sensed (or normalized) image, we have a relationship between M and c as follows:

$$c \approx \frac{M^4}{(1+|\beta|)^4 (1+|\gamma|)^4} \min(\sqrt{\frac{\mu_{02}^{xy3}}{\mu_{20}^{xy}}}, \sqrt{\frac{\mu_{20}^{xy3}}{\mu_{02}^{xy}}}) \tag{21}$$

In the above equation, the notation μ^{xy} means the central moments for the image after the x-shearing and y-shearing operations and the normalized image has the size of M times of the size of the original image.

Similarly, we obtain the result for the XSR normalization method. In this case, the parameter c is given by

$$c \approx \frac{M^4}{\eta^4 (1+|\beta|)^4} \min(\sqrt{\frac{\mu_{02}^{x3}}{\mu_{20}^{x}}}, \sqrt{\frac{\mu_{20}^{x3}}{\mu_{02}^{x}}}) \tag{22}$$

where

$$\eta = |\cos(\theta) + \sin(\theta)| \in [1, \sqrt{2}] \tag{23}$$

In the above equation, the notation μ^x means the central moments for the image after the x-shearing operation and the normalized image has the size of M times of the size of the original image.

In this case, we allow the size of the normalized image to look as same as the original image.

6. THE AFFINE INFORMATION ESTIMATION

We can estimate the affine information matrix between the referenced and sensed images through the method by Pei and Lin or XYS methods. We use the modified versions of the XYS methods instead of the original XYS methods. The algorithm to determine the affine transformation matrix is as follows:

Step 1: We transform the original image to the transformed image through the XSR normalization. Let A_1 be its transform matrix.

Step 2: We transform the sensed image to the transformed image through the XSR normalization. Let A_2 be its transform matrix.

Step 3: The affine transformation matrix from the referenced image to the sensed image results in $A_3 = A_2^{-1} A_1$.

Similarly, we can determine the affine information between the references and the sensed images through the XYS normalization.

7. The experiment

We make the sensed image from the referenced image through the transformation matrix $M = \begin{bmatrix} 1 & 0 \\ y & z \end{bmatrix}$. We change the value of y from zero to one by the increment 0.1 with $z = 0.9$ or $z = 1$. Using the algorithm in Section 6, we can estimate the matrix M as the $\hat{M} = A_2^{-1} A_1$ where A_1 is the associated with the normalization operation into the referenced image and A_2 is the associated with the normalization operation into the sensed image. The matrix $\hat{M}_n$ is normalized using the maximal diagonal element of the matrix $\hat{M}$. Now we define the error e between the true affine matrix and the matrix obtained by the given algorithm:

$$e = \| M - \hat{M}_n \|_2 \tag{24}$$

In this case, we choose the element-wise second norm when we calculate the error e .

The performance result is given by Fig. 2. In the Fig. 1, two normalization methods are applied to the cameraman image. The image used in the experiment is the Cameraman image of size 256 by 256. In Fig 2, the XYS method has better performance than the method by Pei and Lin for $z = 0.9$ and $z = 1$.

(a) (b)

Fig. 1. (a) Method by Pei and Lin (b) XYS Method

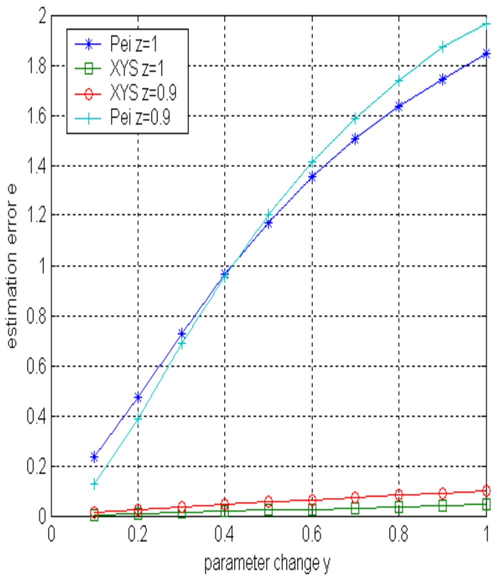

Fig. 2. The estimation error

8. Conclusions

In this paper, we proposed the estimation method for the image affine information for computer vision. The first estimation method is given based on the XYS image normalization and the second estimation method is based on the image normalization by Pei and Lin. Through the experiment, the estimation method based on the image normalization by Pei and Lin and that based on the XYS image normalization have been compared with for an image. The XYS method turns out to have better performance. In addition, we have shown that rotation and aspect ratio information can be obtained using the central moments of both the original image and the sensed image. Finally, we proposed the modified version of the normalization method so that we may control the size of the image.

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