ORIENTATION ESTIMATION WITH APPLICATIONS TO IMAGE ANALYSIS AND REGISTRATION

David Asatryan, Karen Egiazarian, Vardan Kurkchiyan

Abstract: *In this paper, a novel method for image orientation angle determination is proposed. The method is based on the use of parameters of scattering ellipse of an image gradient field. Various problems with application of the proposed technique are considered. The results of the experiments for determining the predominant direction of an image are presented. Three methods of image orientation angle (OA) estimation are compared. It is shown that the method based on scattering ellipse technique is more precise than the histogram-based methods. The term of the "backlash" of image rotation algorithms is submitted and a method for "backlash" estimation is proposed. The "backlash" can be used for determination of the quality of arbitrary rotation algorithm. It is also shown that the proposed technique can be applied to the problems related to the Horizon line tracking.*

Keywords: *Image registration, orientation angle, directionality, regularity, gradient, rotation, scattering ellipse.*

ACM Classification Keywords: *Image Processing and Computer Vision*

Introduction

Image registration is the process of determining the correspondence between all the points in two images of the same scene. Registration of the images is requires in image analysis applications that involve two or more images of a scene. The reference and the referred image could be captured at different times, using different devices, from different angles etc.

The principal problem which is being solved by image registration methods is to find a geometric transformation such that the referred (or template) image becomes similar to the reference image. Successive solution of this problem depends on prior knowledge, available about possible type of deformations of referred image, which could be arrived due to the method of image capturing. Therefore there are huge numbers of image registration methods, described in the scientific literature. We can refer to [1-2], devoted to the survey on image registration methods and applications as well.

The most of registration procedures include image rotation operation, which is performed by the appropriate interpolation technique. The rotation can be performed in two ways. The first way is based on the scanning a set of possible values of rotation angle and performing the image rotation at each value. Then the image of maximal similarity with the reference image is considered as a referred one. The second way is based on preliminary estimation of the difference of orientation angles of the reference and referred images, and rotation the referred image at that angle.

There are a variety of techniques in the literature to estimate orientation angle, including methods using image gradients [3], directional histograms [4], discrete Radon transform [5, 6], modified Radon Transform [7] etc.

In this paper, the second way is considered, therefore a technique for image OA based on using scattering ellipse of image gradient field and related parameters is proposed. The gradient field is obtained by Sobel operator.
The proposed method is based on determination of the scattering ellipse of an image gradient field. The main axis of that ellipse is used for image predominant direction angle determination. In the present paper, the results of various experiments are given, which allows to compare different estimators of image rotation angle, some rotation methods and determinate the “backlash” of rotation algorithm.

Method

The method originates in a new approach to the problem of image quality assessment, described in [8]. According to that approach the measure for quality assessment is based on the usage of the image gradient magnitude distribution. Such measure gives the results similar to the human visual system. But the image gradient field also contains information on image orientation, notably the dominant direction (see, for example, [3]).
Let $I = \{I(m,n)\}$ be a Gray Scale image of size $M \times N$, where $I(m,n)$ is the pixel intensity with coordinates (m,n), $m = 0,1,...,M-1$, $n = 0,1,...,N-1$. Let's denote by matrixes $\|G_H(m,n)\|$ and $\|G_V(m,n)\|$ the horizontal and vertical gradients of an image at the point (m,n), by $\|F(m,n)\|$ the gradient magnitude, and by $\|A(m,n)\|$ the gradient angle, where

$$F(m,n) = \sqrt{G_H^2(m,n) + G_V^2(m,n)}\ , \tag{1}$$

$$\|A(m,n)\| = \left\|\operatorname{arctg}\frac{G_V(m,n)}{G_H(m,n)}\right\|, \tag{2}$$

Consider the gradient field as a two-dimensional sample from random variable with the elements

$$G(m,n) = [G_H(m,n), G_V(m,n)]. \tag{3}$$

Define the scattering ellipse of gradient field (3) as the solution of equation with respect to the variables (g_H, g_V) [9] as follows

$$\frac{1}{1-\rho_{HV}^2}\left[\frac{(g_H-\mu_H)^2}{\sigma_H^2} - \frac{2\rho_{HV}(g_H-\mu_H)(g_V-\mu_V)}{\sigma_H\sigma_V} + \frac{(g_V-\mu_V)^2}{\sigma_V^2}\right] = C^2\ , \tag{4}$$

where μ_H, μ_V, σ_H, σ_V are the sample mean and sample standard deviation of the horizontal and vertical components of the gradient field, ρ_{HV} is the correlation coefficient between them, C is a constant. The large axis of the ellipse coincided with the line of orthogonal regression, and the slope angle α is determined by formula as follows

$$\text{tg}\alpha = \frac{2 * \rho_{HV}}{\sigma_H^2 - \sigma_V^2 + \sqrt{\left(\sigma_H^2 - \sigma_V^2\right)^2 + 4\rho_{HV}^2}} . \qquad (5)$$

We assume that the angle α is measured from the horizontal axis anticlockwise as it is shown in Figure 1.

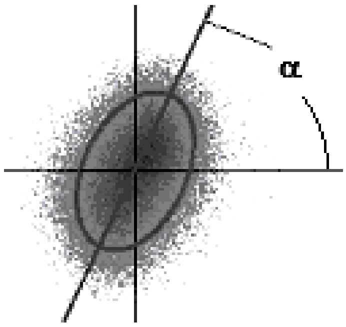


Figure 1. An image scattering ellipse and the orientation angle.

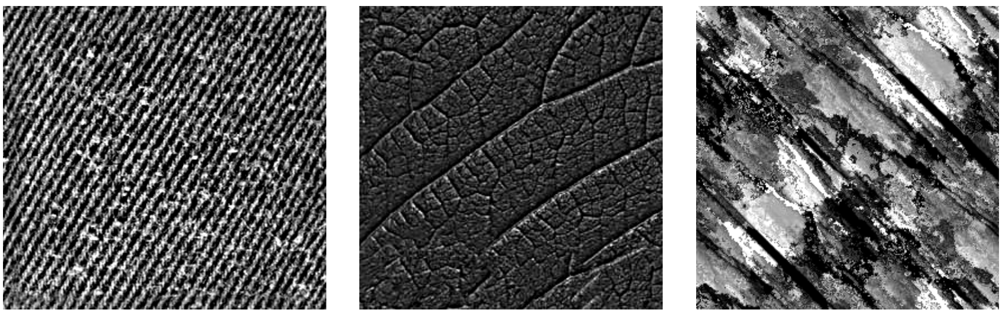
Image orientation angle determination

In this section the results of some experiments, using the technique above, are given and analyzed.

Let I be an original image, I_α be the image I rotated by an angle α using certain rotation algorithm.

Described method of image orientation angle estimation can be applied to certain problem, which is arisen during the registration process, such as:

- determination of an image orientation angle with respect to some prior fixed direction;
- determination of difference between orientation angles of two different parts of an image;
- determination of the rotation angle shift between two different images of the same scene;
- error analysis of different rotation algorithms;
- Horizon line tracking, etc.
-



$\alpha = 65°$ $\alpha = 18°$ $\alpha = 136°$

Figure 2. Determination of the predominant direction of the images.

Experiment 1. Determination of the predominant orientation angle of an image. Three images with predominant orientations, which could be distinctly estimated by visual analysis, are shown in Figure 2. Using the above described method we estimate the angle values which are given below the images. We can see that these values quite correspond to the visual estimation results.

Figure 3. Pisa Tower. The chosen parts of the image are separated by rectangles.

Experiment 2. Determination of the Pisa Tower leaning angle. It is known that the Pisa Tower is leaned at an angle of 5.5 degrees (see Figure 3). We can estimate this angle by subtraction of orientation angle $\hat{\alpha}_T$ of the Tower and orientation angle $\hat{\alpha}_T$ the building on the left of the Tower.

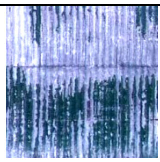
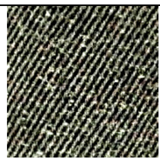
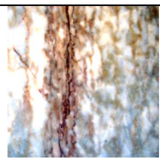
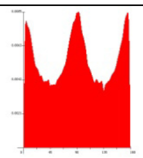
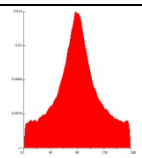
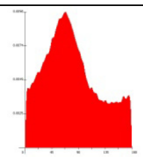
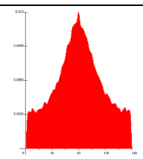
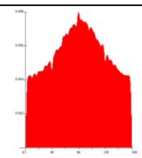
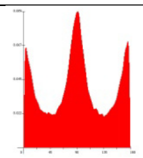
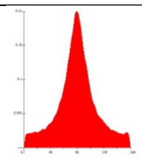
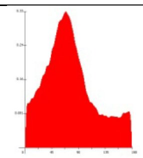
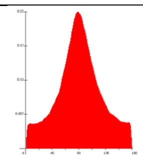
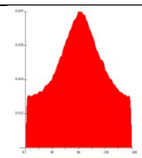
Appropriate areas of image are chosen to increase the estimation precision, as it is shown in Figure 3. The left part is of size 450x180 pixels, and the right part is of size 450x620 pixels. As a result of estimating by formula (5) we obtain $\hat{\alpha}_B = 90.5°$, $\hat{\alpha}_T = 85.1°$, $\hat{\alpha}_B - \hat{\alpha}_T = 5.4°$.

Comparison of orientation angle estimating methods

In this section we compare different methods for OA estimation. Image rotation is performed by algorithm, described in [10].

Experiment 3. Error determination for orientation estimation algorithm. Let $\hat{\alpha}_0$ be the orientation angle of original image I. Rotate the image I by an angle α and estimate the orientation angle $\hat{\alpha}_r$ of the image I_α. Angle $\hat{\alpha}_r - \hat{\alpha}_0$ can be interpreted as the error of orientation estimation algorithm. This approach allows comparing various estimation algorithms by values of mean-square error (MSE) at different rotation angles.

Table 1. Samples of texture images and histograms given by algorithms 2 and 3.

1					
2					
3					

In this experiment we compare three methods of orientation angle estimation:

- Method using the scattering ellipse orientation (Method 1);
- Method based on histogram of individual gradient angle (Method 2);
- Method based on histogram of the gradient magnitude, whereby for the angle α (Method 3), by formula as follows

$$H(\alpha) = \begin{cases} \sum_m \sum_n F(m,n), & \text{if } A(m,n) = \alpha \\ 0 & \text{otherwise} \end{cases},$$

where $A(m,n)$ is the gradient direction, determined by formula (5).

Table 1 shows samples of selected images and corresponding histograms (rows 2 and 3) determined by above specified algorithms. It can be noted that the algorithm 3 provides the histogram with less variation; therefore it can be considered as more precise estimation of the rotation angle.

Table 2. The mean square error of rotation angle estimation using different methods.

Angle α, degree	**Estimation method 1**	**2**	**3**
5	0.739	3.250	3.540
10	1.283	4.366	3.810
15	1.651	4.573	4.419
20	2.132	4.034	6.965
25	2.342	6.888	6.271
30	2.544	8.562	6.365
35	2.477	7.522	7.265
40	2.273	5.028	5.405
45	1.934	4.414	3.282

Rotation of 15 selected images by angles from 5º to 45º by discrete of 5º was performed. The results are given in Table 2. We can see that the algorithm 1 is the most precise and MSE is equal to 1-2 degrees, while other algorithms are worse.

Determination of the “backlash” of an image rotation algorithm

Experiment 4. Determination of the “backlash” for rotation algorithms. The term “backlash” we introduce to describe the results of application of various methods of image rotation, when at first the image is rotated by an angle α, and then it is rotated in backward direction by the same angle. In ideal case the last image will coincide with the original image. But because of distortions due to inevitable application of certain interpolation or other processing technique these images will differ. This difference we call “backlash” of rotating algorithm.

The “backlash” of estimation algorithm includes the following steps:

Step 1. Rotate image I by an angle α.

Step 2. Estimate the rotation angle by subtracting the orientation angles of images I_α and I. Let $\hat{\alpha}$ be the result of subtracting.

Step 3. Rotate the image I_α by an angle $-\alpha$. Let $I_{\alpha,-\alpha}$ be the resulted image.

Step 4. Estimate the rotation angle of image $I_{\alpha,-\alpha}$ by subtracting the orientation angles of images $I_{\alpha,-\alpha}$ and I. The result $\hat{\alpha}_b$ of subtracting is interpreted as the “backlash” of rotation algorithm.

We consider three algorithm of image rotation:

- Using B-spline interpolation technique by [10];
- Using Bi-linear interpolation technique;
- Using Cubic spline interpolation technique.

The MSE of "backlash" for each rotation algorithm applied to the same 15 images are collected in Table 3. We see that there are no significant differences between MSE values for these algorithms, in spite of the differences of used interpolation technique. We also can note that the MSE values don't depend on rotation angle.

Table 3. MSE of "backlash" for various rotation algorithms.

Angle $\hat{\alpha}_b$, **degree**	**Algorithm**		
	1	**2**	**3**
5	0.418	0.592	0.696
10	0.439	0.618	0.706
15	0.442	0.639	0.658
20	0.441	0.623	0.638
25	0.439	0.661	0.650
30	0.438	0.632	0.712
35	0.439	0.644	0.661
40	0.439	0.642	0.804
45	0.441	0.623	0.673

Experiment 5. Determination of the "backlash" for rotation angle estimation algorithm. Here the same 15 images above are rotated using the Algorithm 1 by different angles. Table 4 includes the MSE for specified estimation technique applied to "backlash" determination.

Table 4. MSE of the "backlash" for different estimation methods.

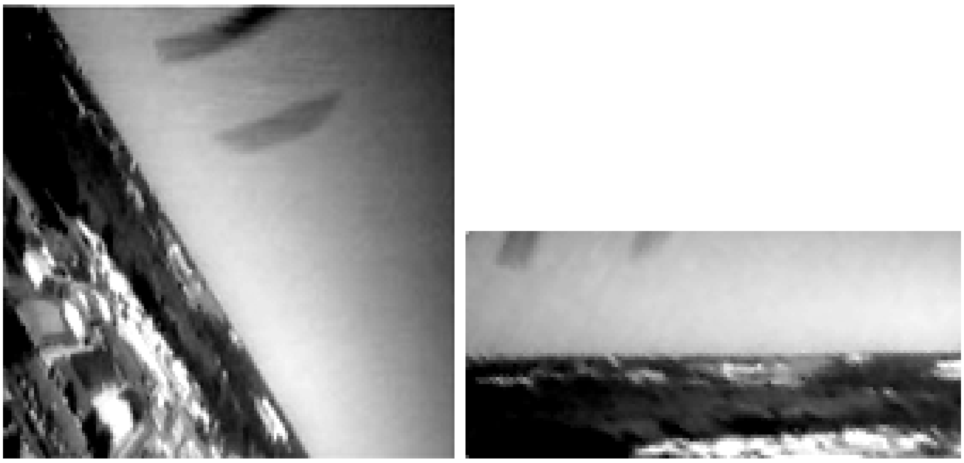
Angle α, **degree**	**Estimation method**		
	1	**2**	**3**
5	0.696	4.960	1.299
10	0.706	2.179	1.847
15	0.658	2.844	2.031
20	0.638	4.496	2.062
25	0.650	4.998	0.935
30	0.712	4.398	0.433
35	0.661	5.054	1.346
40	0.804	4.313	0.968
45	0.673	5.500	1.118

We see that the method based on scattering ellipse properties is better.

Horizon line tracking

Experiment 6. *Horizon line tracking* is an important task for certain applications of image processing methods, such as structural interpretation of seismic images, underground object tracking, coast line determination by remote sensing, flight control of small unmanned aircraft etc. In these cases the central problem is image orientation angle estimation. The knowledge of image orientation angle allows to rotate the image anticlockwise at that angle and to get the image of "normal" orientation, i.e. as if it was taken in the horizontal plane.

An image example containing the sky-ground border (or Horizon line) is shown in Figure 4a. The predominant direction of orientation is estimated by proposed method and resulted to ~60°. A fragment of the image after rotating by angle of 60° counterclockwise is shown in Figure 4b. The residual orientation angle of Figure 4b is equal about 1°.



a b

Figure 4. Image with sky-ground border taken at unknown viewpoint. a – original, b- a fragment of rotated image.

Conclusion

In this paper, a new technique for image orientation angle estimation is proposed. The idea is based on using the slope angle of the main axis of the scattering ellipse of image gradient field. By using the proposed technique some problems related to image orientation determination are considered and the results of numerical experiments are described. Two more methods of orientation angle estimation based on gradient angle histogram are compared with that. The effectiveness of the proposed method is shown. The term of image rotation algorithm "backlash" is submitted and a method for "backlash" estimation is proposed. The "backlash" method is used for determination of the quality of arbitrary rotation algorithm. It is also shown that the proposed technique can be applied to the problems related to horizon line tracking.

Bibliography

[1] Medha V. Wyawahare, Pradeep M. Patil, and Hemant K. Abhyankar, Image Registration Techniques: An overview. International Journal of Signal Processing, Image Processing and Pattern Recognition, Vol. 2, No.3, pp 11-27, 2009.

[2] Zitova Barbara, Flusser Jan, Image registration methods: a survey, Image and Vision Computing, 21, pp 977-1000, 2003.

[3] Mester R., Orientation estimation: Conventional techniques and a new nondifferential approach. In 10th European Signal Processing Conference, Vol. 2, Islamabad, Pakistan, pp. 921–924, 2000.

[4] Manjunath, B. S., Wu, P., Newsam, S., and Shin, H. D. A Texture Descriptor for Browsing and Similarity Retrieval, Journal of Signal Processing: Image Communication, Volume 16, Issue 1-2, page 33-43, 2000.

[5] Hejazi M. Shevlyakov R., G., and Ho Y.S., Modified discrete Radon transforms and their application to rotation-invariant image analysis, In Eighth IEEE Workshop on Multimedia Signal Processing (MMSP2006), Victoria, Canada, pp. 429–234, October 2006.

[6] Jafari-Khouzani K. and Soltanianzadeh H., Radon transform orientation estimation for rotation invariant texture analysis, IEEE Trans. Pattern Anal. and Machine Intell. 27, pp 1004–1008, 2005.

[7] Hejazi Mahmoud R., Ho Yo-Sung, An Efficient Approach to Texture-Based Image Retrieval. Int. J. Imaging Syst. Technol., Vol. 17, pp. 295–302, 2007.

[8] Asatryan D., Egiazarian K., Quality Assessment Measure Based on Image Structural Properties. Proc. of the International Workshop on Local and Non-Local Approximation in Image Processing, Finland, Helsinki, pp. 70-73, 2009.

[9] Cramer H., Mathematical Methods of Statistics, 1961.

[10] Egiazarian K., Saramäki T., Chugurian H., and Astola J., Modified B-spline filters and interpolators, in Proc. IEEE Int. Conf. Acoustics, Speech and Signal Processing, ICASSP'96, Atlanta, Georgia, USA, vol.3, pp. 1743-1746, 1996.

Authors' Information

David Asatryan *– Professor, Head of group of the Institute for Informatics and Automation Problems of NAS Armenia, 1, P.Sevaki Str., 0014, Yerevan, Armenia, e-mail: dasat@ipia.sci.am.*

Major Fields of Scientific Research: Digital signal and image processing.

Karen Egiazarian *– Professor, Head of Transforms and Spectral Techniques Group, International Center for Signal Processing, Tampere University of Technology, P.O.Box 553, FIN-33101 Tampere, FINLAND, e-mail: karen.egiazarian@tut.fi.*

Major Fields of Scientific Research: applied mathematics, signal/image processing, and digital logic.

Vardan Kurkchiyan *– Ph.D student, Russian-Armenian (Slavonic) University, 123, Hovsep Emin Str., 0051, Yerevan, Armenia, e-mail: vakur@gmail.com.*

Major Fields of Scientific Research: Digital image processing.