Embedded Scale United Moment Invariant for Identification of Handwriting Individuality

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Abstract. Past few years, a lot of research on moment functions have been explored in pattern recognition. Several new techniques have been investigated to improve conventional regular moment by proposing the scaling factor of geometrical function. In this paper, integrated scaling formulations of Aspect Invariant Moment and Higher Order Scaling Invariant with United Moment Invariant are presented in Writer Identification to seek the invarianceness of authorship or individuality of handwriting perseverance. Mathematical proving and results of computer simulations are included to verify the validity of the proposed technique in identifying eccentricity of the author in Writer Identification.

Keywords: Handwriting Individuality, Geometric Function, Alternative Scale United Moment Invariant.

1 Introduction

The mathematical concept of moments has been around since 1960s. It has been used in many diverse fields ranging from mechanics and statistics to pattern recognition and image understanding [1]. The main advantage with geometric moments is that image coordinate transformations can be easily expressed and analyzed in terms of the corresponding transformations in the moment space [2]. The use of moments in image analysis and pattern recognition was inspired by Hu [3] and Alt [4]. Hu [3] first presented a set of seven-tuplet moments that invariant to position, size, and orientation of the image shape. However, there are many research works have been done to prove that there were some drawback in the original work Hu [3] in terms of invariant such as Reiss [5], Belkasim [6], Feng [7], Sivaramakrishna [8], Palaniappan [9] and Shamsuddin *e.tal*[10].

The work presented by Hu [3] has been slightly modified by Reiss [5]. Reiss [5] revised the fundamental theorem of moment invariants and produce four absolute moment invariant under general linear transformation and invariant to

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changes in illumination. Further studies in moment invariants were made in order to reach higher reliability. Ding [11] has proved that Hus moments loose scale invariance in discrete condition. Regardless of its scaling invarianceness, Hongtao [12] proposed new moment invariants in discrete condition. Meanwhile, Chen [13] improved moments invariants based on boundary but the derivations are different from Hus. Sivaramakrishna [8] explored the limits applicability of Hus characterization under quantitative skew transformation. Yinan [14] mentioned that all of the above mentioned features are not valuable based on both regions and boundaries simultaneously or the equations are not coincident with Hus moments. Therefore, he derived United Moment Invariants (UMI) based on basic scaling transformation by Hu [3] that can be applied in all conditions with promising and a good set of discriminate shapes features. Hus seven tuplet are invariants under change of size, translation, and orientation for equal scale of image. In the case of unequal scaling of image, Hus invariants would generate different moment values for the same images of different orientations or scale [7], [9], [10], [15]. Nevertheless, moment functions are still actively being used in pattern recognition applications.

Writer Identification (WI) can be included as a particular kind of dynamic biometric in pattern recognition for forensic application. The shapes and writing styles can be used as biometric features for authenticating an identity [16], [17], [18], [19]. It ignited the researchers to explore this field in order to find the best solution to identify the writer of handwriting. The previous work on scaling factor by Feng [7] and Shamsuddin [10] were tested on digit character to validate the invarianceness of their proposed formulation. These two scaling factor were never been tested on word shape image and to be more precise is in Writer Identification (WI) domain. In this paper, an integrated scaling transformation of Aspect Invariant Moment (AMI) [7] and Higher Order Invariant (HOI) [10] with UMI [14] are explored to search for handwriting individuality in WI.

2 Writer Identification

WI distinguishes writers based on the shape or individuality style of writing while ignoring the meaning of the word or character written. Handwriting varied due to the several writing styles. The shape and style of writing are different from one person to another. Even for one person, they are different in times. Manual WI needs an expert of handwriting analysis or graphologist to figure out the uniqueness and individuality of handwriting called features. Identification process is difficult due to the difficulty of handwriting features; they are different according to the varieties of handwriting styles. Features from the question document will be compared to features from a list of handwritten documents. Graphologist will observe and evaluate features from these two documents. When these tasks are adapted into computerized system, it involved the pattern recognition process such as feature extraction and classification. Many previous works on WI problem have been experimented to be solved based on the image processing and pattern recognition technique [20], [21], [22], [23], [24].

2.1 Individuality of Handwriting

Handwriting is individual to personal. Handwriting has long been considered individualistic and writer individuality rests on the hypothesis that each individual has consistent handwriting [16], [19], [23], [25], [26]. The relation of character, shape and style of writing are different from one to another. The challenge in WI is how to acquire the features that represent the authorship for various styles of handwriting [18], [20], [22], [26], [27], [28]; either for one writer or many writers. These features are required to classify in order to identify which group or classes that they are closed to. However, everyone has their own style of writing and it is individualistic. It must be unique feature that can be generalized as individual features or writing styles through the handwriting shape. Furthermore, it can be recognized as individuals features and directly identified the handwritten authorship. Figure 1 shows that each person has its individuality styles of writing. The shape is slightly different for the same writer and quite difference for different writers.

We refer to figure 1 below:

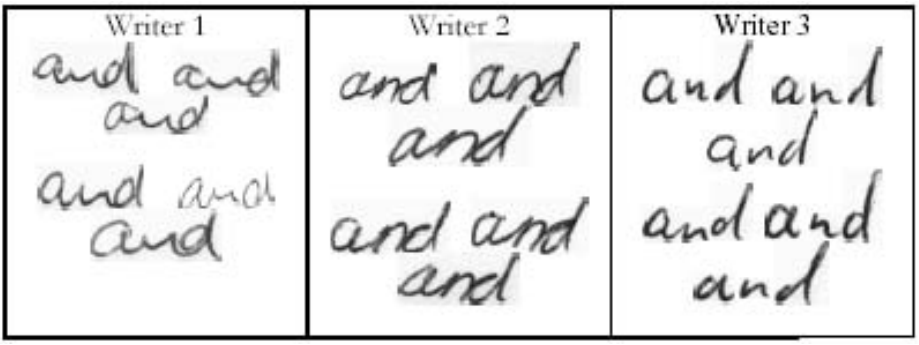

Fig. 1. Same word for different writer

3 United Moment Invariant

Searching for images using shape features has attracted much attention by many researchers. Shape is an important visual feature and it is one of the basic features used to describe image content [29]. However, to extract the features that represent and describe the shape precisely is a difficult task. A good shape descriptor should be able to find perceptually similar shape where it is usually means rotated, translated, scaled and affined transformed shapes. Furthermore, it can tolerate with human beings in comparing the image shapes. Yinan [14] proposed UMI where the rotation, translation and scaling can be discretely kept invariant to region, closed and unclosed boundary. The UMI are good set of discriminate shape features and valid in discrete condition. UMI is related to

geometrical representation of GMI by [3], which consider normalized central moments as shown below:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\frac{p+q+2}{2}}} \tag{1}$$

and Equation (2) as normalized central moments in discrete form :

$$\mu_{pq}^{'} = \rho^{p+q}\mu_{pq},\ \eta_{pq}^{'} = \rho^{p+q}\eta_{pq} = frac\rho^{p+q}\mu_{pq}\mu_{00}^{\frac{p+q+2}{2}} \tag{2}$$

and improved moment invariant by [13] as given in Equation (3):

$$\eta_{pq}^{'} = \frac{\mu_{pq}}{\mu_{00}^{p+q+1}}. \tag{3}$$

Equation (2) can be derived from $m_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^p y^q f(x,y)dxdy$. For unequal scaling, every coefficient of $f(x,y)$ will be an algebraic invariant by the definition of invariants:

$$x^{'} = \alpha x,\ y^{'} = \beta y$$

$$dx^{'} = \alpha dx,\ dy^{'} = \beta dy.$$

Thus,

$$dx^{'}dy^{'}dy^{'} = \alpha\,\beta\,dx\,dy. \tag{4}$$

The moments of the scaled image can now be expressed in terms of the moments of the original image as:The moments of the scaled image can now be expressed in terms of the moments of the original image as:

$$m_{pq} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^p y^q f(x,y)dxdy.$$

and

$$m_{pq}^{'} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} (x^{'})^p (y^{'})^q f^{'}(x,y)dx^{'}dy^{'}.$$

Thus

$$m_{pq}^{'} = \int\int (\alpha x)^p (\beta y)^q (\alpha\beta dxdy). \tag{5}$$

Simplify Equation (5) gives,

$$m_{pq}^{'} = \alpha^{p+1}\beta^{q+1}\int\int x^p y^q dxdy,$$

$$m_{pq}^{'} = \alpha^{p+1}\beta^{q+1}m_{pq}. \tag{6}$$

Each of Equation (1), Equation (2) and Equation (3) has the factor μ_{pq}. By ignoring the influence of μ_{00} and ρ, UMI [14] is given as

$$\theta_1 = \frac{\sqrt{\phi_2}}{\phi_1} \quad \theta_2 = \frac{\phi_6}{\phi_1\phi_4} \quad \theta_3 = \frac{\sqrt{\phi_5}}{\phi_4} \quad \theta_4 = \frac{\phi_5}{\phi_3\phi_4}$$

$$\theta_5 = \frac{\phi 1 \phi_6}{\phi_2 \phi_3} \quad \theta_6 = \frac{(\phi_1 + \sqrt{\phi_2})\phi_3}{\phi_6} \quad \theta_7 = \frac{\phi_1 \phi_5}{\phi_3 \phi_6} \quad \theta_8 = \frac{(\phi_3 + \phi_4)}{\sqrt{\phi_5}}, \tag{7}$$

where ϕ_i are Hus moment invariants, and each component of ϕ_i consists of μ_{pq} . By integrating different scaling formulations of AIM [7] and HOI [10] into Yinans eight formulations, we get our proposed scheme as An Embedded Alternative Scale into United Moment Invariant.

4 Geometric Scaling Invariants

Hu [3] presented moment invariants in 2-D pattern recognition from the first three central moments, specifically tested on automatic character recognition. He claimed that his generated moment sets are invariant to position, size, and orientation of the image shape by derived a scale factor of Equation (1). However, his approach could not cater for images of unconstrained scaling [5],[6],[7],[8],[9],[10], [15],[30]. Feng [7] details the problem of moment invariant by Hu [3] as

- The complete orientation independence property makes it difficult to distinguish digits such as 6 and 9.
- Scaling factor by Hu [3] decreases dramatically as the order increases. This renders high order moments trivial (insignificant) when applied to an MLP classifier. It gives smaller values as the order of p and q increases.
- In the case of unconstrained handwritten digits, various aspect ratios are encountered in different scaling along x and y directions. Hus moment invariants would generate different moments values for the differ-ent scale of two digit images because it meant for images of uniform scaling.

4.1 Aspect Invariant Moment (AIM) Scaling

According to Feng [7], GMI proposed by Hu [3] have several drawbacks. Direct application of these moment invariants to the problem of Multi Layer Perceptron (MLP) based handwritten numeral recognition. Therefore, Feng [7] proposed AIM for images of unequal scale by forming moment invariants which are independent of the different scaling in the x and y directions as below:

$$\eta_{pq} = \frac{\mu_{00}^{\frac{p+q+2}{2}}}{\mu_{20}^{\frac{p+1}{2}} \mu_{02}^{\frac{q+1}{2}}} \mu_{pq}. \tag{8}$$

The numerator and denominator of the scale factor are of the same order. Therefore, the magnitude of the aspect invariant moments will not change dramatically with moment order. This allows the effective use of high order moments to increase the discrimination ability of the system.

4.2 Higher Order Scaling Invariant (HOSI)

Shamsuddin [10] presented an alternative formulation of invariant moments using higher order centralized scaled-invariants for unequal scaling in x and y directions for handwritten digits. Moment invariant for unequal scaling is given as:

$$m_{pq}^{'} = \alpha^{p+1}\beta^{q+1}m_{pq}. \tag{9}$$

Using higher order centralized invariants of the scale normalization yields:

$$\mu_{02}^{'} = \alpha\beta^{3}\mu_{02}; \quad \mu_{20}^{'} = \alpha^{3}\beta\mu_{20}; \quad \mu_{04}^{'} = \alpha\beta^{5}\mu_{04}; \quad \mu_{40}^{'} = \alpha^{5}\beta\mu_{40}. \tag{10}$$

And the proposed improve scale-invariants is given as:

$$\eta_{pq} = \frac{\mu_{20}^{\frac{p+1}{2}}\mu_{02}^{\frac{q+1}{2}}}{\mu_{40}^{\frac{p+1}{2}}\mu_{04}^{\frac{q+1}{2}}}\mu_{pq}. \tag{11}$$

4.3 An Integrated Scaling Factor of ASI and HOSI for UMI

UMI can be related to GMI by Hu[3] which consider Equation (2) in discrete form which is the normalized central moments and improved moment invariant by Chen [13] in Equation (3).

We consider only $\theta_1 = \frac{\sqrt{\phi_2}}{\phi_1}$. From Hu, $\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2$, substitute normalized central moments (Equation (2)) in $\phi_2 = (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2$, we get:

$$\phi_2 = \left(\frac{\mu_{20} - \mu_{02}}{\mu_{00}^2}\right)^2 + \frac{4\mu_{11}^2}{\mu_{00}^4}. \tag{12}$$

Substitute Equation (12) into Equation (2) yields,

$$\sqrt{\phi_2} = \frac{\sqrt{(\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2}}{\mu_{00}^2}, \tag{13}$$

and

$$\phi_1 = \eta_{20} + \eta_{02} = \frac{\mu_{20} + \mu_{02}}{\mu_{00}^2}. \tag{14}$$

Thus

$$\frac{\sqrt{\phi_2}}{\phi_1} = \frac{\sqrt{(\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2}}{\mu_{20} + \mu_{02}} = \theta_1. \tag{15}$$

The same process is evaluated for different scaling factor, i.e., in this study AIM and HOSI, as such the invarianceness is preserved, i.e., $\theta_1 = \theta_1^{'} = \theta_1^{''}$.

Table 1. United Moment Invariant for word 'the'

Image	Feature1	Feature2	Feature3	.....	Feature8	MAE
the	0.163643	0.181177	0.11855	.....	0.495573	-
the	0.266	0.562138	0.0762371	.....	0.800131	0.302756
.....	.....	.....	.....	.....	.....	.....
the	0.166986	2.34851	0.192149	.....	1.1421	1.25566
the	0.169181	0.407081	0.086464	.....	0.66748	0.185356
the	0.189428	0.392837	0.104704	.....	0.473099	0.0802216
						Average of MAE : 0.326363

Table 2. MAE comparison of 'the'

GMI	ASI -GMI	HOSI - GMI
1.08545	0.69487	0.689037
UMI	**ASI - UMI**	**HOSI - UMI**
0.326363	0.708906	0.757507

5 Simulation Result

The integrated scaling factor of AIM and HOSI into UMI are tested on unconstrained handwritten words. The invarianceness of the proposed method is compared with the original GMI, AIM, UMI and HOSI using WI data. The issue in WI domain is to find the individuality of handwriting for each writer based on the nearest unknown handwriting in the database. To achieve this, we implement intra-class testing to find the nearest words within the same class or the same writer with the lowest Mean Absolute Error (MAE) value to obtain authorship invarianceness. The MAE function is given by

$$MAE = \frac{1}{n}\sum_{i=1}^{n} |(x_i - r_i)|. \tag{16}$$

Table 1 shows the results of feature invariants for word the using UMI. The invarianceness of each word can be interpreted from the MAE values using the first image as reference image; small errors indicate that the image is closed to the original image.

Table 2 shows the MAE values for each moment technique. The experiments are further tested on different words, and the results are shown in Table 3 and Table 5.

Table 3. MAE comparison of 'to

GMI	ASI -GMI	HOSI - GMI
0.709941	0.736643	0.629964
UMI	**ASI - UMI**	**HOSI - UMI**
0.311558	0.529274	0.5566

Table 4. MAE comparison of 'been'

GMI	ASI -GMI	HOSI - GMI
0.476016	0.888376	0.522891
UMI	**ASI - UMI**	**HOSI - UMI**
0.157938	1.62514	0.572822

Table 5. MAE comparison of 'was'

GMI	ASI -GMI	HOSI - GMI
0.851661	1.92645	0.808092
UMI	**ASI - UMI**	**HOSI - UMI**
0.324343	2.40222	1.00364

Table 6. Invarianceness of Authorship using word 'the'

Technique	Intra-class (1 writer)	Inter-class (10 writer)	Inter-class (20 writer)
UMI	0.427206	0.779532	0.738287
HOI - UMI	0.523303	0.535963	0.607718
AIM - UMI	0.82022	0.930942	0.776517

The values of MAE from Table 2 to Table 5 show that UMI gives the lowest mean value compared to other moment techniques, and this include the proposed techniques that are incomparable with the original UMI. However the proposed techniques are able to validate the individuality concept in WI by looking at the stability of the invariants in terms of its intra-class and inter-class. The

Table 7. Invarianceness of Authorship using word 'and'

Technique	Intra-class (1 writer)	Inter-class (10 writer)	Inter-class (20 writer)
UMI	0.351629	0.583265	0.405239
HOI - UMI	0.597756	0.603427	0.610202
AIM - UMI	0.893293	1.63293	1.55194

Table 8. Invarianceness of Authorship using word 'to'

Technique	Intra-class (1 writer)	Inter-class (10 writer)	Inter-class (20 writer)
UMI	0.355736	1.38247	0.942613
HOI - UMI	0.499896	0.941884	0.786678
AIM - UMI	0.525682	1.13919	0.983311

Table 9. Invarianceness of Authorship using word 'that'

Technique	Intra-class (1 writer)	Inter-class (10 writer)	Inter-class (20 writer)
UMI	0.299813	0.457836	0.312279
HOI - UMI	0.543199	0.786766	0.830951
AIM - UMI	0.833782	1.30969	1.07363

difference of shape and style of writing of the same writer or intra-class are smaller compared to different writer or inter-class (see Table 6 to Table 9). The feature invarianceness of the same writer is smaller compared to different writer. From the tables, it shows that the proposed technique is able to identify writer authorship, thus the approach can be applied in WI domain to further validate the individuality of handwriting concept.

Individuality of handwriting concept has been proven in many researchers such as Srihari [23], Bin [25], and Liu [31]. However, our objective is to make contributions towards this scientific validation using our proposed techniques for individuality of handwriting concept in WI. In addition, UMI technique has never been tested in WI domain for feature extraction or authorship invarianceness. Therefore, the proposed techniques and UMI are worth for further exploration in WI.

6 Conclusion

This study proposed techniques of integrated scaling factor of Aspect Invariant Moment and Higher Order Scaling Invariant into United Moment Invariant for unconstrained word images. Computer simulations for unconstrained words have been implemented to verify the proposed techniques in identifying writers authorship. Despite of higher MAE values compared to UMI, the invarianceness of the proposed techniques are still preserved, thus conform to theoretical concept of moment invariants. Its authorship invarianceness are also proven, thus it is worth for further investigations for problem solving in WI and Moment Function domain.

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References

[1] Liao, S.X.: Image Analysis by Moment. Ph.D. thesis, University of Manitoba, Canada (1993)
[2] Mukundan, R., Ramakrishnan, K.R.: Moment Functions in Image Analysis - Theory and Applications. World Scientific Publishing Co.Pte.Ltd., Singapore (1998)
[3] Hu, M.K.: Visual Pattern Recognition by Moment Invariants. IRE Transaction on Information Theory 8(2), 179–187 (1962)
[4] Alt, F.L.: Digital Pattern Recognition by Moments. Journal of the ACM (JACM) 9(2), 240–258 (1962)
[5] Reiss, T.H.: The Revised Fundamental Theorem of Moment Invariants. Pattern Analysis and Machine Intelligence, IEEE Transactions 13(8), 830–834 (1991)
[6] Belkasim, S.O., Shridhar, M., Ahmadi, M.: Pattern Recognition With Moment Invariants: A Comparative Study and New Results. Pattern Recognition 24(12), 1117–1138 (1991)
[7] Pan, F., Keane, M.: A new set of moment invariants for handwritten numeral recognition. In: Image Processing, Proceedings. ICIP-94. IEEE International Conference, vol. 1, pp. 154–158. IEEE Computer Society Press, Los Alamitos (1994)
[8] Sivaramakrishna, R., Shashidhar, N.S.: Hu's Moment Invariant: How invariant are they under skew and perspective transformations? In: Conference on Communications, Power and Computing WESCANEX97 Proceedings, Winnipeg, MB, May 22-23, 1997, pp. 292–295 (1997)
[9] Palaniappan, R., Raveendran, P., Omatu, S.: New Invariant Moments for Non-Uniformly Scaled Images. Pattern Analysis & Applications 3, 78–87 (2000)

[10] Shamsuddin, S.M., Darus, M., Sulaiman, M.N.: Invarianceness of Higher Order Centralised Scaled-Invariants on Unconstrained Handwritten Digits. International Journal of Inst. Maths. & Comp. Sciences (Comp. Sc. Ser.), INDIA 12(1), 1–9 (2001)
[11] Ding, M., Chang, J., Peng, J.: Research on Moment Invariants Algorithm. Journal of Data Acquisition & Processing 7(2), 1–9 (1992)
[12] Lv, H., Zhou, J.: Research on Discrete Moment Invariance Algorithm. Journal of Data Acquisition & Processing 8(2), 151–155 (1993)
[13] Chen, C.-C.: Improved moment invariants for shape discrimination. Pattern Recognition 26(5), 683–686 (1993)
[14] Yinan, S., Weijun, L., Yuechao, W.: United Moment Invariant for Shape Discrimantion IEEE International Conference on Robotics, Intelligent Systems and Signal Processing, China, Oktober 2003, pp. 88–93 (2003)
[15] Raveendran, P., Omatu, S., Chew, P.S.: A new technique to derive invariant features for unequally scaled images. In: Systems, Man, and Cybernetics. IEEE International Conference, October 12-15, 1997. Computational Cybernetics and Simulation, vol. 4, pp. 3158–3163 (1997)
[16] Srihari, S.N., Huang, C., Srinivasan, H., Shah, V.A.: Biometric and Forensic Aspects of Digital Document Processing. In: Chaudhuri, B.B. (ed.) Digital Document Processing, Springer, Heidelberg (2006)
[17] Tapiador, M., Sigüenza, J.A.: Writer Identification Method Based on Forensic Knowledge. In: Zhang, D., Jain, A.K. (eds.) ICBA 2004. LNCS, vol. 3072, Springer, Heidelberg (2004)
[18] Yu, K., Wang, Y., Tan, T.: Writer Identification Using Dynamic Features. In: Zhang, D., Jain, A.K. (eds.) ICBA 2004. LNCS, vol. 3072, pp. 512–518. Springer, Heidelberg (2004)
[19] Zhu, Y., Tan, T., Wang, Y.: Biometric Personal Identification Based on Handwriting. In: Pattern Recognition. Proceedings. 15th International Conference, September 3-7, 2000, vol. 2, pp. 797–800 (2000)
[20] Schlapbach, A., Bunke, H.: Off-line Handwriting Identification Using HMM Based Recognizers. In: Proc. 17th Int. Conf. on Pattern Recognition, Cambridge, August 23-26, 2004, pp. 654–658 (2004)
[21] Bensefia, A., Nosary, A., Paquet, T., Heutte, L.: Writer identification by writer's invariants. In: Frontiers in Handwriting Recognition. Proceedings. Eighth International Workshop, August 6-8, 2002, pp. 274–279 (2002)
[22] Shen, C., Ruan, X.-G., Mao, T.-L.: Writer identification using Gabor wavelet. In: Intelligent Control and Automation. Proceedings of the 4th World Congress, June 10-14, 2002, vol. 3, pp. 2061–2064 (2002)
[23] Srihari, S.N., Cha, S.-H., Lee, S.: Establishing handwriting individuality using pattern recognition techniques. In: Document Analysis and Recognition. Proceedings. Sixth International Conference, September 10-13, 2001, pp. 1195–1204 (2001)
[24] Said, H.E.S., Tan, T.N., Baker, K.D.: Writer identification based on handwriting. Pattern Recognition 33, 149–160 (2000)
[25] Bin, Z., Srihari, S.N.: Analysis of Handwriting Individuality Using Word Features Document Analysis and Recognition. In: Proceedings. Seventh International Conference, August 3-6, 2003, pp. 1142–1146 (2003)
[26] Srihari, S.N., Cha, S.-H., Arora, H., Lee, S.: Individuality of Handwriting. Journal of Forensic Sciences 47(4), 1–17 (2002)
[27] Bensefia, A., Paquet, T., Heutte, L.: A writer identification and verification system. Pattern Recognition Letters, Corrected Proof, available online May 23, 2005 (in press)

[28] He, Z.Y., Tang, Y.Y.: Chinese handwriting-based writer identification by texture analysis. In: Machine Learning and Cybernetics. Proceedings of 2004 International Conference, August 26-29, 2004, vol. 6, pp. 3488–3491 (2004)
[29] Zhang, D.S., Lu, G.: Review of shape representation and description techniques. Pattern Recognition 37(1), 1–19 (2004)
[30] Raveendran, P., Omatu, S.: A new technique to derive features for shift and unequally scaled images. In: Neural Networks, Proceedings. IEEE International Conference, November 27-December 1, 1995, vol. 4, pp. 2077–2080. IEEE Computer Society Press, Los Alamitos (1995)
[31] Liu, C.-L., Dai, R.-W., Liu, Y.-J.: Extracting individual features from moments for Chinese writer identification. In: Document Analysis and Recognition. Proceedings of the Third International Conference, August 14-16, 1995, vol. 1, pp. 438–441 (1995)