SLANT ESTIMATION FOR HANDWRITTEN WORDS BY DIRECTIONALLY REFINED CHAIN CODE

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The authors proposed a chain code method[1] for the slant estimation and correction. However the method can usually gives good estimate of the word slant simply, the slant tends to be underestimated when the absolute of the slant is close or greater than 45°. To solve the problem, we propose an 8-directional method which can suppress the underestimate and improves the accuracy of the slant estimation effectively without sacrificing the processing speed and the simplicity. The relationship between the slant estimation accuracy and the directional refinement of the chain code is also discussed. Although the range of linear estimation is extended widely with the increase of directional resolution, the slant tends to be overestimated. However, we find if we neglect the chain elements close to the horizontal line, the overestimate can be suppressed properly.

1 Introduction

Handwritten words are usually slant or Italicized due to the mechanism of handwriting and the personality. In order to simplify the character segmentation task and to improve the accuracy of the character segmentation and recognition, several techniques for word slant estimation have been proposed, e.g. the runlength based technique[2], the projection method[3], the extrema analysis method[4], and the generalized chain code estimator[5].

The authors proposed a chain code method for the slant estimation and correction[1]. However the method usually gives good estimate of the word slant simply, there was a problem such that the relationship between the actual slant and the estimated slant is not linear, and the slant tends to be underestimated when the absolute of the slant is close or greater than 45°.

To solve the problem, the authors proposed an iterative chain code method[6] which repeats the slant estimation and the correction until the slant reduces to sufficiently small. Although the linearity and the accuracy were improved, the computational time was increased proportionally and the slant corrected image got jagged as the number of iteration increased.

In this paper we introduce a new non-iterative method using 8-directional

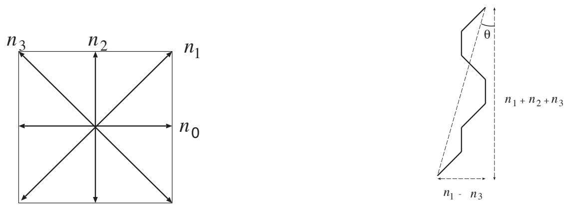

Figure 1: Average slant of a chain code sequence

chain code. In order to study the relationship between the estimation accuracy and the directional refinement of the chain code, we also evaluate the slant estimators with the directional resolution over 8.

2 Chain Code Method of 4-direction

2.1 Slant Estimate and Correction

Average slant of an English word is easily estimated using the chain code histogram of entire border pixels[1]. The estimator is given by

$$\theta = \tan^{-1}\left(\frac{n_1 - n_3}{n_1 + n_2 + n_3}\right) \tag{1}$$

where n_i is the number of chain elements at an angle of i x 45° (/ or | or \). Shear transformation (2) is then applied to correct the slant, where (x, y) and (x', y') are the coordinates of before and after the transformation respectively.

$$\begin{cases} x' = x + y\tan\theta \\ y' = y \end{cases} \tag{2}$$

Figure 1 shows that the slant of a chain code segment is calculated by (1). In this example, $n_1 = 3$, $n_2 = 3$ and $n_3 = 1$. Similarly, the average slant of a whole word is also estimated by (1).

2.2 Evaluation of Estimation Accuracy

In order to evaluate the estimation accuracy for an input pattern, we shear it by every 5° from $-60°$ to 60° and estimate the slant of each sheared word image.

Fig.2 shows the relationship between the angle of shearing and the estimated slant for a test pattern sheared by every 5° from $-60°$ to 60°.

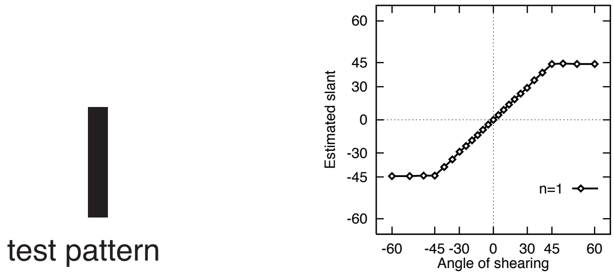

Figure 2: Evaluation of estimation accuracy for a test pattern

In the range of $[-45°, 45°]$, the estimated slant is almost linear and close to the actual slant of the input pattern. However, if the absolute of the slant exceeds 45°, the estimate is no more correct and valid. This phenomenon is attributed to the inequalities $n_1 - n_3 \leq n_1 + n_2 + n_3$ or $|\tan\theta| \leq 1$.

3 Accuracy Improvement by 8-directional Method

3.1 Slant Estimation by 8-directional Method

To avoid the underestimate and to extend the range in which the linearity is preserved, we propose an 8-directional chain code method described below.

Instead of tracing the entire border pixels with 8-neighborhood, we trace the every two pixels. Obtained chain code is then quantized to 8 directions as shown in Fig.3(a). Each direction is numbered 0 to 7 in counter clockwise, and n_i denotes the number of chain code elements in direction i.

The slant estimator of the 8-directional chain code method is given by

$$\theta = \tan^{-1}\{\frac{(2n_1 + 2n_2 + n_3) - (n_5 + 2n_6 + 2n_7)}{(n_1 + 2n_2 + 2n_3) + 2n_4 + (2n_5 + 2n_6 + n_7)}\} \tag{3}$$

where $(2n_1 + 2n_2 + n_3)$ is the sum of horizontal projection of the element 1, 2, 3, $(n_5 + 2n_6 + 2n_7)$ is the sum of horizontal projection of the element 5, 6, 7, and the denominator is the sum of vertical projection of the element 1 to 7.

Fig.3(b) shows the characteristic curve of the 8-directional method for the test pattern. This result shows that the linearity is preserved in wider range, which is potentially $[-\tan^{-1}(2),\ \tan^{-1}(2)]$.

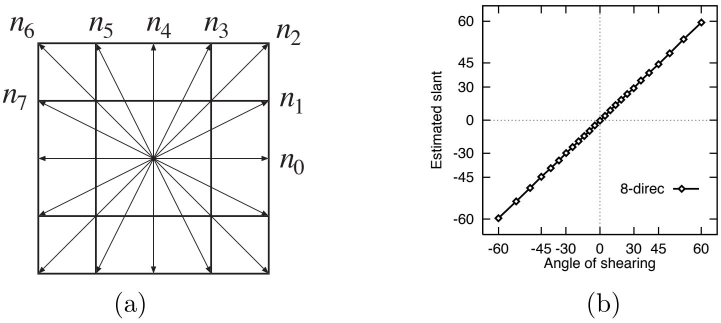

Figure 3: (a)8-directional quantization of chain code (b)Evaluation of estimation accuracy for the test pattern

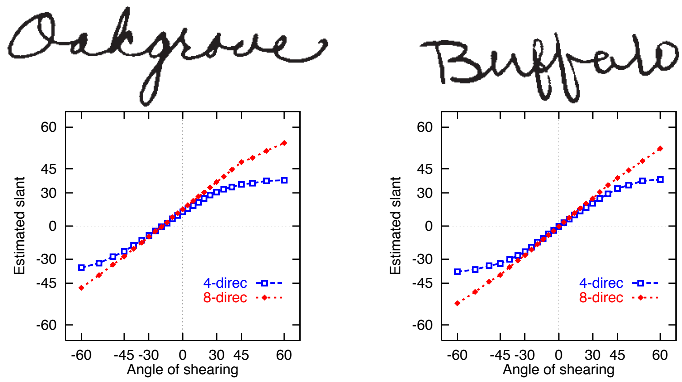

Figure 4: Accuracy comparison of the 4 and the 8-directional method

3.2 Evaluation and Comparison of Estimation Accuracy

Fig. 4 shows the characteristic curves of the 4-directional method and the 8-directional method for two real world data. Compared with the 4-directional method, the linearity in the range $[-60°, 60°]$ is improved by the 8-directional method.

Table 1 shows the average slope of the regression lines and the average correlation coefficients of the two methods for 1000 handwritten words.

Both of the two average statistics of the 8-directional method approach closer to 1 than those of the 4-directional method. The testing word images

Table 1: Average slope and average correlation coefficients

Range	Average of	Slant estimation method	
		4-dire	8-dire
[−45°,45°]	slope	0.63	0.83
	co-co	0.991	0.999
[−60°,60°]	slope	0.53	0.79
	co-co	0.971	0.996

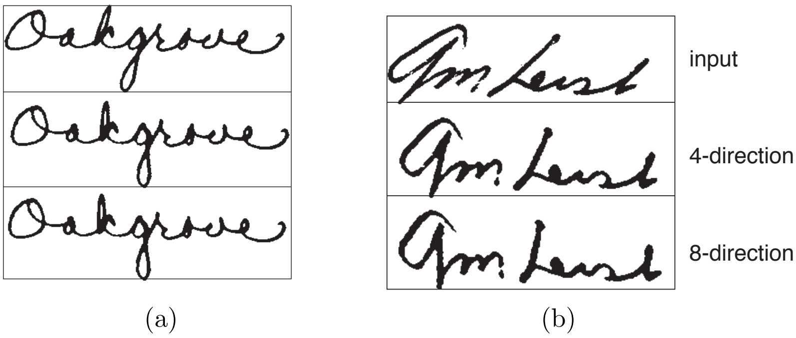

Figure 5: Comparison of slant corrected images

are those extracted from the "bha" database (handwritten address block data collected at Buffalo, New York).

Fig.5 shows examples of slant corrected word images. The upper row shows the input images, the middle and the bottom row show the slant corrected images by the 4 and the 8-directional method, respectively.

When the slant is not very large, both of the two methods give accurate estimates and correct it effectively(Fig.5(a)). However, when the slant is close or greater than 45°, the 8-directional method is obviously superior to the 4-directional method(Fig.5(b)).

4 Chain Code Method of 12-, 16-direction

4.1 Slant Estimators

To study the relationship between the slant estimation accuracy and the directional refinement of chain code, we further increase the directions of the chain code over 8 as described below.

Tracing the every three(four) pixels of the border curve, we can obtain the

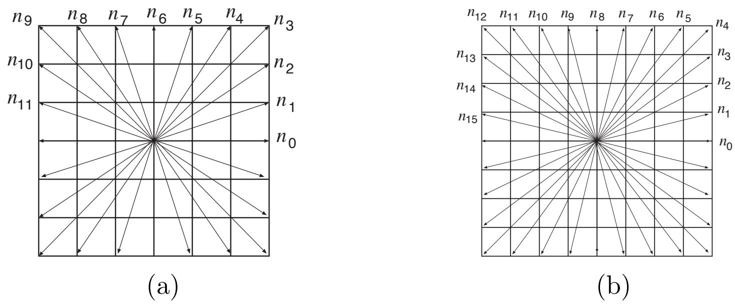

Figure 6: chain code of 12 and 16 directional quantization

chain code quantized to 12(16) directions(Fig.6(a),(b)).

The slant estimator of the 12-directional method is given by

$$\begin{aligned}\tan\theta &= \{(3n_1+3n_2+3n_3+2n_4+n_5)\\ &\quad -(n_7+2n_8+3n_9+3n_{10}+3n_{11})\}\\ &\quad /\{(n_1+2n_2+3n_3+3n_4+3n_5)+3n_6\\ &\quad +(3n_7+3n_8+3n_9+2n_{10}+n_{11})\}\end{aligned} \tag{4}$$

and the slant estimator of the 16-directional method by

$$\begin{aligned}\tan\theta &= \{(4n_1+4n_2+4n_3+4n_4+3n_5+2n_6+n_7)\\ &\quad -(n_9+2n_{10}+3n_{11}+4n_{12}+4n_{13}+4n_{14}+4n_{15})\}\\ &\quad /\{(n_1+2n_2+3n_3+4n_4+4n_5+4n_6+4n_7)+4n_8\\ &\quad +(4n_9+4n_{10}+4n_{11}+4n_{12}+3n_{13}+2n_{14}+n_{15})\}\end{aligned} \tag{5}$$

from the estimator (4), the range of the slant that can be estimated is potentially $[-\tan^{-1}(3),\ \tan^{-1}(3)]$, and from (5), the range is further extended to $[-\tan^{-1}(4),\ \tan^{-1}(4)]$.

4.2 Evaluation and Comparison of the Slant Estimation

Fig.7 shows the characteristic curves of the 4, 8, 12 and 16-directional method, (a) is for the test pattern and (b) for a real handwritten word. With the increase of the directional resolution of the chain code, the linearity is improved and almost approaches perfection in the range of $[-60°, 60°]$.

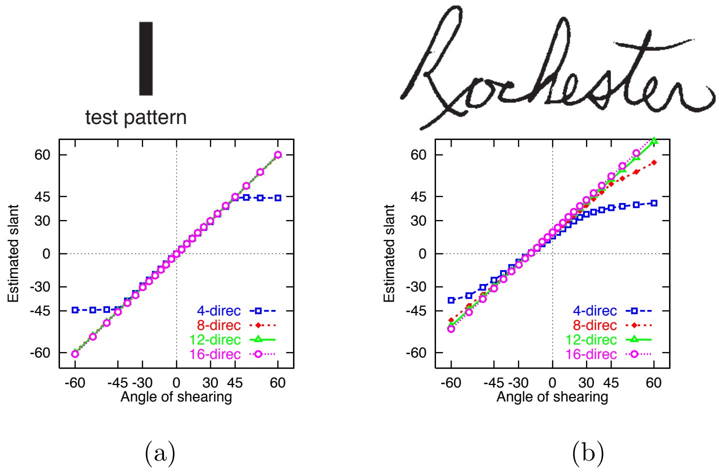

Figure 7: Accuracy comparison of the four methods

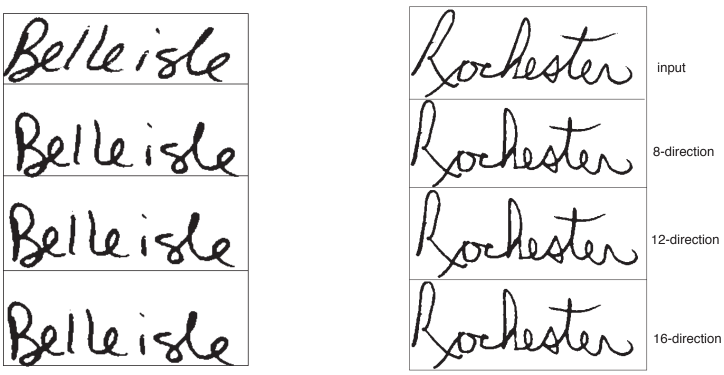

Figure 8: Comparison of slant corrected images by three methods

Fig.8 shows the slant corrected results for two examples by the 8-, 12- and 16-directional method. It seems that either of the three methods can correct the slant perfectly.

However, if an input word image contains close horizontal strokes with slightly right upper direction, the slant maybe overestimated by the 12- or 16-directional method. Fig.9 shows the example of overestimate for an input image. Although the linearity is improved apparently, the slant tends to be

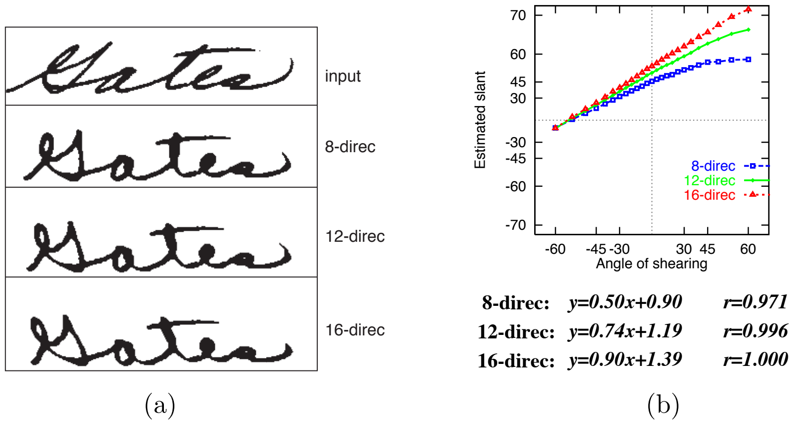

Figure 9: Example of overestimate for a handwritten word

overestimated when the directional resolution exceeds 8 (Fig.9(a)). The difference of the estimating characteristics of the three methods is clearly shown in Fig.9(b).

4.3 Modified 16-directional Method

To avoid the overestimate, we tested a modified 16-directional method which employs the chain elements in direction 2∼14(Fig.6(b)) for slant estimation and neglects the direction 1 and 15 close to the horizontal line.

Fig.10 shows examples of slant corrected word images by the 8, 12, 16 and the modified 16-directional method. The results of the modified 16-directional method are better than those of the 16-directional method and close to those of the 8-directional method.

4.4 Evaluation and Comparison of Processing Time

Average processing time of slant estimate for 100 handwritten words by each method is tabulated in Table 2. Used CPU is a hyper SPARC 125MHz. In the iterative method, the 4-directional method was applied twice successively. Except that the processing time of the iterative method increases proportional to the number of iteration, the processing time of other methods is almost the same.

Figure 10: Comparison of slant corrected images

Table 2: Average processing time for slant estimate

	4-direc	iterative	8-direc	12-direc	16-direc	modified 16-direc
time(sec)	0.50	0.99	0.49	0.50	0.50	0.49

4.5 Comparison with Manual Measurement of Slant

Table 3 shows the slant of ten handwritten English words estimated by the chain code methods and the average of manual measurements with a protractor by 20 persons. The comparative results show that the slant estimated by the 4-directional method tends to be smaller and the slant estimated by the 12-, 16-directional method tends to be larger. The 8-directional and the modified 16-directional method together with the iterative 4-directional method(twice) give good estimates of the manually measured average slant.

5 Conclusion

In this paper, we discussed the slant estimation accuracy by the directional refinement of the chain code. The experimental results show that the 4-directional method has a defect of underestimate while the 12- and the 16-directional methods tend to overestimate. The 8-directional method which

Table 3: Comparison with manual measurement of slant

Image	Estimated slant(degree)						
	4-direc	iterative	8-direc	12-direc	16-direc	M-16	Manual
im01	13.81	16.53	16.87	18.51	19.82	16.50	15.87
im02	19.28	27.44	27.02	31.27	33.54	28.59	29.12
im03	29.27	36.89	36.62	39.97	42.54	38.40	35.25
im04	18.31	22.60	23.47	26.41	28.28	24.14	24.25
im05	-12.88	-16.53	-15.93	-17.88	-19.16	-17.10	-15.12
im06	-22.17	-28.96	-27.72	-30.96	-34.01	-29.41	-29.50
im07	33.25	43.25	42.57	46.48	49.37	42.96	40.25
im08	32.67	45.27	44.95	50.24	53.56	46.97	43.00
im09	33.08	46.24	45.62	52.02	55.97	47.87	44.62
im10	37.75	46.77	45.66	47.99	49.33	47.78	45.05

can improve the linearity and the accuracy of the slant estimate effectively is proved to be totally superior to others.

Estimate of local slant and slant estimate of oriental character strings are remained as future research topics.

References

1. F.Kimura, M.Shridhar and Z.Chen, "Improvements of a Lexicon Directed Algorithm for Recognition of Unconstrained Handwritten Words", Proc. of the 2th ICDAR, pp. 18-22, Oct. 1993.
2. R.M. Bozinovic and S.N. Srihari, "Off-line Cursive Script Word Recognition", IEEE Transactions on PAMI, vol. II, No. 1, pp. 68-83, Jan. 1989.
3. Didier Guillevic, Ching Y. Suen, "Cursive Script Recognition: A Sentence Level Recognition Scheme", Proc. of The 4th IWFHR, pp. 216-223, Dec.1994.
4. Atul Negi, K.S.Swaroop, Arun Agarwal,"A Correspondence Based Approach to Segmentation of Cursive Words", Proc. of the 3th ICDAR, vol. II, pp. 1034-1037, Aug. 1995.
5. L.Simoncini, Zs.M.Kovacs-V, "A System for Reading USA Census'90 Hand-Written Fields", Proc. of the 3th ICDAR, Vol. II, pp. 86-91, Aug. 1995.
6. Yimei Ding, Fumitaka Kimura, Yasuji Miyake, Malayappan Shridhar, "Evaluation and Improvement of Slant Estimation for Handwritten Words", Proc. of the Fifth ICDAR, pp. 753-756, Sep. 1999.