Finger Vein Image Recognition Based on Tri-value Template Fuzzy Matching

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Abstract: This paper presents a tri-value template fuzzy match algorithm to reduce the effect of fuzzy edges and tips of infrared finger vein image in the template matching. The proposed method segments the vein feature image into three areas: subject area, fuzzy area and background area and compute the average distance of non-background point to non-background area as the dissimilarity score between the two templates. The proposed approach is robust against the fuzzy edges and tips, and does not require knowledge of correspondence among those points in the two templates. The minimum error rate, 0.54% to 456 near-infrared finger vein images, shows that the proposed method is feasible and practical.
Key words: infrared finger vein; tri-value template; fuzzy matching

1 Introduction

More and more biometric features are applied in the personal identification, such as fingerprint, iris and face. Compared to these available biometric features, the application of finger vein has four advantages[1]:

Firstly, it does not need physical contact and will not displease the people, much better than fingerprint and iris scanning.

Secondly, it has forceful universality and uniqueness. The adults' finger vein has less change with the age. And different people have different vein patterns.

Thirdly, it is very hard to capture the finger vein image for forgery in normal contact because the vein is hypodermal, better than other biometric features on the surface, such as fingerprint and face.

Lastly, the temperature, humidity and cleanliness have little effect on the vein image.

The finger vein patterns can be adopted for general public use, such as for on-line identification, ATM (Automatic Teller Machines). In medicine field, the patterns can be used for patients recognition and injecting vein(IV).

As light within red and near-infrared band (wavelengths 720nm -- 1100nm) is absorbed intensively by the hemoglobin in the blood of vein and transmits other tissues of finger easily, the finger vein patterns can be captured as dark lines. Figure 1 shows the samples of infrared finger vein images. Vein patterns have many line features, such as trunks and branches, which can be discriminated between different vein patterns.

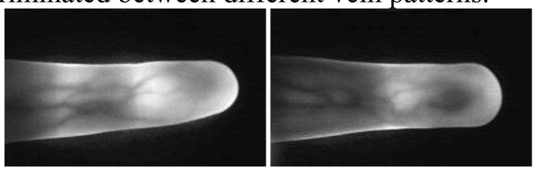

Figure 1 origin infrared finger vein images

Normaly, the infrared finger vein image has low contrast and speckling noise because of two points:
(i) The definition of origin infrared image is quite low and has random speckle noises.
(ii) Brightness is not uniform because the thickness of one finger is asymmetric.

In general, the vein feature has precarious edges and tips by available vein feature extract schemes. Therefore the matching method should have fuzzy tolerance matching capability. We present a tri-value template fuzzy matching, which segments the vein feature image into three areas: subject area, fuzzy area and background area. This matching method compute the average distance of non- background point to non-background area as the dissimilarity score. This method does not need the knowledge of correspondence among points in the two matching templates and has elastic matching capability by optimal distance norm to different non-background areas.

This paper is organized as follows: Section 1 is the introduction. Section 2 dexcribes the procedure of tri-value template fuzzy matching.

Section 3 presents the experiment by proposed method. Section 4 presents the discussion of experimental results. Finally, conclusions are given in Section 5.

2 Tri-value Template Fuzzy Matching

2.1 Tri-value Template Acquisition

Assume that the vein feature image I(i,j) is segmented to three property areas: the subject area which is signed A, the background area signed B and the fuzzy area signed C. Create the tri-value template I3(i,j). The process of segmentation is defined by the following formula (1):

$$\begin{cases} I3(i,j) \in A & I(i,j) \ge T1 \\ I3(i,j) \in B & I(i,j) \le T2 \\ I3(i,j) \in C & others \end{cases} \tag{1}$$

Where, T1 and T2 is the threshold of segmentation. Usually, the subject area involves trunks of veins and the fuzzy area involves ambiguous edges and tips of vein.

2.2 Tri-value Template Fuzzy Matching

The tri-value template fuzzy matching is based on assumption that different non-background area has different amounts of importance for matching. Given two tri-value templates $M1 = M1A \cup M1B \cup M1C$ and $M2 = M2A \cup M2B \cup M2C$. The dissimilarity score between the two templates is measured by the average distance of non-background point to non-background area. Define the directional distance $d_{M1M2}(i,j)$, which is set zero by the conditions of formula (2):

$$\begin{cases} d_{M1M2}(i,j) = 0 & M1(i,j) \in B \\ d_{M1M2}(i,j) = 0 & M1(i,j) \in A, M2(i,j) \in A \\ d_{M1M2}(i,j) = 0 & M1(i,j) \in C, M2(i,j) \in C \end{cases} \tag{2}$$

For other conditions, the directional distance $d_{M1M2}(i,j)$ between a nonzero point M1(i,j) and the non-background area $M2A \cup M2C$ is defined as formula (3):

$$\begin{cases} d(i,j) = 0.5*(d_{M1M2}(i,j) + d_{M2M1}(i,j)) \\ d_{M1M2}(i,j) = \min\{d(M1(i,j), M2A \bigcup M2C)\} \\ d_{M2M1}(i,j) = \min\{d(M2(i,j), M1A \bigcup M1C)\} \end{cases}$$

(3)

The dissimilarity score between M1 and M2 is defined as formula (4):

$$d(M1,M2) = \frac{1}{N_{M1} + N_{M2}} \sum d(i,j) \tag{4}$$

Where N_{M1} and N_{M2} are the number of nonzero points in temple M1 and M2 respectively. The score means the dissimilarity and the more lower score, the more similar the two Templates.

2.3 Calculation of the proposed matching

The tri-value template fuzzy matching is calculated by the following procedure:

Step 1: Create and initialize the tri-value template from finger vein feature image I(i,j). Set threshold T1 = 192 and T2 = 128, initialize the tri-value template I3(i,j) by formula (5):

$$\begin{cases} I3(i,j) = 1 & I2(i,j) \ge T1 \\ I3(i,j) = 0 & I2(i,j) \le T2 \\ I3(i,j) = 0.5 & others \end{cases}$$

(5)

The tri-value template is shown in figure 2:

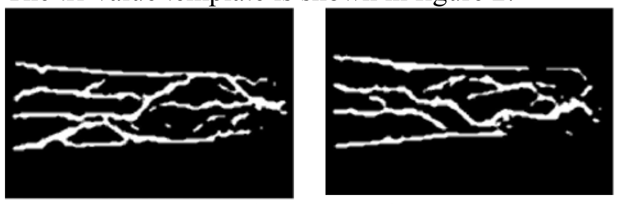

Figure2 Examples of tri-value templates

In the tri-value template, the white area means vein trunk(area A), the gray area means ambiguous edges or tips(area C) and the black part(area B) means background.

Step 2: Calculate the distance maps of the subject (area A) and the fuzzy edge and tip(area C) by different distance norms respectively. The distance norms of area A and C is defined as:

$$\begin{matrix} b & a & b \\ a & 0 & a \\ b & a & b \end{matrix} \quad and \quad \begin{matrix} b' & a' & b' \\ a' & 0 & a' \\ b' & a' & b' \end{matrix}$$

(6)

The final distance map D(i,j) is calculated by formula (7) and shown in figure 3:

$$D(i,j) = \min(DA(i,j), DC(i,j)) \tag{7}$$

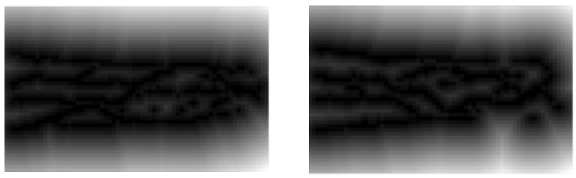

Figure 3 The distance map of tri-value template

Step 3: Calculate the dissimilarity score by formula (8):

$$D(M1,M2) = \frac{1}{2(N_{M1} + N_{M2})} \bullet \left(\sum \left| M1(i,j) - M2(i,j) \right| \bullet (D_{M1}(i,j) + D_{M2}(i,j))\right)$$

(8)

The formula (8) is equivalent to formula (4), and the flowchart of calculating the score of tri-value template fuzzy matching is described in figure 4:

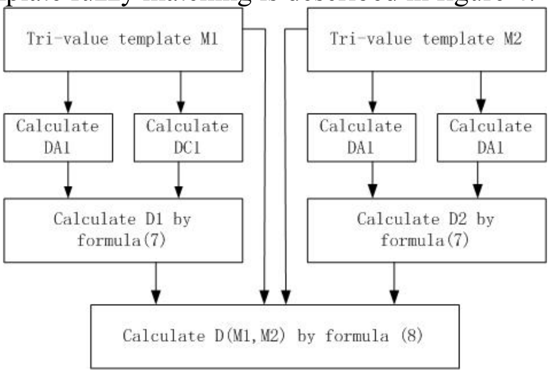

Figure 4 Flowchart of calculate tri-value template fuzzy matching

3 Experiment and result

3.1 Experiment and image acquisition

In the experiment, we capture 456 infrared finger vein images from 76 fingers, 6 images for one finger. The experiment procedure includes the following four steps: infrared finger vein image acquisition, image preprocess, vein feature extraction and matching.

Step 1: The schematic diagram and prototype device for obtain near-infrared finger vein image is decribed in figure 5 (a) and (b):

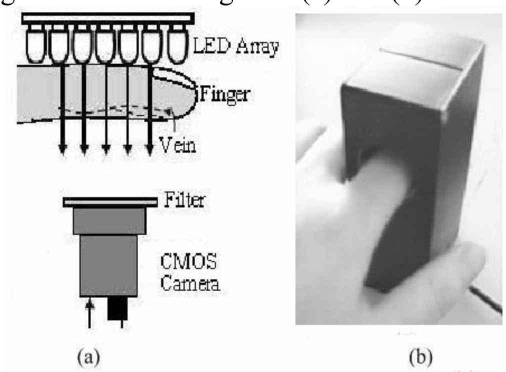

Figure 5 The schematic and prototype device

Using an array of mold type near-infrared LEDs(wavelength 850 nm) as the light source, its intensity of light can be manually adjusted. The dorsal side of the finger is illuminated by the LED array, and a CMOS camera with a infrared filter capture the image.

The size of original gray-scale image captured is 320*240 and figure 1 shows two examples.

Step 2: Pre-process includes low-pass filter, finger edge detection, finger body extraction, finger rotation and size normalization. The figure 6 shows the flowchart of finger image preprocessing.

A 5*5 Gaussian low-pass filter is adopted to remove speckling noises in the original image. Sobel edge detection extracts the finger's outline, which describes the shape of the finger and can be used to extract the finger body. The areas outside finger is zero padded. Use least-squares line-fit of finger outline to estimate the slope angle of the finger. Then the finger image is rotated clockwise to be horizontal by the angle of the slope. At last, the finger image is cut off from the tip to the body by the normalized size 198*132.

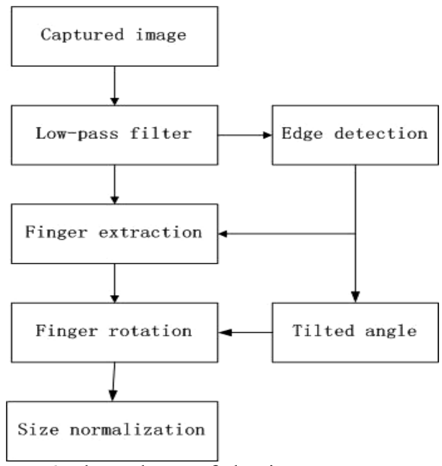

Figure 6 Flowchart of the image preprocess

Step 3: To solve the brightness fluctuations and low contrast problems in the near-infrared finger vein image, we use the repeated line tracking to extract the vein feature[2]. This scheme consists of tracking a dark line, iteratively tracking the lines and obtaining finger vein patterns based on the number of times of tracking.

The preprocessed image and vein feature image are shown in the figure 7 (a) and (b), respectively.

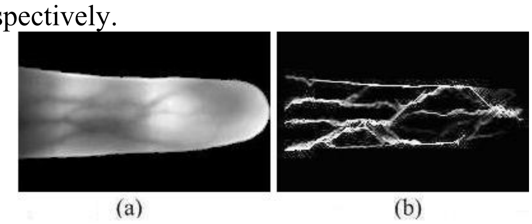

Figure 7 Preprocessed image and vein feature image

Step 4: Tri-value template matching.

The finger edges are reserved for template matching because the shape of finger outline also has distinct line character. In the tip part of finger, the veins are too slight and dense to extract robustly. So the center block(132*88) of the tri-value template is taken as the region of interesting(ROI) to matching, which is shown in figure 8. Correspond to this, the distance map's ROI is its center block(132*88).

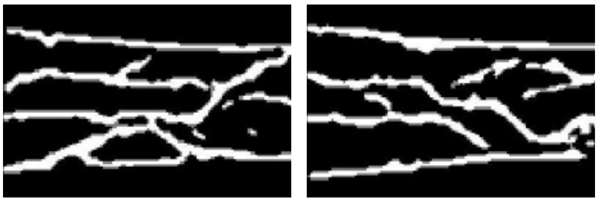

Figure 8 ROI of the tri-value template

To make image matching registration easily, we use sliding window matching. The size of sliding window is 100*60. The minimum score of the sliding match records is regarded as the dissimilarity of the two tri-value templates.

3.2 Matching result

We calculate the tri-value template fuzzy matching of arbitrary two images in the 456 images. The number of matching between identical fingers is: $76 \times C_6^2 = 1140$, which is signed N_1.

And the number of matching between unrelated fingers is:

$C_{456}^2 - 76 * C_6^2 = 102600$, which is signed N_2.

Figure 9 shows the histogram of the matching result by proposed method. Black bars denote the histogram of identical finger and gray bars denote that from unrelated fingers.

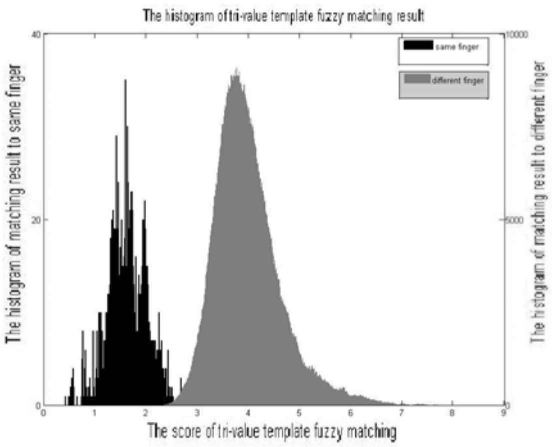

Figure 9 Normalized histograms

Figure 9 shows that finger identification is possible for the same and different finger distributions separately. In addition, overlapping of the two histograms is very little by the proposed matching method. The error rate of identification accuracy include false acceptance rate(FAR) and false rejection rate(FRR), which is defined as:

$$\begin{cases} FAR(D0) = [N(D_d > D0)] / N_2 \\ FRR(D0) = [N(D_s \le D0)] / N_1 \end{cases} \quad (9)$$

Where D0 is the threshold, D_d is the matching score between different fingers and D_s is the matching score between same fingers.

To evaluate the optimal threshold for minimum error rate, Di is defined as a variable which increases 0.01 from 2 to 3. Then we calculate the FARi and FRRi to Di. The FAR and FRR curves is plotted in the figure 10:

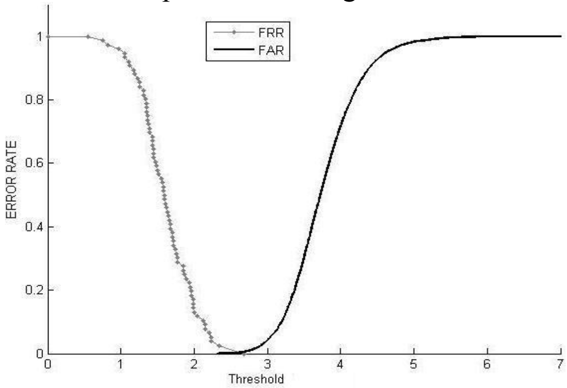

Figure 10 FAR and FRR curves

Finally the EER is determined by searching Di so that FARi + FRRi is minimized. The Di which make FARi = FRRi may not exist since FAR and FRR are discontiguous variable. The error statistics is shown in table 1:

Table 1 The error rate of proposed match method

Threshold(D0)	2.21	2.73	2.84
FAR	0	0.11%	1.28%
FRR	2.36%	0.43%	0
ERR	2.36%	0.54%	1.28%

In our experiment, the minimum EER is 0.54% when threshold D0 = 2.73, FAR = 0.11% and FRR = 0.43%.

3.3 Parameter discussion

In the experiment, Euclidean distance is used in the distance norms. Assume that p is a point belong to area A and q is a point belong to area C in the formula (10). So the distance between the p and its neighbour points should be the minimum value. For example, in the top-left position, there are two possible values: a and b'. It is abvious that a < b' in the distance map. Similarly, a' < b in the top-middle position.

$$\begin{array}{ccc} a(b') & b(a') & \sqrt{5}a(b') \\ p & q & 2a(a') \\ a(b') & b(a') & \sqrt{5}a(b') \end{array} \quad (10)$$

We can draw a conclusion that the value of a' should be in the range (a, b) in the Euclidean distance. Assume that a = 1 and b = 1.414. To evaluate the optimal a' for minimum error rate, we draw the a'—ERR curve in the figure 11:

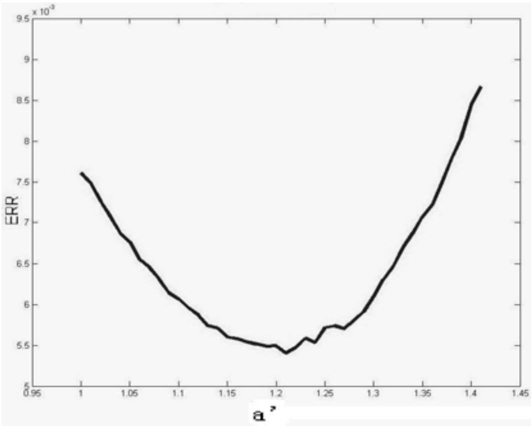

Figure 11 a’—ERR curve

The optimal value of a’ is 1.21 on which make the minimum of ERR 0.54%.

3.4 Result discussion

Based on the experiment data, we also test other three matching method: the direct gray correlation coefficient[3], the modified Hausdorff distance (MHD)[4] and the miss-point statistic match (Miss-Match)[2] method.

The direct gray correlation coefficient is defined as formula (11):

$$r=\frac{\sum_m\sum_n(M1_{mn}-\overline{M1})(M2_{mn}-\overline{M2})}{\sqrt{(\sum_m\sum_n(M1_{mn}-\overline{M1})^2)(\sum_m\sum_n(M2_{mn}-\overline{M2})^2)}}$$

(11) And the result is shown in table 2.

Table 2: The Error statistic of direct correlation

Threshold	0.72	0.86	0.94
FAR	36%	8.3%	0
FRR	0	16%	43%
ERR	36%	24.3%	43%

After preprocessing, the gray images of finger keep the low contrast and unclear edges. Calculation correlation coefficient directly of gray images is not suitable for matching.

The Modified Hausdorff Distance(MDH) is defined as:

$$H_{MHD}(A,B)=\frac{N_A h(A,B)+N_B h(B,A)}{N_A+N_B}$$

(12)

And its test result is shown in table 3.

Table 3: The Error statistic of MDH

Threshold	0.74	0.81	0.92
FAR	0	0.13 %	1.33%
FRR	3.54%	0.72%	0
ERR	3.54%	0.85%	1.33%

Though the MHD method has some fuzzy matching capability, there are many ambiguous edges and tips around the vein which lead to the primary similar error effect in matching. Consequently, MDH is not the optimized method for our experiment.

The miss-point statistic match (Miss-Match)[3] method. This mismatch ratio is defined as

$$Rm=\frac{N_m}{N_A}\times 100\% \tag{13}$$

Here N_m is the sum of overlapped points which belong to vein area and ambiguous area in the two templates, respectively. N_A is the sum of points in vein region in two templates. The test result is shown in table 4:

Table 4: The Error statistic of miss-match

Threshold	0.48	0.52	0.55
FAR	0	0.24 %	2.32%
FRR	6.57%	1.30%	0
ERR	6.57%	1.54%	2.32%

This method ignores the effect of ambiguous area and leads to some additional error rate correspondingly.

The tri-value template fuzzy matching utilizes a priori knowledge that different class regions have different amounts of importance. In measuring the distance between two point sets, we increase the distance norm on the ambiguous area properly. Thus the effect of ambiguous edges around veins is weakened and depressed. Table 1,2,3 and 4 shows the proposed method has the least error rate among these methods.

Also the region of interesting(ROI) is important to the template matching. As mentioned above, the veins in the tip part of finger are too slight and dense to extract robustly. If make the entire images as ROI, the size of template is 198*132, and choose the size of sliding window is 120*90. The matching result of using entire finger as the ROI is shown in table 5:

Table 5 The matching result of entire finger

ROI	Entire finger
ERR of Proposed matching	13.23%
ERR of MDH	15.56%
ERR of Miss-Match	19.62%

Because the veins concentrate in the finger tip, the extracted vein features of each finger are quite similar.

Furthermore, we also test two scheme of the vein feature extraction: matched filter[5] and local threshold[6].

The matched filter concludes four direction enhance filters, in which the horizon filter is defined as formula 14, and the others are this filter rotated by multiples of 45^{O}:

$$\begin{matrix} 26 & 8 & -18 & -32 & -18 & 8 & 26 \\ 26 & 8 & -18 & -32 & -18 & 8 & 26 \\ 26 & 8 & -18 & -32 & -18 & 8 & 26 \\ 26 & 8 & -18 & -32 & -18 & 8 & 26 \\ 26 & 8 & -18 & -32 & -18 & 8 & 26 \\ 26 & 8 & -18 & -32 & -18 & 8 & 26 \\ 26 & 8 & -18 & -32 & -18 & 8 & 26 \end{matrix} \quad (14)$$

The binary image of vein feature by this extract scheme is shown in figure 12:

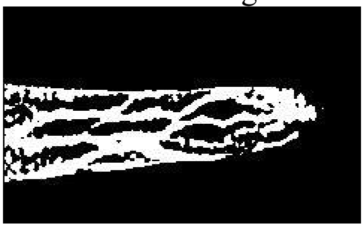

Figure 12 Vein feature of matched filter

The local threshold scheme uses OSUT threshold in the block, which size is 7*7. The binary image of vein feature is shown in figure 13:

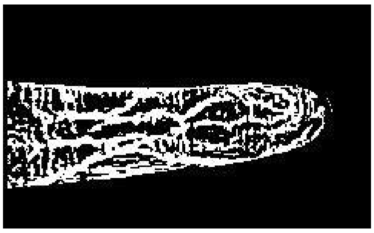

Figure 13 Vein feature of local threshold

The error statistics of these feature extract schemes is shown in table 6:

Table 6 The ERR of other feature extact method

Feature extraction scheme	Matched filter	Local threshold
ERR of propoed mechod	4.32%	4.04%
ERR of MHD	5.15%	4.70%
ERR of miss-match	9.27%	7.48%

From table 1,2,3,4,5 and 6, the proposed matching method has the lowest error rate in the same conditions.

In the experiment, the hardware developement environment includes: Celeron CPU 2.66GHz and 768M Memory and software: Windows XP and Visual C++ 6.0. The response time of image capture, pretreatment, feature extract and matching is below 2 seconds.

4 Conclusion

In this paper, we propose a tri-value template fuzzy matching for finger vein recognition. Experiment results show that the error rate of proposed method is 0.54% and it is feasible for vein fuzzy matching. Further works include searching fast distance transform algorithm and designing better infrared image capture system.

Acknowledgements

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References:

[1] Kono M，Ueki H，Umemura S．Personal identification method using finger vein patterns. 5th Pattern Measurement Symposium Data，p9-12, 2000．

[2] Naoto Miura, Akio Nagasaka, et al. Feature extraction of finger-vein patterns based on repeated line tracking and its application to personal identification [J].Machine Vision and Applications. Digital Object Identifer, 2004,10.1007

[3] Gonzalez, R.C., Woods, R.E.: Digital Image Processing [M] Second edition, New Jersey: Prentice Hall, 2003.

[4] M.P.DUBUSION, A.K.JAIN.A, modified haus- dorff distance for object matching [C].Processing of the 12th International Conference on Pattern Recognition. Jerusalem, Israel:IEEE Computer Society Press, 1994. 566-568.

[5] Hoover A, Kouznetsova V, Goldbaum M(2000) Locating blood vessels in retinal images by piece-wise threshold probing of a matched filter response, IEEE Trans Med Image 19(3):203-210.

[6] Lin Xirong, Zhuang Bo, et al, Measurement and matching of human vein pattern characteristics, J Tsinghua Univ(Sci & Tech), 2003, Vol.43, No.2, pp.164--167