발자국 패턴을 이용한 곤충 판별 기법을 위한 전처리 과정

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Preprocessing Methods for Insect Identification Using Footprints

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요 약

이 논문에서는 트래킹 터널 또는 트래킹 카드를 이용하여 살아있는 곤충의 발자국을 획득한 후 남겨진 발자국 패턴을 이용하여 곤충의 부류나 종류를 판단하는 인식 시스템을 위한 전처리 과정을 살펴본다. 특히 발자국 패턴을 획득하는 과정과 곤충 발자국의 특징을 추출하기에 적합한 스캔된 발자국 이미지의 이진화 과정에 대하여 고찰한다. 이진화 과정에서는 기존에 발표된 대표적인 이진화 알고리듬 3가지를 구현하여 비교 분석하였다. 비교 분석 결과 Abutaleb에 의해 제안된 고차 엔트로피 이진화 알고리듬이 가장 우수한 결과를 보였다.

ABSTRACT

The comparison of 3 conventional binarization methods for insect footprints and the result of performance evaluation using a proposed performance criterion are introduced in this paper. The 3 different binarization algorithms for comparison are based on different category each, and the proposed performance criterion is based on the characteristics of insect footprints which have very smaller foreground area than background area. In the experiments, average performance results using 71 test images are compared and analyzed. The higher-order entropy binarization algorithm proposed by Abutaleb showed the best result for pattern recognition applications of insect footprints.

키워드

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Ⅰ. Introduction

In order to get good pattern recognition results using binarized images, it is important that we should get good binarized images by a suitable binarization algorithm. There have been so many proposed binarization algorithms[meh04] by many researchers until now. But there is no absolutely good binarization algorithm for all kinds of grey images. Some binarization algorithms are good for certain types of grey images but bad for other types of grey images.

So we compared 3 representative conventional binarization algorithms for binarizing insect footprints, which have relatively small foreground area compared to background area, and presented the best binarization algorithm for pattern recognition of insect footprint using a proposed a binarization performance criterion. The proposed binarization performance criterion is based on the characteristics of insect footprints.

In section 2, the detail methods and formulas of 3 binarization algorithms for comparison are explained. In section 3, the proposed binarization performance criterion is presented. In section 4, test images for experiment are shown and the experimental results are presented. And finally we conclude with the conclusion in section 5.

Ⅱ. 3 Binarization Algorithms for Comparison

Researches on binarization of gray images have been done by many researchers for a long time. There are also many papers about binarization algorithms. In [Meh04], 40 binarization algorithms are compared by two kinds of test data set. In the binarization evaluation ranking tables in [Meh04], it shows that the performance of each algorithm is different when different type of test data set is applied.

Because of this reason, we could not decide which is the best binarization algorithm for insect footprints. We selected 3 different binarization algorithms that already considered relatively good for the above two kinds of test data set. The selected 3 binarization algorithms are as follows.

- Rosenfeld's convex hull binarization algorithm[Ros83]
- Abutaleb's higher-order entropy binarization algorithm[Abu89]
- Bernsen's local contrast binarization algorithm[Ber86]

[1] Rosenfeld's convex hull binarization algorithm

This algorithm is based on analyzing the concavities of the histogram h(g) vis-à-vis its convex hull, Hull(g), that is the set theoretic difference |Hull(g) - p(g)|. When the convex hull of the histogram is calculated, the deepest concavity points become candidates for a threshold. In case of competing concavities, some object attribute feedback, such as low busyness of the threshold image edges, could be used to select one of them. In this algorithm, the following equation is used for finding optimal threshold value.

$$T_{opt} = \arg\max\{[p(g) - Hull(g)]\} \qquad (1)$$

[2] Abutaleb's higher-order entropy binarization algorithm

This algorithm assumes the joint entropy of two related random variables, namely, the image gray value g at a pixel, and the average gray value $\bar{g}$ of a neighborhood centered at that pixel. Using the 2-D histogram p(g, $\bar{g}$), for any threshold pair (T, $\bar{T}$), one can calculate the cumulative distribution P(T, $\bar{T}$), and then define the foreground entropy as

$$H_f = -\sum_{i=1}^{T} \sum_{j=1}^{\bar{T}} \frac{p(g,\bar{g})}{P(T,\bar{T})} \log \frac{p(g,\bar{g})}{P(T,\bar{T})} \qquad (2)$$

Similarly, one can define the background region's second order entropy. Under the assumption that the off-diagonal terms, that is the two quadrants [(0, T), ($\bar{T}$, G)] and [(T, G), (0, $\bar{T}$)] are negligible and contain elements only due to image edges and noise, the optimal pair (T, $\bar{T}$) can be found as the minimizing value of the 2-D entropy functional. In this algorithm, the following equation is used for finding optimal threshold value.

$$(T_{opt}, \bar{T}_{opt}) = \arg\min\{\log[P(T,\bar{T})[1-P(T,\bar{T})]] + H_f / P(T,\bar{T}) + H_b / [1-P(T,\bar{T})]\}$$

where

$$H_f = -\sum_{i=1}^{T} \sum_{j=1}^{\bar{T}} \frac{p(g,\bar{g})}{P(T,\bar{T})} \log \frac{p(g,\bar{g})}{P(T,\bar{T})} \quad \text{and}$$

$$H_b = -\sum_{i=T+1}^{G} \sum_{j=\bar{T}+1}^{G} \frac{p(g,\bar{g})}{1-P(T,\bar{T})} \log \frac{p(g,\bar{g})}{1-P(T,\bar{T})} \qquad (3)$$

[3] Bernsen's local contrast binarization algorithm

In the local binarization algorithm of Bernsen, the threshold is set at the midrange value, which is the mean of the minimum $I_{low}(i,j)$ and maximum $I_{high}(i,j)$ gray values in a local window of suggested size w=50. However, if the contrast $C(i,j) = I_{high}(i,j) - I_{low}(i,j)$ is below a certain threshold (this contrast threshold was 50), then that neighborhood is said to consist only of one class, print or background, depending on the value of T(i, j). In this algorithm, the following equation is used for finding optimal threshold value.

$$T(i,j) = 0.5\{\max_w[I(i+m, j+n)] + \min_w[I(i+m, j+n)]\}$$
(4)

where w=50, provided contrast
$C(i,j) = I_{high}(i,j) - I_{low}(i,j) \geq 50$.

In order to find an appropriate binarization algorithm for insect footprints, the above 3 binarization algorithms are implemented and the performances are evaluated using the proposed binarization performance criterion.

Ⅲ. The Proposed Binarization Performance Criterion

There are various conventional performance criteria for evaluation of binarization algorithms. In [Meh04], the following five performance criteria are used for evaluating conventional binarization algorithms: misclassification error(ME), edge mismatch(EMM), relative foreground area error(RAE), modified Hausdorff distance(MHD), and region nonuniformity(NU). In the five criteria, all four criteria except last one need ground-truth images for comparison. In case of insect footprints, it is almost impossible to acquire ground-truth images because nobody can decide easily which area is foreground or background. Because of this difficulty, we decided to use the last criterion, region nonuniformity(NU).

NU measure which does not require ground -truth information, is defined as

$$NU = \frac{|F_T|}{|F_T + B_T|}\frac{\sigma_f^2}{\sigma^2} \quad (5)$$

where σ^2 represents the variance of the whole image, σ_f^2 represents the foreground variance, F_T, B_T denote the foreground and background area pixels in the test image and |.| is the cardinality of the set. It is expected that a well-segmented image will have a non−uniformity measure close to 0, while the worst case of NU=1 corresponds to a image for which background and foreground are indistinguishable up to second order moments[Meh04].

But we found that there is a problem when this criterion applied to insect footprints' binarization. The problem is that the value of this criterion goes near and near to 0 when a threshold value goes lower and lower. To show this result we choose some area from a randomly selected insect footprint image. The chosen area is shown as Fig. 1. The binarized images at several threshold values are shown in Fig. 2.

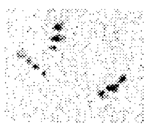

Fig. 1. a sample image

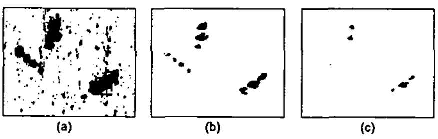

Fig. 2. the binarized image of Fig. 1 by threshold value = (a) 230, (b) 180, (c) 130.

We evaluated the NU values using the sample image of Fig. 1, varying threshold values from 130 to 230. The result is shown in Table 1. In this table, we can see the threshold value goes lower, the NU value becomes smaller, in another word, better. But when we closely loot at the above three binarized images, Fig. 2(b) is better than Fig. 2(c). So the performance criterion of NU could not give an appropriate result on the images such as insect footprints.

Table 1. The NU values by the sample image of Fig. 1.

threshold	NU
230	0.521458
220	0.227144
210	0.153669
200	0.103933
190	0.068894
180	0.044197
170	0.025973
160	0.013889
150	0.006888
140	0.003250
130	0.001024

We proposed a new binarization performance criterion named Minimum Number of Foreground Segments(MNFS), because we considered the conventional binarization performance criteria are improper in our research. In case of insect footprints, it is important that the foreground footprint spots' area pixels to be given 0(black) as many as possible and at the same time the background noise area pixels to be given 255(white) as many as possible. In Fig. 2(a), it is decided that too much pixels to be 0, so many background noise area pixels are converted to 0(foreground spots area). In contrast, it is decided that too little pixels to be 0, so many foreground spots' area pixels are converted to 255(background area) in Fig. 2(c). In these results, we can assume that the good binarized images are having small number of disconnected area but having large number of foreground pixels to be converted to 0(foreground).

The key ideas for choice of an optimal threshold value is to compare the number of disconnected segments(NDS) with the number of foreground pixels($|F_T|$) and to compare the variance of background area. If the ratio of the two numbers(NDS/$|F_T|$) is smaller(that is, threshold value goes lower like A) and the normalized variance of background area($\sigma_b^2(T)/\sigma^2(T)$) is smaller(that is, threshold value goes higher like C), the threshold value can be considered better. So we can consider the binarization algorithm having the minimum value of multiplication of the ratio and the normalized variance is the best for binarization of insect footprints. The proposed binarization performance criterion is defined as:

$$MNFS = \frac{NDS}{|F_T|} \cdot \frac{\sigma_b^2(T)}{\sigma^2(T)} \qquad (6)$$

where NDS indicate the number of disconnected foreground segments.

IV. Test Images and Experimental Results

Our test images consisted of a variety of 16 images of American Cockroach, 30 images of Black Cockroach, and 25 images of Native Bush Cockroach. All images are scanned by 1200 DPI in 8-bit gray image format. Several test images are shown in Fig. 3 The left 2 images are American Cockroach, the middle 2 images are Black Cockroach, and the right 2 images are Native Bush Cockroach.

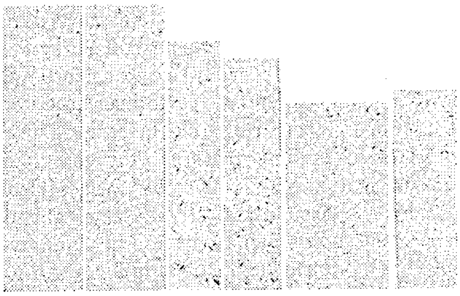

Fig. 3. Six sample images for test.

Visual results are given in Fig. 4 for the sample image of Fig. 1.

Fig. 4. The binarized images by Rosenfeld's, Abutaleb's and Bernsen's Algorithm.

The average MNFS values are given in Table 2 using 71 test images. Abutaleb's algorithm is best for binarization of insect footprints. A binarized test image by Abutaleb's algorithm is shown in Fig. 5.

Table 2. Average MNFS values.

Algorithm	Rosenfeld	Abutaleb	Bernsen
MNFS	0.00561	0.00403	0.00741

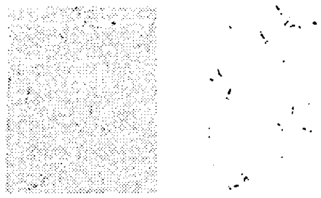

Fig. 5. Binarized test image by Abutaleb's algorithm.

V. Conclusions

We compared 3 different binarization algorithms and proposed a new binarization performance criterion to obtain the best performance for insect footprints. The experimental results showed that the Abutaleb's binarization method based on higher-order entropy algorithm produced the best binarized images in average. It can be used for pattern recognition applications of insect footprints to get the best binarized images of all kinds of insect footprints. Furthermore, this result can give a good help for some kinds of images which have relatively smaller foreground area than background area to binarize optimally.

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