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# 새로운 hit-and-miss 比變換과 注意 標識 分割에의 應用

# (A New Hit-and-Miss Ratio Transform and Its Application to Warning Sign Segmentation)

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## 요 약

잡음에 강하도록 기존의 hit-and-miss 변환을 변형한 새로운 hit-and-miss비 변환을 제안하였다. 이 변환은 정합비함수에 근간을 둔 준 정합 기법을 사용하였다. 그리고 이 변환을 사용한 다치 영상 분할 방법을 제안하였다. 이 분할 방법을 합성 영상과 실제도로주의표지 영상에 적용하여 양호한 결과를 얻을 수 있었다. 이 분할 방법은 이와 비슷하게 실제 자연영상으로부터 특정형태의 대상물 분할에 응용될 수 있을 것으로 본다.

## Abstract

A new hit-and-miss ratio transform is introduced as a modified hit-and-miss transform to be robust to noise, which uses a quasi-matching technique based on the fitting ratio functions. And a new gray-level object segmentation algorithm is proposed, which is based on the hit-and-miss ratio transform and threshold decomposition. The proposed segmentation algorithm shows a successful simulation result from both synthetic and real warning sign images, and is similarly applicable to segmentation of an object with specific shapes from natural real images.


## I. Introduction

Mathematical morphology introduced by Matheron[1] and Serra[2] takes a firm root in nonlinear signal processing and stands as a relatively separate part compared with linear signal processing.

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The hit-and-miss transform (HMT)[2] is an important tool to detect specific shapes exactly matched with given templates in binary images and is used as a basic transform for the other morphological operations such as thinning, thickening, etc..

The HMT is very sensitive to noise. Because it yields matching points only when a pair of disjoint structuring elements simultaneously fit with a template. From this point of view, we are interested in doing the HMT adaptive to noise.

A hit-and-miss ratio transform (HMRT) is developed based on a fitting ratio function (FRF) as an adaptive HMT to noise. And as an application of the HMRT, a gray image segmentation algorithm is proposed, which operates on binary images generated by threshold decomposition[3, 4] of the original gray image.

The paper is organized into four sections. In section II, the HMRT is introduced. In section III, A new image segmentation algorithm is presented. In section IV, the simulation results for a warning traffic sign segmentation from real road scene are shown.

## II. Hit-and-Miss Ratio Transform

1. Binary Morphological Operations

The primary morphological operations are dilation and erosion. From these, the hybrid morphological operations of opening and closing are composed as follows.

Let A and B be sets in 2-D integer space. Then the binary morphological operations are defined as[2]

$$\begin{aligned} &\textit{Dilation} &&: A\oplus B=\{x\,;\,\hat{B}_x\cap A\neq\varnothing\},\\ &\textit{Erosion} &&: A\ominus B=\{x\,;\,B_x\subseteq A\},\\ &\textit{Closing} &&: A\bullet B=(A\oplus B)\ominus B,\\ &\textit{Opening} &&: A\circ B=(A\ominus B)\oplus B, \end{aligned}$$

where $\hat{B}=\{-b\,;\,b\subseteq B\}$ and $B_x$ denotes the structuring element (SE) $B$ translated by $x$.

2. Hit-and-Miss Transform

The HMT[2] is a basic tool to detect specific shapes in binary images and used to template matching, thinning, thickening, pruning, etc..

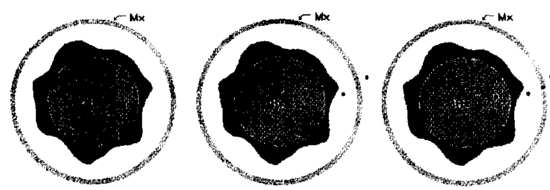
Let H and M be a pair of disjoint SEs that satisfy $H\cap M=\varnothing$. Then the HMT of a binary image A by H and M, denoted $A\circledast(H,M)$, is defined by[2]

$$A\circledast(H,M)=(A\ominus H)\cap(\overline{A}\ominus M)\quad \textit{with}\quad H\cap M=\varnothing, \quad (1)$$

where $\overline{A}$ denotes the complementary of $A$.

In Eq. (1), It uses two SEs : one inner SE H to check inside the object of interest and the other outer SE M for the background of the object.

Now we see the effects of noise on HMT as shown in Fig.1. In Fig. 1(a) and (b), we have $A\circledast(H,M)=\{x\}$, since $H_x\subseteq A$ and $M_x\subseteq\overline{A}$, while in (c) $A\circledast(H,M)=\varnothing$. It is because the HMTs yield matching points, simultaneously, fitting exactly H to the template (' hit ') and M to its background (' miss '). Therefore if there is any one point of mismatch either between the inner SE and the template or between the outer SE and the background, the HMT fails to find out the object of interest. Fig. 1(b) is a rare case happening in real world.



(a) (b) (c)

그림 1. HMT의 잡음 영향

Fig. 1. Noise effects on HMT.

3. Hit-and-Miss Ratio Transform

As we have seen above, a template set corrupted by salt and pepper-like noise can not be detected by the HMT. It is because the HMT requires an exact matching.

To alleviate the effect of noise on the HMT, we propose a new HMRT as a quasi-matching technique, based on the fitting ratio function (FRF) which indicates a degree of how many elements of a given SE fit with a template as follows.

**Definition of HMRT** : The HMRT of a binary image A by a pair of disjoint SEs of H and M is denoted by $A\boxtimes(H,M)$ and its element at the point $x$ is expressed by

$$A\boxtimes(H,M)(x)=R(A,H_x)\cdot R(\overline{A},M_x), \quad (2)$$

where $R(A,H_x)$, called a FRF, is defined as,

$$R(A,H_x)=\frac{Card(A\cap H_x)}{Card(H)}, \quad (3)$$

where $Card(A)$ is a cardinal number of the set A, i.e., the number of the elements of A.

It is not difficult to see in Eqs. (2) and (3) that

$0 \le R(A,H_x) \le 1,$

$0 \le R(\bar{A},M_x) \le 1,$ and

$0 \le A \boxtimes (H,M)(x) \le 1.$

The probability of the existence of a template set and its background much similar to the translated SEs $H_x$ and $M_x$, respectively, becomes larger as $A \boxtimes (H,M)(x)$ tends to 1.

Fig. 2 illustrates graphically the performance of the HMRT for a binary image of regular tetragon degraded by salt and/or pepper noise. The figure shows that the HMRT makes a mountainlike response for all kind of images. Therefore it is necessary to select true matching points in the mountainlike response using a proper method. For example, a threshold technique or a peak detection method can be considered as a possible method.

With considerations of computational efforts and selecting methods of matching points, we now modify slightly the above HMRT into two versions, denoted $A \boxtimes (H,M)_I(x)$ and $A \boxtimes (H,M)_{II}(x)$, as follows.

**Version I** : To reduce complexity of Eq. (2), we use two kinds of operations : clipping operation for each FRF and thresholding for the product of two clipped FRFs. Such a simplified HMRT is defined by

$$A \boxtimes (H,M)_I(x) = [\ \langle R(A,H_x)\rangle_h \cdot \langle R(\bar{A},M_x)\rangle_m\ ]_\theta \qquad (4)$$

where $[\ Y\ ]_\theta$ denotes a binarization of $Y$ by a threshold $\theta$ and $\langle X \rangle_h$ denotes a clipper of $X$ by a threshold h as

$$[\ Y\ ]_\theta = \begin{cases} 1, & Y \ge \theta \\ 0, & Y < \theta \end{cases} \qquad \langle X \rangle_h = \begin{cases} X, & X \ge h \\ 0, & X < h \end{cases} \qquad (5)$$

**Version II** : This transform only uses a binary product of two thresholded FRFs as

$$A \boxtimes (H,M)_{II}(x) = [\ R(A,H_x)]_h \cdot [\ R(\bar{A},M_x)]_m \qquad (6)$$

Thus the execution time of the version II is negligible with respect to the HMRT and its version I.

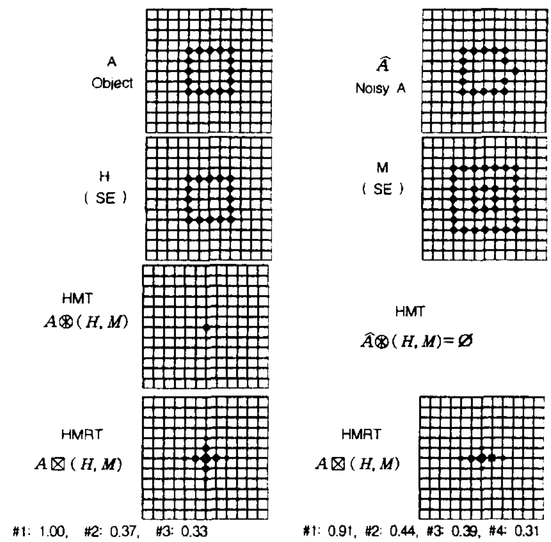



그림 2. 잡음 섞인 정사각형의 HMT와 HMRT 산모양의 HMRT 결과는 면적변조한 것이고, #K는 K번째 높은 값을 뜻한다

Fig. 2. HMT and HMRT for noisy regular tetragon. The mountain-like results of HMRT are depicted by an area modulation and #k denotes the value of the k-th highest group.

## Ⅲ. Application of HMRT to Segmentation of Warning Sign

The traffic signs[5] are of artificial and specific shapes and forms. They may be principally distinguishable from the natural and/or man-made background images with computer vision system as human ability but it is not easily tractable work. Throughout the world, the same traffic signs are not yet adopted but they are very similar in shape, design, color, size and symbol. In Korea, the traffic signs are also classified into four functional categories : warning signs, regulatory signs, indicatory signs, and supplementary signs and there are six standard sign shapes : round, equilateral triangle with one point up and down, pentagon with point up, square, and octagon.

Among them all the warning signs on road have an equilateral triangular shape as shown in Fig. 3(a) where a crosswalk sign is attached to an electric light pole. In this paper, we are only concerned with segmentation of the warning signs.

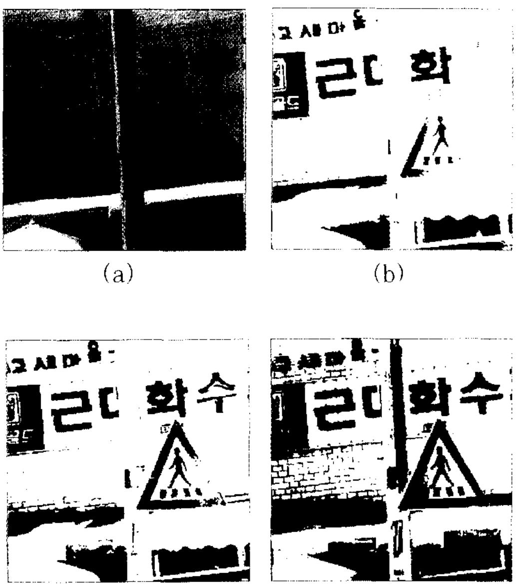


그림 3. 문턱 값에 따른 문턱 분할 결과: (a) 원영상, (b)와 (c) 및 (d)는 각각 문턱 값이 110, 130, 150 일 때의 결과이다.

Fig. 3. Threshold decomposition by different thresholds : (a) original scene, (b), (c), and (d) thresholded binary images by threshold level of 110, 130, and 150, respectively.

To subdivide the warning signs in a real scene, one can use general image segmentation algorithms[3,6] based on properties of discontinuity and similarity. But we propose completely different algorithm based on threshold decomposition and the HMRT.

This algorithm mainly comes from an assumption that if thresholds are properly chosen, then some binary images much similar to the partial shapes of an object of interest can be obtained by threshold decompositions. Fig. 3(b), (c), and (d) show the possibility of the assumption. Here we can partially see, depending on threshold levels, apexes of triangular warning sign, or a triangle-like shape with noise somewhat similar to salt and pepper noise. If we succeed in finding each apex with a certain method, we can then segment the warning sign. Based on these concepts, we propose a new image segmentation algorithm as follows.

**Segmentation Algorithm** : First of all, we determine three pairs of apex-like SEs $H_i$'s and $M_i$'s for I = 1, 2, 3 as shown in Fig. 4, where each pair of SEs is mutually disjoint and adjacent and they are usable for any size of equilateral triangle greater than the outer SE, i.e., scale-invariant.

The segmentation can be accomplished by the following steps :

1) Initially set n = 0. And let Tn = 0.
2) Set n = n + 1 and determine a threshold level $g_n$. And then decompose the original image into the n-th thresholded image Bn with the threshold $g_n$.
3) Obtain each HMRT of Bn, Tn,i , using $H_i$ and $M_i$ for i = 1, 2, 3. And then obtain Tn and Rn for every pixel as

$$Tn = \max\ (\ Tn,i\ :\ i = 1,\ 2,\ 3\ ),$$
$$Rn = \max\ (Tn,\ Tn\text{-}1\ )$$

4) If there are three extrema in Rn greater than a given threshold value and if they can make a specific triangle, then stop (or go to the next stage of inner sign recognition), or else go to step 2 until n is equal to the predetermined N less than the maximum gray level of the

original input image.

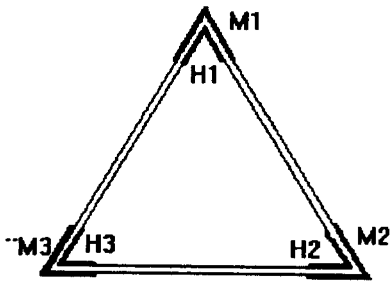



그림 4. 세 쌍의 형태소 : (Hi, Mi), i = 1, 2, 3
Fig. 4. Three pairs of SEs : Hi's and Mi's (i = 1, 2, 3).

Fig. 5 shows the block diagram of the proposed segmentation algorithm. In consideration of absence of triangular shapes according to an improper threshold level, we use a number of thresholded binary images by different threshold levels in above segmentation algorithm. How to choose a proper threshold level is a key problem for a rapid and correct segmentation. Here, as an example, we have chosen threshold levels with a uniform interval as follows.

$$g_{2n+k} = g_1 + (-1)^k nS \quad (7)$$

where the first threshold level $g_1$ is chosen as a mean of image, and S is a uniform interval.

Without a priori knowledge of the number of warning signs, the above algorithm in Fig. 5 may yield an error in case of multiple existence of warning signs.

So far we have proposed the segmentation method using the HMRT in Eq. (2). In cases of its versions I and II in Eqs. (4) and (6), the max operations used for Tn and Rn in the above step 3 and in Fig. 5 must be substituted for the union operations.

## Ⅳ. Simulation Results

To test the performance of the proposed image segmentation algorithm based on the HMRT and threshold decomposition as shown in Fig. 5, two experiments are performed on two synthetic and two real road images using the same three pairs of SEs, $H_i$'s and $M_i$'s for i = 1, 2, 3 as shown in Fig. 4.

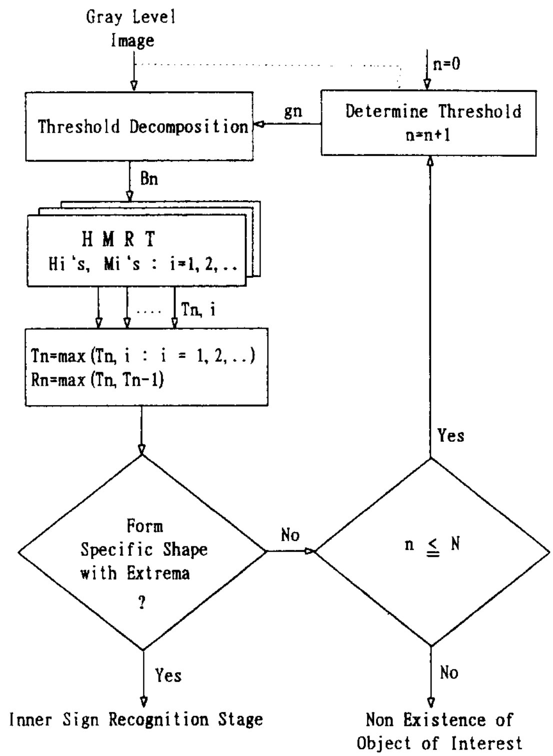



그림 5. HMRT에 의한 영상 분할 블록도
Fig. 5. Block diagram of image segmentation using HMRT.

Fig. 6 shows the simulation results. In Fig. 6, the first columns represent two synthetic and two real original images, and the middle three columns represent one by one the results obtained by each pair of SEs, $H_i$'s and $M_i$'s, for i = 1, 2, 3.

The last columns are final segmented images, where for two synthetic images we have used the version II with h=m=0.8 in Eq.

(6) and for two real ones we have chosen a

uniform interval S=10 in Eq. (7).

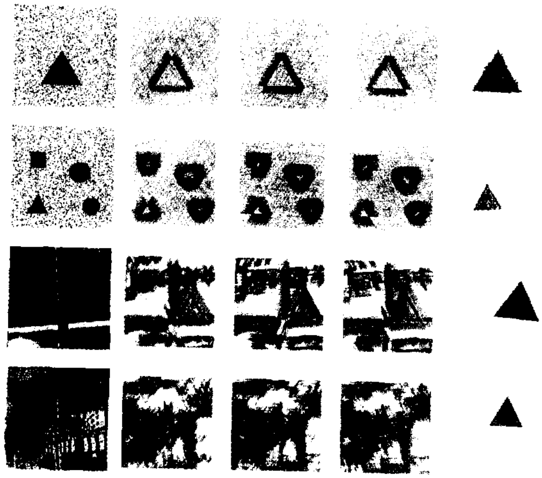


그림 6. 모의 실험 결과
Fig. 6. Simulation results.

## V. Conclusions

We have proposed a new HMRT. It is based on a quasi-matching algorithm using FRF which indicates a degree of how many elements are intersected with two sets. And so it is inherently robust to noise as opposed to the original HMT.

A new image segmentation algorithm of a specific shape is developed, which is based on HMRT and threshold decomposition. Using the segmentation algorithm, we can select out warning signs from real road scenes. But the key point for a rapid segmentation is how to choose a proper threshold level. Further study is necessary for a decision of the threshold.

The HMRT and the segmentation technique will be applicable to pattern matching, image segmentation, binary object restoration, etc..

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