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A novel LBP based algorithm for small target detection in infrared image

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Small target detection is a crucial problem in Infrared Search and Track (IRST) systems. Conventional algorithms encounter a high false alarm ratio under situations with cluttered background. Here a novel algorithm based on modified local binary pattern (LBP) model is proposed to deal with this problem. The modified LBP process will generate a specific uniform pattern at the position where potential small targets exist, while background and other image components will generate different patterns because of their different intensity distribution from target. After potential small target is determined a post process using fusion image of two LBP images is incorporated to preserve target information. The algorithm is real-time. Comparative experimental results demonstrate its efficiency and robustness.

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1. Introduction

Small target detection in infrared imagery is an important area in computer vision for application of aerial defense alertness and early warning. The popular algorithms such as various highpass spatio-temporal filtering encounter a high false alarm rate because of extremely complicated background and low signal to clutter/noise ratio. Tarun Soni *et al.* [1] applied Two-dimensional Least Mean Square (TDLMS) algorithm as prewhitenning filter to small object detection. The TDLMS does not require a priori knowledge and predict image with homogeneous background stably, but it requires "desired image" which is usually obtained by delay of the original image and this makeshift does not have a definite meaning for small target detection and its performance degrades in cluttered scene. Suyog D. Deshpande *et al.* [2] investigated the anti-Max/Median filter's usefulness in detail preserving for small target detection, the filter has shown to be a good method for suppression of structural components in image but not complicated clutter, the followed threshold procedure also has some difficulty to extract potential targets. G.D. Wang *et al.* [3] developed a facet based detection method which fits the underlying intensity surface with the bivariate cubic function and determines the candidate targets using extremum theory. The method is real-time, but it tends to lose targets having gradual intensity surface in homogeneous scene and bring to false extremum pixel in the presence of fragmentary clutter. Here a novel detection method based on the Local Binary Patterns (LBP) model is proposed to detect small targets in various backgrounds. Comparative experiments involving typical infrared images demonstrate its efficiency and robustness.

The paper is organized as follows: A brief description on the basic LBP model is given in Section 2. The algorithm to detect small targets from an infrared image using modified LBP model is proposed in Section 3. Experimental data and results are presented in Section 4 and Section 5 concludes the paper.

2. Basic LBP model

The basic LBP model [4] defines the local neighborhood as a set of sampling pixels evenly spaced on a circle centered at the interesting pixel, as described in Fig. 1, and then assigns a label to the interesting pixel by compares its intensity to its neighbors'. With P neighbors, each of which has a distance of R pixels to the center, the expression of LBP model is

$$LBP_{P,R} = \sum_{i=0}^{P-1} s(g_i - g_c)2^i \tag{1}$$

where g_c is the intensity of the interesting pixel, g_i is the intensity of its i th neighbor, and

$$s(x) = \begin{cases} 1, x \geq 0 \\ 0, x < 0 \end{cases} \tag{2}$$

The intensity of a neighbor with non-integer position can be obtained using interpolation method or approximated by the nearest real pixel in original image.

The LBP value depends on the choice of g_0 and the order of all neighbor pixels, thus the model is modified to achieve rotation invariance for object recognition, but it's not necessary for small target detection, the reason is explained in next section.

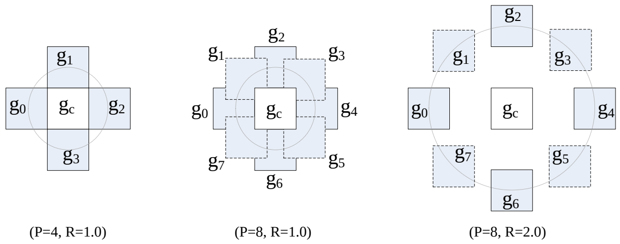


Fig. 1. Structure of circle neighborhood for different (P, R). Square with solid line are real pixels in original image and dashed line represents pixels that have interpolated position.

Fig. 2 depicts the basic LBP operator $LBP_{8,1}$. The nearest real pixel in original image is used as approximation of pixels with non-integer position.

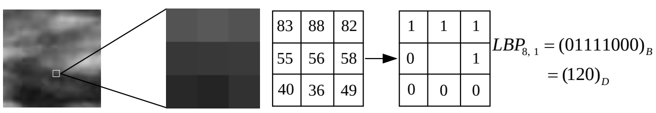


Fig. 2. Basic LBP operator. Subscript "B" represents binary value and "D" decimal value.

3. Detection algorithm for small target

Different components of image, such as small targets, background, corners, edges and clutter, have different intensity distribution. As depicted by Fig. 3, small targets have relative higher intensity than other pixels in its neighborhood, while background is homogeneous in local image and other components (corner, edge, and clutter) also have comparable neighbors.

For detection of small targets, the basic LBP model should be modified from two aspects and followed by specific post process. First the intensity contrast of target and other components should be incorporated in the model [5]. We achieve this by set a empirical threshold th computed based on statistics of image and use $(g_c - g_i)$ to replace $(g_i - g_c)$ under the consideration that targets' intensity is higher than its neighbors. As expressed by equation (3).

$$LBP_{P,R} = \sum_{i=0}^{P-1} s(g_c - g_i - th)2^i \tag{3}$$

where,

$$th = 0.8 \cdot \sigma \tag{4}$$

in which σ represents the standard deviation of the original image.

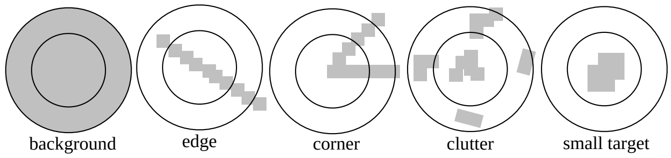


Fig. 3. Different local structures of different components in image. Gray pixels represent higher intensity than neighbors in circular neighborhood.

Second, to describe the LBP difference between small targets and other components in infrared image, two LBP values are computed using two circular neighborhoods that center at current pixel but have different radius, see Fig. 3. All neighbors in two circular neighborhoods have relative lower intensity than target, so the two LBP descriptors must generate a same uniform pattern that '1' presents at all directions and potential target can be detected utilizing this fact. The pattern that has '1' at all directions is isotropic, thus it is not necessary to use a rotation-invariant model. Other components don't have this characteristic, namely, they always have '0' in some directions.

Usually small target appears as a blob and the distribution of target intensity is flattop or campaniform, like 2D Gaussian surface, target's peripheral pixels' intensity is often lower than center pixels, so peripheral pixels could not generate the uniform pattern with '1' at all directions. Therefore the method looking for the uniform pattern could detect center pixels of target but tend to lose peripheral pixels of target. To solve this problem a post process is incorporated.

Two LBP images have been generated to determine potential small targets by applying the above two LBP descriptors to original image. In the post process a fusion image is obtained firstly, in the fusion image a pixel’s value is computed by logic ‘and’ operation on two corresponding LBP values which are respectively in the two LBP images. For restoration of target pixels, one ‘0’ is allowed in a fusion LBP pattern, which means the fusion image is segmented by 127. Then each object in the segmented image is examined, an object is preserved only if a potential target detected by the above method exists at its position, otherwise the object is erased. A preserved object is regarded as containing integrated pixels of the corresponding potential target.

The LBP based small target detection procedure contains three steps:

1. Compute threshold th for an input image using equation (4).

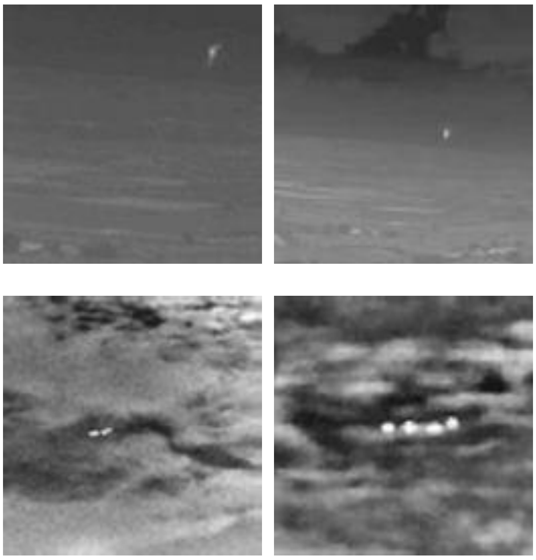
2.Generate a fusion image I_{fusion}: For each pixel (i, j) in original image, calculate $LBP_{8,3}(i, j)$ and $LBP_{8,5}(i, j)$ using equation (3) , then the fusion image is formed by logical ‘and’ of the two values, $I_{fusion}(i, j) = LBP_{8,3}(i, j) \& LBP_{8,5}(i, j)$.

3. Potential targets decision: A pixel is decided to be a target pixel when its two LBP values have equal value 255, i.e. $I_{fusion}(i, j) = (11111111)_B = (255)_D$. All pixels connected to a target pixel and satisfy $I_{fusion}(i, j) \geq (01111111)_B = (127)_D$ are determined as target pixels.

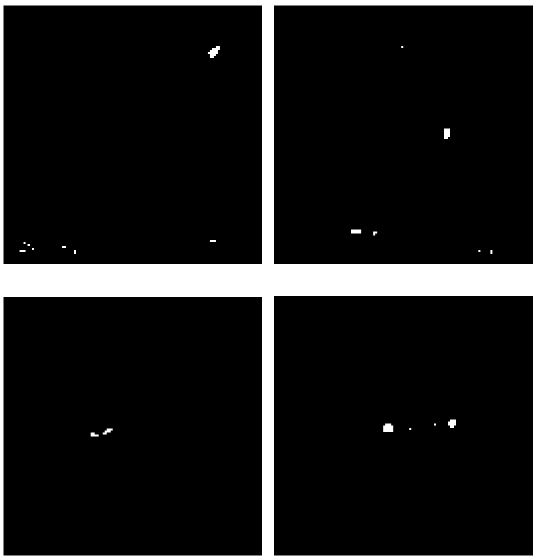
4. Experimental results

The target detection performance of the LBP based method is evaluated by typical infrared images containing small targets. Experimental data and results are shown in Fig. 4. The infrared images’ size is 128×128 pixels, Image 1 and Image 2 have relatively smoothed background and only one small target respectively, while Image 3 and Image 4 contain more clutter and multiple small targets. Target size varies from about 10 pixels to about 30 pixels. Some targets have a simple distribution like a blob while others have a distribution with evident shape.

As comparative methods we also give the corresponding results of anti-Max/Median filter [2] and facet based detection algorithm [3], these two comparative methods are chosen because they are widely used and perform well with cluttered background. In experiments the parameters of facet based algorithm are the same as in [3], anti-Max/Median filter’s window size is set to 11×11 pixels. Fig. 4(a) shows four original images containing one or more small targets, Fig. 4(b) and Fig. 4(c) shows respectively the processed result of anti-Max/Median filter and facet based algorithm. Fig. 4(d) shows the processed result of the LBP based algorithm described above. The intensity of a neighbor pixel with non-integer position is estimated by bilinear interpolation in experiments. It can be seen that anti-Max/Median filter has some false detection and facet based algorithm loses important information of target distribution, while the LBP based algorithm detects small targets with integrated distribution and no false detection.



(a)



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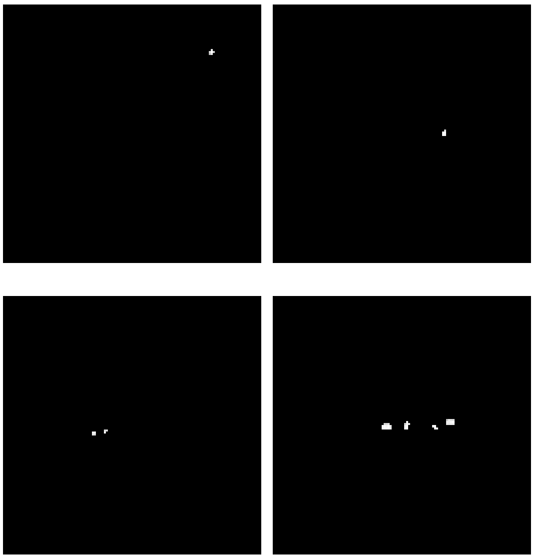
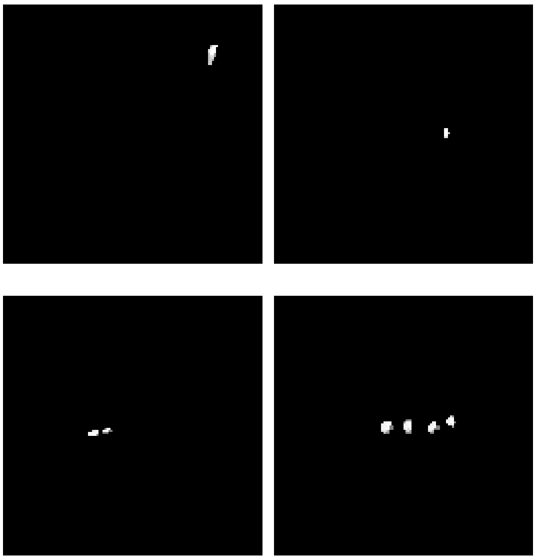


(c)



(d)

Fig. 4 Original images and detection results. (a) Original images (first row: Image1 and Image2, second row: Image3 and Image4), (b) Results of anti-Max/Median filter, (c) Results of facet based algorithm, (d) Results of LBP based algorithm.

The three algorithms used in experiments are implemented by C++ program language and the unoptimized code is run on a computer with an Intel Core2 2.93 GHz CPU and 2 GB memory. The times consumed by anti-Max/Median filter, facet based algorithm and LBP based algorithm are listed in Table 1 when they process images in Fig. 4. The average processing time consumed by the LBP based algorithm is about 43ms, which means the algorithm can process 23 frames in 1 second; therefore the algorithm is efficient for many real-time applications.

Table 1. Consumed time (ms) of three algorithms.

Algorithm	Image 1	Image 2	Image 3	Image 4
Anti-Max/Median	56	51	49	57
Facet based	118	84	101	48
LBP based	38	45	38	51

5. Conclusions

Different local intensity distribution of different components in imagery is investigated based on modified LBP model and a detection algorithm of small target is proposed. The algorithm is theoretically concise and computationally simple. Experimental results demonstrate the algorithm's efficiency and robustness in small target detection.

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