An Adaptive Detection Algorithm for Small Targets in Digital Image

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Abstract. The target detection of digital image is one of the main content in computer vision research, which has a wider use. This paper presents an algorithm of the fuzzy small target detection for digital image. First, all the pixel values are looked as a set of elements with the corresponding address, and the small target is determined according to the need, so the image pixels are divided into two sets which includes target set and its complementary set; then the addresses of the storage target pixels are located; the next step to do is calculating the thresholds of target set and its complementary set; Finally, the binarization operation is applied to the small target set and its complement set by the calculated threshold. The test results show that this algorithm for small target detection is very effective.

Keywords: Digital image · Target detection · Complementary set · Subset · Binarization

1 Introduction

In the process of digital image transmission and acquisition, part of the image information cannot be clearly displayed due to light and environmental factors. Further, this way maybe affects judgment and collection of certain information and then changes the final results. Especially in the military and traffic information collection, target detection is of great significance. the "target" detection refers to the image information with a specific meaning, the purpose is a process that is the more meaningful information can be collected by the human visual system through a certain way which process the original blurred image information.

At present, the target detection in the digital image has been concern by experts and scholars of vision research [1-5], and played a huge role in real life. F.Cao [6] proposed a way to extract the boundary information in the image by the use of mathematical morphology, this algorithm to extract the boundary information effectively improved graph recognition and analysis. S.Mallat [7] used the wavelet transform in the high frequency region which can display the image boundary information characteristics, and to reassemble the high frequency information of image transform in order to achieve the target detection. What is more, there are other papers[8-10] which firstly binaries the digital image, and according to the different structure characteristics the

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binary image is divided into many sets, then the appropriate action will be taken for each set to achieve the purpose of image segmentation. But the target detection after segmentation is not obvious, such as the expression of the target boundary information is still incomplete. These already existing detection algorithms for image border and target detection is of great significance, but they used more mathematical knowledge, in addition, the emphasis is put on the overall image analysis and recovery, so that they are with a high degree of complexity. In practical applications, these algorithms have some certain limitations. In fact, the image target detection is often not the whole image information acquisition, but the meaningful target information collection. So based on this idea, other small targets detection algorithm is proposed in this paper.

The proposed algorithm is based on region of interest (ROI) for small target detection which focuses on how to select the regions of interest, and how to process them locally. It should be noted that the select of interest differ from the ROI [11-14]. It cannot be based on the overall image feature automatically to select the main information, but according to actual needs, the regions are selected artificially. The work of processing includes the characteristic analysis of local pixel values, the calculation of the local threshold and local binarization. The algorithm efficiency is greatly improved because of reducing the processing scope, and has excellent practical value.

2 ROI and Target Selection

In the paper [15], the ways of selecting the ROI regions have been introduced in detail and an algorithm of color transfer automatically and change was proposed on the common region of interest with detailed description and an application. And in the paper [11], a standard of region of interest is an important part of the image with big gray-scale change, while in [12], the inflection point can be better summed up the outline of objects in the image. In the other two methods, the human cognition is considered, and the more representative bottom-up attention models which include the saliency map model [13] and the icon model [14] were made.

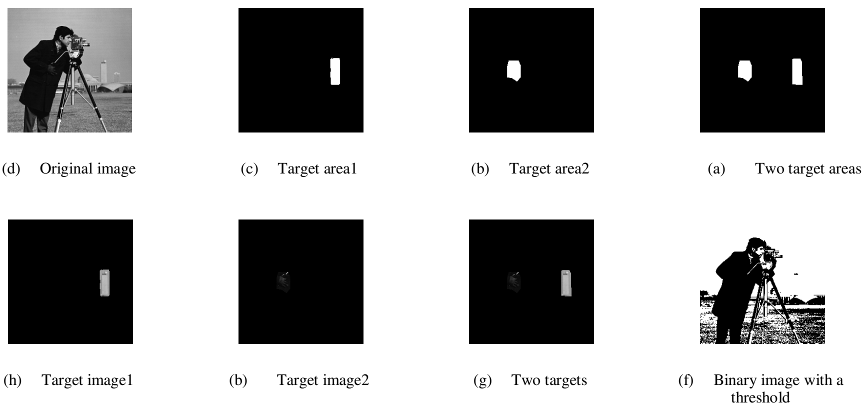

Fig. 1. Target Selection

Here, the target selection is based on the need to make continuous distribution pixels as a region of interest. For example, the information security department is in the investigation of one case to capture information through various means from all sides. Just in time, a part of an image made by the camera is of particular importance in the case, further, this part information does not has big gray-scale change and also not belong to the inflection point pixels. So, the extraction of this information can only be artificially elected, and then continue to process it, to make it clearly shown at last.

In Figure 1, the file named cameraman.tif as an example of MATLAB is used to show the process of the target selection, and the ROIPOLY function without coordinate vector parameters is a tool to get a continuous range according to the need. (b) and (c) of Figure 1 are the selected target areas, the white range is the target. (d) is the merger of the two target areas corresponding to Figure 1 (e). It can be seen that the selected two areas do not have the gray change characteristics in the overall image shown in Figure 1 (e) and (f), and the inflection points are not prominent, but these sections contain the information needed to extract. That is, if the overall image is diarized, they will be almost not shown, and cannot express any meaningful information, which can be seen from Figure 1 (h). If the first target is a considered as a set named as M, the second target as a set named as N, the rest is a set named O, the overall pixels set named as F, then the following equitation is:

$$F = M \cup N \cup O \tag{1}$$

When the ROIPOLY function is used to make a target, its limitation is only selecting a region at a time, if there are multiple detection targets, which need many times to achieve the appropriate selections. In Figure 1, we chose two target areas as the detected objects, one is a distant blur building in the image (Figure 1 (e)), and another is a cameraman's hand (Figure 1 (f). In the binary image, these two parts cannot be displayed (Figure 1 (h)). The following part has discussion and analysis of local information detection, the detection of small target object can be achieved.

3 Threshold Calculation

After determining the target to be detected, the following main work is to extract information on target. As mentioned earlier, the significance of the target extraction is less that it has a invisible position in the overall image. But for various purposes, it must be displayed as much as possible. The threshold calculation has an important role for the extraction of meaningful information; different thresholds can get different information. In Figure 1 (h), the binary image is made by the overall threshold, obviously, it cannot meet the requirements, at least inconsistent, and the target object cannot be detected clearly. That is, the target is almost disappeared after binarization.

There are a variety of methods to get the threshold, they are roughly divided into two categories, one is called global threshold, and the other is the local threshold. Global threshold methods includes: the P-quintile method, the iterative method, the method based on the histogram concave analysis, the maximum between-class variance method, the entropy method, the minimum error method, the maintained moments and the fuzzy sets method. The local threshold methods include dynamic threshold, the interpolation threshold and the waterline threshold. These threshold methods have some effect for some images with the specific characteristics, but most of them have much larger complex, and reduce their application values. Here, a simple calculation method is used to calculate the threshold, that it, the average is as the threshold value, and different targets have different thresholds. The exact calculated equation is as follows:

TM, TN are the thresholds of two sets M, N, then,

$$T_M = \frac{1}{m}\sum_{(i,j)\in M} F(i,j) \tag{2}$$

$$T_N = \frac{1}{n}\sum_{(i,j)\in N} F(i,j) \tag{3}$$

Here, m is the pixel number of set M, n is the pixel number of set N.

The distribution of pixel values of two targets shown in the Figure 1 can be seen in Figure 2. Figure 2 (a) corresponds to Figure 1 (e), Figure 2 (b) corresponds to Figure 1 (f), and there are obvious differences between them. If we only use an overall threshold to extract the information of two targets, the obtained result information does not meet the requirements. The two targets should have their own thresholds which can be respectively calculated according to the formula (2) and (3). Then the threshold in Figure 1 (e) is 166.5042, and another threshold of (f) is 19.9657, while the overall threshold is 118.7245. From Figure 2 (a), we can see, most of the pixel values of the first target are around 166, and the second target's pixel are mostly distributed around 20. If the first target is binaries by 118.7245, then the result will have most of logic value 1, and we can see the first target is shown in white; similarly, the result of the second target will be shown in almost all black, which includes most of logic values. This result can be verified in Figure 1 (h).

(a) distribution of target1 (b) distribution of target2

Fig. 2. Pixels Distribution

4 Target Detection

Here, the image named cameraman.tif is still used as an experimental subject, Figure 1 (e) and (f) has already shown the two detection targets. TM and TN are used as the thresholds of the M and N, where $\overline{M}$ and $\overline{N}$ are the complements of M and N, then the following continuous equation is:

$$F = M \cup \overline{M} = N \cup \overline{N} \tag{4}$$

According to the previously described method of calculating the threshold value, we can also calculate the thresholds of the sets $\overline{M}$ and $\overline{N}$, they are respectively $T_{\overline{M}}$ and $T_{\overline{N}}$, the binarization process is as follows:

$$F_M = \begin{cases} 1 & F(\mathrm{i},\mathrm{j}) > T_M \\ 0 & F(\mathrm{i},\mathrm{j}) \le T_M \end{cases} \tag{5}$$

$$F_{\overline{M}} = \begin{cases} 1 & F(\mathrm{i},\mathrm{j}) > T_{\overline{M}} \\ 0 & F(\mathrm{i},\mathrm{j}) \le T_{\overline{M}} \end{cases} \tag{6}$$

According to the results of the above calculations, the BFM is generated by equation (7), as shown in Figure 3 (a). Also, according to TN and $T_{\overline{N}}$, F_N and $F_{\overline{N}}$ can be got by equation (8). In Figure 3 (b) we can see the result of BFN.

$$BF_M = F_M \cup F_{\overline{M}} \tag{7}$$

$$BF_N = F_N \cup F_{\overline{N}} \tag{8}$$

F_M and F_N will be processed by OR operator by equation (9), then the out is FMN as shown in Figure 3 (c).

$$F_{MN} = F_M \,|\, F_N \tag{9}$$

But in Figure 3 (c), only two targets are shown, and other information of the image does not be shown, which will increase the isolation of the targets, and reduce the significance of their existence. If we make two targets more clearly in the whole image, the relationship between them must be analyzed in the element values and the background element values. On the terms of this image used in this paper, the element values around the first target are mostly 1s (Figure 3 (a)), the element values around the second target are mostly 0 (Figure 3 (b), If a logical operator is selected to merge them into the overall binary image, one of them will disappear. So that, two logic operations will used to retain all the 0s for the first target and retain all the 1s for the second target, the following approach can be achieved as follows:

Step1, calculate the overall threshold T:

$$T = \frac{1}{pq} \sum_{i=1}^{p} \sum_{j=1}^{q} F(\mathrm{i},\mathrm{j}) \tag{10}$$

Step2, binary F, then get the BF as shown in Figure 1 (h):

$$BF = \begin{cases} 1 & F(\mathrm{i},\mathrm{j}) > T \\ 0 & F(\mathrm{i},\mathrm{j}) \le T \end{cases} \tag{11}$$

Step3, use "AND" operator and "OR" operator, merge FM and FN into BF, as shown in Figure 3 (d).

$$BF(\mathrm{i,j}) = \begin{cases} BF(\mathrm{i,j}) \text{ and } F_M(\mathrm{i,j}), & (\mathrm{i,j}) \in M \\ BF(\mathrm{i,j}) \text{ or } F_N(\mathrm{i,j}), & (\mathrm{i,j}) \in N \end{cases} \tag{12}$$

(a) target1 detection (b) target2 detection (c) two detections (d) the last result

Fig. 3. Target Detection

Figure 1 (h) and Figure 3 (d) are compared together; the two small target objects are more clearly detected by this algorithm. If another target is needed to detect, it will be selected again, and this method is used to extract target information. But it should be noted that if multiple detected targets will be captured into the overall binary image, we must take into account the relationship between the target itself and the surrounding elements, then make decision to take the appropriate logical operations, and ensure that the target will still exist after integrating.

5 Conclusions

In this paper, a detection algorithm for small target is based on the ROI, and ROIPOLY function is used to select the target. The select range of this function is not limited to the normal image, its sole purpose is based on actual needs to extract some information within a certain range. For the calculation of the threshold, a relatively simple and common method is to calculate the mean of selected targets; different targets have different thresholds, which is crucial to extract information. When multiple targets were respectively detected, the background values must be considered, and then the target will be incorporated into the overall image. On the other hand, there are many 0s and 1s in the binary image; it is more convenient to select the appropriate logical operations. But when you want to select another more target, the algorithm must be repeated to implement single-target detection, which is need to improve later.

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