

## Forest Image Processing Method based on Fuzzy Membership and Two-Dimensional Entropy

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### Abstract

*From the perspective of the two-dimensional image processing threshold departure, combining the fuzzy theory and two-dimensional entropy algorithm, collecting and processing trees image contained calibration information point, to determine the optimum threshold value, achieve precise image information extraction point of trees. During the experiment, will be gathering information points marked red rectangle on the image of the trees, and the use of binocular vision platform for the collection, then using the membership based on fuzzy theory merge trees image smoothing, the principle of maximum degree of membership criteria for the selection of the pixel template, optimized calibration point boundary and details, combined with the two-dimensional entropy algorithm to determine the optimal threshold, realize precise point of the image information extraction. The results show that the information point for calibration, image processing method adopted fuzzy theory and two-dimensional entropy algorithm combining, extracting information points is more accurate, clear, can better reflect the characteristics of the image information points, and can achieve the wireless remote monitoring studies of trees, and promote the rapid development of information technology forestry laid a good technical and theoretical foundation.*

**Keywords:** Two-dimensional entropy; Image processing; Smooth filtering; Fuzzy theory

### 1. Introduction

Threshold segmentation is a kind of typical area segmentation algorithm [1-2], it plays a very significant role in image processing. The basic idea is to determine a gray threshold in some way, and divide the processed image into target area and background area to complete the segmentation [3]. Among them, using the image histogram to select threshold is one of the major hot spots in image segmentation, especially the fuzzy C-means clustering algorithm. It is a classical image segmentation algorithm, the fuzzy membership matrix and clustering center can be obtained through iteration [4]. In recent years, the method based on entropy, especially based on two-dimensional entropy has drawn the attention of the researchers. Because the two-dimensional entropy can not only provide the image gray level information, but also provide the statistical regulation among the pixels with certain position relationship in images relative to one-dimensional entropy. The method of using two-dimensional entropy can start from building a two-dimensional histogram of the image, choosing the quadrants with edge to define the two-dimensional entropy. Once the two-dimensional entropy reaches the maximum value, the image segmentation can be achieved. The research of tree image processing based on

fuzzy membership and two-dimensional entropy theory has made some achievements at home and abroad: Wang Peizhen *et. al.*, [5] used the two-dimensional threshold and FCM clustering method to process the embroidery images, but this method is complex and time-consuming. In 1985, Kapur *et. al.*, [6] proposed a maximum Shannon entropy threshold method, but the edge detection effect of this method is not ideal. In 1989, Abutaleb *et. al.*, [7] proposed a two-dimensional histogram method using the gray value of 4 neighboring center pixels and other pixels' average value, this method divided the histogram into four quadrants using the threshold. During the calculation, this method only considered two quadrants with the edge of target and background. Once the two-dimensional entropy reaches the maximum value, the image segmentation can be achieved. But this method didn't process the neighboring pixels with same method.

There are many image segmentation methods that are based on threshold. However, due to the complexity and uncertainty of the actual images, it is difficult to find a method that can apply all kinds of images. Based on the above research, we use the maximum membership principle of fuzzy theory to choose the membership template, and process the whole image with pixel membership template. Then we use the two-dimensional entropy theory to determine the best threshold point of the two-dimensional histogram, and segment the images after the membership attribution. Finally, we achieve a good effect, and demonstrate the practicability and feasibility of the image processing method based on fuzzy membership and two-dimensional entropy theory.

## 2. Theoretical Basis

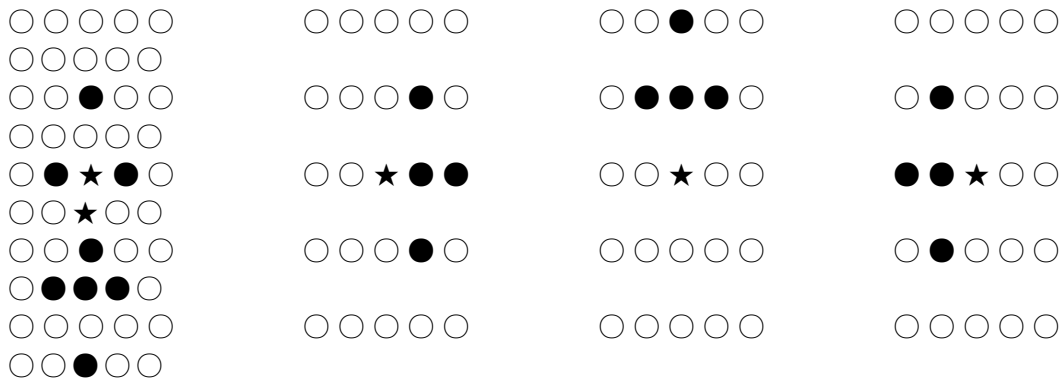
### 2.1. Fuzzy Membership Theory

**2.1.1. Maximum Membership Principle:** Assuming that there are  $m$  kinds of linear subspace  $\varphi_i$  ( $i = 1, 2, \dots, m$ ) in a vector space, and  $\{e_j^{(i)}\} (j = 1, 2, \dots, n_i)$  is a group of base vector its subspace,  $X$  is a random vector of this vector space, then the vector  $X$  which is affiliated to  $\varphi_i$  can be defined as [8-9]:

$$v_{\varphi_i}(X) = \frac{1}{1 + \min \left\| X - \sum_{j=1}^{n_i} \lambda_j^{(i)} e_j^{(i)} \right\|} \quad (1)$$

Where  $\lambda_j^{(i)}$  is a real number, and  $\|\bullet\|$  represents a norm.

**2.1.2. Maximum Membership of the Image:** For the pixels in two-dimensional images, they are only belongs to the following situations: target, background, or noise. Introduce one membership template without orientation and four membership template with orientation, each template includes one center pixel (represented by ★) and four neighboring pixels (represented by ●), which is shown in Figure 1.



**Figure 1. Membership Template**

According to the principle of vector membership [9] and formula (1), the image membership function can be defined as [10]:

$$C_M = 1 - |X_M - f(i, j)| / 2^n \quad (2)$$

Where  $C_M$  is the Mth template membership of center point,  $X_M$  is the average gray value in template M,  $f(i, j)$  is the gray value of center pixel,  $n$  is the quantization bit. This paper uses a 8 bit image, where  $n=8$ , then we have  $C_M \in [0,1]$ . According to the different value  $C_M$  from different template, we use the principle of maximum membership to determine the membership template of center point [9-11], the current pixel value can be replaced by the average value of other pixels in membership template. The specific steps are as follows:

- ① Calculate the average gray value in 5 mask templates respectively, where the pixel coordinate is  $(i, j)$ .

$$\begin{aligned} X_1 &= [f(i-1, j) + f(i+1, j) + f(i, j-1) + f(i, j+1)] / 4, & X_2 &= [f(i-1, j+1) + f(i, j+1) + f(i, j+2) + f(i+1, j+1)] / 4 \\ X_3 &= [f(i-2, j) + f(i-1, j) + f(i-1, j-1) + f(i-1, j+1)] / 4, & X_4 &= [f(i-1, j-1) + f(i, j-2) + f(i, j-1) + f(i+1, j-1)] / 4 \\ X_5 &= [f(i+1, j) + f(i+2, j) + f(i+1, j-1) + f(i+1, j+1)] / 4 \end{aligned}$$

- ② Calculate the membership of the pixel.

According to formula (2), for the current pixel, using these five membership templates, we can calculate five values from  $C_1$  to  $C_5$ .

- ③ According to the principle of maximum membership, judge which template they belong to.

According to the calculated five values from  $C_1$  to  $C_5$ , we choose  $C = \max(C_1, C_2, C_3, C_4, C_5)$ . According to the principle of maximum membership, we can determine the template of the current pixel.

- ④ Select a template to smooth filtering.

When the template of the current pixel is determined, we can use this template for smooth filtering, and use the average pixel gray value of the template to replace the current pixel gray value.

- ⑤ For all the pixels in the image, repeat steps ① ~ ④ until completing the process of the whole image.

After the above processing, we can avoid the fuzzy problem caused by average filtering and median filtering, and get the edge and detail information of the processed image, thus can provide the data information for our further calculation of the two-dimensional entropy of forest tree images.

## 2.2. Two-dimensional Entropy Theory

The key of the threshold segmentation effect is the selection of the threshold. Introducing the entropy value into the image processing is one of the research hot areas in recent years. The principle of the maximum entropy is to maximize the entropy value when we use the selected threshold to segment the image. The basic design idea is to divide the image into two classes by selecting an appropriate threshold, when the sum of the average entropy value of these two classes has the biggest value, the selected threshold is the best threshold.

**2.2.1. One-dimensional Maximum Entropy Method:** Assuming that an event is occurred with the probability of  $P_1, P_2, \dots, P_s$ , the entropy can be defined as:

$E_i = -P_i \cdot \ln P_i$  ( $i = 1, 2, \dots, s$ ). It can be approved that when  $P_1=P_2=\dots=P_s$ , the entropy value is the maximum value, it has the largest amount of information [10-11]. In accordance with the above principle, the one-dimensional entropy algorithm of the image can be described as:

(1) Calculate the distribution probabilities of all pixels in the image.

$$P_i = \frac{N_i}{N} \quad (i=0,1,\dots,255)$$

Where  $N_i$  is the pixel number of gray value  $i$ .

(2) Set a initial threshold  $Th=Th_0$ , divide the image into  $C_1$  and  $C_2$ , calculate their average relative entropy.

$$E_1 = -\sum_{i=0}^{Th} (P_i / P_{Th}) \cdot \ln(P_i / P_{Th}) \quad E_2 = -\sum_{i=Th+1}^{255} (P_i / (1 - P_{Th})) \cdot \ln(P_i / (1 - P_{Th})) \quad P_{Th} = \sum_{i=0}^{Th} P_i \quad (3)$$

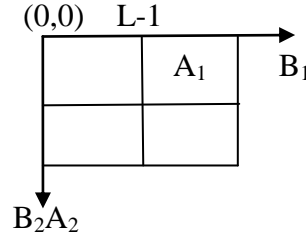
(3) Choose the best threshold  $Th=Th^*$ , after dividing the image into  $C_1$  and  $C_2$ , we have [3-4]:

$$[E_1 + E_2]_{Th=Th^*} = \max\{E_1 + E_2\} \quad (4)$$

**2.2.2. Two-dimensional Entropy Algorithm of the Image:** Information entropy represents the whole statistical characteristics of the information source. For the specific information source, the entropy value is only one [8-10]. The image can be regarded as a two-dimensional gray function, its one-dimensional entropy value will change with the variance of the threshold. We can determine the threshold according to the maximum principle of the entropy value. However, the two-dimensional can fully make use of the spatial relationship between the pixel itself and the neighboring pixels to build the two-dimensional histogram, calculate the maximum entropy value, and determine the best threshold point [1,3,11].

For a digital image with size  $M \times N$ , if we use  $i$  represents the gray value of coordinate  $(x, y)$ ,  $j$  represents the average gray value of the  $k \times k$  ( $k$  is an odd number) neighboring area of this point, then  $i$  and  $j$  can form a binary set, namely the two-dimensional

histogram. Set the gray level of the original image is  $L$ , then the gray level of the neighboring area is also  $L$  [3-4]. When we give a reasonable threshold of each two-dimensional variables, the two-dimensional histogram of the image can be divided into four areas, which is shown in Figure 2:



**Figure 2. Two-dimensional Histogram**

If the target is located in bright area (target with dark area is in the same way), then  $A_1$  is the background area,  $A_2$  is the target area,  $B_1$  and  $B_2$  are the edge and noise area respectively. For general images, most pixel points should be located in the target area and background area, and concentrate near the diagonal area [10-11]. If  $C_{ij}$  represents the pixel pair where the current gray value is  $i$  and the average area value is  $j$ ,  $P_{ij}$  represents the probability of  $C_{ij}$ , then we have:

$$p_{ij} = C_{ij} / (M \times N), \quad \sum_{i=1}^L \sum_{j=1}^L p_{ij} = 1 \quad (5)$$

The maximum threshold method of two-dimensional entropy is to determine the best threshold in area  $A$  ( $A_1$  area and  $A_2$  area), and maximize the information of target area and background area, because in the target and background area, the gray level change is relatively smooth. The discrete two-dimensional entropy of the image can be defined as [9-12]:  $H = \sum_i \sum_j p_{ij} \ln p_{ij}$ , set  $(S, T)$  is the two-dimensional initial threshold, then the two-dimensional entropy of target area and background area can be represented as:

$$H(A_1) = - \sum_{i=S}^{L-1} \sum_{j=T}^{L-1} (p_{ij} / P_{A_1}) \ln (p_{ij} / P_{A_1}) = \ln P_{A_1} + H_{A_1} / P_{A_1} \quad (6)$$

$$H(A_2) = - \sum_{i=0}^{S-1} \sum_{j=0}^{T-1} (p_{ij} / P_{A_2}) \ln (p_{ij} / P_{A_2}) = \ln P_{A_2} + H_{A_2} / P_{A_2} \quad (7)$$

Where

$$P_{A_1} = \sum_{i=S}^{L-1} \sum_{j=T}^{L-1} p_{ij}, \quad P_{A_2} = \sum_{i=0}^{S-1} \sum_{j=0}^{T-1} p_{ij}, \quad H_{A_1} = - \sum_{i=S}^{L-1} \sum_{j=T}^{L-1} p_{ij} \ln p_{ij}, \quad H_{A_2} = - \sum_{i=0}^{S-1} \sum_{j=0}^{T-1} p_{ij} \ln p_{ij}$$

Find the best threshold  $(S^*, T^*)$ , we have:  $H(S^*, T^*) = \max(H(A_1) + H(A_2))$ , the two-dimensional entropy is the largest at this point [4,11-13]. According to the threshold, we can segment the image and accurately extract the calibration points' information of the forest tree image.

### 3. Experiment Design

This paper uses the Microvision MV-VS078FC high resolution industrial camera as the image acquisition device, and the camera lens is AFT-0814MP, the image acquisition card is MV-1394, the image size is 1024\*768, the image format is JPEG, and the image processing software is Matlab 7.1. During the experiment, first we need to mark four red

information points similar to rectangular on the forest tree, then capture the forest tree image with information points, determine the best threshold according to fuzzy theory and two-dimensional entropy algorithm, and accurately extract the image information of the four calibration points.

#### 4. Results and Analysis

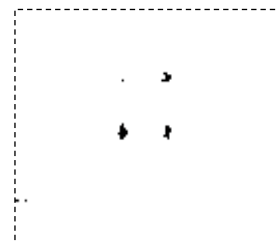
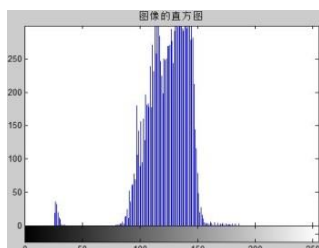
The key of the image processing method which combines fuzzy theory with two-dimensional entropy algorithm is to calculate the membership attribution and two-dimensional entropy value [5, 9]. Because the captured image contains the red information points, we just need to extract the data of red channel. The post-processing only need to process the extracted data [3, 9, 11]. Figure 3 is the original forest tree image with red marked points. Figure 4 is the forest tree image after extracting the red channel information using Matlab [3, 12], the one-dimensional and two-dimensional threshold processing are mainly for Figure 4.



**Figure 3. Collected Original Image**

**Figure 4. Image after Color Extraction**

Figure 6 is the histogram of Figure 5 (the same as Figure 4), Figure 7 is the binarization and negation result of Figure 5, the threshold is 0.45. Figure 8 is the image after membership attribution. Figure 9 is the histogram of Figure 8. Figure 10 is the binarization and negation result of Figure 8, the threshold is 0.6. Figure 11 is the image after two-dimensional entropy processing. Figure 12 is the two-dimensional histogram of Figure 11. Figure 13 is the binarization and negation result of Figure 11, the threshold is (0.5, 0.55).

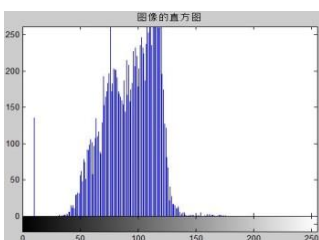


**Figure 5. Image after Color Extraction**

**Figure 6. One-dimensional**

**Histogram**

**Figure 7. Binarized Image (Th:0.45)**



**Figure 8. Image after Membership Merger**

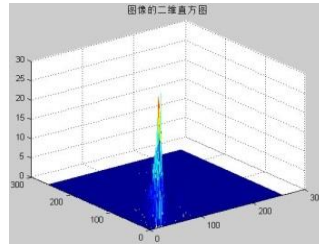
**Figure 9. One-dimensional**

**Histogram**

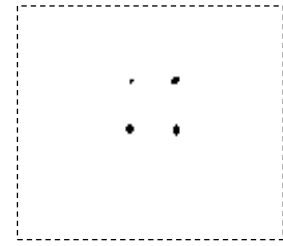
**Figure 10. B Binarized image (Th:0.6)**



**Figure 11. Image after Membership Merger**



**Figure 12. Two-dimensional Histogram**



**Figure 13. Two-dimensional Threshold Image (Th:(0.5,0.55))**

From the results we can see that, after membership attribution and two-dimensional entropy processing, the forest tree image has obvious advantages in definition, histogram and binarization image relative to original image. From Figure 5, Figure 8 and Figure 11 we can see that the definition is strengthened, the information point is clear, it demonstrates that the image after membership attribution has better effect than the original image, the image after two-dimensional entropy processing and membership attribution has higher definition. With different processing method, the effect of the image is different. From the histogram information of Figure 6, Figure 9 and Figure 12 we can see that, the gray value of Figure 6 mostly concentrates between 90 and 180, the gray value of Figure 9 is mainly located between 40 and 170. It shows that after membership attribution, the gray value of the original image becomes smaller, especially the gray value of nearing 15 has obvious change, it shows that this area has obvious effect after membership attribution. The two-dimensional histogram data distribution of Figure 12 is near the diagonal area, it shows that after membership distribution and two-dimensional entropy processing, we have minimize the effect of the noise, and prove the feasibility and accuracy of this method. From the binarization images of Figure 7, Figure 10 and Figure 13 we can see that, in the image of Figure 7, each point is discrete and there are many edge blurs. Especially the information points located in upper right lower left and lower right. It has obvious difference relative to the original image; it shows that the image effect using a direct threshold is not ideal. Figure 10 is the extracted binarization image after membership attribution; it has obvious change relative to Figure 7, but the information points located in lower left and lower right have great difference with the original image. Figure 13 is the extracted image after membership attribution and two-dimensional entropy processing, the four information points are very close to the original image, and has obvious change relative to Figure 7 and Figure 10, it fully shows that using this method to process the information points of forest tree image is more scientific and accurate.

#### 4. Conclusion

This paper captured the tree image with marked points, selected the template and processed the pixels using the membership maximum principle of fuzzy theory, then determined the best threshold according to two-dimensional algorithm and binarized the image, finally we can get the image with four information points. The results show that when we process the image with red marked points using the image processing method combining fuzzy theory with two-dimensional entropy algorithm, the edge and image detail have obvious change, it has better effect in noise elimination, and the information points have higher definition relative to one-dimensional histogram method. It shows that the method using fuzzy theory and two-dimensional entropy algorithm is more feasible and accurate, and can provide strong technical support for realizing the remote wireless monitoring and promoting the forestry informatization.

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