REVIEW OF APPLICATION OF MATHEMATICAL MORPHOLOGY IN CROP DISEASE RECOGNITION

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Abstract: Mathematical morphology is a non-linear image processing method with two-dimensional convolution operation, including binary morphology, gray-level morphology and color morphology. Erosion, dilation, opening operation and closing operation are the basis of mathematical morphology. Mathematical morphology can be used for edge detection, image segmentation, noise elimination, feature extraction and other image processing problems. It has been widely used in the field of image processing. Based on the current progress, this thesis gives a comprehensive expatiation on the mathematical morphology classification and application of crop disease recognition. In the end, open problems and the further research of mathematical morphology are discussed.

Keywords: binary morphology, gray-level morphology, color morphology, erosion, dilation, crop disease

1. INTRODUCTION

Mathematical morphology is a new theory and method, which is used in the field of digital image processing and recognition. Its mathematical background and language is set theory, which has self-contained

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mathematical background. Mathematical morphology was born in 1964, which is firstly proposed by the Ph. D student J. Serra and his academic advisor G. Mathorn. They proposed the "hit/miss Transformation" and they introduced the expression of morphology on the theory level firstly and established particle analysis method. In 1968, they found the "Fontainebleau Mathematical Morphology research institute". Based on the hard work of the researchers in this Institute and other country's researchers, Mathematical morphology is gradually developed and self-contained. In 1970s, with the commercial applications of grain analyzer and the publication of Mathern's "random set and integral set", the development of Mathematical Morphology is focus on gray-level aspects. In 1982, after publish of J.Serra's "image analysis and mathematical morphology", Mathematical morphology is world-wide known. Subsequently, Mathematical morphology was developed vigorously. Because the algorithm of Mathematical morphology has naturally parallel realizing structure, which realizes morphology analysis and parallel process algorithms, the method could be realized by hardware easily, which improves the image process speed and analysis.

Mathematical morphology is found on the self-contained mathematical theory and its ideas and methods have great effect on image process theory and technology and have been used in many subjects' image process and analysis. Moreover, the application of Mathematical morphology in agriculture field has also achieved great improvement. The application is focus on crop disease recognition, including wheat, cotton, vegetable, etc. In this paper, we mainly summarize the applications of Mathematical morphology in agriculture field and discuss open problems and further research.

2. MATHEMATICAL MORPHOLOGY CLASSIFICATION

Through people's efforts, mathematical morphology used in binary image originally was extended to gray-level image and made a rapid progress of the theory and applied study of gray-level morphology by right of the umbrella theory. Recently, the study of the mathematical morphology placed emphasis on the color morphology and made some achievements. According to the expression and display format of the object of study for morphology, this paper divided the mathematical morphology into binary morphology, gray-level morphology and color morphology.

2.1 Binary morphology

Mathematical morphology put forward by Maheron and Serra studied the binary image and was called binary morphology. The morphological transform of binary image in mathematical morphology was a process for sets. The essential of the morphological operator is the interaction between the sets expressed the object and shape and structure element, the shape of the structure element decide the shape information of the signal extracted by the operation. The morphological image processing is the set operation of the moving a structure element in the image and then transforming or combining between structure element and binary image. The basic morphological operations are erosion and dilation.

In the morphological operation, structure element is the most basic and important conception, which plays the role of the wave filtering in the signal process. If $B(x)$ expresses the structure element, for the every dot x of the work space E, the erosion and dilation are defined respectively as:

Erosion: $$X = E \odot B = \{x : B(x) \subset E\} \quad (1)$$

Dilation: $$Y = E \oplus B = \{y : B(y) \cap E \neq \Phi\} \quad (2)$$

From the definition and mathematical expression, binary morphological dilation and erosion can translate into the logical operation of the set, and the algorithm is easy. Because of the facility of parallel processing and hardware realization, binary image can be operated in multiple ways, such as edge detection, image segmentation, thinning, feature extraction, figure analyzing. However, in different condition, the selection of the structure element and the corresponding algorithm is different, different structure element and algorithm is designed for different aim image. The size of the structure element and the selection of the shape will influence the result of image morphological operation. (Huang et al. 2003) adopted round, triangle, square and other basic geometric figure as structure element and eroded the binary image for some times, they detached the section of the hexapod by the segmenting method of filtering image with morphological template at last. The result showed that the segmenting algorithm could get the better effect and established all right basis for extracting the figure character of the disease image. (Bouaynaya et al. 2008) founded the operator of space-variant mathematical morphology in Euclidean space and presented geometric structure element based on space variable, the simulated result illuminated the theory and the huge potentials in many kinds of image processing application.

2.2 Gray-level morphology

Gray-level morphology is the natural extension of binary morphology for gray-level image, which operating object is not any more set but image function. For gray-level morphology, the intersection and union operation used in binary morphology are replaced by maximum and minimum operation. The erosion and dilation process of gray-level image can be calculated directly from the gray-level function of image and structure element. If $g(x, y)$ expresses the structure element, for one dot $f(x, y)$ in the image, the erosion and dilation are defined respectively as:

Erosion:

$$(f \odot g)(x, y) = \min_{i,j} \left\{ f(x - i, \quad y - j) - g(-i, \quad - j) \right\} \tag{3}$$

Dilation:

$$(f \oplus g)(x, y) = \max_{i,j} \left\{ f(x - i, \quad y - j) + g(i, \quad j) \right\} \tag{4}$$

In order to apply the gray-level morphological operation in reality, some scholars proposed many improved algorithms. (Kang et al. 2006) proposed an extended definition of mathematical morphology for the problem that although edge detection methods based on classical morphology has good ability of noise elimination, it could not reflect whole edge characters. And they proposed an edge detection method based on extended mathematical morphology. The simulation result implied that this method not only eliminates noise effectively, but also the edge image by detecting has good edge characters. (Bouaynaya et al. 2008) proposed spatially-variant mathematical morphology, and gave out the geometrical concept of structure function. Simulation results showed the potential power of this theory in image analysis and computer vision applications.

2.3 Color morphology (Fan et al., 2007)

The research of morphology in color image processing area is not that much. Although some scholars have presented some morphology method used in color image, most of them only consider each vector individually, neglecting the relationship between the vectors. It is an effective and reasonable research approach to process the color pixel through vector methods describing relation among each vector. Simultaneously, the research on the morphology transformation in the HIS color space can reflect its relationship with the gray-level morphology.

For the color image $\left\{ V(x);\quad x \in X,\quad X \subset D_V \right\}$ in HIS space, where D_V is the image domain in RGB color space, erosion and dilation in color morphology for the structure element B are as followed:

Erosion: $V\Theta_c B = \max \left\{ V(x+y); (x+y) \in D_V, y \in B \right\}$ (5)

Dilation: $V \oplus_c B = \min \left\{ V(x-y); (x-y) \in D_V, y \in B \right\}$ (6)

In recent years, a lot of scholars have dedicated on the research of color morphology. (Zhang et al. 2006) proposed an edge detecting method based on mathematical morphology. In this method, the image is pre-processed, and then the gradient transformation is done through mathematical morphology. At last, the edges are detected by the edge detecting method based on statistics. The method eliminates the shadow edge caused by the illumination, extracts the contour of objects directly, and has some effect on background noise suppression. (Leozoray et al. 2007) present a new graph-based ordering of color vectors for mathematical morphology purposes. An attractive property of the proposed ordering is its color space independence. A complete graph is analyzed to construct an ordering of color vectors by finding a Hamiltonian path in a two-step algorithm. This method can be used in any color picture.

3. MATHEMATICAL MORPHOLOGY APPLICATION

The basic idea of mathematical morphology and its method could be used in any aspects in the area of picture processing. With the development of computers, picture processing, pattern recognition and computer vision, mathematical morphology is developing quickly, and the application area is becoming vaster. Especially in the area of the crop disease recognition, many great results were achieved. In the existing software system, there are many implementations of mathematical morphology. The mathematical morphology is applied in the many areas, such as edge detection, image segmentation, noise elimination, feature extraction, and etc.

3.1 Edge detection

Mathematical morphology depicts and analyzes image from the angle of set, makes geometrical transformation for the target objects through a "

probe " set (structural element) in order to outburst the required information. Along with the continuously development and improvement of mathematical morphology theory, mathematical morphology has gotten extensive research and application in image edge detection. Compared with the traditional image edge detection algorithm (Sobel operator, Prewitt operator et al.), morphology has unique advantage in image edge detection, and obtains better effect. Morphological method applied in image edge detection can keep preferably the image detail characters, and solves the coordinative problem of edge detection precision and anti-noise performance. (Zhou 2005) firstly made gray-level processing for color image, then used mathematical morphology method for edge detection, where the structure element was 3*3 square template. This method could solve preferably the problems of noise elimination and edge detection of pests in stored grain. (Kang et al. 2006) proposed an extended edge detection method of mathematical morphology in order to solve the problem of not perfectly reflecting the whole edge characters of the classical mathematical morphology. Selection definition of distance operator was given and the concept of multi-resolution analysis was applied in the extended morphological method. Results indicated that this method has good edge detection performance. (Hu et al. 2006) proposed a multi-direction edge detection algorithm based on fuzzy morphological method. The combination of multi-direction characters and fuzzy image characters was introduced to mathematical morphology. Then mathematical morphology was used for edge detection. Results showed that this algorithm could detect the edge successfully, and had better effect than other traditional edge detection algorithms.

3.2 Image segmentation

In the research of image and its application process, people often are interested in certain parts of image. The image segmentation refers to the technology that the image is divided into each characteristic region and withdraws the interest goal. Here the characteristics may be the pixel's gray, color, texture and so on. The image edge segmentation algorithm based on mathematical morphology uses mathematical morphology transformation to divide the complicated target X to the simple subset which a series of does not intersect mutually "X_1, X_2,…, X_N" ,where

$$X = \sum_{i=1}^{N} X_i \tag{6}$$

The segmentation process for goal X can be achieved according to following method: firstly extracts the biggest inscribed circle X_1 of X , then

calculates $X - X_1$, and extracts the biggest inscribed circle X_2 of $X - X_1$,…, respectively, until the set which finally obtained is the null set.

At present some scholars has already applied mathematics morphology to the agricultural crop disease image segmentation. (Huang et al. 2003) proposed a segmentation method that uses morphological template to filter color image, and applied this method for colorized digital image segmentation of vermin in cropper foodstuff. The result indicated that, this segmentation method can obtain good effect. (Xue et al. 2006) firstly use mathematical morphology to segment image in three two-dimensional color subspaces, then make two-dimensional histogram, and implements watershed algorithm respectively for the three two-dimensional histograms, lastly achieves final image segmentation by region splitting-merging process. This method is faster and less memory than the method applied in three-dimensional space, has good segmentation result. (Huang 2007) applies hole filling, erosion, dilation, opening and closing operation of mathematical morphology to extract the whole lesion areas of Phalaenopsis seedling, and obtains good effect.

3.3 Noise elimination

In pre-processing images, it is indispensable to eliminate the noise. The combination of opening and closing operations forms a morphological noise filter.

Concerning the binary image, noise includes noise block around the objects and noise hole inside the objects. The noise block will be eliminated by opening operation to operate A with structure element B. The noise hole will be eliminated by close operator to operate A with structure element B. However, these operations are related to the selection of structure element. When the noise block and the noise hole are smaller than the structural elements, the noise could be eliminated successfully. When they are larger than the structural elements, the noise can not be eliminated. (Jianga et al. 2008) used the erosion and dilation operators of mathematical morphology to filter the selected Apple image, and the structure element is a 3 × 3 structure.

Concerning the gray-scale image, to eliminate the noise is to smooth it morphologically. Actually, we commonly use opening operation to eliminate bright details which are smaller than structure element and keep the overall value of the gray-scale and large bright region invariable. And we use closing operation to eliminate dark details which are smaller than structure element and keep the overall value of the gray-scale and large dark region invariable. With the combination of these two operations, we can get the goal of eliminating noises both in bright and dark areas. (Li 2008) presented

a pre-processing method of plant leaf image based on mathematical morphology, and had very good results by using opening and closing operations of mathematical morphology to eliminate the isolated noise points and fill the internal holes of the leaves. (Pina et al. 2006) first did the closing operation to the image of olive trees with an isotropic structuring element and then did the erosion operation. The noise points can be eliminated successfully.

3.4 Feature extraction

In general, the feature extraction is a transformation, which maps or translates the samples from high-dimensional space to low-dimensional space in order to decrease the dimensional degree. In agriculture disease recognition application, the features such as color, texture, shape have been widely used. By using the mathematical morphology, it will extract not only the disease texture features such as energy, entropy, moment of inertia, but also the disease shape feature like perimeter, area, degree of rotundity, length to width ratio. (Huang 2007) has applied the same method to Phalaenopsis seedling diseases and obtained features like centre coordinate, area, degree of rotundity. (Qian et al. 2003) had extracted the statistical features of framework image sequence by means of framework reconstructing algorithm of mathematical morphology, which provided the basis for further identification. (JR et al. 2003) has proposed a feature extraction method base on morphological operator for the iris identification, resulting that the system has lower complexity and lower storage requires. (Zheng et al. 2007) have used the mathematical morphology to achieve the four shape features of cotton by using the 3×3 square matrix template as the structure element in processing.

4. OPEN PROBLEMS AND FURTHER RESEARCH

The mathematical morphology, used as a powerful tool to analyze and depict the texture and shape signature, has developed rapidly. And the mathematical morphology-based image process system has attracted great attention world widely (Wu et al., 2003). Particularly, the agriculture disease intelligently recognition has drawn great enthusiasms from researchers both home and abroad. So far the mathematical morphology has been applied to the real-system. However, there could be many improvements in real application. So the open problems and further research could be concluded as follows:

(1) The morphology actually is a two-dimensional convolution operation. And the operation speed will be very low in case of the high-dimensional

grey morphology, color morphology or the image morphology. So it is not fit to deal with the real-time process required system.

(2)Selection of structure element plays a decisional role in the morphology operation. However until now there hasn't a standard to the structure elements' selection.

(3)The combination of morphology with the neutral network, the wavelet could be developed further and it could improve the currently used image process method.

(4) Different structure elements can have different effects on the morphology operation' results. And the color image process based on the multi-structure elements could be one of the future researches.

So the development of fast speed algorithms for grey-level and color morphology, the design of the structure elements select standard, and the improvements of the morphology's generality will be the problems for the mathematical morphology. Also the adaptation of the morphology operation must be enhanced. By using the advanced achievements in mathematical morphology, its application to the agriculture disease recognition can enrich and develop the morphology-based image processing method. Meanwhile, the research of color morphology theory and the color morphology operator's application will be the further researches.

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