A SPECIAL PIPELINE ARCHITECTURE FOR MORPHOLOGIC IMAME ANALYSIS AND ITS APPLICATIONS IN FAST THINNING OF CHARACTER

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ABSTRACT

In this paper a new pipeline architecture for morphological image analysis is proposed . Correspondingly, algorithms which is designed for this pipeline architecture are also given to realize mathematical morphological set operations. This system including the pipeline architecture and associated algorithms is high in speed, efficient in computation and flexible in doing different kinds of morphological transformations. The application of this system is given in fast thinning of Chinese characters which can keeps the connecitivity and linearity which is useful information in Chinese character recognition.

1. INTRODUCTION

Many differnt architectures have been proposed or built over past decade for morphilogical image analysis and many algorithms have also been proposed [1] for special image processing . In this paper we proposed a special pipeline architecture for image analysis with its advantages of high speed, flexibility and simple structure . In OCR, the low level processing , such as stroke extracting , thinning, noise cancelling, text segmentation and character cutting, are time consuming . High speed, feasible hardware is very necessary in alleviating it.

A special thining algorithm, which is based on mathematical morphological set operations and can keep the connectivity as well as linearity of a character pattern which is useful information in extracting strokes and their relations, is also proposed as the application of this morphological image analysis system .It's taken as a part in the preprocessing for Chinese character recognition.

At first ,we will give you a brief introduction to the notations and definitions of Mathematical morphology which is used here. Next, the pipeline architecture for morphogical image analysis will be presented and a brief analysis will be taken to demonstrate that all mathematical morphological set operations can be implemented based on this architecture . At last the application of this morphological system will be given for fast thinning of Chinese character.

2. NOTATION AND DEFINITIONS

Mathematical morphology is the study of shape by using the tools of set theory. A survey can be found in the book [1] written by Serra . We now present several basic definitions based on an image X and a structuring element B. Z is discrete plane , "-", (.) denote, respectivly, set difference and set complemention.

Minkowski sum: $X \oplus B = \{a + b : a \in X, b \in B\}$.

Minkowski subtraction: $X \ominus B = (X^c \oplus B)^c$.

Symmetric of B: $B^s = \{-b : b \in B\}$.

Translation of B by $a \in \mathbf{Z}^2$: $B_a = \{a + b : b \in B\}$

Erosion of X by B: $X \ominus B^s = \{a : B_a \subseteq X\}$.

Dilation of X by B: $X \oplus B^s = \{a : B_a \cap X \neq \emptyset\}$.

Closing of X by B: $X^B = (X \oplus B^s) \ominus B$.

Opening of X by B: $X_B = (X \ominus B^s) \oplus B$.

Thinning of X by B: $X \circ B = X - (X \circledast B)$
where $\circledast$ means X hitted by B.

3. PIPELINE ARCHITECTURE FOR BINARY IMAGE PROCESSING

At first we consider the morphological transformation when the size of the two dimensional structuring element is smaller than m*n. Next, it will be further generalized to the structuring elements of arbitray size . The basic pipeline architeture for morphological set operations is shown in Fig.3.1.

Assuming the Image Memory size is M*N (M>>m, N>>n, ">>" means much greater than) .The size of buffer which is for storing the image data send from Image Memory is M*n . The buffer is called Image Buffer. Both of them are used to store binary image . In this pipeline architecture, image data are presented in raster format . The image pixels begins in the upper lefthand corner of the Image Memory and proceeding left to right, top to bottom . The raster pixels are loaded into Image Buffer . The output of Image Buffer is a small two dimensional image with size m*n. The image is correspoding to the part of the image in Image Memory .The origin of the small image is assumed at its center . The output of the buffer is the input of a table with size of 2 .The output of the table which is also the pixels in raster format is rewrited into Image Memory at the position where the origin of the small image in Image Buffer corresponding to.

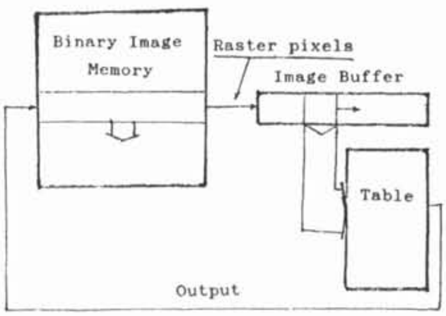

Fig.3.1 The basic architecture for morphological image analysis

Consider again the characterizations for dilation and erosion:

$$X \oplus B = \bigcup_{b \in B} X_b$$
$$X \ominus B = \bigcap_{b \in B} X_b$$

If the size of structuring element of B is smaller than m*n,then the result of dilation or erosion are only concerned with the pixels within the range of m*n. Loosely speaking , if the size of structure element is smaller than m*n , the output of Image Buffer can completely determine the results of dilation or erosion operations.

Any morphological set operations,where the size of structuring element is smaller than m*n , can be regarded as a kind of projection from $E^{2^{m*n}}$ to E' (where E is the set {0,1} which represents binary image) . By changing the content in the table any specified projections can be implemented,including dilation, erosion, etc.It is obvious now that with the previous basic pipeline architecture , any basic morphological set operations with the struturing element size smaller than m*n can be realized.

Using the theory of pattern spectrum which is based on opening and closing set operations , the basic morphological set operations with any structuring element can be realized by a chain of set operations on previous basic morphological system . The complexity of this algorithm is O(log (n)) , where n is the size of an image . So this approach is very efficient in computation compared with others on other architectures with associated algorithms . For more detail information of pattern spectrum please refer to the works done by Lynn Abbott on pattern spectrum [3].

The Practical Consideration:To realize basic logical operations,for example AND ,OR,XOR,etc,among several binary images, seven other binary Image Memories are appended to the basic architecture , and seven other tables are also appended for the purpose of morphological set operations for each binary Image Memory.These eight tables is denoted as first degree table which realize basic morphological set operations parallelly.Another table, denoted as second degree table is used which takes the output of eight first degree tables as input . The size of second degree table is $8*2^8$. Actually, there eight sperated subtables in second degree table with each size 2^8 and the outputs of second tables is eight seperate pixel streams in raster format and are rewrited into eight binary Image Memories repectively.Using second degree table any basic logical operations among several binary image and the exchangings between binary Image Memorys can be realized easily just by setting the table into different contents.

The actual pipeline architecture for performing morphological set operations is illustrated in Fig.3.2:

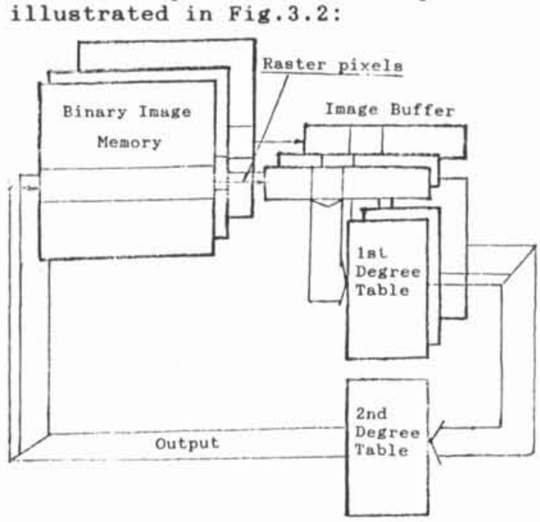

Fig.3.2 The block diagram of the pipeline architecture for morphological set operations.

4.THE APPLICATION OF THIS SYSTEM IN FAST THINNING OF CHARACTER

Because the mathematical morphology is a theory about shape, many processing of binary image in O.C.R. can be realized according to it. Here only the thinning algorithm which keeps connectivity and linearity during thinning will be showed.

If the thinning of a pattern can be regarded as a process which eliminates superflous pixels and retains the pixels which contain useful information in the pattern, the needs for keeping connectivity during thinning is only to delete pixels without destroying these properties . In mathematical morphology it is called conditional thinning.It's clarity in conceptional expression and can be realized on the morphological image processing system with very high speed.Next , the steps of the algorithm will be showed briefly.

At first, the thinning algorithm by morphological set operations will be introduced:

for 8-connected pattern,the structuring element is :

$$L1:\begin{pmatrix} 0 & 0 & 0 \\ . & 1 & . \\ 1 & 1 & 1 \end{pmatrix}$$

$$L2:\begin{pmatrix} . & 0 & 0 \\ 1 & 1 & 0 \\ . & 1 & . \end{pmatrix}$$

0 white
1 black
. either white or black

The thinning of a pattern can be represented as:

(1) $X=(X \bigcirc L1) \bigcirc L2$

(2) Rotating L1,L2 by $\pi/2$, repeating step (2) until there no any more changing in X.

Example of thinning based on morphological transformation is givern in Figure 4.1:

Fig.4.1 Example of thinning based on morphological transformation

The thinning process which can keeps linearity as well as connectivity can be expressed as following:

(1) $Y=X_{S_1} \cup X_{S_2} \cup X_{S_3} \cup X_{S_4}$

$$X=X-((X \bigcirc L1) \cap ((Y \bigcirc L1) \cup (X-Y))) \qquad (4.1)$$

$$X=X-((X \bigcirc L2) \cap ((X \bigcirc L2) \cup (X-Y)))$$

Where S1,S2,S3,S4 are structuring elements for representing strokes:

$$S1=\overset{T}{S3}=(1,1,\ldots,1)$$

$$S2=\overset{T}{S4}=\begin{pmatrix} 1 & & 0 \\ & 1 & \\ & & \ddots \\ 0 & & 1 \end{pmatrix}$$

n is the minimum length of strokes in a specified case.

(2) Rotating L1,L2 by /2,repeating step (1) until there are no more changing in X.

In expression (4.1),XOL1 represents the pixels which can be delate without destroying the connectivity of the pattern. YOL1 represents the pixels on a stroke and can be delete without destroying the linearity of the strokes in the pattern. X-Y represents the pixels not on strokes.So (4.1) can be explained as to delete the pexels which is not on a stroke or can not destroying the linearity of strokes while keeping connectivity . Shortly speaking , keeping linearity and connectivity during thinning.

5.CONCLUSION

We have proposed an approach for morphological image analysis . The pipeline architecture is choosed to overcome the shortage of others in I/O limitation,inflexible and complex in computation. The associated algorithms is also proposed here for implementing morphological set operations . It is simple in computation and has solid theoretical fundamental. All these works are doing in our laboratory.

The new thinning algorithm proposed here, which is composed of morphological conditional thinning , is implemented in this system . It's used as preprocessing for multifont and handwriting Chinese character recognition with its advantage of high speed , flexibility and robustness.

REFERANCES

[1] Lynn Abbott,Robert M.Haralick,Xinhua Zhuang: " Pipeline Architectures for Morphologic Image Analysis", Machine Vision and Applications,No.1,1988.

[2] J.Serra: "Image Analysing and Mathematical morphology", Academic Press, London 1982.

[3] Petros Maragos:"Pattern Spectrum for Images and Morphological Shape size complexity",IEEE Press,1987.

[4] A. Rosenfeld and A. C. Kak:" Digital Picture Processing ", Vol.2, pp 232-233.