Traversal Method for Connected Component Based on Recursion and the Usage in Image Treatment

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***Abstract*-Connected component traversal is a very basic operation in image processing. This paper extends the concept of connected component and traversal and proposes a traversal method based on recursion for connected component. The method uses operation of call a function to traversal and record connected component and uses system stack to save the traversal chain. This method can label the connected component with a single scan of the image. It can also record the whole set of the connected component and its edge at the same time. Four kinds of improvements of the method are given.**

Keywords- Connected Component; Recursion; Image Treatment

I. INTRODUCTION

Connected component traversal is the base operation in most image processing applications and it is the premise of shape analysis and recognition. The efficiency of this operation has a significant impact on the efficiency of the whole system [1-3].

The existing studies on the connected component are mainly concerned with labelling, that is to say to label the connected component in a binary image. Existing labelling methods include methods based on point scanning such as sequential scanning, recursion method, region rising method, and methods based on line segment scanning such as run-length labelling methods. All of those methods can accurately label connected components but the differences are the calculations, representation of the results and memory spaces. Most of those methods need two times of scan for image. Among those methods, methods based on point scanning are easy to understand and apply, so they are used widely. But sequential scan and regional rising pattern requires multiple scans of the image [4-8]. Xu Zhengguang proposed a method of recursion transfer [9], but it also needs to conduct a scan of the image, mark the pair and traverse connection areas by recursive. The basis of this method is still point scanning, so it does not make efficient use of the recursive method.

The concept of connected component is not limited to binary image, the connected component with gray and colour images can also be analyzed. With that analysis, we can do the image segmentation or get continuous edge by connected component analysis of image gradient and improve the efficiency of watershed method with the labelling operation of connected component.

This paper extends the conception of connected component and proposes the traversal method based on recursion. It gives the method to label the domain edge with traversal connected component. It analyzes the traversal method for binary images, grayscale images, color images, and image gradient. It proposes wide-traversal method for connected component that can get results of connected component even the domain fractures in certain ways. Finally the paper analyzes the algorithm for shape analysis, gives the formula for central point, the center of gravity and second-order moment of the domain. It gives analysis method for multiple shapes such as line, circle and rectangle [10].

In this paper, all discussions are limited to gray image with 256 gray level unless special explanation.

II. EXTENDED THE CONCEPT OF THE CONNECTED COMPONENT

The traditional concept of connected component is a point set which the points has adjacent and has the same pixel value in the binary image. Look on the digital images as u , a two-dimension matrix. Connected component can be defined as a collection:

$$T = \{(i, j) \mid u(i, j) = u_t, R(i, j) \bigcap T \neq \Phi\} \tag{1}$$

Where T stands for the point collection of connected component, Φ stands for NULL collection, u_t is the aim gray value of connected component pixel, and $R(i, j)$ represents the neighborhood of point (i, j). Common defines for $R(i, j)$ includes 4-neighborhood and 8-neighborhood.

Traditional label methods for connected component mostly deal with binary image, that is to say the u_t is 0 or 1. For gray images, possible value for a pixel can be 0-255, and the concerned connected component may include pixels which gray value

is in a certain range, for example pixels with gray value higher or lower than a threshold. Then the define of connected component can be expressed as Eq. (2)

$$T = \{(i, j) \mid C(i, j) = 1, R(i, j) \bigcap T \neq \Phi\} \tag{2}$$

Where $C(i, j)$ stands for the judge function for the connected component. With difference application, $C(i, j)$ can be different.

The general form of $C(i, j)$ includes:

1. In binary image, judge by the pixel value (0 or 1).

2. In gray scale image, the upper and lower threshold segmentation.

3. In gray scale image, with a gray area segmentation.

4. In gray image, the gray value of the seed point as the center of a range.

5. In color image, a color value or seed color value as the center of a color measurement area.

6. In gradient image, gradient threshold search for flat areas, edge search information above.

III. THE TRAVERSAL METHOD BASED ON RECURSION

The traditional connected component analysis methods are mark-oriented, that is, connected component will be numbered and marked during the scanning process. In practical work, the more common thing to do is a loop-through, which traverses all the points in a connected component and records or calculates information, such as the calculation of the mean gray value in the connected component, gravity center of connecting area and other information.

The traditional component labelling methods, such as sequential scanning, requires at least two scans to complete the mark. If people want to perform a calculation on a connected component, they will need to scan for the third time; it significantly slows down the speed of operation.

Traversal method processes are as follows: scan image sequentially, enter the recursive function if one point meets the traversal conditions, entering a recursive function $C(i, j) = 1$, first mark the point to scan and then pressing a certain sequence scanning points around the point. If one point corresponds to traverse conditions, we make recursive calls to it as a parameter (one input of the stack) or continue to determine the next, return output of the stack until all finished. Therefore, from the initial entry point on the recursive process, although there are certain directions (the same judgment sequence on the points), because inconsistency returns when periodicity condition is not met, the scanning process can be completed on a complicated graph traversal.

People should take the current point coordinates as a recursive function parameters in the image of the recursive calls. In computing, we need to calculate whether the ranges of the coordinates are in a normal range. For example, access (-1, -1) coordinates, can lead to access the wrong memory error.

In the process of recursion, important operations are: determine whether the point is in line with traversal conditions, determine whether the point is outside the image area, and determine whether the recursion depth exceeds the set value. The discriminate way of connected component is 4 neighborhoods and 8 neighborhoods; it has little effect on the implementation of the method, only a few instructions.

This advantage of this method is the calculation complexity. First the calculation speed is higher than the existing method. Different from the existing traversal method, this method accesses every pixel in the image just one time, while most existing methods need at least two scans of the image. The calculation amount of traversal operation is mostly consisted by offset calculation. An offset calculation needs at least one multiple operation. Accession to a single point needs one time of offset calculation. So the low accession cost needs lower calculation amount. Second, this method needs little memory space. Existing method needs at least two times scan of the image, so there must be a memory space to store the temporary result of the scans. For the method based on recursion, it just needs a space to save the labelling result and this space is needed by other method too.

Flow diagrams of traversal process and recur operation are shown in Fig. 1 and Fig. 2 respectively.

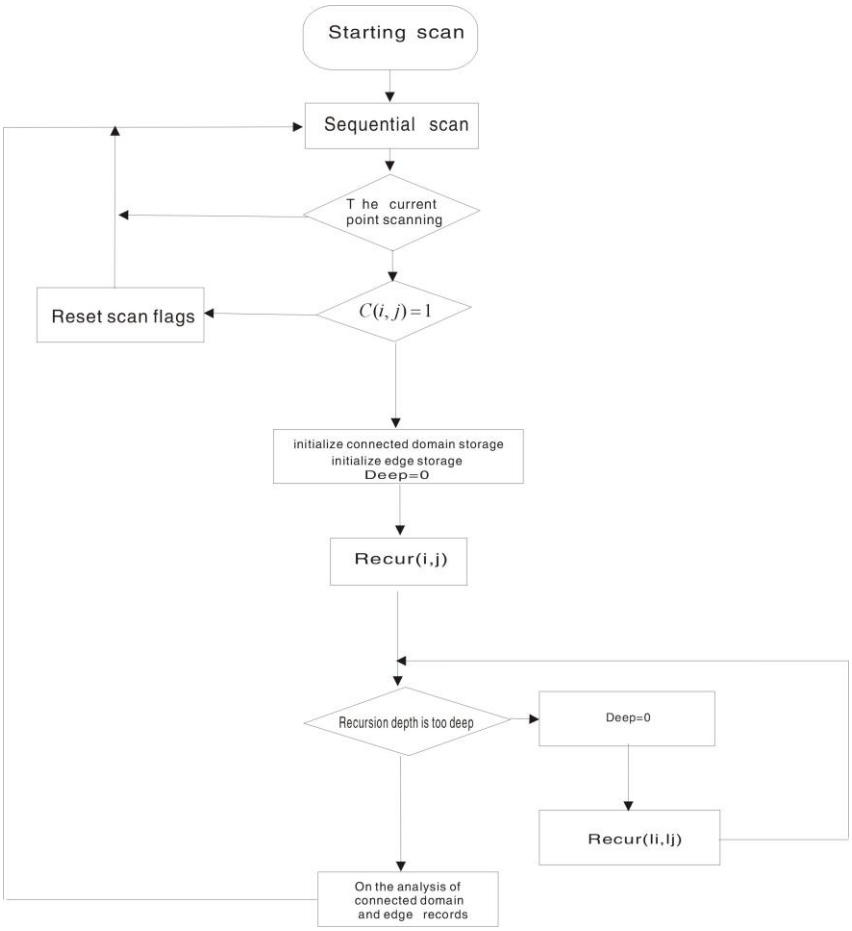


Fig. 1 Flow diagram of traversal process

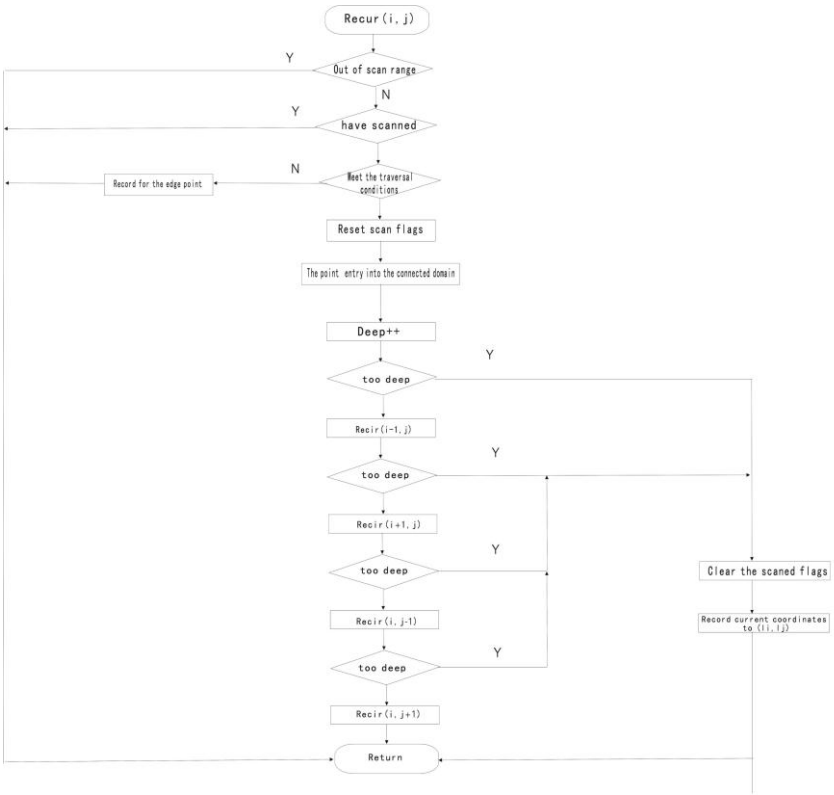
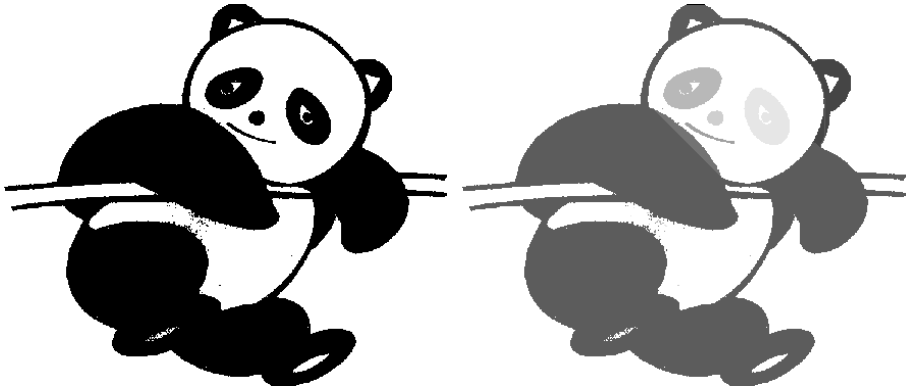


Fig. 2 Flow diagram of recur operation

Experiments: Recursive traversal method is used to some binary images. To the traversal result, different connected components are labelled with different gray level. Orient binary image and label result is shown in Fig. 3 and Fig. 4:

(a) orient image of sample 1 (b) label result of sample 1

(c) orient image of sample 2 (d) label result of sample 21



(e) orient image of sample 3 (f) label result of sample 3

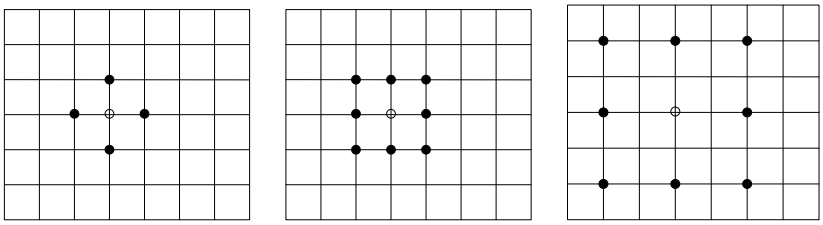
Fig. 3 Traversal and label result

IV. SEVERAL IMPROVED RECURSIVE TRAVERSAL

A. Wide Cables

Connected component in practice often fractures at some location, especially for edge-connected component traversal, at this point we need to ignore the breaking point in the process of the search, so that a more complete connected component can be got.

In the operation, people can expand the definition of $R(i, j)$ in Eq. (2) as follows:



(a) 4 neighbour (b) 8 neighbour (c) expanded neighbour

Fig. 4 Neighbourhood expansion

With the expanded neighbourhood, the traversal operation can stride over the slide disconnected point with a connected component.

B. The Changed Traverse Conditions

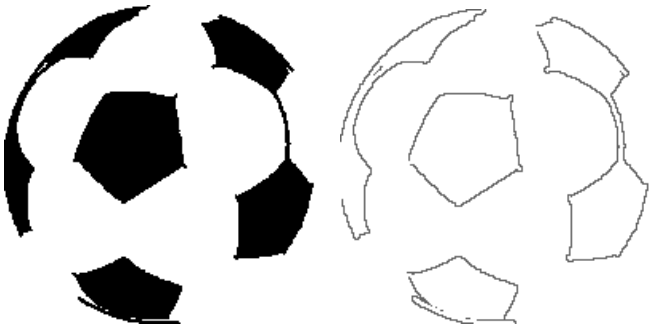
People can change the condition of traversal flexibly in the process of traverse. Common changes include changes in basis

points, threshold changes, changes in scope, and so on. For example, in the process of the gray-scale range, as the traversal condition and connected component changes, we can relax the gray-level criteria to accommodate pixels better and avoid connected component intermediate fracture. When people use gradient to search edge information, they can relax gradient threshold along with the growth of the edge to avoid fracture of the edge.

C. The Record of Connected Component Edge

In the process of recursive, if the current point is judged not to be consistent with recurrent conditions, it returns output stack as a recall. Before returning, we can write down the coordinate of the point, it is the edge of current connected component. When the recursion is completed, people can use the collection of edge points to analyze the shape features of connected component. The edge must be closed and a single line to be beneficial to the analysis of subsequent shape for connected component. For example, the geometric centre, rectangular, circular, length and other information, people can be easily calculated from the edge line.

A record example is shown in Fig. 5:



(a) orient image (b) recorded edge

Fig. 5 Edge record result

D. Handling of the Search Direction

During the search, the search direction to a single order may result in sequential one-sided phenomenon and eventually the sequence of recording point will be more confusing. It may cause trouble for subsequent sorting and processing. In order to solve this problem, it can be started the search before judging which of the current search directions is best. People can calculate the maximum bounding rectangle from the current sets. According to this rectangle, people can calculate the direction of current sets; taking conforming direction or perpendicular direction of the current point sets as needed for first direction to enter the recursion.

V. CONCLUSION

This paper focuses on the connected component recursive traversal method from the connected component and traversal concept, it proposes a traversal method which uses computer stack control function, it improves the speed of connected component traversal approach, at the same time, a complete domain point sets and a single pixel edge line can be attained.

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