

Loop Back Connected Component Labeling Algorithm and Its Implementation in Detecting Face

A. Rakhmadi, M. S. M. Rahim, A. Bade, H. Haron, I. M. Amin

Abstract—In this study, a Loop Back Algorithm for component connected labeling for detecting objects in a digital image is presented. The approach is using loop back connected component labeling algorithm that helps the system to distinguish the object detected according to their label. Deferent than whole window scanning technique, this technique reduces the searching time for locating the object by focusing on the suspected object based on certain features defined. In this study, the approach was also implemented for a face detection system. Face detection system is becoming interesting research since there are many devices or systems that require detecting the face for certain purposes. The input can be from still image or videos, therefore the sub process of this system has to be simple, efficient and accurate to give a good result.

Keywords—Image processing, connected components labeling, face detection.

I. INTRODUCTION

NOWADAYS, there are many applications that use face as the input data. The applications uses it for recognizing face as a biometric information for certain purposes, digital image database, access control for restricted area and human interaction with machine for example focusing camera lens to the human object's face. But all of these things could be happened from a first important process, which is the face detection process.

In an image usually there are some faces with various backgrounds, uncertain illumination and various sizes of faces. For example the image which are taken at the airport, shopping center, from magazine. The image also could be taken by fix lens camera, SLR camera or even a video recording. Like SLR camera that has an auto focus lens that can automatically focusing the lens to the face of the human object or security machine that retrieves the face information,

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the device is limited hardware capability. Therefore, the process of detecting faces should be efficient, simple and accurate.

Face skin color segmentation is one of techniques that can be used to detect faces in a digital image. This technique simplifies the process so it can make the process run efficiently [16]. In the face detection system there is an important process to localize and analyze the component of the color segmented. The process is known as component analysis. In this process the components have to be labeled according to its group to ease the analysis.

Connected component labeling is one of binary morphology. A foreground image, which is the component, is separated from the background image on binary image. Then each component is labeled and displayed as output images [2]. The pixel points in a connected component form a candidate region for representing an object. In machine vision most objects have surfaces. Pixel points belonging to a surface project to spatially closed points. The notion of 'spatially closed' is captured by connected components in digital images. Yet, connected component algorithms usually form a bottleneck in a binary vision system [8].

There are several algorithms of connected component labeling have been proposed [4],[6],[18]–[25]. Mostly the algorithm relies on two subsequent raster-scans of a binary image. In the first scan a temporary label is assigned to each foreground pixel, based on the values of its neighbors (in the sense of 4-connectivity or 8-connectivity) that are already visited. When a foreground pixel with its foreground neighbors carrying different labels is found, the labels associated with the pixels in the neighborhood are registered as being equivalent. The second scan replaces each temporary label by the identifier of its corresponding equivalence class. Another technique is using scan line clustering method. One of the methods was proposed by Yang and Zhang [5], which scans the pixel line by line and searching the neighbors of the pixels.

The purpose of this study is to simplify the process of labeling the connected component for detecting face in a digital image. The method for detecting face is based on the color segmentation technique that distinguishes the face region candidate from the other object. The flow of the system is as follows:

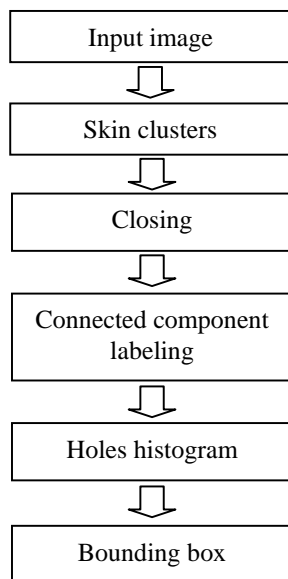


Fig. 1 Face detection system

II. COLOR SPACE SKIN CLUSTERS

The first step in face detection algorithm is using the face skin segmentation to remove the non face object region indicated as much as possible. There are some ways to do that, which are using the RGB color space, YCbCr or HSV color space.

The RGB True Color is based on tri-chromatic theory. It is one of the most commonly used color spaces, with a lot of research activities being based on it. The chosen skin cluster for RGB is [12]:

$$\begin{aligned}
 & (R,G,B) \text{ is classified as skin if:} \\
 & R > 95 \text{ and } G > 40 \text{ and } B > 20 \\
 & \max\{R, G, B\} - \min\{R, G, B\} > 15 \\
 & |R - G| > 15 \text{ and } R > G \text{ and } R > B, \\
 & \text{where } R, G, B = [0, 255]
 \end{aligned} \tag{1}$$

In the RGB color space, each image component (red, green, blue) has its own different brightness. It is different than the YCbCr color space. In the YCbCr color space, the level of brightness is given by the Y component, because the Cb component and the Cr component is not depend on the lumination, so the influence of the lumination can be reduced. This is the advantage of using the YCbCr color space in detecting the face region in digital image.

The corresponding skin cluster is given as [13]:

$$\begin{aligned}
 & (Y,Cb,Cr) \text{ is classified as skin if:} \\
 & Y > 80 \\
 & 85 < Cb < 135 \\
 & 135 < Cr < 180, \\
 & \text{where } Y, Cb, Cr = [0, 255]
 \end{aligned} \tag{2}$$

The HSV skin cluster is defined by [14]:

$$\begin{aligned}
 & (H,S,V) \text{ is classified as skin if:} \\
 & 0 < H < 50 \\
 & 0.23 < S < 0.68, \\
 & \text{where } H = [0, 360] \text{ and } S, V = [0, 1]
 \end{aligned} \tag{3}$$

Although skin color segmentation is normally considered to be a low-level extraction, it is crucial that the skin regions are segmented precisely and accurately. The resulting segmented skin color regions have three common issues:

- Regions are fragmented and often contain holes and gaps.
- Occluded faces or multiple faces of close proximity may result in erroneous labeling (e.g. a group of faces segmented as one).
- Extracted skin color regions may not necessarily be face regions. There are possibilities that certain skin regions may belong to exposed limbs (arms and legs) and also foreground and background objects that have a high degree of similarity to skin color (also known as false alarms).

III. CONNECTED COMPONENT LABELING

The next step is analyzing the region of the face skin candidates using the connected component labeling analysis. In image processing, the connected component labeling algorithm is used to assign or divide each component. Component labeling is executed based on the binary image. It separates background and foreground, making the label list and application label value etc carry out the process for connected component labeling.

Usually, the sequential connected component algorithm system is designed using 4-connectivity, from the very "west" side of the pixel until "north east" of the pixel. This connectivity also called as scanning mask. The first step for dividing each component is to retrieve the binary data from the input image. Then threshold value is applied to the input image. If the input image data value is less than the threshold value, it is considered as background. However, if the input image data value is more than the threshold value, it is considered as foreground. Finally, noise from the threshold result image is removed by using a dilation/erosion algorithm.

The pixel value of foreground is considered as '1' while the background is considered as '0'. Fig 3 shows the input image and the result image after applying the connected component labeling algorithm.

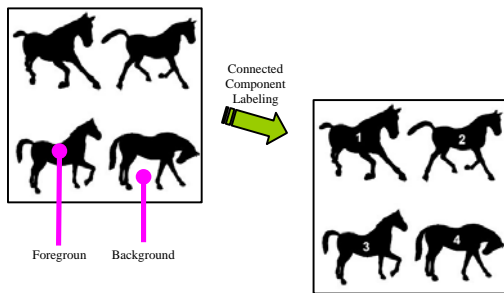


Fig. 2 Connected component labeling

In the real result image, the component label is not displayed on the monitor screen, but in a digit data. This data is very important for the next analysis.

IV. LOOP BACK ALGORITHM

In this study, a loop back approach for connected component labeling was used. This method is using the data of the connected pixels. One of the most important aspects of this approach is to find the head of the found label. This label's head is the beginning of the component group. By using the scanning mask the component's head can be traced.

The rules for component's head are if the West side, North West side, North side, and North East side of the pixel is zero.

0. $p(x, y) > 0$
1. $p(x-1, y) = 0$
2. $p(x-1, y-1) = 0$
3. $p(x, y-1) = 0$
4. $p(x+1, y+1) = 0$

or:

$$p(x, y) = \begin{cases} p_h(x, y), & p_0 > 0 \text{ and } (p_1 + p_2 + p_3 + p_4) = 0 \\ p_{com}(x, y), & \text{otherwise} \end{cases} \quad (5)$$

where $p(x, y)$ is the scanned pixel, $p_h(x, y)$ is the pixel which is assigned as the head of the component. p_0 is the scanned pixel $p(x, y)$, p_1 is the west side of p_0 or described as $p(x-1, y)$, p_2 is $p(x-1, y-1)$, p_3 is $p(x, y-1)$, and p_4 is $p(x+1, y+1)$.

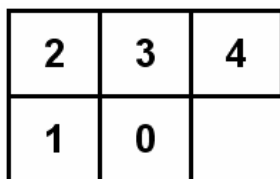


Fig. 3. Pixel position

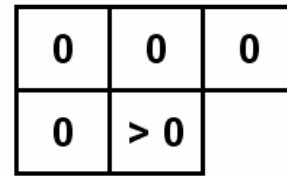


Fig. 4 Head's rules

If the head rules condition is true, then the pixel is considered as the head of the component group. The pixel scanned after the head will follow the component's head by looping back to the head. It is the same situation if a component label changed, then the entire pixel component has to change by looping back as the previous component. So there are always be changes on the component label, if one component has changed, and the label will refer to the previous label.

For example (Fig. 5), if the head of an object is labeled as 2, the next component is labeled as 3, and then the component will loop back and changed to follow the head of the object which is 2.

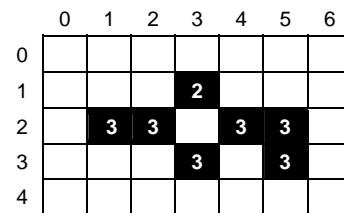


Fig. 5 Component labels

As the figure above, firstly the head detected in the object is label 2. In the second scanning, within the same object the component scanned is labeled as 3, then the last label has to loop back to follow the head of the component label which is 2.

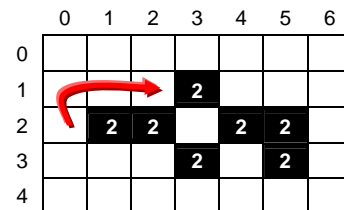


Fig. 6 Labels followed the head label before

To give a clear understanding an example is given as follow. Suppose the input was like Fig. 7. The image has 11 pixels width and 8 pixels height. Inside the image, there are some simple objects that next will be counted using this approach.

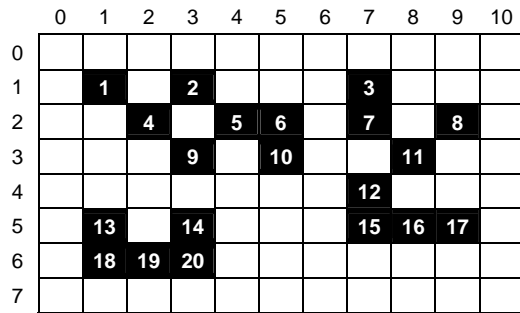


Fig. 7 Pixels Position

The result after the loop back component labeling scanning is shown as the following figure:

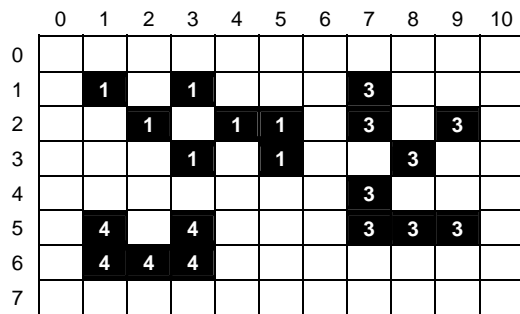


Fig. 8 Component labels scanned

To see the result of this algorithm, some inputs of binary images are given for testing. Some of the testing results (labeled with single number):

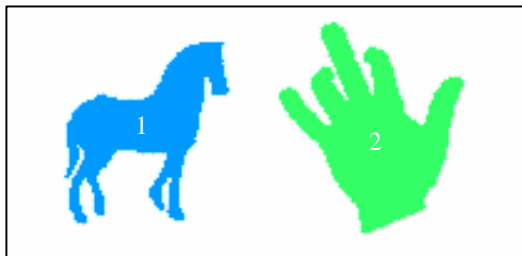


Fig. 9 Image with 2 objects

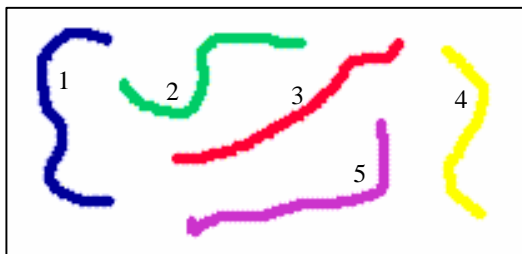


Fig. 10 Image with 5 objects

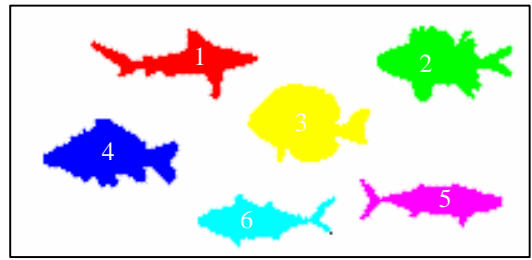


Fig. 11 Image with 6 objects

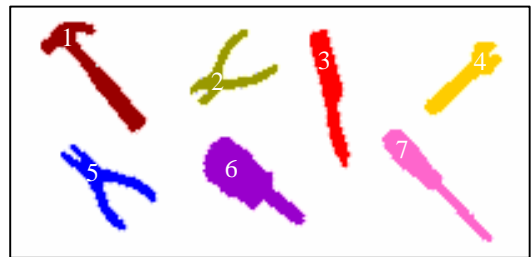


Fig. 12 Image with 7 objects

After the algorithm given some input images, the result gives a good performance in accuracy of labeling and time consuming. For input image Fig. 9, the result output is 2 objects labeled, Fig. 10 5 objects labeled, Fig. 11 six objects labeled, and Fig. 12 seven objects labeled.

V. DETECTION

In order to get the location of the face, so the pixels data of the object segmented is much needed. The data is used for analyzing the character of the face. The face region is defined as the closed area in the image that has one or more holes inside. The region is noted with pixel 1 for binary image which are the black area and the holes are noted with pixel 0 for the black area.

After the possible face region defined, then the face object can be detected by counting the holes inside the region:

$$H = p_c(x, y) - p_o(x, y) \quad (6)$$

where H is the number of holes inside the face candidate region, while $p_c(x, y)$ is the face candidate region after closing process, and $p_o(x, y)$ is the face candidate before the closing process. The x and y are describing the position of the pixel.

So it can be described in connected component data as follows:

TABLE 1. HOLES DATA

No.	Label	Holes
1	2	100
2	4	200
3	7	234

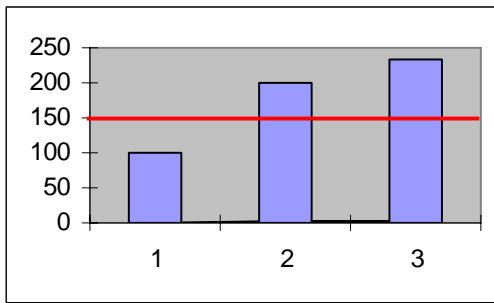


Fig. 13 Holes chart

With this holes map region, the face candidate can be located. Finally, a bounding box is fit over the head. From the face map $p(xMin, yMin)$ to the $p(xMax, yMax)$.

As a final result, the detected face is marked by a bounding box around the head in the input image. Since this system is only evaluating the existence of the holes, this approach works very well with significantly less computational effort compared to other feature-based face detection algorithms.

VI. RESULT AND TESTING

An experiment using the proposed approach is conducted. This system uses some 24bit raster image as the input and displayed the result of faces detected in bounding boxes.



Fig. 14 Input image



Fig. 16 Object candidate



Fig. 17 Closing image

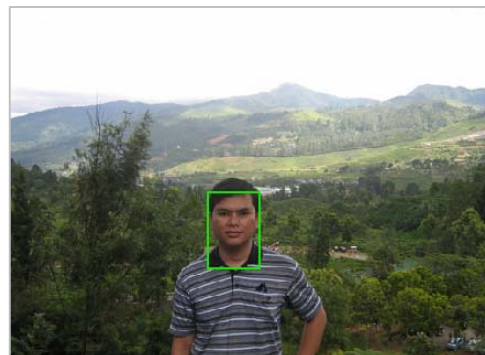


Fig. 18 Result of a detected face

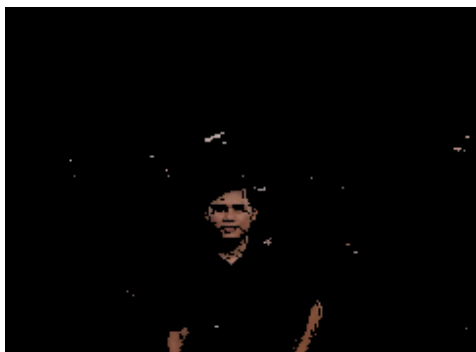


Fig. 15 Color map

In the experiment, the system was given some different number of objects, and all of them are successfully detected. But the problem came out when the object was occluded, for example when two faces are overlapping each other. The system gave a same bounding box. But this problem was not come from the component labeling process.

VII. CONCLUSION

In this paper, a simple algorithm of connected component labeling that uses one time scanning has been presented. The algorithm is intended to reduce the number of step in labeling the component compare to the two time scanning method. This approach is finding the head of the component group, so it makes the algorithm simple both to understand and

implement because the major merits of the proposed algorithm rely its efficiency and simplicity. The experimental results showed that this approach can give a good result with a more simple process so it can increase the hardware performance.

VIII. FUTURE WORK

The proposed approach will be extended to be used in image processing. The approach will be modified to be used for other morphological technique in image processing. For face detection system, the discussed approach will be extended and hybrid with some other technique to get a better result and performance.

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