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Image segmentation with complicated background by using seeded region growing

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ABSTRACT

This study proposes a novel seeded region growing based image segmentation method for complicated background in both color and gray level images. The proposed fuzzy edge detection method, that only detects the connected edge, is used with fuzzy image pixel similarity to automatically select the initial seeds not in the detail and complicated background. The fuzzy distance is used to determine the difference between the pixel and region in the consequent region growing and the difference between two regions in the region merging. The conventional region growing is modified in this study to ensure that the pixel on the edge is processed later than other pixels. Finally, the simulations in study prove that the proposed method is better than other existing segmentation methods.

1. Introduction

Image segmentation is an important technique in the image pre-processing for extracting the interesting object from the background. The existing image segmentation techniques can be classified into the following approaches, thresholding techniques, boundary-based techniques, region-based techniques, clustering-based techniques and hybrid techniques [1–4]. Seeded region growing (SRG) is one of the hybrid methods [1], which starts with assigned seeds and grows regions by merging a pixel into the most similar neighboring seeded region. SRG is robust to the large variety of images because the characteristics of rapid and free to tune the parameters, and the considering of local information including regions similarity, boundaries and smoothness. However, the selection of the initial seeds influences the segmentation results very much. How to assign the initial seeds is a major topic in SRG. The authors in [2,3] assign the pixels between the edge regions to be the initial seeds. The similarity in the local region was also used to select the initial seeds automatically [4]. To avoid the initial seeds appearing in the detail and complicated background, the authors in [5] applied color quantization to the image in advance and then used a smoothness measurement, *J* value, to determine the initial seeds. Nevertheless, the unfavorable quantization leads to the poor segmentation results since the color quantization is a random process. This study proposes a fuzzy theory [6] based method, that is modified from the fuzzy edge detection method proposed in our previous research [7], to detect the connected edge, fuzzy similarity and fuzzy distance in SRG. In the proposed method, the initial seeds are selected and not in the detail and complicated background. This study furthermore modifies the conventional region growing to ensure that the pixel in the detail is processed later than other pixels. Hence this study based on segmentation methods can obtain better image segmentation ability than the existing SRG.

This study is organized as follows: Section 2 introduces the color space used in this study. Section 3 modifies the edge detection method from our previous research [7] to detect the connected edge. Section 4 introduces the proposed SRG based image segmentation method. The simulations results are presented in Section 5. Finally, a brief conclusion is given in Section 6.

2. YC_bC_r color space

In this study, YC_bC_r color space is used since the color difference of human perception can be directly expressed by Euclidean distance in YC_bC_r color space [4]. Therefore, the color image needs to be transformed from RGB color space to YC_bC_r space and each component of any pixel is normalized into [0, 1]. Significantly, the pixel located at position (i,j) in the image is denoted as a vector $\mathbf{x}_{i,j} = [R_{i,j}, G_{i,j}, B_{i,j}]^T$ for a color image or as a scale $x_{i,j} = Y_{i,j}$ for a gray level image. Where $R_{i,j}$, $G_{i,j}$ and $B_{i,j}$ are three components in RGB color space of the pixel located at position (i,j). The transformation

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$\mathbf{x}_1$	$\mathbf{x}_2$	$\mathbf{x}_3$
$\mathbf{x}_4$	$\mathbf{x}_5$	$\mathbf{x}_6$
$\mathbf{x}_7$	$\mathbf{x}_8$	$\mathbf{x}_9$

$\mathbf{x}_{i-1,j-1}$	$\mathbf{x}_{i-1,j}$	$\mathbf{x}_{i-1,j+1}$
$\mathbf{x}_{i,j-1}$	$\mathbf{x}_{i,j}$	$\mathbf{x}_{i,j+1}$
$\mathbf{x}_{i+1,j-1}$	$\mathbf{x}_{i+1,j}$	$\mathbf{x}_{i+1,j+1}$

Fig. 1. The 3 × 3 sliding window with the center $\mathbf{x}_{j,i}$ and its neighboring pixels.

from RGB to YC_bC_r is shown as (1),

$$\begin{bmatrix} Y_{i,j} \\ Cb_{i,j} \\ Cr_{i,j} \end{bmatrix} = \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -39.797 & -74.203 & 112 \\ 112 & -93.786 & -18.214 \end{bmatrix} \times \begin{bmatrix} R_{i,j} \\ G_{i,j} \\ B_{i,j} \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix}. \quad (1)$$

After transforming the color space, the pixel located at position (i,j) in the color image is denoted as a vector $\mathbf{x}_{i,j} = [Y_{i,j}, Cb_{i,j}, Cr_{i,j}]^T$. To simplify the representation of this study, only the equations with vector forms are listed.

3. Connected edge detection

Consider a 3×3 sliding window whose center is the current pixel $\mathbf{x}_{i,j}$, the pixels in the sliding window are represented as $\mathbf{x}_n$, $n = 1, 2, \ldots, 9$ and shown in Fig. 1. An edge usually occurs in one of four possible patterns shown in Fig. 2. In the edge pattern of direction-1, nine pixels can be divided into two sets, S_0 and S_1 as $S_0 = \{\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_4, \mathbf{x}_5, \mathbf{x}_7, \mathbf{x}_8\}$ and $S_1 = \{\mathbf{x}_3, \mathbf{x}_6, \mathbf{x}_9\}$. Similarly, $S_0 = \{\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3, \mathbf{x}_4, \mathbf{x}_5, \mathbf{x}_6\}$ and $S_1 = \{\mathbf{x}_7, \mathbf{x}_8, \mathbf{x}_9\}$ for the edge of direction-2, $S_0 = \{\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3, \mathbf{x}_5, \mathbf{x}_6, \mathbf{x}_9\}$ and $S_1 = \{\mathbf{x}_4, \mathbf{x}_7, \mathbf{x}_8\}$ for the edge of direction-3, and $S_0 = \{\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3, \mathbf{x}_4, \mathbf{x}_5, \mathbf{x}_7\}$ and $S_1 = \{\mathbf{x}_6, \mathbf{x}_8, \mathbf{x}_9\}$ for the edge of direction-4. Then, the fuzzy distance $d_s^{(k)}$ between S_0 and S_1 for direction-k are respectively defined as (2),

$$d_s^{(k)} = \min\left(\frac{\|\mathbf{m}_0 - \mathbf{m}_1\|}{w_d}, 1\right), \quad k = 1, 2, 3, 4 \quad (2)$$

where $\mathbf{m}_0$ and $\mathbf{m}_1$ are the vector means of the pixels in S_0 and S_1, respectively. w_d is a pre-defined parameter of the fuzzy distance which affects the slop of the fuzzy membership function. The smaller w_d that user selected, the more numbers of edge with small variation of color value will be detected. In this study, w_d can be set to 0.4. For the current pixel, (3) and (4) are used to record the maximal edge intensity $E_{i,j}$, which is the fuzzy membership degree of "the current pixel is an edge" and the corresponding edge direction $D_{i,j}$.

$$E_{i,j} = \max_{k \in \{1,2,3,4\}} (d_s^{(k)}), \quad (3)$$

$$D_{i,j} = \text{Arg}\left(\max_{k \in \{1,2,3,4\}} (d_s^{(k)})\right). \quad (4)$$

After all pixels in the image are processed by the above procedures, the edge map E and direction map D of the entire image are generated. Since the edge intensity and the edge direction of the pixel are obtained, the following criteria can be used to determine the fuzzy membership degree $CE_{i,j}$, that is "the current pixel is a connected edge" of each pixel.

$$\text{If } D_{i,j} = 1, \text{ then } CE_{i,j} = \frac{1}{3}(E_{i-1,j} + E_{i,j} + E_{i+1,j}). \quad (5a)$$

$$\text{If } D_{i,j} = 2, \text{ then } CE_{i,j} = \frac{1}{3}(E_{i,j-1} + E_{i,j} + E_{i,j+1}). \quad (5b)$$

$$\text{If } D_{i,j} = 3, \text{ then } CE_{i,j} = \frac{1}{3}(E_{i-1,j-1} + E_{i,j} + E_{i+1,j+1}). \quad (5c)$$

$$\text{If } D_{i,j} = 4, \text{ then } CE_{i,j} = \frac{1}{3}(E_{i+1,j-1} + E_{i,j} + E_{i-1,j+1}). \quad (5d)$$

In the end of edge detection, define a fuzzy membership degree of "the current pixel is not a connected edge" $NCE_{i,j}$,

$$NCE_{i,j} = 1 - CE_{i,j}. \quad (6)$$

Both fuzzy membership degrees $CE_{i,j}$ and $NCE_{i,j}$ of each pixel must be recorded since they will be used in the following SRG.

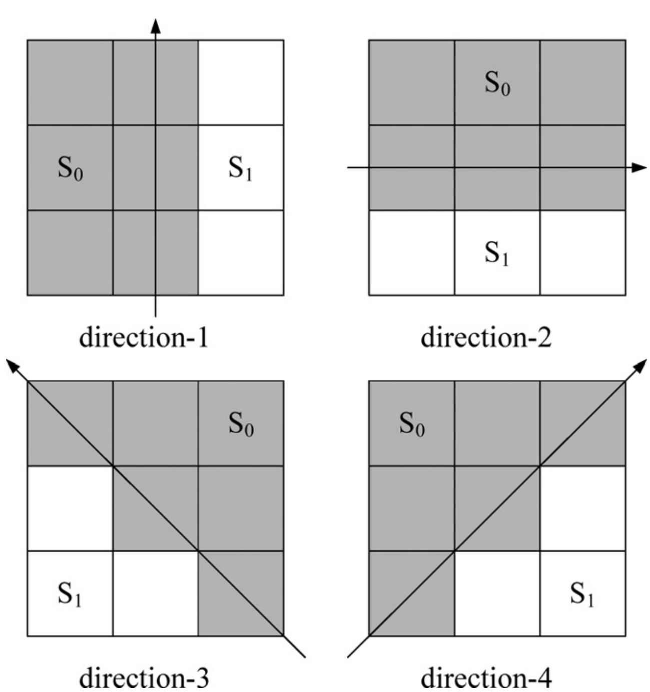

Fig. 2. Four possible edge patterns of different edge directions.

4. SRG based image segmentation

The conventional SRG is composed of three major steps, i.e. seeds selection, region growing and region merging. To select the initial seeds appropriately, the proposed method has one more step of pre-processing than the conventional SRG. The entire proposed segmentation method is now introduced in detail below.

4.1. The pre-processing of SRG

First, we use the edge detection method proposed in Section 2 to determine $CE_{i,j}$ and $NCE_{i,j}$ of each pixel. Then, use (7) to detect the fuzzy similarity $S_{i,j}$ between each current pixel $\mathbf{x}_{i,j}$ and the corresponding neighbors.

$$S_{i,j} = 1 - \frac{1}{9}\sum_{n=1}^{9} \min\left(\frac{\|\mathbf{x}_n - \mathbf{x}_{mean}\|}{w_s}, 1\right), \quad (7)$$

where $\mathbf{x}_n$, $n = 1, 2, \ldots, 9$, and $\mathbf{x}_{mean}$ are nine pixels in the sliding window whose center is $\mathbf{x}_{i,j}$ and the mean of their vector, respectively. w_s is also a pre-defined parameter which affects the slop of the fuzzy membership function. If a small w_s is selected, the current pixel will be treated as the same similarity (i.e. $S_{i,j} = 1$) regardless $\|\mathbf{x}_n - \mathbf{x}_{mean}\|$ is small or big. w_s is also set to 0.4 in the common case.