Extended Active Contour Algorithm Based on Color Variance

Seung-tae LEE, Young-jun HAN, Hern-soo HAHN

(*Dept. of Electronic Engineering, Soongsil University, Seoul* 156-743, *South Korea*)

Abstract – General active contour algorithm, which uses the intensity of the image, has been used to actively segment objects. Because the objects have a similar intensity but different colors, it is difficult to segment any object from the others. Moreover, this algorithm can only be used in the simple environment since it is very sensitive to noise. In order to solve these problems. This paper proposes an extended active contour algorithm based on a color variance. In complex images, the color variance energy as the image energy is introduced into the general active contour algorithm. Experimental results show that the proposed active contour algorithm is very effective in various environments.

Key words – *extended active contour algorithm*; *color variance*; *segmentaion method*

1 Introduction

Image segmentation is one of important fields in high level image processing. Many algorithms have been developed to segment images more efficiently and accurately. Among these algorithms, active contour algorithm is an effective method to segment an interesting object in an image. General active contour algorithm can be classified into two categories. One category is a parametric active contour which uses many kinds of energy[1]. This active contour algorithm has initial curve. Objects can be segmented by using many kinds of energy. The concepts have been implemented to solve different shape estimation problems.

The other is a geometric active contour algorithm[2]. The algorithm detects the contour of an object by using level set method. It is easier to apply the algorithm to various contours of the objects than does the active contour method. Moreover, it can be simultaneously applied to many objects at the same time. But this algorithm cannot segment the interesting area in the image in detail, and the capacity of the algorithm is influenced by the complexity of the image.

On the other hand, the parametric active contour algorithm is apt to converge into the boundary of an interesting object. And this algorithm is less influenced by the complexity of the image compared to the geometric one[3]. The first parametric active contour algorithm proposed by Kass can fast rapidly and accurately segment the interested object from the image. But this algorithm has problems on geometric changed value and floating environment. Xu and Prince's algorithm[4] proposed a solution to the geometric changed value. The image energy of a common active contour algorithm has a strong value near the contours of the objects. So it is apt to fall into a local minimum around the boundary of an uninteresting object. Xu and Prince suggested the image energy value which is uniformly distributed on the entire region of the image. However, this algorithm has similar problems to Kass's algorithm for a complex image.

To solve this problem, many researchers have used the active contour algorithm based on the color model. The color contains more information about the objects than the intensity. From the color, the location of an interesting object in the image can be known. The advantage of the color model has been proved by A. Koschan[5]. Experiments are conducted on RGB, HSI, and YUV color space, respectively. L. PI extended the general 2D image model to a 5D model[6]. General active contour algorithm based on the color model has two common problems of determining initial threshold values and analyzing the color distribution in the image.

To solve this problem, this paper proposes an extended active contour algorithm with color variance energy instead of the image energy. Because the algorithm is based on the statistics of the color variance, it can robustly and precisely segment the interesting objects in the complex image.

2 The active contour algorithm

2.1 The parametric active contour algorithm

The classical parametric active contour algorithm is proposed by Kass[1]. As shown in Eq. (1), this type of algorithm is composed of three kinds of energy, the internal energy, the external energy, and the image energy

$$E_{total} = E_{IN} + E_{EX} + E_{IM}. \tag{1}$$

This algorithm is formulated by minimizing an energy function, which reaches a minimum value when the contours are smooth and reside in the boundary of the object. And the active contour algorithm detects an object with moving control points, constructing an active contour in the boundary of the interesting object where the energy function is minimized.

The internal active contour energy is defined by dynamic relationship among the active contour control points. It is composed of tension and stiffness. By using tension, it gets the same distance for each active contour control point. In the case of stiffness, it plays a role to straighten the bended active contour. Those energies can be increased and reduced according to application methods. The Internal energy functions are

$$F_{elastic}(s) = [\alpha(s)X_s(s)] = \alpha(s) \mid \frac{dv_s}{ds} \mid^2, \tag{2}$$

$$F_{rigid}(s) = [\beta(s)X_{ss}(s)] = \beta(s) \mid \frac{d^2 v_s}{ds^2} \mid^2, \tag{3}$$

where the coefficient α and β are used to control the strength of the contour's elasticity and rigidity. In practice, the coefficient α is usually a positive constant and the coefficient β is usually close to zero.

The external active contour energy is used to decide convergence or divergence. The energy of the formulation results from the gradients of the scalar potential functions. So, it can be decided whether to continue the process of the active contour algorithm by checking this energy, or not.

The image energy is defined as the function that transforms an image intensity to an useful energy (Eq. (4)). Because the energy decides the final result, its term is very important.

$$F_{image}(s) = \gamma_{line} F_{line}(s) + \gamma_{edge} F_{edge}(s) + \gamma_{term} F_{term}(s). \tag{4}$$

2.2 Filtering

An ordinary image usually contains various kinds of noises, and thus some filter are used to remove the noises and get the useful information on the preprocessing step. Sobel operator is one of the useful filters to generate the edge image.

The filter used to remove noises has a 3 by 3 mask. This mask decides whether a pixel value contains noises or not through the threshold. If the sum of pixel values with-
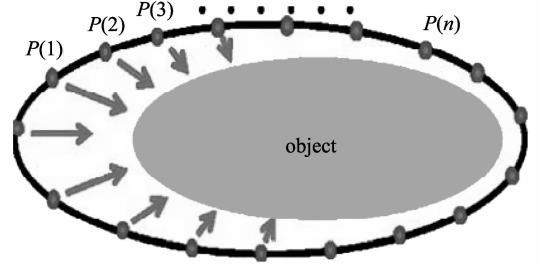

Fig.1 Concept of active contour process

in the mask area is higher than in the threshold, a pixel value is considered as the real value, otherwise, as a noise. The noise removing filter is similar to vector median filters[7], only adding thresholds of intensity.

3 Extended active contour algorithm based on color variance

3.1 Flowchart of the color variance active contour

Fig.2 shows the simple flow of the proposed algorithm. The proposed algorithm replaces the image energy term with the color variance energy term in previous active contour algorithm. This flowchart shows that the proposed one repeats over the number of active contour control points in turn. And this loop continually iterates to detect an object.
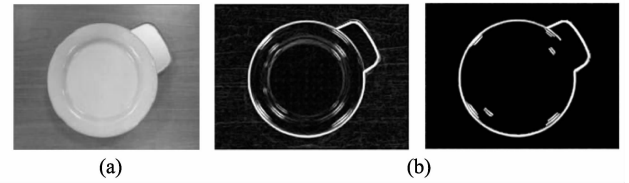

(a)   (b)

Fig.2 Comparison of gray sobel on noise removing result: (a) original image, (b) gray sobel and noise removing filter

3.2 A color variance

3.2.1 Basic ideas of color variance active contour

A color variance of the interesting area provides the statistics of a color distribution to the active contour method. Generally, pixels within an object have similar color values. So, the color variance has the minimum value even if the active contour is placed within the same object. But, the color variance has the relatively high variance value if the active contour is placed in two or more objects.

The more control points of the active contour approximate to the boundary of the interesting object, the smaller the color variance. The energy of the color variance is

$$E_{var} = \gamma_1 E_{var(R)} + \gamma_2 E_{var(G)} + \lambda_3 E_{var(B)}, \tag{5}$$

where $E_{\text{var}(R)}$, $E_{\text{var}(G)}$ and $E_{\text{var}(B)}$ are the color variance energy of RGB model respectively. And γ_1, γ_2 and γ_3 are the weight of each color variance. The energy of the color variance is used as the one of the proposed energies.
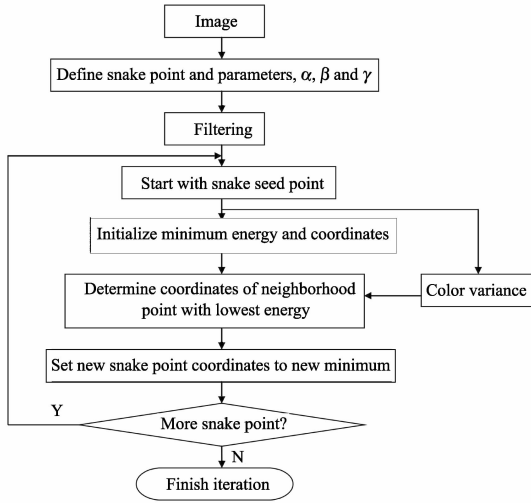

Fig. 3   Flowchart of the proposed active contour algorithm

3.2.2   Color variance active contour method

The following Eq. (6) is the average of the color intensities of pixels within the active contour.

$$E[S(x,y)] = \frac{1}{N} \sum_{S(x) \in R} \sum_{S(y) \in R} S(x,y), \qquad (6)$$

where N is the number of the pixels within the active contour, and $S(x,y)$ is the color intensity of a pixel. The energy of the color variance energy is defined as

$$E_{\text{var}(s)} = \frac{1}{N} \sum_{S(x) \in R} \sum_{S(y) \in R} (S(x,y) - E[S(x,y)])^2, \qquad (7)$$

where $S(x,y)$ is the color average that is defined as Eq. (6). As each control point of the active contour approximates to the boundary contour of the interesting object, the color variance is getting smaller. Therefore, the proposed extended active contour algorithm can effectively segment the interest object in a comparatively complex image.
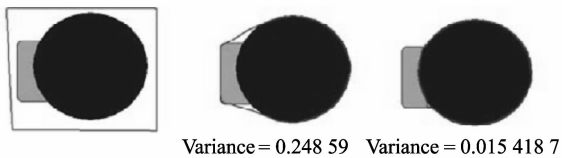

Variance = 0.248 59   Variance = 0.015 418 7

Fig. 4   Color variance value

Variance=0.146 331   Variance=0.000 507 747

Fig. 5   Color variance value

It can be observed that the color variance energy is the minimal when the active contour exists within the boundary of the same object.

4   Experiments and results

In this paper, to evaluate the proposed extended active contour algorithm based on color variance, comparision is made between the extended active contour algorithm and the general active contour algorithm in various complex images. Segmentation results of the two active contour algorithms are shown from Fig. 6 to Fig. 9.
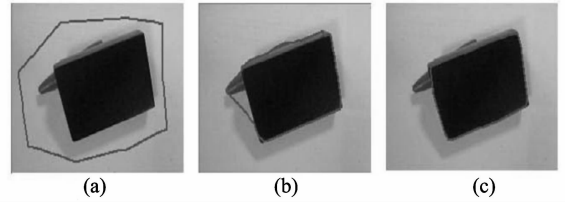

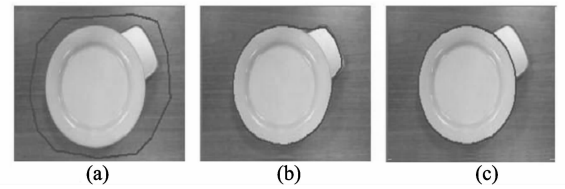**Fig. 6**   (a) The initial contour, (b) General algoritm, (c) Result of new model

Fig. 7   (a) The initial contour, (b) General algoritm, (c) Result of new model

Fig. 8   (a) The initial contour, (b) General algoritm, (c) Result of new model

Fig. 9   (a) The initial contour, (b) General algoritm, (c) Result of new model
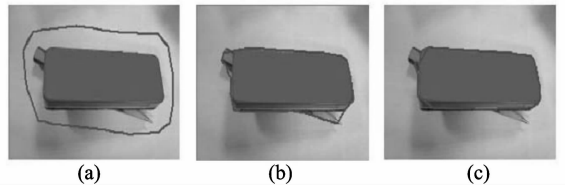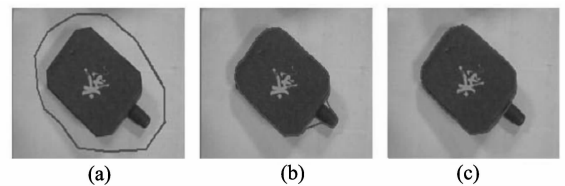
As shown in the above figures, the interesting object is overlapped with another object with a different color. The general active contour algorithm can't go through the overlapping region. But the proposed one converges in the boundary of the interesting object.

Because the general active contour algorithm uses

only the pixel intensity, it is difficult for the general one to segment the interesting object in the situation where the overlapped or overlapping objects have similar intensity to that of the interesting object. But the proposed one can effectively segment the interesting object from the overlapped or overlapping objects in the situation where the overlapped or overlapping objects have similar intensity. And the proposed one can also converge to the boundary of interesting object even if lots of noises exist within the interesting area because noises uniformly spread over the entire area of the image.

4 Conclusion

This paper proposes an exteneed active contour algorithm which can segment the interesting object in a complex image where there are overlapping or overlapped objects. The algorithm improves the previous active contour algorithm by using the color variance as the image energy, which is the statistical variance about color intensities of pixels within the active contour. However, its processing takes much time because the variances about color intensities in the interesting area must be calculated. Sometimes, the final active contour cannot converge to the boundary of the interesting object because the energy function falls into local minimum around the overlapped area of two or more objects. Future work will be devoted to reducing the area detection error and detecting the object robustly under complex circumstances.

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