Chapter 65
Color Image Segmentation Algorithm of Rapid Level Sets Based on HSV Color Space

Yue Zhao, Xin Xu, Chao Chen and Dan Yang

Abstract In order to solve the problem on how to segment the color image, we put forward the color image segmentation of rapid level sets based on HSV color space. First, we adopt the method of rapid level sets based on CV mode to improve the segmentation speed. Next, the segmentation of color image can be made with the introduction of the concept of color difference under HSV color mode. In this case, the segmentation can be made exactly even the gray color is very close since the color information is fully employed. The experiment result shows this method mentioned here is more effective in segmentation than the traditional segmentation method of level sets.

Keywords Level set • C–V model • Image segmentation • Color difference • HSV color space

65.1 Introduction

Image segmentation as the basic link of the image processing has been a hot and difficult problems in image engineering. For decades, researchers continue to explore new image segmentation method, so that solving the problem is more close to practical application. Level set model was first proposed by Osher, and Sethian for tracing the interfaces among different phases of fluid flows [1]. Level set method as a new image processing method based on partial differential equations, with free topological transformation as well as easy integration a variety of features. Or more of the advantages of the method have recently been the concern of many scholars in the field of image segmentation. However, because of it built

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on the image gray level information on the basis of the color image segmentation is less effective, and split the slower, to the practical application difficult.

Chan and Vase [2] combined with level set ideas and Mumford-Shah model, the CV level set model. CV level set model to extract the object boundary does not depend on the gradient of the image, and it is applied to the gradient meaningless or fuzzy edge image. Ref. [3] proposed a fast level set algorithm, which greatly improves the segmentation speed, but the algorithm provides only two fast segmentation model, based on threshold and scope of these two models based on the gradient of the fast model. Ref. [4] based on the color gradient of the level set method, which uses the HSV color model, combined with the use of the Bayesian classification model (use the Bayesian classification model), and integration of the color of statistical characteristics of the region to determine the contour of the target area boundary, but the split speed. The color level set model in [5] gives a new convex nature of the variation formulation and its rapid calculation method, the new model can truly reflect the characteristics of the color image boundary detection function duality principle, but the color the use of information is not sufficient.

How fast segmentation of color images, we propose a fast level set for color image segmentation algorithm based on HSV color space. First, in order to improve the segmentation speed, we use fast level set method to evolve. Second, for color images, we introduce the concept of color difference in the HSV color model space to segment image.

65.2 Fast Level Set Segmentation Method

65.2.1 Level Set Method

The level set method is a method to solve the active contour model, initially applied to the fluid mechanics field, was widely used in various curve evolution of scientific research and engineering. Compared with the parametric active contour model, the level set segmentation model free topological transformation, solving without parameters, etc.

Level set method, the plane closed curve implicit expression for the surface of the three-dimensional continuous function $\varphi(x, y)$, one has the same function value with the value curve $\varphi(x, y)$, called the level set function, embedded closed curve as zero level set $\{\varphi = 0\}$.

The initial level set function $\phi\,(x, y, 0)$ usually in accordance with the distance function is defined as:

$$\varphi(x, y, 0) = \begin{cases} d(x, y, C), if\ x \text{ is inside } C \\ 0, f\ x \text{ is on } C \\ -d(x, y, C), if\ x \text{ is outside } C \end{cases} \tag{65.1}$$

where d $(x,\ y,\ C)$ is on behalf of the distance which from the point $(x,\ y)$ to the curve C.

65.2.2 C–V Model

Mumford-shah model is an ideal image segmentation model, but in the specific solving more difficult. Chan and Vase proposed the C–V model is the level set based thinking and the Mumford-shah model. It does not use gradient information, but to minimize the energy functional square evolution curve. On Mumford-shah model Another difference is that the CV level set model in the energy function, an increase of the area (inside (C)) and the Mumford-shah model of the original length of the Length (C) promote the evolution curve reaches the object boundary.

Join the area and length, the CV method, the energy functional is expressed as:

$$\begin{aligned}\varepsilon(u_1, u_2, C) = \lambda_1 \int_{\text{inside}(C)} |I(x,y) - C_1|^2 \,\mathrm{d}x\mathrm{d}y + \\ \lambda_2 \int_{\text{outside}(C)} |I(x,y) - C_2|^2 \,\mathrm{d}x\mathrm{d}y + \nu \cdot \text{Length}(C) + \mu \cdot \text{Area}(C)\end{aligned} \tag{65.2}$$

where, C is the boundary of the region Ω1 and Ω2. C_1, C_2 is a constant value, respectively, the average gray scale of the internal region of the curve C and the outer region. Contour C in the actual boundary, that is, $C = C_0$ (C_0 is the boundary of the segmented regions), the energy functional $\varepsilon(\varphi)$ to obtain the minimum.

Joining the Heaviside function, it is the following:

$$\begin{aligned}\varepsilon(\varphi) =& \lambda_1 \int_{\Omega} |I - C_1|^2 H(\varphi)\mathrm{d}x\mathrm{d}y + \lambda_2 \int_{\Omega} |I - C_2|^2 (1 - H(\varphi))\mathrm{d}x\mathrm{d}y \\ &+ \mu \int_{\Omega} \delta(\varphi) |\nabla\varphi| \,\mathrm{d}x\mathrm{d}y + \nu \int_{\Omega} H(\varphi)\mathrm{d}x\mathrm{d}y\end{aligned} \tag{65.3}$$

$$\Omega_1 = \{x, y : \varphi(x,y) <; 0\}, \text{meanvalue}(\Omega_1) = C_1 \tag{65.4}$$

$$\Omega_2 = \{x, y : \varphi(x,y) > 0\}, \text{meanvalue}(\Omega_2) = C_2 \tag{65.5}$$

$$\Omega = \Omega_1 + \Omega_2 + C \tag{65.6}$$

Using the variation method and gradient descent flow Eq. (65.3) to minimize operator can obtain the following form:

$$\frac{\partial\varphi}{\partial t} = \delta(\varphi)\left[\mu\nabla\cdot\left[\frac{\nabla\varphi}{|\nabla\varphi|}\right] - \lambda_1(I - C_1)^2 + \lambda_2(I - C_2)^2 - \nu\right] \tag{65.7}$$

65.2.3 Improved C–V Model

Shi et al. [3], a fast real-time level set segmentation method, greatly improved the segmentation speed. But its speed is based on threshold and gradient, thus

affecting the use of the algorithm. So that the algorithm has to improve the general applicability of Goal Orientation and other people in the literature [7], creating a new CV speed, as follows:

$$F(x, y) = |I(x, y) - c_{out}| - |I(x, y) - c_{in}| \tag{65.8}$$

Among them: the c_{out}, c_{in} respectively, the average gray value of the contour line of external and internal, $I(x, y)$ to point (x, y) at the gray-scale value. The average gray value of the difference between where the two points gray values and contour the outer region and inner region, In order to speed power curve evolution Fast Level Set as CV-based fast level set segmentation algorithm can be described as follows:

The level set function is discredited into four integer values:

$$\phi(x) = \begin{cases} 3 & \text{if } x \text{ is an exterior point} \\ 1 & \text{if } x \in L_{\text{out}} \\ -1 & \text{if } x \in L_{\text{in}} \\ -3 & \text{if } x \text{ is an interior point} \end{cases} \tag{65.9}$$

Among them, the level set value is negative, the area within the contour area, marked as Ω_{in}, the level set for the positive region is the external area of the contour, denoted by Ω_{out}. The region of level set is -3 called the internal region, the region of value of $+3$ called the outer region. Internal lists and external linked list can be defined as follows:

$$L_{\text{in}} = \{x \,|x \in \Omega_{\text{in}} \text{ and } \exists\ y \in N(x) \text{ such that } y \in \Omega_{\text{out}}\} \tag{65.10}$$

$$L_{\text{out}} = \{x \,|x \in \Omega_{\text{out}} \text{ and } \exists\ y \in N(x) \text{ such that } y \in \Omega_{\text{in}}\} \tag{65.11}$$

where, $N(x)$ is the point of the neighbors around the point x the upper and lower's domain? Through the exchange of elements in the internal lists and external list achieve the evolution of the curve. The linked list elements of the exchange the switch in and switch out two-step operation to complete the linked list L_{out} of the switch in operating point x exchange to the linked list in L_{in}, will no longer belong to the elements of the internal linked list L_{in} delete, switching to the internal region, the operating curve outward expansion; contrary switch out the operation will be the point of the linked list L_{in} exchange to the linked list L_{out}, the operating curve inward contraction.

Two lists of elements in the exchange to be decided by the speed F of positive and negative. Point L_{out}, when F is greater than 0 the switch in operation, the point of exchange within the contour; point L_{in} to F is less than 0 perform switch out operation, the point of exchange to the outside of the contour. Fast Level Set Segmentation Method based on CV without solving partial differential equations, without re-initialization of the signed distance function, only width of 2 pixels in the narrow-band region is calculated, so the split speed has greatly improved.

65.3 Level Set Segmentation Algorithm Based on HSV Color Space

65.3.1 The Color Space Selection

Traditional level set segmentation drawback is that the segmentation of color images is not satisfactory. The curve evolution is to rely on gray-scale information-driven. Therefore, when the object and the background gray level information is difficult to distinguish, the power of curve evolution is not enough, leading to the split failure. The gray value of the target and background the same size but different color segmentation must not be correctly segmented target, using the CV model. Therefore, we introduced the color space for color image segmentation will be more effective.

Select the appropriate color space is effectively split the image, but also relates to methods and strategies used. Common RGB space all colors as a combination of three primary colors, but there is a strong correlation between the three-component, and thus not suitable for directly used for the independent operation of three components-based image segmentation. Space close to the human eye color perception of hue, saturation, and brightness (hue, saturation, value, and HSV) space, which, hue and saturation are collectively referred to as chrome, not only describes the color wavelength component distribution, but also that the depth of shade of colored light, Luminance component and color information. The image processing and computer vision algorithms can be in the HSV color space, easy to use, they can be dealt with separately and independent of each other. Therefore, in the HSV color space can greatly simplify the image analysis and processing workload. HSV color space and RGB color space is just a different representation of the same physical quantity, and thus exists between them, the conversion relations.

65.3.2 Conversion of RGB Space to HSV Color Space

Point was transformed into the HSV color space from RGB space that can be defined as:

$$V = \max(R, G, B) \tag{65.12}$$

$$S = (V - \min(R, G, B)) / V(\text{当时}, V = 0 \;\; S = 0) \tag{65.13}$$

$$H = \left\{ \begin{array}{ll} 60\,(G - B) \big/ (V - \min\,(R, G, B)) & \text{if } V = R \\ 120 + 60\,(B - R) \big/ (V - \min\,(R, G, B)) & \text{if } V = G \\ 240 + 60\,(R - G) \big/ (V - \min\,(R, G, B)) & \text{if } V = B \end{array} \right\} \tag{65.14}$$

If the proceeds of $H < 0$, then $H = H + 360$. Such hue information H in the range of 0–360°. V and S ranges from 0 to 1.

65.3.3 The Color Difference on HSV Space

Effective segmentation of color images, the color difference in the HSV color space to further the introduction of CV-based fast level set. HSV color space, H denotes the hue (hue), S means the saturation (saturation), and V represents the brightness (value).

Remember HSV space color values for $P_1 = (H_1, S_1, V_1)^T$ and $P_2 = (H_2, S_2, V_2)^T$, the color difference is defined as:

$$\Delta_{\mathrm{HSV}}(P_1, P_2) = \sqrt{(\Delta_I)^2 + (\Delta_C)^2} \tag{65.15}$$

The color difference in (65.15) instead of (65.8) gray, to get fast level set based on the HSV color model speed:

$$F(x, y) = \nabla_{\mathrm{HSV}}(P(x, y), V_{\mathrm{out}}) - \nabla_{\mathrm{HSV}}(P(x, y), V_{\mathrm{in}}) \tag{65.16}$$

Where V (x, y) point (x, y) at the color value, V_{out} and V_{in} were the average of the external area of the contour and the internal region of the color value. Color level set segmentation model to make full use of the image information, considering the image's hue, saturation and intensity, so you can get a better segmentation results.

65.4 Experimental Results

In order to verify the feasibility and effectiveness of the proposed method, the real image data were simulated. In the dual-core 2.0 GHz Pentium processor, we used matlab2010b to achieve the proposed algorithm. We denote by CV model and the proposed fast level set segmentation algorithm based on the HSV color space to test contrast.

It can be seen from the results Figs. 65.1 and 65.2 classic CV model of the level set method to split the color image, part of the foreground objects were mistakenly split into the background, goals and background intensity close to background as foreground segmentation.

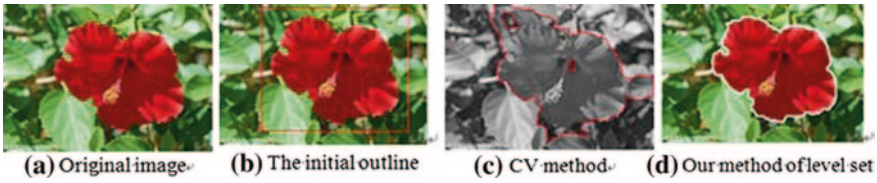

Fig. 65.1 Red flower

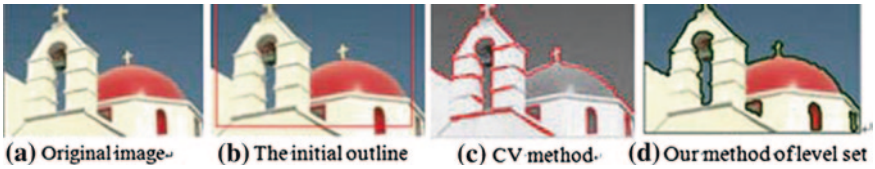

Fig. 65.2 Church

65.5 Conclusions

This paper presents a fast level set for color image segmentation algorithm based on HSV color space. First, in order to improve the segmentation speed, fast level set method based on CV model evolution. Second, the segmentation of color image can be made with the introduction of the concept of color difference under HSV color mode. In this case, the segmentation can be made exactly even the gray color is very close since the color information is fully employed. The experimental results show that compared with the traditional level set segmentation, our approach has better color image segmentation.

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