Face detection using active contours

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Abstract : *This paper proposes an active contour model to detect facial regions in a given image. Accordingly we use the color information of human faces which is represented by a skin color model. We evolve the active contour using the level set method which allows for cusps, corners, and automatic topological changes. Experimental results show the effectiveness of the proposed method.*

1. INTRODUCTION

Automatic recognition of human faces is becoming a very important task in many applications, such as videoconference and security systems. Facial region detection is interesting because it is usually the first important step of a fully automatic human face recognizer. Recently, many researchers have been used a stochastic model, which characterizes skin colors of human faces [6]. Here, we focus on boundary detection of one or more facial regions by a deformable model known as the "active contour model" introduced in [1].

Active contour models (also called snakes), which minimize an energy function along a curve, are often used to detect object boundaries in a given image [1, 2, 3]. The curve, or snake, moves toward its interior normal and has to stop on the boundary of the object [2]. Let $I(x,y) = R$ be a given image and $C(p) = \{x(p), y(p)\}$ be a parameterized curve, where R is real value, (x,y) is a coordinate of image, and p [0,1] is an arbitrary parameterization. The energy of an active contours can be written as

$$E = \alpha\int_0^1 |C'(p)|^2 dp + \beta\int_0^1 |C''(p)| dp - \lambda\int_0^1 |\nabla I(x(p), y(p))|^2 dp \quad , \tag{1}$$

where α, β, and λ are positive constants. Minimizing the first two terms make the contour smooth. And when the third term is minimized, it acts as edge-detector. In problems of curve evolution, The Osher-Sethian [5] level set method has been used extensively. When $\phi(x,y): R^2 \rightarrow R$ is a representation of the curve C, such that $C = \{(x,y) : \phi(x,y) = 0\}$, evolving C in normal direction with speed F amounts to solve the differential equation[5].

$$\frac{\partial\phi}{\partial t} = |\nabla\phi| F \ , \ \phi(0,x,y) = \phi_0(x,y) \ , \tag{2}$$

where the set $\{(x,y) \mid \phi_0(x,y) = 0\}$ defines the initial contour. This formulation enable us to implement curve evolution on the x,y fixed coordinate system. The convergence of this level set function for active contours is achieved using constraints derived from image features. Gradient based edge function is used extensively[7][8]. Based on this method, the constrained level set PDE with gradient based edge function is given below as

$$\frac{\partial\phi}{\partial t} = g(|\nabla I|)|\nabla\phi| F \ . \tag{3}$$

The gradient based edge function is generally derived from gradient feature of intensity image I.

$$g(|\nabla I|) = \frac{1}{1 + |G_\sigma * |\nabla I||^p} \tag{4}$$

where G_σ is Gaussian smoothing filter, '*' is convolution operator, and p is positive integer.

However, this Gaussian smoothed gradient-based edge function dissolves weak edges and looses the boundary location information due to blurring. So accuracy reduces by way of using edge constrained Eq.(3) [7]. In this paper, we proposes the level set method based active contour model using the color information of human faces instead of gradient of a given image.

2. PROPOSED METHOD

2.1 Skin Color Model

Detecting facial regions with the color of skin provides a reliable method for detecting and tracking faces. In the RGB space obtained by most video camera, a RGB representation includes not only color but also brightness. So, RGB is not necessarily the best color representation for detecting facial regions with skin color [6]. The brightness may be removed by dividing the three components of a color pixel, (R, G, B) by the intensity. This space is known as chromatic color that is intensity normalized color vector with two components(r,g). The color distribution of human faces is clustered in a small area of the chromatic color space and can be approximated by a 2D-Gaussian distribution [6]. Therefore, the skin color model is represented by a 2D-Gaussian model $N(m,\Sigma)$, where $m=(\bar{r},\bar{g})$ with

$$r=\frac{R}{R+G+B},\ g=\frac{G}{R+G+B},$$
$$\bar{r}=\frac{1}{S}\sum_{i=1}^{S}r_i,\ \bar{g}=\frac{1}{S}\sum_{i=1}^{S}g_i,\ and,\ \Sigma=\begin{bmatrix}\sigma_r^2 & \rho_{X,Y}\sigma_g\sigma_r\\ \rho_{X,Y}\sigma_r\sigma_g & \sigma_g^2\end{bmatrix}. \tag{5}$$

2.2. Energy Function Formulation

The energy function of the proposed active contour model is given by

$$\begin{aligned}E(\bar{r},\bar{g},c,C) &= \mu\cdot Length(C)+v\cdot Area(inside(C))\\ &+\lambda_1\int_{inside(C)}(\left|\bar{r}-r(x,y)\right|^2+\left|\bar{g}-g(x,y)\right|^2)dxdy\\ &+\lambda_2\int_{outside(C)}\left|I(x,y)-c\right|^2dxdy\ ,\end{aligned} \tag{6}$$

where μ, v, λ_1, λ_2 are constant, c is the average of I outside C, and $inside(C)$ and $outside(C)$ are the inside and outside of the contour C, respectively.

2.3. Level Set method

In this paper, the contour is represented by zero level set of the level set function ϕ, such that

$$\begin{cases}C=\{(x,y):\phi(x,y)=0\},\\ inside(C)=\{(x,y):\phi(x,y)>0\},\\ outside(C)=\{(x,y):\phi(x,y)<0\}.\end{cases} \tag{7}$$

Now, we can represent the energy as a level set formulation that the unknown variable C is replaced by the unknown variable ϕ [2].

$$\begin{aligned}&E(r,g,c,\phi)\\ &=\mu\int_0^{M-1}\int_0^{N-1}\delta(\phi(x,y))\left|\nabla\phi(x,y)\right|dxdy\\ &+v\int_0^{M-1}\int_0^{N-1}H(\phi(x,y))dxdy\\ &+\lambda_1\int_0^{M-1}\int_0^{N-1}(\left|\bar{r}-r(x,y)\right|^2\\ &\qquad+\left|\bar{g}-g(x,y)\right|^2)H(\phi(x,y))dxdy\\ &+\lambda_2\int_0^{M-1}\int_0^{N-1}\left|I(x,y)-c\right|^2(1-H(\phi(x,y)))dxdy,\end{aligned} \tag{8}$$

where $N\times M$ is the size of a given image, $H(j)$ is the Heaviside function, and $\delta(j)=(d/dj)H(j)$. For more detail, refer [2]. In order to compute the associated Euler-Lagrange equation for unknown function ϕ, we can use $H_r(j)=arctan(j)$, and $\delta_r(j)=1/(1+j^2)$ which are the slightly regularized versions of the function H and δ, respectively. The associated Euler-Lagrange equation can be deduced as

$$\begin{aligned}\frac{\partial\phi}{\partial t}&=\delta_r(\phi)[\mu\, div(\frac{\nabla\phi}{|\nabla\phi|})-v\\ &-\lambda_1\{(\bar{r}-r)^2+(\bar{g}-g)^2\}+\lambda_2(I-c)^2],\end{aligned} \tag{9}$$

where $div(\nabla\phi/|\nabla\phi|)$ is the mean curvature of the level set

2.4. Implementation

In the proposed method, we evolve the initial contour by solving eq.(9) iteratively until the stopping criteria is satisfied. The principal steps of the proposed method are :

I. Initialize ϕ_0 using the initial contour inputted by m anually. n=0
II. Compute c which is the average of I outside C.
III. Compute the equation(9), to obtain ϕ_{n+1}.
$(\phi_{n+1}=\phi_n+\frac{\partial\phi}{\partial t})$
IV. Check whether the stopping criteria is satisfied. If not, $n=n+1$ and repeat II,III,and IV.

The stopping criteria is satisfied, when the difference of the number of the pixel inside C is less than a threshold.

After each iteration, contour C, zero level set, is reconstructed. This is obtained by determining the zero crossing grid location in the level set function. A cell on the level set function belongs to the contour C if one or more cells of it's 4-neighborhood are positive and one or more cells of them are negative at the same time. The mean curvature of the level set is computed using Eq. given by

$$div(\frac{\nabla u}{|\nabla u|})=\frac{\phi_{xx}\phi_y^2-2\phi_x\phi_y\phi_{xy}+\phi_{yy}\phi_x^2}{(\phi_x^2+\phi_y^2)^{3/2}}. \tag{10}$$

Several possible finite difference schemes exist for implementing the mean curvature. But it hardly makes difference using any scheme[7].

Fig.1 shows the steps of the proposed method.

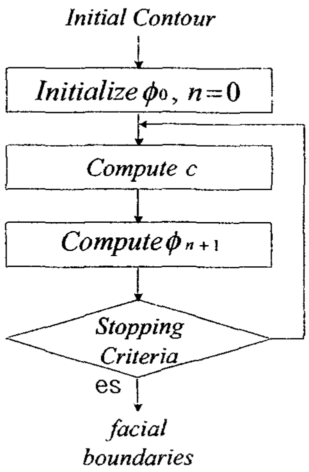


Fig. 1 The proposed method

3. EXPERIMENTAL RESULTS

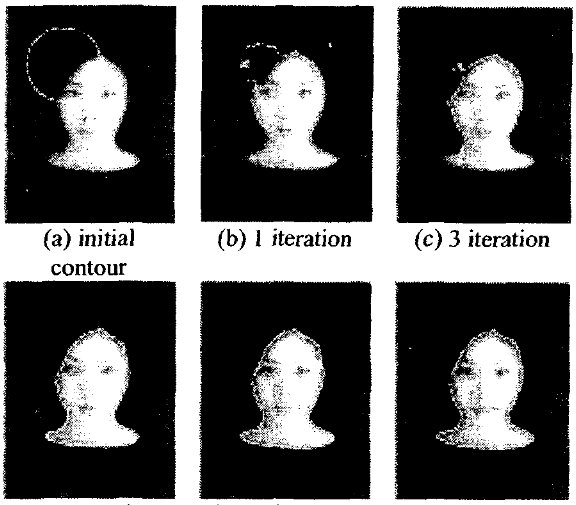
The experiments were performed using 200 color images including facial regions on a Pentium IV system with MS Visual C++ 6.0.

We trained the means and covariance matrix of the skin color model from 200 sample images. Table 1 shows the parameters of the skin color model. Since the model only has six parameters, it is easy to estimate and adapt them to different people and lighting conditions.

Table 1. Actual 2D-Gaussian parameters

Parameters	Values
$\bar{r}$	117.588
$\bar{g}$	79.064
σ_r^2	24.132
$\rho_{X,Y}\sigma_g\sigma_r$	-10.085
$\rho_{X,Y}\sigma_r\sigma_g$	-10.085
σ_g^2	8.748

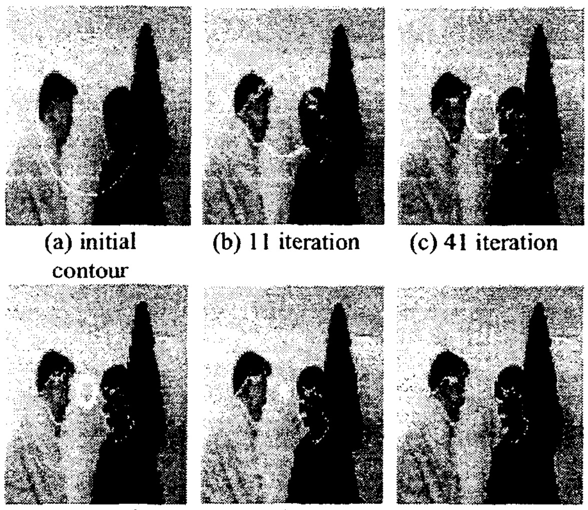
In our experiments, we chose the parameters as follows: $\mu = 1, \nu = 0, \lambda_1 = 5, \lambda_2 = 1$. The result of the proposed active contour model is shown in Fig.2. (a) shows the initial contour inputted by manually, and (b) – (f) are the evolutions of the proposed active contour model. The stopping criteria is satisfied, when 24 of iteration, and the contour stopped on the boundary of the face. The threshold of stopping criteria used in this experiment is 10



(a) initial contour (b) 1 iteration (c) 3 iteration
(d) 7 iteration (e) 13 iteration (f) 24 iteration

Fig. 2 the evolution of the proposed active contour model. Initial$\phi = 38 - [(x-58)^2 + (y-61)^2]^{1/2}$

Another experiment result on the image which includes more than one faces is shown in Fig.3. The contour split up several parts, and finally two of them are converged to boundaries of faces and others are disappeared. This result represents that the proposed method runs independently on the number of faces in the given image. The threshold of stopping criteria used in this experiment is 0.



(a) initial contour (b) 11 iteration (c) 41 iteration
(d) 71 iteration (e) 111 iteration (f) 161 iteration

Fig. 3 the evolution of the proposed active contour model. Initial$\phi = 83 - [(x-135)^2 + (y-111)^2]^{1/2}$

V. CONCLUSION

This paper proposed a model for active contours to detect human faces in a given image. To detect facial region, we combined a level set method based active contours with a skin-color model. The proposed method can detect multiple human faces in a complex background environment. The effectiveness of the proposed method was shown in experimental results.

References

[1] M. Kass, A. Witkin, and D. Terzopoulos, "Snakes: Active contour models," *Int. J. Comput. Vis.*, vol. 1, pp.321-331, 1988.

[2] T. F. Chan, and A.Vese, "Active Contours Without Edges," *IEEE Transactions On Image Processing*, vol. 10, No. 2, pp.266-277, 2001

[3] W. N. Lie, C. H. Chuang, "Fast and accurate snake model for object contours detection," *IEE Letters*, vol. 37, No. 10, pp.624-626, 2001

[4] R. Goldenberg, R Kimmel, E Rivlin, and M Rudzsky, "Fast Geodesic Active Contours," *IEEE Transactions On Image Processing*, vol. 10, No. 10, pp.1467-1475, 2001

[5] S. Osher and J. A. Sethian, "Fronts propagating with curvature-dependent speed: Algorithms based on Hamilton-Jacobi Formulation," *J.Comput. Phys.*, vol. 79, pp.12-49, 1988.

[6] J. Yang, and A. Waibel, " A real-time face tracker," Proceedings of the Third *IEEE Workshop on Applications of Computer Vision*, Sarasota, Florida, 1996, pp.142-147 ("Tracking Human Faces in Real-Time," Technical Report, CMU-CS-95-210, 1995).

[7] S. Kulkarni, and B. N. Chatterji, "Accurate shape modeling with front propagation using adaptive level sets," *Pattern Recognition Letters*, to be published.

[8] V. Caselles, F. Catte, T. Coll, and F. Dibos, "A geometric model for active contours in image image processes," *Numer. Math.*, vol. 66, pp.1-31, 1993.