*Advanced Materials Research* *Online: 2012-07-09*
*ISSN: 1662-8985, Vols. 546-547, pp 553-558*
*doi:10.4028/www.scientific.net/AMR.546-547.553*


# Texture Segmentation of Natural Images Based on Active Contour Model

Zhan Wang[a], Yun-hui Yan[b], De-wei Dong[c], Ke-chen Song

School of Mechanical Engineering & Automation,Northeastern University,Shenyang, China

[a]juven1126@163.com, [b]yanyh@mail.neu.edu.cn, [c]weidragon007@sina.com,

**Keywords:** texture segmentation; level set; active contour; Feature extraction

**Abstract.** To segment complex texture natural environment images; the first, the texture features of natural images should be analysed and the texture features should be extracted; The second, texture images segmengtation can be achieved by using Mumford-Shah active contour model, this segmentation model can better process fuzzy, default boundary, and this model can be solved by level set method. This method can express well complex texture signal features of natural images. Through making texture segmentation experiment for standard texture synthesis image and natural environmental image, its results show that the texture segmentation based on Mumford-Shah active contour model can segment natural images.

## Overview

Image texture segmentation is the hardest and the most important research subject in the image process and computer vision. Recent years, along with it is applied widely to industrial detection, medical image analysis, remote sensing image analysis, image retrieval based on content, people pay more attention to the texture segmentation research. But natural environmental images have complex texture. If this research can make progress in texture segmentation of natural images, it promote immensely research and application of computer vision.

## Technology Analysis of Texture Segmentation

**Texture Feature Extraction.** The extraction of texture information is one of very important steps in the process of texture segmentation, because we can just get the correct segmentation result only when we extract texture information accurately. At present, some methods are used to describe texture features, and they are Gabor filter, Gabor wavelet, wavelet transform, Fourier transform window, local histogram, local structure tensor, etc. For example, some people including S. Chen[1] who choice the Gabor wavelet of different scales and direction extract image texture features; Some people including B. Sandberg[2] who choice the Gabor filter of different scales, directions and centre frequencies extract image texture features; Some people including M. Rousson[3] put forward texture feature extraction method based on classical structure tensor; Some people including You Jianjie[4] who analyze the energy parameters of image clarity, detail signal and edge signal get image texture feature informations. Everyone have its own advantage in these methods, and no one is the best method which is choiced by the specific image features.

In this paper we use Gabor filter to extract texture information. We get multidimensional texture feature space through selecting Gabor filter of different scales, directions and centre frequencies. There are two reasons which can explain that we use Gabor filter to extract texture information: The first, stuies show that Gabor filter can imitate characteristics of simple cells in the visual cortex[5,6]; The second, Gabor filter can get best joint resolution of space and frequency domain. Then we shall introduce in detail Gabor filter and the process of texture extraction: Gabor filter which is a kind of aeolotropic and plural sine function modulated by Gaussian function can extract local frequency features in the given region. A typical 2-D Gabor function has the following form:

$$G_{\sigma,F,\theta}(x,y) = g_{\sigma}(x,y)\exp[2\pi jF(x\cos\theta + y\sin\theta)]. \quad (1)$$

$g_\sigma(x,y)$ is Gaussian function which is modulated, and $F$ is center frequency of plural sine function, and defecting angle of Gabor filter along principal axis. Gaussion function usually can be expressed as the following form:

$$g(x,y)=\frac{1}{2\pi\sigma_x\sigma_y}\exp[-\frac{1}{2}(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2})]. \tag{2}$$

$\sigma_x$, $\sigma_y$ are respective the standard deviation of $x$ and $y$ coordinates, and the two parameters decide region's size of Gabor filter's function. In this paper we will take the same value for the two standard devistion, so Gabor filter in general can be expressed as:

$$G_{\sigma,F,\theta}(x,y)=\frac{1}{2\pi\sigma^2}\exp[-\frac{1}{2}(\frac{x^2+y^2}{\sigma^2})+2\pi jF(x\cos\theta+y\sin\theta)]\cdot \tag{3}$$

We want the real part and imaginary one of Gabor filter to do convolution with texture image reapectively, for this reason we can extract texture informations of image:

$$S(x,y)=\sqrt{(G_R*I_0)^2+(G_I*I_0)^2}\ . \tag{4}$$

$S(x,y)$ is texture feature of image.

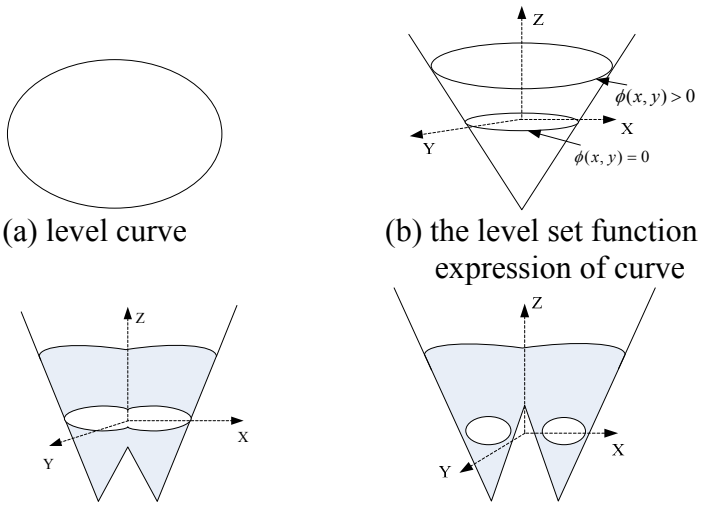
**Image Segmentation on Active Contour.** Active contour model is a kind of nonparametric model, which is proposed by some people as Malladi[7] and another ones as Caselles[8]. This model is based mainly on curve evolution theory and level set method, the principle of which is that the closed curve si expressed impliedly as level set of three-dimensional continuous function's curved surface, namely point set of the same function value, then the evolution of curve is solved impliedly by the evolution of curve surface.

(1).Basic principle of level set method. The level set method was proposed originally by Osher and Sethian[6], which is a kind of method used for solving the curve evolution, and express impliedly plane closed curve and avoid track and parameterization in the process of curve evolution. In the level set method, the plane closed curve is expressed impliedly as a contour curve of three dimensional continuous function curved surface $\phi(x,y)$ and the same function value. $\{\phi=0\}$ is usually known as zero level set, while $\phi(x,y)$ is known as level set function. $\phi(x,t)$ is defined according to the following ways:

$$\begin{cases}\phi(x,t)>0 & x\in\Omega\\ \phi(x,t)<0 & x\notin\Omega\\ \phi(x,t)=0 & x\in\partial\Omega=\Gamma(t)\end{cases} \tag{5}$$

In this equation $\Gamma$ is curve surface of given $R^n$ space; $\Omega$ is the opening connection region surroundded by boundary. So, through analysing the motion of $\phi(x,t)$ with time, we can describe curve surface $\Gamma$ by use of set of points whose function value is zero. In the process of numerical calculation, this kind of way of defination can describe very well fission and fusion of curve surface topological structure.

The following figures show the way by which level set function express closed curve. Figure(a) is a plane closed curve; Figure(b) is implicit expression of the level set function of curve, and $\phi(x,y)=0$ is plane curve of connotative zero level set in (a); Figure(c) is the shape of zero level set curve after the level set updates; Zero level set curve has devided into two curves in the figure(d).




(a) level curve (b) the level set function expression of curve

(c) the level set function structure (d) changed curve topological evolution

Fig.1 Curve evolution with level set method

We will introduce briefly mathematical expression of level set method and model relationship about level set method and curve evolution model.

Supposed that continuous function $\phi(x,y,t)$ is implicit expression of closed curve $C(p,t)(0 \le p \le 1)$ at the time $t$, namely at the time $t$, $C(p,t)$ correspond to zero level set of $\phi(x,y,t)$:

$$\begin{cases} C(p,0) = \{(x,y) | \phi(x,y,0) = 0\} \\ C(p,t) = \{(x,y) | \phi(x,y,t) = 0\} \end{cases} \tag{6}$$

$\phi$ is the plane closed curve corresponding to zero level set:

$$\phi(c(t),t) = 0 \tag{7}$$

In order that $\phi(x,y,t)$ is always satisfied with partial differential equation of curve evolution in the evolution process, we make total differential for equation (7), and the result is:

$$\nabla\phi \frac{\partial C}{\partial t} + \frac{\partial \phi}{\partial t} = 0 \tag{8}$$

In this equation $\nabla\phi$ is gradient of $\phi$. According to the definition of the level set, variable quantity of $\phi$ along the tangent direction of curve is zero, and is satified with the following equation:

$$\phi_s = 0 = \phi_s x_s + \phi_y y_s = <\nabla\phi, C_s> \tag{9}$$

According (9), we know that $\nabla\phi$ and $C_S$ are orthogonality, namely tangent of closed curve and gradient $\nabla$ are vertical, therefore the direction of $\nabla\phi$ and normal of $C$ are the same. Suppose that function $\phi$ in the interior of $C$ is negative, while exterior is positive. Consequently unit vector of level set $C$ is

$$\boldsymbol{N} = -\frac{\nabla\phi}{|\nabla\phi|} \tag{10}$$

We will bring (9) and (10) in (8), and the result is

$$\phi_t = -\nabla\phi V(k)\boldsymbol{N} = \nabla\phi V(k)\frac{\nabla\phi}{|\nabla\phi|} = V(k)|\nabla\phi| \tag{11}$$

Suppose that $V_{ext}(x)$ is velocity field in which $V(C)$ is expanded to all the level set, and the result is

$$\phi_t = V_{ext}|\nabla\phi| \tag{12}$$

We get the curvature of C(p,t) from equation (12)

$$k = \nabla\frac{\nabla\phi}{|\nabla\phi|} = \frac{\phi_{xx}\phi_y^2 - 2\phi_x\phi_y\phi_{xy} + \phi_{yy}\phi_x^2}{(\phi_x^2 + \phi_y^2)^{3/2}} \tag{13}$$

The level set method realize active contour evolution, which substantially it is a kind of description on that a low dimensional model is embedded in a high dimensional space. Although this transformation make the problem become more complicated in form, there are many outstanding advantages in the method of solving problem.

(2).Mumford-Shah model. Mumford and Shah propose Mumford-Shah model in 1989, and this model in theory is a kind of the variational problem of low dimensional measurement and the energy of volume, whose energy function contains the description of image region and edge. In the process of segemntation we don't need any prior knowledge, and get segmentation result driven by image datas, whose theory is as follows:

Suppose that definitional domain of image $I(x,y)$ is $\Omega$, and contour curve $C$ will devide image $I(x,y)$ several approximately homogeneous regions so as to get image $I_0(x,y)$ of segmentation. The Mumford-Shah image segmentation model which look for the real image boundary $C_0$ will devide image $I(x,y)$ into several homogeneous regions, and the error of se mentation images $I_0^{MS}(x,y)$ and $I(x,y)$ smaller than the error of all the segmentation images and original images, namely minimality is shown by the following energy equation.

$$F^{MS}(I_0, C) = \mu L(C) + \lambda\int_{\Omega}|I - I_0|^2 dxdy + \int_{\Omega/C}|\nabla I_0|^2 dxdy \tag{14}$$

Thereinto $\mu$ and $\lambda$ is larger constant than zero and $L(C)$ show the length of curve $C$ so as to keep evolution curve smooth; The second term of the right side in equation is data fidelity one so as to look for approximate image $I_0$ taking the place of original image $I$ and control the similarity of segmentation image; The third term which make segmentation image keep smooth is positive one. This model has global optimization and has the merit on getting image outline and image restoration, while this model is still seen as curve evolution and also has the ability of comprehensive high-level knowledge and support man-machine interactive operation, therefore it is applied widely in the image processing.

**The Procedure of Image Texture Segmentation.** In this paper we adopt Mumford-Shah texture segmentation model of multi-channel piecewise constant. We suppose that $C$ is the outline of evolution. The number of Gabor filter is $N = num(\sigma)*num(F)*num(\theta)$, $num(\sigma)$, $num(F)$ and $num(\theta)$ still respectively show that we have selected the number of scale, centre frequency and direction. We will mark $u_0^i$ for the feature image which is filtered by Gabor filter of number $i$, then we suppose that $c_+^i$ and $c_-^i$ are respective Grayscale average of interior and exterior devided by curve $C$.Finally we bring these values in Mumford-Shah model, and we can get the following equation:

$$E(C,\overline{c}_+,\overline{c}_-)=\mu.Length(C)+\int_{inside(C)}\frac{1}{N}\sum_{i=1}^{N}\lambda_i\left|u_0^i(x,y)-c_+^i\right|^2dxdy+\int_{outside(C)}\frac{1}{N}\sum_{i=1}^{N}\gamma_i\left|u_0^i(x,y)-c_-^i\right|^2dxdy \quad (15)$$

The first term on the right make evolution curve keep smooth effect, while the second and the third terms are both fitting error functions.

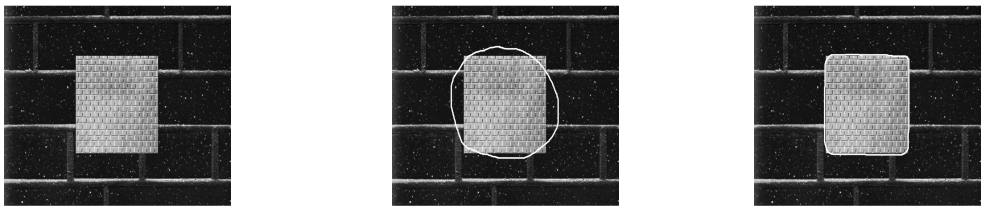
The parameters $\lambda_i$ and $\gamma_i$ are positive for $i=1,...,N$, and they are used to control the energy weight of interior and exterior at channel $i$. In general the both values are taken as 1.

The whole process of texture segmentation is as follow:

1. Active contour is initialized as symbol distance function.
2. Original texture images are filtered through multi-channel, and $u_0^1,u_0^2,...,u_0^N$ an be obtained.
3. Curve evolution is operated by use of equation (15).
4. Judge by using definite formula whether curve is convergent. If yes, iterative process will stop; If no, iterative process will continue back to the second step.

## Experimental Results and Analysis

In the experiment the first images is composite image which different style textures combine. The following images are respective original image, pilot process, final result.



(a) original image (b) pilot process (c) final result

Fig.2 Texture segmentation process

From the result of image segmentation, the method used by us in this paper has maken the segmentation for the image containing two kinds of texture, and basically segments the middle texture region in the image. We get a better segmentation effect. The following image show that a zebra stand in the grass, which is complicated texture image. The two kinds of different textures are the stripe texture of zebra skin and grass texture. The following experiment prove that zebra contour in the grass is segmented by our method. The following images are reapective original image, pilot process image, final result image.

(a) original image (b) pilot process image (c) final result image

Fig.3 Texture segmentation of natural image

From the result of experiment, we have segmented the mezra contour in the natural enviromental image, and we can recognize difference of zebra contour and background through observing segmentation image. The result explain that our method also have a good effect on complicated texture image. Therefore, Mumford-Shah active contour model have a satisfying effect on texture segmentation od natural image.

## Conclusion

In this paper we utilize segmentation method of Mumford-Shah active contour model to segment complicated natural enviromental texture image through technical analysis of texture segmentation. This method can describe signal feature of complicated texture and extract the texture feature very well, and can segment image based on extraction of texture feature, then we can segment texture region of interested object by using Mumford-Shah model. Our experiment demonstrates that our method doesn't only can segment accurately and effectively regular texture image, but also can segment object contour effectively for natural environmental image of complicated texture. The application in this paper on which segmentation method of Mumford-Shah active contour model segment natural enviromental image have certain application value on visual effect and algorithm.

## Acknowledgment

This research is supported by the National Natural Science Foundation of China (50574019) and the National High Technology Development Program of China (863) (2008AA04Z135).

## References

[1] S.Chen, A.Nir, Y.Yehoshua: "Integrated Active Contour for Texture Segmentation". IEEE Transaction on Image Processing, 15, 6. 1633-1646, (2006).

[2] B.Sandberg, T.Chan, V.Vese. "A level-set and Gabor-based active contour algorithm for segmenting textured images" , IEEE transactions on Image Processing, 15, 6. 02-39, (2002).

[3] M.Rousson, T.Brox, R.Deriche. "Active unsupervised texture segmentation on a diffusion based feature space", IEEE Computer Society Conference on Computer Vision and Pattern Recognition, 2. 699-704. (2003).

[4] You Jianjie, Wang Pingan, Xia Deshen. "Active Contour Model Combined Unsupervised Texture Segmentation ". Journal of Computer-Aided Design & Computer Graphics, 18, 12. 1897-1903, (2006).

[5] He Yuan, Luo Yupin, Hu Dongcheng. "Unsupervised Texture Segmentation Based on Geodesic Active Regions", Journal of Software, 18, 17. 592-599, (2007).

[6] Tai.Sing.Lee. "Image Representation Using 2D Gabor Wavelets". IEEE Transation on Pattern Analysis And Machine Intelligence, 18, 10. 959-971, (1996).

[7] R.Malladi, J.A.Sethian, B.C.Vemuri. "Shape modeling with front propagation:A level set approach". IEEE Transation on Pattern Analysis And Machine Intelligence, 17, 2. 158-175, (1995).

[8] V.Caselles, R.Kimmel, G..Sapiro. "Geodesic active contours". International Journal of Computer Vision, 22. 61-79, (1997).

[9] S.Osher, J.A.Sethian. "Fronts propagating with curvature-dependent speed:algorithms based on Hamilton-Jacobi formulations". Journal of computational physics, 79. 12-49, (1988).