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Ultrasonic image Segmentation Based on Extended Gradient Vector Flow field model

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Abstract - A new region growing method for ultrasound image segmentation based on extended gradient vector flow field is presented in this paper. A new type of diffusion equation is proposed to obtain the gradient vector field, which generates an external force on each pixel in the image domain. Here diffusion scheme is based on the magnitude and orientation of vectors. Image segmentation is performed in two steps. First, the seed points are automatically selected based on the direction of local gradients and followed by region growing using the automatically determined seed point to obtain segmentation. The proposed method is automatic and requires no human interaction and found to be robust to 1) The position of seed points with in the abnormal portion 2) Number of training samples were used 3) Can segment multiple objects at a time and running time for segmentation is in seconds. The corresponding results demonstrate that this method is reliable and effective.

Key words: GVF, region growing, EGVF

I INTRODUCTION

Ultrasound image segmentation is a critical issue in medical image analysis and visualization. Ultrasound images have poor quality compared to other medical images. Inspite of this, in many ways ultrasound is an ideal diagnostic tool. It is non-invasive, externally applied, non traumatic and can be performed in a regular clinical office outside hospital settings.

A wide range of segmentation approaches has been studied. Active contours [5] and region growing [1] [3] are the two main techniques. The active contour models are suitable for finding edges of a region whose gray scale or some other features are significantly different from the surrounding region. These models utilize a closed contour to approach object boundary by iteratively minimizing an energy function.

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The energy depends upon the shape (internal energy) and image gradient (external energy) where the contour resides and its minimization results in a desired boundary, but this model requires human interaction to draw the initial contour.

Moreover ultrasonic images always have strong speckle noise and attenuation artifacts. If the initial contour is far away from the true object boundary, the snake will be extremely affected by local noise and the result will be inaccurate. On the other hand, the region growing methods [1] [3] starts with a selected seed pixel to group pixels into region based on the homogeneity property, but an important issue is how to choose the seed without the interaction of users.

In this paper, we present a new class of external forces to address the problems listed above. An algorithm based on an extended gradient vector flow (E-GVF) field model is used for object segmentation. These vector fields are derived from images by minimizing an energy function in a variational framework. The minimization is achieved by solving a set of decoupled linear partial differential equations, which diffuses the gradient vectors of a gray-level, or binary edge map computed from the image. The region-growing algorithm starts with an initial set of seeds, which are automatically chosen by considering properties of local free vectors around each pixel. This method is automatic and has the capability of processing multiple objects.

The remainder of this paper is organized as follows. In section 2, we present the gradient vector flow and extended gradient vector flow estimation and its equation are considered. While in section 3, algorithm to grow the region is considered. Experimental results are presented in section 4. Conclusion appears in section 5.

II METHODOLOGY

1. Gradient vector flow fields

Gradient vector flow (GVF) fields are dense vector fields, generated by diffusing the gradient vectors of a gray-level or binary edge map, derived from an image [5]. The diffusion process grants to the GVF an increased capture range. Thus, an initial feature point can be guided to a desired boundary even when it is initialized away from this boundary. It should be also mentioned that GVF fields preserve boundary concavities.

In [6] Xu.etal defined a GVF model as a force field of vectors. In order to derive a GVF field the following energy functional should be minimized

$$E= \iint \mu\ (u^2_x+ u^2_y+ v^2_x+v^2_y) +|\nabla f|^2|V-\nabla f|^2 dxdy.$$

Where, $V(x, y) = [u(x, y), v(x, y)]$ is the GVF vector field, f is the edge map and μ is the regularization parameter, set according to the amount of image noise and controlling the tradeoff between the first and the second term. It can be observer that this formulation (equation (1)) creates smooth results when no data exits, since for small $|\nabla f|$ the energy is dominated by partial derivatives of the vector field.

Based on the above information, the GVF field can be found by solving the following Euler equations.

$$\mu\nabla^2 u-(u-f_x)\ (f_x^2 + f_y^2) = 0 \qquad (2\ a)$$
$$\mu\nabla^2 v-(v-f_y)\ (f_x^2 + f_y^2) = 0 \qquad (2\ b)$$

Treating u and v as function of time solves the previous equations. Consequently, we have

$$u_t(x,y,t) = \mu\nabla^2 u(x,y,t)-[u(x,y,t)- f_x(x, y)].S_{xy} \quad (3\ a)$$
$$v_t(x,y,t) = \mu\nabla^2 v(x,y,t)-[v(x,y,t)- f_y(x, y)].S_{xy} \quad (3\ b)$$

Where $S_{xy} = [f_x(x, y)^2+f_y(x, y)^2]$

It should be noticed that the equations 3(a,b) are known as generalized diffusion equations and can be solved as separate scalar partial differential equations in u and v. Each GVF vector will point toward object boundaries even if it is far away from them. Models based on GVF field can approach object boundaries even if the initial contour is located far from them. However these models still require human interaction.

In this paper, we extend the GVF field for use in an automatic seed selection and region growing process, which not only makes best use of GVF's diffused gradient information but also resolves the drawbacks it presents prior.

2. Extended Gradient Vector Flow Field

In our method, a four component field $[u(x, y), w(x, y), p(x',y'), q\ (x',y')]'$ is defined first where u, w, p, q represents the amplitudes (i.e., projections) in the x, y, x′, y′ directions. (as shown in Fig. 1)

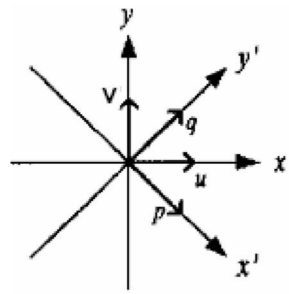

Figure 1 Four-Component vector definition for E-GVF field model

Among them (x, y) and (x′, y′) constitutes two sets of Orthogonal co-ordinate Systems with a rotation of 45º. By Extending the GVF field model [1], the force field can be given as

$$V(x, y) = [V_1(x, y), (V_2(x, y))]' = [[u, w], [p, q]]' \quad (4)$$

In order to derive a GVF field the following energy function must be minimized

$$E = \iint \mu\ |\nabla V_1|^2+|\nabla f|^2|V_1-\nabla f|^2 dxdy + \iint \mu\ |\nabla V_2|^2+|\nabla g|^2|V_2-\nabla g|^2 dx'dy' \ (5)$$

Where, $\nabla f = (I_x, I_y)$
$\nabla g = (I_{x'}, I_{y'})$ are the gradients of Image I in (x, y) and (x′, y′) co-ordinate Systems and μ is a regularization parameter (set according to noise). The gradient operators are defined as $\nabla = (\partial/\partial x, \partial/\partial y)$ and $\nabla' = (\partial/\partial x', \partial/\partial y')$.

Using the calculus of variations, it can be shown that the GVF can be found by solving the following Euler equations by applying calculus of variations to the energy function.

$$\mu\nabla^2 u-(u-I_x)\ |\nabla f|^2 = 0 \qquad (6\ a)$$
$$\mu\nabla^2 w-(w-I_y)\ |\nabla f|^2 = 0 \qquad (6\ b)$$
$$\mu\nabla^2 p-(p-I_{x'})\ |\nabla g|^2 = 0 \qquad (6\ c)$$
$$\mu\nabla^2 q-(q-I_{y'})\ |\nabla g|^2 = 0 \qquad (6\ d)$$

where, ∇^2 represents the Laplacian Operator. We note that in a homogeneous region, the second term in each equation is zero because, the gradients of I(x,y), I'(x, y) is zero. Therefore, within such a region u, v, p and q are determined by laplace's equation and the resulting EGVF field is interpolated from the region's boundary reflecting a kind of competition among the boundary vectors. This explains why GVF yields vectors that point in to boundary concavities. Equation (6) can be solved by treating the force vectors (u, w, p, q) as function of time n. The time step is simply set to 1. Therefore we get the following iterative equations.

$$u_{n+1} = u_n + \mu\nabla^2 u_n - (u - I_x)\,|\nabla f|^2 \qquad (7\text{ a})$$
$$v_{n+1} = v_n + \mu\nabla^2 v_n - (v - I_x)\,|\nabla f|^2 \qquad (7\text{ b})$$
$$p_{n+1} = p_n + \mu\nabla^2 p_n - (p - I_x)\,|\nabla g|^2 \qquad (7\text{ c})$$
$$q_{n+1} = q_n + \mu\nabla^2 q_n - (q - I_x)\,|\nabla g|^2 \qquad (7\text{ d})$$

The steady-state solution of these linear parabolic equations is the desired solution of the Euler equation (6). The equations in (7) are known as generalized diffusion equations.

To setup the iterative solution, let the spacing between pixels be ∇x and ∇y. The time step for each iteration be 'n'. Then the required partial derivatives can be approximated as

$$u_n = \frac{1}{n}(u_{n+1} - u_n) \qquad (8a)$$

$$v_n = \frac{1}{n}(u_{n+1} - u_n) \qquad (8\text{ b})$$

$$\nabla^2 u = \frac{1}{\Delta x \Delta y}\left(u_{i+1,j} + u_{i,j+1} + u_{i-1,j} + u_{i,j-1} - 4u_{i,j}\right) \qquad (8\text{ c})$$

$$\nabla^2 v = \frac{1}{\Delta x \Delta y}\left(v_{i+1,j} + v_{i,j+1} + v_{i-1,j} + v_{i,j-1} - 4v_{i,j}\right) \qquad (8\text{ d})$$

The initial conditions are set to $\mu_o = I_x$, $w_o = I_y$

$p_o = I_x'$, $q_o = I_y'$

The values of u, w, p and q for each pixel (x, y) are substituted in to Equation (5) to get energy value E in each iteration. The convergence of iterations can be reached when the energy value is hardly decreased. Fig (2) gives an example of converged energy value.

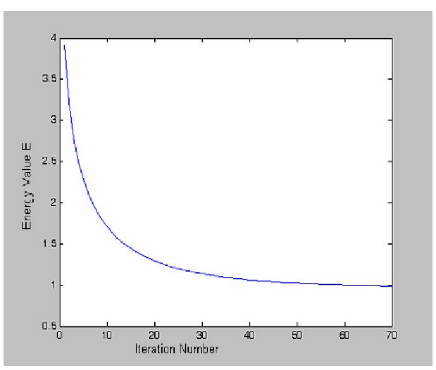

Figure 2 Curve of energy value E vs Iteration number

Basically the main goal of this iterative process is to diffuse the gradient properties all over the image to form the force field for region growing that follows. After calculating the force vector V(x, y)'s, they are computed to obtain the signs only

$$\hat{u} = u/|u|,\ \hat{w} = w/|w|,\ \hat{p} = p/|p|,\ \hat{q} = q/|q| \qquad (9)$$

The sign value roughly indicates the direction of force on a specific axis and is zero when the force component has a zero amplitude. The force will be in the opposite direction when the normalized amplitude in that axis is-1. Consequently, each pixel is considered to connect outwards to 4 of its 8-neighborhood pixels by the strengths u, w, p, and q . Via this linking, we can track to the true object boundaries.

To search for the starting seeds, we score the status of force vectors from 8-neighborhoods for each pixel. We call this the seed selection process. Figure (3) shows some examples of status. Basically, the score counts the number of neighboring pixels whose force vectors do not point inwards to the considered pixel. All pixels have seed selection scores ranging from 0 to 8. Since the force direction generally indicates the gradient directions onwards object boundary, pixels of higher scores will be chosen as the seeds.

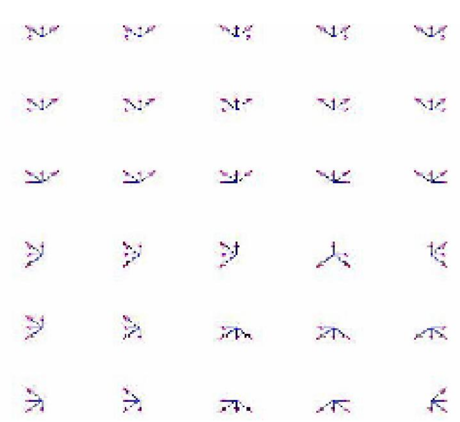

Figure 3 Example of force from 8 neighbourhoods

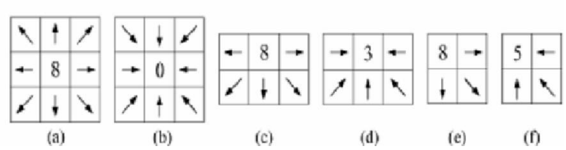

Figure 4 : Scoring

III REGION GROWING PROCESS

A region growing method is used to segment ultrasound images. The seeds selected in the previous step are utilized to segment the image. The region growing approach is as follows,

- Start by choosing an arbitrary seed pixel and compare it with neighbouring pixel.
- Region is grown from the seed pixel by adding in neighbouring pixels that are similar, increasing the size of the region.
- When the growth of one region stops we simply choose another seed pixel which does not yet belong to any region and start again.
- This whole process is contained until all pixels belong to some region.

This region growing method gives very good segmentation that corresponds well to the observed edges.

The procedure is outlined in the form of algorithm as,

Let f be an image for which region are to be grown.Define a set of regions, R1, R2, R3 ..Rn each containing atleast one seed pixel

Repeat

for i = 1 to n do
for each pixel, p at the border of R_i do
for all neighbours of p do
Let x, y be the neighbour's coordinates
Let m_i be the mean grey level of pixels in R_i
If the neighbour is unassigned and $|f(x,y) - mi| \leq \nabla$ then
Add neighbour to R_i
update m_i
end if
end for
end for
end for

until no more pixels are being assigned to regions

IV EXPERMENTAL RESULTS

First, we use a single object ultrasonic image for simulation. The number the iterations to get the force vector field is varied and the regularization parameter μ is set to 0.2. Figure (2) shows the curve of energy value vs. iteration number. Obviously, the force vector field, we score the status of force vectors from 8-neighborhoods for each pixel.

Then the modified force vector field $[\hat{u}(x,y),\ \hat{w}(x,y),\ \hat{p}(x',y'),\ \hat{q}(x',y')]$ guides the seed pixels to grow. Normally, there may be more than one seed in an object. They will however be merged together during the growing process. Then the proposed algorithm is applied to multi object Ultrasonic Image.

A few ultrasonic images, their seeds and their segmented images are presented here. The Figure 5 shows original ultrasonic image. Figure 6 shows the selected region and the figure 7 shows their seed points and segmented image is shown in figure8.

Figure 5

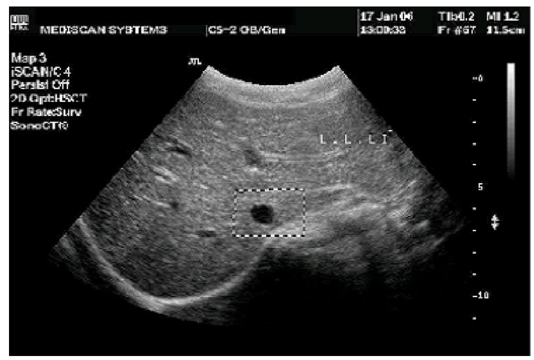

Figure 6a

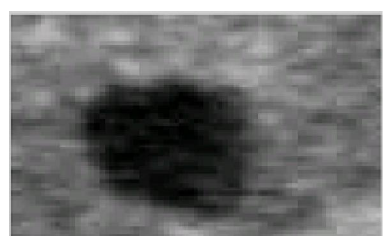

Figure 6b

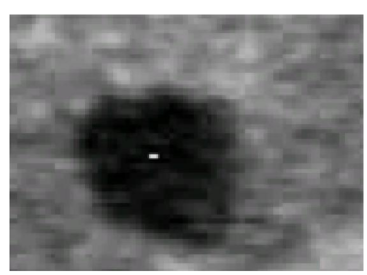

Figure 7

Figure 8 a

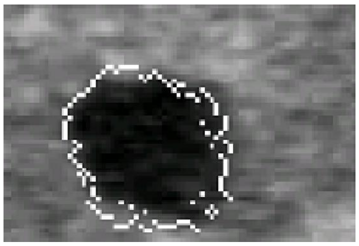

Figure 8 b

V SUMMARY AND CONCLUSION

We have introduced a new external force model for automatic seed selection, which we called as Extended gradient vector flow field. The field is calculated as diffusion of the gradient vectors of a gray or binary image. This method is proposed for automatic multiobject segmentation. Since this model gives 8 neighbourhood gradient information toward the object boundary, it can be used for accurate image segmentation than traditional GVF. Scoring and seed selection are done based on the local gradient direction information around each pixel. This step is automatic and requires no human interaction, making our algorithm much suitable for practical application.

REFERENCES

1. Cheng-Hung Chung and Wen-nung Lie, "Region growing based on Extended Gradient vector flow field model for multiple object segmentation," IEEE transactions on image processing, 2001.
2. Haiyan Wang and Bijoy ganesh, "Geometric active deformable models in shape modeling," IEEE transactions on image processing, Vol. 9 No.2, pp.302-308, 2000
3. Hojjatoleslami S.A. and Kittler.J., "Region growing: a new approach", IEEE Transactions of image processing,vol.7,No.7, pp 1079-1084, July1998.
4. R.Adams and L.Bischof," seeded region growing", IEEE Transaction pattern anal.machine intell ,vol.16,No.3, pp 641-647, June 1994.
5. Xu.c and J.L.Prince, 1998. snakes, shapes and gradient vector flow, IEEE Transaction image processing,vol.7,No.3, pp 359-369, March 1998.