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An Enhanced Procedure for Image Segmentation and Smoothing

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Abstract: This study aims at the development of an enhanced procedure for image segmentation and smoothing. The segmentation procedure uses region growing and merging process around seeds. This study identified different segmentation methods and their limitations. The recent developments in image segmentation and smoothing are very sensitive to broken edges. This research proposes an enhanced procedure to overcome this limitation. Our enhanced paradigm is developed on some broken images (like the Diatom images in this analysis). The concepts of PDE (Partial Differential Equations), markers, anisotropic filters and neighborhood interpolation are used for this purpose. We have prepared an enhanced procedure called SoS for image segmentation and smoothing.

Key words: Markers, region growing, image denoising, partial differential equations, interpolation, over segmentation

INTRODUCTION

Digital Image Processing aims high on image segmentation. Image segmentation (Gonzalez and Woods, 2006) is the most challenging task in image processing. Usually the segmentation process relies on poor (raw) information and hence is considered as a low level treatment (Cocquerez and Philipp, 1995). We use pre and post processing steps of image segmentation for various reasons. Pre processing with certain filters usually smooth the image.

The various methods developed till now varies from one image to other. Over segmentation is also another problem to be discussed in image analysis. The active contours method presented by Caslles *et al.* (1992) and the front propagation method specified by Malladi *et al.* (1995, 1996) simplify the topological problem but do not address the initialization and convergence issues. The geometrical version of the active contours method is stable and retrieves simultaneously several contours but do not retrieves angles. The bubbles method specified by Tek *et al.* (1997) simplifies the initialization process by allowing, for instance, contours to be initialized at the image minima or at predefined grid cells having homogeneous statistical properties. But bubbles method requires fine tuned parameters in order to achieve simultaneous convergence of bubbles.

The seed-region-growing method proposed by Cocquerez and Philipp (1995) and Mehnert *et al.* (1997) sensitive to seed initialization and produce jagged boundaries. The region competition method of Zhu *et al.* (1996) produces jagged boundaries and depends on seed initialization, which eventually might lead to leakage through diffuse boundaries, if the seeds are asymmetrically initialized (Sebastian *et al.*, 2000).

Similarly the non-hierarchical watershed method (Vincent, 1990; Vincent and Soille, 1991) leads to a strong over-segmentation if proper image smoothing is not provided. Watershed method proposed by Meyer (1991) is optimal since each pixel and its immediate neighborhood are visited only once.

Present study concentrates on the improvements of the previously developed methods. It considered the latest flooding simulation algorithms and image segmentation and smoothing algorithms. This study presents SoS algorithm for image segmentation and smoothing which is the enhanced version of the previous methods.

MATERIALS AND METHODS

The previous simulation algorithms and image smoothing segmentation procedures works well on all gray scale images. But they are sensitive to broken edges. Due to this we may obtain some wrong segmentation results also.

Our enhanced paradigm is developed on some broken images (like the Diatom images in this analysis). We have

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developed this procedure (SoS) with the help of PDEs, user specified markers, anisotropic filters and neighborhood interpolation principles.

Partial differential equations for image smoothing: Image segmentation and denoising are the two important wings of image processing. Image denoising reduces the noise introduced by the image acquisition process, where as image segmentation recovers the regions associated to the object. For image denoising, partial differential equations and controlled curvature motion (Yezzi, 1998) are used to modify the image topology.

Let F(x,y,z (t)) is a 3D time-dependent surface image. By deforming this surface with the help of vertical projection of its mean curvature will effectively removes non-significant image extreme. The surface height at any point (x,y) is the value of the local gray scale.

The term anisotropic refers to the case where the diffusivity is a scalar function varying with the location. But in terms of partial differential equation community this case is termed as non-homogeneous non-linear isotropic diffusion. The non-homogeneous isotropic diffusion limits the smoothing of an image near pixels with a large gradient magnitude, which are necessarily the edge pixels. As the diffusion near an edge is minimal, the noise reduction near the edge is also small. To tackle this we used anisotropic filter repeatedly on the image.

The local surface deformation is computed from the local mean curvature as follows.

$$K = \frac{F_{xx}(1+F_y^2) - 2F_x F_y + F_{yy}(1+F_x^2)}{2(1+F_x^2+F_y^2)^{3/2}} \quad (1)$$

The image I is witnessed on three dimensions like F_x, F_y, F_z etc. and Ķ is the local surface deformation.

The edge preserving anisotropic filter is used repeatedly to evolve the image F as a surface under the modified level set curvature motion.

$$\frac{I(k+1) - I(k)}{\Delta t} = A(I(k))I(k) \quad (2)$$

Where I(k) denotes the image at time step k and A(I (k)) I (k) is a discretization of delta. And the anisotropic filter can be computed from the above mentioned local surface deformation.

$$F_i + 1 = F_i + Ķ \quad (3)$$

Region growing and merging process for segmentation: Region growing is a procedure that combines pixels or subregions into larger regions based on predefined criteria. The general approach is to begin with a set of seed points and from these grow regions by appending to each seed those neighboring pixels that have similar properties as that of seed.

An alternative is to subdivide an image initially into a set of arbitrary, disjointed regions and then merge the regions.

In this two tier process, the first step is to expand regions with a specified sorting procedure. Generally the regions grow until the growing process finally stops thus defining the location of the edges. Sorting the heights of the pixels in ascending order allows the growing process automatically start from the minima of the sorted surface. The height of the surface is computed as the mean curvature at z(x,y).

In the second step merge all the grown regions with the help of user-placed seeds.

Sorting all image pixels according to a convenient relation between each pixel z (x,y) and its neighborhood N(z) is sufficient to impose this processing order. By adding a merging mechanism controlled by user placed seeds the region growing and merging procedure is complete.

The SoS algorithm

Step I: Use the anisotropic filter on to the image (repeatedly). This process should stop at appoint where the desired result is achieved.

Step II: Place markers (one per region). The user chooses to place markers on the regions

Step III: Sort all image pixels in ascending order according to the mean curvature at the current pixel.

Step IV: For each pixel z, find the number of positive labeled pixels exist in its neighborhood.

Step V: By using nearest neighborhood interpolation, merge all nearest pixels with high gray levels to combine broken or leaky edges.

Step VI: Conclude the segmented image.

Pseudo-Code

No. of labels = NO:

S: labels 1 to N are used for markers and labels N+1 to NO are for seeds.

Put one marker per region label from 1 to N;

Sort all pixels in ascending order.

For each pixel do

begin
find number of label exist in N(z)
if(labeled pixels = 0)
current pixel receives a new label starting a new temporary region.
Else if (labeled pixel = 1)
Current pixel receives this label
Else if (labeled pixels > = 2)
Current pixel receives an edge label
Else if (labeled pixels is a negative number)
Use linear interpolation principle to interpolate them for finding nearest neighbor pixels to combine the broken images and leaky images. (can also use Mexican hat)
Else
begin
Merge all neighbors into one region;
Current pixel gets this label
End
End
(The Laplacian of a Gaussian is sometimes called the Mexican hat function)

Applications: Diatoms are microscopic single celled alga, which build highly ornate silica shells or frustules. In the following diatom images (Pech-Pacheco and Cristobal, 2002), we placed markers which are shown with colored dots.

Figure 1-3 shows SoS procedure adopted on Diatom images. The pixels on the edges were sorted and processed according to the original intensity of the gray levels. As Fig. 2 explodes homogenous regions these pixels were sorted in ascending order and processed by considering the difference between maximum and minimum gray levels.

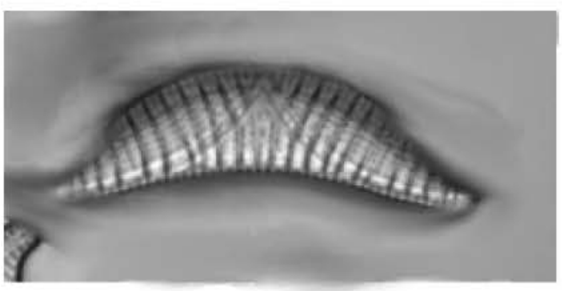

Fig. 1: Original diatom image with breaks

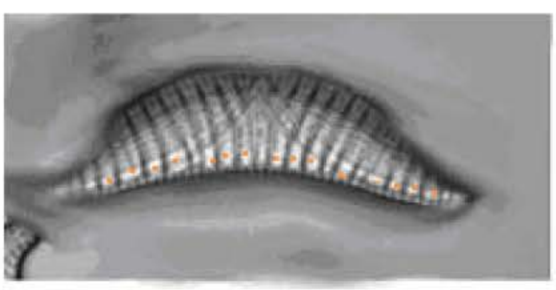

Fig. 2: Applied with 25 markers

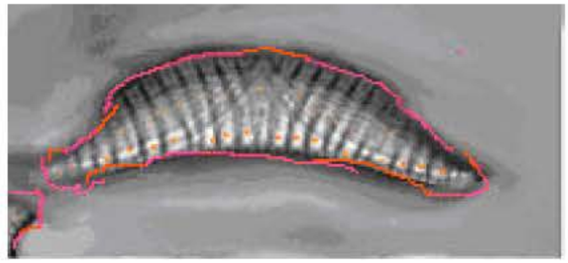

Fig. 3: Diatom image applied with SoS algorithm

The results shows that for 13 min of denoising time, the segmentation is achieved in 20 min. Similarly for 16 min of denoising time segmentation results are obtained in 21 min. Where as the results are obtained for 578 min of denoising time and the segmentation duration is 1052 min.

CONCLUSIONS

This study mainly focuses on the improvement of image smoothing and segmentation techniques. The procedure used here reduces the over-segmentation and its execution time is directly proportional to the image size. It also has the ability to change the image topology by using merging mechanism. However SoS is not applicable to video segmentation.

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