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Initial Contour Generation Approach in Level Set Methods for Dental Image Segmentation

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Abstract— **Segmentation is challenging process in medical images especially on dental x-ray images. Level set methods have effective result on medical and dental image segmentation. Initial Contour (IC) is the essential step in level set image segmentation methods due to start the efficient process. However, the main issue with IC is how to generate the automatic technique in order to reduce the human interaction and moreover, suitable IC to have accurate result. In this paper a new region-based technique for IC generation, is proposed to overcome this issue. The idea is to generate the most suitable IC since the manual initialization of the level set function surface is a well-known drawback for accurate segmentation which has dependency on selection of IC and wrong selection will affect the result. We have utilized the statistical and morphological information inside and outside the contour to establish a region-based map function. This function is able to find the suitable IC on images to perform by level set methods. Experiments on dental x-ray images demonstrate the robustness of segmentation process using proposed method even on noisy images and with weak boundary. Furthermore, computational cost of segmentation process will be reduced.**

Keywords- Segmentation, dental x-ray, initial contour, level set, binarization.

I. INTRODUCTION

Image segmentation is a significant and a challenging process in computer vision and image processing applications. Extensive researches have been done and many methods and approaches have been proposed in this regard [9, 26]. Active contour models (ACMs, also called deformable models or snakes) [1,2,9,12,22] are the most successful and accurate methods in image segmentation. Furthermore, in dental image segmentation many methods have been performed and implemented which researches proves that the level set segmentation method has accurate and efficient result [5,21].

Active contours models presented by by Caselles et al. [2] and Malladi et al. [12]. The models are on the basis of curve development hypothesis [10] and level set method [6]. The principal goal is to designate contours in as the zero level set of an implicit function determined in a higher dimension, generally described as the level set function, and to develop the level set function under a partial differential equation (PDE). Level set method was introduced by Osher and Sethian [15] for front propagation. The existing geometrics active contours or level set methods [1,12] are represented implicitly as level sets of a two-dimensional function that evolves in an Eulerian framework. Geometric active contours are independently introduced.

The level set image segmentation has two main methods, region-based [3] and edge-based method [2]. To extract the Region of Interest (ROI) in region-based method the prior energies of an object is required, while, in the edge-based method to specify the pixels in edge the gradient magnitude of each pixel of image is essential [19]. Nevertheless, the both methods may have some drawbacks. The region-based method is very sensitive to the variation of intensities in object and also the lack of edges in edge-based method which affect the results. Zhang et al. [27] proposed the method by combining the strength of both methods together to remove their drawbacks. However, the segmentation of images still relies on the position of initial contour (IC) on the image.

Xie [23] introduced the initial contour independency method for LS image segmentation. Xie [24], utilized the magnetostatic active contour for persuade the contour to move through the constant points of vector flow which is the drawback of Generalized Gradient Vector Flow [25]. However, the method, [23] to place the new contour, is depends on the boundary of object and edge detection processes from initiation.

In most of the image segmentations using level set function the contour level zero or IC has been chosen by manually for all images [5,7,20,21], and segmentation process is done without selecting the proper IC which has effect on segmentation the results. Selection of proper ICs by manually for each image also is time consuming process. Those images which are very noisy or need to segment the local regions will fail with using this method. As it shows on figure 1 the global segmentation with manual IC selection and performed Chan and Vese (C-V) level set method [3] which is failed to fulfill the segmentation of ROI. C-V Level set model is most popular region-based image segmentation method which is based on Mumford-Shah segmentation approach [13]. C-V method claims that it is not dependent on initial contour to start and automatically can detect the all of the contours. However, result in this paper demonstrates that the method is more accurate and faster by using suitable algorithm to generate the IC. Comparatively, the C-V model can extract the object more accurately when the IC is surrounds its boundary and accuracy reduces when IC is not covered the proper area on image.

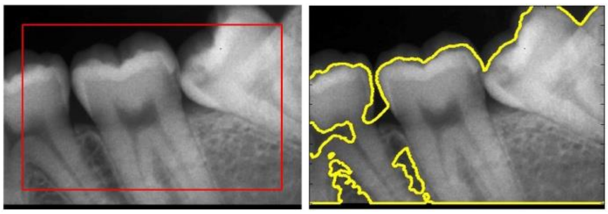

Figure 1: Predefined IC selection with corresponding segmentation result.

In this paper, we propose a new local initial contour selection for level set method, which shares the advantages of active contour methods and morphological operations on dental x-ray image. We utilize the statistical and morphological information inside and outside the contour to establish a region-based map function which is able to find the suitable IC on dental images to perform by level set method. Furthermore, the proposed method has no limitation on image conditions which can perfectly provide the IC and object boundary in segmentation process.

This paper is organized as follows: In Section 2, we review the classic level set method. Section 3 describes the formulation of our method and how to generate the initial contour. The numerical method of the proposed method is also summarized in this section. Additionally, we provide description about implementing our method to segment various objects with dissimilar intensities. The advantages of our method over the manual IC selection are also discussed. Section 4 evaluates our method by extensive experiments on dental x-ray images. Section 5 concludes the paper.

II. LEVEL SET METHOD

The level set method was proposed by Osher and Sethian [15] for "front propagation, being applied to models of ocean waves and burning flames". Malladi [12] applied Osher [15] method for medical imaging purposes. Level set methods have attracted more and more attention of researchers from different areas [4,8,14]. The concept of the level set method is to enclose a curve within a surface. Because of robust detection in image characteristics such as corners and topological changes, the level set method has been used extensively. The segmentation boundary can be defined as a part of the surface where the contour level is 0, i.e., the zero level set. Let φ represent the implicit surface such that

$$\varphi(X,t)=\pm d \quad (1)$$

Where x is a position in domain (the image), t is time, and d is the distance between position x and the zero level set. The sign in front of d is positive if x is inside the zero level set. Otherwise, the sign is negative.

$$\varphi(x,y,0)=\begin{cases} d(x,y,\gamma)\, if\,(x,y) \;\; insid\ the\ front \\ 0 \\ -d(x,y,\gamma)\, if\,(x,y) \;\; outsid\ the\ front \end{cases} \quad (2)$$

The concept of level set method is to enclose a curve within a surface. To move the level set surface, let define velocity field F, which specifies how contour points move in time. Based on application-specific physics such as time, position, normal, curvature, image gradient magnitude will be specifies. Then the initial value for the level set function, φ (x,y,t), based on initial contour will be computed. The value of φ will be adjust over the times and current contour defined by φ (x(t),y(t))=0. Then the iteration will be repeated until the convergence on the boundary of curve. The last obtained curve is the segmented area and final level in level set calculation. The algorithm of level set segmentation method is described as below:

Step 1: *Initialize the front γ(0)*

Step 2: *Compute φ (x,y,0)*

Step 3: *Iterate:*

φ (x,y,t+1) = φ (x,y,t) + Δ φ (x,y,t)

until convergence

Step 4: *Mark the front γ(tend)*

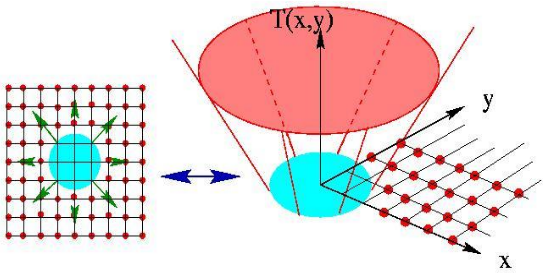

Figure 2: Progress of level set method from initial contour level.

$$T_i=\begin{cases} T=0.3 \;\text{ if }\; 20\le \mu f\,(i,j)<65 \\ T=0.35 \;\text{ if }\; 65\le \mu f\,(i,j)<90 \\ T=0.45 \;\text{ if }\; 90\le \mu f\,(i,j)<140 \\ T=0.55 \;\text{ if }\; 140\le \mu f\,(i,j)<220 \end{cases} \quad (3)$$

Ma and Manjunath [11] described that in implementation, under such a scheme, a front might stop evolving at a position of two equidistant edges. In this condition, even edge seems like a realistic option to evolve or stop moving. Moreover, if the zero level set is affected only by vectors of just one edge, situation will be worse and the whole set will fail into that edge. It might happen if the zero level set is very near to only one side of object in the image. In other word, generating the full vector field which covers the whole area and using only that is possible [18].

However, effective level set methods cannot be used directly in all types of images due to several reasons: (1) vast of computation; (2) complexity of parameter settings; and (3) finding the initial contours which are very sensitive where (a) the speed of the level set method highly depend on the size and position of initial curves as well as the complexity of objects, and also (b) in some conditions, coupled level set functions cannot converge the some placements of the initial contours.

III. INITIAL CONTOUR GENERATION

Zero level is used to represent the initial contour and start point for expand or shrink in LSF. As mentioned in [17], the same initial contour or even in different embedded LS methods will produce the same final result. Therefore, with produce the suitable zero level the result will be more accurate on image segmentation. In implementation of traditional LS methods [2,3,6,12,17], the upwind techniques are used to provide the numerical stability.

A. Binarization.

The digitized dental x-ray images are generally manipulated and represented as gray scale image. Background of images which is darker than teeth and gum regions can be eliminated using binarization. In this regard, the binarization algorithm has been employed using variation of threshold values. The suitable threshold value will prevent the wrong selection of initial contours and furthermore segmentation process. Therefore, with histogram based image thresholding and average of corresponding pixels in original gray-scale image, we can obtain the proper threshold value. Because of variety in image qualities and imaging difficulties using well-known thresholding methods such as Otsu's algorithm [16] is not efficient. Proposed algorithm contains four classes of pixel ranges to converts the grayscale image to a binary image. The output image replaces all pixels in the input image with luminance greater than level with the value 1 (white) and replaces all other pixels with the value 0 (black). The four specify levels are in the range [0,1]. This range is relative to the signal levels possible for the image's class. The Equation 3 shows the threshold values and their pixel ranges.

Suppose f(i,j) is the gray-level value of pixel (i,j), and T is the threshold level value for image. Where T has been selected by specified gray-level average value.

After applying thresholding value to the image and obtain the binarized image, the white sections will be the most probable ROI area and black area consider as background.

B. Remove Undesired Objects

The binarized image may contain many objects which are not desire for our computation. The aim of this stage is to analysis the connected components based on geometric properties (area and dimension) and then remove the undesired objects. The morphologically open binary image technique applied to remove the all connected components (objects) that have fewer than Predefined Pixels Value (PPV) and produce another binary image. PPV value can be chosen based on the resolution and dimension of image. Summation of each small area compared to PPV and if it is lesser than that then definitely the object is undesired area and it might be the noises or unnecessary objects on images. Figure 3 shows the process using morphologically open binary image technique on dental radiograph image by using disk structuring element and PPV=200 pixels of neighboring size.

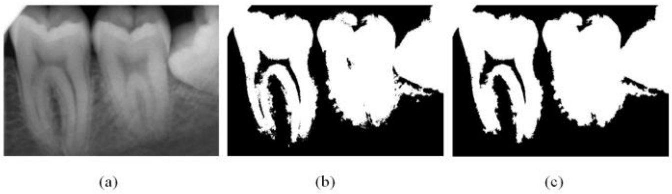

Figure 3: Refinement process; (a) Original image. (b) Binarized image. (c) Removed undesired objects.

C. IC Map

We assumed the rectangular area for generate the contour which is fast for implementing and has a better result in segmentation process. Therefore, to select the IC for each image, image is divided to into four areas (A). The scanning process will scan the regions and respectively labels the each connected regions in current areas. Let $f(x_n, y_m)$ be a subject image for segmentation, the divided four areas defined as follows:

$$A = \begin{cases} A1: \ f(x_1 : x_{n/2}, y_1 : y_{m/2}) \\ A2: \ f(x_{(n/2)+1} : x_n, y_1 : y_{m/2}) \\ A3: \ f(x_1 : x_{n/2}, y_{(m/2)+1} : y_m) \\ A4: \ f(x_{(n/2)+1} : x_n, y_{(m/2)+1} : y_m) \end{cases} \quad (4)$$

The first connected pixels in Ai will be labeled by a number and scanning trough the each connected 8 neighboring pixels in current area and labeling will be continued until all connected components finishes. Suppose if f(i,j) is our binary image then the first connected pixels of ones (white pixels) in position (i,j) will be labeled by number one as first connected region.

In each area the biggest connected component must be kept and the other labeled connected components will be eliminated. The labeled region i in area Ai defined as:

$$R_i = region_i$$

And the actual number of pixels in each region or weight of region defined as:

$$w_i = |R_i|$$

The centroid of biggest labeled connected component or region W_i in each area considered as the desired point for initial contour of area Ai. The region selection defined as follows:

$$W = \{w_1, w_2, w_3, \ldots, w_n\}$$

$$r_j = Max(W)$$

Where W is set of all the regions in area Ai and r_j is the biggest area with position j.

Figure 4 demonstrates the original gray scale tooth image with four divided area and labeled regions. As it shows there are many regions in each area.

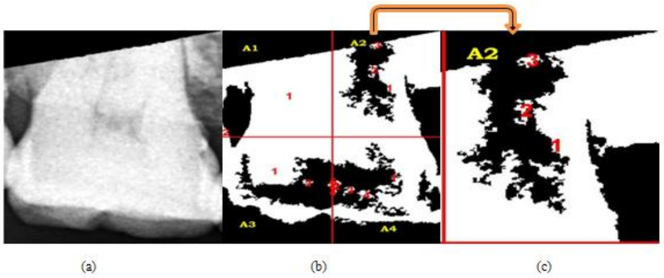

Figure 4: (a) The original gray scale dental x-ray image, (b) Four divided areas and labeled regions, (c) Enlarged area A2 which shows the labeled regions.

After finding the connected pixels and labeling all the four areas of image, now we can measure the set of features of image such as: Mean Intensity, Area, Perimeter, Centroid and Diameter for each labeled region. For indicating the initial contour we can use the feature Area, Perimeter or Diameter. The highest weight of each feature is the region with more connectivity pixel and most probable object area. Table 1 and 2 shows the extracted features of area A1 and A2.

TABLE 1. EXTRACTED FEATURES OF EACH REGION IN AREA *A2*.

Region NO	Mean Intensity	Area	Perimeter	Centroid	Diameter
1	124.6	17534.0	749.4	84.9 123.2	149.4
2	102.1	124.0	63.3	3.5 191.3	12.6

TABLE 2. EXTRACTED FEATURES OF EACH REGION IN AREA *A2*.

Region NO	Mean Intensity	Area	Perimeter	Centroid	Diameter
1	104.9	169.0	1673.1	71.7 108.4	147.0
2	97.1	142.0	101.3	52.7 75.6	13.4
3	96.0	98.0	61.4	57.0 28.6	11.2

The centroid of region with biggest area is the initial contour point in current area. Figure 5 shows the labeled regions and centroid of each selected region with biggest weight by subjecting to generate the initial contour. The selected IC is the image area which is taken into account in order to perform the segmentation with level set method. Figure 6 demonstrates IC selection and segmentation process using proposed method.

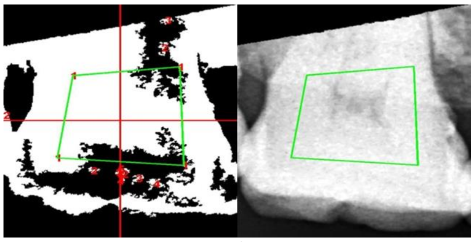

Figure 5: Selected initial contours in four areas within threshold image and respectively generated initial contour on original image.

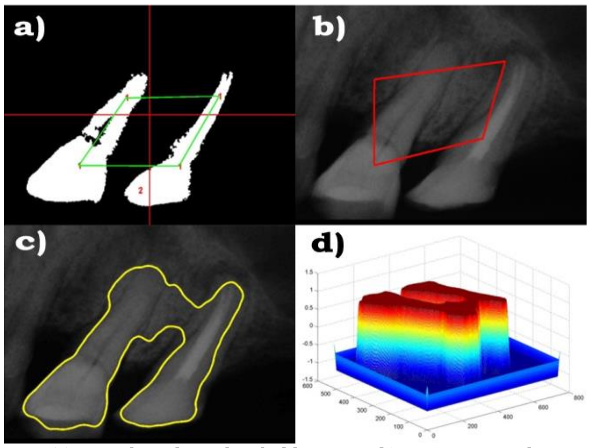

Figure 6: (a) IC selected on threshold image, (b) IC on original image, (c) segmented image, (d) domain surface of segmented image.

Nevertheless, during the thresholding process some divided areas of image may contain zero pixels and without any region. To overcome this issue the pixel values of each part will be verified and if the value of area is equal to zero, then the thresholding value will be reduced by 0.1. The process will repeat until the pixel value is greater than zero which means there is at least one region to select.

IV. RESULTS AND DISCUSSION

Proposed method generates more suitable initial contour to employ in level set based function for dental x-ray image segmentation. The statistical and morphological information of each image has been extracted to establish a region-based map function. However, compare with traditional manual IC generation, the result demonstrates that the proposed method have more accuracy and faster which is also easy to implementation.

Our algorithm is implemented on Matlab 7.12 on a 2.0-GHz Intel Pentium IV PC. In each experiment we choose the level set (C-V) method [3] parameters as sigma= 5, μ= 3, Δ= 5, and time step Δt=1.

Figure 7 shows the result of a grayscale dental image with the ROIs inside the image, the figure 7 (a) demonstrates the original image with our proposed method for selection of initial contour which is inside the considered regions. The figure 7 (b) shows the corresponding segmentation result with using traditional method on IC selection respectively. By using our method, the result of level set function converges in 60 iterations and takes only 0.36 min, while the segmentation converges in 280 iterations and takes for 2.2 min using manual and predefined IC.

Figure 7: (a) Segmentation process using predefined IC selection. (b) Segmentation using proposed method.

Segmentation on noisy images is very challenging process which the level set method has an advantage on that but our experiments shows that segmentation of noisy images depends on accurate selection of IC. Figure 8 demonstrates the IC selection using proposed method which covers inside the object on very noisy image. The result shows the segmentation process has accurately segmented the object. On second row the IC selection has been done pre-defined, result shows the object is segmented but there are many unwanted segmented objects which cause the problem in segmentation.

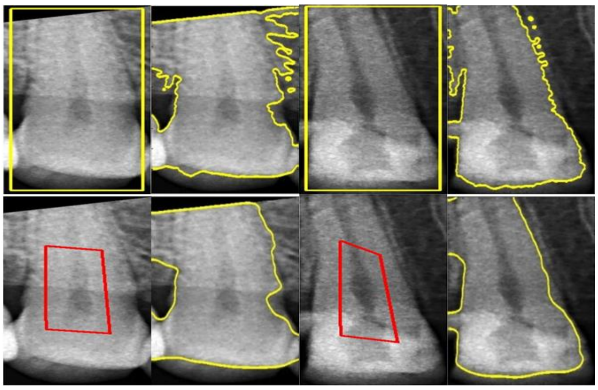
Figure 8: Some segmentation result on noisy dental images, the first row using proposed method and second row using predefined IC selection.

The experiment show segmentation with using level set function is depends on proper IC selection. Iteration of level set and time of segmentation process will changes based on selection of IC. Even the size of images affects the segmentation time. Table 3 demonstrates results on three images with using proposed method and predefined IC selection method.

TABLE 3: SOME EXTRACTED SEGMENTATION PROCESS RESULTS USING PROPOSED METHOD AND PREDEFINED METHOD.

Sample		Methods: RIBC	Methods: Predefined
Figure 8 Size: 400×284	Time	0.2	2.45
	Iteration	40	300
	Result	Ok	Failed
Figure 10 Size: 512 × 522	Time	0.42	2.5
	Iteration	70	300
	Result	Ok	Failed
Figure 11 Size: 542 × 550	Time	0.85	4.25
	Iteration	100	300
	Result	Ok	Failed

V. CONCLUSION

In this paper, we proposed a region-based IC generation for dental x-ray image segmentation with utilizing level set function. Most level set methods have quite dependency to selection of IC position on image to start the process of segmentation. Comparatively, the C-V model can extract the object more accurately when the IC is surrounds its boundary and accuracy reduces when IC is not covered the proper area on image.

Proposed region-based initial contour generation method generates the most suitable IC for level set function. The method extracts the statistical and morphological information of image to produce the IC. Extensive experiments on dental x-ray images compared with predefined IC selection method and results demonstrates the more accuracy and higher speed with using proposed method for level set image segmentation process. Furthermore, proposed method is easy to implement and robust which can be used with any images as well as noisy and weak edge images and it has no limitation on image conditions. Furthermore, for future work, the proposed method can be performed with other level set and active contour methods with extensive medical standard datasets.

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