

# STUDY ANALYSIS ON TEETH SEGMENTATION USING LEVEL SET METHOD

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## **ABSTRACT**

*The three dimensional shape information of teeth from cone beam computed tomography images provides important assistance for dentist performing implant treatment, orthodontic surgery. This paper describes the tooth root of both anterior and posterior teeth from CBCT images of head. The segmentation is done using level set method with five energy functions. The edge energy used to move the curve towards border of the object. The shape prior energy provides the shape of the contour. The dentine wall energy provides interaction between the neighboring teeth and prevent shrinkage and leakage problem. The test result for both segmentation and 3D reconstruction shows that the method can visualize both anterior and posterior teeth with high accuracy and efficiency.*

## **KEYWORD**

*Level set, cone beam computed tomography, tooth segmentation*

## **1. Introduction**

### **1.1 Related work**

Dental x-rays provide two dimensional shapes of the teeth. The two dimensional view of tooth root do not provide an accurate shape. In dental treatment, the accurate shape of teeth and root plays an important role. Hence, three dimensional views of teeth used to represent an accurate spatial orientation of tooth roots which is used for dental treatment such as orthodontic treatment. The crown and root information must be clear which avoids treatment simulation. Thus we use tomography scan image. In orthodontic treatment, dentists will gradually move teeth from original position to target position. The Multi Slice Computed Tomography (MSCT) is used to obtain 3D images with high amount of ionizing radiation which may leads to cancer. Nowadays, the dentists using Cone Beam Computed Tomography (CBCT) image for treatment due to lower radiation.

There are various segmentation algorithms to extract root from the teeth. In adaptive threshold method [5] under segmentation or over segmentation problem occur due to non homogeneous intensity distribution inside teeth. Edge based segmentation methods [11] fails to segment the tooth boundary. The region based segmentation [2] fails to separate the object when region inside the region of interest has similar intensity value. The intensity distributions and edge information are combined in hybrid segmentation method [8] so tooth boundary can be easily segmented. It

fails to avoid shrinking and leakage problem. The extraction of root of the teeth is designed by distance regularized level set evolution (DRLSE) [7]. This method is applied for orthodontic treatment but it fails to segment the small portion of the root [1].

The level set method [3] with five energy function is applied to segment the anterior teeth. In our proposed system we applied these energy functions for both anterior teeth and posterior teeth.

## 2. ENERGY BASED APPROACH

The adjacent teeth segmentation problem can be avoided by external edge energy which gives the desired edge of the teeth. The tooth root is segment into tooth pulp and tooth dentine. The energy based approach computationally derives to segment the object. Figure 1 show the methodology to segment the teeth.

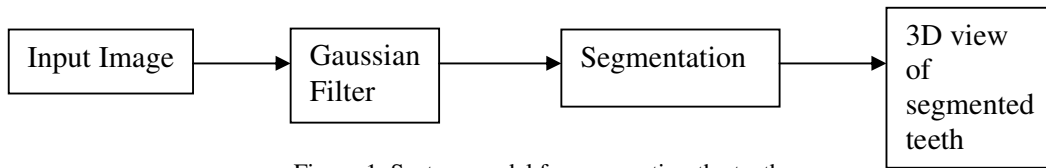


Figure 1. System model for segmenting the teeth

### 2.1 GAUSSIAN FILTER

Images are often corrupted by variation in intensity and illumination value which can not be directly applied so we apply some filter to image. Gaussian smoothing operator is used to blur images and remove detail and noise. Gaussian filter is a non-uniform low pass filter works by using 2D distribution as a point spread function. Gaussian filter is more effective at smoothing image. It has its basis in human visual perception system. Gaussian kernel coefficient are sampled from 2D Gaussian function,

$$G(x, y) = \frac{1}{2\pi\sigma^2} e^{-x^2 + y^2 / 2\sigma^2} \quad (2.1)$$

In one dimension, Gaussian function is

$$G(x, y) = \frac{1}{\sqrt{2\pi}\sigma} e^{-x^2 / 2\sigma^2} \quad (2.2)$$

Where  $\sigma$  is standard deviation of distribution.

### 2.2 LEVEL SET SEGMENTATION

Level set segmentation is a generic numerical method for evolving fronts in an implicit form. The central idea is to represent the evolving contour using a signed distance function. The distance function is negative inside the curve and positive outside. By choosing a suitable speed function  $F$ , we may segment an object in an image. The standard level set segmentation speed function is:

$$F = 1 - \epsilon\kappa + \beta(\nabla \cdot \nabla |V|) \quad (2.3)$$

Where 1 causes contour to inflate inside the object.

- $\epsilon\kappa$  (viscosity) term reduces the curvature of the contour.  
edge attraction term pulls the contour to the edges.

It can be used to efficiently address the problem of curves propagation in an implicit manner. It handles topological changes of the evolving interface. The re-initialization method of level set function fails to assign the original place of contour [6]. According to Dong Xu Ji and Sim Heng Ong [3] the level set function  $\phi$  can develop shocks, very sharp and flat shape during the evolution, which makes inaccurate computation. To avoid these problems, a common numerical scheme is to assign signed distance function before the evolution and then reshape the function  $\phi$  periodically during the evolution. Thus the level set is applied with five energy term as shown in Eq. (2.4)

$$J_R(C) = \lambda_1 J_1(C) + \lambda_2 J_2(C) + \lambda_3 J_3(C) + \lambda_4 J_4(C) + \lambda_5 J_5(C) \quad (2.4)$$

Where,

$J_R(C)$  – total energy term to segment the tooth root.  
 $J_1(C)$  – penalizing energy term.  
 $J_2(C)$  – the region energy term.  
 $J_3(C)$  – edge energy term.  
 $J_4(C)$  – shape prior energy term.  
 $J_5(C)$  – the dentine wall thickness energy term.  
 $\lambda_i$  – weight for the  $i^{\text{th}}$  energy term.

According to the energy function the above equation can be rewritten as

$$J(\phi) = \lambda_1 J_1(\phi) + \lambda_2 J_2(\phi) + \lambda_3 J_3(\phi) + \lambda_4 J_4(\phi) + \lambda_5 J_5(\phi) \quad (2.5)$$

### 2.2.1. PENALIZING ENERGY:

$$J_1(\phi) = \int \frac{1}{2} (|\nabla \phi| - 1)^2 dx dy \quad (2.6)$$

Where  $\nabla$  is the gradient operator. During evolution, the deviation of  $\phi$  is penalized from signed distance function. This avoids time consuming re-initialization step of level set method.

### 2.2.2 REGION ENERGY:

The segmentation is to segment the region into two regions, the object region  $\Omega_1$  and the background region  $\Omega_2$ . This can be done using the region based model using the intensity distributions difference. The contour is derived by maximizing the likelihood function:

$$J_0(C) = p(u|C, M_1, M_2) \quad (2.7)$$

Where  $p(u|C, M_1, M_2)$  is the joint probability density function for intensities  $u$  given the contour  $C$  and the two models. The intensity distribution within each region and the contour  $C$  is the zero level of the SDF  $\phi$  is shown in Eq. (2.8).

$$J_2(\phi) = \int -\ln(p_1(u(x,y)|\Omega_1)H(-\phi)) dx dy + \int -\ln(p_2(u(x,y)|\Omega_2)(1-H(-\phi))) dx dy \quad (2.8)$$

### 2.2.3 EDGE ENERGY:

The edge based term pulls the contour  $C$  to the edges of the image. This is evaluated by minimizing the following functional:

$$J_3(\varphi) = \int_C g ds \quad (2.9)$$

Where  $ds$  represent the Euclidean arc length of  $C$ ,  $\varphi$  is the SDF of  $C$ .

$$J_3(\varphi) = \int_{\Omega} g \delta(\varphi) |\nabla \varphi| dx dy \quad (2.10)$$

Where  $g$  is the positive and decreasing function serving as an edge detector and  $\delta$  is the smoothed dirac function given by,

$$\delta_{\epsilon}(z) = 1/2\epsilon [1 + \cos(\Pi z/\epsilon)], \text{ if } |z| \leq \epsilon \quad (2.11)$$

### 2.2.4 SHAPE PRIOR ENERGY:

The shape prior term is used to evolve the contour  $C$  to the final segmentation contour  $C_0$  in Eq. (2.12). The point model is used to derive the boundaries of the shape [10]. The equal weights are given to all pixels in shape prior [4].

$$J_4(C) = \int_C \varphi_0^2(x,y) ds \quad (2.12)$$

Where  $\varphi_0$  is the SDF of the segmented tooth region of previous slice,  $\varphi$  is the SDF of  $C$ .

$$J_4(\varphi) = \int_{\Omega} \varphi_0^2(x,y) \delta(\varphi) |\nabla \varphi| ds \quad (2.13)$$

### 2.2.5 DENTINE WALL THICKNESS ENERGY:

The dentine is the area between the enamel and the tooth. The tooth pulp is used to refine the contour by penalizing the tooth dentine thickness where the dentine wall is thin. Define  $D((x,y), C_p)$  as the distance between a point and the curve  $C_p$ , and  $D(C, C_p)$  as the collection of all such distance of points on  $C$ .  $D_{avg}$  denotes the average value of  $D_{thin}(x,y)$ .

$$\varphi_t(x,y) = \varphi_p(x,y) - D_{avg} \quad (2.14)$$

Where  $\varphi_p(x,y)$  is the SDF of the contour of the tooth pulp  $C_p$ ,  $\varphi_t(x,y)$  is the SDF of the shape which is an enlarged version of the tooth pulp.

$$J_5(\varphi) = \int_{\Omega} \varphi_t(H(\varphi_t) - H(\varphi)) dx dy \quad (2.15)$$

### 2.2.6 OVERALL ENERGY FUNCTIONAL:

Summing up five energy function is shown in Eq. (2.16).

$$\begin{aligned} J(\varphi) = & \lambda_1 \int_{\Omega} \frac{1}{2} (|\nabla \varphi| - 1)^2 dx dy + \\ & \lambda_2 \left( \int_{\Omega} -\ln(p_1) H(-\varphi) dx dy + \int_{\Omega} -\ln(p_2) (1 - H(-\varphi)) dx dy \right) \\ & + \lambda_3 \int_{\Omega} g \delta(\varphi) |\nabla \varphi| dx dy \\ & + \lambda_4 \int_{\Omega} \varphi_0^2 \delta(\varphi) |\nabla \varphi| dx dy \\ & + \lambda_5 \int_{\Omega} \varphi_t (H(\varphi_t) - H(\varphi)) dx dy. \end{aligned} \quad (2.16)$$

This energy function leads to 1000 iteration to segment the object in the image. In evolution of this iteration the contour will shrink to reach the boundary of the teeth. The iteration value is based on the value of shape prior term.

### 2.3 3D RECONSTRUCTION

3D reconstruction is the process of capturing the shape and appearance of tooth from various slices. The dentistry requires accurate 3D representation of the teeth and jaw for diagnostic and treatment purposes. It is based on the shading of the image, 3D points and smoothness of the image. The accuracy of teeth is increased using shape from shading with 2D PCA shape priors. The accurate segmentation of the root of a buried tooth such as buried upper canine and the neighboring teeth structures provides orthodontics a clear 3D anatomic map for simulating trajectories and pathways for moving the buried canine into the dental arch. The segmented individual teeth of every slice of CBCT scan image is combined together to form a 3D complete view of teeth.

## 3. EXPERIMENTS AND RESULTS

We have applied this procedure for 12 patients CBCT scan image. CBCT scanner rotates around patient's head obtaining up to nearly 600 distinct slice images. The Gaussian filter is applied first to remove noise as shown in Figure 2. We choose Gaussian filter of size 15 x 15 and standard deviation 1.5 to suppress noise.

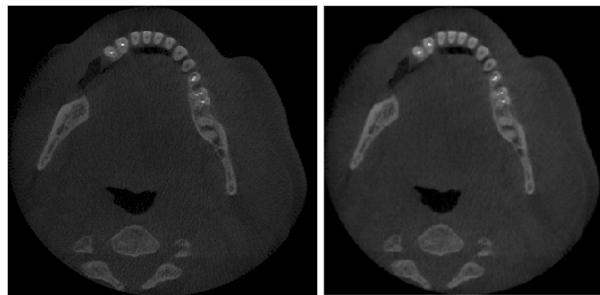
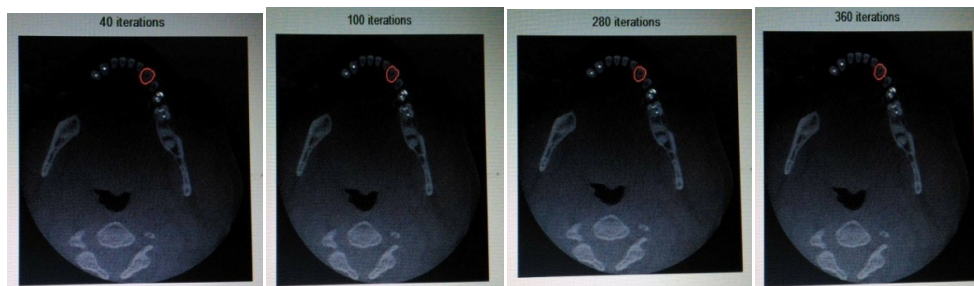


Figure 2: Original CBCT scan image and smoothing image

The level set method is applied to each slicing image and the result is saved in database. The contour is drawn using volume along with surface of image [12]. The data aspect ratio determines the relative scaling units. First we segment the crown and then root.



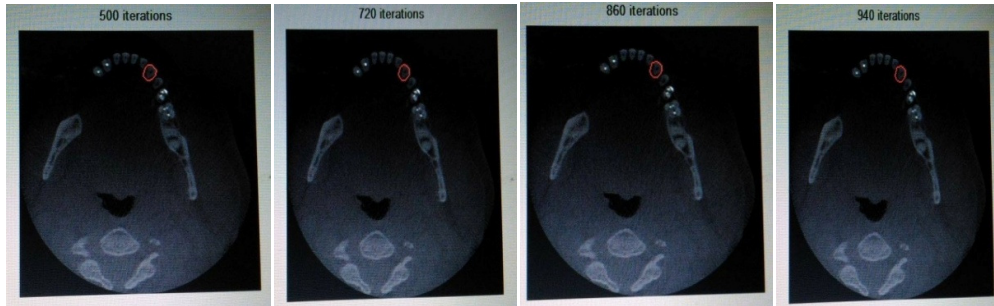


Figure 3. Red line displays the segmentation results for single slice.

The coupled level set method is used to segment the crown and tooth dentine contour is used to segment the root. The segmentation is applied from initial slice to root tip for individual teeth as shown in Figure 3. This segmentation result is more accurate and efficient. The 3D reconstruction is done using matlab. Collection of segmented results in three dimensional axial views used to display the teeth. We applied this segmentation technique for posterior teeth which have multiple roots. The average time consume per teeth is 228 s.



Figure 4. 3D view of premolar teeth

#### 4. CONCLUSION

This study presents a level set algorithm to detect the contour of the anterior and posterior teeth. In this method the topology tooth changes when root splits. The average time consume is less in this method than the Dong Xu Ji method. The accuracy of segmentation depends on image quality. The tooth dentine wall avoids leakage problem. The shape and intensity value avoids shrinking problem. The adjacent teeth are segmented carefully. The root profile value may be varying for each individual tooth. Thus this can be improved by the gray value distribution around the root. Using this method we try to segment the whole tooth set of the patient by which dentist can improve treatment process. This method provides more accurate and robust segmentation results for both anterior and posterior teeth of the patients. In future automatic segmentation technique is created to detect the tooth, thus the dentistry can easily diagnosis the treatment in timely manner.

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