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Teeth Segmentation Analys is 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*

I. Introduction

1.1 Relatedwork

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 spatialorientation oftoothrootswhichisusedfordentaltreatmentsuchasorthodontictreatment. 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 toothboundary. The region based segmentation[2] fails to separate the object when region inside theregion of interesthas similar intensity value.The intensity distributions and edge information are combined in hybrid segmentation method[8] so tooth boundary canbe 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 setmethod[3]withfiveenergyfunctionisappliedtosegmenttheanteriorteeth.Inour proposed system we applied these energy functions for both an teriorteeth and posterior teeth.

II. Energy Basedapproach

Theadjacentteethsegmentationproblemcanbeavoidedbyexternaledgeenergywhichgivesthedesirededgeoftheteeth.Thetoothrootissegmentintotoothpulpandtoothdentine.Theenergybasedapproachcomputationallyderives tosegmenttheobject.Figure1showthemethodologyto segment theteeth.

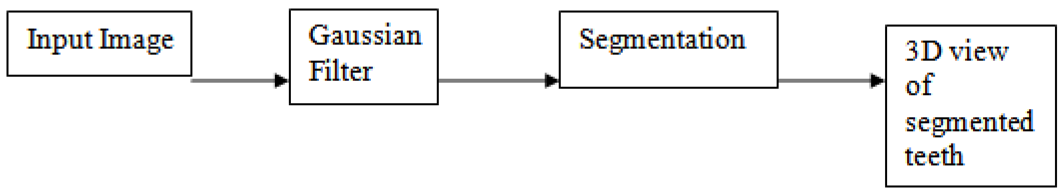

Figure 1. System model for segmenting the teeth

1.2 GAUSSIANFILTER

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 basisinhumanvisualperceptionsystem.Gaussiankernelcoefficientaresampled from 2D Gaussianfunction,

G(x, y) =1 e^ x^2+y^2/ (2.1)

2Ma²
2a²

In one dimension, Gaussian function is

G(x,y)= 1
√2Ma²
e x²/2a²
(2.2)

Where σ is standard deviation of distribution.

1.3 LEVEL SETSEGMENTATION

Levelsetsegmentationisagenericnumericalmethodforevolvingfrontsinanimplicitform.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,wemay segment an objectinan image.Thestandardlevelsetsegmentationspeedfunctionis:

F=1–cκ+β(❑❑❑|) (2.3)

Where 1 causes contour to inflate inside the object.

-cκ (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 XuJi and SimHengOng [3] the level set function φ can develop shocks, very sharp and flat shape during the evolution, which makes inaccurate computation. To avoid these problems, a common numerical schemeisto assignsigned distance functionbeforetheevolutionandthenreshapethefunctionφ periodically during the evolution. Thus the level set is applied with five energy term as shown in Eq. (2.4)

$J_R(C)=\lambda_1 J_1(C)+\lambda_2 J_2(C)+\lambda_3 J_3(C)+\lambda_4 J_4(C)+\lambda_5 J_5(C)$ (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.
λ_i – weight for the i^{th} energy term.

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

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

1.3.1. PENALIZING ENERGY:

$J_1(\varphi)=f$ ½(|❑ |−1)^{2}dxdy (2.6)

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

2.2.2 REGIONENERGY:

The segmentation is to segment the region into two regions, the object region fi1 and the background region fi2. This can be done using the region based model using the intensity distributions difference. The contour is derived by maximizing the likelihood function:

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

Wherep$(u|C,M_1,M_2)$isthejointprobabilitydensityfunctionforintensitiesugiventhecontourC and the two models. The intensity distribution within each region and the contour C is the zero level of the SDF φ is shown in Eq.(2.8).

$J_2(\varphi)=f\text{-}\ln(p_1(u(x,y)|fi_1)H(-\varphi)dxdy+f\text{-}\ln(p_2(u(x,y)|fi_2)(1-H(-\varphi))dxdy$ (2.8)

2.2.3 EDGEENERGY:

TheedgebasedtermpullsthecontourCtotheedgesoftheimage.Thisisevaluatedby minimizing the following functional:

$J_3(\varphi)=f_C g ds$ (2.9)

Where ds represent the Euclidean arc length of C, φ is the SDF of C.
$J_3(\varphi)=f_{fi} g\delta(\varphi)|❑\varphi|dxdy$ (2.10)
Where g is the positive and decreasing function serving as an edge detector and δ is the smoothed dirac function given by,

$\delta_c(z)=1/2c[1+\cos(\Pi z/c)],\text{if}|z|<=c$ (2.11)

2.2.4 SHAPE PRIORENERGY:

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].

$J_4(C)=f_C\varphi_0{}^2(x,y)ds$ (2.12)
Where φ_0 is the SDF of the segmented tooth region of previous slice, φ is the SDF of C. $J_4(\varphi)=f_{fi}\varphi_0{}^2(x,y)\delta(\varphi)|❑\varphi|ds$ (2.13)

2.2.5 DENTINE WALL THICKNESSENERGY:

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 $D_{thin}(x,y)$.

$\varphi_t(x,y) = \varphi_p(x,y)–D_{avg}$ (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.

$J_5(\varphi)=f_{fi}\varphi_t(H(\varphi_t)–H(\varphi))dxdy$ (2.15)

2.2.6 OVERALL ENERGYFUNCTIONAL:

Summing up five energy function is shown in Eq. (2.16). $J(\varphi)= \lambda_1\ f_{fi}½\ (|❑\varphi|-1)^2\ dx\ dy\ +$
$\lambda_2\ (f_{fi}\ -\ \ln\ (p_1)\ H(-\varphi)\ dx\ dy + f_{fi}\ -\ \ln\ (p_2)\ (1-H(-\ \varphi))\ dx\ dy)$
$+ \lambda_3 f_{fi} g\delta(\varphi)\ |❑\varphi|\ dx\ dy$
$+ \lambda_4 f_{fi}\ \varphi_0{}^2\delta(\varphi)|❑\varphi|\ dx\ dy$
$+\lambda_5 f_{fi}\varphi_t(H(\varphi_t)–H(\varphi))dxdy.$ (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.

1.4 3DRECONSTRUCTION

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.

III. Experiments Andresults

We have applied this procedure for 12 patients CBCT scan image. CBCT scanner rotates around patient'sheadobtaininguptonearly600distinctsliceimages.TheGaussianfilterisappliedfirst to remove noise as shown in Figure 2. We choose Gaussian filter of size 15 x 15 and standard deviation 1.5 to suppressnoise.

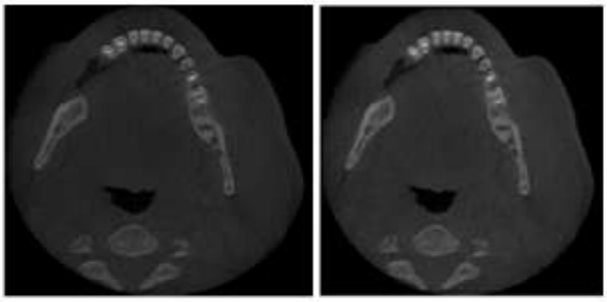

Figure 2: Original CBCT scan image and smoothing image

The level set method is applied to each slicing image and the result is saved in database. The contourisdrawnusingvolumealongwithsurfaceofimage[12].Thedataaspectratiodetermines the relative scaling units. First we segment the crown and thenroot.

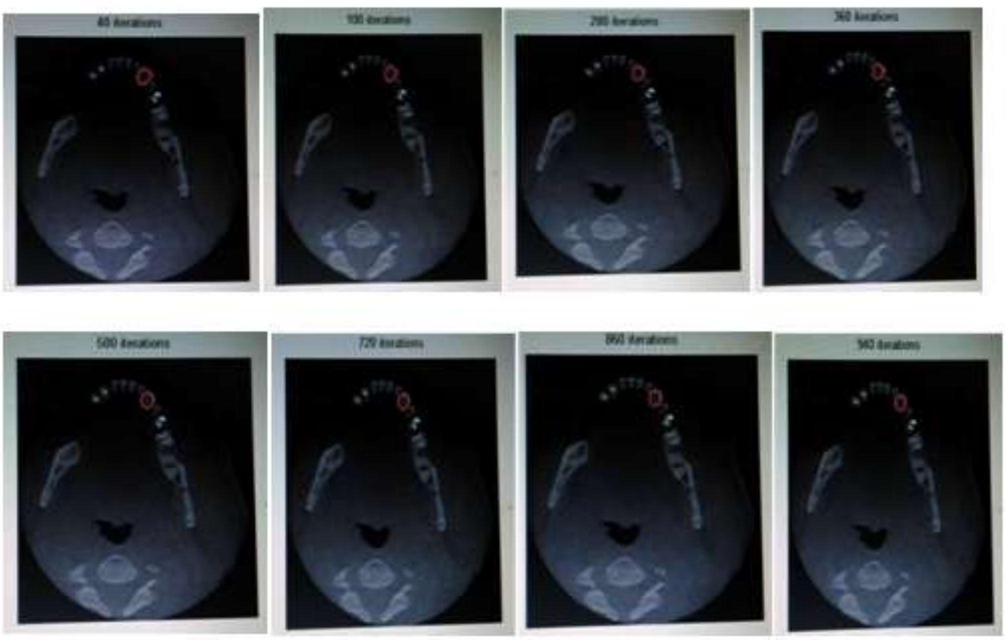

Figure 3. Red line displays the segmentation results for single slice.

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 showninFigure3.Thissegmentationresultismoreaccurateandefficient.The3Dreconstruction is done using matlab. Collection of segmented results in three dimensional axial views used to displaytheteeth. Weapplied this segmentation technique for posteriorteeth which havemultiple roots. The average time consume per teeth is 228s.

Figure 4. 3D view of premolar teeth

IV. 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 XuJi 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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