Segmentation of Lung Tumor in Cone Beam CT Images Based on Level-Sets

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Abstract
Automatic segmentation of tumor in low dose scans like the Cone Beam Computed Tomography (CBCT) is quite challenging. We use a semi-automatic approach to segment tumor from non tumor using the classical level-set formulation.
• A pipeline of techniques, mainly involving gradient-based level-sets (GB) and Local Rank Transform (LRT) is used to achieve the tumor segmentation.
• To improve the edge strength in the CBCT image at tumor and non-tumor interface, we propose to use the edges obtained from the LRT-attractor of the image.
• The gradient-based level-sets with LRT-attractor (GBLA) is a non-linear technique that helps in strengthening the latent tumor and non-tumor boundary.
We compare the GBLA level-sets with the GB level-sets technique, and report our results on 307 volumes of 45 patients. It was found that average precision is improved by 10% when using GBLA.

Introduction
• CBCT images are prone to noise, the edge strength at the tumor and non-tumor boundary is very low.
• Supervised and automatic segmentation or classification techniques perform poorly in noisy conditions.

Main Objectives
• To segment the Gross Tumor Volume (GTV) from CBCT images of lung cancer patients.

Methodology

• A curve (C) represented by level-set (φ) satisfies:
  \[ \phi = 0, \text{ at the curve} \]
  \[ \phi > 0, \text{ interior of the curve} \]
  \[ \phi < 0, \text{ exterior of the curve} \]
  \[ C = \{ (x,y) \mid \phi(x,y) = 0 \} \]
• The normal \[ \vec{N} = \frac{\nabla \phi}{\|\nabla \phi\|} \]
• Curvature of a level-set : \[ k = div(\frac{\vec{N}}{\|\vec{N}\|}) \]

Curve Evolution using Level-sets
Curve evolution is in the direction of the normal at a curve. An example flow:
\[ C_t = e^\varepsilon N_t \]
\[ \frac{d\phi}{dt} = \phi N \cdot \nabla C_t = e^\varepsilon N \cdot \nabla \phi \]
• Other flows: \[ C_t = e^\varepsilon N ; k \text{ is curvature} \]

Level-sets Segmentation

• Curve evolution based on image properties
• Gradient stepping function
• Gradient stepping function is given as:

\[ \frac{d\phi}{dt} = \frac{1}{1 + \varepsilon^2 (C_{ext} + I)} \]

(1)

• The evolving level-set(φ) [3] is given as:

\[ \frac{d\phi}{dt} = [\nabla \phi \cdot (g_k + \nabla \phi, \vec{N})] + \nabla \frac{div\left(\begin{array}{c} g_k \\ g \end{array}\right)}{N} \nabla \phi \]

(2)

Local Rank Transform (LRT)

• Rank of an element x in a sequence S is the number of elements less than x.
• LRT [2] of a sequence (\(2, 1, 4, 2, 3, 2, 0\)) is (0, 1, 0, 2, 0, 1, 0, 0).
• LRT of a sequence is the number of elements less than by at least \(\delta\) amount.
• LRT at (2, 1, 4, 2, 3, 2, 0) with \(\delta = 1\) is (0, 0, 0, 0, 0, 0, 0).

Dilation
Non-Tumor
Non-Tumor
I
Segmented output
LRT Attractor
Multiply
Gradient Stopping Function, g
Dilation
Level-Sets
Segmentation
Select seed
point
Initialize
sphere
I
Segmented output

Figure 1: Block diagram of the GBLA Level-Sets segmentation of CBCT images.

Figure 3: Gradient Stopping Function in the typical Gradient Based Level-Sets.

Figure 4: Gradient Stopping Function in the typical Gradient Based Level-Sets Attractor Level-Sets.

Figure 5: Profile of the grey level values of the gradient of a typical sequence.

Figure 6: Gradient Stopping Function in the typical Gradient Based Level-Sets Attractor Level-Sets.

Figure 7: Segmentation result of GB level-sets. Red region is the false positive and the yellow region is false negative. Green region is the true positive.

Figure 8: Segmentation result of GBLA level-sets. Red is the false positive and the yellow region in false negative. Region in the false positive and the yellow region is false negative. Green region is the true positive.

Conclusions
• There is a 10% significant increase in the mean precision. The mean recall value decreases when compared to the method without using the LRT-attractor.

Forthcoming Research
A comprehensive analysis of segmentation results with varying seed points.

References

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