PET TUMOR SEGMENTATION: COMPARISON OF GRADIENT-BASED ALGORITHM TO CONSTANT THRESHOLD ALGORITHM

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Introduction

Accurate tumor segmentation is very important in patient diagnosis and management. Commonly used methods, such as constant threshold methods, suffer from an inability to accurately define small tumors, tumors with low source-to-background ratio (SBR), and tumors with varying levels of perfusion and metabolism. A gradient-based algorithm was developed to overcome these limitations and allow for more accurate tumor segmentation.

Constant threshold algorithms typically delineate a structure by including all voxels within a user defined region that have counts that are greater than a fixed percentage of the maximum count level in that region.

Gradient based algorithms delineate a structure by detecting the change in image counts at the border.

Purpose

To compare the consistency and accuracy of a gradient-based algorithm with a constant threshold algorithm, for delineating positron emission tomography (PET) spheres of varying size and source-to-background ratio (SBR).

Method and Materials

PET scans were acquired for cylindrical phantoms with fillable spheres on five different scanners including GE, Phillips and Siemens, emulating clinical conditions of activity levels, acquisition and reconstruction at that institution. Image reconstruction methods included OSEM, RAMLA 3D and FBP. Phantom studies were also acquired with different contrast levels on a single camera to illustrate the influence of SBR with the SBR ranging from 2:1 to 70:1. The spheres were detected in the scans using the gradient algorithm and 37% constant threshold algorithm [1]. The radii calculated from each detected sphere volume for both methods were compared to the known actual radius of the sphere in order to quantify the accuracy of each algorithm. The sphere radii were 5mm, 6.5mm, 8.5mm, 11mm, 14mm and 18.5mm.

Results

The gradient-based algorithm performed consistently for different scanners, varying SBR and sphere size. The constant threshold algorithm accuracy deteriorated with decreases in both SBR and phantom size. For the gradient-based algorithm, the mean of absolute radius percentage differences for the spheres with less than 10mm radius was 8.16% and the standard deviation was 0.1, whereas for the constant threshold algorithm, the mean of the absolute percentage differences for the same phantoms was 55.98% and the standard deviation was 0.46. The statistics for the spheres with greater than 10mm radius were 3.84% and 0.03 for gradient method, 8.45% and 0.05 for constant threshold. Similar trends in percentage difference appeared for the same scanner and phantom set when the SBR decreased from 70:1 to 2:1. The gradient-based algorithm was robust to user initialization and resulted in less than 5% difference over several measurements for the same sphere.

Figure 1
Different Cameras, Similar Source to Background Ratio

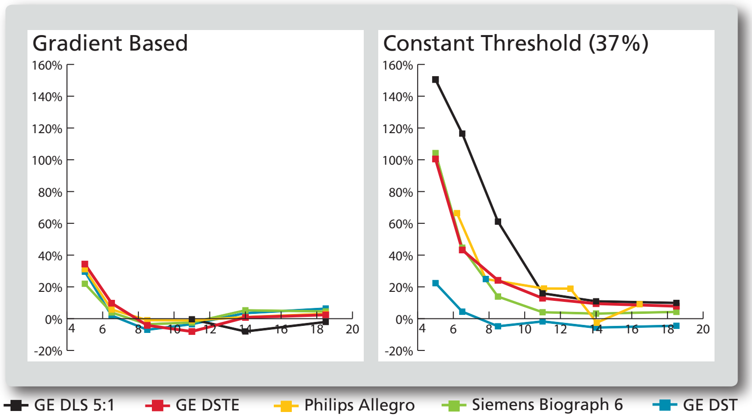


Figure 2
Same Camera, Varied Source to Background Ratios

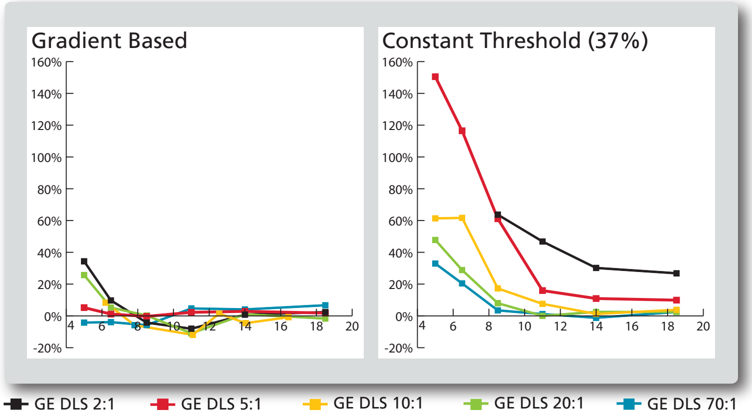
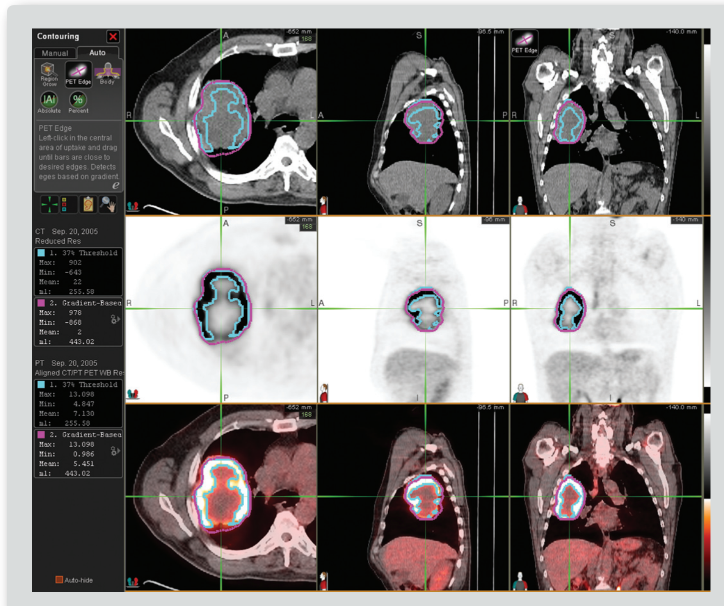


Figure 3
Patient with Large Apical Lung Tumor



Patient studies are ongoing demonstrating the accuracy of the gradient-based algorithm in the clinical setting as well. The above example illustrates the ability of the gradient-based edge detection method to accurately define the tumor while the constant threshold method failed due to the varying levels of metabolism within the tumor. The magenta outline is the tumor boundary defined by the gradient-based algorithm and the blue outline represents the boundary as determined by the constant threshold method. Note how the gradient-based boundary closely follows the tumor boundary as seen on the CT scan.

Conclusions

The gradient-based algorithm is more robust, which leads to consistent results for different scanners and better accuracy than the constant threshold algorithm when evaluated in terms of varying SBR and phantom size for the in-vitro phantom studies. It is anticipated that the gradient threshold method will also have improved accuracy when activity levels vary in the structure of interest (see figure 3).

References

[1] Erdi Y, Mawlawi O, Larson S, et al. "Segmentation of Lung Lesion Volume by Adaptive Positron Emission Tomography Image Thresholding." Cancer, vol. 80, pp.2505-9, 1997.

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