Robust Tumor Segmentation for Radiotherapy Target Definition

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Accurate tumor delineation is important for radiotherapy treatment planning since underdosing a tumor may lead to recurrence while over-dosing of the surrounding tissue could lead to normal tissue complications. It is also beneficial for treatment assessment since it will lead to more reliable quantitative analysis. It has been shown that the inclusion of positron emission tomography (PET) in the planning process further improves tumor delineation. However, PET images are affected by uncertainties introduced in the reconstruction process. The goal of this research work is to introduce a novel PET-based auto-segmentation algorithm that is robust under variation of the reconstruction parameters.

A new parameter free auto-segmentation method (Gradient Assisted Non-connected Automatic Region (GANAR)) was developed, validated, and evaluated under different PET acquisition modes and reconstruction parameters. The GANAR method consists of three stages. Stage 1: generation of five highly discriminant texture feature images to enhance distinct properties of the tumor. Stage 2: a parameter free non-connected region-growing (NCRG) algorithm is applied to the original PET and texture feature images. The ROIs obtained from NCRG are assessed using two independent cost functions, (1) based on the total variance between the foreground and background and (2) based on sharp transitions between the foreground and background. This process leads to twelve ROIs. Stage 3: final segmented region is obtained using the previous twelve regions as an input for an expectation-maximization algorithm. GANAR was compared against threshold-based, gradient-based and region-growing methods. The accuracy of the GANAR method was assessed using thirteen inhomogeneous and irregular-shaped lesions from a Monte Carlo phantom as well as clinical data. The robustness of the GANAR method was assessed with FDG PET images of twenty patients acquired in both 2D/3D modes, and reconstructed with varying parameters. Segmentation accuracy and robustness were quantified using Dice, sensitivity, positive predictive value and Modified Hausdorff Distance.

Using Dice, GANAR (0.89 ± 0.04) was more accurate than the threshold (0.83 ± 0.07), gradient (0.75 ± 0.07), and region-growing (0.80 ± 0.08) methods. Likewise, using MHD GANAR (0.2 ± 0.1 cm) was more accurate than the threshold (0.4 ± 0.2 cm), gradient (0.5 ± 0.1 cm), and region-growing (0.4 ± 0.2 cm) methods. GANAR was more robust, with Dice coefficient range of [0.85-0.98], than the threshold, gradient and region-growing methods with Dice coefficient ranges of [0.69-0.93], [0.66-0.98], and [0.46-0.91], respectively. Similarly, the MHD range of [0.02-0.18]cm was smaller for GANAR, than the range of [0.08-0.23]cm for threshold, [0.01-0.26]cm for gradient-based, and [0.13-0.70]cm for region-growing methods. In both accuracy and robustness, the new method outperformed the other segmentation methods.