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AUTOMATIC CONTOURING ANALYSIS OF LUNG CANCER FOR RADIOTHERAPY RADIATION PLANNING FROM CT-SIMULATOR IMAGE

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Abstract

Accurate determination of tumor and radiotherapy target volume is crucial to prevent local and regional failure in lung cancer. Radiotherapy planning considers critical normal tissue structures or Organs at Risk (OAR). While manual contouring is the gold standard in radiotherapy planning, it is still susceptible to intra- and inter-observer variation. A digital image processing system capable of automatically and semi-automatically determining tumor targets and OARs through computer programming can assist in the contouring process. The study aims to create a digital contouring computer program to aid in planning radiotherapy irradiation for lung cancer cases, guided by CT-Simulator image guidance. The research involved contouring CT-Simulator images of lung cancer cases using automatic segmentation, semi-automatic segmentation, and a combination of automatic, semi-automatic, and manual segmentation. Contour accuracy was assessed by a radiation oncologist. Automatic segmentation showed high accuracy for lungs (>95%), moderate for tumor targets (72.22%) and the heart (73.33%), but low accuracy for the esophagus (34.44%) and spinal cord (36.67%). Semi-automatic segmentation achieved high accuracy for the esophagus (96.67%) and spinal cord (95.56%), and moderate accuracy for tumor targets (73.33%), heart (66.67%), right lung (66.25%), and left lung (72.94%). The combination of automatic, semi-automatic, and manual segmentation resulted in high accuracy for tumor targeting and OARs (>95%). Automatic or semi-automatic segmentation using location and gray level classification methods for lung cancer cases did not produce optimal results. However, a contouring program combining automatic, semi-automatic, and manual segmentation proved more effective, balancing human interaction and automation in the lung cancer contouring process. This digital contouring program offers valuable support for radiation oncologists, potentially leading to improved treatment outcomes for lung cancer patients.

Keywords: automatic contouring; lung cancer; radiotherapy

INTRODUCTION

Radiotherapy is considered one of the most effective cancer treatment methods. It involves the utilization of ionizing radiation, which is high-energy radiation capable of displacing electrons from atoms and molecules. The primary goal of radiotherapy is to destroy cancer cells and inhibit their growth (Aselmaa et al., 2017; Marcus, 2020; Sebaaly et al., 2019). CT-Scan is essential in radiation planning or radiotherapy treatment planning, as it offers high geometric accuracy in locating tumors and surrounding tissues and organs at risk, enabling precise identification. Additionally, CT-Scan provides electron density information maps for various tissues, which are used for dose calculation in the treatment planning system (TPS) (Davis et al., 2017). Local irradiation, such as radiotherapy, relies heavily on the accuracy of the imaging procedure to precisely identify the target tissue. This accuracy serves as the foundation for successful irradiation while minimizing potential complications (Sterzing et al., 2011).

Until recently, contour segmentation was predominantly a manual task performed by radiation oncologists, and radiation technology was considered the gold standard (Kerenhapukh, 2022; Sudarsa, 2019). However, contouring can be time-consuming, and published data demonstrate a high level of inter-observer variability (Cacicedo et al., 2019; Silva et al., 2018). Automated or semi-automated contouring tools are increasingly being employed in tumor delineation for radiotherapy. While fully automatic contouring tools have not yet achieved optimal efficiency, semi-automatic contouring tools prove to be more effective as they strike a balance between human interaction and automation (Aselmaa et al., 2017).

RESEARCH METHODS

The patient data used in this study were CT-Simulator lung images from lung cancer patients in DICOM format. Target volume and risk organ volume (OAR) must be precisely contoured to produce an accurate treatment plan (Nelms et al., 2012). The OARs included are the heart, esophagus, spinal cord, left lung, and right lung (Men et al., 2020).

This research is an experimental study which was tested qualitatively (Lee et al., 2013). The research sample (lung CT-Simulator images from lung cancer patients) applied three types of segmentation (automatic segmentation, semi-automatic segmentation and a combination of automatic, semi-automatic, and manual segmentation). The three types of segmentation were compared for their accuracy values rated by radiation oncologists. Radiation oncologists rated of accuracy on a predetermined scale. After assessing the accuracy of contouring, the data is then processed with SPSS (Santoso, 2017).

The contouring accuracy data for the three types of segmentation are averaged. In addition, the data was calculated using a non-parametric test. Kruskal-Wallis test followed by Tamhane's post hoc analysis.

RESULTS AND DISCUSSION

In this study, the experiment was conducted using MATLAB software to process the image. Contouring was performed using three types of segmentation: automatic segmentation, semi-automatic segmentation, and a combination of automatic, semi-automatic, and manual segmentation (Hidayati et al., 2017). The automatic segmentation utilized the K-Nearest Neighbor method and thresholding, while the semi-automatic segmentation employed the active contour method and the manual method of Region of Interest (ROI) for manual segmentation. The study results are depicted in Figure 1.

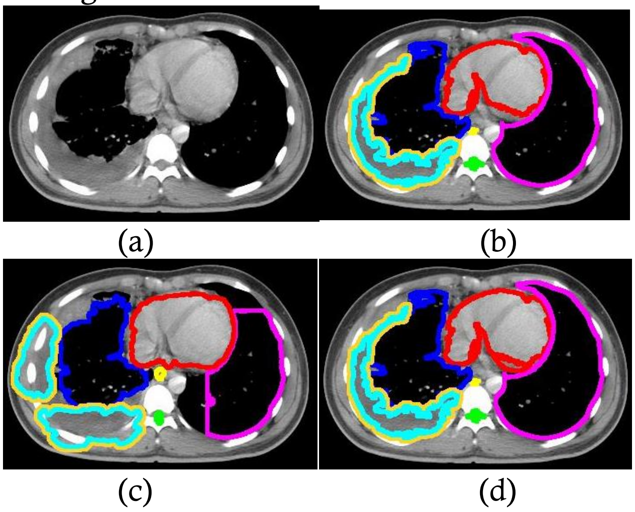

Figure 1. Original image (a), automatic segmentation (b), semi-automatic segmentation (c), combination of automatic, semi-automatic and manual segmentation (d).

The contouring results obtained from the segmented image are subsequently assessed for accuracy by radiation oncologists concerning the tumor target and OAR, as shown in Table 1. The results of the Kruskal-Wallis test are presented in Table 2, and the outcomes of Tamhane's post hoc test can be observed in Table 3.

Table1. Average Contouring Accuracy Score

	Otomatis	Semi-Otomatis	Combination
Tumor Target	72,22	73,33	97,78
Heart	73,33	66,67	93,33
Esophagus	34,44	96,67	97,78
Spinal Cord	36,67	95,56	97,78
Right Lung	97,5	66,25	98,75
Left Lung	98,82	72,94	98,82

Table 2. Kruskal-Wallis Test Results

Variable		*p-value*
Tumor Target	Otomatis	0,000
	Semi-Otomatis	
	Combination	
Heart	Otomatis	0,225
	Semi-Otomatis	
	Combination	
Esophagus	Otomatis	0,000
	Semi-Otomatis	
	Combination	
Spinal Cord	Otomatis	0,000
	Semi-Otomatis	
	Combination	

Variable		p-value
Right Lung	Otomatis	0,000
	Semi-Otomatis	
	Combination	
Left Lung	Otomatis	0,000
	Semi-Otomatis	
	Combination	

Table 3. Mann-Whitney Test Results

Variable		*p-value*
Otomatis and Semi-Otomatis	Tumor Target	0,673
	Heart	0,700
	Esophagus	0,000
	Spinal Cord	0,000
	Right Lung	0,000
	Left Lung	0,000
Otomatis and Combination	Tumor Target	0,001
	Heart	0,400
	Esophagus	0,000
	Spinal Cord	0,000
	Right Lung	0,780
	Left Lung	1,000
Semi-Otomatis and Combination	Tumor Target	0,000
	Heart	0,100
	Esophagus	0,791
	Spinal Cord	0,584
	Right Lung	0,000
	Left Lung	0,000

The average accuracy grade of the automatic segmentation contouring results indicates a low score for the esophagus and spinal cord. However, both the tumor and heart targets have not received a moderate score. High scores are only observed in both right and left lungs.

In the semi-automatic segmentation method, high scores are obtained for the esophagus and spinal cord, while the target values for tumor, heart, right lung, and left lung still receive moderate scores. It should be noted that the esophagus and spinal cord are small-sized organs, whereas the tumor, heart, and lungs are larger organs.

The combination of automatic, semi-automatic, and manual segmentation represents an improvement over relying solely on automatic and semi-automatic segmentation methods. This editing process enhances the accuracy and yields high-quality results in contoured areas. While fully automated tools may still lack efficiency, utilizing tools that strike a balance between human interaction and automation can prove to be more effective(Aselmaa et al., 2017).

In this study, the development of a program using fully automatic and semi-automatic segmentation has shown to be less effective due to various factors, such as gray level inconsistencies leading to incorrect contouring of certain organs. However, the contouring program's effectiveness significantly improves when a combination of automatic, semi-automatic, and manual segmentation methods is utilized, finding a balance between human interaction and automation. This enables users to make additional adjustments to contours based on other considerations beyond the CT-Simulator image. The incorporation of this process results in accurate contouring according to the ICRU guidelines.

From the results of the Kruskal-Wallis test were < 0.05 except for the heart, it was concluded that there was at least a difference between the two groups. The next test is post hoc using Mann-Whitney to find out between groups that have differences (Sopiyudin, 2014). The results of the Mann-Whitney test, it can be ascertained that there is no difference in the results according to contouring on variables with p-vaue > 0.001. The variable with p-value < 0.001 indicates a difference in the two groups.

CONCLUSION

Fully automatic segmentation with location classification methods and fully semi-automatic segmentation with methods that use a closed curve model, which widens or narrows at the same degree of gray level in the CT-Simulator image of lung cancer cases, have not achieved maximum results. The combination of automatic, semi-automatic, and manual segmentation can increase the accuracy of contouring due to the editing process to improve the contouring results that are less accurate than automatic or semi-automatic segmentation in lung cancer cases. Contouring programs are more effective as they balance human interaction and automation. With this balance between human interaction and automation, the approach minimizes time, reduces inter-observer variability, increases contour accuracy, and enables adjustments to contour areas according to the doctor's preferences based on various considerations.

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