Calculation of Lung Cancer Volume of Target Based on Thorax Computed Tomography Images using Active Contour Segmentation Method for Treatment Planning System

Fiet Patra Yosandha, Kusworad Adi, and Catur Edi Widodo
Post Graduate Program of Physics Department of Diponegoro University, Indonesia

E-mail: fiet.patra@st.fisika.undip.ac.id

Abstract. In this research, calculation process of the lung cancer volume of target based on computed tomography (CT) thorax images was done. Volume of the target calculation was done in purpose to treatment planning system in radiotherapy. The calculation of the target volume consists of gross tumor volume (GTV), clinical target volume (CTV), planning target volume (PTV) and organs at risk (OAR). The calculation of the target volume was done by adding the target area on each slices and then multiply the result with the slice thickness. Calculations of area using of digital image processing techniques with active contour segmentation method. This segmentation for contouring to obtain the target volume. The calculation of volume produced on each of the targets is 577.2 cm³ for GTV, 769.9 cm³ for CTV, 877.8 cm³ for PTV, 618.7 cm³ for OAR 1, 1,162 cm³ for OAR 2 right, and 1,597 cm³ for OAR 2 left. These values indicate that the image processing techniques developed can be implemented to calculate the lung cancer target volume based on CT thorax images. This research expected to help doctors and medical physicists in determining and contouring the target volume quickly and precisely.

1. Introduction
One method to detect lung cancer is an examination of computed tomography (CT). The results of the examination will distinguish normal and abnormal lungs[1]. For the case of not-normal-lung, in this case is lung cancer, one treatment that can be done is radiation therapy or radiotherapy. In radiotherapy, planning is required to determine the amount of radiation dose received by a tissue. Dose planning in radiotherapy is called treatment planning system (TPS).

The initial phase of the TPS is contouring the cancer or target volume. The results of this phase are area and volume of the target. However, the process was done manually, requiring skilled medical personnel, and needing a long time in the process. This process can be done quickly by using segmentation which classifies the object pixels into a regions or parts. Segmentation can be done by several methods, one of them is the active contour segmentation method which is a method using models of closed curves that can move widened or narrowed.

Keshani et al. did a research to segment and identify pulmonary nodul. Image segmentation was performed by using active contour segmentation method and support vector machine (SVM) classification. Image segmentation use masking having the shape of non-isolated nodules and isolated nodules. The classification process was done using various SVM method of variations of the kernel...
function, named dehmeshki, taghavi, and farag. The results from this research were obtained an average accuracy of 89% [2].

Other researchers, Jin et al. conducted research delineation of lung tumors for therapy planning area in the image GTV PET/CT. Used image segmentation method is optimum contour selection (OCS). Jin et al. propose an contouring automatic algorithm based on optimal selection contour. Lung tumors in PET images are identified with thresholding method. Furthermore, the CT image segmentation is fixed using PET image segmentation results. Then the area GTV on CT images is contoured by using OCS [3].

Sari et al. did a study for the measurement and calculation of the volume of the object of the CT image. Tube-shaped object under investigation is assumed to be a tumor. The images generated from CT modalities, slice per slice. This calculation uses the trapezoid integration method. Before calculating the volume of the object, the object area of the base was calculated. Base area of the object is a slice thickness area in the image converted into a binary image. After obtaining the area of the base object, the volume of the object was calculated. From several variations of the position of the studied object, the object positioned perpendicular to the central ray will get a more accurate volume calculations [4].

In this research was done development of lung cancer detection system of the CT images. This detection to determine lung cancer target volume with image processing segmentation method. Segmentation in this research using active contour method. This segmentation for contouring to obtain the target volume. This research expected to help doctors and medical physicists in determining and contouring the target volume quickly and precisely.

2. Literature Study

Target volume is a prerequisite for 3-D treatment plan in obtaining accurate dose. ICRU Report No. 50 and 62 explain the multiple targets and volumes of critical structures that assist in the treatment planning process and provide a basis for comparison of the results of therapy [5, 6]. The following volume is defined as the primary volume associated with 3-D treatment planning that is gross tumor volume (GTV), clinical target volume (CTV) and planning target volume (PTV). Figure 1 shows how the different volume is associated with each other [7]. Part of the target volume Illustration can be seen in Figure 1.

![Figure 1. Illustration of parts of the target volume [8]](image)

2.1. GTV (Gross Tumor Volume)

GTV is part of the tumor which is palpable and can be seen visually with the help of tools such as endoscopes, plain to contrast radiography, CT scans, MRI or PET. GTV is part of both primary and metastatic of an organ or whole organ. GTV cannot be identified after surgery treatment [8]. GTV
usually performed based on information from the modality diagnostics (pathology and histological report) and clinical examination [7].

2.2. CTV (Clinical Target Volume)
CTV is the tissue volume containing GTV which has proved its sub-clinical microscopic malignant disease that has to be eliminated. CTV usually covers an area that immediately adjacent to the GTV that may be presenting microscopic disease and considered at risk and in need of treatment (e.g. lymph node positive). CTV is a clinical and anatomic volume usually determined by the radiation oncologist, performed after an examination conducted by a specialist such as a pathologist or a radiologist. CTV is usually expressed as a fixed or variable margin around the GTV (e.g. CTV = GTV + 1 cm margin). However, in some cases it is the same as the GTV (e.g. prostate gland increases only). There can be some CTV non-contiguous requiring total dose different to achieve the goal of treatment [7].

2.3. PTV (Planning Target Volume)
PTV are geometric concepts defined to select the right bricks by considering the net effect of all the variations of geometric in order to ensure that the prescribed dose is actually absorbed in the CTV [5]. PTV includes internal target margin [6] and an additional margin for set-up uncertainty, tool tolerances and intra-treatment variations. PTV is described as CTV plus a margin fixed or variable (e.g. PTV = CTV + 1 cm). PTV depends on tools precision such as immobilization and laser devices that require additional margin during the planning [7]. In the process of the formation of this PTV, patient's body movements dynamics factor is noticed, such as the movement of the cardiac, respiratory and other dynamic processes [8].

2.4. OAR (Organ at Risk)
OAR is the organ that is sensitive to radiation. Special attention should be given to the organs at risk, although it is not directly adjacent to the CTV. OAR must have a very low tolerance dose (e.g. eyelens on asopharyngeal or brain tumors). Organ with radiation tolerance dependent on the fractionation scheme should be fully described to minimize the exposure dose of radiation during treatment planning evaluation [7].

2.5. Active Contour
Active contour, which is also called snake, is a segmentation method using a model of closed curves that can move widened or narrowed. This method works by minimizing the energy associated with the contour of the current amount of internal and external energy. Active contour can move widened or narrowed by minimizing energy image using external power, and it is also influenced by the characteristics of the image such as lines or edges.

Active contour is described as a point of control which is followed each other. Determination of the object in the image through active contour is an interactive process. Users must estimate the initial contours determined nearly approximates the shape of the object features. Furthermore, the contour will gravitate toward the features in the image due to the influence of the internal energy [9].

2.6. Spatial Resolution
Spatial resolution reflects the details of the data about the objects that can be tapped from a remote sensing system in a size of the smallest object that can be presented, distinguished and recognized in image called pixel/picture element [10].

The spatial resolution image is the minimum distance between the two objects that are still distinguishable. The image spatial resolution of the imaging system is defined as the ability to distinguish two separate points in space. The higher the spatial resolution of the image, the smaller the distance that can be distinguished [11].
3. Method

3.1. Instruments and materials

The used tools are computer and programming method Matlab. Used digital image is the image of the thorax with DICOM format by the acquisition of CT scan modality. This digital image is used as an input image that will be processed through the computational programming. The variables in this study are an area target volume (mm$^2$), the volume of the target (cm$^3$), the spatial resolution (pixels/mm), the number of slice, and the slice thickness (mm).

3.2. Procedure

The process begins by determining image slice conducting cancer and organ that must be protected. The image Slice that there is no cancer and protected organ will not be segmented. On thorax CT image, slice containing cancer and organ that must be protected, initialization masking was done by firstly determining the appropriate iteration. Initialization used in this study is impoly. This process will produce a contour. After that, the target area on each slice is calculated. Then the volume of the target is calculated too by summing the target area multiplied by the slice thickness. The results of these calculations will be obtained the volume of the target of GTV, CTV, PTV and OAR.

4. Results

This study, discuss the results of the determination of the target volume and volume of targets in lung cancer by computed tomography images using active contour segmentation method for Treatment Planning System. There are the types of the processed target volume. Those are GTV, CTV, PTV, OAR 1, OAR 2 right, OAR 2 left. Imagery used in this study consists of 75 slice by slice thickness of 3 mm. This image is 512 x 512 pixels and has a spatial resolution of 1.0216 pixels / mm.

4.1. Target volume

Image contouring process have been done on target volume. In this study, the process of image contouring was done using active contour segmentation method. Contouring process begins with segmenting the image of GTV, which the main target volume of the primary tumor in each slice images is contained cancer. Image containing lung cancer is as much as 38 slice occurred in the slice 59 to 96. The GTV contouring results sample performed on slice to 78 are shown in Figure 2.

![Figure 2. Contouring results GTV on slice to 78](image)

Figure 2 shows the GTV contouring process performed on slice to 78. GTV contouring have been done right at the primary tumor that can be seen. After doing GTV contouring, the next process is to segment the CTV. CTV contouring is the margin of 1 cm from the GTV or CTV = GTV + 1 cm. GTV areas is used as masking initialization for CTV contouring. Image used for segmentation CTV is similar to the image used for GTV contouring, as many as 38 slice occurred in the slice 59 to 96. The CTV contouring results sample performed on slice to 78 are shown in Figure 3.
Figure 3. Contouring results CTV on a slice to 78

Figure 3 shows the CTV contouring process performed on slice to 78. CTV contouring performed at 1 cm margin of GTV contouring. After doing CTV contouring, the next process is to segment the PTV. PTV contouring is the margin of 1 cm from CTV or PTV = CTV + 1 cm or PTV = GTV + 2 cm. CTV areas is used as masking initialization for PTV contouring. Image used for image PTV segmentation is similar to image used for GTV and CTV contouring, as many as 38 slice occurred in the slice 59 to 96. The PTV contouring results sample performed on slice to 78 are shown in Figure 4.

Figure 4. Contouring results PTV on slice to 78

Figure 4 shows the PTV contouring process performed on slice to 78. PTV contouring is performed at 1 cm margin of CTV contouring. After doing PTV contouring, the next process is to segment the OAR. In this research, there are two OAR, OAR 1 is an organ that is the cardiac and OAR 2 is the lungs. OAR 2 is divided into two, OAR 2 right represents the right lung and the left lung is represented by OAR 2 left. Contouring process for OAR 1 segmentation, which is the target volume for each the image slice containing of the cardiac organ. Images containing cardiac are as many as 27 slice occurred on slice 69 to 95. The OAR 1 contouring results sample performed on slice to 69 are shown in Figure 5.
Figure 5. Contouring results OAR 1 on slice to 69

Figure 5 shows the image contouring process performed on slice to 69. OAR 1 contouring was done right in the cardiac organ that can be seen. After OAR 1 contouring, OAR 2 right contouring have been done. Contouring process for OAR 2 right segmentation, which is the target volume for each slice images containing right lung organ. The image containing right lung organ is as much as 70 slice occurred on slice 23 to 92. The OAR 2 right contouring results sample performed on slice to 67 are shown in Figure 6.

Figure 6. Contouring results OAR 2 right on slice to 67

Figure 6 shows image contouring process performed on slice to 67. OAR 2 right contouring was done right on the right side of lung organs that can be seen. After OAR 2 right contouring, OAR 2 left contouring was done. Contouring process for OAR 2 left segmentation, which is the target volume for each slice contained the image of the left lung organ. The image containing the left lung organ as much as 72 slice occurred on slice 24 to 95. The OAR 2 left contouring results sample performed on slice to 70 are shown in Figure 7.
Figure 7. Contouring results OAR 2 left on slice to 70

Figure 7 shows image contouring process performed on slice to 70. OAR 2 left contouring was done right on the left side of the lung organ that can be seen. The result of the whole target volume contouring process can be combined into a single image. The whole sample results of target volume contouring process that have been done to slice 69 are shown in Figure 8.

Figure 8. The results of the all contouring on slice to 69

Figure 8 shows the entire process of the target volume contouring performed on slice to 69. After the target volume contouring process is complete, then the volume of the target is calculated.

4.2. Volume Target
Volume of the target calculation begins by calculating the target area on each slice foremost. Initially the image is segmented by using active contour segmentation method to get the binary image. After obtained a binary image segmentation results for each of the target, then the target area is calculated by counting the number of pixels of 1 in the binary image. The result of this calculation is still in pixels$^2$, so it need to be converted into units cm$^2$ with equation (1).

$$L \ (cm^2) = L \ (pixel) / \ resolution^2 \quad (1)$$

Sample of target area calculation results performed on slice 78 are shown in Table 1.
After calculating the area of the target, then the volume of the target is calculated by summing area of the target multiplied by the slice thickness. The volume of target calculation with developed system can be obtained using equation (2).

$$V = \left(\sum A\right) \times S$$  \hspace{1cm} (2)

with $V$ is the volume of target (cm$^3$), $A$ is the area of the target (cm$^2$), and $S$ is the slice thickness (mm). The results of calculation of the volume of target using the developed systems are shown in Table 2.

| Target | Calculated volume with the system (cm$^3$) |
|--------|------------------------------------------|
| GTV    | 577.2                                    |
| CTV    | 769.9                                    |
| PTV    | 877.8                                    |
| OAR 1  | 618.7                                    |
| OAR 2 Right | 1,162                                   |
| OAR 2 Left  | 1,597                                   |

Table 2 shows the value of calculation the volume on each of the target.

5. Conclusions

The calculation of volume produced on each of the targets is 577.2 cm$^3$ for GTV, 769.9 cm$^3$ for CTV, 877.8 cm$^3$ for PTV, 618.7 cm$^3$ for OAR 1, 1,162 cm$^3$ for OAR 2 right, and 1,597 cm$^3$ for OAR 2 left. These values indicate that the image processing techniques developed can be implemented to calculate the lung cancer target volume based on CT thorax images.

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