Volume Target Delineation for Brain Tumor in Mri Images Using Active Contour Segmentation Method

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Volume Target Delineation for Brain Tumor in Mri Images Using Active Contour Segmentation Method

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Abstract
Radiotherapy is a tumor treatment process using high dose of radiation. Hence, it is essential that radiotherapy is carefully planned with a Treatment Planning System (TPS). The first step in TPS is delineation that aims to get a better picture of the tumor and the target volume value. This research investigated volume target delineation for brain tumor against the MRI image of the head in axial position. Calculated target volumes include GTV (Gross Tumor Volume), CTV (Clinical Target Volume), PTV (Planning Target Volume), and OAR (Organ at Risk). Images were segmented using the active contour method. Segmentation result from each
Slice is then calculated for its area, which then in turn, integrated to get the target volume. This research yields calculated volume and 3D visualization of each target. These two parameters are parts of a Treatment Planning System (TPS) used as a guideline in radiotherapy.

Keywords: volume definition, brain tumor, active contour, axial

INTRODUCTION

Brain tumor is one of the most commonly tumors, especially in males. In the United States, brain tumor accounts for 85-90% of all central nerve system tumors. Incidence level of this disease is around 6.6 per 100,000 people per year, with a mortality rate of 4.7 per 100,000 people per year [1]. Brain tumor can be recognized using some modalities. One of them is Magnetic Resonance Imaging (MRI) that can clearly display soft tissues images.

Brain tumor is not always fatal as it comes in both benign and malignant form. Nonetheless, a proper and timely treatment is necessary to prevent any further complications. Brain tumor can be treated using high dose radiation that kills tumor cells. This treatment is known as radiotherapy. As it uses high dose of radiation, a precise planning must be made. A system that ensures this is the Treatment Planning System (TPS). The first step in TPS is delineation that aims to get a better picture of the tumor and the target volume value in 3D [2].

Delineation is commonly carried out by medical physicists or physicians. This is prone to lengthy procedures and is subjective in nature. It will be better if the process is done automatically. This goal is made possible with the presence of digital image processing that allows image interpretation to gain more information from it. Hence, digital image processing can be applied in the process of target volume delineation. The stages of which include image segmentation (contouring), 3D image reconstruction, and target volume calculation [3,4].

Basyid et al., (2014) conducted a research on medical image segmentation to recognize cancer objects using the active contour method. This method employs a loop curve method that is able to move inside and outside. The segmentations for each target volume include GTV (Gross Tumor Volume), CTV (Clinical Target Volume), PTV (Planning Target Volume), and OAR (Organ at Risk). Segmentation results were then reconstructed and visualized in 3D [5].

Another researcher, Aslian et al., (2013) conducted a research on target volume delineation using active contour. This research was only limited to CTV delineation. Results show good accuracy and they also confirm that the active contour algorithm is capable of determining the CTV [6].

Research on the application of digital image processing has been conducted by many researchers across the globe [7,8,9,10,11]. Based on that earlier research this research carried out target volume delineation for brain tumor in MRI images using active contour segmentation method. The delineation process included calculation of GTV, CTV, PTV, and OAR on images of head in axial position. Contouring results are then reconstructed and visualized in 3D. Results of target volume calculation and visualization are parts of a Treatment Planning System (TPS) that serves as a guide in radiotherapy.

LITERATURE STUDY

Volume Definition

Volume definition is a prerequisite for meaningful 3-D treatment planning and for accurate dose reporting. ICRU Reports No. 50 and 62 define and describe several targets and critical structure volumes that aid in the treatment planning process and that provide a basis for comparison of treatment outcomes. The following volumes have been defined as principal volumes related to 3-D treatment planning: gross tumor volume (GTV), clinical target volume (CTV), internal target volume (ITV) and planning target volume (PTV). Figure 2.1 shows how the different volumes are related to each other [12].

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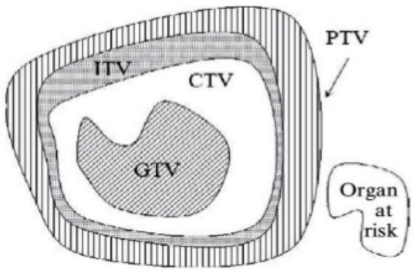


Figure 2.1 Graphical representation of the volumes of interest, as defined [8,9].

Gross Tumor Volume (GTV)

The Gross Tumor Volume (GTV) is the gross visible/ demonstrable extent and location of malignant growth" [13]. The GTV is usually based on information obtained from a combination of imaging modalities (computed tomography (CT), magnetic resonance imaging (MRI), ultrasound, etc.), diagnostic modalities (pathology and histological reports, etc.) and clinical examination.

Clinical Target Volume (CTV)

The clinical target volume (CTV) is the tissue volume that contains a demonstrable GTV and/or sub-clinical microscopic malignant disease, which has to be eliminated. This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation [13].

The CTV often includes the area directly surrounding the GTV, which may contain microscopic disease and other areas considered to be at risk and requiring treatment (e.g. positive lymph nodes). The CTV is an anatomical–clinical volume and is usually determined by the radiation oncologist, often after other relevant specialists such as pathologists or radiologists have been consulted. The CTV is usually stated as a fixed or variable margin around the GTV (e.g. CTV = GTV + 1 cm margin), but in some cases it is the same as the GTV (e.g. prostate boost to the gland only). There can be several non-contiguous CTVs, which may require different total doses to achieve treatment goals [12].

Internal Target Volume (ITV)

The ITV consists of the CTV plus an internal margin. The internal margin is designed to take into account the variations in the size and position of the CTV relative to the patient's reference frame (usually defined by the bony anatomy); that is, variations due to organ motions such as breathing and bladder or rectal contents [14].

Planning Target Volume (PTV)

The planning target volume (PTV) is a geometrical concept, and it is defined to select appropriate beam arrangements, taking into consideration the net effect of all possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV [13].

The PTV includes the internal target margin [9] and an additional margin for set-up uncertainties, machine tolerances and intra-treatment variations. The PTV is linked to the reference frame of the treatment machine and is often described as the CTV plus a fixed or variable margin (e.g. PTV = CTV + 1 cm).

Usually a single PTV is used to encompass one or several CTVs to be targeted by a group of fields. The PTV depends on the precision of such tools as immobilization devices and lasers, but does not include a margin for the dosimetry characteristics of the radiation beam (i.e. penumbral areas and buildup region), as these will require an additional margin during treatment planning and shielding design.

Organ at Risk (OAR)

The organ at risk is an organ whose sensitivity to radiation is such that the dose received from a treatment plan may be significant compared with its tolerance, possibly requiring a change in the beam arrangement or a change in the dose.

Specific attention should be paid to organs that, although not immediately adjacent to the CTV, have a very low tolerance dose (e.g. the eye lens during nasopharyngeal or brain tumor treatments). Organs with a radiation tolerance that depends on the fractionation scheme should be outlined completely to prevent biasing during treatment plan evaluation [12].

Active Contour

Active contour, also known as *snake*, is a segmentation method that uses the closed curved model capable of widening and narrowing. This method works by minimizing the energy related to the present contour as the amount both internal and external energy. Active contour can widen and narrow itself by minimizing the image energy using an external energy. It also affects the image characteristics such as edges. The energy that affects active contour is formulated as [15]:

$$E = \int_0^1 E_{\text{int}}(\vec{\gamma}(s))ds + \int_0^1 E_{ext}(\vec{\gamma}(s))ds \qquad (2.1)$$

where E_{int} is the internal energy affected by image curves, whereas E_{ext} is the external energy that that drags the contour wider or narrower to the desired object. $\vec{\gamma}(s)$ is a two dimensional curve as $\vec{\gamma}(s):[0,1] \to \Re^2$. The internal energy is written as [15]:

$$E_{\text{int}} = \left(\alpha(s)\left|\vec{\gamma}_s(s)\right|^2 + \beta(s)\left|\vec{\gamma}_{ss}(s)\right|^2 \right)/2 \qquad (2.2)$$

The values of $\alpha(s)$ and $\beta(s)$ determine curve movements. The first term causes the curve to move like a membrane, while the second term makes the curve moves like thin plate. The external energy is formulated as [15]:

$$E_{ext} = \left|\nabla G(\vec{\gamma}(s))\right|^2 \qquad (2.3)$$

where G is the image to be segmented. This system consists of a number of points connected and controlled by a straight line, as depicted in Fig. 2.2. Active contour is described as a controlled string of points.

Object determination in an image using active contour is an interactive process. An operator must estimate an initial contour, as can be seen in Fig. 2.4. The estimated contour will look almost like the real object. Next, this contour will be drawn toward the features of the image due to the effects of internal energy.

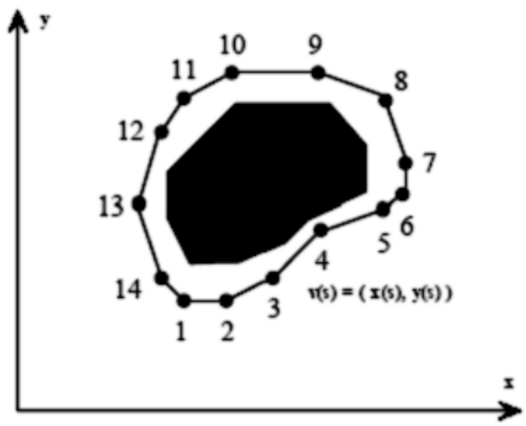


Figure 2.2. Active contour as a group of controlled coordinate points [15].

METHOD

Materials

The main material used in this research is an image of brain tumor from an MRI scanning in an axial position. It is 256 x 192 pixels in size and consists of 19 slices. Each slice is 0.5 cm thick, with a spatial resolution of 10.24 pixels/cm.

Instruments

The instruments used in this research include:

Hardware

The hardware is a notebook of Intel (R) Core (TM) i3-5010U CPU @2.10 GHz and Installed memory (RAM) of 4.00 GB.

Software

a. The software used to run image processing is Matlab R2015b. It is utilized to delineate brain tumor images and calculate target volumes.
b. The operation system used is Microsoft Windows 10 Enterprise 64-bit (10.0, Build 10586).

Image Processing

The image processing stages is given in Fig. 3.2.

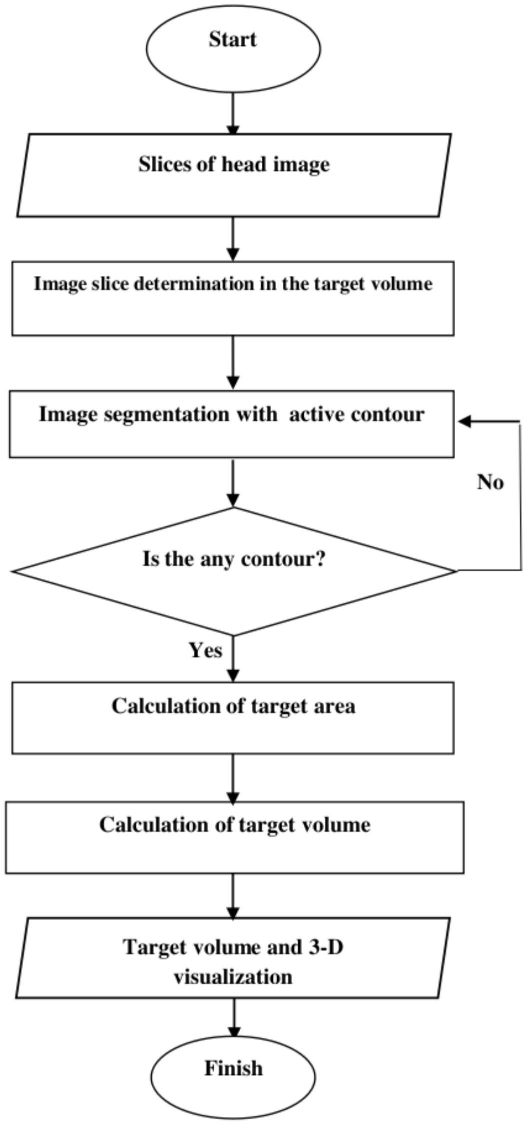


Figure 3.2: Flow Chart of Image Processing

a. Image Slice Determination
The process begins with determining the image slice of the tumor and the organs that need to be protected (OAR) from each slice. Images that do not have tumor and OAR will not be segmented.
b. Masking Initialization
Masking initialization for MRI head image begins with determining the proper iteration. The initialization used in this research is an ellipse. This process results in a contour.
c. Target Area Calculation
Calculation of target area is conducted using Simpson integration, which is calculating the area of each slice.
d. Target Volume Calculation

Target volume calculation is also conducted using Simpson integration. It is done by adding target areas and multiplying them with slice thickness. This process results in either axial, coronal, or sagittal target volume.

RESULT AND DISCUSSION

Image Acquisition

Image acquisition is carried out by scanning a patient's head for brain tumor using the modality of Magnetic Resonance Imaging (MRI) in the axial position. The axial image position in this research is of 256 x 192 pixels resolution with 19 slices and a slice thickness of 0.5 cm. This image has a spatial resolution of 10.24 pixels/cm. Each image slice in the axial position is given in Fig. 4.1.

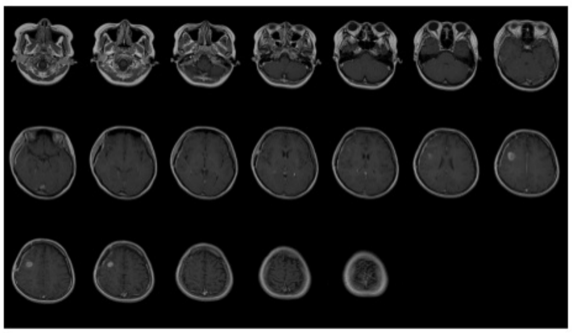
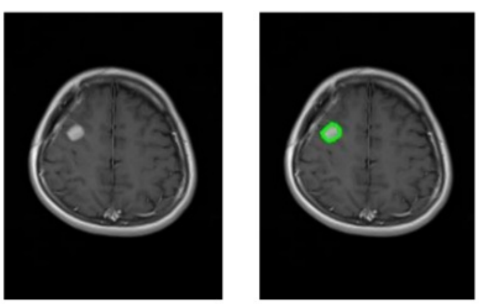


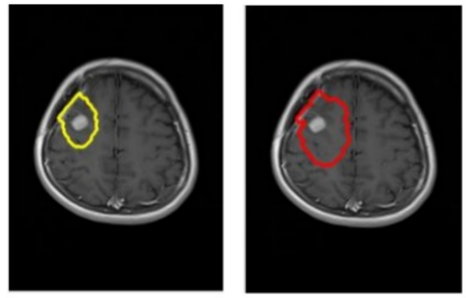
Figure 4.1 Slices of head image in axial position.

Target Volume Delineation

Delineation process in this research consists of calculations for GTV (Gross Tumor Volume), CTV (Clinical Target Volume), PTV (Planning Target Volume), and OAR (Organ at Risk). Slices of axial image with tumors are numbered 12, 13, 14, 15, and 16, whereas slices of axial image with OARs are the left and right eyes that are numbered 4, 5, 6 and 7. Delineation process is conducted by contouring using active contour. This method starts with giving a mask in the form of circle on the target volume. This masking will then grow automatically to form an area in the target volume. Resulting samples of GTV, CTV, and PTV contours on slice number 16 is depicted in Fig. 4.2.



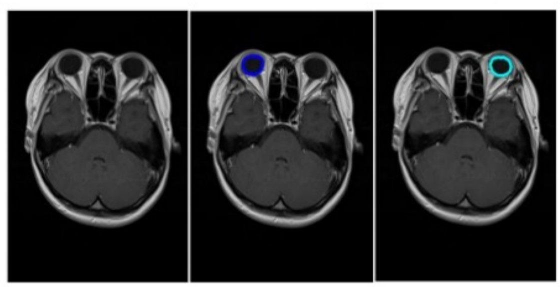
(a) (b)



(c) (d)

Figure 4.2: Contouring results of the axial image on slice number 16 (a) Initial image (b) GTV contour (c) CTV contour, and (d) PTV contour.

Fig. 4.2 describes the process of axial image contouring for slice number 16. GTV contouring is done for the primary tumor with an initial circular masking. CTV contouring then ensues with 1 cm margin from GTV contouring, that is CTV = GTV+1 cm. For CTV contouring, the resulting area from GTV contouring is used as an initial masking. Next is PTV contouring with 1 cm margin from CTV, that is PTV = CTV+1 cm or PTV = GTV+2 cm. For PTV contouring, the resulting area from CTV contouring is used as an initial masking. Once GTV, CTV, and PTV contouring are done, the subsequent process is OAR1 and OAR 2 contouring. Contouring for each OAR is done with an initial circular masking. In this axial image slice, OAR 1 and OAR 2 are on the same slices, they are slices number 4, 5, 6, and 7. Resulting OAR contours are given in Fig. 4.3.



(a) (b) (c)

Figure 4.3 Contouring results of the axial image on slice number 6 (a) Initial image, (b) OAR 1 contour, and (c) OAR 2 contour.

Fig. 4.3 shows an example of contouring process for OAR 1 and OAR 2 on slice number 6. OAR 1 is the right eye that is marked with a resulting blue contour, while OAR 2 is the left eye that is marked with a resulting cyan contour. OAR contouring starts with slice number 4, which is taking the initial image and then followed by contouring the right eye. The same steps are taken for slices number 5, 6, and 7. All resulting contours are then kept in a database for the next process of 3D image reconstruction and target volume calculation.

3D Image Reconstruction

3D image reconstruction starts with taking the 2D contour data that have been stored before. These target volumes are then reconstructed and visualized in 3D along with all slices of axial images. Visualization of target volume in 3D on the axial position is depicted in Fig. 4.4.

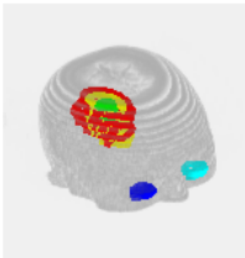


Figure 4.4 Target volume 3D visualization on the axial position.

Fig 4.4 depicts 3D visualization of all target volumes on the axial position. Green indicates GTV, yellow shows CTV, red represents PTV, blue depicts OAR 1, and cyan describes OAR 2.

Target Volume Calculation

Calculation of target volume begins with calculating the target area for each slice. Target area calculation itself starts with calculating the number of pixels that make up a segmented object. The resulting pixels are then converted into cm^2 using the following equation:

$$A' = A \ / res^2 \quad (4.1)$$

where

A' = target area (cm^2)
A = target area (pixel)
res = image spatial resolution (pixel/cm)

Results of target area calculation on the axial image slice are given in Table 4.1.

Table 4.1. Target volume calculation result on the axial image slice.

Target volume	Manual target area calculation (cm^2)
GTV	12.9413
CTV	57.7068
PTV	97.4369
OAR 1	7.4673
OAR 2	7.6199

➢ Volume

Target volume calculation is carried out by adding all target areas and multiplying them with slice thickness. The formula used for target volume calculation is:

$$V = S \times \sum A \quad (4.2)$$

where

V = target volume (cm^3)
S = slice thickness (cm)
A = target area (cm^2)

Results of target volume calculation on the axial image slice are given in Table 4.2.

Table 4.2. Target volume calculation results on the axial image slice.

Target volume	Manual target volume calculation (cm^3)
GTV	6.4707
CTV	28.8534
PTV	48.7185
OAR 1	3.7337
OAR 2	3.8100

Table 4.2 shows that GTV calculation result is compared to those from CTV and PTV, while calculation result of OAR1 volume, which is the right eye, is almost the same as for OAR 2, which is the left eye. Calculation results for each target volume and their 3D visualizations can be used as guidance in the process of Treatment Planning System (TPS).

CONCLUSION

This research has delineated target volume head images from MRI scans on the axial position. The target volumes calculated comprise GTV (Gross Tumor Volume), CTV (Clinical Target Volume), PTV (Planning Target Volume), and OAR (Organ at Risk). Image segmentation was carried out using the active contour method. Segmentation results for each slice were then calculated for their area, which in turn were integrated, to obtain the target volume. The final outcomes are calculated target volume and 3D visualization of each target. Both results are parts of the Treatment Planning System (TPS) that provides guidance in radiotherapy.

ACKNOWLEDGMENT

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