Calculation of Phantom Volume for Computed Tomography (CT) Scan Images

by Kusworo Adi

Calculation of Phantom Volume for Computed Tomography (CT) Scan Images

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***Abstract*— CT scan is a radiological examination that uses X-ray to produce cross-sectional images of an object. Its aim is to determine abnormalities such as cancers in human organs using ionizing radiation X-ray. Cancer is a term that refers to abnormal cell growth. Currently there are more than 100 types of cancer. Cancer cells can form any body tissue and continue to grow uncontrolled. Cancer cells are derived from normal body cells' damaged DNA (deoxyribonucleic acid), a cellular material that controls the characteristics and growth of cells. Approximately 14.1 million new cancer patients are diagnosed every year and about 8.2 million of them die it. The top five cancers in men are lung, prostate, colon, stomach and liver cancers, whereas in women, there are breast, colon, cervix, lung and uterus cancers. On the other hand, available cancer treatment modalities include surgery, chemotherapy, radiation therapy, hormonal therapy, immune therapy and stem cell transplant. Cancer treatment options depend on the type, stage of cancer, patient's physical condition and preferences. In general, different treatment options come with different results and side effects. Recently, there has been rapid development in cancer therapy modalities and a decrease in cancer related mortality. Calculation of volume changes in cancer treatment processes is very important to know the success level of the therapy. Therefore, cancer volume calculations prior and after treatment are important. This research developed a method of image processing to calculate phantom volume. The phantom material which is used is polymethyl methacrylate (PMMA). This phantom is assumed as cancer cell in patient's body that the volume will be calculated. Image processing and area calculation were conducted on each phantom image slice by thresholding and trapezoidal integration method. Then phantom volume was calculated by integrating all areas with slice thickness. These calculation results were then compared with those from manual calculation. This yielded an error value of 3.63%.**

Keywords: phantom volume; ct scan; image processing; trapezoidal integration

INTRODUCTION

CT scan is a diagnostic imaging modality that uses the tomographic principle to produce body parts images in axial, sagittal, coronal, or 3D format [1]. The aim of which is to determine abnormalities in human organs such as cancer using ionizing radiation X-ray.

Cancer is a term that refers to abnormal cell growth. Currently there are more than 100 types of cancer. Cancer cells can form any body tissue and continue to grow uncontrolled. Cancer cells are derived from normal body cells' damaged DNA (deoxyribonucleic acid), a cellular material that controls the characteristics and growth of cells. Approximately, 14.1 million new cancer patients are diagnosed every year and about 8.2 million of them die from it. Top five cancers in men are lung, prostate, colon, stomach and liver cancer, while in women; there are breast, colon, cervix, lung and uterus cancers [2].

Available cancer therapy modalities include surgery, chemotherapy, radiation therapy, hormonal therapy, immune therapy and stem cell transplant. Cancer treatment options depend on the type and stage of cancer, patient's physical condition and preferences. In general, different treatment options come with different results and side effects. Recently, there has been rapid development in cancer therapy modalities and a decrease in cancer related mortality [3]. Calculation of volume changes in cancer treatment processes is very important to know the success level of the therapy. Hence, cancer volume calculations prior and after treatment are important.

I. THEORITICAL BACKROUND

A. CT Scan

CT scan is a radiological examination that uses X-ray to produce cross-sectional images of an object. CT scan uses the attenuation principle of X-ray in an object. The human body is composed of various organs and tissues with different composition and density. The composition and density of the tissues are crucial in determining the X-ray radiation value absorbed by those tissues [4]. The scanning method used for this purpose consists of the sequential and spiral methods. In the sequential method, data acquisition is carried out without moving the table, while in the spiral method, an X-ray tube rotates continuously around the patient and an examination table also moves at a constant velocity.

B. Binary Image

Binary image is an image that has only two levels of gray value (black and white). Grayscale images can be converted into a binary image by using thresholding method. In this operation, the level of gray value of each pixel is grouped into two classes, black (0) and white (1) [5]. The equations used in a thresholding operation are:

$$g(i,j)=\begin{cases}1, f(i,j)\geq T\\ 0, f(i,j)<T\end{cases} \qquad (1)$$

Where

$g(i,j)$ is the binary image,

$f(i,j)$ is the grayscale image, and

T is the threshold value

C. *Trapezoidal Integration*

Trapezoidal integration method is applied by integrating the linear interpolation formula, written as follows [6]:

$$I=\int_a^b f(x)dx=\frac{b-a}{2}\left[f(a)+f(b)\right] \qquad (2)$$

Equation (2) can be extended to many intervals. For N interval with step distance h, the expansion of the trapezoidal rule is as follows:

$$I=\frac{h}{2}\left[f(a)+\sum_{j=1}^{N-1} f(a+jh)+f(b)\right] \qquad (3)$$

where

$$h=\frac{(b-a)}{N} \qquad (4)$$

The equation can be written in an equivalent form as:

$$I=\frac{h}{2}\left(f_0+2f_1+2f_2+\ldots+2f_{N-1}+f_N\right) \qquad (5)$$

where,

$$f_0=f(a) \qquad (6)$$

$$f_1=f(a+h) \qquad (7)$$

$$f_i=f(a+ih) \qquad (8)$$

II. Method

This research uses the following instruments: a CT scanner as the radiation source and an acrylic cylindrical PMMA phantom as the object. This phantom is assumed as cancer cell in patient's body that the volume will be calculated. The equipment used is shown in Figure 1.

(a) CT Scan (b) Body Phantom PMMA

Figure 1. Research instruments

The phantom is mounted perpendicular to the central ray. It is then scanned and figured out that its phantom body specifications are; 320 mm in diameter, 130 kV in voltage, has a tube current of 93 mAs, and a slice thickness of 8 mm. Once the image data is acquired, the phantom volume can be calculated. Calculation of phantom volume employs the trapezoidal integration method. A flowchart of this research is shown in Figure 2.

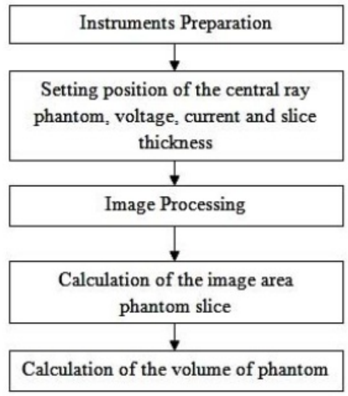


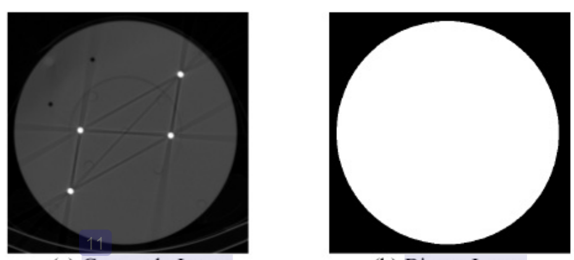
Figure 2. Research flowchart.

III. Result and Discussion

This research uses two instruments: a CT scanner as the radiation source and an acrylic cylindrical PMMA phantom as the object. The equipment used is shown in Figure 1.

A. *Image Processing*

Phantom image processing begins with the acquisition of CT Scan images in DICOM format. Acquired images consist of 18 slices, each with 512 x 512 pixels and 8 mm slice thickness. Each slice area is then calculated, before being integrated with the slice thickness to obtain its volume. Image processing is conducted by the process of transforming gray scale image into binary images. One of the gray scale images of the samples and its resulting binary image is shown in Figure 3.



(a) Grayscale Image (b) Binary Image

Figure 3. Image processing results.

B. Phantom Slice Area

Calculation of phantom slices area is done by calculating each area of the image using the following equation:

$$A = \frac{h}{2}\left[L_0 + 2L_1 + 2L_2 + \ldots + 2L_{511} + L_{512}\right] \quad (9)$$

Where,

A is the area of phantom slice

h is the spacing between pixels

L is the area of each column

The resulting phantom slice area is still in pixel unit. Therefore, it must be converted into mm^2 unit with the following formula:

$$A\left(mm^2\right) = \frac{A\left(pixel\right)}{spatialresolution^2} \quad (10)$$

The resulting area is then compared to phantom slice area manual calculation results. This manual calculation itself employs the following formula:

$$A = \frac{1}{4}\pi d^2 \quad (11)$$

where A is the area of phantom slice (manual) and d is the diameter of phantom (manual). Comparisons between manual and automated calculation results are shown in Table I.

TABLE I. AREA OF PHANTOM SLICE

Slice number	Area (mm2)		Error (%)
	Manual	System	
1	80424.77	79921.34	0.63
2	80424.77	79748.25	0.84
3	80424.77	79756.47	0.83
4	80424.77	79738.66	0.85
5	80424.77	79732.73	0.86
6	80424.77	79723.59	0.87
7	80424.77	79718.57	0.88
8	80424.77	79699.85	0.90
9	80424.77	79697.11	0.90
10	80424.77	79691.17	0.91
11	80424.77	79690.71	0.91
12	80424.77	79679.75	0.93
13	80424.77	79679.29	0.93
14	80424.77	79669.70	0.94
15	80424.77	79671.07	0.94
16	80424.77	79664.22	0.95
17	80424.77	79675.64	0.93
18	80424.77	79859.23	0.70

C. Phantom Volume

Calculation of phantom volume is carried out by integrating each area of phantom slice with its slice thickness using the following equation:

$$V = slice\ thickness \times \sum A \quad (12)$$

Where V is the volume of phantom, while A is area of phantom slice.

The resulting phantom volume is them compared to the manual phantom volume calculation results. This manual calculation itself employs the following formula:

$$V = A \times h \quad (13)$$

Where V is the volume of phantom (manual), A is the area of phantom slice (manual), and h is the height of phantom (manual)

Comparisons between manual and method developed calculation results are shown in Table II.

TABLE II. VOLUME OF PHANTOM

Number	Volume (mm3)		Error (%)
	Manual	System	
1	11581167.16	11160708	3.63

Calculation results of phantom volume show that the method developed is capable of calculation with high accuracy.

IV. CONCLUSION

This research successfully developed an image processing method that calculates phantom volumes. It is made possible by with the help of thresholding operation and trapezoidal integration method for each image slice of the phantom. Phantom volume is then subsequently calculated by integrating all area with the slice thickness. Compared to phantom volume calculation with the manual method, the method developed here has an error value of only 3.63%. Hence, this method is highly accurate.

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