Imaging Analysis of Thresholding Image Filtering, Brain Abnormalities Morphology, and Dose Report CT Scan Records

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Abstract. The abnormalities identified in the brain have been widely understood to be a form of disorder but displaying the data medically has been a problem. This study, therefore, proposes an imaging analysis to comprehensively investigate the thresholding method, morphology, and the medical imaging simulation approach using the CT scan. The focus was to identify the image of abnormalities in the brain starting with the illumination of the patient's head using X-rays and enhancing the image results. Moreover, irradiation results are also in the form of an image and output dose displayed on the Digital Imaging and Communication in Medicine using the radiology monitor. Thresholding methods and morphological operations are useful for determining the geometry of the area, depth, and volume of the brain using PHP programming. Furthermore, numerical calculations were applied to determine the value of the effective dose while statistical samples were used for 30 years and above. The results, therefore, showed the largest volume to be at the greatest effective dose value. Meanwhile, some data were not detected due to the abnormalities in the geometry of the brain object network, thereby, showing no significant difference in intensity values.

1. Introduction
There is continuous development in the study of brain disorders in the medical world with the data from the USA "Surveillance Epidemiology End Result Registry" reporting 38,000 new cases of primary brain tumors between 1973-1995 and 180,000 cases in 2001. Brain tumors are more frequently found in men as observed in 6.3 out of 100,000 population than women which is 4.4 of 100,000 population and the most susceptible age range is 65-79 years [1]. Meanwhile, tomographic analysis has not been able to determine and resolve the position and problem areas of the patient's brain, therefore, there is a need for a radiology examination and statistics have shown 20% of the patients treated in clinics to be experiencing headaches [2].

The headache is, however, influenced by several factors including gender, genetic makeup, age, background, and lifestyle. A study conducted in New York showed the percentage of headaches in women was 78% while men were 22% and, based on ethnicity, the prevalence is 31% Hispanic, 44% Kausia, 12% African-American, and 6% Asian. Another research in Singapore found headaches to be 53% in women and 47% in men as well as 6% in Indians, 14% in Malays, 79% in Chinese while others were just 1% [3]. Generally, patients diagnosed with headaches due to brain tumors in certain positions usually experience other symptoms such as vomiting, seizures, and changes in behavior but these are not exhibited by all of them. Moreover, those with severe migraines mostly have swelling
and, therefore, require clinical testing with a more precise examination [4]. Medical imaging is an appropriate diagnostic technique to determine the image of internal organs and cell tissues of the human body [5].

The use of this technology in radio-diagnostics is growing rapidly as observed with Computed Tomography Scan (CT Scan) which has the ability to record images, show abnormal parts, and body disorders therapy procedures. Moreover, the identification of human organs is easier and more accurate with the use of X rays due to their very short wavelength and ability to penetrate human organs. However, it is possible to find errors in CT Scan data analysis due to the misinterpretation from experts. Therefore, this research was conducted to facilitate the investigation and analysis of error-free data through an imaging study on the tumor area approached by medical personnel from the CT scan results. It also discusses the geometry and effective dose using a combination of the thresholding method in the segmentation process and morphological operations to determine the CT images geometry using software tools while numerical calculations were applied to obtain dose values. The outputs are expected to help radiologists investigate the abnormalities in the brain.

2. Literature Review

There is rapid development in radio-diagnostic technology, especially the use of CT scans with X-ray sources and this is evident from the study by Habifah which showed that 60% of decisions on medical treatment are based on the results of a CT scan diagnosis. Moreover, the development of computer tomography technology prioritizes increasing the speed of imaging using a multi-slice detector, improving image resolution, and reducing the radiation dose received by patients. This is more influenced by digital image processing technology in 2 or 3 dimensions which ensure different types of examinations once considered invasive are replaced by non-invasive and highly accurate CT. The use of these enhanced imaging methods ensures the human body part is not affected by the superposition of different anatomical structures. Meanwhile, one of the imaging on the brain is a tumor and its cells have been reported to usually undergo uncontrollable changes in their character, shape, and kinetics apart from normal growth [6]. The diagnosis of brain tumors is based on clinical features, signs of elevated intracranial pressure, focal neurological manifestations, and investigations. It has also been reported that brain abnormalities are usually diagnosed based on clinical examinations supported by others such as radiology and pathology [7]. Meanwhile, a CT scan has been found to have the ability of providing a clear picture of the process of intracranial space pressure, brain tumors, brain infarction, epidural hematoma [4], and bleeding in stroke [8].

The use of X-rays in medical radio-diagnostics increases patients’ exposure to radiations due to the tube current parameter (mA), rotation time (s), slice thickness, and tube potential difference (kVp). Meanwhile, the quality of the rays penetrating the object is usually determined by HVL (Half-value Layer) which is the thickness of the absorbent material reducing the X-ray intensity to half the true value. It is, however, affected directly by factors such as kVp and filter, and this further influences the radiographic contrast. A thicker object has been reported to have higher kVp and this causes shorter wavelength [9]. Filters are also used in reducing radiation dose as well as in blocking low energy X-ray photos and larger wavelength values considered harmful to patients.

The photon emitted from X-rays usually has a lower wavelength, high energy, and a higher penetration rate. Its kV and filtration values are constant, linear to mA in such a way that mA value is reduced to half the initial mA value, and this further decreases the radiation dose by 50% [10].

The dosage received by patients from irradiation varies, for example, objects thinly sliced during examination cause the dose distribution to be more coincided and this makes the average dose to be higher. Computed Tomography Dose Index (CTDI) is one of the output doses of the scanning area against the object slice thickness (T) which is expressed by:

$$CTDI = \frac{\text{Scanning Area}}{T} \ (mGy)$$

The effective dose is the single parameter describing the risk of a patient to be exposed to radiation while considering the quality of radiation and tissue sensitivity. It is usually calculate using the following relationship.

$$DE = DLP \cdot k$$
where \( k \) is the empirical weight factor (mSv.mGy\(^{-1}.cm^{-1}\)) and DLP (Dose Length Product) of the CT machine output dose [11]. As a diagnostic imaging modality, the processing pipe rotates while firing rays at the objects from different angles in the form of slice variations by scanning and transverse sections of the objects.

Image is a continuous function of light intensity in a two-dimensional plane and this is observed in the situation where an object is illuminated by the light source and then reflected due to some part of the beam with the reflection captured by an optical instrument and the object image recorded [12]. The basic principle of a CT Scanner is similar to a radiographic device which utilizes the intensity of the continuous radiation after passing through an object to form an image. The difference is in the technique used in producing the images with those generated from the radiographic technique observed to overlap while those from CT scan does not overlap when displaying the cross-sectional information of the object. Moreover, the CT Scan uses the principle of X-ray attenuation in objects with a certain density and tissue absorption composition [13]. The image results display a gray level [14] but have certain disadvantages due to the volume effect with low contrast between the brain object networks and others which leads to almost the same intensity [15].

The image results are, however, processed by thresholding segmentation and morphological operations to obtain the volume of the object using the PHP (HyperText PreProssecors) program. The segmentation aspect aims to separate the object area from the background area based on the similarity of image attributes for easy analysis. There is a lot of information in the image results such as noise, decreased quality, contrasting colors, and blur which makes it difficult to interpret, thereby, requiring manipulations to achieve better quality [16]. The thresholding method is, therefore, used to convert a grayscale image into a black and white binary image. The binary process of a grayscale image can be written as

\[
g(x, y) = \begin{cases} 1 & f(x, y) \geq T \\ 0 & f(x, y) < T \end{cases}
\]

where \( g(x, y) \) is the binary image of the grayscale image \( (x, y) \), and \( T \) is the thresholding value. This is usually followed by the morphological operation consisting of dilation, erosion, opening, and closing [17].

The dilation process displays the objects disconnected due to the disturbance of the image by noise, poor resolution, and object damage and has been discovered to be useful for the determination of the maximum value points. If the object's input image is represented by \( A \), structuring element (SE) by \( B \), and \( Bx \) shows that \( B \) is located on \( x \), then it is possible to use the following relationship to represent the dilation operations of \( A \) and \( B \).

\[
(A \oplus B) = \{x|(B)_x \cap A \neq \emptyset\}
\]

The dilation is denoted by \( A \oplus B \) and \( \emptyset \) expressed as the empty set [18].

The set of all points \( x \) is such that \( (B)_x \) of \( A \) obtained from the intersection of the sets \( (B)_x \) and \( A \) is not an empty set while a greater size of \( SE \) has been observed to be leading to more changes. Moreover, the effect of dilation on a binary image is to enlarge the object boundaries while the holes in the middle of the object appear smaller.

The erosion process is obtained from differences and intersections, while dilation is produced from differences and combinations but the transformation through dilation depends on the erosion process which is represented as follows due to the fact that it is the starting point of the morphological processing.

\[
A \ominus B = \{x|(B)_x \subseteq A\}
\]

The erosion is denoted by \( A \ominus B \) and for the set \( A \) and \( B \) in \( Z^2 \), the erosion of image \( A \) by SE \( B \) is the set of all points \( x \) which is translated by the \( (B)_x \) involved in \( A \). Figure 1 illustrates the application of dilation and erosion by SE \( B \) in an object.
Figure 1. Illustration of dilation and erosion operations by SE B on binary images [19]

A is a set (image) while set B is a square of SE and the erosion of A by B is shown in gray color. Furthermore, there is an elongated structure and occurrence of erosion in A by the same elements while the formula \( A \Theta B = \{ x \mid (B)_x \subseteq A \} \) describes the ability of the operator \( \Theta \) to convert all boundary points to the back points of the input image A based on SE B. The erosion process, therefore, produces narrowed or shrunken objects while their holes get enlarged.

The opening process involves the dilation operation for the overall result obtained from the image erosion of an SE B by the same forming element [20]. The opening process for \( A \circ B \), as presented in the following equation, is useful for removing small parts which appear bright with white spots or noise through the erosion process. The \( A \Theta B \) is followed by \( \oplus \) operator for dilation based on SE B with the use of any size for SE.

\[
A \circ B = (A \Theta B) \oplus B
\]

Equation 6 describes the operation of set A by SE B as denoted by AoB while the erosion of image A by SE B is represented by \( A \Theta B \). The closing process involves the application of the image dilation by the forming element B followed by the erosion of the overall result through the same forming elements and is useful for removing parts of the detail which are dark leaving the unobtrusive bright parts. It is considered a double opening process produced from the dilation \( A \Theta B \) followed by the operator \( \Theta \) for erosion B and written as:

\[
A \bullet B = (A \Theta B) \Theta B
\]

Equation 7 shows the closing process of set A by SE B is represented by \( A \bullet B \) while Figure 2 indicates the application of opening and closing processes to an object in the binary image with SE B. The opening operation involves two stages for the image and these include the erosion process followed by dilation with a smooth appearance, removal of small objects as well as the division and limitation of the object area without significant changes.

Figure 2. The illustration of the filter in opening and closing operation using the B element structure[19]
The result of the closing operations involves the dilation process followed by erosion, the combination of adjacent objects, and the filling of small holes in objects. Meanwhile, the formulation of erosion and dilation in a 3X3 SE matrix as well as the pixels with the matrix coefficient is denoted as follows:

\[
\begin{bmatrix}
(i-1,j-1) & (i-1,j) & (i-1,j+1) \\
(i,j-1) & (i,j) & (i,j+1) \\
(i+1,j-1) & (i+1,j) & (i+1,j+1)
\end{bmatrix}
\]

3. Methodology

The survey of medical image recording data on radio-diagnostic CT-Scan and dose reports for each patient are the methods usually used for the initial identification of abnormalities in the brain. Moreover, image data is useful in detecting the size of the object area to be observed and analyzed from the radiodiagnostic medical action results. It is usually applied as the primary data (Radiology Installation data) using the DICOM (Digital Imaging and Communications in Medicine) format containing imaging artifacts in image format, slice scan direction including axial, sagittal, or coronal and sample identification on the film.

Image data processing was conducted using PHP and numerical calculations to obtain an effective dose of patients from the dosimetry data as indicated in the stages of Figure 3 which were used to obtain the area and volume. The first stage includes the original CT Scan image of the object from the X-ray irradiation results while the grayscale image was used to equalize the degree of grayness and also to simplify the process of binarization through the use of thresholding for black and white images. The image was further refined and sharpened using morphological operations to make the area of interest clearer and analyzed for abnormal volume.

![Figure 3. The flow of object imaging](image)

The image was resized to ensure uniformity and also focused on segmentation. The process of resizing changed its size into a defined scale from 512 x 512 pixels to 256 x 256 pixels. Moreover, the image displayed on the MikroDicom software was converted from Dicom to jpeg format in order to facilitate the segmentation process. It was further processed at Semen Padang Hospital using thresholding segmentation to detect and document the objects.

The algorithm used the thresholding method as well as size feature extraction and morphological operations in the form of digital images consisting of dilation, erosion, opening, and closing. The dosimetric data from dose reports on the radiologist's DICOM computer were used to determine the effective dose for each patient.
Figure 4. The flow of the effective dose

The stages involved in determining the effective dose of the sample using the dosimetric data values from the output dose on the radiologist's monitor are presented in Figure 4. It involves multiplying the DLP (Dose Length Product) function with the empirical weight factor (k) value. It is important to note that the k value for each patient is different and serves as the function of the object being illuminated as well as the patient's age.

4. Result and Discussion

The result of the image processing is presented in Table 1. First, the image was converted into jpeg format and from RGB (Red, Green, Blue) to grayscale mode using the thresholding method. This is necessary to make all the color standard values in the image even and also to improve its quality. The grayscale image was formed by a matrix with a value ranging from 0 to 255 and the gray level value of the digital image was used to convert the grayscale image into a binary image.

Second, the thresholding method as used to convert the grayscale image into a binary image with the first step conducted by selecting the gray limit value (T) while the thresholding value obtained was used as a reference to convert the image produced into a black and white image. Table 1 shows the threshold image, obtained area, and object background. Meanwhile, in a situation the T-value in the background is more than 128, this means the image around the object is white but when the value is lesser, the abnormality is clearly and this facilitates the segmentation process using image morphology operations.

Table 1. Image results using the Thresholding method and Morphology operations
The results of the thresholding process were improved using morphological, dilation, and erosion processing. The dilation process smoothed the thresholding image and generalized all pixels other than the object using the results of the larger geometric object. The erosion process produced edge detection values by drawing color lines on the object where all the pixel values in the SE around the object were clarified by increasing the gray intensity and creating unnecessary parts. These findings were used to determine the area and volume of the object to be reduced to ensure easy analysis.

Table 2. Results of volume abnormal measurement

| No | Patient Name | Depth (Pixel) | Area (Pixel) | Volume (Pixel) |
|----|--------------|---------------|--------------|---------------|
| 1  | BR 1         | 173           | 13           | 2236          |
| 2  | BR 2         | 172           | 13           | 2236          |
| 3  | BR 3         | 151           | 11           | 1661          |
| 4  | BR 4         | 150           | 10           | 1500          |
| 5  | AM           | 45            | 95           | 4275          |
| 6  | NR           | 131           | 9            | 1179          |
| 7  | HD           | 48            | 92           | 4416          |
| 8  | BH           | 144           | 3            | 432           |

The size geometry of the brain abnormalities in Table 2 shows each patient has a different depth, area, and volume with the highest depth found in those classified as BR 1 while the lowest was in those with AM at 45 pixels. Moreover, the largest area of 95 pixels was found in AM while the smallest, 3 pixels, was in BH. Meanwhile, the largest volume amounting to 4416 pixels was recorded in HD while the smallest, 432 pixels, was obtained in BH.

This stage showed two samples, 7 and 8, which did not show the shape of the abnormal area as indicated in Table 1. This was associated with the lack of significant difference in the intensity values while the areas of abnormality for other samples are presented due to the sharp contrast in the intensity value.

Table 3. Effective dose using numerical calculation

| No | Patient Name | Age | CTDI vol (mGy) | DLP (mGy) | Effective Dose (mGy) |
|----|--------------|-----|----------------|-----------|----------------------|
| 1  | BR 1         | 45  | 78.46          | 2256.72   | 4.739112             |
| 2  | BR 2         | 45  | 78.46          | 2256.72   | 4.739112             |
| 3  | BR 3         | 45  | 78.46          | 2256.72   | 4.739112             |
| 4  | BR 4         | 45  | 78.46          | 2256.72   | 4.739112             |
| 5  | AM           | 40  | 76.84          | 2517.29   | 5.286309             |
| 6  | BH           | 39  | 77.66          | 35,2598   | 0.074045             |
| 7  | NR           | 73  | 59.08          | 1581.06   | 3.320226             |
| 8  | HD           | 60  | 60.09          | 3209.08   | 6.739068             |

Table 3 shows the value of the effective dose processed from the use of numerical calculation on dosimetry data from DICOM and CT Scan Optimal. All the patients with brain disorders were observed to be more than 30 years old, therefore, the empirical weighting factor used was k = 0.0021 mSv.mGy-1.cm-1 [21] for the head organs. The dosimetry data obtained were CTDI vol and DLP values and were found to be different for each patient. Moreover, the use of the dosimetry data or DLP function and a predetermined weight factor also showed the effective dose value is different for each patient with the highest, 6.739068 mGy, found in HD patients while the lowest was with 0.074045 mGy in BH patients. It was also discovered that a greater effective dose leads to greater value for the volume. The effective dose was also observed to be proportional to the depth but the depth is not
necessarily a reference due to two conditions which are its placement above and below the surface of the object being illuminated as indicated in the AM and HD patient data in Tables 2 and 3.

5. Conclusion
The geometry of the area, volume, and effective dose of the patient have different values. The results of segmentation with the thresholding method and morphological operations as well as numerical calculations showed a large volume of abnormality has a large effective dose. Similarly, a small value for an effective dose leads to a small volume and some images observed not to be deformed due to the geometry of the brain tissue did not have a significant difference in intensity values.

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