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Optimizing Treatment Planning: Enhancing Precision in Radiotherapy Treatment through the Estimation of Hounsfield Unit Values from CT-Scan Data Calculation

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Abstract

This study aims to increase precision in radiotherapy treatment planning by optimizing the estimated Hounsfield Unit (HU) value through calculating CT-scan data as a template. Radiotherapy is a therapy commonly used in the health sector to treat abnormal and uncontrolled growth of organism cells, such as lung cancer, brain tumors, leukemia and bone tumors. Radiotherapy utilizes gamma rays to eliminate abnormal cells through copying, taking into account appropriate radiation dose limits to minimize damage to normal tissue during the copying process. The level of absorption or radiodensity of a network can be expressed in Hounsfield Unit (HU) values. This simulation application design is supported by computer equipment with Intel i3 2 GHz processor specifications supported by 2 GB RAM (Random Access Memory), VGA (Video Graphics Adapter) 1 GB and 160GB hard disk. The device is used to determine the attenuation value (radiation absorption coefficient for each tissue) using the air attenuation value as a reference. The data processing method uses Green Foot software based on the multiplatform Java programming language. The program input is a CT-scan image with Grayscale analysis, and the output is Hounsfield values. The results of this study show that the use of CT-scan data and Hounsfield Unit (HU) calculations can increase the accuracy of radiotherapy planning. Using this technology, the radiation dose can be adjusted more effectively to the targeted area, while still minimizing the impact on surrounding healthy tissue. The integration of CT-scan and HU calculation in this study provides a strong basis for further development, with a focus on improving the precision and efficiency of radiotherapy.

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INTRODUCTION

Research regarding the involvement and modification of radiotherapy in the last decade has been carried out extensively by many researchers in the medical field (Price, Prabhakaran, & West, 2023; Keall, et al, 2022; Mondini, Levy, Meziani, Milliat, & Deutsch, 2020; De Ruysscher, Niedermann, Burnet, Siva, Lee, & Hegi-Johnson, 2019; Thariat, Hannoun-Levi, Sun Myint, Vuong, & Gérard, 2013). This was triggered by the fact that radiotherapy is one of the treatment methods commonly used in the medical realm. Utilization of radioactive energy as the main source of ionizing radiation is used to deactivate target cells in tissue (Chen & Kuo, 2017; Schaue & McBride, 2015; Baker, Dahele, Lagerwaard, & Senan, 2016). Thus, the use of radiotherapy allows more effective control of abnormal or pathological cell growth in an organism (Wang, Zhu, Hong, & Zheng, 2019). The principle of radiotherapy in this context involves administering a dose of radiation that can destroy genetic material in a predetermined area (target volume), while the surrounding normal tissue only receives the smallest possible dose. Therefore, before shining radiation on a patient, a doctor and radiographer carry out careful planning regarding the exposure dose that will be received by the treatment target and the surrounding healthy tissue (Moore, 2019).

Furthermore, the planning process, which is carried out by paying attention to the radiodensity level of each tissue that the beam passes through, is the core of producing informative and high-quality radiological images. Previous research succeeded in developing various aspects related to planning by utilizing algorithms that automate the planning process and optimize dosimetry exchange. The use of such algorithms significantly increases the efficiency of treatment planning and ensures consistent overall plan quality (Cilla, et al, 2021; Cilla, et al, 2020; Wu & Mohan, 2000). In addition, advances in computed tomography (CT)-based radiotherapy planning have also been achieved. Previous research succeeded in combining conventional and modern methods in developing treatment planning, including the diagnostic accuracy of physical examination (PE), ultrasonography (US), contrast-enhanced computer tomography (CT) as well as the utilization of CT scanning parameters and their influence on image quality (Kim & Pareek, 2003; Sorooshfard, Tahmasbi, Chegeni, & Tahmasebi Birgani, 2023). However, although much research has been conducted in the field of radiotherapy, most of the research that has been conducted tends to focus on aspects of the use of radiotherapy in general, with an emphasis on the relatively high costs associated with this method. Therefore, researchers propose a program that is economical, attractive and can be used on various platforms for all device operations and is affordable, with the aim of increasing accuracy in radiotherapy treatment planning through optimizing the estimation of HU values from CT-Scan data.

The Green foot Java application is used as a tool to develop Java-based applications designed to perform Hounsfield scale calculations. This program is optimized to receive input in the form of grayscale images from CT scans. The results of medical records using CT-Scan in file form can of course be correlated with reference for planning treatment with radiation. The efficiency of radiation results by minimizing damage to healthy tissue through which the rays pass can be done by paying attention to absorption capacity. Absorption capacity can be seen from the minimum value of the Hounsfield scale. This application is expected to provide a more affordable and effective solution in the context of radiotherapy treatment, in line with efforts to achieve the Sustainable Development Goals (SDGs), especially in increasing the accessibility and quality of health services for the community.

METHODS

In this research, a simulation application will be developed to calculate network Hounsfield values based on greyscale conversion values on imputed CT-Scan images. The program used to prepare the simulation application is Java with the Green foot application programming interface

(API) supported by a collection of computers with Intel i3 2 GHz processor specifications supported by 2 GB RAM (Random Access Memory), 1 GB VGA (Video Graphics Adapter) and a hard disk 160GB. The creation of this application is expected to provide an initial overview of the copy planning that will be carried out by operators that is easy to use before using the actual copying computing tool set.

The input data for this program is some CT scan image data in several image file extensions (*.jpg, *.png) with varying window level values and window width value settings. The difference in the range of Hounsfield values and greyscale values is obtained by setting the window width value with a bit depth of 8-bit, which means it has a color variation of 0 - 255. The window level is set to form an arithmetic series with a difference equal to the window width value. The first value is close to the maximum Hounsfield and the lowest value is close to the minimum Hounsfield. With the above process, the Hounsfield value for each pixel will be determined and the output for this program is Hounsfield value data in the *.hu file format. The program framework can be illustrated in Figure 1.

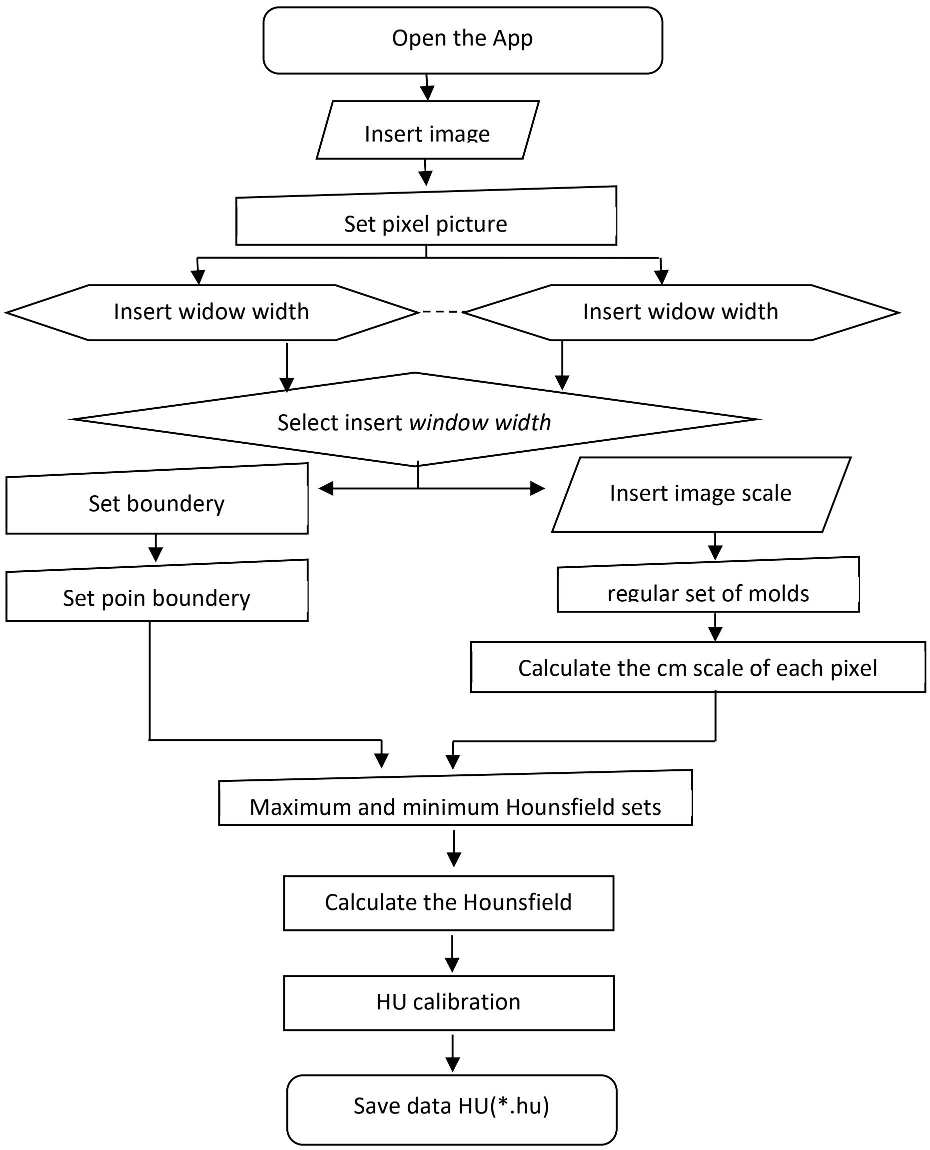

Figure 1. Framework Generate Hounsfield (HU) program

RESULT AND DISCUSSION

The Generate Hounsfield (HU) program is a sophisticated solution for calculating Hounsfield Unit (HU) values which is specifically designed to manage and analyze input data in the form of CT-Scan images. By applying the grayscale value linearization method, this program dynamically adjusts key parameters, such as window width and window level, in the image. This gives users the flexibility to detail and obtain highly accurate information from CT-Scan images, strengthening interpretation and diagnosis capabilities in the medical realm. The display of the program prepared in this research is presented in Figure 2.

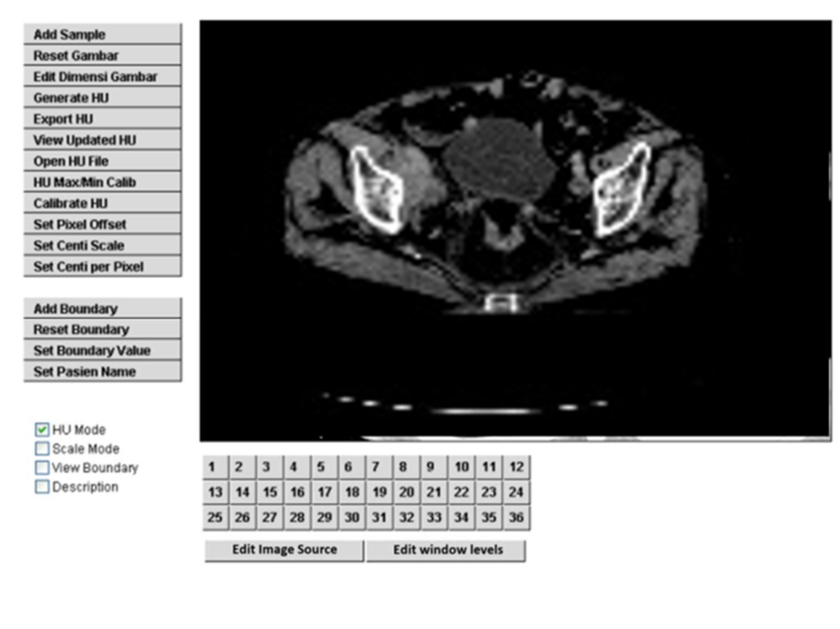

Figure 2. Generate Hounsfield program display

Based on Figure 2, it shows that this program was specifically developed by prioritizing ease of use. All buttons, including add text, insert data, and detailed data output, are designed to ensure users have an intuitive and efficient experience. This program is capable of receiving input in the form of CT scan image data with file extensions such as *.jpg and *.png. Apart from that, the advantage of this program lies in its ability to set various window level and window width values which almost cover the Hounsfield range. The window width value setting used is ≤ 250 to obtain a linear relationship between the greyscale value and the Hounsfield value in each image. In the image, the window level is also set, which is determined from the middle value of the range of Hounsfield values which is connected linearly to the window width of each image. The characteristics of the input image for the Generate Hounsfield program are presented in Figure 3.

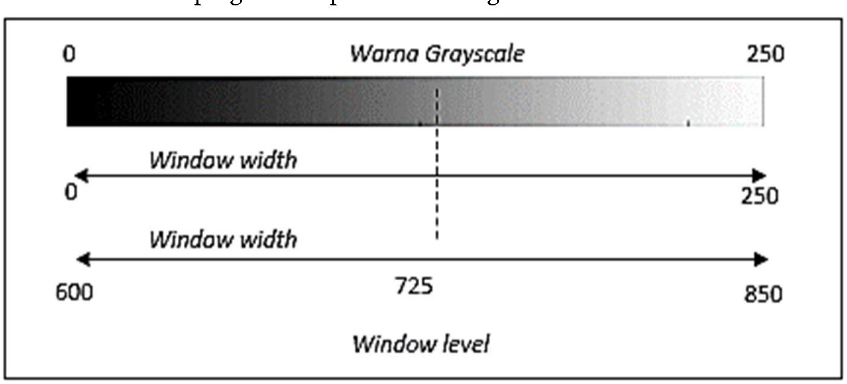

Figure 3. Input image characteristics for the Generate Hounsfield program

From the illustration in Figure 3, we can conclude that hounfield value of each pixel is determined by linear comparison between grayscale and window width value with the middle value. calculated by the equation:

$$HU = \frac{b \times W}{255} + \min \quad (1)$$

with b value is greyscale value on the pixel, W is a window width, and min obtain form L – 0.5 W. Based on the equation above we can give an idea the maximum value of setting the series is the value specified. approaching the known maximum Hounsfield minus half of the specified window width and the minimum value is obtained from a value that approaches the minimum Hounsfield value minus half the window width.

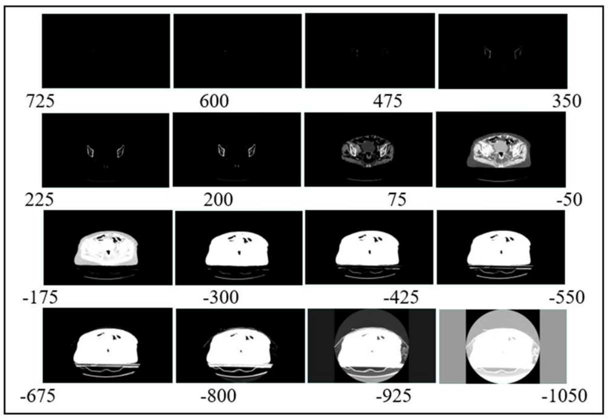

Figure 4. CT-scan distance scale

The illustration in Figure 4 is CT-Scan data which has a maximum Hounsfield value of 825 and a minimum Hounsfield value of -1024. The image data is set with a window width of 250 and the window level forms an arithmetic series with a maximum value of 725 and a minimum value of -1050. The window with and window level values are input manually in the form of Popup to be generated as a range of linear values Input the window width and window level values. The Input the window width and window level values will be presented in figure 5.

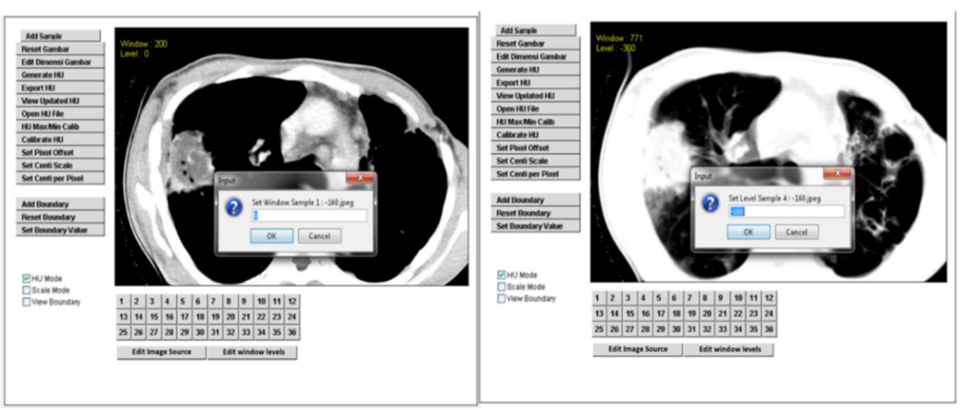

Figure 5. Input the window width and window level values

Based on the explanation above, information can be obtained that in the comparison between Hounsfield and grayscale values there will be a deviation between the generated Hounsfield values and the actual Hounsfield values. To solve this problem the program has been equipped with Hounsfield value calibration. In the image there are parts of the image that are parts outside the patient's body. This part can allow errors in the dosimetry process. The Hounsfield generation program includes steps to eliminate this influence by making the image outside the patient's body air with a known minimum Hounsfield value in the image. This step is carried out by providing a boundary for the area outside the patient's body. In dosimetry, apart from the boundary with the outside of the patient's body, the distance scale is very important for determining the dose value. 4. At this stage, to provide boundaries, press the "B" button and direct the cursor to determine the boundary area. To calibrate the size of the shading for making the boundary, press the "B" and "N" (reduce) "B" and "M" (enlarge) simultaneously while moving the cursor.

Figure 6. Creating boundaries and entering minimum Hounsfiels values

The output of this program will display the grayscale and Hounsfield values for each area indicated by the cursor. To display the Hounsfield value per pixel on the screen, press the "H" button and move the cursor to the area. If you want to display the greyscale value on the screen, press the "W" button while moving the cursor to determine the area to be displayed.

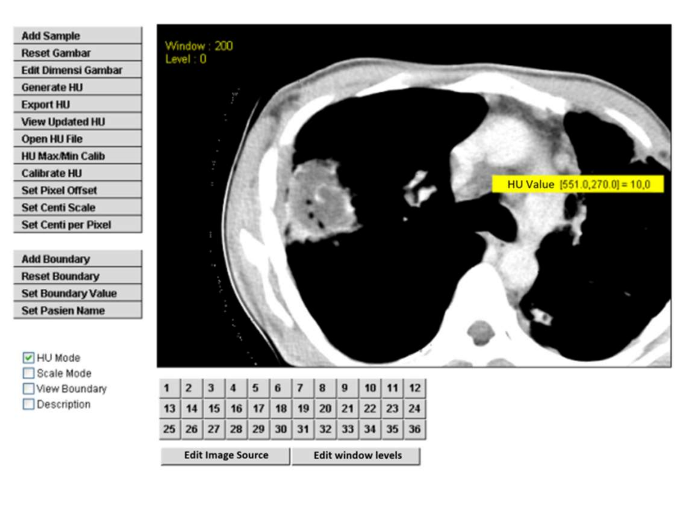

Figure 7. The final result display is the Hounsfield value

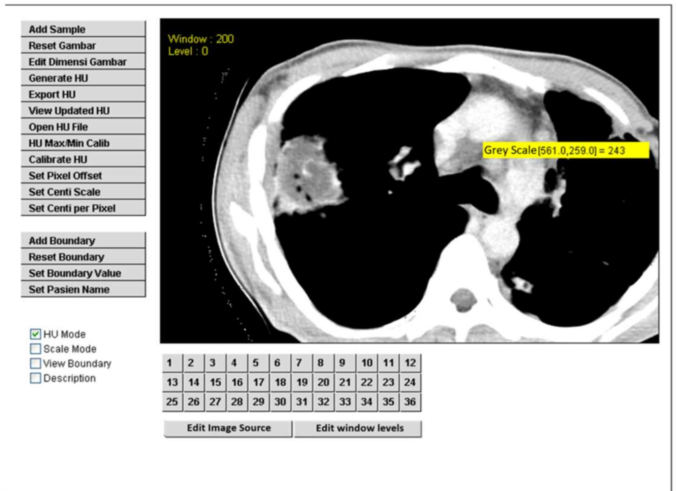

Figure 8. The final result display is a grayscale value

Based on figure 7 and figure 8. It can be observed that In the Hounsfield generate program, the comparison scale of the input image with the actual scale of the patient's body can be done by utilizing the image scale reference on the CT-scan which shows the actual scale. With this feature, this program can also determine the output comparison scale with the corresponding data on the patient's body. The Distance scale for CT scan results will be presented In figure 7.

Figure 9. Distance scale for CT-scan result

CONCLUSION

From the research results, it can be concluded that the use of CT-scan data and Hounsfield Unit (HU) calculations positively improves the precision of radiotherapy treatment planning. This provides an opportunity to deliver a more effective radiation dose to the target tissue, while still minimizing the impact on surrounding healthy tissue. The integration of CT-scan technology and HU calculations in this research provides a solid foundation for further development, with the aim of increasing the precision and efficiency of radiotherapy. This conclusion emphasizes the importance of continuing to encourage innovation in the advancement of the health care field, especially in the context of radiotherapy treatment planning.

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