Automatic detection method for CT image quality control

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ABSTRACT

CT plays an irreplaceable role in modern medical diagnosis, and its quality directly affects doctors' judgment of diseases. Therefore, realizing the quality control of CT images to ensure that the image quality meets the diagnostic standards is an important measure to guarantee medical quality and patient safety. In this paper, MATLAB is used as a tool to realize the automated detection of CT quality control, and the detection items include CT number of water, noise and layer thickness. The program is written to replace the manual detection steps to realize the measurement automation, and the interface is designed to form an APP through APP Designer. Experiments show that the automatic detection results of this software are more accurate and less time-consuming than the traditional way, which can be used for CT quality control detection.

Keywords: CT image quality control, automated detection, CT number, noise, layer thickness

1. INTRODUCTION

In recent years, the application of CT equipment in medical and industrial fields has become more and more extensive, and CT quality control has attracted much attention as a key link to ensure the performance and image quality of CT equipment. CT equipment quality control mainly refers to the use of professional testing modules and equipment to test the technical indexes and performance parameters of the CT equipment, in order to assess the quality of the CT equipment and the practicability of whether it meets the clinical needs, and to ensure that the CT equipment meets the medical needs. Quality control of CT is the process of evaluating the quality and utility of CT equipment to ensure that it meets clinical needs.

Quality control of CT is an important part of CT imaging. It not only concerns the accuracy of medical diagnosis, but also directly affects the treatment effect and life safety of patients. Under the premise of safe radiation dose, CT quality control can ensure that the equipment provides sufficiently clear and accurate diagnostic information to help doctors make accurate judgment and treatment decisions. At the same time, effective quality control can also minimize the potential radiation risk to patients and reduce the damage caused by radiation to the patient's body[1].

Since the world's first commercial CT was applied to the clinic in 1972, experts and scholars have recognized the importance of CT quality control. Since then, Europe, the United States and other developed countries have invested a large amount of research resources in this field, and have continuously optimized the techniques and methods of quality control. For example, Germany has achieved remarkable results in the accuracy of detection equipment, the United States is in a leading position in the research of radiation dose control, and Japan has made outstanding contributions to the improvement of image clarity and resolution.

China's CT equipment quality control work started late, and the technology is relatively behind Germany, the United States, Japan and other developed countries. However, with the introduction of the first CT equipment in 1979, China's research and practice in related fields has gradually increased. In terms of testing technology, from the initial dependence on foreign technology, to today's independent research and development of a series of high-precision and high-efficiency testing methods; testing module has also developed from a simple copy of the development of independent innovation to meet the needs of different types of CT equipment; supervision and management, from the initial lack of norms to the establishment of a comprehensive regulatory system to ensure that the quality control of CT equipment can be effectively carried out. supervision and management, from the initial lack of standardization to the establishment of a perfect regulatory system to ensure the effective implementation of CT equipment quality control. The quality control of CT equipment in China has

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developed rapidly, and the detection technology, detection model, supervision and management have been continuously improved and perfected [4].

At home and abroad, many studies have been devoted to CT quality control automation, and certain results have been achieved, but there are still some limitations. In foreign countries, the relevant research mainly focuses on the use of advanced technology and equipment to improve the automation level of CT quality control. For example, some studies have adopted high-precision detection modules and instruments to obtain more accurate detection data; and some studies have been devoted to the development of intelligent detection systems that can automatically identify and analyze problems in CT images. For example, in 2020, Polaris Imaging (NSI) introduced the robotiX fully automated X-ray CT scanning system [5], which integrates industrial robotics with standard digital imaging and computed tomography X-ray equipment to improve the automation capabilities and flexibility of industry CT systems. However, these methods tend to be costly and may be limited by a variety of factors in practical applications.

The current means of CT image detection are manually detected by human beings, which is time-consuming and laborious and may have subjective errors. To address this deficiency, this study makes full use of the powerful image processing function of MATLAB and combines it with APP Designer to design an independent APP to realize the automation of CT quality control. Compared with the existing automatic methods, this method has the following features and advantages:

a. Cost advantage. Some foreign researchers use high-precision detection modules and instruments with high cost, while this method makes full use of the image processing function of MATLAB and combines with APP Designer to design an independent APP, which has a relatively low cost.

b. Simple operation. By optimizing the algorithm and program design, it reduces the complex operation steps and makes the CT quality control more convenient.

c. High accuracy. Adopting precise region of interest (ROI) selection and calculation methods ensures the accuracy of detection results and reduces subjective errors.

d. Development potential. With the continuous development of technology, the method can be combined with other advanced technologies, such as artificial intelligence and big data, to realize more intelligent CT quality control [6].

2. CODE IMPLEMENTATION OF MATLAB-BASED DETECTION AUTOMATION

At present, CT quality control process in China is mainly based on the implementation of two standards, respectively, "JJG961-2017 medical diagnostic spiral computed tomography device (CT) X-ray radiation source verification procedures" [7] and "GB17589-2011 X-ray computed tomography device quality assurance testing specifications" [8]. According to China's current "Radiological Diagnosis and Treatment Management Regulations" regulatory requirements, according to the standard GB17589-2011 [8], the quality control of CT equipment includes three aspects: acceptance testing before use, annual condition testing and daily stability testing.

2.1 Testing program

The testing items include diagnostic bed positioning accuracy, positioning light accuracy, scanning frame inclination accuracy, reconstruction layer thickness deviation, CT-weighted dose index, consistency between images, CT number, uniformity, noise, CT number linearity, spatial resolving power (rate), contrast resolving power (rate) [8]. In this paper, several items of CT number, noise, and layer thickness of water are automated.

(1) CT number of water

CT number represents the attenuation value of X-rays absorbed through human tissues, which can quantitatively measure the absorption rate of tissues for X-rays, and its unit is Hounsfield (HU). The CT number of a substance is equal to 1000 times the ratio of the difference between the attenuation coefficient of the substance and water to the attenuation coefficient of water [10]. The formula for calculation is:

$$CT = \frac{\mu_{substance} - \mu_{water}}{\mu_{water}} \times 1000 \tag{1}$$

(2) Noise

CT image noise is the variable in which the CT number of a given region changes relative to its mean value in a homogeneous CT image, and is the random fluctuation of CT number between points in a CT image derived from a homogeneous body scan. These fluctuations in CT number can mask lesions or structures within the ROI, which can interfere with the examination or diagnostic task. In CT quality control evaluation, the amount of noise is usually expressed by the standard deviation of the CT number in the center region of the ROI. The formula is:

$$n = \frac{\sigma_{water}}{CT_{water} - CT_{air}} \times 100\% \tag{2}$$

Where: σ water --- standard deviation of the measurement in the ROI of the water model; CT water --- the CT number of water; CT air --- the CT number of air; CT water ---CT air - contrast scale (1000).

(3) Layer Thickness

CT layer thickness refers to the length of the computed tomography cross-sectional image covered in a direction perpendicular to the subject or examination bed. "Layer" refers to the ability of the CT data acquisition system (Data Acquisition System, DAS) to acquire images synchronously, which simply means the number of DAS channels that synchronize the acquisition of images or the number of layers that synchronize the acquisition of images when the rack is rotated. Detection of layer thickness in CT quality control ensures that the thickness of the slice reconstructed by CT is consistent with the thickness selected by the inspector on the CT equipment, thus avoiding result errors caused by inaccurate layer thickness.

2.2 Basis of testing

The detection module used in this paper is CatPhan500 phantom (shown in Figure 1), CatPhanTM500 includes four detection modules: CTP401: layer thickness, CT number linearity and contrast scale, CTP528: high contrast resolution, CTP515: low contrast resolution, CTP486: field uniformity and noise[11]. In this paper, we specifically utilize CTP401 and CTP486, and the detection indexes are CT number, noise and layer thickness of water, respectively.

CT quality control is detected when the CT number of the water in the homogeneous body water model (Figure 2), by the CT number of the formula can be obtained, the CT number of water should be 0, so the detected performance requirements: the CT number of the water should be within ± 4 (acceptance testing); ± 6 range (state testing).

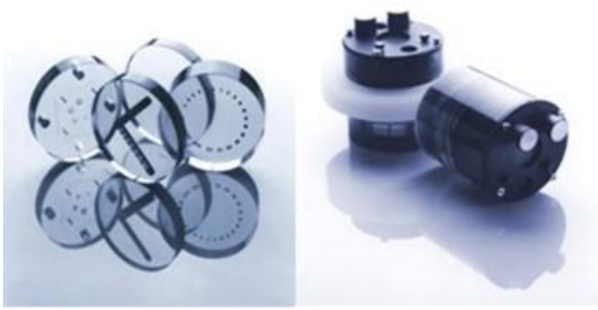

Figure 1. CatPhanTM500

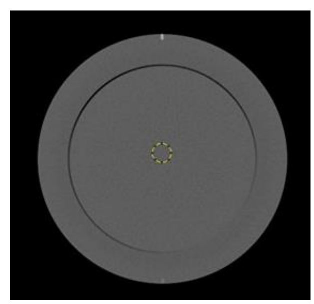

Figure 2. Water modle layer for measurements

2.3 Code implementation of the CT number of water and the noise section

Firstly, CT images are read and preprocessed, CT image data are usually saved in DICOM file format by medical devices or imaging software. The CT image data (DICOM format) was read using the dicomread function (Digital Imaging and Communications in Medicine) [6] and grayscaled using imshow (I,[]).

In this paper, obtaining ROI region link belongs to a semi-automatic process, first of all, use plot and poly2mask function to convert ROI region to region mask to realize the extraction of ROI region. When using the plot function to draw a circle, the center of the circular region is obtained by calculating the center of mass, i.e., the coordinates of the center of mass are found by setting a threshold and performing a binary loop on the image data to find the center of mass, thus realizing the center of mass, and then the center of mass is used as the center of the circle to successfully draw a 500 pixel-point circle. The ROI region in this paper refers to the circular region of 500 pixel points in the center of the image required in the CT number of water and noise detection project, as well as the small window region where the line segments need to be cut out for convenient processing in layer thickness detection.

2.4 Code implementation of the layer thickness detection part

Layer thickness detection is to measure the length of the metal diagonal line in the image, according to the requirements of the half-value width and height, you need to find the highest CT number of the line L2, as well as the average CT number of the background L1. In this paper, we use the imbinarize function for the grey-scale image binarization, and then use the bwlabeln function for the connectivity component to label, to find the background region and diagonal area, and then calculate L1 and L2. The automatic setting of the window position is L=(L1+L2)/2, and the window width is adjusted to the minimum. It can make the line segments to be measured can make the line segments to be measured (the four line segments in Fig. 3) partially visible (as in Fig. 3), omitting the step of conventional manual detection to find the optimal window position, and also more accurately through the pixel points to calculate the length directly [12].

Marking the connected components is to find each connected region in the binary map and mark it with some kind of notation, so that the number and location of connected regions can be determined. In the layer thickness detection part, it is necessary to find the position of the line segment to be measured, which can be regarded as a connected component, and the rest of the interfering scatter is another region, by this way, the line segment and the interfering scatter can be separated in the matrix, which is the basis for further point selection and calculation. In the layer thickness detection part of this thesis, the bwlabeln function is applied to a part of the intercepted area to create a labeling matrix using 4-connected objects. The effect of using this is shown in Figure 4.

Labeling after the acquisition of the coordinates of the target region, as shown in Figure 4, connected region labeling after the line segment region and other regions in the matrix of different numbers, this step needs to do is to find the number of regions and get the endpoint coordinates, the next step can be used to calculate the distance only with these coordinates. In this paper, in order to achieve this purpose, we first use histc function to find out the number of line segment region represented by the number, screening out the most consecutive occurrences of the number of times, and then use find function with the value of the same time restrictions to find the line number of the largest and smallest of the two points as well as to get the coordinates.

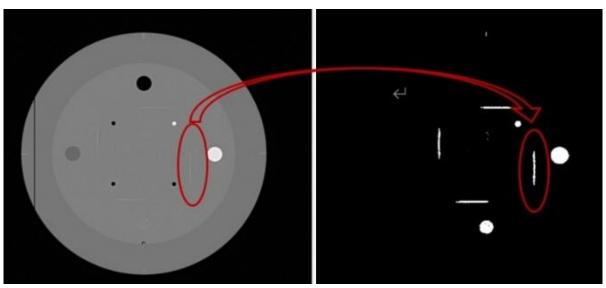

Figure 3. Comparison of original and binarizedlayer thickness

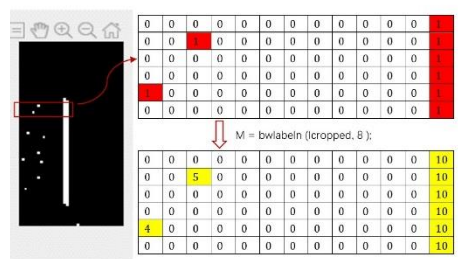

Figure 4. Effect of the bwlabeln function detection images

3. INSPECTION SOFTWARE DESIGN BASED ON APP DESIGNER

3.1 Brief description of Matlab APP Designer

APP Designer is a MATLAB application design platform that does not require users to have a background in software design and high-end computer design, but only need to drag and drop visual components to realize the graphical user interface (GUI) design layout, followed by controls, layouts, callback functions, and other features to quickly build function and data-driven application program interface, you can output a simple APP.

3.2 Sharing data within APP Designer

Each callback of APP Designer is relatively independent, the program and data behind each button are not connected, and in the program design of this paper, there is a need to call the data of other callback modules, for example, the detection process requires the pictures in the coordinate system, and the measurement value of CT number is required for the calculation of noise. Using attributes is the best way to share data within an App. If you want to share data that needs to be accessed by an intermediate result or multiple callbacks, you can define public or private attributes to store the data. This thesis uses the addition of private properties to enable data sharing between individual callbacks.

3.3 General framework design of CT quality control software

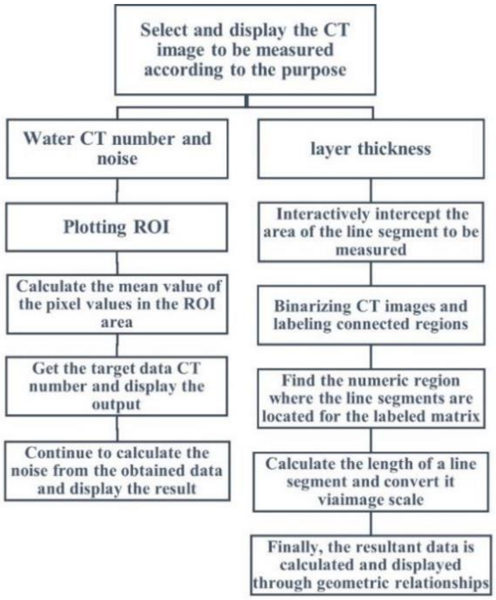

Figure 5. Software Testing Program Flow

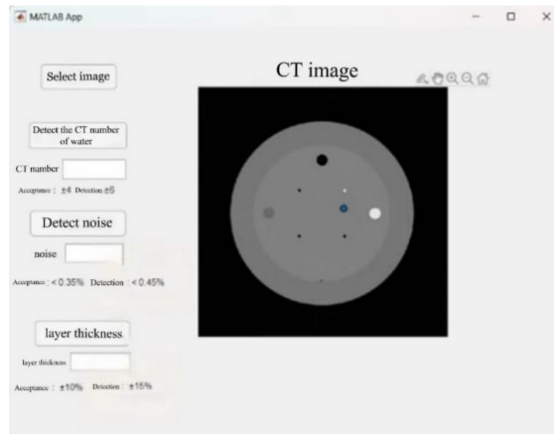

Figure 6. App interface for CT number, noise and layer thickness detection

The CT quality control inspection software is divided into two modules containing three inspection items, and the specific design flow is shown in Figure 5. The specific APP design interface is shown in Figure 6, which mainly consists of the coordinate area and the three detection project buttons and their data output text boxes, in addition to placing the button to select the image. In the use phase, more emphasis is placed on the output of the results so the amount of process is reduced to show a more concise interface and simpler operation. When measuring the CT number and noise of water just click the button to automatically select the ROI and output the result. For layer thickness detection, you only need to interactively click on the desired area to get the vertex coordinates to intercept the image for the next step of calculation.

3.4 Main function modules and realization

(1) Select image module. the main function is to display the image to be tested. In APP Designer, the imshow function can display the image by inputting a restrictive statement, while this thesis adopts the uigetfile function to realize that the user can open the folder to select the image for detection.

(2) Detect the CT number of water and noise module. the main function is to draw ROI according to the center of mass coordinates and then for the points in the ROI using the mean function to find the average pixel value, and then use this as the basis for calculating the noise. The design of the method of obtaining ROI is shown in 2.3, and the APP interface is shown in Fig. 7.

(3) Layer Thickness module. It mainly realizes the detection of layer thickness. The drawpoint function is used to enable the user to interactively select the vertex coordinates of the part to be intercepted, and then imcrop is used to intercept the picture. The purpose of the screenshot is to make the line segments to be measured clearer and clearer, which is conducive to the subsequent calculation. Then, according to the binarization and labeling of the processed image, the coordinates of the two ends of the line segment are found, and according to the coordinates, the distance between the two points is found by substituting them into the norm function, and then the thickness of the layer is calculated according to the geometrical relationship. The design of the main methods of image binarization, labeling and finding the coordinates of the two ends of the line segment is detailed in 2.4 of this paper. the APP interface is shown in Figure 8.

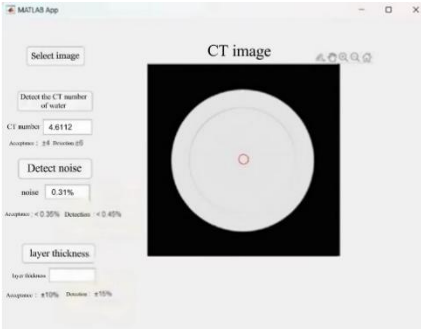

Figure 7. App interface for water CT number and noise detection

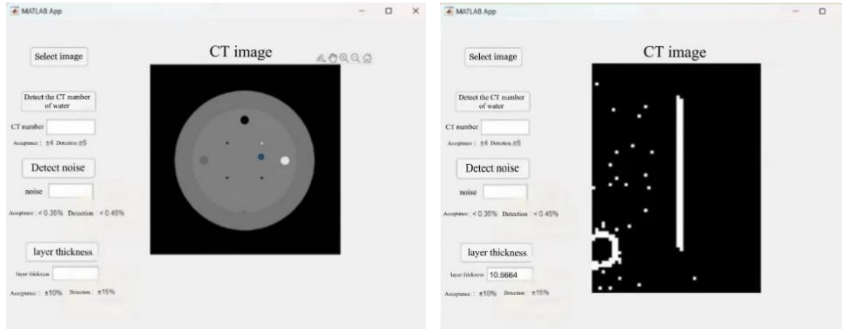

Figure 8. APP interface for layer thickness inspection

4. RESULT AND DISCUSSION

In this experiment, the measurement results of manual testing and the developed CT quality control software were compared, and the results are shown in Table 1.

Table 1. Comparison of measurement results between the two methods

Measurement Method	ROI Area	CT Number Result	Noise	Layer Thickness
Manual Detection	514	4.362	0.31%	0.83
Automatic detection	500	4.6112	0.31%	10.56

As can be seen from Table 1, the results of the detection software in this thesis are very similar to the manual detection results, and the results are informative, which can solve the error problems in manual detection, and compared to the inevitable errors in the manual detection process, such as inaccurate selection of the ROI range in the process of CT number detection, and accidental errors brought about by the measurement of the length of the layer thickness in the process of layer thickness detection, the automated detection software can solve all these problems, and the faster and more efficient. Therefore, this study can be used for daily CT quality control inspection.

5. CONCLUSION

In this thesis, with the standard of CT quality control, the powerful image processing ability of MATLAB software and the environmental support of APP Designer, we have designed the convenient and simple CT quality control inspection software, meanwhile, this thesis has designed all the inspection items into a whole software through page design and callback routine, which is hoped to be used for CT quality control inspection.

Meanwhile, it can be improved in the following aspects in the future project research:

(1) Increase detection programs. First of all, in-depth research on spatial resolution can be carried out to design corresponding detection methods and indicators. For example, specific test modules can be used to assess the ability of CT equipment to resolve fine structures, and spatial resolution can be quantitatively measured by analyzing the clarity and legibility of fine objects in an image; detection methods for low-contrast resolution can also be explored to better assess the performance of CT equipment in displaying low-contrast objects. This may involve the use of special modalities and image processing algorithms to accurately measure the smallest contrast difference that the device is able to detect; in addition to this, homogeneity detection can be performed: specific protocols for homogeneity detection can be developed to ensure that the quality of the image remains consistent throughout the scanning field of view. Uniformity can be assessed by taking image data at different locations and analyzing the consistency of this data.

(2) Optimize functions and algorithms. The first step is to keep learning and researching: pay close attention to the latest research results in related fields to learn and discover more suitable functions or algorithms. Regularly review academic literature and attend academic conferences to obtain the latest technical information. Then conduct experimental validation and comparison, experimentally validate the newly discovered functions or algorithms, compare them with existing

methods, and evaluate their performance in terms of accuracy, efficiency, and error incidence. And gradually optimize and improve, according to the experimental results, gradually optimize the statements and algorithms in the software, so as to make them more concise and efficient, and at the same time to ensure the improvement of precision and reliability.

(3) Expand the source of experimental data. Actively seek cooperation with more medical institutions or research institutes to obtain more CT image data to improve the generalization ability of the model; diversify the data sources and try to collect data from different types of CT devices and different clinical application scenarios to make the experimental data more representative; formulate a detailed clinical validation plan, including cooperating with clinicians to carry out large-scale clinical trials to verify the software's effectiveness and reliability in actual clinical application, including cooperation with clinicians to carry out large-scale clinical trials to verify the effectiveness and reliability of the software in actual clinical application.

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