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Traditional Detection Methods and Improvement Strategies for Medical CT Image Quality

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Abstract: *With the continuous development of medical imaging technology, computed tomography (CT) plays an increasingly important role in clinical diagnosis. The quality of CT images directly affects the diagnostic accuracy and treatment effectiveness of diseases. In recent years, deep learning technology has shown great potential as an emerging image analysis method in CT image quality detection. This article reviews the traditional methods of medical CT image quality detection, analyzes their limitations, and proposes an improvement strategy based on deep learning. By optimizing and innovating existing detection methods, combined with the automatic feature extraction capability of deep learning, this paper aims to improve the accuracy, real-time performance, and consistency of CT image quality detection. In the future, with the continuous advancement of technology, image quality detection methods based on deep learning will be more widely applied in the field of medical imaging, promoting the development of medical image analysis towards greater intelligence and precision.*

Keywords: *medical CT images, quality inspection, traditional methods, deep learning, image processing*

1. Introduction

With the continuous advancement of modern medical imaging technology, computed tomography (CT), as an important medical imaging technique, has been widely used in clinical diagnosis, disease monitoring, and treatment planning. CT scanning not only provides detailed images of the internal structure of the human body, but also has high spatial resolution and short examination time. Therefore, CT has become an indispensable and important tool in the diagnosis of many diseases, especially in fields such as tumors, cardiovascular diseases, and neurological diseases, showing irreplaceable advantages. However, the quality of CT images directly affects the diagnostic accuracy and treatment effectiveness of diseases. Therefore, how to ensure that the quality of CT images is always in the best state has become a key issue that urgently needs to be addressed in the field of imaging.

Traditional CT image quality detection methods often combine physical quantification detection with manual evaluation. Physical quantification detection mainly relies on standardized test images for objective evaluation of image quality, with common indicators including resolution, noise, artifacts, etc; However, manual evaluation relies on radiologists to subjectively evaluate the images. However, these traditional methods have some obvious limitations. Although physical quantification testing can provide some quantitative evaluation criteria, it often cannot fully reflect the performance of images in clinical practice; However, manual evaluation heavily relies on the experience and subjective judgment of doctors, which may result in inconsistent evaluation results due to individual differences or fatigue. In addition, traditional methods are often limited to detecting static images and cannot monitor the dynamic changes in image quality in real time. They are also difficult to cope with individualized needs of different patients and image quality issues under complex pathological conditions.

With the continuous development of technology, there is an urgent need for improvement and innovation in CT image quality detection methods. In recent years, image processing and automated quality assessment systems based on artificial intelligence have gradually emerged as an important supplement to CT image quality detection. By introducing deep learning algorithms, automated image recognition and quality assessment can be achieved, improving detection efficiency and accuracy. In addition, the continuous development of new image reconstruction algorithms and scanning technologies has provided strong support for improving image quality. For example, reconstruction methods based on iterative reconstruction and deep learning can effectively reduce noise, improve image resolution, and ensure image quality while reducing radiation dose.

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Therefore, this paper aims to conduct an in-depth analysis of the traditional detection methods for medical CT image quality, explore their advantages and disadvantages in practical applications, and propose a series of improvement strategies based on the latest technological advances. By studying the detection and improvement methods of CT image quality, it is expected to provide theoretical basis and practical guidance for the further development of medical imaging technology, thereby promoting the application effect of CT technology in clinical diagnosis and improving the quality of medical services.

2. Quality of medical CT images and traditional detection methods

2.1 The relationship between CT imaging principle and image quality

CT imaging is the process of reconstructing different tissues of the human body using computer algorithms after X-rays penetrate and are received by detectors [1]. The CT scanning process involves three main parts: X-ray source, detector, and computer reconstruction system. The X-ray beam emitted by the X-ray source passes through tissues of different densities in the patient's body, and some of the radiation is absorbed, while the other part penetrates to the detector array on the opposite side. After the signals received by the detector are converted, the computer uses a series of complex mathematical algorithms, such as filtering backprojection or iterative reconstruction algorithms, to convert this information into images and form fault images.

The quality of CT images is influenced by multiple factors. Firstly, spatial resolution determines the smallest distinguishable detail in an image. Higher spatial resolution can display finer structures, but typically requires higher radiation doses. The spatial resolution is closely related to factors such as detector array design, scanning speed, and reconstruction algorithms. Secondly, contrast resolution reflects the grayscale differences between different tissues, which affects the ability to identify different tissues or lesions. It is directly related to the energy of X-rays, scanning parameters, and reconstruction algorithms. Thirdly, noise is a random signal in CT images, usually caused by factors such as instruments, environment, and patients. The presence of noise can degrade image quality and increase diagnostic difficulty. The level of noise is closely related to scanning time, radiation dose, and detector sensitivity. Fourthly, artifacts are illusions caused by technical issues during the scanning process or factors such as patient movement, which may be due to patient movement, metal implants, or scanner hardware failures. In summary, the quality of CT images not only depends on the technical parameters during the scanning process, but is also closely related to the performance of the imaging system, imaging reconstruction algorithms, and post-processing effects.

2.2 Traditional CT image quality detection methods

The traditional CT image quality detection methods mainly include two methods: physical quantification evaluation and manual evaluation, which provide the basic framework for CT image quality evaluation, but each has certain limitations. Physical quantitative evaluation is conducted through standardized test images and equipment for objective quantitative evaluation. Common detection indicators include resolution testing, noise measurement, contrast resolution testing, and linear response testing. For example, resolution testing uses line to contrast plates to evaluate the spatial resolution of CT images, noise measurement quantitatively evaluates the noise level by calculating the standard deviation of pixel values in the image area, and contrast resolution testing evaluates the ability of images to distinguish tissues or lesions at different contrasts through testing with different density materials. In addition, linear response testing ensures that the grayscale value of the image is consistent with the physical density of the tissue through CT value testing of materials with different densities. On the other hand, manual evaluation relies on the subjective judgment of radiologists to assess the quality of images through experience and training. Common methods include image clarity assessment, artifact detection, and image sharpness and contrast assessment. Doctors determine whether diagnostic criteria are met based on image clarity and detail resolution ability. Although manual evaluation methods are simple and intuitive, and can provide feedback in practical applications, they lack objectivity and consistency. The evaluation results are easily influenced by doctors' experience, fatigue, and subjective factors, making it difficult to achieve standardization and quantification.

2.3 Factors affecting the quality of medical CT images

The factors affecting the quality of CT images are very complex, involving multiple aspects such as

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scanning parameters, imaging system performance, and patient factors. Firstly, the scanning parameters directly determine the image quality. Tube voltage (kVp) affects the energy of X-rays. Higher tube voltage enhances penetration ability and improves image contrast, but may increase noise; The tube current (mA) is related to radiation dose, and higher currents help reduce noise and improve image quality, but also increase patient radiation dose. The rotation time and slice thickness determine the scanning speed and image spatial resolution, with thinner slices providing higher resolution but increasing scanning time and radiation dose. The choice of reconstruction algorithm is also crucial. Traditional filtering backprojection methods may generate noise, while modern iterative reconstruction algorithms can effectively reduce noise, especially in low-dose scanning, which can improve image quality. Secondly, the performance of CT imaging systems, such as detector sensitivity, resolution, and linear response, also directly affects image quality. High performance detectors can provide finer images, but at a higher cost. Individual differences among patients are also an important factor. Obese patients may experience reduced image contrast due to low fat density, and larger volumes require higher radiation doses to obtain high-quality images. Finally, artifacts are an important factor affecting image quality, and common artifacts include motion artifacts, metal artifacts, and so on. Slight movement of the patient during the scanning process may cause image blurring, thereby affecting diagnosis. Metal objects, such as implants, can cause X-ray distortion and produce artifacts, further affecting the clarity of the image. Overall, the quality of CT images is influenced by multiple factors, and optimizing various parameters can help improve image quality.

3. Improvement strategies and technologies

Medical imaging, especially in computed tomography (CT) technology, has seen continuous improvement in image quality with the advancement of technology[2]. With the increasing demand for imaging diagnostic accuracy, traditional image reconstruction techniques and scanning parameters have gradually exposed some limitations, especially at low radiation doses. Ensuring image quality without increasing patient radiation exposure has become a key technical challenge. In order to meet modern medical needs, this section will explore how to improve the quality of CT images from three aspects: new image reconstruction algorithms, optimized scanning parameters and technologies, and intelligent detection and evaluation systems.

3.1 New image reconstruction algorithm

Image reconstruction is a core component of CT technology [3]. Although traditional reconstruction algorithms such as filtered backprojection (FBP) can obtain good images under certain conditions, they can easily lead to increased image noise and loss of details in low radiation dose application scenarios. Therefore, the development of new image reconstruction algorithms, especially those based on deep learning and iterative reconstruction, has become a research hotspot in recent years.

3.1.1 Iterative reconstruction algorithm driven by deep learning

Deep Learning (DL), as a powerful data processing method, trains massive amounts of data through deep neural networks to extract more accurate features from the data and optimize image quality. In CT image reconstruction, iterative reconstruction algorithms based on deep learning can reduce radiation dose while maintaining high image quality compared to traditional algorithms. Specifically, deep learning driven iterative reconstruction algorithms typically consist of two steps: image reconstruction, which directly reconstructs high-quality CT images from raw projection data through neural network models. Noise suppression and detail enhancement, based on image reconstruction, further optimize the image through deep learning models to remove noise, improve contrast, and enhance details. Experimental data shows that using iterative reconstruction algorithms based on deep learning reduces image noise by about 30%, increases signal-to-noise ratio (SNR) by 20%, and significantly improves detail clarity compared to traditional filtered back projection (FBP) methods, as shown in Table 1.

Table 1: Comparison of CT image quality based on deep learning and traditional algorithms

Index	FBP algorithm	Deep learning iterative reconstruction algorithm
Image noise (noise standard deviation)	9.2 ± 1.4	6.3 ± 1.1
Signal to Noise Ratio (SNR)	8.5 ± 0.5	10.2 ± 0.6
Contrast (HU value difference)	36 ± 4	43 ± 3

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3.1.2 Reconstruction speed and efficiency

Although traditional iterative reconstruction algorithms have improved image quality, they have long computation times and low processing efficiency. With the continuous development of computing hardware, deep learning based algorithms not only improve image quality, but also significantly enhance reconstruction speed. CT image reconstruction based on Convolutional Neural Network (CNN) has improved processing speed by about 50% after hardware optimization, which is of great significance for real-time requirements in clinical applications.

3.2 Optimizing scanning parameters and techniques

Optimizing scanning parameters and techniques is another important strategy to improve CT image quality and reduce radiation dose. In the process of CT scanning, the selection of scanning parameters has a direct impact on the final image quality, especially how to ensure the clarity and details of the image while ensuring a lower radiation dose.

3.2.1 Personalized scanning parameter settings

In traditional CT scans, doctors usually use standard scanning protocols and ignore the impact of individual differences in patients. Personalized scanning parameter settings are tailored to different scanning plans based on factors such as the patient's body shape, health status, and lesion location. By adjusting the scanning tube voltage, tube current, and slice thickness, it is possible to effectively reduce radiation dose while improving image quality.

For example, for pediatric patients and smaller patients, lower tube current and tube voltage can be used, combined with thinner slice thickness, to reduce radiation dose; for larger adult patients, the scanning parameters can be appropriately increased to ensure image clarity, as shown in Table 2.

Table 2: Effects of different scanning parameters on CT image quality and radiation dose

Scanning scheme	Tube current (mA)	Tube voltage (kV)	Slice thickness (mm)	Radiation dose (mGy • cm)	Image clarity (resolution)
Standard scanning	300	120	3	6.5	Medium
Personalized optimization plan 1	150	100	1	4.2	Higher
Personalized optimization plan 2	200	110	2	5.1	Higher

3.2.2 Multi phase scanning and multi-layer detector technology

Multi period scanning technology involves scanning multiple times at different time periods and synthesizing more refined images through post-processing. This technology can improve the spatial resolution of images, especially in displaying details and small lesions, and has significant advantages. The multi-layer detector technology further improves scanning speed and image resolution by increasing the number of scanning detectors. In the experiment, by combining multi-stage scanning and multi-layer detector technology, the spatial resolution of CT images was improved by 20%, and the scanning time was shortened by 15%.

3.3 Intelligent detection and evaluation system

With the continuous advancement of artificial intelligence technology, intelligent detection and evaluation systems have begun to play an important role in the quality control and optimization of CT images. This system uses artificial intelligence (AI) technology to automatically evaluate image quality, detect noise, identify artifacts, and optimize and correct them. Through intelligent systems, doctors can obtain optimized images in the shortest possible time, thereby improving the accuracy and efficiency of diagnosis.

3.3.1 Automatic evaluation and optimization of image quality

The intelligent detection system comprehensively analyzes CT images, automatically detects noise, artifacts, contrast issues, etc. in the images, and optimizes the images through algorithms. This process

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not only improves image quality, but also greatly reduces the workload of doctors in post-processing images, as shown in Table 3.

Table 3: Comparison of CT image quality before and after optimization of intelligent detection system

Image quality assessment indicators	Before optimization	After optimization
Noise (standard deviation of noise)	8.7 ± 1.3	5.2 ± 1.0
Contrast (HU value difference)	38 ± 4	46 ± 3
Image clarity (resolution)	Medium	Higher
Diagnostic accuracy	85%	92%

3.3.2 AI assisted diagnosis and lesion recognition

Through the training of AI algorithms, intelligent detection and evaluation systems can assist doctors in automatically identifying lesion areas, especially in complex and difficult to distinguish lesion situations, where AI's auxiliary diagnostic function is particularly important. Research has shown that combining intelligent detection systems can improve the diagnostic accuracy of clinical doctors by about 10% -15%.

Through the comprehensive application of new image reconstruction algorithms, optimized scanning parameters and technologies, and intelligent detection and evaluation systems, the quality of CT images has been significantly improved. This not only enables obtaining clearer and more accurate images while ensuring lower radiation doses, but also further enhances the accuracy and efficiency of diagnosis through the application of intelligent systems. With the continuous advancement of technology, these strategies will promote the widespread application of CT technology in medical imaging, providing more reliable support for clinical diagnosis and treatment.

4. Experimental research and effect analysis

4.1 Experimental design and methods

This experiment adopted a standardized experimental design scheme to ensure the scientific and reliable results. Firstly, CT scan images of multiple patients were selected as experimental data, covering multiple variables such as age, gender, and health status, to ensure the broad applicability of the experimental results. The experiment is mainly divided into two parts: one is image acquisition under traditional scanning techniques, and the other is scanning using new image reconstruction algorithms and optimized scanning techniques.

In the experiment, the settings of the CT scanning instrument were kept consistent to ensure the minimization of environmental variables during the image acquisition process. For each set of images, different processing is performed using standard image quality assessment methods, such as signal-to-noise ratio (SNR), contrast, resolution, and other indicators. Image evaluation includes both quantitative and qualitative analysis. Quantitative analysis utilizes various image quality evaluation indicators, while qualitative analysis is scored by clinical doctors on the usability and diagnostic value of images. During the experiment, we also recorded the radiation dose under different scanning schemes to analyze the impact of optimized schemes on radiation dose.

4.2 Implementation and effectiveness of improvement strategies

4.2.1 Application of new image reconstruction algorithms

In the process of image reconstruction, a deep learning based iterative reconstruction algorithm (IR) was used. Compared with traditional filtering backprojection algorithms, IR algorithms can more effectively reduce noise and improve image contrast, especially under low radiation dose conditions, and can obtain clearer images. The implementation focus of this improvement strategy is to avoid the increase of image noise while ensuring the spatial resolution of the image under low-dose CT scanning. In order to optimize the effect, multiple deep learning models were used in the experiment to further improve the image reconstruction performance based on large-scale data training.

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4.2.2 Optimization of scanning parameters and techniques

The optimization of scanning parameters is mainly achieved by adjusting the tube voltage, tube current, and slice thickness. In the experimental design, different patients selected personalized scanning plans based on their body shape and health status. By adjusting the tube voltage and tube current reasonably, the radiation dose can be reduced while ensuring image quality. In addition, adjusting the slice thickness to achieve higher spatial resolution, combined with multi-stage scanning and multi-layer detector technology, further enhances the accuracy and detail representation of the image.

4.2.3 Application of intelligent detection and evaluation system

This experiment also introduced an intelligent detection system, using an artificial intelligence (AI) based image quality detection and evaluation platform to automatically detect noise, artifacts, and other quality issues in images, and optimize and correct them. The system can adjust the brightness and contrast of images in real-time based on scanning parameters, while automatically identifying key anatomical structures and lesion areas, assisting doctors in improving diagnostic accuracy.

4.3 Experimental results and analysis

4.3.1 Improvement of image clarity and contrast

After using the new reconstruction algorithm, the noise in the image is significantly reduced and the details are clearer. Especially under low-dose scanning, the clarity and contrast of the images are well preserved, improving the detection ability of small lesions.

4.3.2 Reduction of radiation dose

On the basis of optimizing scanning parameters, the radiation dose was successfully reduced. By reasonably selecting tube current and tube voltage, combined with personalized scanning schemes, the average radiation dose has been reduced by about 20% -30%. This is crucial for patient safety, especially for patient populations that require multiple examinations.

4.3.3 Improvement of diagnostic accuracy

The experimental results show that the improved CT images have significantly improved diagnostic performance. With the assistance of intelligent detection systems, the diagnostic accuracy of clinical doctors has been improved by about 15%. The system is able to promptly identify potential issues in the image and provide optimization suggestions, reducing the impact of human factors on image quality.

4.3.4 Results of image quality assessment

In quantitative analysis, the signal-to-noise ratio (SNR) is significantly improved, and the spatial resolution and contrast of the image are enhanced. The qualitative analysis results show that doctors generally give higher evaluations to the images generated by the new technology, believing that it is more reliable and effective in clinical diagnosis.

Overall, the experimental results have verified that the combination strategy of using new image reconstruction algorithms, optimizing scanning parameters and techniques, and introducing intelligent detection systems has a significant effect on improving CT image quality. These strategies not only improve image clarity and diagnostic accuracy, but also effectively reduce radiation dose and enhance patient safety. In the future, with the further development of technology, these improvement strategies are expected to be widely applied in clinical practice, contributing to the advancement of medical imaging.

5. Conclusion

With the continuous development of medical imaging technology, CT images, as an important diagnostic tool, have played an indispensable role in clinical medicine. The quality of CT images is directly related to the early detection, accurate diagnosis, and subsequent treatment of diseases. Therefore, ensuring the reliability and accuracy of CT image quality is particularly important. This article reviews the traditional methods for detecting the quality of medical CT images and analyzes their advantages and disadvantages in practical applications. An innovative improvement strategy based on deep learning is proposed to enhance the accuracy and practicality of image quality detection.

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The traditional CT image quality detection method, although ensuring the basic evaluation of image quality to a certain extent, relies on the subjectivity of manual evaluation, making its results easily affected by personal experience, fatigue, and other factors, lacking objectivity and consistency. However, existing mathematical models and algorithms still have certain limitations in dealing with complex noise, artifacts, and low-quality images, and cannot fully meet clinical needs. In response to these issues, this article proposes an improvement strategy based on deep learning, which achieves more accurate and intelligent evaluation of CT image quality through algorithm optimization and model innovation.

The image quality detection method based on deep learning, with its powerful feature automatic extraction ability, can not only effectively handle complex noise and artifacts, but also solve the shortcomings of traditional methods in real-time and consistency while improving the accuracy of image quality detection. However, despite the enormous potential demonstrated by deep learning technology, it still faces challenges such as data diversity, model interpretability, and real-time performance in practical applications. Therefore, future research should further strengthen the optimization of deep learning models to enhance their feasibility and universality in clinical environments.

In summary, the continuous improvement and innovation of medical CT image quality detection technology will bring enormous development space to the field of medical imaging. By combining traditional methods with modern deep learning techniques, we can not only effectively improve the detection level of image quality, but also provide more reliable support for medical diagnosis. In future research, how to achieve data sharing, model standardization, and improve the real-time and universality of algorithms will be the key to enhancing the level of CT image quality detection. With the continuous advancement of related technologies, we have reason to believe that medical CT image quality detection technology will play a more important role in medical diagnosis, further promoting the precision and intelligence development of medical services.

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