Experimental Study on Computer Simulation of CT Image Reconstruction

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Abstract. In recent years, CT technology has become increasingly mature. However, the existing CT imaging methods still have great difficulties in large object imaging, high resolution imaging and radiation dose reduction. In fact, many engineering applications do not require global CT imaging of a complete object, only the object images of some regions of interest can be obtained, especially in clinical medical diagnosis, as long as the image of suspicious lesions can be achieved. The theory of CT image reconstruction is the basis of medical imaging technology. In order to help medical imaging students better understand the idea of CT image reconstruction, this paper studies the method of CT image reconstruction for regions of interest. Three kinds of image reconstruction methods for projection data under different truncation modes are introduced. The corresponding numerical simulation experiments are designed and the numerical simulation results are given. Finally, the potential application of CT imaging technology in engineering is prospected.

Keywords: Computer Simulation, CT, Image Reconstruction

1. Introduction
Current mainstream CT algorithms are all global reconstruction methods for complete objects, requiring X-ray beams to completely cover the fault of the object, and it is difficult to deal with the case of truncated projection data. Therefore, when imaging large or irregular objects at present, it is often difficult to complete scanning directly. It is necessary to reconstruct the final image by approximate conversion methods such as data rearrangement after multiple scans, which has a negative impact on the speed and accuracy of CT imaging. On the other hand, medical irradiation has become the largest source of ionizing radiation for the whole people. Reducing X-ray dose of CT examination is of great significance to the health of the whole society and its descendants.

2. The technical basis of CT imaging
2.1. CT imaging technology
In recent years, the theory of CT reconstruction has made great progress. A cone-beam spiral CT precise reconstruction algorithm based on filter back projection has solved the problem of long object reconstruction well. In the case of Z-axis projection data truncation, the algorithm can still accurately reconstruct the object image of the scanned part. The improved BPF algorithm is used to solve the problem of accurate image reconstruction in semi-detector CT system when there is one end truncation in all angle projections\cite{1}. Ultrashort scanning and BPF algorithm can solve ROI imaging problems under certain conditions, which is the theoretical basis of ROI imaging research.

2.2. Image accurate reconstruction method based on ROI

The core problem of ROI imaging is to study the method of CT image reconstruction based on ROI. Then, according to the reconstruction method, the corresponding CT scanning scheme is designed for specific ROI imaging problems, that is, ROI imaging strategy. At present, ROI imaging theory is still based on PI line, which is slightly different from the original definition of PI line. Image reconstruction on PI line is the basis of ROI image reconstruction. Compared with FOV and object support, PI line can be reconstructed in three cases: two endpoints of PI line are outside the object support, as shown in figure 1 (a). This problem can be solved by using the traditional BPF method, but the BPF algorithm under the new orbit needs to be deduced again for the specific scanning orbit.

The PI line has only one end point outside the support of the object\cite{2}. As shown in figure 1 (b), this problem has been theoretically proved to be able to reconstruct accurately. ROI reconstruction can be achieved by POCs (Projections on Convex Sets) iteration method. However, POCs method is sensitive to projection noise, so it is necessary to solve the problem of stable reconstruction of POCs under noisy projection.

As shown in figure 1 (c), the problem is very difficult. Because the end points of PI line are all in the object support, the projection of each scanning angle of PI line is truncated, and the existing filtering back projection or back projection filtering methods cannot reconstruct the image. However, the existing iterative reconstruction algorithms, such as ART, EM, OSEM, cannot reconstruct the image on PI line because projection truncation cannot converge. This problem can be reconstructed by using POCs method and prior knowledge that constrains its convergence effectively.

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{figure1.png}
\caption{ROI imaging under different FOV}
\end{figure}

For different objects and ROI, according to the precise reconstruction method, corresponding CT scanning schemes can be designed. The X-ray beam widths at different positions in the scanning orbit can be different. Using these projection data of different widths, ROI images can also be accurately reconstructed\cite{3}. Compared with traditional global CT, this method of data acquisition and reconstruction can reduce imaging time, X-ray dose and artifacts in reconstructed images. The core of ROI imaging optimization is to design shorter scanning paths and narrower X-ray beam width for different ROI on the premise of satisfying CT reconstruction. Shorter scanning paths mean less scanning time and image reconstruction time. Narrow X-ray radiation width means less X-ray radiation dose, which is particularly important for medical diagnostic imaging.
3. Computer simulation experiment

3.1. Computer simulation results
Under the two-dimensional Tharox model, the above methods are studied by computer simulation experiments for different ROIs. Figure 2 (a) is the Tharox model. Figure 2 (b) is a selected circular ROI region, which is reconstructed only by X-ray projection from the ROI region. Figure 2 (c) is a selected rectangular ROI region, which is reconstructed iteratively using only X-ray projection from the ROI region and the known image information of the ROI inner region[4].

![Figure 2. Tharox model.](image)

Figure 3 is the reconstruction result of rectangular ROI region. Figure 3 (a)-3(d) uses POCS iteration method instead of TV (Total Variation) method, and iterates at different times. Figure 3(e)-3(h) uses POCS + TV iteration method at the same time, and iterates separately. From the results, it can be found that when only using POCS iteration method to reconstruct images, the results of image reconstruction do not always converge to a good result as the number of iterations increases. When TV iteration is added to POCS iteration process, the convergence process of reconstructed images is effectively controlled[3].

![Figure 3. ROI region.](image)

3.2. Computer simulation results analyses
These linear artifacts exist in the reconstructed image in the numerical simulation experiment. This is because the reconstructed process is completed on the PI line. Each different PI line corresponds to different PI line integral values, and the sensitivity of the integral values to the values is directly
reflected in the reconstructed results of the whole PI line[6]. On the one hand, the angle sampling density is not high enough in numerical simulation, and on the other hand, the algorithm has not been optimized accordingly. This part of the content and experimental verification using real CT data should be completed in the follow-up work.

4. Conclusion
From the current development trend, the traditional global CT reconstruction methods cannot meet all the needs of Engineering practice, especially for large and dynamic objects, which make it imperative to explore and study local CT imaging methods for ROI. At present, there are still many problems in the existing precise image reconstruction algorithm under projection truncation, so that it cannot be applied to the actual CT system. It is an urgent need to study the precise reconstruction method and imaging design of CT images based on ROI, which is of great practical significance in the fields of industrial Non-Destructive Testing (NDT), medical clinical diagnosis and so on. The reconstruction process in this paper can be seen as two parts: The back projection reconstruction and iterative optimization. Back-projection reconstruction only needs to be computed once, and the efficiency of implementation is the same as that of traditional filtering back projection method. Iterative optimization is accomplished on the back-projection reconstruction image, which does not involve forward/backward projection. It is completely carried out between the image domain and Hilbert domain, so its speed is much faster than that of the back-projection reconstruction, even if the TV iteration part is added. In addition, compared with the traditional global reconstruction, the total computation speed of this method is faster.

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