Removal of Artifacts in X-ray CT by Using Extended ROI

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Abstract

Filtered back projection (FBP) is widely used in commercial computed tomography (CT) algorithms. Using this principle, the reconstructed tomographical images usually contain streak artifact due to interpolation along projection lines. A simple method is proposed in this paper to reduce the streak artifacts. The method utilizes artifact information in extended region of interest (ROI). Numerical experiments using modified Shepp-Logan phantom shows that it reduces significant streak artifact.

1 Introduction

Computed tomography (CT) is a non-destructive technology for reconstructing the internal structure of an object by using its images projected from a series of perspectives [1]. Filtered back projection (FBP) algorithm is the most prevalent CT method due to its simple hardware realization and fast processing time. Although FBP originated from an analytical solution by Radon [2], it has some intrinsic limitations from practical implementation point of view.

In X-ray CT, line integration of attenuation is made known corresponding to different angles of projection. Mathematically it can be expressed by Equation (1), where $f(x, y)$ represents the attenuation of X-ray going through the internal structure in two dimensional plane, θ shows perspective angle of projection lines, and t corresponds to distance from origin to the projection line.

$$P_\theta(t) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} f(x, y)\delta(x\cos\theta + y\sin\theta - t)dxdy \qquad (1)$$

The objective of CT is to obtain tomographic image, i.e., $f(x, y)$ from projection data $P_\theta(t)$ along various angles θ. This inverse problem has unique analytical solution as proposed by Radon as given in Equation (2), where $S_\theta(\omega)$ is Fourier transform of $P_\theta(t)$. This reconstruction solution is known as the filtered back projection (FBP) CT algorithm.

$$f(x,y)=\int_0^{\pi} Q_\theta(x\cos\theta + y\sin\theta)d\theta$$

where

$$Q_\theta(t)=\int_{-\infty}^{+\infty} S_\theta(\omega)|\omega|e^{j2\pi\omega t}d\omega \qquad (2)$$

At first glance, the FBP algorithm seems to have provided an exact solution to the inverse problem of CT. However, errors exist because the integration process is usually implemented digitally and the filter with transfer function $|\omega|$ in frequency cannot be implemented in practice. In the reconstruction using FBP algorithm, interpolation is required along the radial direction because only discrete number of data is available in order to obtain reconstruction by using the limited number of projections. The interpolation introduces streak artifacts in the reconstructed image and in turn results in misinterpretation of tomography especially when the sample has a lot of line features. The streak artifacts are also significantly dependent on the object inside the region of interest (ROI). One simple way to remove the streak artifacts is to base the CT reconstruction on more projection images. However, by doing so one will increase the data acquisition time and the exposure time of the source which is usually radioactive. Acquiring more projection images may also introduce motion artifacts. Recently, it is shown that under certain specific conditions, the sum of images reconstructed from data collected within different sampling geometries is free of streak artifacts [3]. This method does reduce streak artifacts efficiently in certain case, but it requires collecting the projection data twice in each projection angle.

In this paper, we present a method to remove the streak artifacts in CT. The method utilizes artifact information in extended region of interest (ROI). Significant streak artifact reduction by using this method has been demonstrated by simulation using modified Shepp-Logan phantom.

2 Methodology

The proposed method performs the CT reconstruction over an extended region of interest (ROI) which encloses the object under reconstruction. The construction of an extended ROI is always feasible in general because the location of outermost object of interest is known after we obtain the reconstruction. Thus, we can always obtain the background of ROI by removing the region enclosing the object. Recalling analytical solution using FBP in Equation (2), it is clear that this background image is supposed to have zero or other prescribed values, as there is no object left in this region. Hence, it contains only the interpolation errors that are formed in the same way as those in the region enclosing the object. Hence, a filter that is designed to remove the artifacts in this extended ROI can also be used to remove the artifacts in the region enclosing the object. Based on this idea, we design a filter by analyzing the frequency responses of streak artifacts in extended ROI, and apply the filter to remove the streak artifacts in the reconstructed CT image.

3 Simulation result

In the paper, we demonstrated our idea by reconstructing a modified Shepp-Logan phantom as illustrated in Fig.1 which compares the regular FBP reconstructed image against the image obtained from the proposed method.

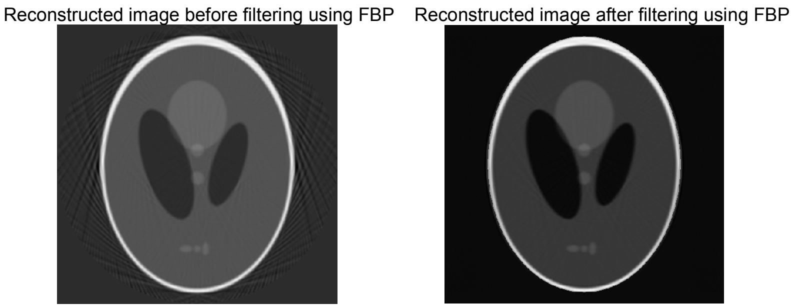

Fig.1 Removal the line artifacts in CT reconstruction (a) modified Shepp-Logan phantom (b) CT image after removal of artifacts

It is clearly shown that not only streak artifacts outside outermost ellipse but also the ones inside that ellipse are filtered out. Thus, the proposed method can significantly reduce the streak artifacts and hence it enhances the quality of reconstructed image. In addition, the proposed method does not increase the data acquisition time and it is simple to use in practice.

4 Conclusion

In this paper, a method of constructing an extended ROI is proposed to remove the streak artifacts in CT. It makes use of information of artifacts in the extended ROI to design a filter to remove artifacts inside ROI. Modified Shepp-Logan phantom is used to illustrate the feasibility of the method. It is shown that significant streak artifact reduction can be achieved by the proposed method. Compared to other methods for artifact removal, the proposed method does not require increasing data acquisition time and it is simple to implement in practice.

References:

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