Dictionary Learning based Low Dose Helical CT Reconstruction With Longitudinal TV Constraint

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***Abstract*— Multi-slice helical Computed Tomography (HCT) has been widely applied in clinical applications. Due to the potential radiation risk, it has attracted an increasing attention to reduce radiation dose while maintaining the diagnostic performance. Inspired by the longitudinal sampling inconsistencies of helical CT scanning, in this paper, we develop a statistical iterative reconstruction algorithm based on three-dimensional dictionary learning to improve image quality for low-dose HCT. The longitudinal Total Variation (TV) is added to change the image noise distribution. The classical distance-driven projection and back-projection models are employed to avoid artifact-inducing. To enhance the computational performance, Graphics Processing Unit (GPU) implementation, Order Subset technology and Nesterov's acceleration strategy are employed in our iterative reconstruction codes to accelerate the optimization. The Contrast Noise Ratio (CNR) index of reconstructed images and the subjective evaluation of medical practitioners all verify the superiority of our proposed algorithm.**

Keywords—low dose HCT; longitudinal constraint; dictionary learning; distance driven; GPU implementation

I. INTRODUCTION

Multi-slice helical Computed Tomography (HCT) has been widely used in clinical applications. With the increasing of helical CT scans, its potential radiation risk attracts increasingly public concerns. How to reduce radiation dose while maintaining the diagnostic performance is a hot topic in current CT field. Decreasing the X-ray flux towards each detector, which is usually implemented by adjusting the operating current of the X-ray tube, results in a reduced radiation dose. Analytic reconstruction algorithms such as filtered backprojection (FBP) have been extensively used for HCT image reconstruction because of their computational efficiency. These algorithms generally consider the cone-beam geometry by calculating equivalent image planes to minimize the error between the reconstruction plane and the projection ray paths in 2D back-projection step, such as ASSR [1], AMPR [2] or wFBP [3]. However, the reconstructed images suffers from noise and streaking artifacts which severely degrade image quality. While the performance of analytic reconstruction algorithms is insufficient for low-dose conditions, iterative techniques have a great potential to reconstruct better image quality with substantially reduced artifacts aided by certain prior information with the increased computational cost.

Considering the properties of received photon numbers on each detector cell in low dose cases, statistical iterative reconstruction (SIR) [4] optimizes the maximum-likelihood or penalized-likelihood function formulated according to the statistical characteristics of projection data, which promises high reconstruction quality from noisy projection data. Meanwhile, the addition of a stabilizing function in terms of a regularizer may further reduce noise and artifacts. It is very easy to incorporate some kinds of prior information of target images into the regularizer. This provides another tool to control image quality. Till now, many types of prior information have been proposed, including total variation (TV) [5], dictionary learning (DL) [6], and so on.

Considering the longitudinal sampling inconsistencies of helical scanning, in this paper, we develop a statistical reconstruction algorithm based on three-dimensional dictionary learning. The goal is to improve image quality of low-dose HCT by adding the longitudinal TV to change the noise distribution of the images. Our method consists of two components. The first component is the SIR routine that enforces the statistical knowledge of the projections. The second component is the dictionary penalty with the longitudinal TV as a prior information of the image space distribution. Furthermore, because the reconstruction accuracy is affected by mathematical affinity and similarity between the actual implementation of the forward and back-projection, the classical distance-driven model [7], which matched between the actual implementation of the forward projector and back-projector, is used to improve the performance of the entire iterative procedure. In the optimization procedure, we use a separable quadratic surrogate algorithm for Poisson loglikelihood function and Newton's gradient method for image update. Furthermore, the order subsets and the Nesterov's acceleration strategy [8] are used to accelerate the optimization. Besides, the proposed method is implemented in a Graphics Processing Unit (GPU) for efficient computing. The dataset supported by Low Dose CT Grand Challenge was employed to validate our proposed algorithm.

The rest of this paper is organized as follows. In the second section, the algorithm details are described. In the third section, the results are presented. Finally, some related issues are discussed and the conclusion is drawn.

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