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Exploiting symmetries for weight matrix design in CT imaging☆

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ABSTRACT

In this paper we propose several methods of constructing the system matrix (SM) of a Computed Tomography (CT) scanner with two objectives: (1) to construct SMs in the shortest possible time and store them in an ordinary PC without losing quality, (2) to analyze the possible applications of the proposed method to 3D, taking into account SMs' sizes, computing time and reconstructed image quality. In order to build the SM, we propose two new field of view (FOV) pixellation schemes, based on a polar coordinate system (polar grid) by taking advantage of the polar rotation symmetries of CT devices. Comparisons between the SMs proposed are performed using two phantom and a real CT-simulator images. Global error, contrast, noise and homogeneity of the reconstructed images are discussed.

1. Introduction

Algebraic Reconstruction Techniques (ART) for CT are based on the construction and resolution of systems of linear equations. The resolution of these linear equations, due to their size, is normally carried out using iterative methods, such as MLEM, Kaczmarz, OSEM, etc. Most of them produce high image quality, however, this technique type is not used in routine clinical computed tomography because of the high computational requirements. Since the SM is the core of the ART algorithms, the construction of the SM is crucial to providing accurate reconstruction. Usually, more precise SMs have higher computational cost and complexity which may become unfeasible in 3D.

In order to decrease computational complexity, a number of methods focused on exploiting the symmetries of SM have been proposed using polar pixels [1], blob grids [2–4]. Furthermore, several approaches are based on polar pixel grids for the Compton-camera [5], SPECT [1], commercial CT [6] and CT for medical imaging [7].

To obtain a CT image, many rotations are usually needed. The objective of polar discretization is to arrange the pixels on the FOV using a grid that reflects the geometry of the scanner. Thus, the pixel in a polar grid is a more natural discretization than square pixels and the quality of polar pixel images is better than in the equivalent Cartesian ones [7]. Moreover, each projection can be considered as the repetition of one rotated pattern.

Exploiting rotation symmetries in CT with a polar grid is a useful new technique which reduces computation time and data storage, and has been used for industrial applications [6] where keeping the spatial resolution of the scanner is not an essential requirement, and recently for medical applications [7].

As has been previously studied [7], pixels in a polar grid involve additional observations in medical applications:

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