Chapter 52
Comprehensive Survey on Metal Artifact Reduction Methods in Computed Tomography Images

Shrinivas D. Desai
B V B College of Engineering and Technology, India

Linganagouda Kulkarni
Vivekanad Institute of Technology, India

ABSTRACT

Over the past few years, medical imaging technology has significantly advanced. Today, medical imaging modalities have been designed with state-of-the-art technology to provide much better in-depth resolution, reduced artifacts, and improved contrast –to – noise ratio. However in many practical situations complete projection data is not acquired leading to incomplete data problem. When the data is incomplete, tomograms may blur, resolution degrades, noise increases and forms artifacts which is the most important factor in degrading the tomography image quality and eventually hinders diagnostic accuracy. Efficient strategies to address this problem and to improve the diagnostic acceptability of CT images are thus invaluable. This review work, presents comprehensive survey of techniques for minimization of streaking artifact due to metallic implant in CT images. Problematic issues and outlook for the future research are discussed too. The major goal of the paper is to provide a comprehensive reference source for the researchers involved in metal artifact reduction methods.

1. INTRODUCTION

Computed tomography (CT) has become an invaluable imaging tool for the diagnosis or further evaluation of various medical conditions. With evolving technology, decreasing acquisition times, and improving resolution, the usage of CT has increased tremendously over recent years.[1,2] It is estimated that more than 85 million CT scans were performed in the United States in 2011.[3] The increasing use of CT has been documented by a number of investigators.[4, 5] Trauma is one of the medical domains to attract wide usage of CT modality. In India more than 1.2 million patients are reported with trauma cases every year.

DOI: 10.4018/978-1-5225-0571-6.ch052

Among these trauma cases one common problem reported is streaking artifacts in CT images near the metal implant.

Metallic implants inside the legs, head, femur or teeth, aneurysm clips/coils(brain), dental fillings, pacer wires, surgical clips, bullet/shrapnel/lead shot, shoulder/hip/knee replacement, temporal neck screw, spinal rods, orthopedic plates, pedicle screws, depth electrodes (brain), cryoblation probes, iodinated contrast which cannot be removed from the body during CT study are reported to produces metal artifact.[6] Metal artifact comes from the fact that X-ray in the diagnostic energy range is strongly attenuated after passing through metal pieces, and much fewer signals are detected by the detectors in these regions. Beam hardening, scatter, noise, exponential edge gradient effect and under-sampling are reported to be the main causes of this metal artifact.[7] These artifacts deteriorate image quality and often superimpose structures of interest leading to prevention of recognition and management of complications of areas close to the implants.

Filtered Back Projection (FBP) algorithm is the most widely used reconstruction technique in X-ray CT, where transformations between the sinogram (projection) and image domains are performed using the forward and inverse radon transforms respectively.[8] The radon transform of a function $f\left(x,y\right)$, denoted as $g\left(s,\theta\right)$, is defined as its line integral along a line inclined at an angle θ from the y-axis and at a distance "s" from the origin. It is also called as sinogram and is written mathematically as:

$$g\left(s,\theta\right) = \int\int_{-\infty}^{\infty} f\left(x,y\right)\delta\left(xcos\theta + y \ \ sin\theta - s\right)dx \ \ dy \tag{1}$$

Given the sonogram $g\left(s,\theta\right)$, we would like to reconstruct the image described in (x, y) coordinates. Basically it works by subsequently "smearing" the acquired $g\left(s,\theta\right)$, across an empty plane. This is referred as simple back projection, and is given as:

$$f'\left(x,y\right) = B\left(g\left(s,\theta\right)\right) = \int_0^{\pi} g\left(x\cos\theta + y\sin\theta,\theta\right)d\theta \tag{2}$$

The simple back projection yields a blurry laminogram (reconstructed image from sinogram) that must be deconvolved by a filter to yield the original image. This shall be done by filtering the projections in the fourier domain and back projecting the inverse fourier transform of the result. A formal derivation of the FBP method uses the fourier-slice theorem as follows:

$$f\left(x,y\right) = \int_0^{\pi} d\varnothing p'\left(x \ cos\varnothing + y \ sin\varnothing,\varnothing\right) \tag{3}$$

where:

$$p'\left(\xi,\phi\right) = \int_{-\infty}^{\infty}\left|v\right|P\left(v,\phi\right)e^{-j2\pi v\xi}dv = p\left(\xi,\phi\right) * b\left(\xi\right) \tag{4}$$