Detection of Low-Dose CT Reconstruction Artifacts Using a Bi-Modal Approach

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Abstract

Low-dose Computed Tomography (CT) has the benefit of exposing patients to less radiation. However, low dose CT requires special reconstruction techniques to improve the clarity of the image. Unfortunately, these special reconstruction techniques often cannot remove all of the low- dose artifacts. It is important to recognize these artifacts else we run the risk of obscuring important detail or adding false features. In this work, we present a simple scheme which allows us to detect these artifacts. Our technique applies to the specific low-dose CT strategy in which the number of X-ray views taken from the patient is reduced. The first step uses directional interpolation in the low dose sinogram to add more views. While the image created from this interpolated sinogram does not have any artifacts it lacks significantly in clarity due to blurring. Our scheme then compares this image with the image created with a low-dose CT reconstruction technique which has better detail but also some remaining artifacts. The comparison reveals these artifacts which we then remove by simple pixel replacement.

Introduction

Computed Tomography (CT) requires dense angular sampling of views in order to reconstruct an object. For parallel beam sampling the relation between the number of views N and the number of rays per view M has the relation, $N = \frac{M\pi}{2}$ [1]. If the number of views is too small, streak artifacts begin to show in the result [1][2]. Lately there has been a lot of emphasis on low-dose CT because it exposes patients to less radiation. However as explained previously image quality suffers in low dose. Various reconstruction techniques are used to improve the clarity of the image. One technique is interpolation, where we increase the sample density by using angular interpolation. This was first investigated by Weiss *et al.* [3], which focuses on linear interpolation. Bertram *el al.* [4] investigate the use of directional interpolation.

Other than linear interpolation there are various other methods such as Total Variance (TV) minimization[5]. The algorithm can be divided into two steps, in the first step we use an iterative formula to update a reconstruction image for data discrepancy reduction, in the second step we use a search method is used iteratively for TV minimization. There is a possibility that these techniques might introduce artifacts to the image. It is thus important to identify these artifacts otherwise we run the risk of obscuring important detail.

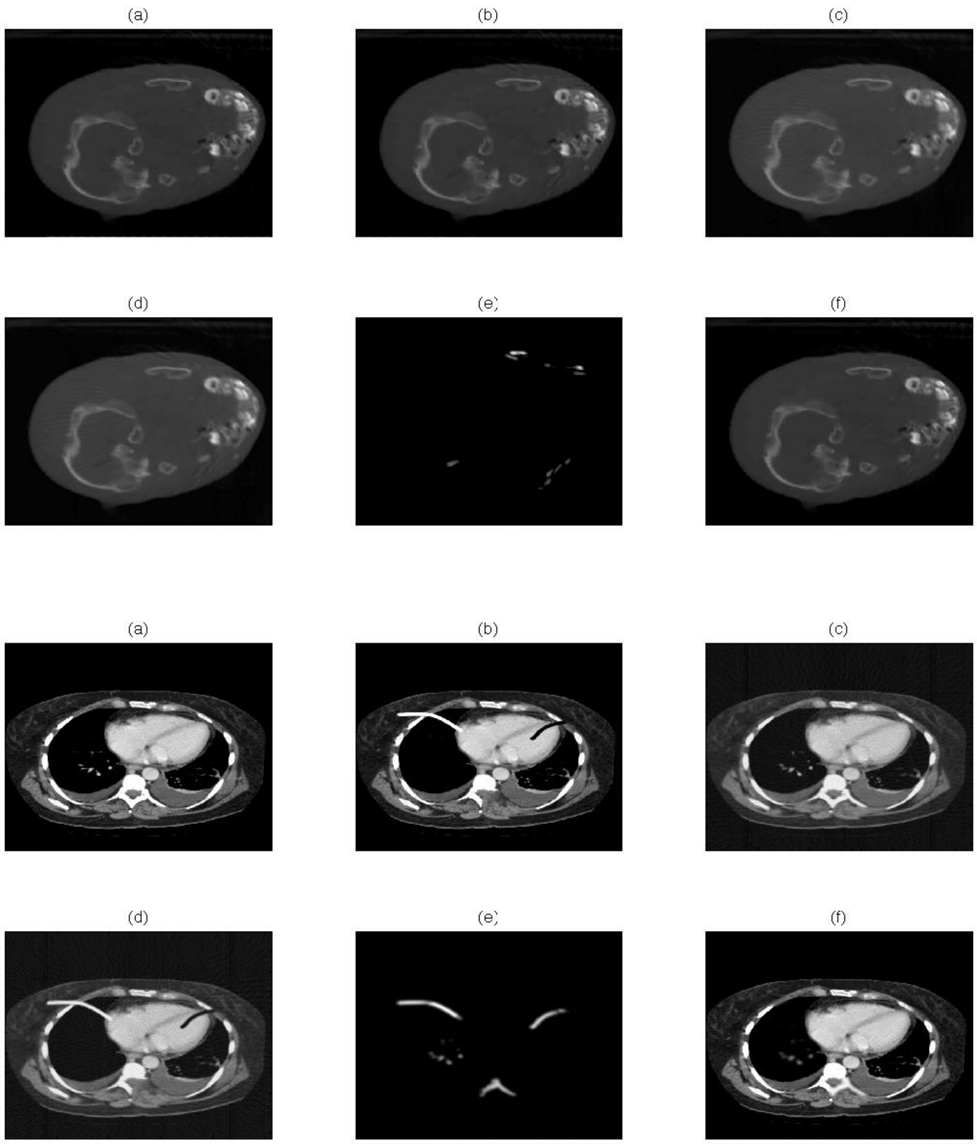

Figure1. In these images (a) is the original CT image, (b) the reconstructed image, (c) the directional interpolation of the original image, (d) the directional interpolation of the reconstructed image, (e) the difference between (c) and (d) and (f) is the final output.

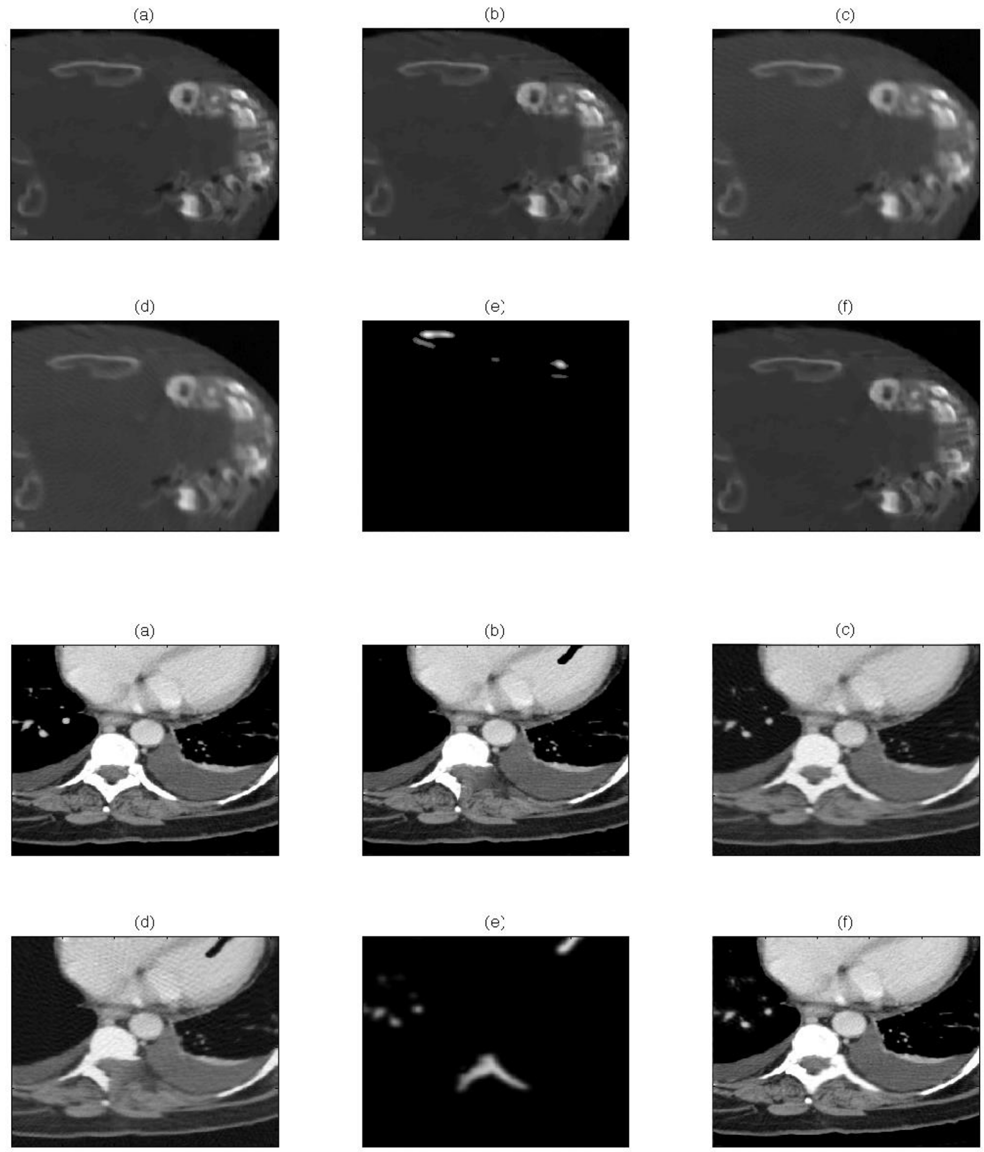

Figure2. In these images (a) is the original CT image, (b) the reconstructed image, (c) the directional interpolation of the original image, (d) the directional interpolation of the reconstructed image, (e) the difference between (c) and (d) and (f) is the final output.

Detection of Artifacts

The method we propose is based on the observation that regularization works in the object domain and takes advantage of the coherency in the local domain. Directional interpolation of a sinogram on the other hand is a global procedure. Regularization might mistake artifacts for features whereas the interpolation does not see small features.

We apply the directional sinogram interpolation on the low-dose sinogram. In the directional sinogram interpolation [4] process the value of an intermediate point is determined by first determining the interpolation weights of the support points in its neighborhood. For all points y the interpolation weights w are calculated using the following equation

$$w(y) = \frac{1}{|\Delta|}.(1 + \frac{\sum_{i=1}^{2}(\lambda_i . e_i . e_\Delta)^2}{c.\sum_{i=1}^{2}\lambda_i^2})$$

Here $y\Delta = y - x_0$ is a vector between the interpolation site and the point to be weighed c > 0 is a constant, and $e_\Delta = \frac{\Delta}{|\Delta|}$. The interpolated gray value $g(x_0)$ is calculated from the points in the region defined by E as a weighted average

$$g(x_0) = \frac{\sum_{y \in E} w(y).g(y)}{\sum_{y \in E} w(y)}$$

The sinogram we get from the interpolation process is then converted to an image. This image doesn't contain any artifacts but it is a little blurry. We will use this image as a reference point to find artifacts in the reconstructed image. In order to make an accurate comparison between this image and the reconstructed image we will apply the same process to the reconstructed image. The reconstructed image is converted into a sinogram. Some projections from the sinogram are removed such that now it has the same projections as the original low-dose sinogram. We apply directional interpolation on the sinogram and then recreate the image from this sinogram.

Finally we subtract the two images from each other. The difference between the two images will show the artifacts in the reconstructed image. The artifacts can be removed by any post processing technique. In the examples we have used pixel replacement to remove the artifacts. For each pixel in the reconstructed image which is detected as an artifact,
This method is explained in Figure 3.

Experiments

The results of this process are shown in Figure 1 & 2. Figure 1 is obtained after reconstruction with Non-Local Means (NLM) [6]. In Figure 3 which we have added some noticeable streaks and some parts of the image have been changed. Image (a) shows the original image, image (b) shows the reconstructed image. Image (c) is obtained after directional interpolation in the original low-dose sinogram. The original sinogram had 90 views, by using directional interpolation we increased this to 180 views. We observe that although the image is blurry there are no artifacts in the image. Image (d) shows the reconstructed image after it has been recreated using directional interpolation. Image (e) shows the difference between the two images. Image (f) shows the result after the reconstructed image is corrected using the results in image (e). Figure 5 &6 show enlarged versions of the same images.

The biggest questions related to this method are its resistance to the size of the artifact and it's resistance to the contrast with the background. In order to test these we tested this data on the phantoms in Figure 4. In the first row the minimum thickness of the streak is 1 pixel and the size of each subsequent streak is

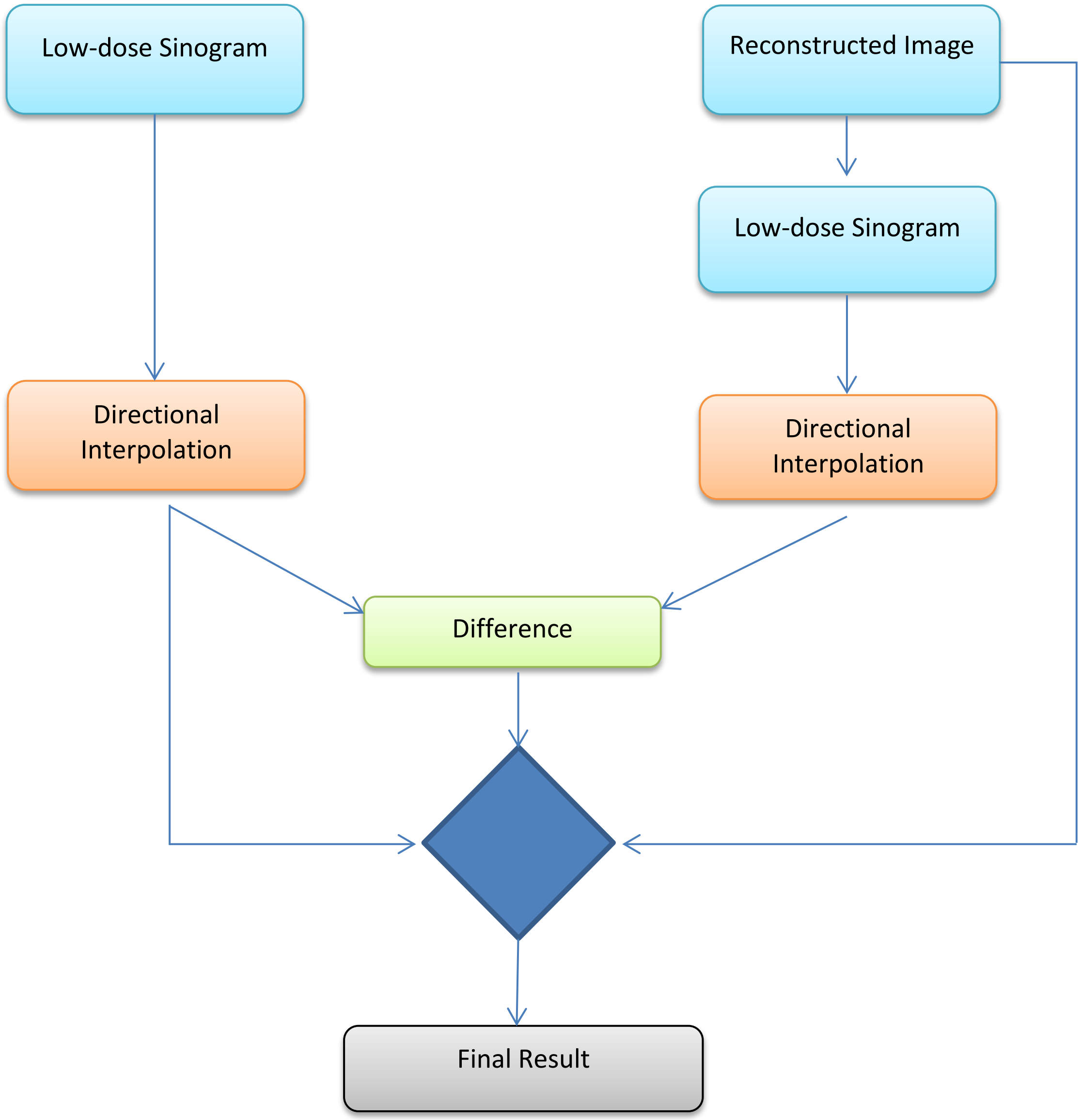

Figure3. This image shows the working of the method

increased by a pixel. It is clear from part c in the image 1 that this method is able to recognize artifacts; however the artifact with thickness 1 pixel is not immediately apparent in part (d) of image 1. This is because of blur introduced by directional interpolation method and also because the thickness of the line is only 1 pixel. In the second row the minimum contrast change is 2 and for each subsequent streak the contrast is increased by 2. In part (3) of image 2 we can see that method fails when the contrast between the background and the artifact is 2. However the method is able to recognize artifacts with a greater contrast.

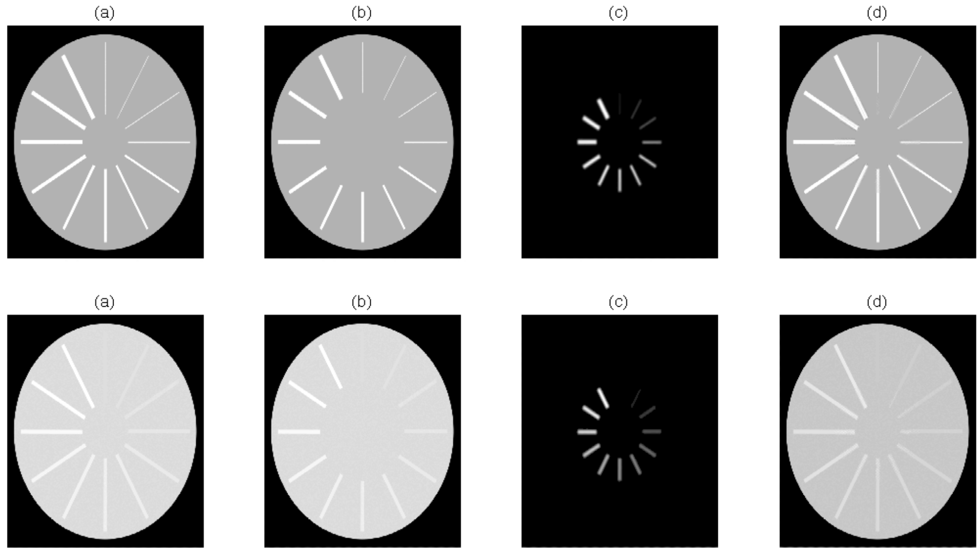

Figure4. In these images (a) is the original CT image, (b) the reconstructed image, (c) the location of the streaks (f) is the final output.

Conclusion

Directional Interpolation is a very useful tool in the identification of artifacts. Al- though Directional Interpolation does not produce clear results, it can be very helpful in identifying remaining artifacts which can then be taken care of with additional post processing.

Bibliograpy

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