Comparison of Image Reconstruction Algorithms in Low Dose Computed Tomography

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Abstract- *Nowadays, 3D cone beam Computed Tomography is sorely investigated field. This paper we analyze FDK Algorithm for 3D cone beam reconstruction with flat detector method image quality. To increase the angular steps between the projections, it allows dose reduction and shorter acquisition time. In addition to this, compares the three such CBCT image reconstruction algorithms, the FDK, MLEM and the SART, in terms of their performances when a limited number of projections are used. To compare the performance of different filters used in FDK reconstruction method.*

Keywords- Computed tomography, Image reconstruction, Reconstruction algorithms, and Projection algorithms.

I. INTRODUCTION

Over the last few years, Cone Beam Computed Tomography has attracted increasingly interest in medical imaging. Compared to CT scanners, it equipped with 2D detector provide more efficient sampling and faster data acquisition for 3D reconstruction. Important Advantages in X-ray tomography is reconstruction using a limited number of projections. Thus the X-ray dose to the patient can be decreased while the acquisition time is reduced.

Many reconstruction algorithms are available for cone beam reconstruction. The most popular is the Feldkamp-davis-kreiss (FDK) algorithm. In which the 2D fan beam Filtered Back projection (FBP) is generalization to 3D. FDK is an approximate reconstruction algorithm that requires number projections taken around 360◦.

Algebraic approaches to provide better results when a limited number of projections are used. We choose Simultaneous Algebraic Reconstruction Techniques (SART). We expected to be more efficient in implementation than other algorithms. It could be a method of considerations if provide better performances than FDK.

Iterative Reconstruction Algorithm which can reduce the X-ray dose. The MLEM (Maximum Likelihood Expectation maximization) algorithm can achieve high image quality.

This Paper aims to investigate the performance of FDK, SART and MLEM methods for CBCT reconstruction in case of limited number of projections.

II. MATERIALS AND METHODS

The FDK is an analytical reconstruction method. It involves Three steps are 1) Generate weighted projection data, 2) Filter projection images row-wise, 3) back project the filtered projection data into the volume.

In SART technique reconstruction involves where the unknowns are the image function values, to solving the linear equation iteratively.1) Initial guess f(0), 2) Estimated image f(k), 3) Forward projection for the estimated image, 4) To compare forward projection and measured projection, 5) Correction term in projection space, 6) Back projection for the image, 7) Correction term in image space, 8) Update the estimated image.

In MLEM technique involves the reconstruction, 1) Estimate the slices, 2) Forward projection for the estimated image slices, 3) To divide the estimated projections and measured projections, 4) Back projection for ratio projections, 5) Update the estimated slices with ratio slices.

The performances of these three techniques for reconstructing volumes were investigated. The projections were limited over 360◦ which has been show to provide acceptable error and reduce the acquisition time.

The following categories were studied for these three reconstruction methods.

Mean Square Error (MSE) is a criterion and the choice is the one that minimizes the sum of squared errors due to bias and due to variance.

$$\text{MSE(f,g)}=\frac{1}{mn}\sum_{i=0}^{m-1}.\sum_{i=0}^{n-1}[f(x,y)-g(x,y)]^2$$

Where f(x,y) is the original image and g(x,y) is the reconstructed image and M,N are the rows and columns of input image.

Peak Signal to Noise Ratio (PSNR) is defined as the ratio between the original image and the power of distorting noise that affects the quality of its representation.

$$PSNR(f,g)=20\log(maxN)/(\sqrt{MSE})$$

Mean Absolute Error is defined as in any dimension is the mean error magnitude of the corresponding direction.

$$MSE(f,g)=\frac{1}{N}\sum_{i=1}^{N}[f(x,y)-g(x,y)]$$

Normalized Absolute Error (NAE) is given by,

$$NAE(f,g)=\frac{1}{k}\sum_{k=1}^{K}\frac{\sum_{i,j=0}^{N-1} f(x,y)*g(x,y)}{\sum_{i,j=0}^{N-1} f(i,j)^2}$$

Where f(x,y) is the original image and g(x,y) is the reconstructed image and M,N are the rows and columns of input image.

III. RESULTS

Figures present the FDK, SART and MLEM reconstruction when three different projections were used. Fig1. Shows the input image generated from CBCT.

Table shows Comparison of the performance characteristics NAE, MSE, PSNR for FDK, SART and MLEM reconstruction algorithms.Fig2. Shows the FDK reconstructed image for the generated CBCT image.

Fig3.Shows the SART reconstructed image for the generated CBCT image. SART provided better results than FDK. Because, it involves repeated projection and back projection operation and it requires more reconstruction time than FDK.

Fig4. Shows the MLEM reconstructed image for the generated CBCT image. MLEM also provided better results than FDK. Because, it requires more reconstruction time compared with SART.

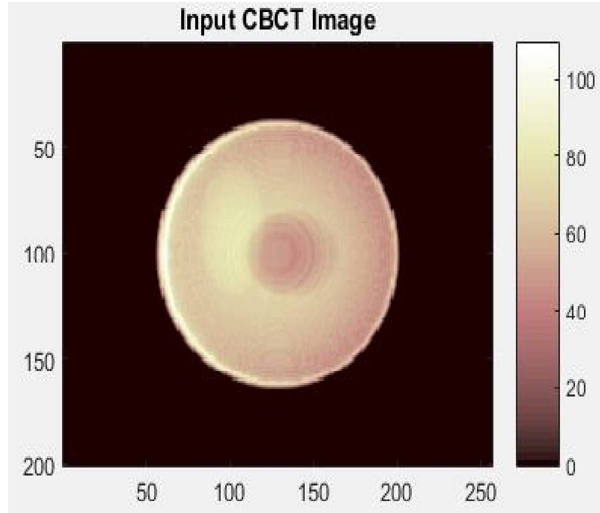

Fig1. Input Image from Cone Beam Computed Tomography

Images affected by the image artifacts. The different image artifacts are artifacts by patient, metal detector etc…

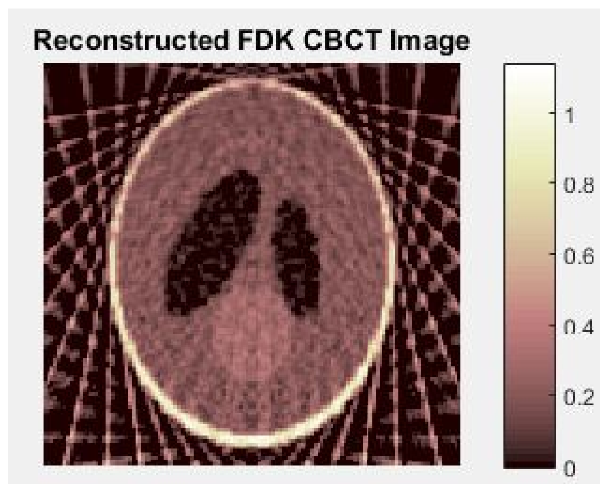

Fig2. Reconstructed Image Using FDK method

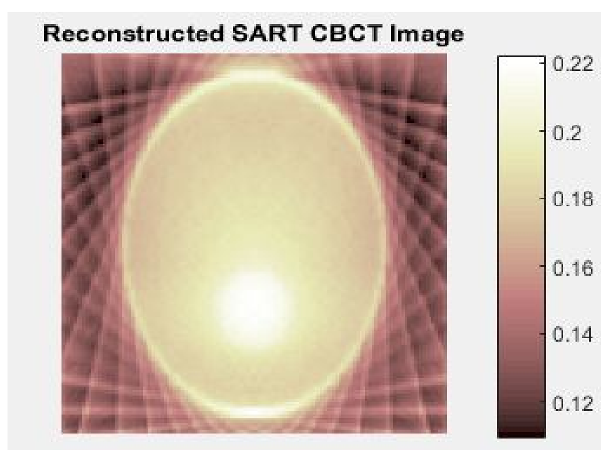

Fig3. Reconstructed Image using SART Method

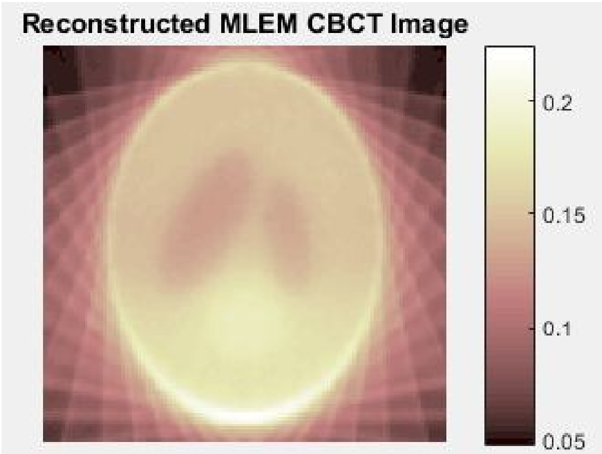

Fig4. Reconstructed Image using MLEM Method

These artifacts are removed by using the limited angle projections. The projection value depends on the directions (clockwise or anticlockwise), angular step size, Angle. The measurement values differ for the corresponding projection value.

TABLE1. Shows for the performance comparison between the FDK, SART and MLEM for the projection value=19 (Angle=180◦, Anti-clockwise direction, Angular step size=10).

TABLE2. Shows the performance comparison between the FDK, SART and MLEM for the projection value=43 (Angle=210◦, Clockwise direction, Angular step size=5).

TABLE3. The performance comparison between the FDK, SART and MLEM for the projection value=121(Angle=360◦, Clockwise direction, Angular step size=3).

The Measurement values also differ for the corresponding filter (ram-lak, cosine, hamming, hann , sheep-logan) change in the give setup.

TABLE4. Shows the measurement values differ for the FDK with corresponding filter.

The image artifacts are produced by longer acquisition time. It also affected the machine by heating. These disadvantages are overcome by SART method. It allows dose reduction and shorter acquisition time. MLEM only allows particular projections. It also reduces the dose of X-ray and shorter time for projection. The filters are used to remove the unwanted noise in the generated CBCT image. Filter optimization also one of the major problem in CBCT.

The major disadvantages are it requires to measure impulse response by the additional scan. Then, for a specific system, analytically derives the filters. It has not been generalized for other geometrics. We provide general scheme to estimate the set of filters without knowledge about the projection data during the reconstruction process to solve the problem of filter optimization.

TABLE1. The performance comparison between the FDK, SART and MLEM for the projection value=19(Angle=180◦, Anti-clockwise direction, Angular step size=10).

Angle : 180◦
Angular Step Size : 10
Direction : Anti Clockwise
Projection Value : 19

PARAMETER	FDK	SART	MLEM
MAE	0.0614	0.2145	0.9168
NAE	1.9474	15.2629	0.9168
MSE	1	1	1
PSNR	9.6262	9.6262	9.6262
MD	0.8392	0.4432	1

TABLE2. The performance comparison between the FDK, SART and MLEM for the projection value=43(Angle=210◦, Clockwise direction, Angular step size=5).

Angle : 210◦
Angular Step Size : 5
Direction : Clockwise
Projection Value : 43

PARAMETER	FDK	SART	MLEM
MAE	0.0539	0.2145	0.9186
NAE	1.1416	15.2629	0.9186
MSE	1	1	1
PSNR	9.6262	9.6262	9.6262
MD	0.7123	0.4432	1

TABLE3. The performance comparison between the FDK, SART and MLEM for the projection value=121(Angle=360◦, Clockwise direction, Angular step size=3).

Angle	: 360◦
Angular Step Size	: 3
Direction	: Clockwise
Projection Value	: 121

PARAMETER	FDK	SART	MLEM
MAE	0.0497	0.9193	0.9186
NAE	0.8419	0.9193	0.9186
MSE	1	1	1
PSNR	9.6262	9.6262	9.6262
MD	0.8710	1	1

TABLE4. Shows the measurement values differ for the FDK with corresponding type of filter

FILTER TYPE	Cosine	Hanning	Hamming	Ram-Lak
MAE	0.0497	0.0526	0.9168	0.0484
NAE	0.8419	0.8388	0.9168	0.8827
MSE	1	1	1	1
PSNR	9.6262	9.6262	9.6262	9.6262
MD	0.8710	0.8568	1	0.8949

IV. CONCLUSIONS

Thus the SART and MLEM method are proved to give better results than FDK, when a limited number of projections were used for 3D CBCT reconstruction. Such cases are considering the dose reduction as well as faster acquisition time.

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