Fan Beam Reconstruction Algorithm for Shepp Logan Head Phantom and Histogram Analysis

Nitin Kothari
CTAE, Udaipur
Ph.D. Scholar
Department of ECE

Sunil Joshi, Ph.D
CTAE, Udaipur
Professor & Head
Department of ECE

Navneet Agrawal,
Ph.D
CTAE, Udaipur
Assistant Professor
Department of ECE

P.C. Bapna, Ph.D
CTAE, Udaipur
Associate Professor
Department of ECE

ABSTRACT

Computer tomography has become a most important area in biomedical imaging system to reconstruct 3D image. Several exact CT reconstruction algorithms, such as the generalized filtered-back projection and back projection-filtration methods and fan beam reconstruction algorithm have been developed to solve the long object problem. Although the well-known 3D Shepp–Logan phantom is often used to validate these algorithms, it is deficient due to the discontinuity of the SLP. The need for a practical method of reconstruction gave rise to the back projection technique [1]. There are two method of filter back projection the first method back projection the measurements at each projection are projected or `smeared' back along the same line.

The other method is filtered back projection is still the standard technique in commercial scanners used to correct the blurring encountered in back projection method.

A basic difficulty in imaging with X-rays is that a two-dimensional image is obtained of a 3D object. This means that structures can overlap in the last image, even though they are completely separate in the object. This is particularly worrying in medical diagnosis where there are many anatomic structures that can interfere with what the physician is trying to see. Thus filter back projection algorithm is the easiest way to reconstruct the image.

In this paper present Fan Beam projection data of Shepp-Logan head phantom was created using the arc fan sensor geometry with an angular beam spacing of 0.05, 1.75, 1 .25, 2.75 and 3 degrees using the Fan Beam algorithm. The results were implemented for the CT scan test image using MATLAB 7.5.0 (R2007b) software. The image quality was found to be dependent on the beam spacing. It was observed that the image reconstructed for lower angular beam spacing had a better visualization as compared to those for higher angular beam spacing. Further, the image quality was found to be optimum between the 2 angular beam spacing of 0.15 and 0.75. The image quality of test image was found appreciably degrade to higher values of angular beam spacing as well as lower values of angular beam spacing from optimum values.

Keywords

X-rays, computer tomography, filter back projection, fan beam projection, Histogram

1. INTRODUCTION

The word "tomography" is resultant from the Greek letter tomos meaning slice or section and graphein meaning to write. Computed axial tomography was originally known as the "EMI scan" as it was developed at a research branch of EMI. It was also identified as computed axial tomography

Computed tomography is a medical imaging method employing tomography created by computer processing Digital geometry processing is used to generate a 3D image of the inside of an object from a large series of 2D X-ray images taken around a single axis of rotation [6].

Computed Tomography scanning uses special X-ray equipment to generate multiple views of the inside of the body these multiple X-ray views are reconstructed into cross-sectional images of the body using computer systems [8]. Radiologists use CT scan imagery to more easily diagnose medical problems such as some cancers, cardiovascular disease, trauma, and musculoskeletal disorders.

2. FILTER BACK PROJECTION

The need for a practical method of reconstruction (i.e. performing the inverse radon transform) gave rise to the back projection technique. In back projection the measurements at each projection are projected or `smeared' back along the same line as in figure 1and 2.
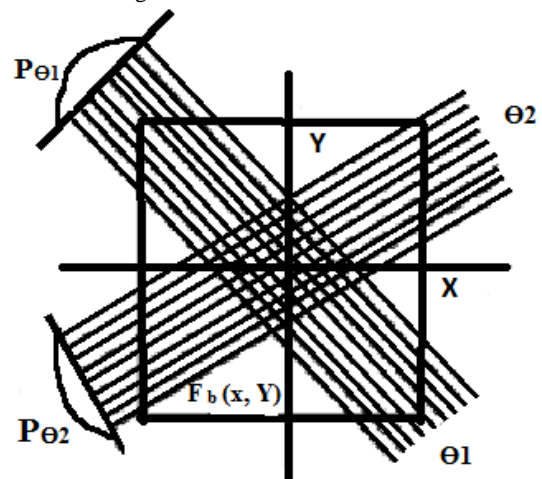

Fig 1: Filter back projection process. These two projections are added together where they overlap to form the summation image

Filtered back projection is a technique to correct the blurring encountered in simple back projection. As illustrated in Fig. 2, each view is filtered before the back projection to counteract the blurring PSF. That is, each of the one-dimensional views is convolved with a one-dimensional filter kernel to create a set of filtered views. These filtered views are then back projected to provide the reconstructed image, a close approximation to the "correct"
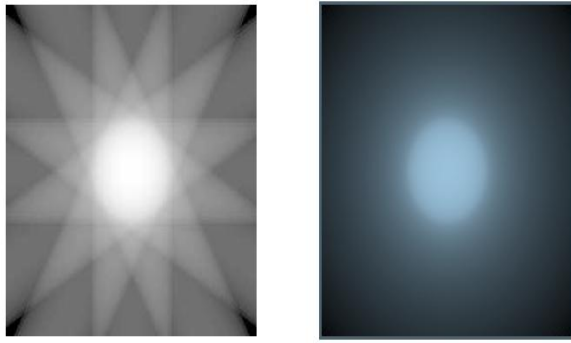
(a)   (b)

Fig 2: Filtered back projection reconstructs an image by filtering each view before back projection (a) using six views (b) using many views.

In fact the image produced by filtered back projection is identical to the "correct" image when there are an infinite number of views and an infinite number of points per view. When there are an infinite number of views and an infinite number of points per view [2].

The image in this example is a uniform white circle surrounded by a black background. Each of the acquired views has a flat background with a rounded region representing the white circle. Filtering changes the views in two significant ways. First, the top of the pulse is made flat, resulting in the final back projection creating a uniform signal level within the circle. Second, negative spikes have been introduced at the sides of the pulse. When back projected, these negative regions counteract the blur.

The filtered back projection involves following steps:
(i) One method is to find the 2D Fourier transform of equation 1.1, weight the result with the 2D transform of the reciprocal of 1=r and then perform an inverse transform of the product. This is a de convolution, and gives rise to interpolation errors in the Fourier domain.

$$f_b(x,y) = f(x,y) ** \frac{1}{r}$$

(1)

(ii) The other method is to use filtered back projection it can be shown that f $_b$(x; y) results when each projection has been weighted by w-1, as mentioned above. The $\bar{x}$ for this is to pre-weight the Fourier transform of each 1D projection with $|w|$ prior to back projecting. This is known as filtering the projections and is still the standard technique in commercial scanners. This method is efficient because it only involves a one-dimensional Fourier transform, and the FFT algorithm is used in practice [3][5].
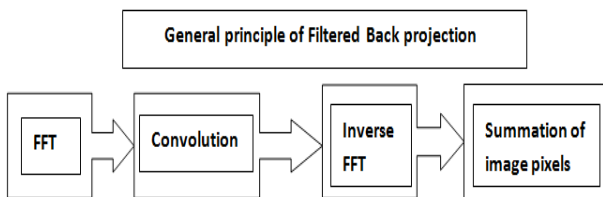

Fig 3: General principle used in filtered back projection

(iii) The result is inverse transformed and then back projected.

3. FANBEAM RECONSTRUCTION ALGORITHM

A much faster approach to generate the line integrals is by using fan beams projection. There are two categories of fan projections depending upon whether a projection is sampled at equiangular or equispaced intervals. This is shown in fig4.

If the detectors for the dimension of line integrals are set on the straight line D1D2, this implies unequal spacing between them however the angle between rays is constant. If the detectors are set on the arc of a circular arm whose centre is at S, they may now be positioned with equal spacing along this arc the second one of fan projection is generated when the detectors are rotated such that they shift by equal angular displacements along the arc centered at S
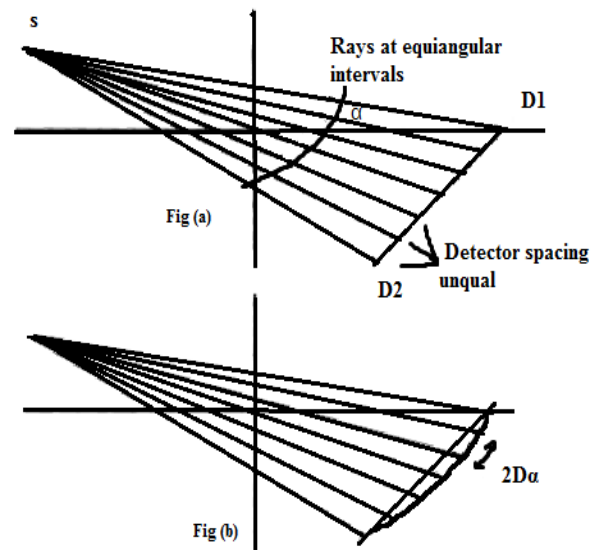

Fig 4: Detector positions used in fan beam projection in (a) equiangular mode and (b) equispaced mode

4. SIMULATED RESULTS

The reconstruction of 3D Shepp–Logan phantom image from fan-beam projection data has been implemented in MATLAB 7.5.0. The fan-beam projection data was created using the arc fan sensor geometry, with beams spaced at 1 degree angles and projections taken at 1 degree increments over a full 360 degree range [4]. The Shepp-Logan head phantom image is processed in MATLAB which illustrates many of the qualities that are found in real-world topographic imaging of human heads [7].

Histogram modeling through spatial domain technique is of utmost importance in digital image processing since histogram of image provides global description of the appearance of Shepp Logan head phantom. Hence, we have also written the code for generating the histograms of the images obtained at various arc fan sensor spacing using MATLAB 7.5.0. (R2007b) Histogram of image represents the relative frequency of occurrence of the various gray levels in a reconstructed image. Thus using MATLAB codes for histogram we provide better graphical representation of different angle of rotation of the fan beam algorithm for easy analysis for small change in rotation angle.
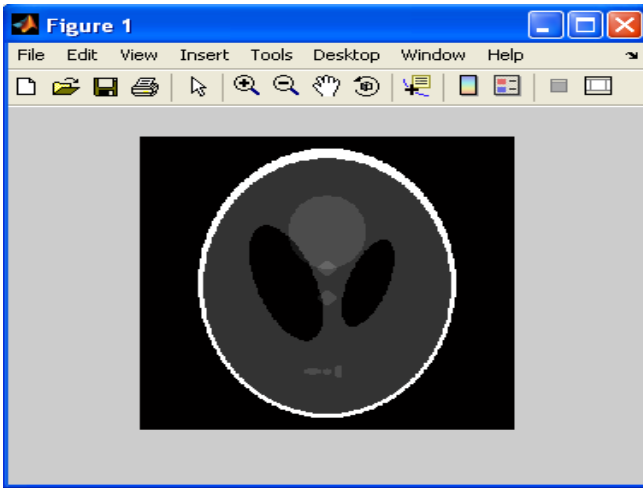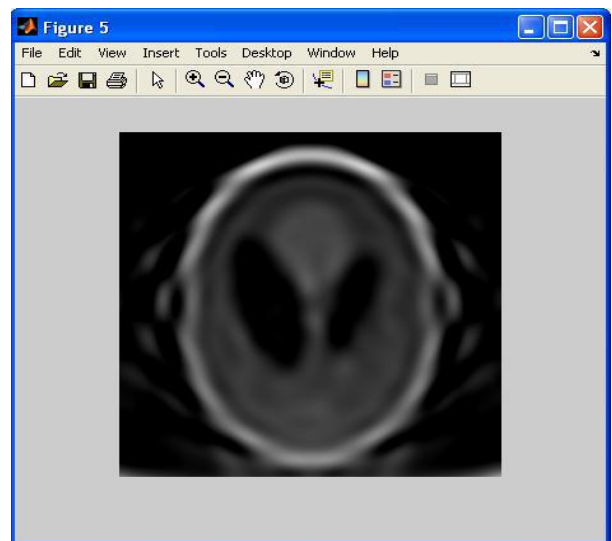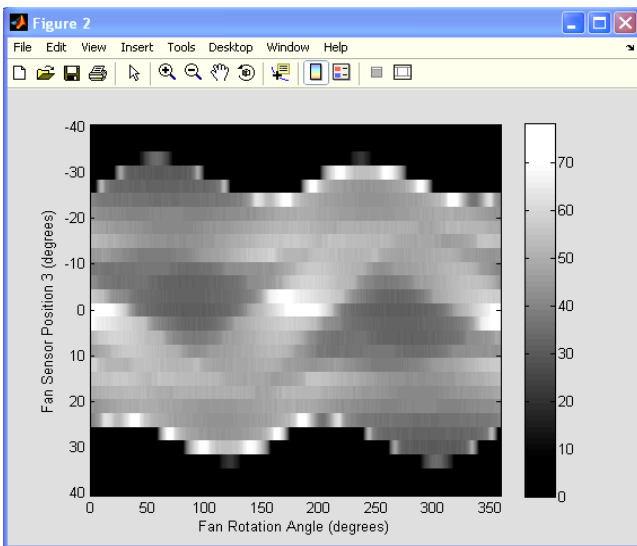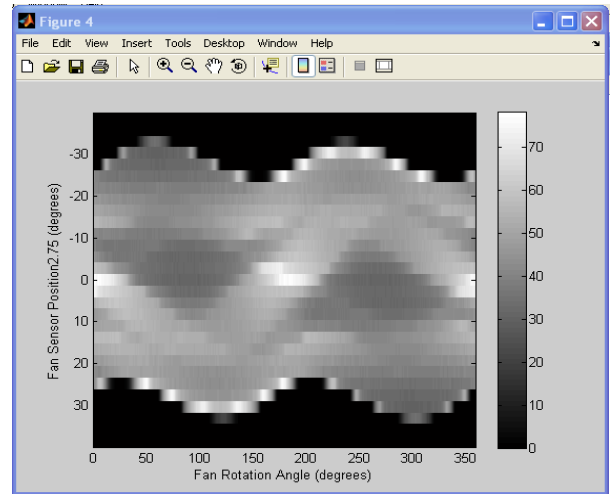
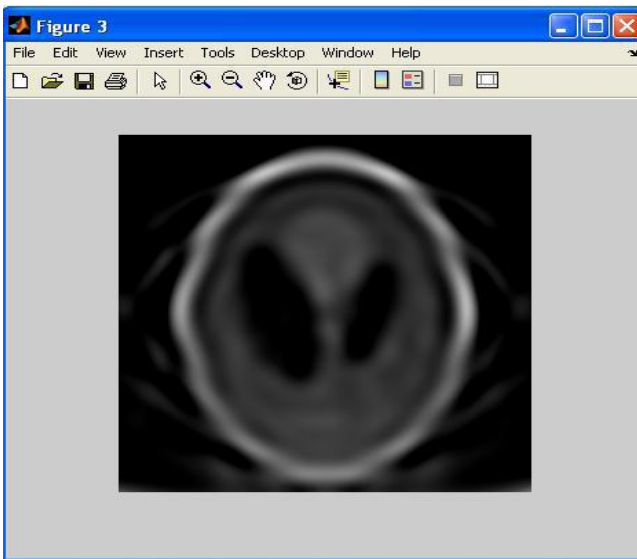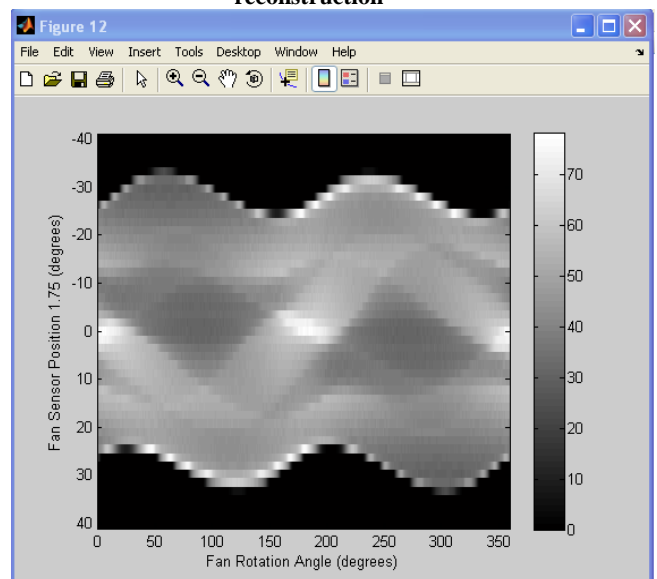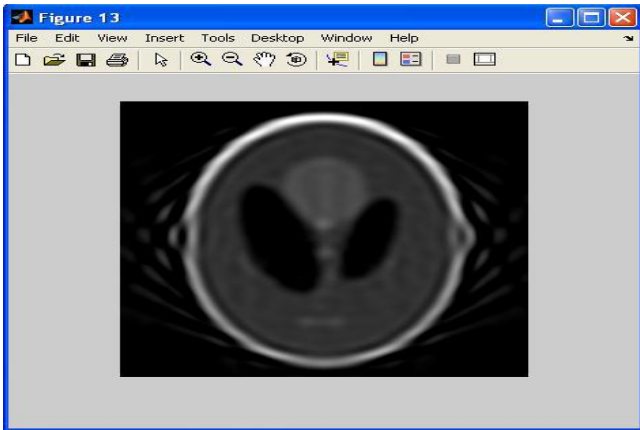**Fig 5: Shepp-Logan Phantoms**

Fig 6: Projection of Fan Beam at 3 degree Fan Sensor Positions and its Shepp Logan head phantom image reconstruction

Fig 7: Projection of Fan Beam at 2.75 degree Fan Sensor Positions and its Shepp Logan head phantom image reconstruction

Fig 8: Projection of Fan Beam at 1.75 degree Fan Sensor Positions and its Shepp Logan head phantom image reconstruction
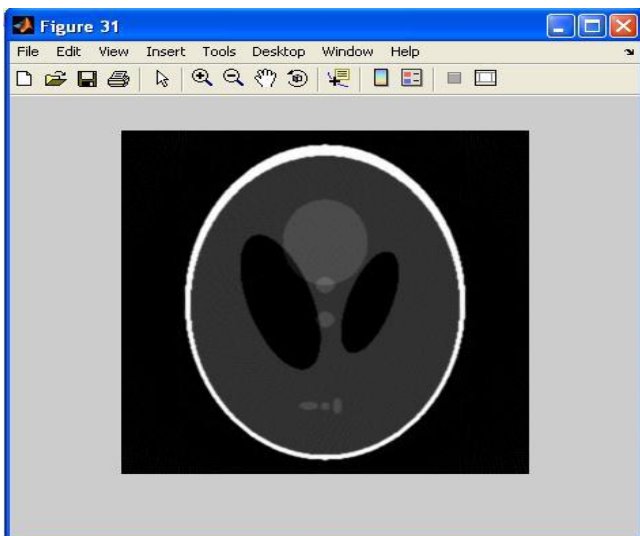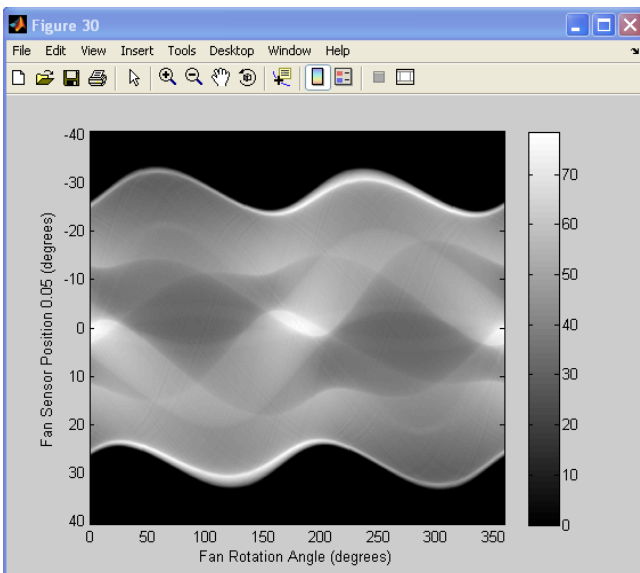

Fig 9: Projection of Fan Beam at 0.05 degree Fan Sensor Positions and its Shepp Logan head phantom image reconstruction

Thus Histogram of test image represents the relative frequency of occurrence of the various gray levels. MATLAB tool utilized to write the code for histogram it provides better graphical representation of different angle of rotation of the fan beam algorithm for easy analysis for small change in rotation angle.
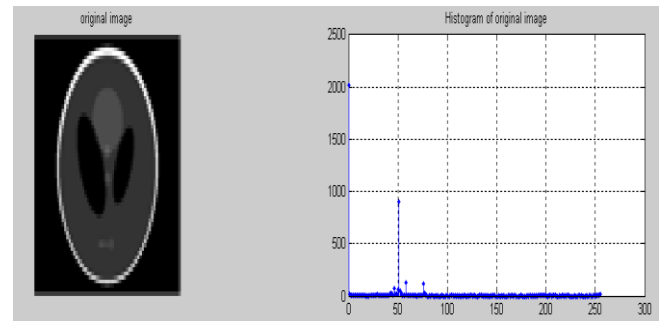

Fig 10: Original image of the Shepp Logan head phantom at and its corresponding histogram
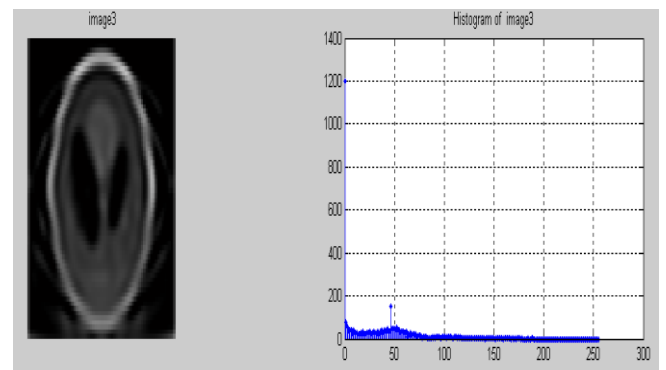

Fig 11: Image of the Shepp Logan head phantom at 3 degree arc sensor spacing and its corresponding histogram
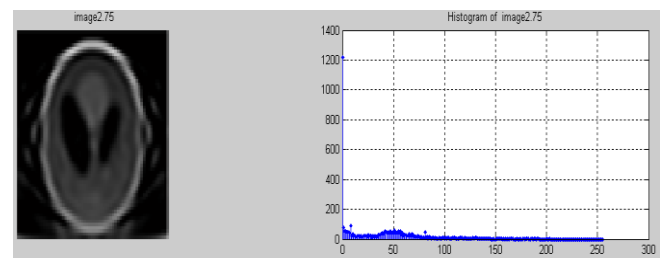

Fig 12: Image of the Shepp Logan head phantom at 2.75 degree arc sensor spacing and its corresponding histogram
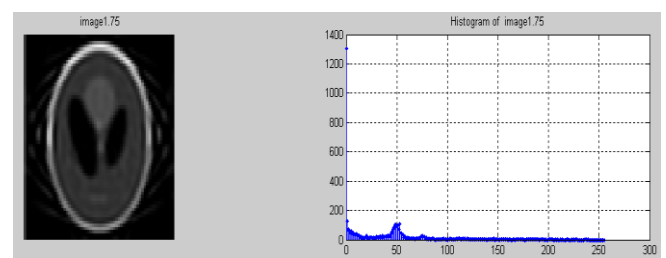

Fig 13: Image of the Shepp Logan head phantom at 1.75 degree arc sensor spacing and its corresponding histogram
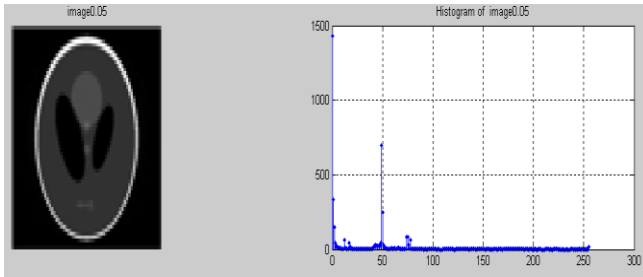
Fig 14: Image of the Shepp Logan head phantom at 0.05 degree arc sensor spacing and its corresponding histogram

5. CONCLUSION

This paper resolves the problem of reconstruction of fast data acquisition method for 3D X-ray computer tomography. The proposed method continuously rotates an X-ray source and a 2D detector, and simultaneously a patient is translated in the field of view of the X-ray source. This method is natural extension of the back projection and filter back projection algorithm [9].

An approximate fan beam image reconstruction algorithm for a Shepp-Logan head phantom has been derived and performances of the proposed method an image have been analyzed using MATLAB 7.5.0 (R2007b) software. Using fan beam reconstruction algorithm the quality of the reconstruction gets better as the number of beams in the projection increases. The Shepp Head Logan phantom image quality was found to be dependent on the beam spacing and the image quality was concluded to be better at angular beam spacing's of 0.05. On changing the value of angular beam spacing in the algorithm to higher as well as lower values than the above values, the image quality was found to significantly degrade in test image.

6. REFERENCES

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