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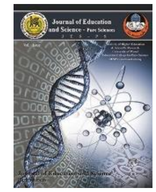

Assessment of The Effects of The Number of Projections And Use of Selected Filters on A Reconstructed Artificial Phantom

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Abstract

Appropriate selection of features may lead to the specificity of classification methods and identify the most critical features from all sparse or dense impact data using a filter based on the recognition selection method characterized. Filtration is used to reduce sample complexity, improve the clarity of viscous samples, and reduce background signals, resulting in increased signal-to-noise ratios in analytical tests. Depending on the filtration method applied, particles are separated based on properties such as size. This study assessed the impact of filter selection and the variation in the number of projections on the final reconstructed artificial phantom images. Utilizing image reconstruction techniques, it delves into the application of mathematical transforms, including Radon and Fourier, to improve image quality and resolution, particularly in medical imaging modalities such as CT and MRI. The research predominantly focuses on the application of the Filtered Back Projection (FBP) algorithm to reconstruct images from changing numbers of projections. The results underscore the main role of filter choice in removing noise, with the Ramp filter presenting the most promising results. The investigation concludes that reducing the number of projections results in a decline in image contrast and an increase in image noise.

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1. Introduction

Increasing the number of projections is the main way to get higher image quality [1]. Furthermore, it is the FBP graphical user interface (GUI) that offers the essential parameters to influence the quality of analytically reconstructed images [2]. A sinogram is a method utilized to display multiple data sets. It is a shorter and clearer method of showing an array of data. The sinogram obtains its name from the method of resembling many sine waves set together. In such an image, each sine wave depicts a pixel in the spatial domain. In other words, a sinogram is the raw data acquired from a tomographic reconstruction, a visual image of the Radon transforms. Each row of the sinogram represents a different projection through the object [3].

These techniques are utilized to create 2D and 3D images from groups of one-dimensional projections to enhance the resolution and quality of images. These imaging reconstruction algorithms build up the basis for common imaging modalities, such as CT and MRI, and are essentially used in medicine, biology, earth science, archaeology, physics, and science [4]. These methods are used because the observed image is blurred by many causes, like scatter radiation and noise, and the detected data alone is not helpful for medical diagnosis. Noise degrades the quality of medical images, which happens as a result of the inaccuracies executed by the nature of the scanners or motion blurring from a moving body. In addition, noise has a high frequency [5]**.**

Filters are used through image process to eliminate noise, interference, and blurring [6]. The filters are varied during the experiment, depending on which is best to; they rely on mathematical transforms (Radon, Fourier) to obtain better results but use the same ideas [7]. The frequency of the noise and the frequencies that the filter removes. FBP is one of the image reconstruction techniques widely used in CT image reconstruction. It converts the data file back from a sinogram into an image that can be tested. In fact, back projection represents that a signal is projected back along its incoming path [8].

Joël et al. evaluated the effects of a deep-learning reconstruction algorithm powered by artificial intelligence on radiation reduction and image quality in chest CT for various clinical indications in comparison to a hybrid infrared algorithm. It was observed that as the levels of smoother were increased, the noise magnitude decreased (-66.3 ± 0.5% for mediastinal images and 63.1 ± 0.1% for parenchymal images across all dose levels), the average NPS spatial frequency decreased (-13.3% ± 2.2% for parenchymal images and 35.3 ± 2.2% for mediastinal images), and the detectability (d′) of the three lesions increased [9]. Chun et al. [10] utilized filtered back projection, adaptive statistical iterative reconstruction-Veo, and deep learning image reconstruction to reconstruct eight CT images of a phantasm. They demonstrated that in the phantom study, an increase in radiation dose, deep learning image reconstruction, and adaptive statistical iterative reconstruction-Veo strength all resulted in less noise. As the tube current increased, the noise power spectrum peak and average spatial frequency of the deep learning image reconstruction algorithms approached those of the filtered back projection. Conversely, as the level of adaptive statistical iterative reconstruction-Veo and deep learning image reconstruction increased, these values decreased. In contrast to adaptive statistical iterative reconstruction-Veo, the noise power spectrum average spatial frequency of deep learning at low was greater.

Finally, the projection's number can be defined as the number of angles at which an image has been taken, and there will be a projection for each angle, which can be back-projected [11]. In other words, the predictions can be calculated for a range of projection angles varying from 0 to $2\boldsymbol{\pi}$ for both 2D and 3D objects [12]. Thus, the number of projections and the number of filters that are applied per projection and their effects on the quality of the image have been studied as the main part of this project [13]. The simplest example of a point source will be used to describe FBP; put a point source in the x-y plane (anywhere you want), measure the projections, and implement the back projection; then, you will always obtain the same star shape [14]. The most basic example of a point source is used to explain FBP. Many projections are used in order to investigate the effect of the number of projections on image quality over a different number of projections (256,128, 64, 32, 16, and 8), with the number of positions for all at 256 [13].

2. **Materials and Methods:**

The process of assessing the effects of filter selection and projection number variation on the final reconstructed artificial phantom images consists of the subsequent stages: generate a sinogram of the base images before reconstructing them with FBP, the artificial phantom images were generated, create and analyze artificially constructed images, and sinogram allows a number of intensities set to be presented and analyzed as one set.

1- The FBP algorithm should be investigated for a set of base images (phantoms), which may consist of a single point source, multiple point sources, and a phantom (graphic) image. Additionally, generate a sinogram of the base images before reconstructing them with FBP.

2- JAVA program FBP GUI was used to investigate the essential parameters that influence the quality of analytically reconstructed images. Then, create artificial phantom images and use them to examine the impact of the choice of filter and the number of projections on the final reconstructed image.

3- Generate and analyze artificially constructed images utilizing the Generated Sinogram and FBP GUI programs.
4- Beginning with the Windows program Paint, generate several basic images that are saved in "PNG" format. It is advisable to maintain uncomplicated images, with bitmap dimensions not surpassing 256 x 256 pixels. The program "FBP GUI" can be utilized for data analysis.
5- There are 256 positions and 256 projections in a 256 x 256 grid. In the case of alternative projections (128, 64, 32, 16, and 8), 256 positions are designated with a Sigma noise value of 0.0. The fundamental concept conveyed in this section is that the sinogram facilitates the presentation and analysis of multiple intensity sets as a single set, which is subsequently reconstructed into an image utilizing the image reconstruction algorithms provided by the FBI. All the processes can be

represented by these figures, from projections of the ideal image to sinogram until the filtered reconstructed image is obtained, as shown in Figure 1.

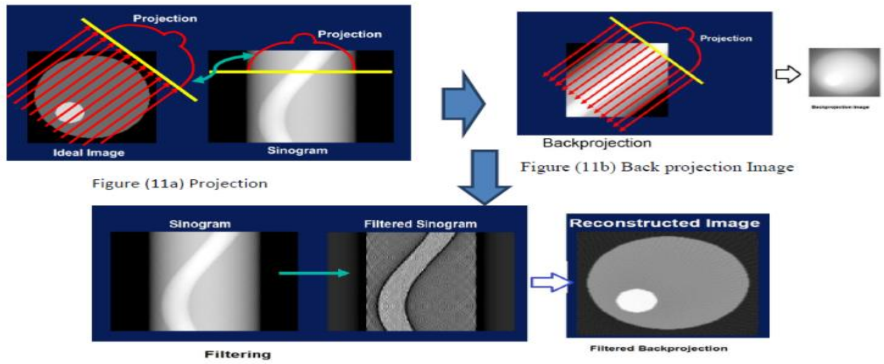


Figure 1. Filtered Back projection

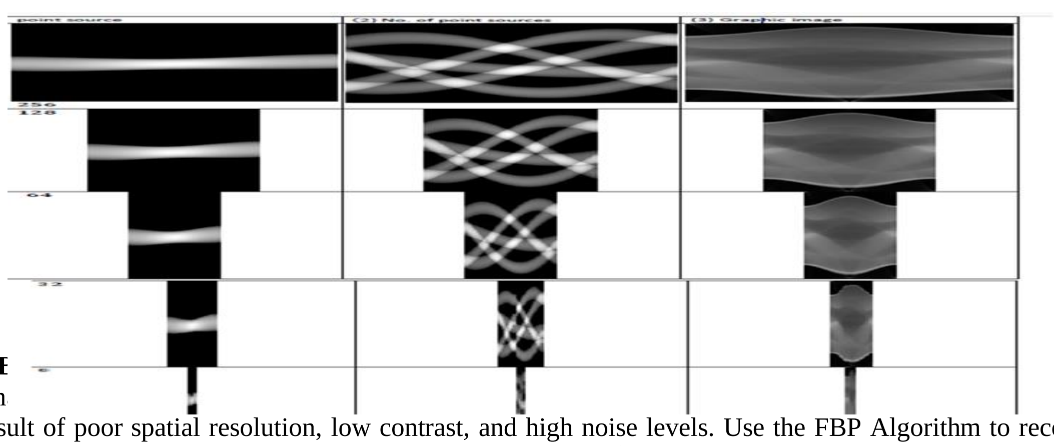
3. Results and Discussion

The results of analyzing the impacts of filter selection and projection number modification on the final reconstructed artificial phantom images will be discussed. This is comprised of the following stages: Sonograms of the base images, as well as the FBP Algorithm.

3.1-Sinograms of base images

The sinograms of varying numbers of projections for a simple point, number of point sources, and graphical image are shown in pictures in Figure (2) below. Production of a sinogram is an essential step in the image reconstruction process. There are sonograms for the three sets of images of varying projection numbers, starting from the maximum number of 256 to the minimum number used, 8.

Firstly, the sinogram of a simple point (located in the first column in Figure (2)) is entirely central, tracing out a sinusoidal path (signal) in the sinogram, which means that if a sinogram is a display technique (a medical device like CT), then whose relative distance does not differ at all as the detectors rotate that is shown as a straight line (mentioned this above in the definition of sinogram). Tomography-based scans can be explained as data taken at many varying angles. If this can be shown in the spatial domain, this would mean a figure 256 x 256. In reality, a figure of such magnitude cannot be analyzed by the human eye. It is clear that by reducing the number of projections, these images are a result of poor spatial resolution, low contrast, and high noise levels. In contrast, when increasing the number of projections, the image quality improvements can be seen clearly, for example, at 256 projections for all three. Column 2 (Figure 2) shows many point sources and their respective sinogram because they consist of many point sources. There are five points and, therefore, five sine waves. We can clearly see the graphical image in column 3 (phantom, origin image is 256 × 256 pixels) sinusoidal patterns in the sinogram because the source and detector are rotating about the object in case of using standard CT reconstruction algorithms [14]. In reality, the steps are much better and the projections much thinner, generating a smoother sinogram and, therefore, an image with better resolution.



3.2- The FI

Im f the image that is a result of poor spatial resolution, low contrast, and high noise levels. Use the FBP Algorithm to reconstruct the three

Figure 2. Sinograms of base images

base images: a simple point source, number of point sources, and graphical image, after producing a sinogram of all these three images at different projections. This is explained below in detail:

The FBP Algorithm of a graphical image (Phantom):

The original 256×256 pixels head phantom image is shown in Figure (18a). After that, it is reconstructed using the FBP algorithm with different reconstruction filters shown in Figures (18c) and (19a-g). Usually, a phantom is chosen that is a close approximation to the organs of interest, and different count densities are essential in our images; if it is high, this causes lower noise levels in relation to the image's power spectrum.

After applying the varying filters available, the images are shown on the next page. Sixty-four projections and 256 positions (64 256) are used to assess the noise in the edges and determine which filter can reduce the effect of noise and show the best image contrast. In a graphical image, the impact of the filter is more evident than in the sample point source image because the graphical image's supposed phantom image in this experiment clearly shows different parts (for example, the supposed lungs), which have different densities for each part.

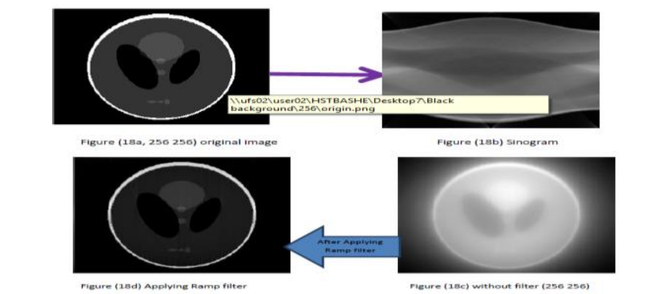


Figure 3. After Applying the Ramp filter.

When applying different filters, the results of using the different types of filters vary a little, but the variation is not high enough to discard any kind of noise. In this case, better results are obtained surprisingly with the simplest Ramp, followed closely by the Shepp-Logan filter, which is used because it decreases high-frequency noise. From Figure (4), applying other filters has mostly the same ability to remove the noise, including Cosine and Ramp, especially at edges, but their ability to contrast is lower than the ramp.

It is clear that at 64 projections, the noise can be seen at the edges (corners) of the images, and the same thing goes for 32, 16, and 8 (Figure (4)). Eight projection images are too noisy, so many image details need to be recovered. In addition, the shape has sharper corners, giving rise to ringing artifacts in the reconstructed image (that means decreasing the number of projections would lead to reduced image contrast and cause noise).

The ramp functions as an outcome of the theory of image reconstruction and is required to remove the 1/r blurring existing from applying the back projection algorithm. Its effect should not be regarded as a high pass or edge enhancement filter that is used for the projection data. The scale of the Hann filter begins to decrease from zero frequency earlier than the other filters and provides the most smoothing and loss of resolution. The Butterworth filter has two factors that define its shape. In addition to the cut-off frequency nm, the order 'n' limits how fast the filter rolls down from a value of unity at zero frequency to zero at a higher frequency. A smaller n value leads to a slower rolling down at higher frequencies, thus reducing artifacts and noise amplification [14].

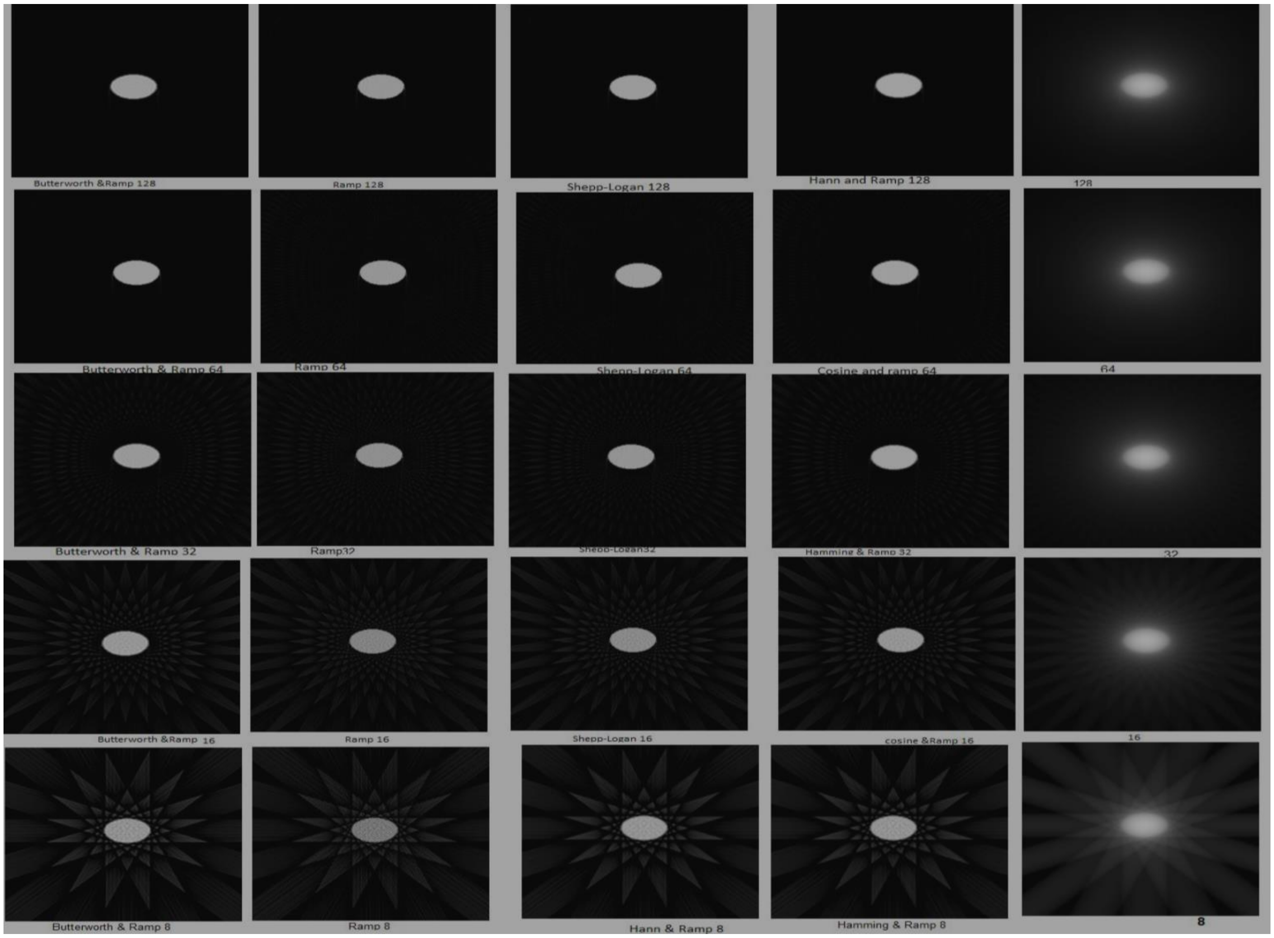


Figure 4. Filtered back projection for graphical image for different projections (128, 32,16, and 8)

4. Conclusion

It is also significant for a user to know the minimum number of possible projections in order to obtain a good-quality image. The Java program FBP GUI investigates the quality of reconstructed images. Different numbers of projections at which the image was studied affected the sizes of the sinogram. At 256 positions per projection, the images are sensible. Different available filters are applied in order to reduce noise and obtain the best images from a simple point source, a number of point sources, and a graphical image (phantom). It is useless to attempt to form an image using back projection without using a filter; therefore, the filter must be applied. The main difference between filters is the selected frequency of the noise to remove. Generally, the Ramp filter was shown to be of the most value, offering the highest image quality. The Hann & Ramp filter, too, provided a good image.

However, the difference between the two was insignificant for most cases and even offered very little difference between the other types of filters. Here, the Ramp filter is the most acceptable due to the frequency of the noise in the data. In the graphic image (phantom), the minimum number of projections leads to low contrast images and noisy images, especially at 64 projections and less; therefore, we cannot see many organs for other projections, especially for 16 and 8.

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تأثير تقييم اختيار المرشحات وعدد الإسقاطات على الوهم الاصطناعي النهائي المعاد بناؤه

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الملخص:

قد يؤدي الاختيار المناسب للميزات إلى خصوصية طرق التصنيف وتحديد أهم الميزات من جميع بيانات التأثير المتناثرة أو الكثيفة باستخدام مرشح يعتمد على طريقة اختيار التعرف المميزة . يتم استخدام الترشيح لتقليل تعقيد العينة، وتحسين وضوح العينات اللزجة، وتقليل إشارات الخلفية مما يؤدي إلى زيادة نسب الإشارة إلى الضوضاء في الاختبارات التحليلية. اعتمادًا على طريقة الترشيح المطبقة، يتم فصل الجزيئات بناءً على خصائص مثل الحجم قيمة هذه الدراسة تأثير اختيار المرشح والتباين في عدد الإسقاطات على الصور الوهمية الاصطناعية النهائية المعاد بناؤها. باستخدام تقنيات إعادة بناء الصور، فإنه يتعمق في تطبيق التحويلات الرياضية، بما في ذلك الرادون وفورييه، لتحسين جودة الصورة ودقتها، لا سيما في طرق التصوير الطبي مثل التصوير المقطعي والتصوير بالرنين المغناطيسي. يركز البحث في الغالب على تطبيق خوارزمية الإسقاط الخلفي المفلتر (FBP) لإعادة بناء الصور من الأعداد المتغيرة للإسقاطات. تؤكد النتائج على الدور الرئيسي لاختيار المرشح في إزالة الضوضاء، حيث يقدم مرشح Ramp النتائج الواعدة. ويخلص التحقيق إلى أن تقليل عدد الإسقاطات يؤدي إلى انخفاض في تباين الصورة وزيادة في ضوضاء الصورة.