Original Article :

Impact of number of projections on image quality of X-ray Computed Tomography.

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Abstract

Background and Aims:
This research aims to find the image quality of the computed tomography (CT) imaging technique, in terms of noise as a function of the number of projections.

Methods:
The X-ray Computed Tomography set is started using the rocker switch and the MeasureCT32 program is allowed to run, all devices at two different projections (20 and 300) are implemented.

Results:
The results of the experiment made clear that increasing the number of projections effectively reconstructs high-quality images in CT image reconstructions, e.g. when implementing 300 projections. This was also clarified with a lower number of projections giving reduced quality of the image, as shown in 20 projections.

Conclusions:
As increasing, the number of projections that leads to obtain high-quality images, clearer, and less noisy in CT image reconstructions as shown in 300 projections. Thus, reducing the number of projections results in reducing image quality.

Keywords:
Image reconstruction, Number of projections, and X-ray computed tomography.

Introduction:

Firstly, X-ray Computed Tomography (XRCT) is a commonly used technique in medical radiology providing good information through cross-sectional images and volume reconstruction. CT can be utilized to produce two-dimensional (2D) and three-dimensional (3D) images of anatomical structural imaging and functional imaging of organs or tissues, both further explained later on. X-ray CT: This technique is presently the most well-known tomographic technique used in the clinical setting. CT utilizes an external X-ray beam

and pictures the tissue-dependent X-ray absorption[1-3].

A major parameter of the imaging geometry is the number of projections utilized. Reducing the number of projections used for the reconstruction can reduce the radiation dose to the patient. However, reducing the number of projections will also reduce image quality because of the sparser sampling of image data[4].

These techniques are utilized to create 2D and 3D images from groups of one-dimensional projections to improve 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, physics, and science[5].

These methods are used because observed images are blurred by many causes, like scatter radiation, and noise, and the detected data alone is not useful for medical diagnosis. Noise degrades the quality of medical images, which happens because of the inaccuracies executed by the nature of the scanners or motion blurring from a moving body. In addition, noise has a high frequency. It is to be expected that a lower number of projections would result in a lower image quality[6-8].

Filters are used through image reconstruction to remove noise, interference, and blurring. The filters are varied during the experiment, depending on which is best to use, to obtain information; they rely on mathematical transforms (Fourier) to get better results but using the same idea9.

Methods:

This study aims to obtain insight into the effects of the number of projections on noise. In the first part of this experiment, the XRCT set is started using the rocker switch, and the MeasureCT32 program is allowed to run.

The green indicators next to the photo of the X-ray unit indicate no detected problems with the X-ray rotary stage and X-ray camera. After all X-ray unit indicators are set, the unit is calibrated, e.g. making sure any sample is removed at this point, and the unit door is closed and locked. A W type of X-ray tube (tungsten) is used which has an optimal voltage of 80 KeV, which was available at the laboratory, with calibration defaults of 342mm for the camera and 286mm for the rotary stage.

The settings of the X-ray unit usually lead to good results; 35kV, 1.00mA, and exposure time 0.5 sec. The software is divided into 4 basic stages: Parameters, CT scan, Reconstruction, and 3D view.

For the software, calibration may take several minutes. At this point of the experiment, an “Ethernet” connector sample is used. Once the CT scan option is selected,

two different projections are used (20 and 300 projections). On completion, several examples of image projections were produced. The selected Volume Viewer Page option allows the image to be seen in, for example, Sagittal and 3D image projections. The Volview program (used to view CT data as if a "virtual radiograph") is used to export to the Volview software; an interactive program for volume visualization allowing researchers to quickly assess and analyze complex 3D medical or scientific data on Windows, Mac, and Linux computers. By using and manipulating all default values available, the best possible 2D and 3D images of the scanned sample are produced. The aim of this part of the experiment is to determine the relationship between the number of projections and the quality of the final image achieved.

Results and Discussion

20 projections:

Twenty images were obtained with different directions (Z-axis rotation of the sample to be analyzed) at each applying projection, however, more images are required to show all the details. In other words, in the 3D viewer, the 3D dataset is presented in 4 views. In the 'Axial', 'Sagittal', and 'Coronal' view windows, the three slices in different directions through the volume are given according to the slicer indicator. When this indicator is moved around in any one of the three views, the corresponding slice is updated in the other two views. By moving the 'projection angle' cursor, views from another direction are imaged. We can see that more clearly by using the software VolView.

Before using the Volview software, the 3D image from measureCT program is obtained, shown in Fig 1A.

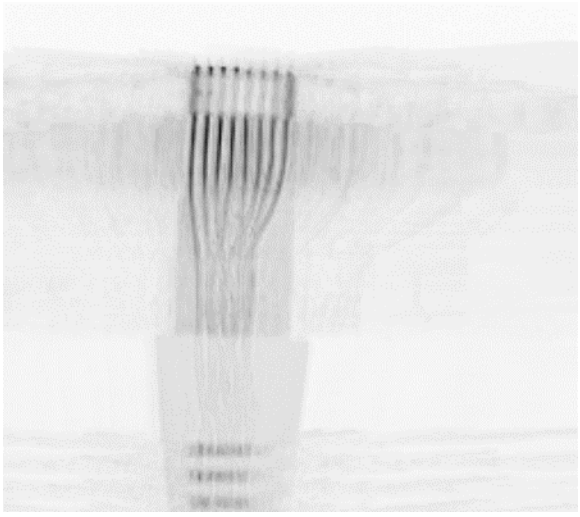


Fig 1A. 3D image of "Ethernet" connector sample-20

It is clear that the image is noisy, without great detail, and has poor contrasts. This means that decreasing the number of projections (in this case 20) leads to an inappropriate image and therefore need to use software to reconstruct the image, such as the Volview program (with an example used in this experiment and discussed later in more detail). After using the VolView 3.4 program for the two cases, it has become evident that the first (20 projections), due to lots of noise, has become blurred,

whereas the other is the best image possibly achieved using the program after alterations of parameters and manipulations.

However, there is still a considerable amount of noise because of the lower number of projections, and one aim of this experiment is to determine the minimum number of projections that produce an acceptable image. Since the final image is still blurred using 20 projections, this is not very useful for CT scan imaging (see Fig 1 B).

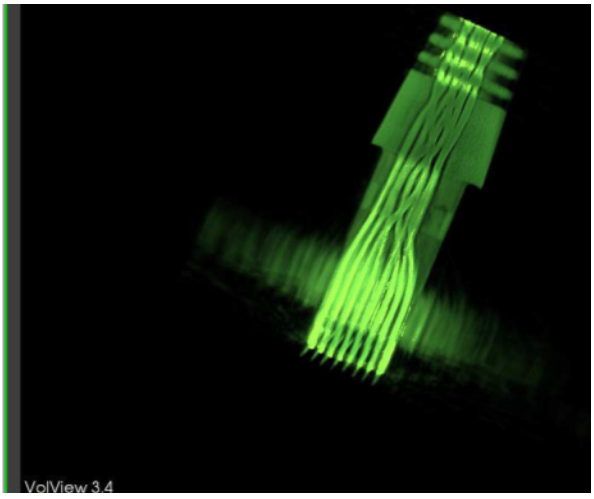


Fig 1B. VolView image (after using available tools)

300 projections:

For this part, 300 images were obtained, increasing the number of projections to achieve a good image quality. A large number of projections or reconstruction methods are available to acquire an image from the measured projection data, and this method is most widely used in industrial and medical CT. The image obtained in 300 projections is clear, concise, and less noisy, as shown in Figure 2A. By increasing the number of projections, FBP effectively reconstructs high-quality images in CT image reconstructions, such as the 300 projections used in this experiment.

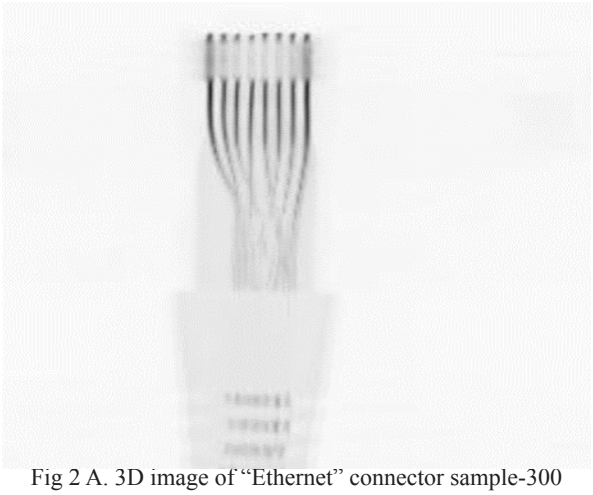


Fig 2 A. 3D image of "Ethernet" connector sample-300

In other words, reducing the number of projections will reduce image quality because the sampling of the image data is too low. So for this part of the experiment, it was determined that the number of projections can be found to mainly affect the contrast and the noise, and has much less influence on resolution. The image using 20 projections amounted to the most noise (noisy image in Fig.1 a), hence using 20 projections is not acceptable.

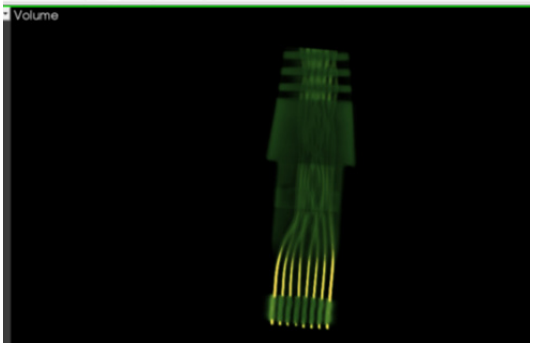


Fig 2B. VolView image (after using available tools)

Decreasing the voltage may also increase tissue attenuation in CT, therefore increased noise, mostly in larger patients. Most CT scanners use a limited number of choices for kVp values when doing CT scans. Routine body CT for adult patients is normally implemented at 120 to 140 kVp. The usage of 80 kVp is good to reduce radiation doses in pediatric patients. In other words, radiation protection is required for both cases of projections (300&20) and they have the same exposure values as we use the same (mAs and voltage tube).

There are many types of noise in the reconstructed CT images, and the main types are image noise, random noise, statistical noise, electronic noise, artifactual noise, and structural noise. For example, random noise in a CT image eventually limits the radiologist's ability to distinguish between two areas of different densities. Such noise cannot be entirely removed from the image, leaving some uncertainty in the explanation of the image. There is strong evidence that random noise in CT scanners is because of the statistical inaccuracies arising from the finding of a finite number of transmitted X-ray quanta[11].

There is much research about image projection umbers such as Xuanhao Z, et al. study 2022 found image has more detailed information and less noise with the increase of the number of projections, with 240 projections that are a good quality despite that an appropriate number of projections for reconstruction. However, I used 300 projections which means more efficient for image quality. Recently, in 2023, Salek MF et al published a study about gaining high-quality images with a high number of projections (400- 4,500), they found a higher number of projections provides better quality and vice versa so 400 projections result in the amount of noise[12-13].

Conclusions

In this research, increasing the number of projections effectively reconstructs high-quality images in CT image reconstructions, e.g. when implementing 300 projections, and vice versa. This was also clarified when a lower number of projections had reduced the quality of the image, as shown in 20 projections. The Volview software, a powerful volume visualization tool, created the best images in 2D and 3D. However, there remained a lot of noise, because of the source of noise; random, statistical noise.

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