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ORIGINAL ARTICLE CT-Scan Image Analysis

CT-Scan Image Optimization with Tube Current Variation in Some Kernel Filters Based on Signal to Noise Ratio (SNR) Value

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Abstract

Computed Tomography Scan (CT-Scan) is a diagnostic tool that determines human organs using x-rays, contemporary tomography, and computational procedures. As a result, an optimal image is required in order for the object examination to be appropriately diagnosed. Based on the Signal to Noise Ratio (SNR) value, this study attempts to optimize CT-Scan image with tube Current Variations on Several Kernel Filters. The goal is to understand the influence of variations in tube currents on numerous filter kernels on image quality on CT-Scan based on SNR, as well as the value of tube current and kernel type. This study begins by scanning the water phantom with variations of tube currents of 150 mA, 200 mA, 250 mA, and 300 mA, a total of three scans for each tube current variation to obtain 12 raw data. Furthermore, the filter step employs two types of kernel filters, soft and edge, for each raw data. The filtered data is searched for Region of Interest (ROI) on the object and background in order to obtain the signal value (mean) and noise (standard deviation) in the

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image, which can then be used to determine the SNR value. The SNR value demonstrates that differences in tube currents and kernel filters have an impact on the CT-Scan image's quality. The use of the Soft kernel filter and a tube current of 300 mA produced the best results with the maximum SNR.

KEY WORDS

Tube Current; Kernel Filters; Region of Interest (ROI); Signal to Noise Ratio (SNR)

Introduction

The rapid development of technology in the area of digital technology has impacted various fields, particularly the medical field. One application of digital technology in the medical area is the use of medical images to enable faster and more accurate diagnoses [1]. CT Scan (Computed Tomography Scan) is one of the medical imaging modalities that is fast and accurate in exhibiting tissue abnormalities or features of human inside organs [2].

One of the quality control procedures for the usage of CT-Scan aircraft is a noise test with a largely water phantom [6]. Water is recommended as a CT-Number determinant since it accounts for more than 90% of soft tissue shrink in humans. Meanwhile, phantom is employed as a replacement material to allow measurements to be repeated while research is being conducted. As a result, the obtained value will be more accurate [7].

The quality of the CT-Scan image is a critical problem because it is used to make the diagnosis. Noise is one of the elements that affect the quality of the CT-Scan image [8]. Noise is variation or standard deviation of the CT-Number value in a homogeneous tissue or material. The amount of x-ray photons detected, physical limits in the device, and reconstruction parameters are the three main sources of noise at specific image spots [9].

When photons are collected by multiple detectors, the noise value decreases [10]. Several factors can influence the quantity of photons detected by the detector, including scanning technique, scanner performance, and patient such as tissue density and thickness. The scanning technique involves X-ray tube tension, tube current, incision thickness, scanning speed, and helix pitch [11].

Almuslimiati et. al., (2019) stated that the ambient noise value depends on the type of kernel filter used [7]. His research also found that the use of exposure factors (one tube current) and other things that affect the noise value need to be optimized so that the noise value generated during data processing is reduced so that the physical component being examined can be appropriately diagnosed. The investigation did not concentrate on tube currents. So, in this study, we will try to take advantage of the tube current used to produce a low noise value, accompanied by the application of a kernel filter.

In this study, the CT-scan image quality will be improved by lowering the noise value utilizing various tube currents (mA). Changing the tube current changes, the number (intensity) of electron beams, which can impact the X-ray intensity. The intensity of the X-rays increases with tube flow [12]. The higher the tube current value, the more radiation reaches the detector and the lower the noise [13].

After scanning, the raw data will be obtained. The data obtained, a reference to a mathematical filter or often a reference to a kernel filter. This process is also often referred to as conformity. By using this kernel filter, it improves image quality by removing the blurring effect on the image. When the resulting image has a small fuzzy effect, the noise will also be reduced [9].

Selection of the right filter kernel can effectively reduce noise so that image quality can be improved [14]. Optimal image quality is indicated by the high value of the Signal to Noise Ratio (SNR) [15]. SNR is the ratio between signal strength (mean) and noise strength (standard deviation). If the noise in the image is lower, the resulting SNR value will be higher [12].

Material and Methods

The study lasted three months and was conducted at Dr. Moh. Saleh Hospital's Radiology Installation in Probolinggo. Computers and CT-Plane with the trademark General Electric (GE) 128 iris with Optima 660 and 5512CT0066 series are utilized as tools. A water phantom with a diameter of 32 cm and a CD-ROM are employed.

The independent variables of the study were variations in tube current (150 Milliamperes, 200 Milliamperes, 250 Milliamperes and 300 Milliamperes) and variations in the filter kennel (Soft and Edge). While the dependent variable is the value of the Signal to Noise Ratio (SNR) generated by the image. This study also has control variables, namely tube voltage of 120 kV, slice thickness of 5 millimeters, large field of view (FOV) of 500 millimeters, one second rotation duration and region of interest (ROI) in the background (1.796 centimeters^2) and object (0.8553 centimeter^2).

The first procedure is to set the CT-plane so that it is ready for scanning and to position the phantom on the examination table. Furthermore, the tube variation flow is affected by controlled factors and independent variables. The second stage is checking, with each variation of the flow tube verified three times and twelve raw photos obtained.

The raw data is then processed by applying numerous variants of the kernel filter by selecting "Retro Recon." Then, for each image, a different variation of the filter kennel, namely soft and edge, will be applied. As a result, twenty-four images were obtained after filtering. The next stage is data acquisition, which is doing ROI of object and background areas on twenty-four images obtained using the RadiAnt DICOM Viewer application.

The data acquisition process is a process of X-ray collection that is passed after passing through a particular patient or object. First, X-ray tubes and detectors surround scanned objects to collect data for transmitting value or data. X-rays passing through objects will suffer a note of softening because some of it is absorbed by the material. As a result, the intensity of the X-ray after the item is less than the intensity

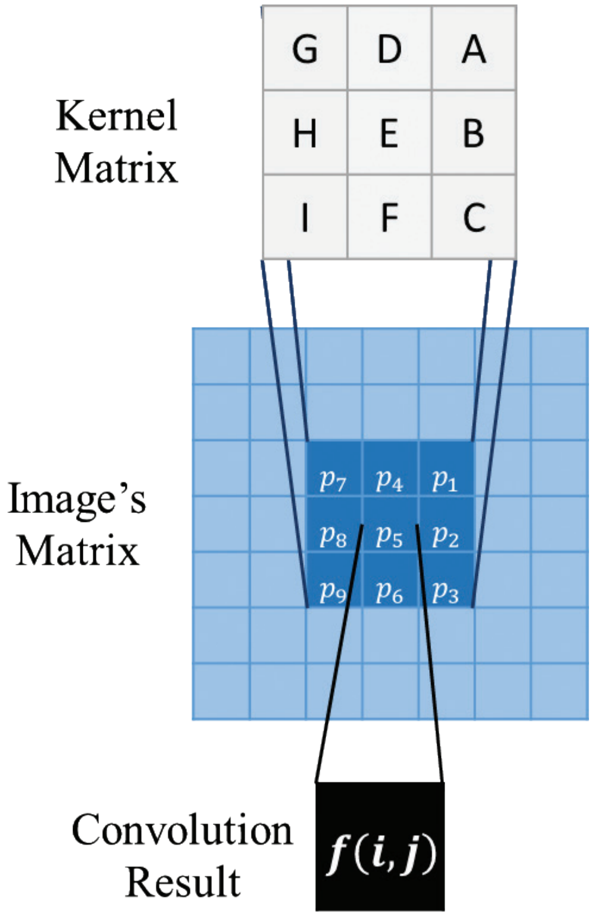

Fig. 1. *Kernel Convoluting Illustration*

of the X-ray before the object [11]. The intensity of the X-ray once it develops is exponential and follows the Lambert-Beer equation on equation 1 [16].

$$I = I_0 e^{-\mu x} \quad (1)$$

Where I is X-ray intensity after passing the object, I_0 is initial X-ray intensity, μ is linear coefficients and x is the thick of ingredient. A connection between the intensity of the X-ray and the stream of the tube can be seen in the equation 2 [15].

$$I_0 \approx mA \quad (2)$$

Where I_0 is the X-ray intensity which is spreaded from X-ray tube, mA is the current of the tube used. The intensity of the X-ray transmitted (I) will arrive in the detector. Next, the detector reads the results of an X-ray attenuation and it will be sent to the computer and stored as raw data.

The quantity of photons measured on the detector influences the amount of noise in images. When a

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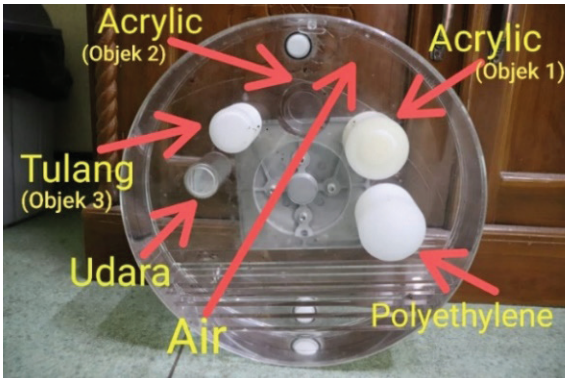

Fig. 2. *Water Phantom*

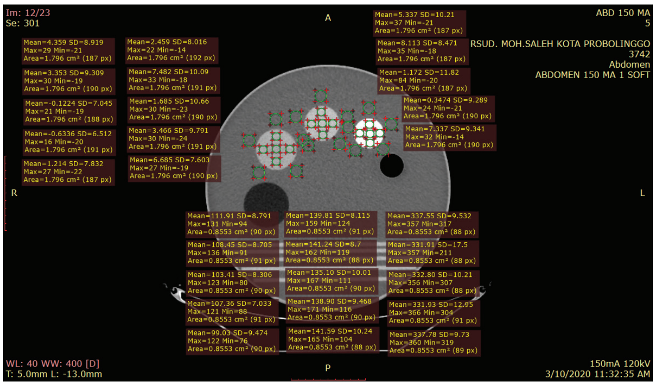

Fig. 3. *ROI technique on the CT-Scan image*

large number of photons are captured by a big group of detector sets, the noise value is reduced [6]. According to the *SNR* formula which is used in equation 1, it can be known that *SNR* value is affected by the signal value and noise value of image. Noise value is inversely proportional to *SNR* value. If noise is generated small, then SNR scores will be higher. It is signified that image that is produced has better quality.

Raw data will be collected after scanning with different tube flow changes. Then the computer goes through the image reconstruction process. Digital image consists of two-dimensional Numbers called the matrix. The matrix consists of columns and rows arranged by small boxlike areas called image or pixels. Each pixel in the CT-scan image had one CT-number relating to the linear coefficient attenuation (μ) from a network [6].

Raw data picked up, filtered using a math filter or called a kernel filter, the process is also referred to as a convolutionl technique. Convolution is a technique to smooth image or to illuminate image by replacing pixels with a number of corresponding pixels [17]. This technique eliminates the blurred effects that form on the images. When the fuzzy effect on the small image, then noise generated will also decrease. Selection the right kernel can be effectively in reducing noise so that the quality of the resulting image will increase [9]. Convolution technique of the kernel can be seen in figure 1.

Convolution technique means operating a shifted kernel matrix pixel per pixel on the image's matrix. The result will be saved in the new matrix. The outcome of convolution result is avowed in *f (i,j)*. the way to get outcome value *f(i,j)* can be seen in equation 3 [17].

$$f(i,j) = Ap_1 + Bp_2 + Cp_3 + Dp_4 + Ep_5 + Fp_6 + Gp_7 + Hp_8 + Ip_9 \quad (3)$$

Kernel matrix is generally 3x3 sized. The values of each pixel on the kernel matrix is *weighting factor* or convolution coefficient. Every kernel filter has different *weighting factor* value, it depends on the type of processing of desired image [6]. The variations of kernel filters used in this research are *soft* and *edge*. The result of the research shows that using a soft kernel filter produces a higher SNR value than using the edge kernel filter.

Soft filter kernel uses *low pass filter* which is operated on the image with the aim of getting a subtle image output and reducing noise [17]. The matrix that is used in soft kernel filter is

$$s \begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}.$$

Soft filter kernel can reduce noise on image as well as can demonstrate good soft-tissue anatomy. As a result, the soft kernel filter can be utilized in tests when changes in soft tissue are visible in low contrast structures [6].

Edge kernel filter uses *high pass filter* that is operated on the image with a view to getting a sharp output image. Matrix that is used in edge kernel filter is

$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix}.$$

Edge kernel filter will provide reinforcement on the margins of the network and can improve details and sharpen images but can produce noise in images. Edge kernel filter is good to use on examinations that

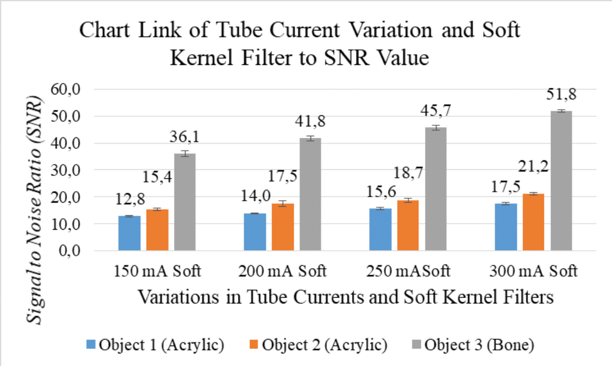

Fig. 4. *Tube Current Variation and Soft Kernel Filter Against SNR Value*

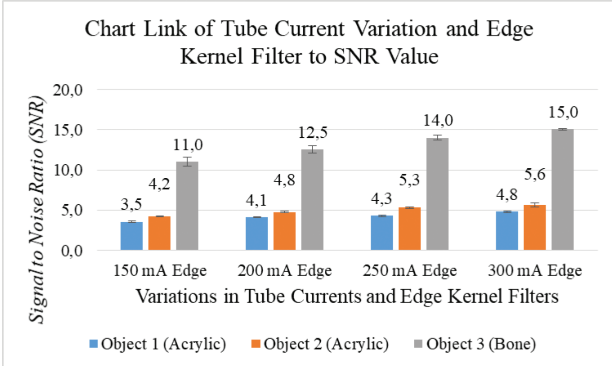

Fig. 5. *Tube Current Variation and Edge Kernel Filter Against SNR Value*

require detailed results. For example, the entrails, the bone structure, the pulmonary structure [6].

The filtered data is searched for Region of Interest (ROI) on the object and background. ROI will be performed for three objects in each image. These objects are acrylic materials (Objects 1 and 2) and objects that have a density similar to bone (Object 3). The Phantom used can be seen in figure 2.

The ROI in the object must use as small an area as feasible to identify the signals on the item. Background ROIs employ larger areas to communicate the value of the signal to the other, which can identify the enormous amount of noise generated by images [16]. Figure 3 shows an example of the ROI approach.

The ROI method will produce a mean and deviation standard for each image, allowing the data analysis phase to proceed. The image will be processed using SNR analysis and statistical tests are performed. The acquired SNR value would determine the quality of the CT-scan image, allowing the current value of the tubes and the appropriate kernel type of filter to be determined. Equation 4 shows how to perform an SNR analysis [17].

$$SNR = \frac{\sum_i (x_i - \bar{x}_{BG})}{\sigma_{BG}} \qquad (4)$$

Where x_i is signal value (*mean*) in every pixel *i* of image, $\bar{x}_{BG}$ the average of signal value (*mean*) on the *background* and σ_{BG} and is deviation standart value on the *background* that is homogeneous on image. After obtaining an SNR score for each image, a statistical test will be obtained. The linear regression statistical test was applied in this result.

Results and Discussion

Table 1 shows the average SNR value for each tube stream variation and kernel filter variation of 24 images. Table1 is visually shown in figures 4 and 5, which show a graph of tube current and kernel filter against SNR value. The SPSS test was performed using a linear regression test after the SNR value of each modification of the tube and kernel filter current was determined. Table2 shows the results of the linear regression statistical test.

On table 2a, which is the summary model table contains about the power of the relationship between independent variables (Tube current variation and kernel filter) to dependent variable (*SNR* Value). R Value is *multiple coefficient correlation* that is valueable between -1 untill 1. If the result of R value gets closer to -1 or 1 it is indicative of stronger relationship, but if the value gets closer to 0 then it suggests weak relationship. Whereas R^2 value is coefficient determination that is valuable between 0 until 1. If it approaches 1 (100%), the model is improving since all of the independent factors can explain the diversity of dependent variables combined.

Table 2b, which is Coefficient table, represents the influence of independent variable (tube current variation and kernel filter) to dependent variable (*SNR* value) partially. With a hypothesis H_0: Regression coefficient is not significant ($\beta = 0$), H_1: Regression coefficient is significant ($\beta \neq 0$). H_0 is rejected if the odds were even smaller than the alpha's ($p < \alpha$ ($\alpha = 5\%$) $\rightarrow$ H_0 is rejected). From such analysis, it can be concluded that partially the variations of the tube current af-

Table 1. Signal to Noise Ratio values

Variation		SNR value		
Tube Current	**Kernel Filter**	**Object 1**	**Object 2**	**Object 3**
150 mA	*Soft*	12,8 ± 0,3	15,4 ± 0,5	36,1 ± 1,1
200 mA	*Soft*	14,0 ± 0,2	17,5 ± 1,1	41,8 ± 0,9
250 mA	*Soft*	15,6 ± 0,5	18,7 ± 0,8	45,7 ± 0,9
300 mA	*Soft*	17,5 ± 0,3	21,2 ± 0,5	51,8 ± 0,5
150 mA	*Edge*	3,5 ± 0,1	4,2 ± 0,0	11,0 ± 0,6
200 mA	*Edge*	4,1 ± 0,1	4,8 ± 0,1	12,5 ± 0,4
250 mA	*Edge*	4,3 ± 0,1	5,3 ± 0,1	14,0 ± 0,3
300 mA	*Edge*	4,8 ± 0,1	5,6 ± 0,3	15,0 ± 0,1

Table 2 Statistical test result of linear regression. a) Summary model, b) Coefficient, c) ANOVA

a) Summary Model

Dependent variable	Result of R		Result of R^2	
	Value R	**Conclusion**	**Value R^2**	**Conclusion**
SNR Value of Object 1 (Acrylic)	*0,993*	Powerful relationship	0,986	very good model
SNR value of Object 2 (Acrylic)	*0,993*	Powerful relationship	0,986	very good model
SNR Value of Object 3 (Bone)	*0,991*	Powerful relationship	0,982	very good model

b) Coefficient

Dependent Variable	Model	Result	
		Sig.	**Conclusion**
SNR value of Object 1 (Acrylic)	Tube Current Variation	0,015	significant
	Kernel Filter variation	0,000	significant
SNR value of Object 2 (Acrylic)	Tube Current Variation	0,014	significant
	Kernel Filter variation	0,000	significant
SNR value of Object 3 (Bone)	Tube Current Variation	0.013	significant
	Kernel Filter variation	0,000	significant

c) ANOVA		
Dependent Variable	**Result**	
	Sig.	Conclusion
SNR value of Object 1 (Acrylic)	0,000	Significant
SNR value of Object 2 (Acrylic)	0,000	Significant
SNR value of Object 3 (Bone)	0,000	Significant

fect the value of the SNR and the variations of kernel filters affect the value of the SNR.

The ANOVA table, Table 2c, is used to evaluate whether or not there is an influence on some independent factors on dependent variables at the same time. With a hypothesis H_0: Regression coefficient is not significant ($\beta = 0$), H_1: Regression coefficient is significant ($\beta \neq 0$). H_0 is rejected if the odds were even smaller than the alpha's ($p < \alpha$ ($\alpha = 5\%$) $\rightarrow H_0$ is rejected). From such analysis it could be concluded that simultaneously independent variables (tube current variation and kernel filter) are affected to dependent variable (*SNR* value).

Based on the analysis of *Signal to Noise Ratio* value, it is obtained that the higher the current of the tube is used that the SNR value will be greater, and it is valid for all kernel filter used. The greater the value of the SNR produced signifies the better the image. Because the SNR value has importance when it comes to describing an object. The value of SNR produced determines how well an observer can perceive an image. According to Albert Rose, an excellent image has an SNR value of 5 [18].

The quality of the CT-Scan image depends on the production of the X-rays produced. The production of the X-rays was affected by an exposure factor, they are: a tube current (mA), Tube voltage (kV) and time of exposure (s). The main step that can be taken to optimize the CT-Scan image is to optimize the voltage and flood currents. The selection the value of the tube stream is associated with the number of electrons that would pound the target and produce X-rays. The resulting x-rays will be detected in detectors that then it will create an image [19].

The tube current Settings will cause a change in number intensity an electron file so it can affect the intensity of an X-ray [7]. The more current is given in an X-ray tube, the more electrons will be produced in the cathode. That is in the filament. After the electrons in the cathode are formed, it is given a high potential difference between the cathode (negative) and the anode (positive) so the formed electrons would accelerate from the cathode to anode. Electron movement to anode is directed by *focusing cup* so it hits the right target. The electron hitting the target would lose its kinetic energy and turn most of it into heat and a fraction of it turns into an X-ray. If the electron that is obtained is more so the intensity that is obtained is getting higher [20].

The tube current arrangement will affect the intensity of the X-ray. The higher the flow of the tube used, the intensity of the resulting X-ray is also increased, as shown in equation 2. From the equation 2 it may be known that the disposition of the tube current greatly affects the intensity of the X-ray produced so is essential to properly control the flow of the tube being used. Related with equation 1, is known that the intensity of the X-ray after passing through the object is comparable to the initial intensity of the X-ray which means the greater the value of the initial X-ray intensity (I_0) so that the magnitude of the X-ray result would be greater after passing through the object (I). Assuming the value of the absorption and thick of the material used has the same value.

Image disturbance is normally a variation in the intensity of a pixel with no correlation to the intensity of a neighbor's pixels. Ailing pixels generally have high frequency values. Every disturbance on this image is called noise [21]. So that, soft kernel filter has better quality of image rather than edge kernel filter. Because soft kernel filter uses *low pass filtering* process, pixels will have low frequencies so that it can reduce the noise on image. Whereas in the edge kernel filter uses *high pass filtering* process, pixels will have high frequency values so that it can cause noise in images.

In this study, a phantom containing a homogeneous water material was employed as a reference in assessing the abdomen, because abdomen is soft tissue (most of which is composed of water). CT-Scan scanning of the abdomen requires low noise value in order to give a better quality to the abdomen of CT scan image [22]. The high noise value on the Abdomen will result in inadequate contrast resolution, resulting in poor anatomical information. The abdomen is a thick object that demands a high exposure factor to provide the best image quality.

The study focused on reducing noise values in the CT-scan image so that it was suitable for use in abdominal examination that required low noise scores. The tube current employed in the evaluation of abdomen is one aspect that can be maximized. The higher the flow rate of the tube, the better the image quality, as measured by the SNR value. Thus, this study can be used as a reference to abdomen for examination primarily in the organ of *liver*, *spleen*, *adrenal gland*, *kidney*, *pancreas* dan *abdominal wall* [24].

Conclusion

The CT-scan image is affected by variations in tube currents (mA) and kernel filter depending on the Signal to Noise Ratio (SNR) value. The greater the flow rate of the tubes employed, the greater the value of the SNR, which represents the quality of the CT-scan image. Kernel filters, as well as style and shortening, can be employed to improve image quality. The used of kernel filter, the less noise produced, and thus the greater the SNR, the better the quality of the CT-scan image. The tremendous value of the tube currents that produce the maximum SNR value is as high as 300 mA, and the filter kernel that produces the best image is soft filter kernel.
Further study should be conducted on patients in order to properly define the SNR value on each organ and compute the value of the dose on each protocol employed. As a result, it can produce a high-quality image while still ensuring that the patient receives a safe dose.

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