Jurnal Penelitian Fisika dan Aplikasinya (JPFA)
p-ISSN: 2087-9946
e-ISSN: 2477-1775

Volume 09, Issue 02, December 2019
DOI: 10.26740/jpfa.v9n2.p132-139
https://jpfa.unesa.ac.id

Research Article

Automated Universal Image Quality Index Measurement vs. Automated Noise Measurement: Which Method is Better to Define CT Image Quality?

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Abstract

Automatitation method in defining the quality of CT image is needed to optimize CT Scan treatment planning. So, the optimization of treatment planning can also be done automatically. There are various methods proposed to define the quality of an image. The purpose of this study was to find the simple and precision method to define CT image. We compared the performance of Automated Noise Measurement (ANM) and Automated Universal Image Quality Index (UIQI). We also compared them with the Manual noise measurement method based on the level of convergence in homogeneous images. The first step of Automated Noise Measurement was to create binary density slice using threshold values. Then, a masked image was performed by masking the original image and binary image. The standard deviation of every pixel for a certain kernel size was calculated by using a sliding window operation. The fourth step was to make a noise histogram from the noise map and determine the final noise in the image as the histogram peak. Then this calculation was normalized by the peak of the Hounsfield Unit (HU) histogram. All these steps were done with various kernel sizes for different slices in-homogenous phantom. In the Automatic UIQI method, the steps in the ANM method are carried out until the masked image stage, then UIQI is calculated for the masked image. The results show that automatic UIQI was more convergence in defining image quality than manual noise measurement and automated noise measurement by the lowest standard deviation which was only 0.00032867.

Keywords: *CT Image, Automated Noise Measurement, Manual Noise Measurement, Universal Image Quality Index (UIQI)*

Perhitungan Noise Otomatis vs Universal Image Quality Index Otomatis: Metode Mana yang Lebih Baik untuk Mendefinisikan Kualitas Gambar CT?

Abstrak

Diperlukan metode otomatisasi dalam menentukan kualitas gambar CT untuk mengoptimalkan perencanaan pengobatan dengan CT Scan, sehingga optimalisasi perencanaan pengobatan juga dapat dilakukan secara otomatis. Ada berbagai metode yang diusulkan untuk menentukan kualitas suatu gambar. Tujuan dari penelitian ini adalah untuk menemukan metode sederhana dan resep untuk menentukan *gambar CT. Kami membandingkan kinerja Automated Noise Measurement (ANM) dan Automated Universal Image Quality Index (UIQI). Kami juga membandingkan dengan metode pengukuran noise manual berdasarkan tingkat konvergensi pada gambar yang homogen. Langkah pertama ANM adalah untuk membuat irisan densitas biner menggunakan nilai ambang batas. Kemudian, masked image dilakukan dengan menutupi gambar asli dan gambar biner. Standar deviasi dihitung untuk seluruh piksel pada ukuran kernel tertentu dengan menggunakan sliding window. Langkah keempat adalah membuat histogram noise dan menentukan noise akhir pada gambar sebagai puncak histogram. Kemudian perhitungan ini dinormalisasi dengan puncak histogram Hounsfield Unit (HU). Semua langkah ini dilakukan dengan berbagai ukuran kernel untuk irisan yang berbeda dalam phantom homogen. Dalam metode UIQI Otomatis, langkah-langkah dalam metode ANM dilakukan hingga tahap masked image, lalu UIQI dihitung untuk masked image. Hasil penelitian menunjukkan bahwa UIQI otomatis lebih konvergen dalam menentukan kualitas gambar daripada pengukuran noise daripada pengukuran noise manual dan pengukuran noise otomatis dengan standar deviasi terendah yang hanya 0,00032867.*

Kata Kunci: *Citra CT, Pengukuran Noise Otomatis, Pengukuran Noise Manual, UIQI*

PACS: 87.57.Ce, 87.57.cj, 87.57.cm, 87.57.-s

Article History: Received: April 5, 2019 Approved with minor revision: November 8, 2019
Accepted: December 3, 2019 Published: December 31, 2019

How to cite: Lestari F P, et al. Automated Universal Image Quality Index Measurement vs. Automated Noise Measurement: Which Method is Better to Define CT Image Quality? *Jurnal Penelitian Fisika dan Aplikasinya (JPFA)*. 2019; **9**(2): 132-139. DOI: https://doi.org/10.26740/jpfa.v9n2.p132-139.

I. INTRODUCTION

Computed Tomography (CT) Scan has been widely used in the world for medical purposes due to its ability to produce cross-section images of the body [1,2]. However, the question "how accurate the CT image to represent the patient body" still cannot be solved. For years, people are researching to quantify image quality to answer that question [3-5].

There are several methods proposed to quantify image quality. One of them is universal image quality index (UIQI). Universal Image Quality Index model describes images as a combination of three factors: loss of correlation, luminance distortion, and contrast distortion [6,7].

The ability to detect object precisely are dependent on the contrast and noise in the image. Noise measurement can also be used to describe the quality of the image. Noise measured by calculating the standard deviation of Region of Interests (ROIs) selected by the operator [4,8]. Christianson et al. already proposed a method to measure noise in CT images automatically [5,9]. This method does not rely on manual selection of ROI's in uniform areas to measure image noise [10-12], because this method can measure the global noise of a CT image. We proposed an improvement in the detection patient body in the CT image so that the noise map can be more accurate by eliminating outside the patient's body.

Anam *et al* proposed an improved algorithm [13] that next we called Automated Noise Measurement (ANM). Nevertheless, the automated noise measurement had to be evaluated compared to other methods to quantify the quality of the CT image. The purpose of this study was to find the simple and precision way to define CT image. We compared the performance of Automated Noise Measurement (ANM) and Automated

Universal Image Quality Index (UIQI). We also compared them with the Manual noise measurement method based on the level of convergence in homogeneous images.

II. METHOD

The methods consist of three main parts of the calculation: Manual Noise Measurement (MNM) [5], Automated Noise Measurement (ANM) [7], and Automated Universal Image Quality Index. We compared the performance of these three methods in defining the quality of homogeneous CT images.

Manual Noise Measurement (MNM)

CT Images used in this study were 30 samples of 155 slices of homogeneous phantom image. The manual noise measurement was given by calculating the average of standard deviation [8,12,14-17] of 36 ROIs of every slice (see Figure.1) by using MATLAB.

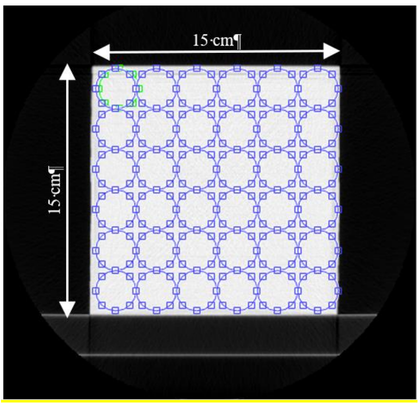

Figure 1. Areas to be Calculated in Manual Noise Measurement

Automated Noise Measurement (ANM)

To calculate ANM, we built a program in MATLAB that follows these steps [7,18-19]. First, we create a binary density slice using threshold values so that we can obtain Figure 2(b). Second, we create masked image (Figure 2(c)) by masking original image (Figure 2(a)) and binary image (Figure 2(b)). Then, we calculate the standard deviation of every pixel for a certain kernel size by using a sliding window operation. After that, a noise histogram was made from the noise map (Figure 2(d)). The final noise in the image was determined as the peak of the histogram (see Figure 3). The last step was normalization of calculation by the peak of the HU histogram. All these steps were done for all 30 samples slices for three different kernel sizes, including 2.9 mm, 8.7 mm, and 26 mm.

Automated Universal Image Quality Index (AUIQI)

UIQI is calculated as the product of three components: correlation coefficient, mean luminance, and contrast luminance [6,20]. Mathematically, this product is written as

$$Q = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2\bar{x}\bar{y}}{(\bar{x})^2 + (\bar{y})^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2} \quad (1)$$

Q represented the UIQI value, x represented the original image while y represented the binary image. So, σ_{xy} was the standard deviation between image x and image y, σ_x was the standard deviation of image x, σ_y was the standard deviation of image y, $\bar{x}$ was the average of grayscales of image x, and $\bar{y}$ was the average of grayscale of image y. All of the calculations were made using MATLAB. The Automatic UIQI method combined the ANM method and the UIQI calculation. We created the masked images automatically to do segmentation between organ and background. Then we calculated UIQI automatically by MATLAB program that we developed.

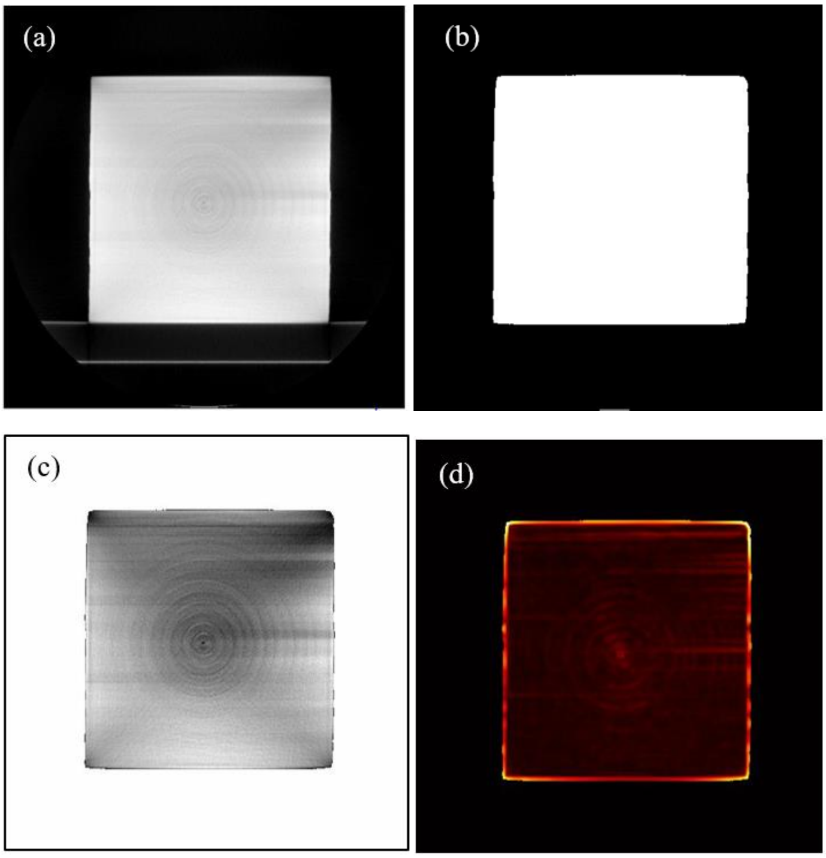

Figure 2. (a) Original Image; (b) Binary Image; (c) Masked Image; (d) Noise Map

III. RESULTS AND DISCUSSION

The manual noise measurement result was shown in Figure 3. The mean value was 18.63738 HU with a 0.653067 standard deviation.

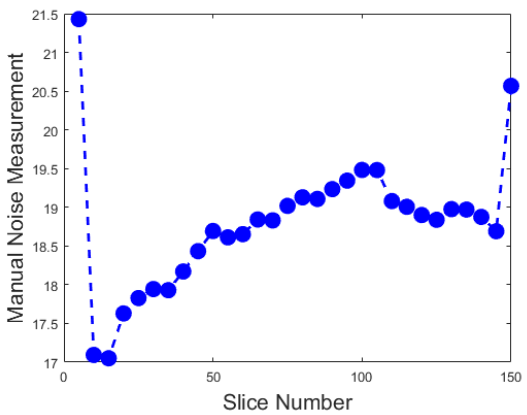

Figure 3. Manual Noise Measurement

Figure 4 shows one of the sample's noise histogram which was used in automated noise measurement. The final automated noise measurement was defined as the peak of this noise histogram. For example, in Figure 4, the noise value was 9.5 HU, which was the mean value of the bar with the highest frequency. All automated noise measurement results were shown in Figure 5. For kernel size 26 mm, the mean value was 14.842857, with a 0.4376836 standard deviation. For kernel size 8.7 mm, the mean value was 14.32857, with a 0.320713 standard deviation. Meanwhile, for kernel size 2.9 mm, the mean value was 11.707142, with a 0.4729173 standard deviation.

The results show that different kernel sizes give different values of Automated Noise Measurement (ANM). If kernel size is too small, large noise will not be calculated. This result [5,21] so that the ANM of small kernel size is lower than the others. However, if kernel size is too big, the boundary will also be calculated. Therefore, kernel size has to be chosen based on organ size [5].

Figure 6 shows the universal image quality index measurement. The mean value was 0.48979534, with a standard deviation of 0.00032867. Because the object is a homogeneous phantom, the calculation with a lower standard deviation is better [1,22-25].

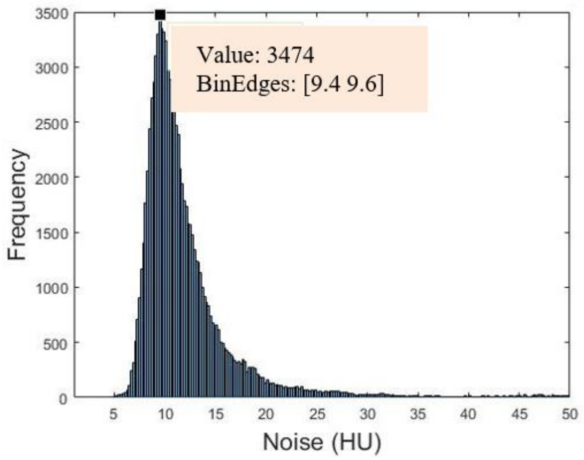

Figure 4. Noise Histogram

Manual Noise Measurement has the highest standard deviation, following by ANM (kernel size 8.7 mm), ANM (kernel size 26 mm), ANM (kernel size 2.9 mm), and automatic UIQI. So that, Universal Image Quality Index was more convergence in defining image quality than manual noise measurement and automated noise measurement. Other research which was done to the common picture also stated that automatic UIQI was better than noise measurement [20].

The automatic UIQI for the first slice and the last slice were significantly different from the others because the X-ray source was set to give good contrast for the center of the phantom [26]. Therefore, the automatic UIQI of the images on the edge of the phantom was different.

Automated UIQI is simpler than MNM and ANM. The algorithm is much easier than the others, while MNM is too much manual work by the user than ANM and Automated UIQI [27].

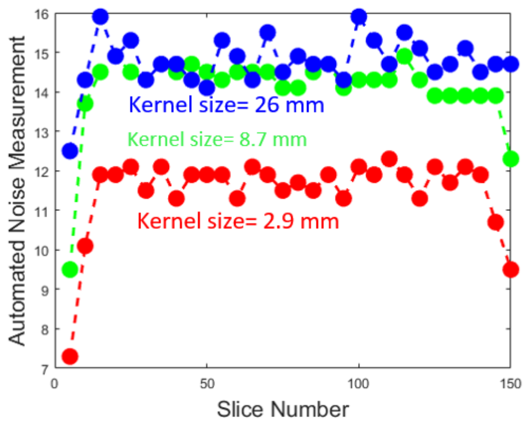

Figure 5. Automated Noise Measurement

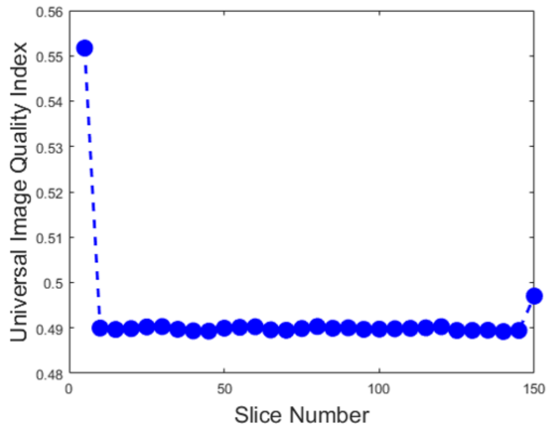

Figure 6. Universal Image Quality Index Measurement

We have not made a comparison to the real patient CT image. If we did the algorithm to the real patient CT image, there would be a little bit different in ANM calculation on the edge of the patient's body or the edge of the patient organ because of the limitation kernel size [5,7,14,28-29].

Najjah *et al* also find that UIQI is easier and consistent than calculating noise in defining quality images [20]. Our result is agreed with this finding especially in CT image. CT images can be treated as other common images to determine the quality image.

This automatization is very simple and easy to be implemented in medical physics to define image quality. The medical physicist may improve their treatment planning by knowing the CT-image quality.

IV. CONCLUSION

Automated Universal Image Quality Index (Automated-UIQI) was more convergence in defining image quality than manual noise measurement (MNM) and automated noise measurement (ANM) by the lowest standard deviation which was only 0.00032867. Therefore, this simplified automated noise measurement method is better than ANM. The algorithm of Automated UIQI is also simpler than the others. Implement this automation may give an improvement in optimizing dose calculation for the patient.

ACKNOWLEDGMENT

This study was funded by the Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019, Ministry of Research Technology and Higher Education of the Republic of Indonesia with contract number 1170f/I1.C01/PL/2019.

REFERENCES

[1] Bauhs JA, Vrieze TJ, Primak AN, Bruesewitz MR, and McCollough CH. CT Dosimetry: Com-Parison of Measure-Ment Techniques and Devices. *RadioGraphics*. 2008; **28**(1): 245-253. DOI: https://doi.org/10.1148/rg.281075024.

[2] Verdun FR, Racine D, Ott JG, Tapiovaara MJ, Toroi P, Bochud FO, Veldkamp WJH, Schegerer A, Bouwman RW, Giron IH, Marshall NW, and Edyvean S. Image Quality in CT: From Physical Measurements to Model Observers. *European Journal of Medical Physics*. 2015; **31**(8): 823-843. DOI: https://doi.org/10.1016/j.ejmp.2015.08.007.

[3] Podgorsak EB. *Radiation Oncology Physics: A Handbook for Teachers and Students*. Vienna: International Atomic Energy Agency; 2005. Available from: https://www-pub.iaea.org/mtcd/publications/pdf/pub1196_web.pdf.

[4] Goldman LW. Principles of CT: Radiation Dose and Image Quality. *Journal of Nuclear Medicine Technology*. 2007; **35**(4): 213-225. DOI: https://doi.org/10.2967/jnmt.106.037846.

[5] Christianson O, Winslow J, Frush DP and Samei E. Automated Technique to Measure Noise in Clinical CT Examinations. *American Journal of Roentgenology*. 2015; **205**(1): W93-W99. DOI: https://doi.org/10.2214/AJR.14.13613.

[6] Medda A and DeBrunner V. Color Image Quality Index Based on the UIQI. *Proceeding of 2006 IEEE Southwest Symposium on Image Analysis and Interpretation*. Denver; 2006. DOI: https://doi.org/10.1109/ssiai.2006.1633753.

[7] Anam C, Fujibuchi T, Toyoda T, Sato N, Haryanto F, Widita R, Arif I, and Dougherty G. A Simple Method for Calibrating Pixel Values of the CT Localizer Radiograph for Calculating Water-Equivalent Diameter and Size-Specific Dose Estimate. *Radiation Protection Dosimetry*. 2018; **179**(2): 158-168. DOI: https://doi.org/10.1093/rpd/ncx241.

[8] Hara AK, Paden RG, Silva AC, Kujak JL, Lawder HJ, and Pavlicek W. Iterative Reconstruction Technique for Reducing Body Radiation Dose at CT: Feasibility Study. *American Journal of Roentgenology*. 2009; **193**(3): 764-771. DOI: https://doi.org/10.2214/AJR.09.2397.

[9] Chen B, Christianson O, Wilson JM, and Samei E. Assessment of Volumetric Noise and Resolution Performance for Linear and Nonlinear CT Reconstruction Methods. *Medical Physics*. 2014; **14**(7): 071909. DOI: https://doi.org/10.1118/1.4881519.

[10] Geyer LL, Schopf UJ, Meinel FG, Nance JW, Bastarrika G, Leipsic JA, Paul NS, Rengo M, Laghi A, and de Cecco CN. State of the Art: Iterative CT Reconstruction Techniques. *Radiology*. 2015; **276**(2): 339-357. DOI: https://doi.org/10.1148/radiol.2015132766.

[11] Shekhar R, Walimbe V, and Plishker W. Medical Image Processing. *Handbook of Signal Processing Systems Second Edition*. New York: Springer; 2013: 349-379. DOI: https://doi.org/10.1007/978-1-4614-6859-2_12.

[12] Kaza RK, Platt JF, Goodsitt MM, Al-Hawary MM, Maturen KE, Wasnik AP, and Pandya A. Emerging Techniques for Dose Optimization in Abdominal CT. *RadioGraphics*. 2014; **34**(1): 4-17. DOI: https://doi.org/10.1148/rg.341135038.

[13] Anam C, Arif I, Haryanto F, Widita R, Lestari FP, Adi K, and Dougherty G. A Simplified Method for The Water-Equivalent Diameter Calculation to Estimate Patient Dose in CT Examinations. *Radiation Protection Dosimetry*. 2018; **185**(1): 34-41. DOI: https://doi.org/10.1093/rpd/ncy214.

[14] Solomon JB, Christianson O, and Samei E. Quantitative Comparison of Noise Texture across CT Scanners from Different Manufacturers. *Medical Physics*. 2012; **39**(10): 6048-6055. DOI: https://doi.org/10.1118/1.4752209.

[15] Stock M, Pasler M, Birkfellner W, Homolka P, Poetter R, and Georg D. Image Quality and Stability of Image-Guided Radiotherapy (IGRT) Devices: A Comparative Study. *Radiotherapy and Oncology*. 2009; **93**(1): 1-7. DOI: https://doi.org/10.1016/j.radonc.2009.07.012.

[16] Gervaise A, Osemont B, Lecocq S, Noel A, Micard E, Felblinger J, and Blum A. CT Image Quality Improvement Using Adaptive Iterative Dose Reduction with Wide-Volume Acquisition on 320-Detector CT. *European Radiology*. 2012; **22**(2): 295-301. DOI: https://doi.org/10.1007/s00330-011-2271-7.

[17] Suhardi, Setiabudi W, and Anam C. Upaya Peningkatan Kualitas Citra MRI Dengan Pemberian Media Kontras. *Berkala Fisika*. 2013; **16**(1): 9-14. Available from: https://ejournal.undip.ac.id/index.php/berkala_fisika/article/view/5001.

[18] Anam C, Haryanto F, Widita R, and Arif I. New Noise Reduction Method for Reducing CT Scan Dose: Combining Wiener Filtering and Edge Detection Algorithm. *AIP Conference Proceedings*. 2015; **1677**: 040004. DOI: https://doi.org/10.1063/1.4930648.

[19] Anam C and Santoso HB. Perbandingan Kinerja Algoritma C4.5 dan Naive Bayes untuk Klasifikasi Penerima Beasiswa. *ENERGY: Jurnal Ilmiah Ilmu-Ilmu Teknik*. 2018; **8**(1): 13-19. Available from: https://ejournal.upm.ac.id/index.php/energy/article/view/111.

[20] Al-Najjar YAY and Soong DC. Comparison of Image Quality Assessment: PSNR, HVS, SSIM, UIQI. *International Journal of Scientific & Engineering Research*. 2012; **3**(8): 1-5. Available from: https://www.ijser.org/researchpaper/Comparison-of-Image-Quality-Assessment-PSNR-HVS-SSIM-UIQI.pdf.

[21] Kalra MK, Maher MM, Kamath RS, Horiuchi T, Toth TL, Halpern EF, and Saini S. Sixteen-Detector Row CT of Abdomen and Pelvis: Study for Optimization of Z-Axis Modulation Technique Performed in 153 Patients. *Radiology*. 2004; **233**(1): 241-249. DOI: https://doi.org/10.1148/radiol.2331031505.

[22] Massoumzadeh P, Don S, Holdebolt CF, Bae KT, and Whiting BR. Validation of CT Dose-Reduction Simulation. *Medical Physics*. 2008; **36**(1): 174-189. DOI: https://doi.org/10.1118/1.3031114.

[23] Roodt Y, Robinson P, Nel A, and Clarke W. Robust Single Image Noise Estimation from Approximate Local Statistics. *Proceedings of the Twenty-Third Annual Symposium of the Pattern Recognition Association of South Africa*; 2012: 47–53. Available from: https://core.ac.uk/download/pdf/54204840.pdf.

[24] Nuzula NF, Adi K, and Anam C. Correction of 2D Isodose Curve on the Sloping Surface

using Tissue Air Ratio (TAR) Method. *Jurnal Sains dan Matematika*. 2015; **23**(3): 65-72. Available from: https://ejournal.undip.ac.id/index.php/sm/article/view/9272.

[25] Yani S, Lestari FP, and Haryanto F. Could Water Replace Muscle Tissue used in Electron and Photon Beams? A Monte Carlo Study. *Proceedings of 2nd International Conference on Biomedical Engineering (IBIOMED)*. Institute of Electrical and Electronic Engineers (IEEE); 2018: 70-75. DOI: https://doi.org/10.1109/IBIOMED.2018.8534894.

[26] Ng KH, Wong JHD, and Clarke GD. X-Ray Production. *Problems and Solutions in Medical Physics*. Boca Raton: CRC Press; 2018: 9-21. DOI: https://doi.org/10.1201/9781351006781-2.

[27] Wilson JM, Christianson OI, Richard S, and Samei E. A Methodology for Image Quality Evaluation of Advanced CT Systems. *Medical Physics*. 2013; **40**(3): 031908. DOI: https://doi.org/10.1118/1.4791645.

[28] Anam C, Haryanto F, Widita R, Arif I, and Dougherty G. An Investigation of Spatial Resolution and Noise in Reconstructed CT Images Using Iterative Reconstruction (IR) and Filtered Back-Projection (FBP). *Journal of Physics: Conference Series.* 2019; **1127**: 012016. DOI: https://doi.org/10.1088/1742-6596/1127/1/012016.

[29] Anam C, Fujibuchi T, Budi WS, Haryanto F, and Dougherty G. An Algorithm for Automated Modulation Transfer Function Measurement Using an Edge of a PMMA Phantom: Impact of Field of View on Spatial Resolution of CT Images. *Journal of Applied Clinical Medical Physics*. 2018; **19**(6): 244-252. DOI: https://doi.org/10.1002/acm2.12476.