International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

http://ijpsat.ijsht-journals.org
Vol. 24 No. 2 January 2021, pp. 248-253

# *Automatic Calculation Of Lateral Diameter For Size-Specific Dose Estimate Using A Matlab-Based Kinect Camera*

Ariij Naufal[1], Choirul Anam[1*], Catur Edi Widodo[1], Geoff Dougherty[2]

[1]Department of Physics, Faculty of Mathematics and Natural Sciences, Diponegoro University, Jl. Prof. Soedarto SH, Tembalang, Semarang 50275, Central Java, Indonesia.

[2] Department of Applied Physics and Medical Imaging, California State University Channel Islands, Camarillo, CA 93012, USA.



**Abstract – In this paper, we develop a Matlab-based program on a Kinect camera to automatically calculate lateral diameter ($D_{lat}$) for estimating size-specific dose estimate (SSDE). SSDE is a metric used to express the patient's dose in a CT examination. This metric depends on two other parameters, namely the volume computed tomography dose index ($CTDI_{vol}$) and specific parameters of the patient's body size, especially the effective diameter ($D_{eff}$). CTDIvol can be accessed from the control panel at the time of the CT examination, while $D_{eff}$ can be estimated using $D_{lat}$. A segmentation technique applied to the depth image was used to obtain $D_{lat}$ from the binary image of the participants with a total of 61 individuals with an average age of 22 years. Data analysis showed that $D_{lat}$ measurements using the Kinect camera and a ruler had a mean absolute difference of 6.10% with $R^2$ of 0.76. Meanwhile, $D_{eff}$ estimated from both $D_{lat}$ measurements showed a mean absolute difference of 7.11% with $R^2$ of 0.75. The Kinect camera was able to calculate the participants' $D_{lat}$ and $D_{eff}$ quite well from binary images using segmentation techniques to replace manual and patient's axial image calculation. The advantages of this method are no radiation, insignificant background noise, efficient measurement, and high portability.**

**Keywords – Lateral Diameter, Effective Diameter, SSDE, Depth Image, Kinect Camera, Image Segmentation.**

## I. INTRODUCTION

CT scan is a radiological imaging modality that provides the highest radiation dose. Over the decades, the use of CT has had a constant rate of increasing radiation exposure within a range of populations [1, 2]. Therefore, the radiation dose received by a patient must be accurately calculated so that risk estimation is accurately predicted. In addition, accurate dose estimation is one way to reduce a patient's dose on a CT examination [3]. Currently, the volume CT dose index ($CTDI_{vol}$) and dose length product (DLP) are two most commonly used metrics to express a patient's dose on CT examination. $CTDI_{vol}$ is measured on Polymethyl Methacrylate (PMMA) phantom with a diameter of 16 or 32 cm and this quantity represents the average patient dose within a given volume scan coverage. Meanwhile, DLP is obtained by multiplying $CTDI_{vol}$ by the scan range. However, these two metrics are unable to accurately estimate the patient's dose because patient's dose is highly affected by size of patient which is different for each patient individually [4, 5]. These two metrics do not accurately represent the quantity of radiation absorbed by the patient, but rather the radiation exposed to the patient from CT [6, 7].

In 2011, American Association of Physicists in Medicine (AAPM) recommended using the size-specific dose estimate (SSDE) for CT examination and it can be estimated by the patient's effective diameter ($D_{eff}$). SSDE is considered as a metric of radiation dose received by each patient individually and depends on body size characteristics, such as $D_{eff}$. The $D_{eff}$ is the diameter calculated from the anterior-posterior diameter ($D_{ap}$) and lateral diameter ($D_{lat}$) [8]. However, $D_{ap}$ and $D_{lat}$ measurements may be laborious and time-consuming work in busy CT centres. Therefore, several alternative methods have been developed to automatically measure these parameters from axial CT images [9] or using other modalities such as the Kinect camera [10, 11].

The Kinect camera is able to detect movement and contours of the human body in real-time [12, 13]. This camera features an infrared transmitter and sensor, and a frame rate of 30 fps. The features are able to map the depth to any surface of an object within its frame area and represent it to a depth image. A modality such as the Kinect camera is very cheap when compared to most medical imaging modalities, but it has great potential for identifying various useful parameters in clinical applications [14]. The depth information obtained by the Kinect camera is useful for assessing various sizes of the human body, such as body diameter.

Cook et al. [10] has developed a method for estimating body size using depth map. However, the accuracy and reliability of the calculations need to be evaluated, especially for patients with loose clothing. Based on these results, another investigator [11] has developed a more accurate calculation by installing the camera on the CT gantry. By using the edge detection algorithm in the depth image of the abdomen, the estimation of $D_{ap}$ and $D_{lat}$ produces very high accuracy. However, installing a Kinect camera on the CT frame causes less portability because one camera can only be used for one modality. In this study, we propose an automated image segmentation method to obtain data of the lateral diameter of the human body in a standing position to estimate SSDE using Kinect camera.

## II. METHOD

### 2.1. Research procedure

A total of 61 participants (44 men and 17 women) with age of 21.91 ± 3,830 years, height of 162.77 ± 8,301 cm, and weight of 61.07 ± 11,175 kg were enrolled in this study. This study surveyed the participants' body size data, including body weight, height, and $D_{lat}$ using a scale and a ruler. The Kinect camera was also used to measure the height and $D_{lat}$ automatically. Participants stand upright with their arms folded forward at a distance of 1 meter in front of the background and 2.5 meters facing the Kinect camera which stands 1 meter high so that the camera can capture the whole body up to a height of about 2 meters. Positioning the participants at a distance of 1 meter was intended to accurately segment and separate objects from the background. The depth image was then captured by a Kinect camera connected to a computer running an automatic body measurement program. The segmented depth image automatically generates a binary image with objects that resemble the silhouette of a human body. Finally, the results of $D_{lat}$ calculation were compared with conventional measurements. The $D_{eff}$ was obtained by converting from $D_{lat}$ using AAPM 204 Table 1B.

### 2.2. Kinect camera calibration

Calibrating the camera is needed before taking the participants' depth image data. This is due to a shift in the imaging parameters depending on the computer running the program. We used a Kinect box with dimensions of 15 x 12 x 37 cm as an object. This object was positioned in front of the camera at a distance of 1 to 1.25 m with an interval of 1 cm at each depth image captured. At each variation, the pixel number of the box' side was calculated using the provided ruler (**Fig. 1**). By dividing each pixel number by the dimensions of the box in cm, we obtained the pixel size for each distance. A linear relationship between distance-pixel size was established and used as a calibration factor in the program.

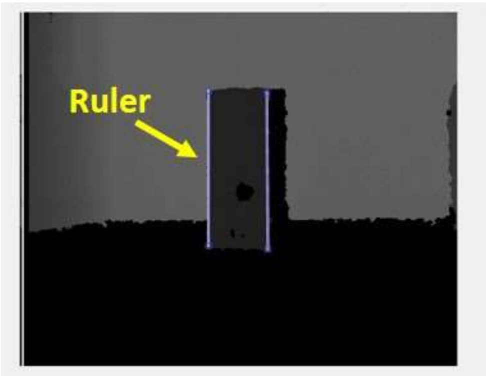


**Figure 1**. Calculating pixel number of the box in the Kinect camera calibration process.

### 2.3. Calculating $D_{lat}$

All depth images were automatically segmented using a method developed by [15]. A range of pixel intensity values was used as a threshold to separate objects from the background in an 8-bit grayscale image. In this program, we used a threshold of 65-85 so that any pixel with an intensity between the threshold ranges will be converted to 1, while those outside the threshold range will be converted to 0. Therefore, a binary image with an object in the form of a human body silhouette was generated (**Fig. 2**). The $D_{lat}$ was calculated automatically by summing all the pixel values with the same y-coordinate, where the y value was determined automatically at the navel position of the participants. Once all of the $D_{lat}$ data have been obtained, the $D_{eff}$ calculated by the ruler and the Kinect camera were compared in a scatter plot to determine their relationship.

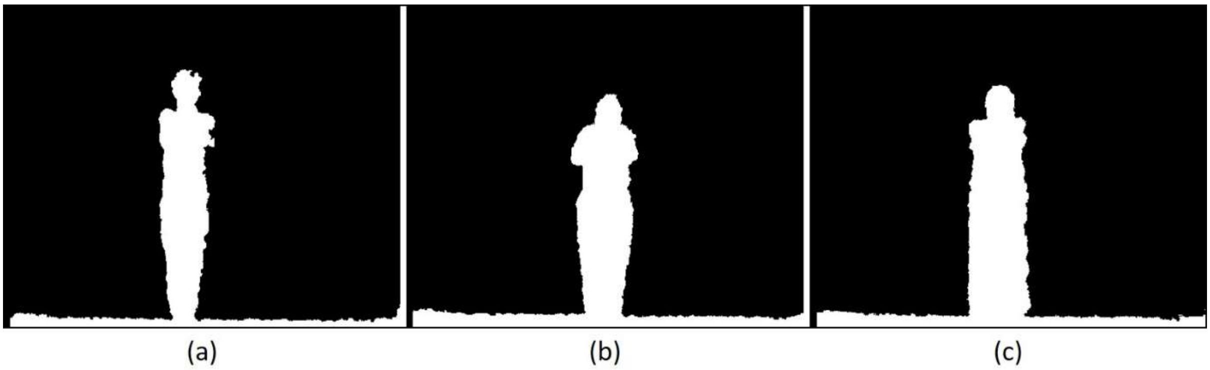


**Figure 2**. Binary image of participants with $D_{lat}$ calculated by a Kinect camera (a) 24 cm, (b) 30 cm, and (c) 37 cm.

### 2.4. Determining $D_{eff}$

The $D_{eff}$ was determined from $D_{lat}$ data obtained from the ruler and the Kinect camera. The conversion was taken from AAPM RPT 204 Table 1B. Both results were compared using a scatter plot to find the $R^2$ coefficient. The $D_{eff}$ will affect the patient CT dose in terms of SSDE.

## III. RESULTS

### 3.1. Relationship between $D_{lat}$ by Kinect and ruler

We analyzed the two measurements of $D_{lat}$ to find the relationship of $D_{lat}$ calculated using the Kinect camera and using a ruler (**Fig. 3**). It can be seen that the measurement result using the Kinect camera is slightly higher than the manual measurement. The $D_{lat}$ calculated using a Kinect ruler and camera showed a mean of 28.79 cm and 29.96 cm, respectively. The mean absolute difference for all data was 6.10% and $R^2$ was 0.76. This indicates that $D_{lat}$ measurement using a Kinect camera is quite accurate. The p-value was 0.0000015 which is less than 0.05, indicating that the two methods of $D_{lat}$ measurements are not significantly different.

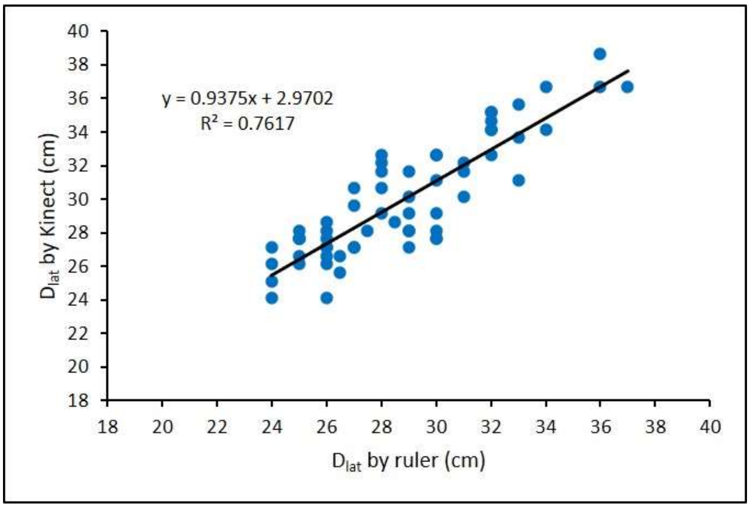


**Figure 3**. Scatter plot of $D_{lat}$ values measured by ruler and by Kinect with $R^2$ of 0.76.

### 3.2. Conversion of $D_{lat}$ values measured by Kinect and by ruler into $D_{eff}$

**Figure 4(a)** shows the relationship between $D_{lat}$ measured by Kinect and $D_{eff}$. While **Fig. 4(b)** shows the relationship between $D_{lat}$ measured by ruler and $D_{eff}$ which is converted by the same method. $D_{lat}$ by Kinect conversion with an average of 29.96 ± 3.46 cm resulted in a $D_{eff}$ of 24.79 ± 3.28 cm and $D_{lat}$ by ruler with an average of 28.79 ± 3.22 cm resulted in a $D_{eff}$ of 23.69 ± 2.98 cm. It can be seen that the distribution of both $D_{eff}$ values is not much different from both $D_{lat}$ with $R^2 > 0.99$. This is because the conversion table is very consistent and robust so that each change in $D_{lat}$ value that is converted to $D_{eff}$ will generate a consistent value, both for manual measurement and by Kinect. Both $D_{eff}$ measured by Kinect and by ruler data are also relatively lower than the two $D_{lat}$ values, respectively.

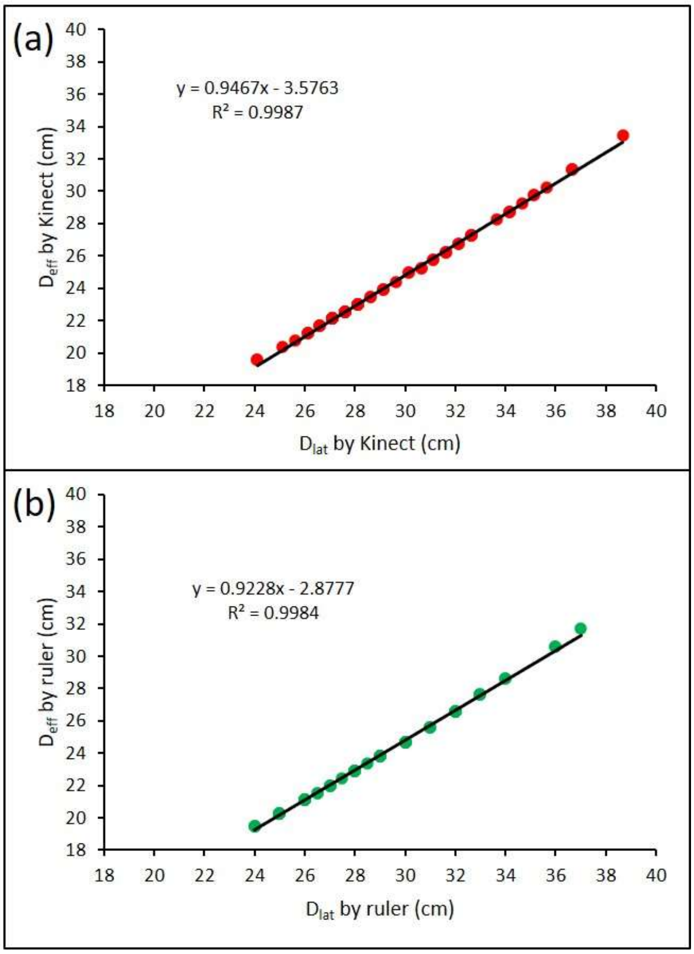


**Figure 4**. Scatter plot of $D_{lat}$ and Deff by: (a) Kinect and (b) ruler.

### 3.3. Relationship between $D_{eff}$ by ruler and by Kinect

After both $D_{lat}$ are converted to $D_{eff}$, they are compared to establish the relationship as shown in Fig. 5. It can be seen that $D_{eff}$ by Kinect is slightly higher than $D_{eff}$ by ruler. Both methods matched quite well with $R^2$ of 0.77. The point distribution occurs because $D_{eff}$ was directly generated from $D_{lat}$ using Table 1B AAPM 204. Therefore, all $D_{eff}$ values depend on Dlat measurements.

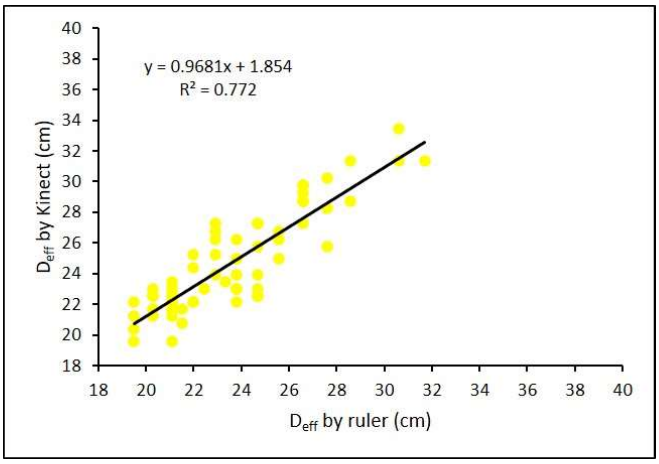


**Figure 5**. Scatter plot of both Deff by ruler and Kinect with $R^2$ of 0.77.

## IV. DISCUSSION

This study focuses on developing a program for calculating human body size, that is, the $D_{lat}$ using a Kinect camera. The method used to calculate $D_{lat}$ is different from previous studies, namely using image thresholding based on the pixel intensity value. The depth image that was acquired using the Kinect camera has a pixel intensity value and represents the depth of an object's surface to the sensor. Segmentation will separate the object from the background based on the intensity value, resulting in a binary image. Apart from the fast processing time, segmentation using image thresholding is also insensitive to background noise.

The difference in results for both $D_{lat}$ and $D_{eff}$ was caused by several factors, such as the participants' clothing and the positioning. In this study, the participants were drawn from general individuals and not hospital patients so that they came wearing a variety of everyday clothes with various colors. Thick clothing can causes differences in diameter measurements, especially for female participants, who mostly wear loose clothing. The standing position of the participants at the time of image acquisition also contributed to distortion because there was no area holding the clothes against the body surface like when they were lying down. As a result, some of the research data had relatively large calculation deviations and had to be excluded from the analysis. To solve this problem, we folded the participants' clothes back and pinned them so they didn't come loose again. As a result, the measurement difference is not as big as expected. This deviation is caused by the remaining wrinkles of the clothes resulting in a relatively higher $D_{lat}$ measurement and $D_{eff}$ calculation by the Kinect as shown in **Fig. 3** and **Fig. 5**.

The standing position of the participants can also be a factor in measuring differences. Each individual's posture is unique. Individuals who have an upright standing posture will produce a more accurate navel position determination so that $D_{lat}$ from Kinect calculation is closer to the manual measurement. The weight supported by the legs while standing will make the standing position more unstable, unlike when lying down where all body weight is supported by an examination table.

Wu et al. [11] reported that the color of the clothes covering the acrylic phantom will not make a significant difference in the depth value of the pixel intensity image produced by the Kinect camera. Therefore, the color of the participants' clothes would not be a significant factor in the $D_{lat}$ calculations. The measurements using the Kinect camera are robust when done in an indoor environment or a place that is protected from direct sunlight. This is because the Kinect camera in addition to emitting infrared rays, the sensor captures the reflection of the light again to be displayed as a depth image in the form of a grayscale, where each intensity value represents the depth of the object's surface to the sensor. Therefore, infrared rays from other sources, such as the sun, will affect the image acquisition. An acquired image in direct sunlight will result in a distorted image. Based on this situation, we tried to find the right place and time for image acquisition, that was, a semi-closed room at night time.

The Kinect camera can be a good instrument for measuring body size such as $D_{lat}$ to determine $D_{eff}$ so that it can estimate SSDE on abdominal CT examinations. The $CTDI_{vol}$ information can be accessed from the console screen and used to determine the conversion factor according to the patient's $D_{eff}$. The advantages of our proposed method are no radiation, automatic procedures, efficient measurement, and the portability of the instrument which can be used on other CT modalities whenever needed.

## V. CONCLUSION

An automated system for lateral and effective diameter of human body using a Kinect camera and a dedicated graphical user interface (GUI) has been developed. The results revealed that both the automatic and manual measurements of $D_{lat}$ are fairly accurate with errors of 6.10% and $R^2$ of 0.76. The conversion of both $D_{lat}$ values measured by Kinect and by ruler into $D_{eff}$ are matched very well with both $R^2 > 0.99$. Finally, the relationship between both $D_{eff}$ values is fairly accurate with $R^2$ of 0.77. Therefore, the Kinect camera was able to accurately measure $D_{eff}$ for estimating CT patient dose in terms of SSDE.

## REFERENCES

[1] F. A. Mettler *et al.*, “Radiologic and nuclear medicine studies in the United States and worldwide: Frequency, radiation dose, and comparison with other radiation sources - 1950-2007,” *Radiology*, vol. 253, no. 2, pp. 520–531, 2009, doi: 10.1148/radiol.2532082010.

[2] L. Lambert *et al.*, “Growing number of emergency cranial CTs in patients with head injury not justified by their clinical need,” *Wien. Klin. Wochenschr.*, vol. 129, no. 5–6, pp. 159–163, 2017, doi: 10.1007/s00508-016-1025-6.

[3] C. Anam, F. Haryanto, R. Widita, I. Arif, G. Dougherty, and D. McLean, “Volume computed tomography dose index (CTDIvol) and size-specific dose estimate (SSDE) for tube current modulation (TCM) in CT scanning,” *Int. J. Radiat. Res.*, vol. 16, no. 3, pp. 289–297, 2018, doi: 10.18869/acadpub.ijrr.16.2.289.

[4] W. Huda and F. A. Mettler, “Volume CT Dose Index and Dose-Length Product Displayed,” *Radiology*, vol. 258, no. 1, pp. 236–242, 2011, doi: 10.1148/radiol.10100297/-/DC1.

[5] J. Xu, X. He, H. Xiao, and J. Xu, “Comparative study of volume computed tomography dose index and size-specific dose

estimate head in computed tomography examination for adult patients based on the mode of automatic tube current modulation," *Med. Sci. Monit.*, vol. 25, pp. 71–76, 2019, doi: 10.12659/MSM.913927.

[6] C. H. McCollough, S. Leng, L. Yu, D. D. Cody, J. M. Boone, and M. F. McNitt-Gray, "CT dose index and patient dose : They are not the same thing," *Radiology*, vol. 259, no. 2, pp. 311–316, 2011, doi: 10.1148/radiol.11101800.

[7] R. Smith-Bindman and D. L. Miglioretti, "CTDIvol, DLP, and effective dose are excellent measures for use in CT quality improvement," *Radiology*, vol. 261, no. 3, p. 999, 2011, doi: 10.1148/radiol.11111055.

[8] Anonymous, "Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body CT Examinations," in *American Association of Physicists in Medicine TG 204*, 2011.

[9] C. Anam, F. Haryanto, R. Widita, I. Arif, and G. Dougherty, "The evaluation of the effective diameter (Deff) calculation and its impact on the Size-Specific Dose Estimate (SSDE)," *Atom Indones.*, vol. 43, no. 1, pp. 55–60, 2017, doi: 10.17146/aij.2017.617.

[10] T. S. Cook, G. Couch, T. J. Couch, W. Kim, and W. W. Boonn, "Using the microsoft kinect for patient size estimation and radiation dose normalization: Proof of concept and initial validation," *J. Digit. Imaging*, vol. 26, no. 4, pp. 657–662, 2013, doi: 10.1007/s10278-012-9567-2.

[11] J. Wu, R. P. Han, and Y. L. Liu, "Using a Somatosensory Controller to Assess Body Size for Size-Specific Dose Estimates in Computed Tomography," *Biomed Res. Int.*, vol. 2018, pp. 8–10, 2018, doi: 10.1155/2018/2734297.

[12] Y. Yao and Y. Fu, "Contour model-based hand-gesture recognition using the kinect sensor," *IEEE Trans. Circuits Syst. Video Technol.*, vol. 24, no. 11, pp. 1935–1944, 2014, doi: 10.1109/TCSVT.2014.2302538.

[13] D. Kim, D. H. Kim, and K. C. Kwak, "Classification of K-pop dance movements based on skeleton information obtained by a kinect sensor," *Sensors (Switzerland)*, vol. 17, no. 6, 2017, doi: 10.3390/s17061261.

[14] S. T. L. Pöhlmann, E. F. Harkness, C. J. Taylor, and S. M. Astley, "Evaluation of Kinect 3D Sensor for Healthcare Imaging," *J. Med. Biol. Eng.*, vol. 36, no. 6, pp. 857–870, 2016, doi: 10.1007/s40846-016-0184-2.

[15] N. Afrieda, C. Anam, W. Setia Budi, and G. Dougherty, "Automated patient position in CT examination using a Kinect camera," *J. Phys. Conf. Ser.*, vol. 1505, no. 1, 2020, doi: 10.1088/1742-6596/1505/1/012034.