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Automatication of Thickness Slice Measurement Using Non-Rotation Method on Three Ladder Objects from Computed Tomography

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Abstract: To perform slice thickness calculation automatically using the non-rotational method on the three ladder objects in the AAPM CT Performance Phantom image. Phantom was scanned with a GE Healthcare 128-slice CT scan scanner using slice thicknesses of 0.625 mm, 5.0 mm, and 10.0 mm. The software was developed with a non- rotational method to be able to measure the FWHM value and the mean on the three rungs of the object. In addition, the FWHM of the non-rotational method was compared with the rotational method The FWHM value from automatic measurement for slice thickness is 0.625 mm in three slice variations with non-rotational method 1.68 mm and rotation method 1.61 mm while for slice thickness 5.0 mm on non-rotation method is 6.51 mm, rotation method is 6.68 mm. , and for a slice thickness of 10.0 mm for the non-rotational method 9.58 mm and the rotational method 9.75 mm. The results of the non-rotational method were slightly lower (i.e. 1,74%) than the results of the rotational method for each nominal slice thickness, except for the smallest slicethickness The automatic slice thickness measurement algorithm on AAPM CT Performance Phantom has been improved using a non-rotational method. The improved algorithm can overcome the widening problem that occurred in the previous method due to object rotation.

Keywords: CT-scan; Slice thickness; Non-rotational method; AAPM CT Performance Phantom

Introduction

Computed Tomography (CT) has developed rapidly in terms of technical performance and clinical applications, making it one of the most important X-ray imaging methods in the world. The images produced by CT-scans must be of good quality, in order to facilitate clinical staff in diagnosing an abnormality in the patient's body. Image quality is determined by several parameters, one of which is slice thickness (Kartika Sari, Bahagia, Hartoyo, & Muliyati, 2021). The thickness of the axial image slice is one of the most important factors in clinical practice.

The associated image quality can provide clear diagnostic results in detecting serious anomalies (Teroci et al., 2024). The thickness of the slices on CT scan images usually ranges from submillimeter to 5 mm or more, depending on the anatomy to be imaged. The thickness of the slice affects the spatial resolution of the image (Safitri, Evi, & Heru, 2011). This is one of the image quality parameters that indicates the ability to visualize an object or organ with high contrast values.

The thickness of the thin slices can be used for examination of organs. Small anomalies can provide more detailed images and conversely, thick slice thickness is required for images of large organs (Madja,

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Ali, & Loho, 2013). However, the thinner slice thickness causes the image noise level to also increase.

Therefore, the determination of the slice thickness is highly dependent on the imaging objective. For one particular type of examination, the required slice thickness may differ from other types of examination. Measurement of slice thickness accuracy can be done using various types of phantoms. In the ACR CT Accreditation Phantom (Gammex Inc., Middlenton, WI, USA), slice thickness measurements were performed on the axial image by counting the number of discrete lines at the top and bottom (Kusumawardani, Theresia, & Muslihatun, 2010). The AAPM CT Performance Phantom (Model 610, CIRS, Virginia, USA), on the other hand, provides a layer thickness measurement for center stair image objects (Rahmah, Rahmah Akademi Teknik Radiodianostik dan Radioterapi Bali, Kadek Yuda Astina Akademi Teknik Radiodianostik dan Radioterapi Bali, & Bagus Gede Dharmawan Akademi Teknik Radiodianostik dan Radioterapi Bali, 2023).

Coating thickness measurements are usually calculated and obtained manually by a medical practitioner. Although accurate results can be obtained by manual calculation, the process is time consuming so that automatic calculation of slice thickness has been proposed externally for more objective and accurate measurements(Saputri, Santoso, Oktavianto, & Anita, 2019). The method was evaluated by Lasiyah et al. (2021) to test the accuracy of the slice thickness for filter variability and variation in distance from the iso-center The previous method uses the Hough transform to detect the slope angle of the ladder object, and then rotates it according to that angle. By rotating the image, the stair object is slightly wider and will affect the measurement accuracy. Measurements using the rotation method resulted in five variations of layer thickness with a difference ratio of 1.0 at the configured slice thickness(Hariani, Prasetya, & Mahendrayana, 2024)

The AAPM CT Performance Phantom has three ladder objects. Measurements on these three objects must provide more accurate and consistent results. Therefore, in this study, we have compared the automatic FWHM measurement for all stair objects (top, middle, bottom) with rotational and non-rotational methods(Jurnal et al., 2024). Automated slice thickness measurement methods based on Hough transform and image rotation, while offering efficiency, have the potential to introduce bias due to apparent widening of the ladder objects. Furthermore, the AAPM CT Performance Phantom, commonly used in CT scanner performance evaluation, intrinsically has three separate ladder objects (top, middle, and bottom).

Theoretically, slice thickness measurements performed on these three objects should yield identical or very similar values if the measurement method is accurate and free from artifacts. The use of these three ladder objects offers the opportunity to improve the reliability and validity of the measurements, as it provides three independent data points for each slice thickness configuration. Previous studies have tended to focus on measurements on a single ladder object, thus ignoring the potential additional information that can be obtained from the other ladder objects(Karulina Imanda Muhamad et al., 2022).

Therefore, this study is very important because it addresses a gap in the existing literature and methodology. This study systematically compares automated FWHM measurements of slice thickness on the three ladder objects (top, middle, and bottom) available on the AAPM CT Performance Phantom. This comparison is made between two methodological approaches: (1) a method involving image rotation based on the Hough transform (as previously proposed), and (2) a new method that does not involve image rotation (non-rotation), thus eliminating potential bias due to apparent dilation.

Method

This study was conducted using the AAPM CT Performance Phantom (Model 610, CIRS, Virginia, USA) and a 128-slice CT scanner installed in the Radiology Installation of Indriati-Solo Hospital. The slice thickness of the phantom image was measured using the 610-04 module (slice thickness insert). This module consists of three aluminum plates tilted at an angle of 450. This module creates an axial image in three-dimensional form on the riser object that represents the nominal thickness of the image slice. Slice thickness variations of 0.62, 5.0 mm and 10.0 mm were used as shown in Figure 1. The CT input parameters are shown in Table 1.

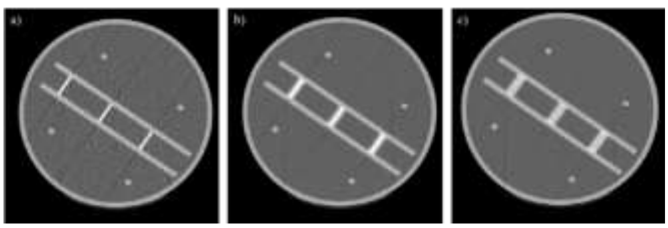

Figure 1. Image of three rung objects for slice thickness (a) 0.625, (b) 5.0 and (c) 10.0 mm

Table 1. Scan parameters

Scanner	GE Revolution EVO
Scan option	Helical
Voltage (kV)	120
Tube current (mA)	100
FOV (mm)	272
Position	*Iso Center*
Rotation time (s)	1
Slice Thickness (mm)	0.625, 5.0 and 10.0

Automatic Measurement with Rotation Method

Automatic measurement of slice thickness by rotating objects has been investigated by Sofiyatun et al. (2020) on the stair object (middle) in a phantom where the object is rotated so that the profile curve is formed from a straight line (Ricky Richard Ivanson Tude, Aris Diartama, & Made Purwa Darmita, 2024). Figure 2 demonstrates this calculation on an image with a slice thickness of 0.625.

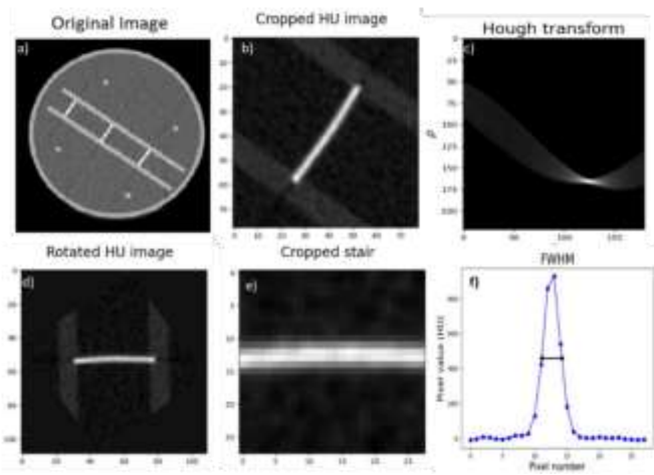

Figure 2. Automatic measurement of slice thickness with rotation method. (a) the original CT scan image of the ladder object, (b) the image showing the middle of the ladder (middle), (c) the image showing the Hough transform to detect the slope angle of the ladder object, (d) the ladder object (middle) being cut and rotated, (e) Image rotated according to the angle, (f) FWHM graph of automatically determined straight line.

Automatic measurement by Non-rotation method

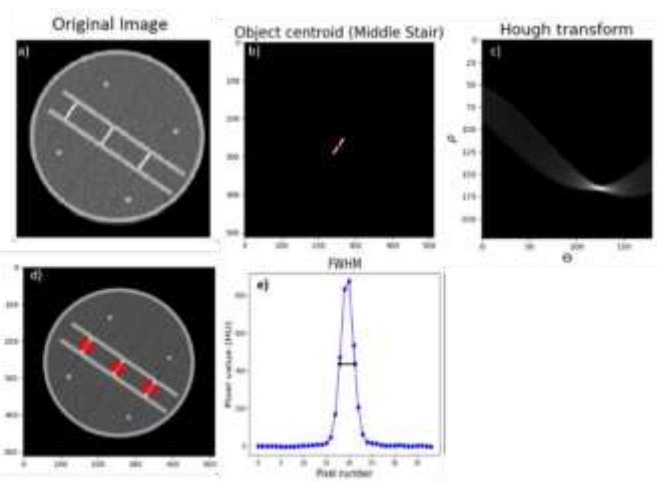

Figure 3. Image processing for automatic slice thickness measurement with non-rotational method. (a) original CT scan image of the ladder object, (b) Image showing the segmented ladder object. (c) Figure showing the results of the Hough transformation for automatic angles for the three ladder objects. (d) Draw slanted lines on the three stairs objects. (e) Profile the average of the FWHM values of automatically defined slashes.

In the non-rotation method, the original image of the ladder object (Figure 3a) is segmented and labeled for the three rungs objects, which are represented by the ladder object (middle) (Fig. 3b). The angle of the ladder object is automatically determined using the Hough transform (Fig. 3c). Based on the detected slope angle, 11 profile lines were placed on each rung of the image in Hounsfield Units (HU) (Fig. 3d). These profile lines will take the value of each pixel they pass through. These pixel values are then averaged over all the steps, so that the profile curve of the ladder object is obtained (Fig. 3e). This curve represents the slice thickness profile so the slice thickness FWHM value is automatically determined by the non-rotation method for a single slice thickness of 0.625 mm.

Result and Discussion

Picture. 4 shows the FWHM graph on each of the set values for the rotational method and the non- rotational method. The y-axis represents the pixel value (HU) and the x-axis represents the pixel number value. The FWHM values for all slice thicknesses are tabulated in Table 2, along with the results from the measurements by the rotation method. Figure 4 shows that the FWHM for the three rungs of the non-rotational measurement is lower than that of the rotational method, except for the slice thickness of 0.625 mm.

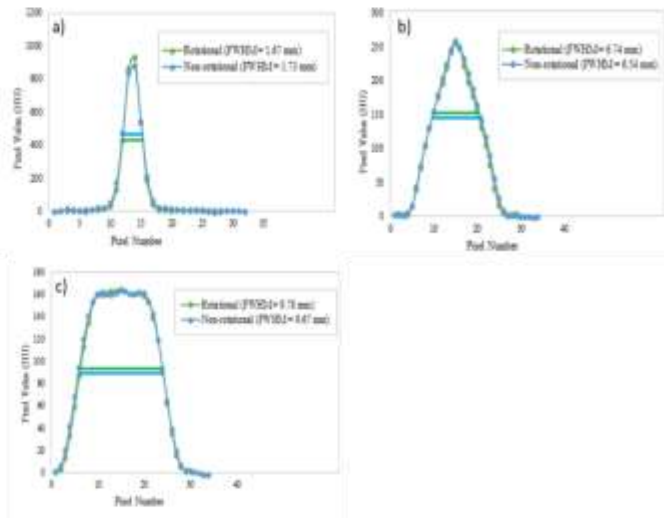

Figure 4. Profile of pixel values, with the y-axis being the FWHM indication of slice thickness in the image for rotational and non-rotating methods at slice thickness variations from (a) 0.625 mm, (b) 5.0 mm, (c) 10.0 mm

The two calculation methods are compared to determine the relationship between them as shown in Figure 5. It can be seen that the results obtained by the rotation method are higher than the non- rotational method except for the slice thickness of 0.625 mm. These two methods match R2 > 0.99, indicating that the two calculation methods are closely related.

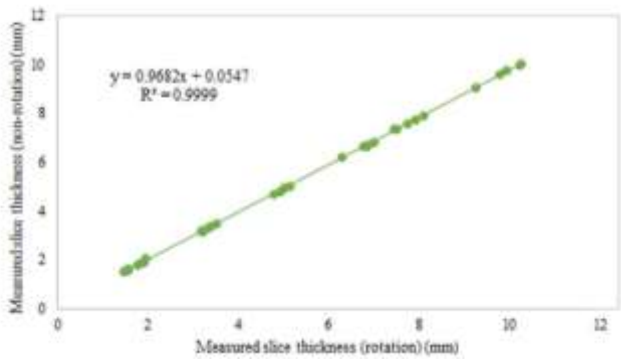

Figure 5. Graph of the relationship between rotational and non-rotational methods

Table 2. Automatic measurement of non-rotational and rotational methods of FWHM results and the average value of the three ladder objects. Measurements were carried out on three slice variations for each set value.

Slice thickness			Difference
Set	Rotation method	Non-rotation method	
0.625	1.61 ± 0.06	1.68 ± 0.04	0.07
5.0	6.68 ± 0.16	6.51 ± 0.05	0.17
10.0	9.75 ± 0.44	9.58 ± 0.07	0.17

The automatic slice thickness calculation algorithm for AAPM CT Performance Phantom has been previously developed with the rotation method first proposed by Sofiyatun et al. (2020) using the ladder object (middle) (Hikmah, Indah Purnama, Prayugo Hariyanto, & Nur Afifah Zen, 2023). The measurement of the thickness of the slices automatically with the non-rotational method was developed to overcome the weakness of the rotation method, which is suspected when the object of the stairs is rotated will experience widening. In addition, the algorithm that we developed also utilizes the three rung objects to obtain optimal FWHM(Setiawan, Radiodiagnostik dan Radioterapi Bali, & Radiologi Rumah Sakit Primaya Tangerang, 2024).

Based on the data in Table 2, the non-rotational method produced a smaller FWHM than the rotational method (Sambawitasia, 2022). Compared to automatic measurement using the rotation method, the automatic measurement using the non-rotational method that has been developed can reduce the measurement deviation so that the measurement error value obtained is also lower (Fitriyasari, 2023). In the previous calculation algorithm, FWHM is searched only from one of the three rung objects. Meanwhile, in this study, all three were used to make the profile curve(Irfan Irfan & Rahmat Widodo, 2024).

Simultaneous selection of these three objects is carried out with the aim of obtaining optimal FWHM. In some cases, the object of the stairs can be distorted by artifacts, either from clogged air, or from the metal material itself(Glorianismus, Maharani, Watiningsih, Ayu, & Trevesia, 2023). Especially in thin slice thickness, the image noise is relatively large, so taking FWHM from one object is not enough. The selection of these three objects at once is intended(Rohadi et al., 2023) to obtain optimal FWHM provided that the three objects look intact and are not distorted by the slice position that is too close to the module next to it(Fitriania, Kurnia, Ramadani, & Fatimah, 2022).

Thus, the results of the FWHM measurement with the non-rotational method on the three stair objects provide increasingly more accurate values, as shown in Table 2. In accordance with Table 2. it is known that the accuracy of the automatic measurement results with the non-rotational method depends on the magnitude of the value. set slice thickness used except for slice thickness 0.625 mm.

This research focuses on the development of an automated Full Width at Half Maximum (FWHM) measurement method to determine slice thickness in CT-scan images, using the AAPM CT Performance Phantom. In particular, we propose a non-rotation method as an alternative to the rotation method used in previous research (Listiyani et al., 2021).

The main motivation behind the development of this non-rotation method is to overcome the inherent weakness of the rotation method, namely the potential(Maghfirah, Rahim, & Fadhlin, 2024). Pseudo-widening of the ladder object when the image is rotated(Kartika Sari et al., 2021). This apparent widening, although minimal, can systematically affect the FWHM calculation, which in turn can reduce the accuracy of slice thickness measurement(Anggraeni, 2023). In addition, the algorithm we developed uniquely utilizes all three ladder objects available on the phantom, in contrast to previous approaches that focused on only one ladder object (Kastiwi, 2022).

The results of this study, presented in Table 2, consistently show that the non-rotation method produces a smaller FWHM value compared to the rotation method(Destri Bestari Palimbong, Anak Agung Aris Diartama, & I Kadek Sukadana, 2023). This difference is statistically significant, and indicates that the non-rotation method provides an estimate that is closer to the actual slice thickness value (the value that has been configured on the phantom)(Puspaningrum, Putu, Jeniyanthi, & Darmita, 2023).

This finding is in line with our initial hypothesis that eliminating the rotation stage will reduce distortion in the ladder objects and improve measurement accuracy (Utami, Azizah, Maulana, Susanto, & Oviyanti, 2023). As stated by (Abdulkareem et al., 2023), accuracy in the measurement of image quality parameters, such as slice thickness, is crucial to ensure optimal quality of diagnosis and therapy planning [10]. Our results show that non-rotation methods contribute to this accuracy improvement.

One of the key aspects of the algorithm we developed is the utilization of all three ladder objects on the AAPM CT Performance Phantom to generate the intensity profile curve(Utami et al., 2023). This approach is fundamentally different from previous research by Lasiyah et al. (2021), which uses only one ladder object (Setiawan et al., 2024).

The selection of these three ladder objects is based on the consideration that in some cases, one or more ladder objects can be distorted by artifacts, such as trapped air bubbles or the influence of metal materials, especially in thin slice thicknesses where image noise tends to be higher(Annisa, 2025).

By using all three ladder objects, we can minimize the influence of these artifacts and obtain a more robust and reliable FWHM estimate(Safitri et al., 2011). This strategy is similar to the ensemble learning approach in machine learning, where several models (in this case, measurements from several ladder objects) are combined to improve prediction accuracy and stability(Aprilyanti, Milvita, Prasetio, & Yuliati, 2013)(Sofiyatun, Anam, Zahro, Rukmana, & Dougherty, 2021) .

Furthermore, the results of our study show that the use of three ladder objects, combined with the non-rotation method, produces increasingly accurate FWHM measurements as the set slice thickness (the slice thickness set on the CT scanner) increases, as shown in Table 2.

This trend indicates that our method performs very well on thicker slice thicknesses, which are often used in various clinical applications(Virgin, Astina, & Pratista, 2023). However, it should be noted that at a slice thickness of 0.625 mm, there is a deviation from this trend, where the accuracy decreases slightly.

This is likely due to a significant increase in image noise in very thin slices, which can affect FWHM calculations, even with the use of all three ladder objects. This phenomenon is consistent with the basic principle of CT imaging, where there is a trade-off between spatial resolution (which increases with thin slices) and image noise (which also increases with thin slices) (Rahmawati et al., 2024)

It is important to compare the results of this study with the findings of previous research. Lasiyah et al. (2021) reported a difference ratio of 1.0 between the slice thickness values measured by the rotation method and the configured slice thickness values(Virgin et al., 2023). Although this ratio seems ideal, keep in mind that their measurement was based on only one ladder object and involved a rotation process that had the potential to introduce bias(Dewilza et al., 2023). In our study, although we did not directly report the difference ratio, the smaller FWHM value and lower measurement error that we obtained with the non-rotation method indicate that our method provides slice thickness estimates that are closer to the true value. In addition, the use of all three objects produces more reliable data(Noveranty, Purwaningsih, & Fendriani, 2024).

This study has successfully developed an automatic FWHM measurement method without rotation that shows improved accuracy and consistency compared to the previously used rotation method(Herlinda, Fitriyani, & Marzuki, 2019). The utilization of the three ladder objects on the AAPM CT Performance Phantom has been proven effective in minimizing the influence of artifacts and image noise, resulting in more reliable slice thickness estimation(Puspitaningtyas, 2023).

Despite the limitations of very thin slices, the overall results of this study have positive implications for improving the quality of slice thickness measurements on CT scans, which in turn will contribute to improving the accuracy of diagnosis and therapy planning in clinical practice(Wahyuni & Amalia, 2022). Further Research can be focused on developing more sophisticated denoising algorithms to overcome the challenges of measuring thin slices, as well as validating this method on various types of phantoms and CT scanners(Bisra, Hulmansyah, & Artata, 2024).

Conclusion

An improved algorithm to measure FWHM values with slice thickness variations using non-rotational methods on the three rungs of the object in the AAPM performance phantom has been successfully developed. We have compared between the FWHM values for each set of values for the three-slice variation and the average values for each of the three variations in the measurement of the three stair objects using the rotational and non-rotational methods (0.17%) of the rotation method except for the smallest slice thickness of 0.625 mm.

Author Contributions

All authors have made significant contributions to completing this manuscript.

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Conflicts of Interest

The authors declare no conflict of interest

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