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# Distance between Slices Investigation on Siemens CT Phantom Images

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ABSTRACT

This study aims to develop an algorithm for automatic measurement of distance between slices on a Siemens CT phantom with variations of slice thickness and field of view (FOV). The Siemens 64-slice Somatom Perspective CT scanner was utilized to acquire the Siemens phantom image data, with slice thickness variation (i.e., 1, 2, 3, 4, and 5 mm) and FOV variation (i.e., 220, 240, and 300 mm). The distance between slices was calculated by comparing two images from different slice positions. The first stage was opening the images. The second stage was segmentation of the ramp object from image slice-1. The third stage was determination of the centroid coordinates of the ramp object from image slice-1. The fourth stage repeated the processes at second and third stages for slice-2. The fifth stage was calculating the distance between slices. The measured distances were compared with the set distances extracting from DICOM header for every slice position. The developed algorithm can measure distance between slices for variations of slice thickness and FOV. The results of automatic measurement of distance between slices have strong linear correlation ($R^2 > 0.99$) with the set distances. The differences between automated measurement results and set distances are more than 2 mm for distances up to 50 mm or the differences are around 23% for both slice thickness and FOV variations.

**Keywords :** CT SCAN, Siemens PHANTOM, SLICE THICKNESS, FOV, Distance Between Slices

## I. INTRODUCTION

Computed tomography (CT) is one of the imaging modalities used for patient diagnoses and radiation treatment simulation [1, 2]. The CT image quality is influenced by input scan parameter, detector system, image reconstruction techniques, and other parameters [3]. The CT image quality is characterized by many metrics, such as image noise, CT number accuracy, CT number uniformity, spatial resolution, low contrast detectability, and slice thickness [4, 5].

The slice thickness is one of the important parameters affecting volumetric accuracy of the object within body [6]. Accurate volumetric measurement is crucial for detecting and staging of diseases, and detecting tumor response to treatment [7]. In addition to slice thickness, the distance between slices (also known as slice interval) is also an important factor affecting the volumetric accuracy of the organ or disease [8, 9]. It is important to note that slice thickness and distance between slices are two distinct parameters. Slice thickness represents the thickness of the slice of the image [10], while the distance between slices refers to the gap between two axial image slices along the z-axis.

Unlike slice thickness measurement, which already has a special phantom and has a standard method for measuring it, the distance between slices measurement still doesn't have a standard method or a special phantom for measuring it. However, the ramp of objects in several available phantoms, for example the Siemens CT phantom, the distance between slices can be measured. However, it requires a special approach to its measurement. In this study, we propose an approach to measure the distance between slices on a Siemens CT phantom. To facilitate a more objective and efficient measurement of the distance between slices, we develop a software to automatically measure that parameter. It is noted that the Siemens CT phantom has ramp object positioned at angle 23°. We measure distance between slices for various distances at two variations of slice thickness and field on view (FOV). The results will be compared with the distances between slices extracted from DICOM header.

Until recently, the accuracy of the distance in the z-direction was only determined by using two markers placed at a certain distance. However, unfortunately on the Siemens CT phantom, two markers for the z-axis accuracy is not yet available. Thus, the method proposed in this study can be an alternative for measuring the distance of two objects on this z-axis.

## II. METHODS AND MATERIAL

### A. CT scanner and phantom

The CT scanner used to acquire the Siemens CT phantom images was the Siemens 64-slice Somatom Perspective CT scanner (Figure 1a). The Siemens CT phantom was model No.10662318 (Figure 1b). The phantom module used was the slice thickness module (i.e., ramp object) positioned at a 23° degree. The phantom was scanned with two variations of slice thickness and FOV. Table 1 displays input parameters used for data acquisition.

Table 1. Parameters used in data acquisition for slice thickness and FOV variations

| Input Parameter | Variation of slice Thickness | Variation of FOV |
|---|---|---|
| Mode | Helical | Helical |
| Tube voltage | 130 kV | 130 kV |
| Tube current | 146 mA | 150 mA |
| Pitch | 0.9 | 0.85 |
| Field of view | 260 mm | 220, 240, and 300 mm |
| Rotation time | 1.5 s | 1.5 s |
| Slice thickness | 1, 2, 3, 4 and 5 mm | 5 mm |

### B. Distance between slices measurement

To measure the distance between slices, two axial images from different slice positions were used. This study proposed that the distance between slices was measured as the distance between the centroid coordinates of the ramp object from two axial images with different positions. The flowchart of the slice distance measurement is displayed in Figure 2.

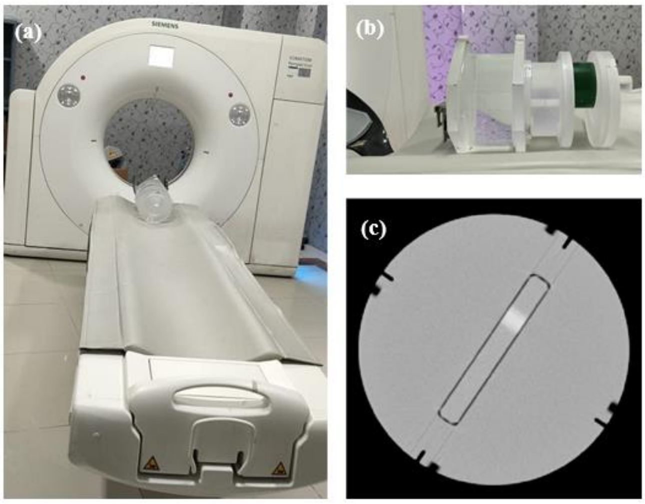


**Figure 1**. (a) Photograph of Siemens 64-slice Somatom Perspective CT scanner, (b) Photograph of the Siemens CT phantom, and (c) Example of axial image of the ramp object for slice thickness measurement.

The first step was segmentation of the ramp object on the Siemens CT phantom image (Figure 2b) using a threshold of 150 HU. This segmentation process is employed to separate the ramp objects from its background. The segmentation result generates a binary image, where the foreground represents the ramp objects (Figure 2e). The second step was calculating the centroid coordinates of the ramp object within the first image using the equations (1) and (2). Equation (1) was for determining the X-axis and equation (2) was for determining the Y-axis.

$$X_{c1} = \frac{1}{|R|} \cdot \sum_{(i,j)\in R} i \quad (1)$$

$$Y_{c1} = \frac{1}{|R|} \cdot \sum_{(i,j)\in R} j \quad (2)$$

The third step was repeating the processes from the first and second steps, but for image at slice number-2 (Figure 2c), which has a different slice position compared to slice-1. Centroid coordinates from slice-1 were indicated by ($X_{c1}$, $Y_{c1}$) for slice-1, and centroid coordinates from slice-2 were indicated by ($X_{c2}$, $Y_{c2}$). The results of segmentations of two ramp objects from two axial images were combined into one image (Figure 2f). The next step was to calculate the distance between two slices. Since the ramp object in the Siemens phantom is positioned at angle 23°, the calculation of the distance between slice-1 and slice-2 can be performed using equation (3).

$$d_m = \sqrt{(X_{c1} - X_{c2})^2 + (Y_{c1} - Y_{c2})^2}\, tan\, 23° \quad (3)$$

$d_m$ represents the measured distance between the two axial images located at two locations in pixel units. To convert $d_m$ from pixel unit to mm, it was multiplied by the pixel spacing extracted from DICOM header.

To evaluate the accuracy of the proposed method in this study, the distance between slices was also calculated from the DICOM header information. It is noted that each slice position is saved in the DICOM header. By obtaining two positions from two slices ($s_1$ and $s_2$), the set distance between slices ($d_{set}$) can be calculated using equation (4).

$$d_{set} = |s_1 - s_2| \quad (4)$$

After obtaining the measured distance between slices ($d_m$) and distance between slice from DICOM header or set distance ($d_{set}$), the difference between the two values ($\Delta d$) can be calculated using equation (5).

$$\Delta d = |d_m - d_{set}| \quad (5)$$

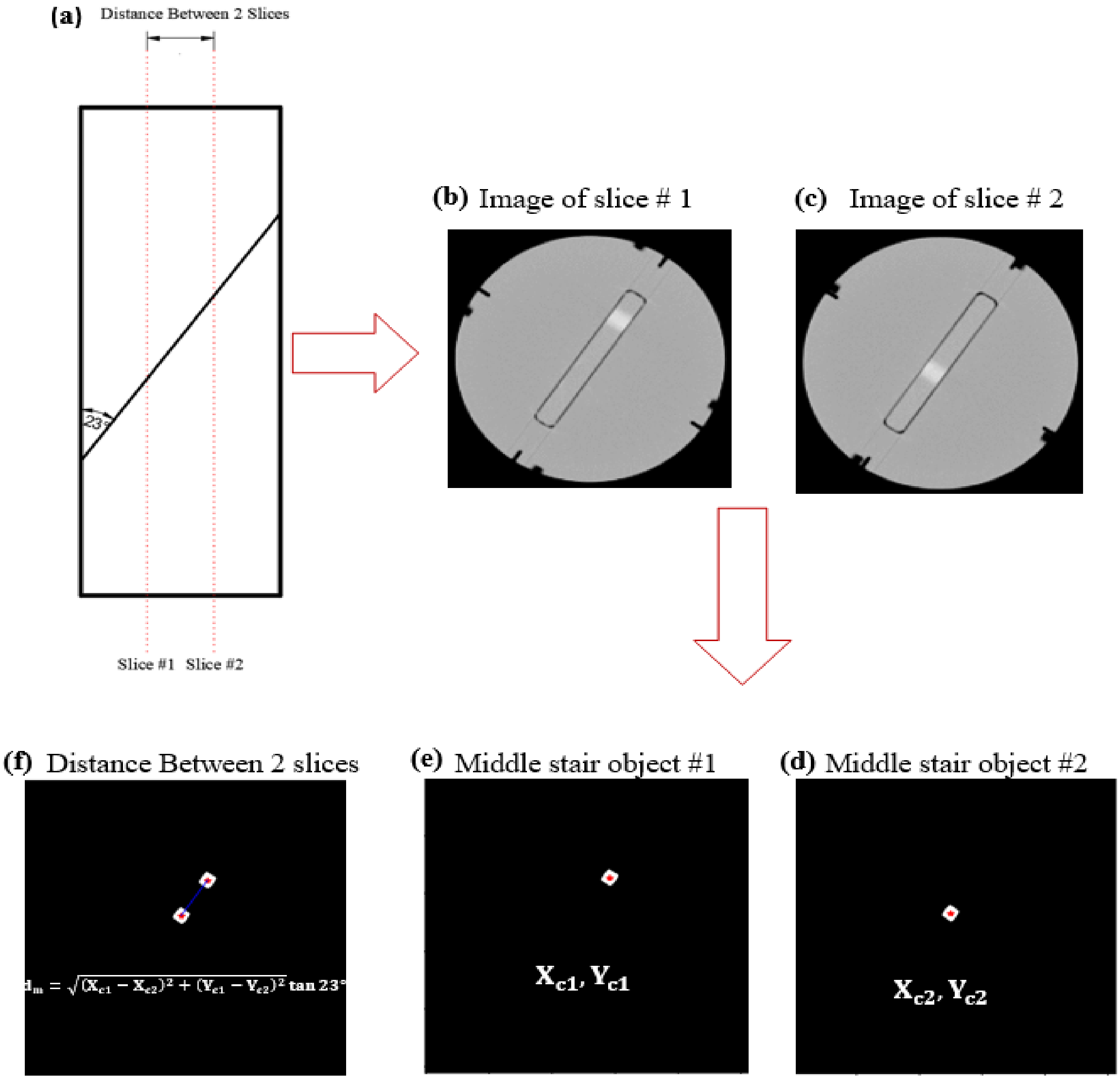


**Figure 2**. Steps for automated distance between two slices on the Siemens CT phantom.

All steps in measuring the distance between slices ($d_m$) and distance between slice from DICOM header ($d_{set}$) were integrated to IndoQCT software. The graphical user interface (GUI) of the IndoQCT is depicted in Figure 3.

## III.RESULTS AND DISCUSSION

### A. Slice thickness variation

Figure 4 displays the images of the Siemens phantom for variation of slice thickness (i.e., 1, 2, 3, 4, and 5 mm). Figure 5 presents the relationships between results of automated measurement of the distance between slices ($d_m$) and the set distance between slices ($d_{set}$) for various slice thicknesses. The results indicate strong linear correlations with $R^2 > 0.99$ for all slice thicknesses used. This indicated that automated measurements perform well for all slice thicknesses used. Figure 6 indicates the absolute differences between the automated measurement results ($d_m$) and the set distance between slice ($d_{set}$) for various slice thicknesses. It is found that the absolute difference ($\Delta d$) increases linearly with the set distance between slice ($d_{set}$). However, the percentage differences are relatively constant with average of 23%.

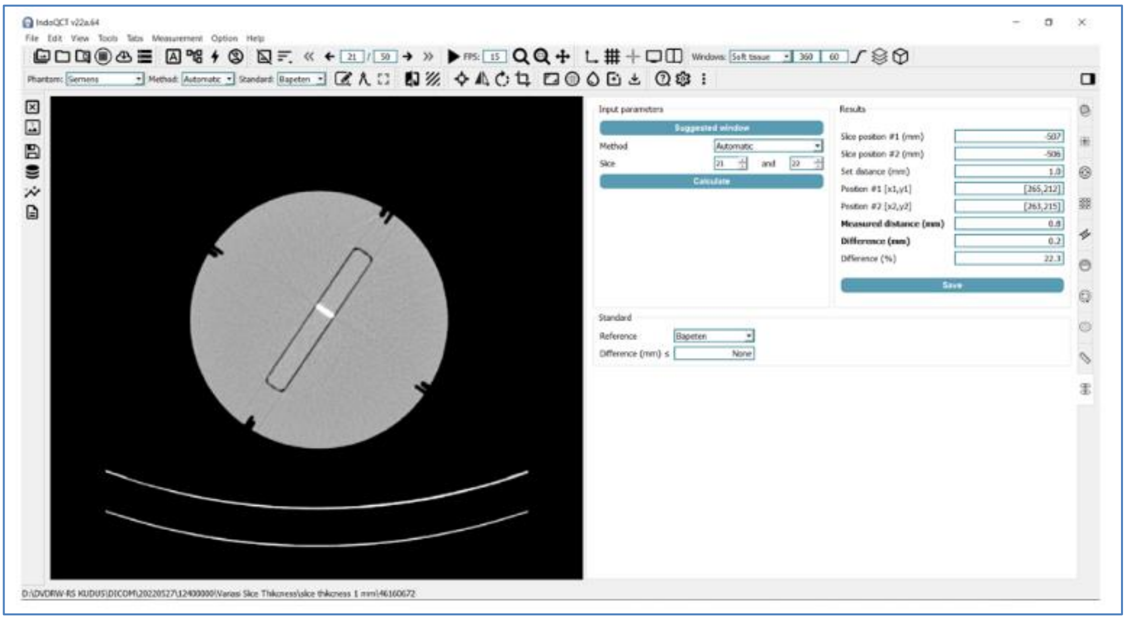


**Figure 3**. Screenshot of IndoQCT for measuring distance between slices on the Siemens CT phantom.

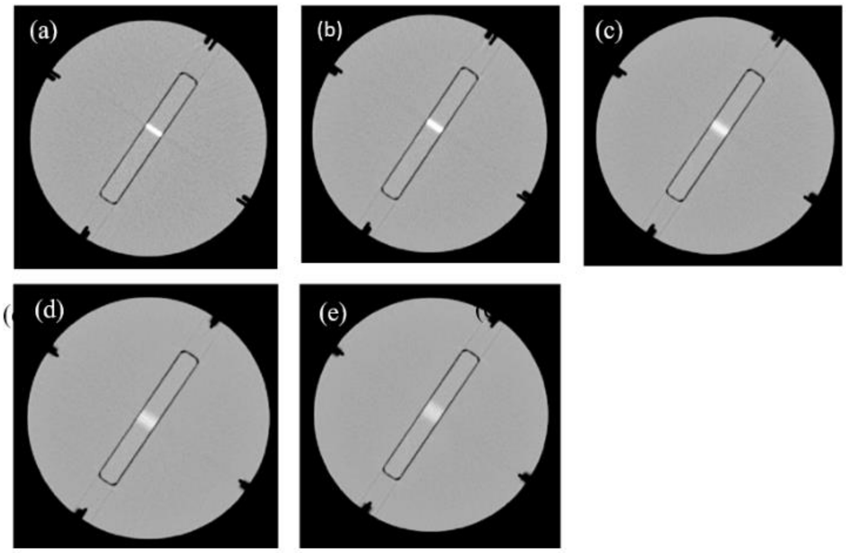


**Figure 4**. Phantom images for various slice thicknesses: (a) 1 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm, and (5) mm.

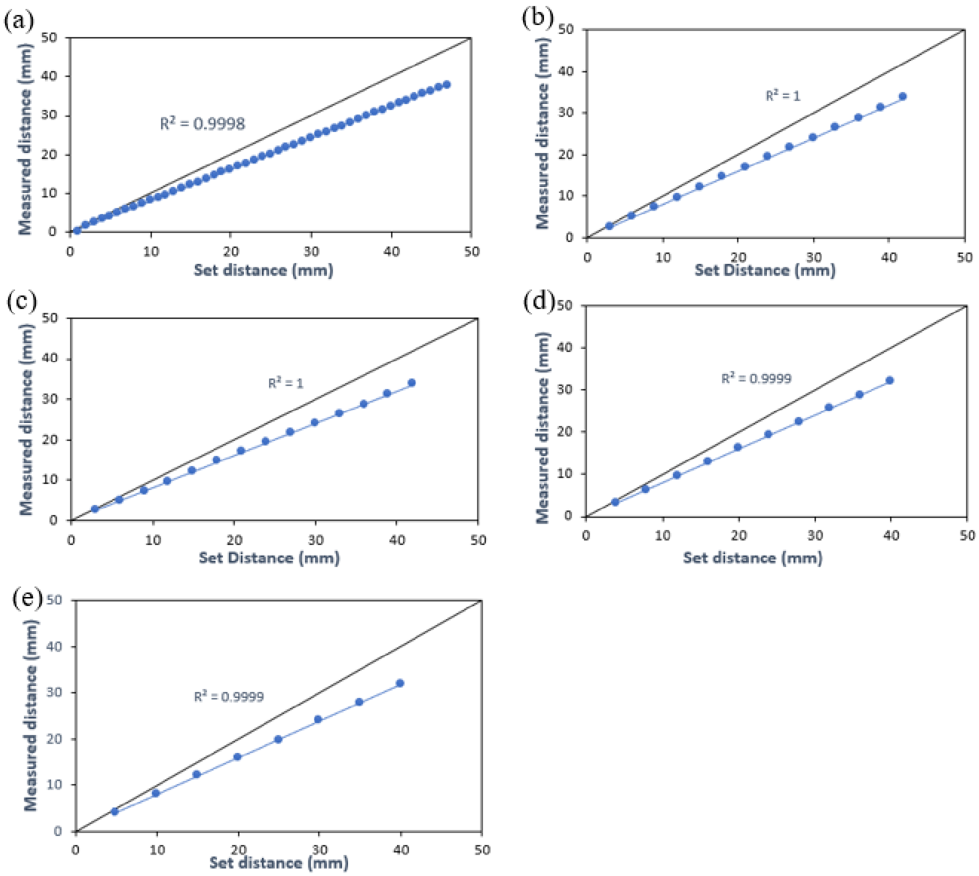


**Figure 5**. Relationships between the results of automated measurement of distance between slice and set distance between slices for various slice thickness: (a) 1 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm, and (e) 5 mm.

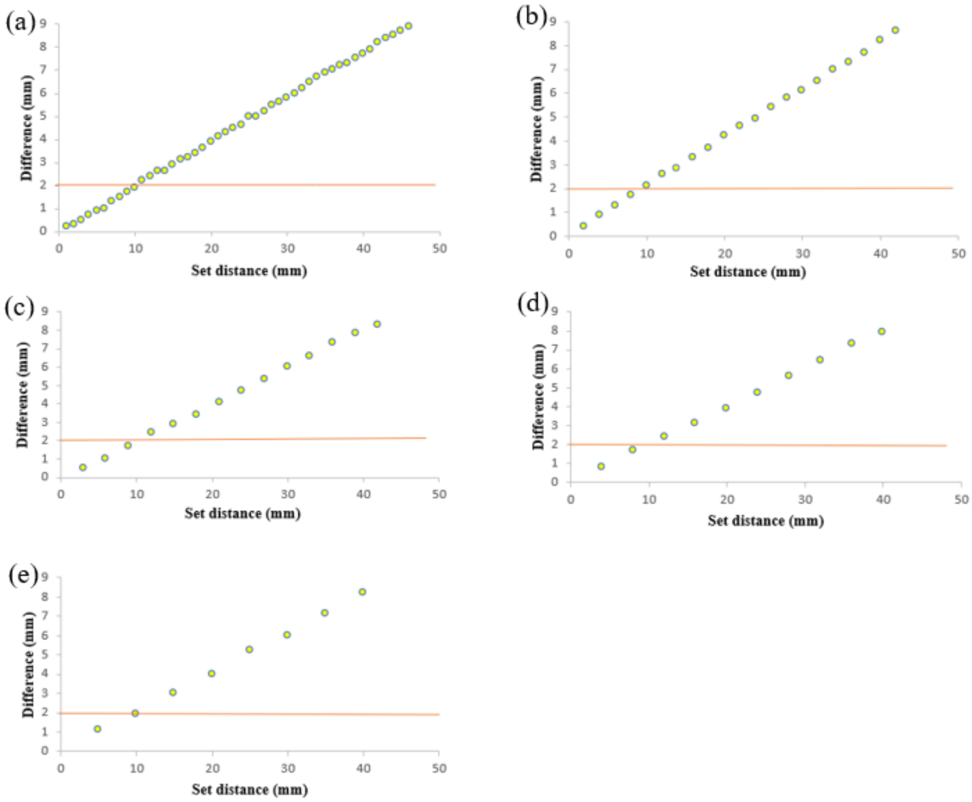


**Figure 6**. The absolute differences between the results of automated measurement and set distance for various slice thickness: (a) 1 mm, (b) 2 mm, (c) 3 mm, (d) 4 mm, and (e) 5 mm.

### B. FOV variation

Figure 7 displays the images of the Siemens CT phantom for FOV variations of 220, 240, and 300 mm. Figure 8 shows the correlation between automated measurement results and the set distance for three different FOVs. The results exhibit linear correlations with $R^2 > 0.99$ for all FOVs. Figure 9 shows exhibits the absolute differences between the automated measurement results ($d_m$) and the set distance between slice ($d_{set}$) for three different FOVs. Similar to the variation in slice thickness, the absolute difference ($\Delta d$) increases with increasing of the set distance for all FOVs. The percentage differences are also relatively constant with average of 23%.

### C. Discussion

In recent advancements of modern CT, 3D volumetric measurements of any organs or lesions are important. In addition to being influenced by the accuracy of the slice thickness, the accuracy of the volume of an object is also influenced by the accuracy of the distance between slices. Unlike the accuracy of slice thickness, for which there is a specific method for measuring it and slice thickness measurement becomes an integral part of the quality control program, but until now there is not available method for determining the accuracy of the distance between slices. With a special approach, the accuracy of the distance between slices can be determined from the available phantom which is commonly used to evaluate the accuracy of slice thickness. One of the phantoms that can be used to measure slice thickness is the Siemens CT phantom, which is a module consisting of ramp objects. In this study, we propose a method to measure the distance between slices on the Siemens CT phantom. For effectiveness and objectivity, this study also proposes an automated method for measuring the distance between slices.

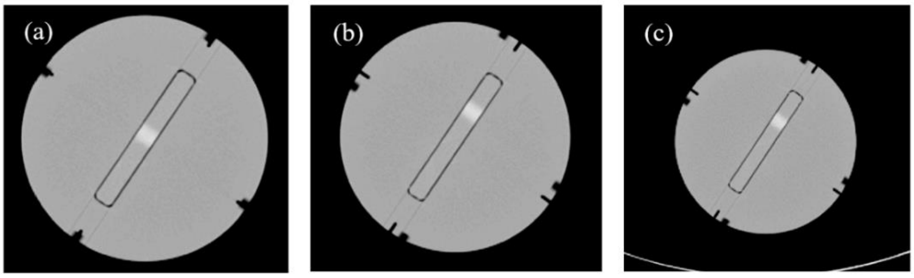


**Figure 7**. Phantom images at FOV variation: (a) 220 mm, (b) 240 mm, and (c) 300 mm.

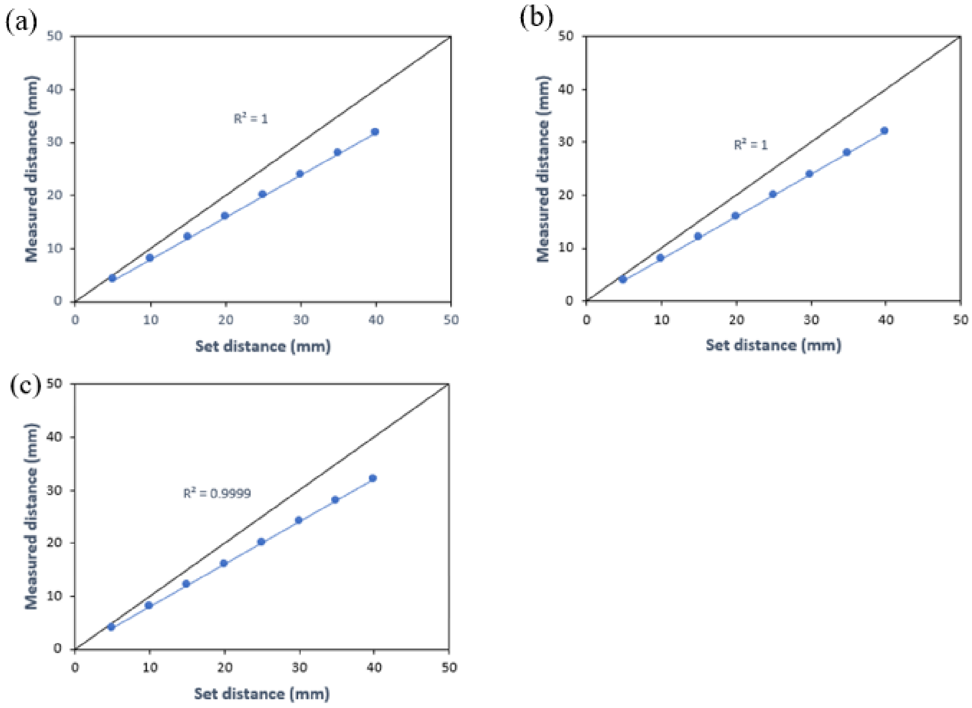


**Figure 8**. Relationships between the results of automated measurement and set distances for various FOVs: (a) 220 mm, (b) 240 mm, and (c) 300 mm.

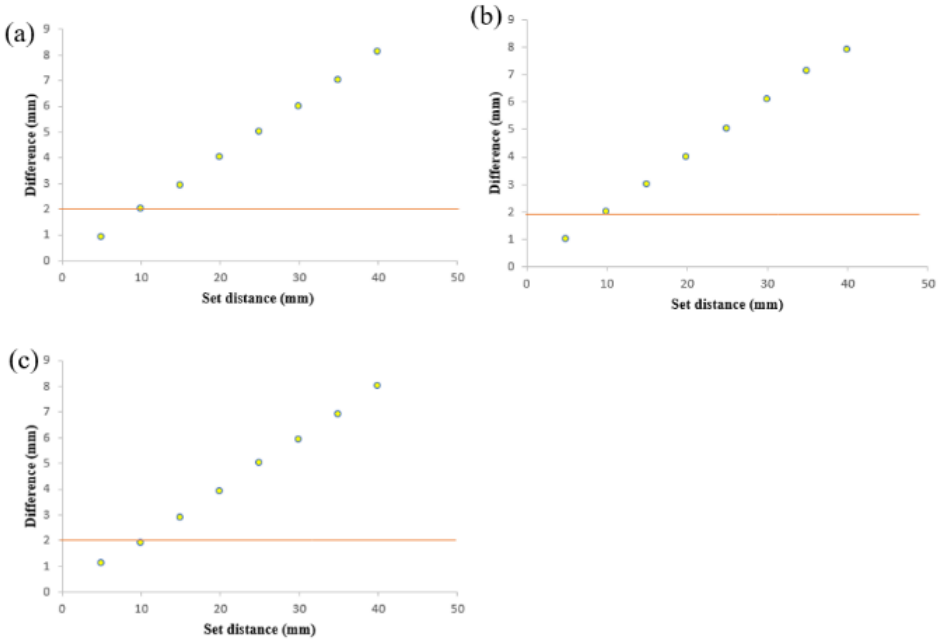


**Figure 9**. The absolute differences between the results of automated measurement and set distances for various FOVs: (a) 220 mm, (b) 240 mm, and (c) 300 mm.

It is known that the Siemens CT phantom consists of a ramp object made from aluminum. The ramp object is embedded in phantom at a specific angle, i.e., 23°. Thus, the distance between measured must be corrected with that angle. It is noted that the distance between slices can only be measured from the image containing the object's ramp. Hence, the distance between slices is very limited. With this proposed technique, we cannot measure distances up to 10 cm, for example.

In order to test our proposed method on several input parameters, in this study, we tested it on variations of slice thickness and FOV. The slice thickness variation was 1, 2, 3, 4, and 5 mm, while the

FOV variation was 220, 240, and 300 mm. We found that the proposed method can accurately measure the distance between slices on variations of slice thickness and FOV. The automated method resulted the distance between slices correlates linearly with the set distances with an $R^2$ value > 0.99 for two variations. The percentage differences between measured distance between slice and set distances are within 23%.

The percentage differences are relatively constant for all distances. This shows that the differences are systematic. These differences are possibly caused by a slight error in the phantom alignment. Therefore, it is recommended, before measuring the distance between slices, phantom alignment needs to be performed first. However, these differences could be due to inaccuracies in the set distance values. This needs to be re-evaluated.

One limitation of this study is that it is only able to measure the distance between slices in the phantom for thin thicknesses. When using thicker slice thicknesses, there is a significant decrease in pixel values, which can lead to errors in segmentation and measurement. This is due to partial volume averaging (PVA), which occurs when an object composed of multiple types of tissue or materials (e.g., ramp and air) appears within a single pixel in the image. In addition, we tested the proposed algorithm only on two variations, namely slice thickness and FOV. Testing the algorithm on various input parameters also needs to be performed. For example, a helical mode of CT with various pitches will produce images with different profile of ramp objects, the proposed algorithm may not successfully perform segmentation for pitch more than 2. At low tube current or low tube voltage, image noise will be high. There is a possibility that the segmentation of the ramp object will fail, so that the measurement of the distance between slices will also fail. This needs further investigation. Testing the accuracy of the distance between slices also needs to be compared with the accuracy test for the distance between two objects on the z-axis. However, because in the Siemens CT phantom there are no marker objects for measuring distances on the z-axis, we did not perform that in this study. To compare that measurements, it is necessary to do this on other Siemens CT phantoms or with additional markers.

## IV. CONCLUSION

The proposed algorithm for measuring the distance between slices was successfully implemented on images of the Siemens CT phantom scanned with variations of slice thickness and FOV. The developed algorithm was able to measure the distance between slices for different slice thicknesses and field of views (FOV). The results obtained from automated method have linear correlations with the results from the set distances with $R^2$ > 0.99. The percentage differences between measured distances and set distances are around 23%.

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