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# Arduino-based object rotator for modified 3D Micro-CT for non-destructive testing application

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**Abstract.** This paper presents the development of an object rotator to be applied in digital radiography to modify it as 3D micro-CT. The device was developed using I2C LCD *display*, tactile buttons and a stepper motor with an L293D motor shield. The first development stage was testing all components. The circuit was designed and then realized using the components that were tested. The device was designed to rotate discretely from rotation angle of 0 – 360° in 256 steps. For performance testing, the device was tested for a rotation angle range of 0° to 90°. The images of each rotation were captured and measured by Inkscape to determine the magnitude of the rotate angle of the object rotating device. The measurement results are compared with theoretical data to determine device error. The highest error was 4.79%. The device was then applied in digital radiography as an object rotator so that the digital radiography functioned as a micro-CT. By using a phantom as an object, the device as an object rotator in micro-CT was tested. The results showed that the device could capture and develop a 3D image of the phantom.

## 1. Introduction

*Microcomputed tomography (micro-CT)* is an X-ray radiographic imaging method which records objects from different directions and produces a three-dimensional (3D) image. *Micro-CT* is a development of X-ray radiography which is commonly used for medical observation such as measuring rib cortical thickness [1], saw mark analysis on human bone [2] and post-mortem trauma evaluation [3]. Due to its ability to determine material properties, micro-CT is also used for non-destructive test (NDT) applications. By obtaining a 3D image of an internal structure using micro-CT, information about the material being studied and quantitative information about properties such as material distribution, inclusion, deformity and cracks can be identified [4]. Various NDTs uses of micro-CT have been reported such as investigation of damage in concrete [5], cement paste characterization, [6] and fracture evaluation in concrete [7].

Due to the high cost of micro-CT, X-ray radiography remains irreplaceable in many non-destructive evaluations since it provides more economical benefits. This issue has also resulted in slow development of micro-CT in research areas [8]. However, to provide a low cost micro-CT device, an X-ray radiography could be modified so that it could be used as a micro-CT. Modification of conventional X-ray radiography to function as digital radiography has been demonstrated by the author [9]. The modified-digital radiography could be further upgraded as micro-CT by adding a device to obtain 2D images from various viewpoints. By reconstructing the 2D images, the 3D image could be obtained. The series of 2D images from various viewpoints could be achieved by either rotating the emitter and detector or rotating the object itself. However, since micro-CT is specifically

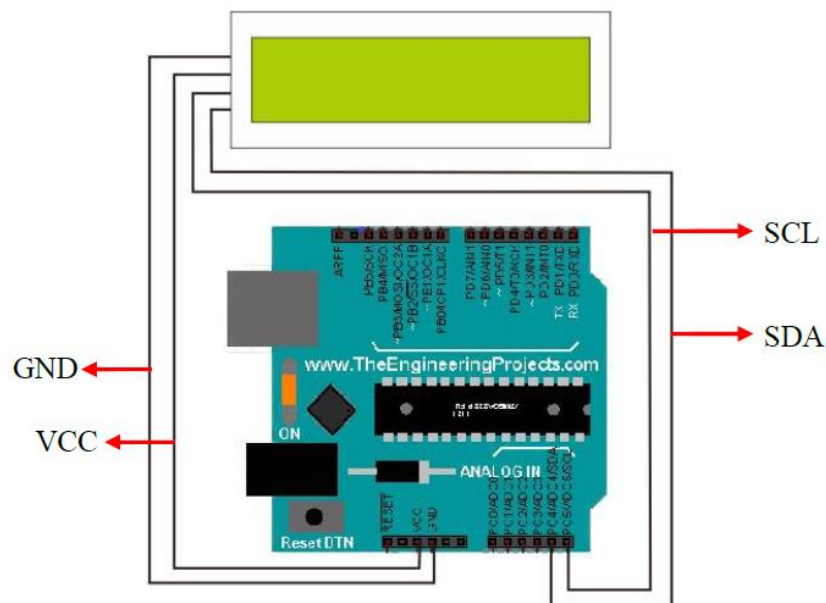


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for the analysis and characterization of small objects, then rotating the object is more convenient than rotating the emitter and detector. Therefore, in this work we designed and developed an object rotator to be applied in modified-digital radiography so that it could be used as a micro-CT device.

## 2. Method

The modules used to develop the rotator were I2C LCD display module, tactile button, microcontroller (Arduino Uno) and 28byj-48 5V stepper motor with the L293D motor shield module. Prior to circuit designing, all modules were first tested to check the performance and to ensure that all modules worked properly. Then, all modules were combined based on the circuit design to form an object rotator. The angular rotation was programmed to be  $1.40625^\circ/\text{step}$ . To test the rotator performance, its movement was recorded using a digital camera until it reached  $90^\circ$  of the rotation. The rotation angle was then measured from the image by using Inkscape software. The I2C LCD was tested by displaying characters that was programmed using sketch on the LCD, as shown in Figure 1. The tactile button was tested by assigning it to do a process that was programmed.



**Figure 1.** Schematic diagram for I2C LCD testing.

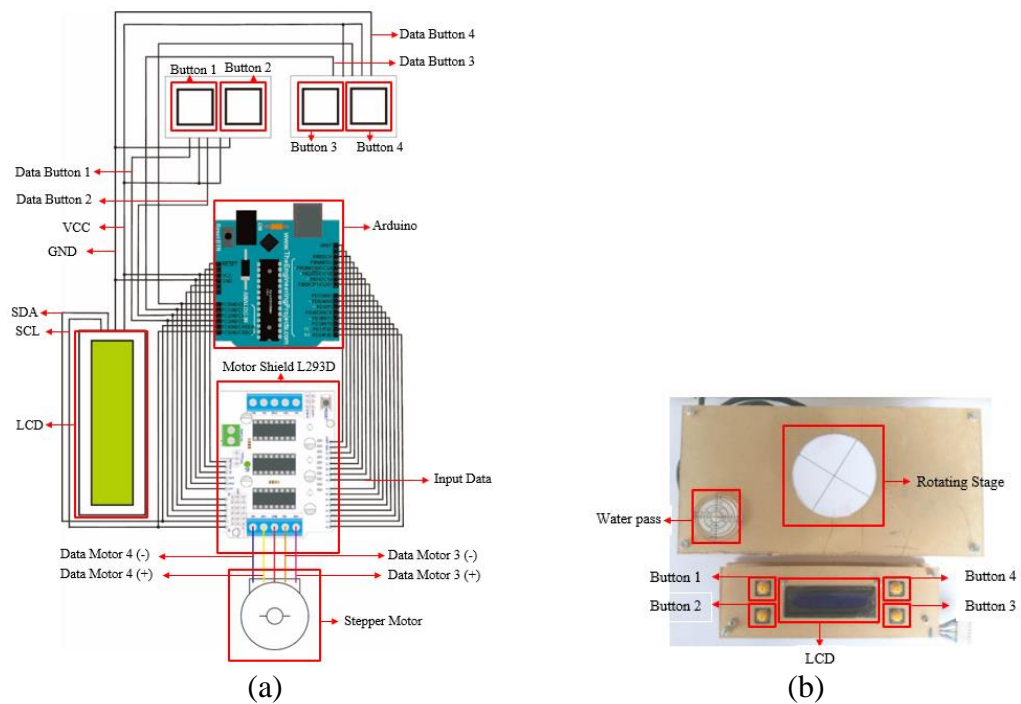
The next step was an implementation of the rotor in the digital radiography so that it can perform as a micro-CT device. The modified micro-CT was examined by using a statue as an object. The stepper motor was rotated counter clock wise with angle of  $1.40625^\circ$  and then the radiography image of the object was taken. The object was rotated until it reach angle of  $360^\circ$  and the image was taken at every rotation steps. The total steps to reach  $360^\circ$  were 256 times. Therefore, there were 256 images that were recorded. The images were then reconstructed to obtain 3D image of the object.

## 3. Results and Discussion

The object rotator comprises of stepper motors and motor shield as an actuator, tactile buttons as a trigger, Arduino Uno as a microcontroller and I2C LCD as a display. Arduino was connected to the motor shield in which the IC of the motor driver is located. The motor driver IC functions as an interface between Arduino and the stepper motor. The device circuit is shown in Figure 2(a). The tactile button was connected to Arduino via pin A0 to A3 and LCD was connected to pin A4 and A5. Meanwhile, the motor shield L293D was connected to the digital input 8. The tactile button, LCD and motor shield were also connected to VCC and ground. The input at stepper motor at digital pin 8 was

connected with IC L293D at pin 3, 6, 10 and 15. Meanwhile, the IC L293D input was connected to the output of IC 74HC595N. IC 74HC595N has function as a shift register which convert serial data to parallel data. The conversion of serial data to parallel data was done to simplify the control process of the stepper motor.

As shown in Figure 2(b), the rotator used 4 buttons. Button 1 is connected to analog pin 3 (A3) which functions to rotate the object back to its original position. Meanwhile, button 2, which is used to reset the value to zero, is connected to analog pin 2 (A2). Counter clockwise rotation is performed by pushing Button 3, which is connected to the analog pin 1 (A1). To make clockwise rotation, the rotator uses Button 4, which is connected to the analog pin 0 (A0). The rotator was designed to rotate with a rotation angle of  $1.40625^\circ/\text{step}$  so that it takes 256 steps to reach  $360^\circ$ . The angle step was lower to that obtained by Louk et al. which is  $1^\circ/\text{step}$  [10]. However, the resulted torsion is sufficient for the micro-CT application since the object to be rotated has small dimension and low mass. In every step, the X-ray image of the object was captured and recorded. Therefore, it produced 256 2D images. The 2D images were then reconstructed to form a 3D image. Specification of the device is tabulated in Table 1.



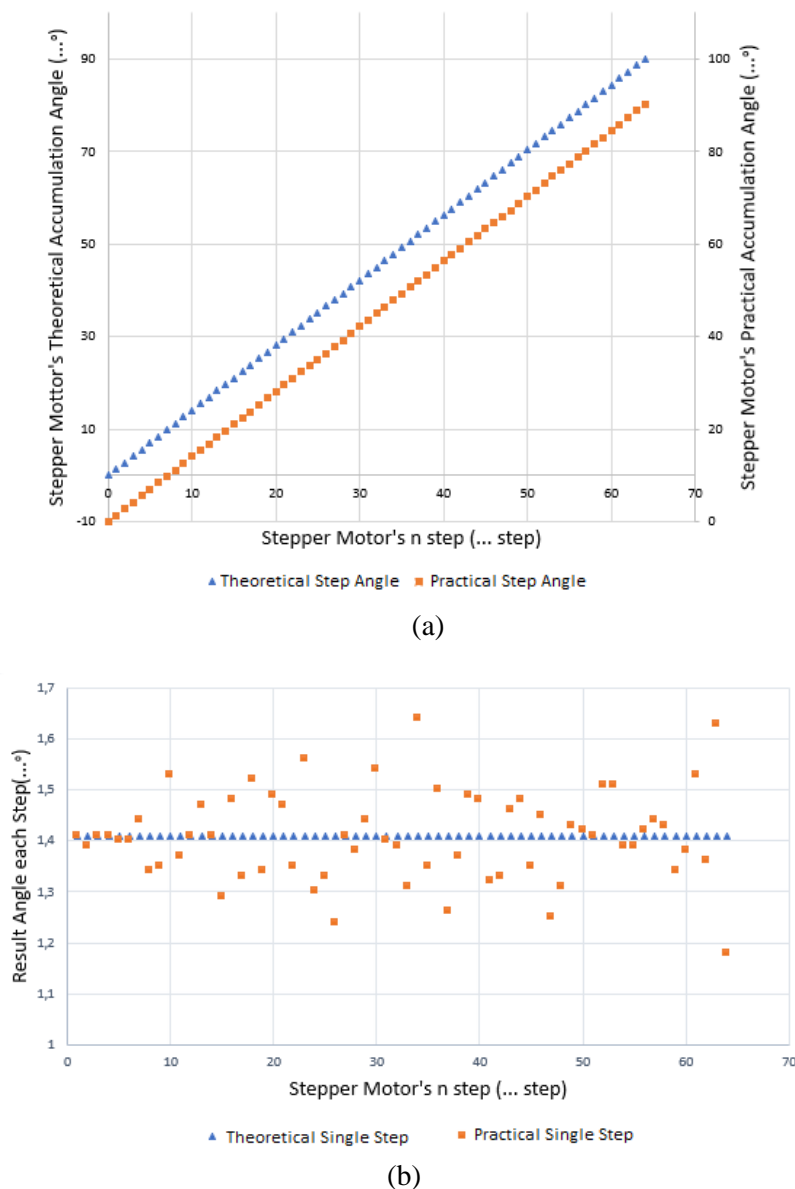
**Figure 2.** Circuit of object rotator (a) and the developed object rotator (b).

**Table 1.** Specification of the object rotator.

Specification	Value
Voltage	5V DC
Stepper Motor	28byj-48
Rotation angle	$1.40625^\circ/\text{step}$
Control button	4
Step number/rotation	256 steps

The object rotator performance in terms of rotation angle was investigated from  $0^\circ$  to  $90^\circ$  which were from step 1 to step 64. The tests were only conducted for the first quadrant since it could represent the other quadrants. The total rotation angle which resulted from the experiment was compared to the results from the theory as shown in Figure 3 (a). The rotation angle which resulted from a single step is shown in Figure 3(b). It was shown that the experimental results deviated from the theoretical results with the average error being 4.79%. The deviation occurred due to errors in the measurement tool and stepper motor design. Error from the measurement tool, which is Inkscape, accumulated as the number of steps increased. Meanwhile, error from the stepper motor resulted from electric field distribution and magnetic force between the rotor and stator.

Rotation step of the stepper motor also depends on the type of stepper motor and the number of pole from the permanent magnet of the motor, more higher magnetic poles make smaller single step [11, 12]. Škofic et al [13] showed that these kind of errors occurred due to the motor design. Since the errors was resulted from the motor design, so far we could not totally eliminate it. The effort to minimize the errors was done by programming the motor to move with large rotation angle or using microstepping to increase the accuracy [14, 15].

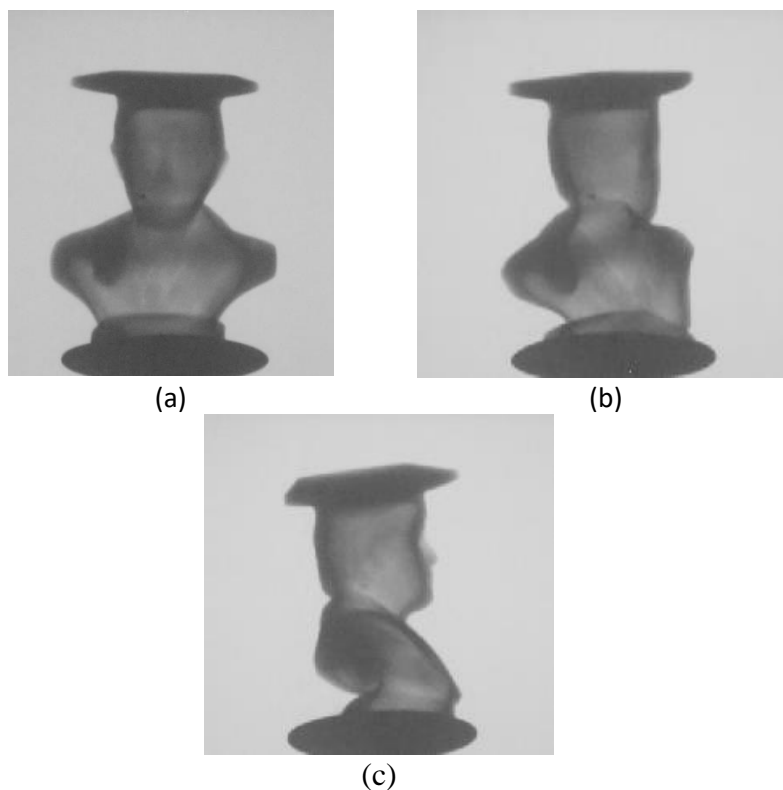


**Figure 3.** (a) Total rotation angle at each steps and (b) single rotation angle of each steps.

The object rotator was then implemented in the digital radiography to rotate the object under investigation. An x-ray image was captured at each step from an angle of  $0^\circ$  until  $360^\circ$ . The object is shown in Figure 4. The X-ray image captured at the angles of  $0^\circ$ ,  $45^\circ$  and  $90^\circ$  are shown in Figure 5. It was shown that by rotating the object using the developed object rotator, images from various viewpoints could be obtained.



**Figure 4.** An object used in the implementation of object rotator in micro-CT.



**Figure 5.** The images captured at the angles of (a)  $0^\circ$ , (b)  $45^\circ$  and (c)  $90^\circ$ .

#### 4. Conclusions

Arduino-based object rotator has been successfully created using a stepper motor, Arduino Uno, L293D motor shield, LCD and tactile button. The device operates at input voltage of 5V DC and rotates clockwise with a rotation angle of  $1.40625^\circ/\text{step}$ . The device was able to rotate with the average error of rotation angle being 4.79% as compared to the theory. The object rotating device has been applied to X-ray digital radiography to retrieve data using the micro-CT method so that it could record images from different angles, from  $0^\circ$  to  $360^\circ$ .

#### References

- [1] Hostetler Z S, Stitzel J D and Weaver A A 2019 *Comput. Biol. Med.* **111** 103330
- [2] Norman D G, Baier W, Watson D G, Burnett B, Painter M and Williams M A 2018 *Forensic Sci. Int.* **293** 91-100
- [3] Baier W, Mangham C, Warnett J M, Payne M, Painter M and Williams M A 2019 *Forensic Sci. Int.* **297** 27-34
- [4] Sarkar P S, Ray N K, Pal M K, Baribaddala R, Agrawal A, Kashyap Y, Sinha A and Gadkari S C 2017 *Rev. Sci. Instrum.* **88** 023702
- [5] Skarżyński and Tejchman J 2019 *Mater. Charact.* **154** 40-52
- [6] Kim J S, Kim J H and Han T S 2019 *Mater. Charact.* **155** 109807
- [7] Skarżyński, Marzec I and Tejchman J 2019 *Int. J. Fatigue* **122** 256-272
- [8] Susilo, Supriyadi, Sutikno, Sunarno and Setiawan R 2014 *J. Pendidik. Fis. Indones. (Indonesian J. Phys. Educ.)* **10** 66-74
- [9] Stock S 2009 *Microcomputed Tomography: Methodology and Applications* (New York: CRC Press)
- [10] Louk A C 2015 *Int. Conf. Exp. Mech. 2014* **9302** 93020Y
- [11] Škofic J, Koblar D and Boltežar M 2014 *Stroj. Vestnik/Journal Mech. Eng.* **60** 255-64
- [12] Škofic J and Boltežar M 2014 *IET Electr. Power Appl.* **8** 155-163
- [13] Defoort M, Nollet F, Floquet T and Perruquetti W 2009 *IEEE Trans. Ind. Electron.* **56** 3337-3346
- [14] Anish N K, Krishnan D, Moorthi S and Selvan M P 2012 *IEEE 7th International Conference on Industrial and Information Systems* 1-5
- [15] Lyshevski S E 2014 *Energy Convers. Manag.* **85** 245-253