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3D Scanner Using Infrared for Small Object

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Abstract— Three-Dimensional scanning is a method to convert various distances set into object visualization in 3-dimensional form. Developing a 3D scanner has various methods and techniques depending on the 3d scanner's purpose and the size of the object target. This research aims to build a prototype of a 3D scanner scanning small objects with dimensions maximum (10x7x23)cm. The study applied an a-three dimensional(3D) scanner using infrared and a motor to move the infrared upward to get Z-ordinate. The infrared is used to scan an object and visualize the result based on distance measurement by infrared. At the same time, the motor for rotating objects gets the (X, Y) ordinates. The object was placed in the center of the scanner, and the maximum distance of the object from infrared was 20cm. The model uses infrared to measure the object's distance, collect the result for each object's height, and visualize it in the graphic user interface. In this research, we tested the scanner with the distance between the object and infrared were 7 cm, 10 cm, 15 cm, and 20 cm. The best result was 80% accurate, with the distance between the object and the infrared being 10cm. The best result was obtained when the scanner was used on a cylindrical object and an object made of a non-glossy material. The design of this study is not recommended for objects with edge points and metal material.

Keywords-3D scanner; small object; distance measurement; infrared.

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I. INTRODUCTION

One such disruptive technology is 3D scanning, which has applications in various industries, including healthcare, product development, simulation, and the arts [1]. 3D scanning is a method to convert various distances set into object visualization in 3-dimensional form. Various methods and techniques of 3D scanning are applied in several ways. The main process in 3D scanning is measuring distance and convert to visualization. The distance set was collected by scanning the object's surface using a distance measurement tool. Distance measurement tools used in 3D scanning variously.

Laser is quite popular for designing and implementing 3D scanner. Other studies also using lasers for 3D scanning [2]–[6]. Meanwhile, a high dynamic range laser with the single-shot raw image of a color camera is also used to mitigate the detrimental of a sharp change in the laser stripe's intensity [7]. The camera is another tool technique to create a 3D scanner. The camera used for designing and building 3D scanners have different types and numbers of the camera. The depth camera system was used for mass customization but had issues with smaller geometric and sharp edges objects [8]. Some other studies applied 100 cameras to scan human body [9], and

present an event-based structured light system for high-speed 3D scanning using event camera [10].

Farahani et al [11] used a circular laser and camera for 3D modelling a wind tower. Combination of laser and camera are also used by Musaharpa et al [12] and Wang [13]. The projected light and the offset camera for a scanned item are used by structured and laser 3D scanners to triangulate points. Lines are produced on the object by a laser 3D scanner, and a digital projector's concentrated grid is projected by structured light [14]–[16].

In meantime, Rehman et al [17] analyzed both laser and camera methods for making 3D points cloud. The first is a 3D point cloud based on a camera utilizing the structure from the motion technique, and the second is a 3D point cloud based on a laser scanner. The outcome demonstrates that the laser scanning method is robust; the camera-based 3D point cloud method created dense point clouds but was sensitive to outliers. Also, the camera is far more affordable than a laser scanner.

Besides laser and camera, there are various way that used for distances measurement tools in 3D scanning: infrared [18]–[21], ultrasonic sensor [22]–[26], scanning from heating methods [27] are various ways using imaging and sensors methods [19], [28]–[31] for 3D image reconstruction. In this research was developed a scanner for a small object—the hardware designs for the small object with a maximum dimension (10x7x23) cm. The recent research used infrared [32], and the scanning time was 10-12 minutes. Meanwhile, this research proposed a scanner with a scanning time of 3-10 minutes.

The recent development of a 3D scanner by Athira et al. [18] used two infrareds to scan the object, and in this research, [12] rotated the object. The proposed study applied and proposed a scanner with this specification:

- Infrared to measure the object's distance and use two motors to move up infrared and rotate the object.
- It combines methods [18], [12].
- It aims to reduce blind spots and minimalize the number of infrareds from 2 infrareds become one infrared.
- The small object for object test with max dimension (10x7x23) cm
- Data from infrared is X, Y, and Z components for visualization.
- Scanning time is less than 10 minutes.

II. MATERIAL AND METHODS

This system was built using infrared to measure the distance between the scanner and the object, and Arduino to process and collect the result of X, Y, and Z. The result was sent to a computer for visualizing the result using Matlab. The block diagram of the system is shown in Figure 1.



Fig. 1 Block Diagram System

The hardware part consisted of an Infrared controller and object controller. The infrared controller is developed to measure object's distance from bottom to top. Thus, the object controller rotates the object while infrared reads the distance from the object. The infrared is in the bottom center of the infrared controller, with stepper motors that can make infrared move upward. Infrared will go up 1 step after the object controller rotates one round. Every 1 step, infrared will go up 1mm..

The motor stepper at the infrared controller is called motor 1. The infrared controller has 28 cm height from bottom to top, 10 cm length and 7 cm width. The infrared can go up to 20 cm. Detail dimension and form of the infrared controller are shown in Figure 2.



Fig. 2 Infrared Controller

The object holder has one motor stepper. A motor stepper in the object holder, motor 2, can rotate objects 360 degrees. With one rotation, the motor will stop, motor one will be up 1 step, and motor two will rotate, and so on. Each round will stop; after the motor steps up one step, the motor in the object holder will rotate again. It goes on until the infrared is the untouched object. The object's marker is not detected if the infrared detects more than 20 cm. It is based on the maximum distance of object detection, then the position of the object holder is a maximum of 20 cm from the infrared position.

The movement of the infrared controller and object holder was controlled by Arduino, which Arduino was used to process data from infrared. Then it also recorded the movement of the motor stepper. After that, movement motor one was recorded as a Z coordinate. Finally, the object rotation was converted to X and Y coordinates. Figure 3 is the top view of the system.



Fig. 3 Top View System

This system designed the rotating object to determine the X and Y coordinate. Equation (1) and (2) is the formula to determine X dan Y coordinates.

$$X = r * \cos \theta \tag{1}$$

$$Y = r * \sin \theta \tag{2}$$

Value of θ , in this system, has a range 0° to 360°. The value of θ is from motor rotation in the object holder. The value of r is formulated as equation (3):

$$r = A - L \tag{3}$$

Variable L represents the length of the object's edge from infrared, which is distance data from Infrared. Variable A is the distance infrared from the center of object. The wiring diagram of hardware development is shown in Figure 4. Arduino connects to the motor and driver motor as output and infrared as input.



Fig. 4 Wiring Diagram

The software part is a part for visualization object. We used Matlab for the visualization of object 3D. Coordinate data from Arduino sent by port serial. Then, every coordinate data X, Y, and Z is plotted and visualized as scanned objects. The flowchart of this system is shown in Figure 5.



Fig. 5 Flowchart System

The work system on a 3-dimensional object scanner mechanical system will be scanned by infrared. If the object's distance is less than 20 cm, then the stepper motor will move with every rotation of the moving object, infrared will move up one step to scan the object. After that, the object has been scanned with the condition that the distance to the object is more than 20 cm, the scanning process will be completed, and the stepper motor will return to its initial position. With the completion of this process, distance data obtained from infrared and coordinates obtained from the stepper motor as the driver can be generated. Then, the data from the object in Matlab.

III. RESULT AND DISCUSSION

The design system of the 3D scanner using infrared, and two motors are tested on five different objects. The object was placed on the object holder, and the distance is 7, 10, 15, and 20 cm between infrared and the object's center. The tested object was shaped objects:

- Cylinder, cylinder object with a diameter 5 cm and 2.5 cm height. This object has a curved surface, and the material is plastic. The object is shown in Figure 6.
- Cube, cube object with dimension 5 cm x 5 cm x 5 cm with a carton as material. The cube object has an edge surface. The object is shown in Figure 7.
- Prism, a triangular prism with pedestal 6cmx6cm and 6.5 cm in height. The material of triangular prism object is a carton. The object is shown in Figure 8.
- Ball, Globe shape with 5 cm diameter. The material is plastic. The object is shown in Figure 9.
- Random Shape. Take the example from cup shape, cup with metal material. The dimension is 7.5 cm diameter and 5 cm height, and the surface is non-uniform surface. The object is shown in Figure 10.

This testing was aimed to find out time scanning from each object. Each object was scanned at various distances: 7, 10, 15, and 20 cm. The results of manual distance measurements with a ruler are compared with the results of distance readings by infrared.



Fig. 6 Cylinder Object



Fig. 7 Cube object



Fig. 8 Prism Object



Fig. 9 Globe Object



Fig. 10 Random object

The scanning results of this prototype were visualized in 3D form. Each object has different scanning results, depending on the objects' distance to the scanner.



Fig. 11 Visualization from Testing Result Cylinder Object with distances (a) 7 cm (b) 10cm (c) 15cm (d) 20cm



Fig. 12 Visualization from Testing Result Cube Object with distances (a) 7 cm (b) 10cm (c) 15cm (d) 20cm



Fig. 13 Visualization from Testing Result Triangle Object with distances (a) 7 cm (b) 10cm (c) 15cm (d)



Fig. 14 Visualization from Testing Result Globe Object with distances (a) 7 cm (b) 10cm (c) 15cm (d) 20cm



Fig. 15 Visualization from Testing Result Random Object with distances (a) 7 cm (b) 10cm (c) 15cm (d) 20cm

Figure 7 shows visualization results that the closest to the object's shape occurs at a distance of 10 cm. Figure 12 shows the visualization result from the cube object. The visualization does not detect the edge point, so the shape is the more likely cylinder. Figure 13 is the visualization result of the triangular prism. Scanning with 7 cm and 10 cm distance measurements is the closest shape to the real object. The edge point is not strongly detected. Figure 14 shows that the closest virtualization to a real object occurs in 10 cm distance measurement. Figure 15 shows that based on the distance measurement, the form of the visualization results to get the best distance is 15cm. Then the form of visualization has a 50% accuracy because the object on the visualization results form an irregular result.

The scanning results of this prototype were visualized in 3D forms. Each object has different scanning results, depending on the object's distance from the scanner. Table 1 shows the distance readings by infrared compared to the actual distance. On the cylindrical object, the distance reading had a difference of 0.86-3.69cm; on the cube, the reading difference was 0.72-2.3; on the prism was 0.61-2.4. On the Globe was 1.14-2.31, and on the random object was 2.83-10.33. The random object had the worst results in the reading distance by infrared.

 TABLE I

 The distance reading results by infrared

Distance	Infrared (measurement)							
(cm)	Cylinder	Cube	Prism	Globe	Random			
7	7.86	7.72	7.82	8.14	12.63			
10	11.39	10.77	10.61	11.33	12.85			
15	18.69	15.99	16.15	17.31	25.33			
20	21.60	22.30	22.40	21.21	22.83			

Table 2 shows the scanning time for each object. The measurement results show that the distance between the object and the scanner does not affect the duration of the scanning process. The scanning time is under 10 minutes for all objects.

TABLE II OBJECT SCANNING TIME TO DISTANCE

Distance	Time(minute)						
(cm)	Cylinder	Cube	Prism	Globe	Random		
7	3	5	5	7	4		
10	3	5	5	7	4		
15	3	5	5	7	4		
20	3	5	5	7	4		

IV. CONCLUSION

Hardware development for 3D Scanner using infrared and two motor steppers need to evaluate and improved. The best result average is 80% accuracy of distance measurement and the best visualization in 10 cm distance measurement, with a scanning time of 3-7 minutes. The best result was obtained when the scanner was used on a cylindrical object and made of a non-glossy material. The design of this study is not recommended for objects with edge points and metal material. For the following research, we recommended a mobile version to visualize the scanner's output and use the wireless device for communication between hardware and software, such as Bluetooth wireless.

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