Prototype Implementation of Dual Laser 3D Scanner System Using Cloud to Cloud Merging Method

Teguh Musaharpa G, Inung Wijayanto
School of Electrical Engineering
Telkom University
Bandung, Indonesia
teguhmusaharpa@gmail.com, iwijayanto@telkomuniversity.ac.id

Sugondo Hadiyoso
School of Applied Science
Telkom University
Bandung, Indonesia
sugondo@telkomuniversity.ac.id

***Abstract*—This research designed a three-dimensional (3D) laser scanner using dual laser to scan object placed in a rotating table with maximum dimension is 15 x 15 x 15 cm. Two lasers and one camera are placed and positioned with certain calculation so it can meet the requirements for triangulation technique. From the scanning process, obtained two point clouds which needed to be merged. We propose a new technique to obtain a good point clouds merger. The merging process of the point clouds is done by find the center of z axis as its overlap point then rotate one of the point clouds with a corresponding direction. Merged point clouds obtained by re-plotting the rotated point clouds to the other point clouds.**

I. Introduction

Three-dimensional (3D) scanner technology, also known as real-scene copying technology, is a technology that can be used to scan real 3D objects into digital 3D form. This technology collects 3D object data called point clouds and converts it into digital data form then it is processed by the computer to be reconstructed to form a 3D model [1].

3D laser scanning developed during the last half of the 20th century in an attempt to accurately recreate the surfaces of various objects and places. The technology is especially helpful in fields of research and design [2], [3].In general 3D scanner technology is used to scan various objects in order to make a copy or re-design. A variety of sectors use this technology, such as the automotive part industry, architecture, 3D design, creative industries and many more.

In the previous research, the design of 3D scanning system acquired the coordinates of 3D object point clouds by using triangulation method. With this method, the coordinates of the point clouds are determined from the parameters involving the laser light, the camera, and the angle formed by the laser light and the camera [4].

Ahmed et al propose a technique to find a length of an object by using dot shaped pointer [5]. This technique also used by David et al to find the coordinate of point clouds. Using simple trigonometric calculations, the method is able to read the point clouds coordinates of the 3D object which captured by the camera [4]. But in practice the 3D scanner system is still unable to get whole surface of the object, especially when it is used to scan a random object. This condition happened because there are some blind spot so that the laser light is covered by the object it self, so it can not be captured with the camera. In this research we propose a new technique to solve the blind spot problem. We use dual laser to capture blind spot area that can not be reached by using one laser.

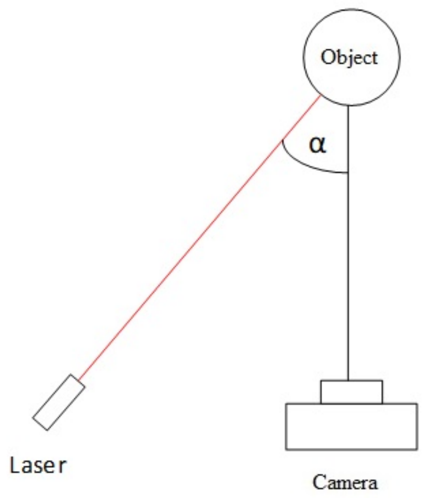

Fig. 1. Triangulation Method

A. Triangulation Method

Triangulation method is a method to obtain the position of the points on the line of laser lines that fall on the object which put on the turntable. In this method the laser projector, the laser beam point, and the camera are positioned to form a triangle with each other. By knowing the distance between the camera and the laser projector, as well as the angle of the laser projector, the camera's tilt angle can be determined through the fall of the laser line beam on the camera image. These three information can be used to determine the size and shape of the triangle circuit and the position of the fall of the laser beam point on the object. [6]

We designed a special condition in the rotating platform to help determine the 3D point clouds coordinates. The turntable placed right on the middle of camera's frame is used to help find the radius of the laser position. The radius is used to determine the 3D point clouds coordinates [4]. It represents

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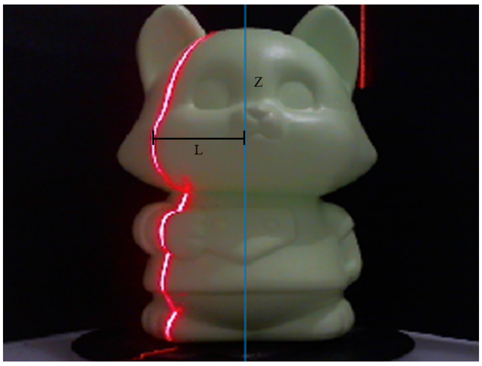

Fig. 2. Laser Light use to Determine 3D Point Clouds

the center of z axis which give information that the center of turntable rotation is right in the middle of the camera's frame. This information will lead us to obtain an easy way to merge some point clouds. In addition we have done some calibration to make sure that we obtained the right information about the center of z axis. Following is simplified formula to determine x and y coordinates.

$$x_i = L * \cos(\theta) \quad (1)$$

$$y_i = L * \sin(\theta) \quad (2)$$

Variable L represent length from center of motor rotation to the edge of laser point which has the highest threshold value. By using variable L, the value of x and y can be obtained even it's not represent the real length value of the object. While for the calculation of z coordinate points, it can use the location value of each row pixel on the laser line contained in the 2-dimensional frame of scanning results. Where the first pixel row represents the value of $z = -1$ and the pixel line of the nth laser line is the value of $z = -n$ [4].

B. Cloud to Cloud Merging Method

The cloud to cloud merging method is one of the methods used to combine 3D point clouds scans. In this method, the binding points used for merging process are obtained from the recording object points. The requirements for this method to make point clouds can be combined optimally, the point clouds must have an overlap points between one point clouds with the other [7]. In this research, the center of z axis of the object becomes the reference of overlap between one point clouds with the other. The z axis is represent the center of turntable rotation.

Point clouds obtained from the results of the scanning process using two lasers have different angle according to the magnitude of the angle between the camera with laser 1 and laser 2. The amount of angle between laser and camera that has been adjusted is equal to 45^o, thus total difference of angle between scanned point clouds using laser 1 and 2 is 90^o.

One point clouds obtained from scanning using these two lasers needs to be rotated by 90^o with a corresponding direction to match each other so it can be directly combined without

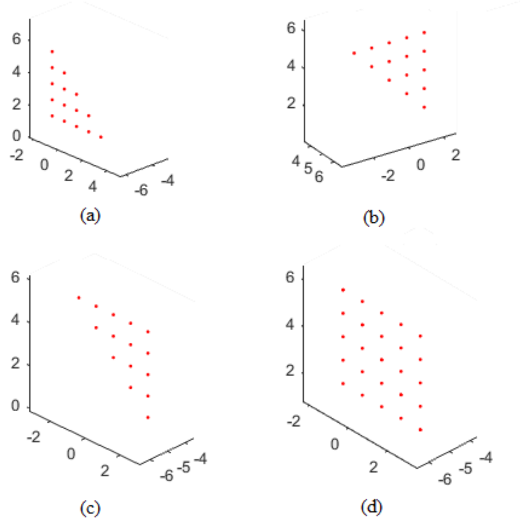

Fig. 3. (a) Point Cloud 1, (b) Point Cloud 2, (c) Rotated Point Cloud 2, (d) Merged Point Cloud 1 and 2

finding the overlap points. Equation 3 and 4 are used to rotate the point clouds with rotary axis at center point (0,0) with turn angle α. The value of α corresponds to the angle difference between laser 1 and laser 2.

$$x' = x\text{cos}\alpha - y\text{sin}\alpha \quad (3)$$

$$y' = x\text{sin}\alpha + y\text{cos}\alpha \quad (4)$$

After obtaining two points clouds that corresponding each other, then the merging process can be directly done by re-plotting point clouds from one to the other point clouds. The re-plotting process can be done from point clouds laser 1 to point clouds laser 2 or vice versa.

II. System Design

In general the system designed in this research is a development of previous system [4]. The use of dual lasers is to obtain data from blank spot area that can not be reach if only use one laser, so it can obtain more optimal digital form of the scanned objects. The design of dual laser scanning system is shown in the figure 4.

The process of converting 3D objects into digital form through two major stages: scanning and reconstruction. In the scanning process, the object is placed on a turn table that has been integrated in the system. Two lasers and a camera are placed in such a way so they meet the requirement of triangulation method. The scanning process is done several times in a stages accompanied by rotating turntable.

In reconstruction process, the results of scanning in the form of images are transformed into point clouds form. It can be done by doing segmentation process first to separate the laser light that will be used as a reference to determine the point clouds. Then point clouds that have been obtained are combined and plotted into digital 3D form.

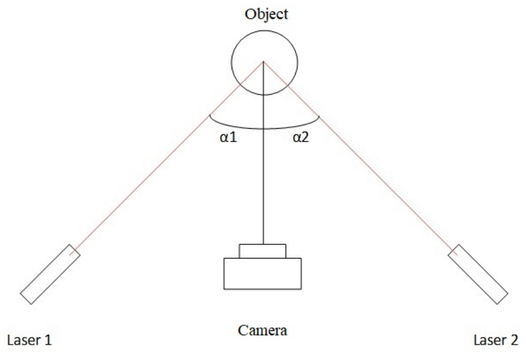

Fig. 4. Dual Laser 3D Scanner System

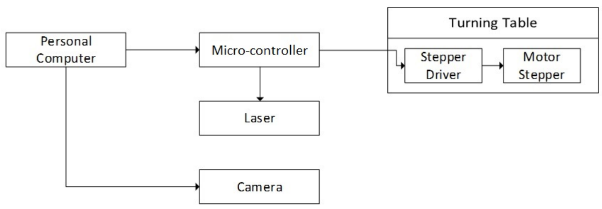

Fig. 5. Diagram Block of Hardware System

A. Hardware Design

The hardware used on the system includes personal computer, micro-controller, lasers, camera, stepper driver and stepper motor. All these components are integrated so they can run the scanning system. The diagram block on figure 5 shown the whole integrated hardware system.

In this research we use red line laser as light source. The red laser is the most common from all the type of lasers, the typical operation of most red lasers is between 635 670 nm. Because of how the human eye perceives frequencies and wavelengths, 635 nm is relatively brighter of the red lasers. Some manufacturers of red dot scope systems provide 630 nm wavelengths and are generally brighter than most of the red wavelength [8].

Object that being scanned is placed on the turntable which consist of motor stepper and its driver. The driver used in this research is A4988 motor stepper driver. This driver is a complete micro stepping motor driver with built-in translator. The driver output drive capacity of up to 35 V and 2 A. It is designed to operate bipolar stepper motors in full-, half-, quarter-, eighth-, and sixteenth-step modes [9].

B. Software Design

To process the image received from the camera, then it's need to build software system to perform signal processing. Signal processing on the system includes segmentation stage, point clouds determination and reconstruction of point clouds into 3D form. The software system design described in the figure 6.

In accordance with the objectives of the research, the flow chart on figure 6 show the process of scanning objects with two lasers. In one step, two pictures are taken by the camera in a turn. The first image with condition only laser 1 is on, while the second image with only laser 2 is on.

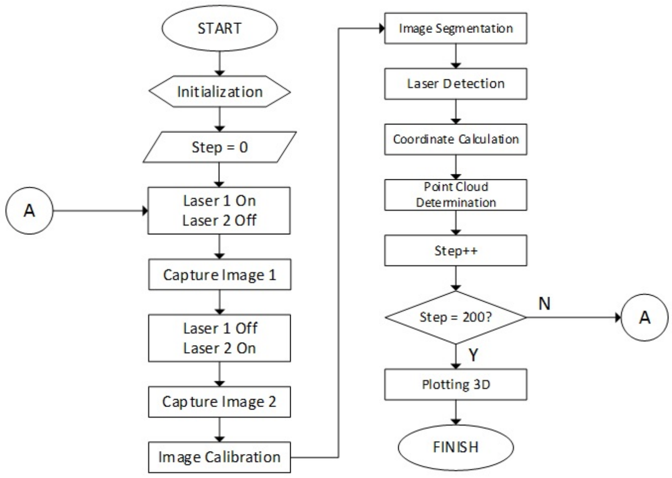

Fig. 6. Software System Flow Chart

After the image obtained then the process is continued by doing segmentation process to separate the laser beam and other objects in the image. The author uses thresholding method to segment the image. Mesko and Chmelar used laser line that has characteristics of red color and high intensity. In this research author took the reference of red laser that has Hue is (0, 70, 70) to (255, 255, 255) in 0 - 255 intensity level of RGB color space. This range was then used as threshold to segment the red laser line from the background. Pixels in the cropped images whose intensity fall within both thresholds was then marked with red color, otherwise it was a non-laser object and marked with current image's color [10]. The laser line obtained in the image used as a reference to calculate the coordinate point and determine the point clouds. The process is done 200 times or as much as one full cycle.

After one full rotation, the point clouds that have been obtained need to be combined to form a digital 3D object. The center of z axis made as its reference point for combining the point clouds. After all point clouds is merged, it is need to be plotted in 3D graph so it can be seen in 3D form and represent the scanned object.

III. Result and Analysis

System testing is done in a room with light intensity 14 lux by using an object with a size of 10 x 10 x 15 cm. Testing done several times until obtained the best result of 3D point clouds as shown on figure 7. After obtained two point clouds, the next step is merging process. This process done by rotating second point clouds clockwise by 90^o then re-plot it to the first point clouds. The result of merging process shown on figure 8. After scanning process complete, we obtained a merged of two point clouds that consist of point clouds from laser 1 and laser 2.

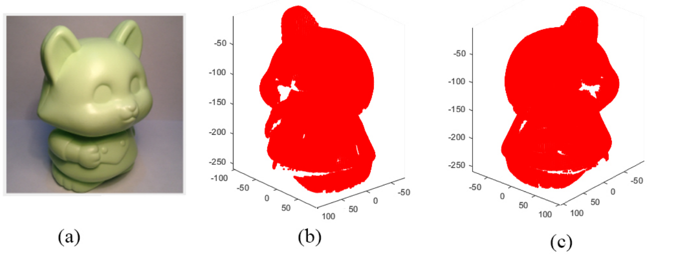

Fig. 7. (a) Object Sample, (b) Scanned Object use Laser 1, (c) Scanned Object use Laser 2

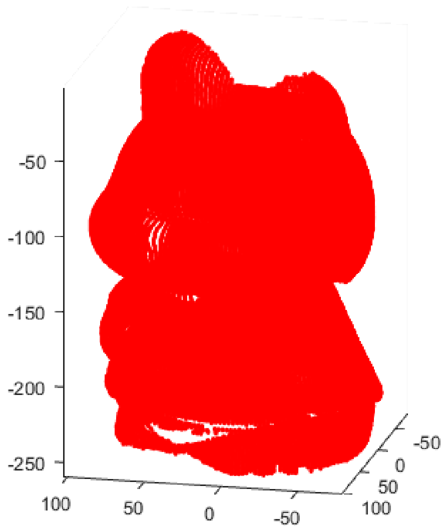

Fig. 8. Merged Point Cloud

A. *Scale Precision Parameter*

The level of scale precision can be known by looking at the difference between the ratio of the actual object and the ratio of scanned 3D object. The smaller the ratio difference, the higher precision level of the scanning result. In this test, we use cubical shape object to know the ratio between length, width and height of the object. Table 1 show the difference ratio of an object and the level of its scale precision.

From table 1 we can get information that the ratio of scanned 3D object and the original object has some differences. The differences are caused by several errors during scanning process. The placement of the laser and the determination center of z axis are the most affecting parameters. When the placement of laser is not exact in the middle of turntable and when we determine wrong center of z axis, it made the laser line which captured by camera shifted. This shifting influenced the determination of point clouds coordinates.

TABLE I
SCALE PRECISION FROM SCANNING RESULT

Object Element	Original Size (cm)	Ratio	Scan Result Size (pixel)	Ratio	Precision Level
Length	10	1	732.13	1.02	98%
Width	10	1	720.14	1	100%
Height	10	1	710.25	0.98	98%

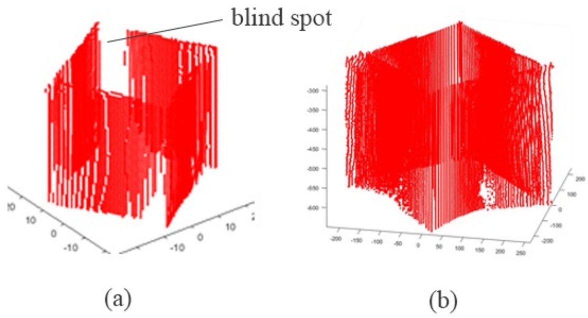

Fig. 9. (a) Scanned Object use Single Laser 3D Scanner, (b) Scanned Object use Dual Laser 3D Scanner

TABLE II
SAMPLE DATA COORDINATE X AND Y FROM POINT CLOUD 1 AND 2

z	x_1	x_2	y_1	y_2
-301	190	183	212	208
-302	191	184	212	209
-303	191	185	212	209
-304	192	185	212	210
-305	192	185	214	211
-306	192	185	214	211
-307	193	186	216	212
-308	194	186	216	213
-309	194	186	217	213
-310	194	186	217	214

B. *Merging Accuracy*

Merging process in this system has been solved the blind spot problem as we mentioned before. Figure 9 shown the result of scanning process using single laser and dual laser. We can see that the blind spot on the result of scanning process using single laser can be covered by using dual laser.

After the problem solved, we need to know the merging accuracy to obtain the best result of scanning process. Merging accuracy can be known by looking at the point clouds coordinates of scanned object. When point clouds 1 and 2 merged, then the result must be an overlap points of these two point clouds.

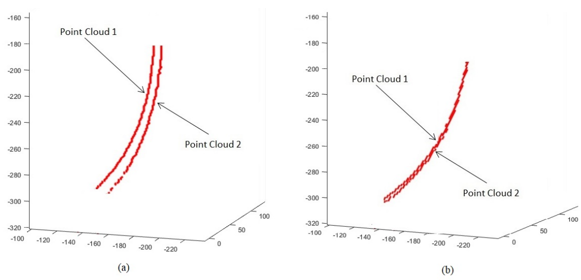

Fig. 10. (a) Merged Point Cloud Before Calibration, (b) Merged Point Cloud After Calibration

Table 2 show us that there are some differences coordinates between point clouds 1 and 2. This is caused the merging process not done correctly, the point is shifted instead of overlap. As well as difference on scale precision parameter, cause of this error is the wrong placement of the laser and bad determination center of z axis.

When the placement of laser is not exact in the middle of turntable and when we determine wrong center of z axis, it made the laser line which captured by camera shifted. This shifting influenced the determination of point clouds coordinates, as well as the merging process. To prevent from data error obtaining, we have to do some calibration to make sure that the laser light placement is exact in the middle of turntable and the center of z axis is determined correctly, and by doing it the merging accuracy increased. Figure 9 show the merging result before and after calibration.

IV. CONCLUSION

Dual laser 3D scanner built in this research is able to do scanning process on the object with maximum size of 15 x 15 x 15 cm. The result is quite satisfying, it's able to scan an object and convert it into digital form with level of scale precision approaching 98%. The accuracy of merging process still needs to be improved, the detail calibration must be done before scanning process to make sure that we obtaining the right x, y and z coordinates of the point clouds.

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