

# Development of 3D Laser Scanner for Robot Navigation

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**Abstract**—Autonomous robotic systems need an equipment like a human eye for their movement. In this study a 3D laser scanner has been designed and implemented for those autonomous robotic systems. In general 3D laser scanners are using 2 dimension laser range finders that are moving on one-axis (1D) to generate the model. In this study, the model has been obtained by a one-dimensional laser range finder that is moving in two –axis (2D) and because of this the laser scanner has been produced cheaper.

**Keywords**—3D Laser Scanner, embedded systems.

## I. INTRODUCTION

LASER scanners are being used in many research areas such as defense industry, robotic systems, reverse engineering, manufacturing architecture, banking and finance, etc. Furthermore Laser scanners find application areas in modeling a mechanical object, road direction of the robots, restructure studies, security systems that have sense motion. Therefore, the important point for laser scanners is the speed and resolution. When they are needed to make clearer modeling, laser scanners systems can be used with cameras.

In this study, the scanner can model a 10 m radius area and this view can be 3D modeled in AutoCAD. Scanner is consisting of a 2D Laser range finder (LRF), motors that let move it over those axes, electronic cards and software. The name of the LRF model which is used in this study is SICK DT 00P1113 and is able to measure the only one point of the range image. LRF is fixed on the mechanic component which is controlled by 2 step motors. While the step motors are rotating 0.9 degree in each segment, mechanic component is the mechanism that rotates in the angle of  $\theta$  and  $\varphi$  and it is able to scan in the spherical area. The scanning area is being showed in Fig. 1. This scanning area can be changed with the help of computer software.

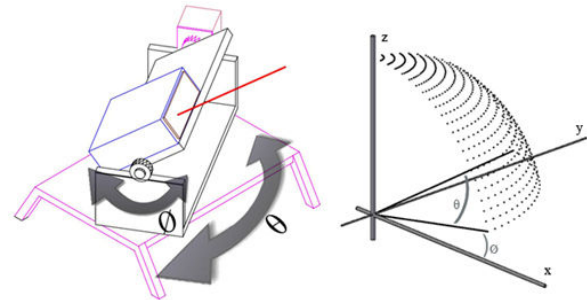


Fig. 1 Mechanical part of scanner and scanning area

## II. LITERATURE

The aim of this study is to design and produce a low cost laser scanner. In the literature it can be seen that different researchers has used 2D Laser Range Finder (LRF) to model the environment [1]-[6]. These types of laser scanners are more expensive than 1D LRF and because of this the cost will be more expensive to design it with 2D LRF. In addition the electronic cards used in these systems are for general purpose applications and this may also increase the costs. To reduce the costs control cards should be used for the purposes that are need. In this study, it has been aimed to reduce the costs with producing our own electronic cards and using 1D LRF instead of 2D LRF.

## III. EXPERIMENT SET UP

3D Laser scanner LRF consists of LRF, mechanical parts, power supply and electronic cards. The hardware is connected to the computer via RS232 port. These components and main board run in real-time duplex communication. The schema of hardware is shown in Fig. 2.

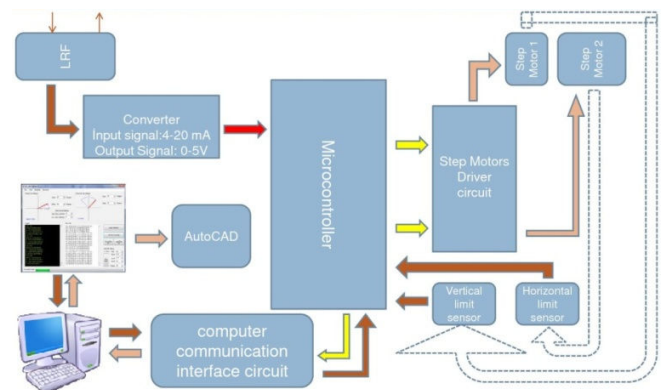


Fig. 2 Device modeling

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### A. 2D Movable Mechanical Part

A mechanical device has been designed in a way that can move in both axes in order to provide the LRF spherical coordinator motion. This designed device has two flexible parts and it moves along with the  $\theta$  and  $\phi$ . With the help of this LRF  $\theta$  can move with the range of  $0, +170$  and  $\phi$  angle can move with the range of  $-180+180$ . This mechanic mechanism is shown in Fig. 1. These angle ranges provide us wide range of scanning. We can think of the area that we are going to scan as cube which has 10 meter radius. Scanning area is shown in Fig. 1. When the scanning area increases, number of measurement increases as well. Number of measured point can be express in:

$$\text{\#of measured point} = \frac{\phi \times \theta}{\psi^2} \quad (1)$$

$\psi$  : Step Angle 0.9 degree

$\phi$  : Vertical angle

$\theta$  : Horizontal angle

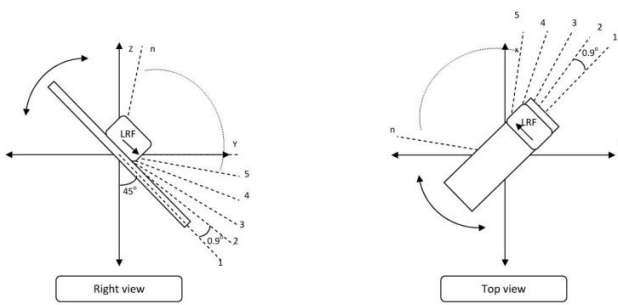


Fig. 3 The view of axis

### B. Computer Software and Monitoring

The computer program has coded by using C sharp programming language on .NET platform. The duty of program is to collect and monitor the information that comes from the hardware. Furthermore the computer software has sent the information to related user scanning parameters to scanner with the help of UI. In addition, this program has drew the shape of the scanned object with AUTOCAD program by using the data. Setting of the  $\theta$  and  $\phi$  axis scanning area, speed and AutoCAD drawing parameters has done through the program. Program adjusts the color changes automatically according to distance change while drawing on the AUTOCAD. This is completely designed to model he user dream the atmosphere easily. The angle setting in the program determines the starting point and the scanning area of the scanner. The setting of high edge and low edge determines the structure of the pulse that is being sent to the motor. Software UI is shown in Fig. 4.

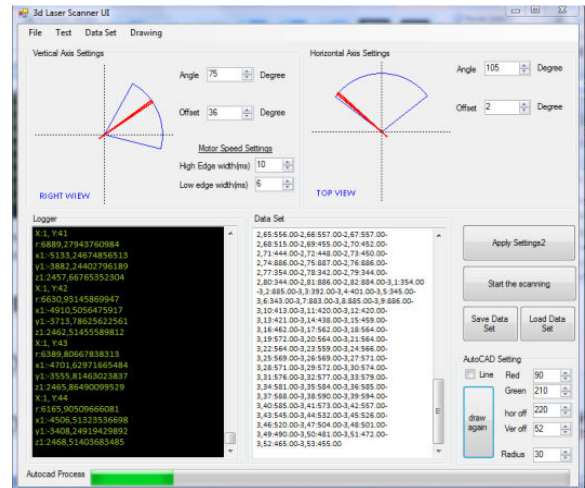


Fig. 4 Software User Interface

The software has generated a matrix which of size related to number of measured points. After Scanner has completed the scanning process, the computer software has generated 3D Model by using generated matrix on AutoCAD. The matrix has consisted from distance and angle information so measure values have converted to Cartesian coordinating system from polar coordinating system. This conversion and drawing has completed by computer software. Sample matrix A structure shown in (2).

$$A = \begin{bmatrix} 373.00 & 374.00 & 372.00 & 737.00 & 717.00 & \dots & v \\ 372.00 & 374.00 & 381.00 & 386.00 & 395.00 & \dots & \\ 387.00 & 385.00 & 390.00 & 730.00 & 738.00 & \dots & \\ 377.00 & 380.00 & 386.00 & 387.00 & 395.00 & \dots & \\ 398.00 & 399.00 & 401.00 & 732.00 & 758.00 & \dots & \\ \dots & \dots & \dots & \dots & \dots & \dots & \\ h & \dots & \dots & \dots & \dots & \dots & vxh \end{bmatrix} \quad (2)$$

$$v = \frac{\text{vertical\_angle}}{\text{Step\_angle}}, h = \frac{\text{horizontal\_angle}}{\text{Step\_angle}} \quad (3)$$

$\text{Step\_angle} = 0.9^\circ$

### C. LRF (Laser Range Finder)

In this Project 1D-Laser Range Finder is used. The number of LRF is DT50-P1113, and the measurement range is 0.02 and 10 meter. LRF measure the distance using laser light. Technical feature of the LRF that we used is given in Table I. Sensor that we used has an analog output and additionally it has one digital output but analog output is enough for our study. The sensor used in this study gives output between the range of 4 and 20mA. 20 mA is equal to 10 meter, 4 mA can be equal to 0.02 meter. Since the micro controller is able to read analog voltage rather than analog current we have changed the 4-20 mA output signals to 0-5 voltage output signal.

#### D.Parallel Running between C# and AutoCAD

Autodesk firm is the manufacturer firm of the AutoCAD program. Autodesk firm designed API which enables applications to be connected without having a user connection with program called AUTOCAD. Firm published great tutorial and sample codes related to usage of these API on their websites. We can use the AUTOCAD program by having a relation between AUTOCAD and C# with the help of the API that Autodesk firm enabled. We can model the objects automatically with the help of the data that we received from scanner. AUTOCAD program and the scanner which is the popular program used by all around the world has used in a combined way by this method.

#### IV. RESULT

Fig. 5 shows the area which has been scanned.



Fig. 5 Photograph of the area which has been scanned

3D model views of different perspectives can be seen on Fig. 6. The scanning features are shown below:

$\psi$  : Step Angle 0.9 degree

$\theta$  :  $90^\circ$

$\theta$  :  $105^\circ$  Scanning time: 6 min 18 sec

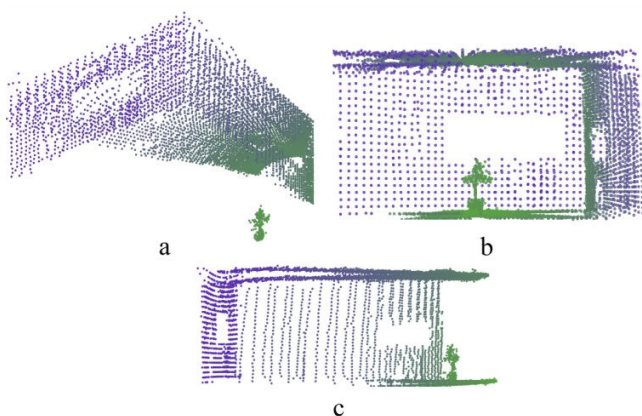


Fig. 6 View of 3D model that printout from AutoCAD (a: Perspective view, b: Opposite view, c: Right view)

#### V.CONCLUSION

In this study, a scanner is creating a 3D model of the objects. The scanner is consisting of 1 LRF sensor, 2

electronic cards and 1 computer. All units are working in real-time with each other. Total cost of this created device is lower than other equivalent scanners. According to the scanned area or points a robot can navigate between them easily. The scanning time depends on the motors and LRF distance sensor. The scanning time of a point that is measured by LRF is approximately 20-30 ms as written on the datasheets. Due this information the complete scanning time depends on the scanned area. During this study, we get experienced about laser scanning design, 3D model implementation, motor drivers and real-time streaming.

#### A. Future Work

This device's motion can be provided by moving it on the robotic system. Moreover, system can be improved by using servo motors, different LRF and fast microprocessors. Well-designed laser scanners can be used as short range radar. For instance, it can define the shape of the bird or a plane. Laser scanners are used in our houses with the smart televisions. The increased addition of technological development and robotic systems show that usage of laser scanners will increase.

#### APPENDIX

TABLE I  
 FEATURES OF LASER RANGE FINDER

Measuring range	200 ... 10,000 mm
Resolution	1mm
Accuracy	$\pm 10$ mm
Response time	20/30 ms
Output rate	4ms
Resolution analog outputs	16 bit

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