Utilizing LIDAR Technology and Arduino Interfacing for Image Processing and Recognition

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The Idea

With the recent advances in machine learning and artificial intelligence, computer science and technology is becoming the frontier of human civilization. Self-driving cars, autonomous rescue platforms, and unmanned aerial drones all have the ability to position themselves in the surrounding area. Last year, this ability to perceive the surrounding environment fostered my interest to pursue a project based on LIDAR, the novel instrument used by smart machines to map their environment. Last year I showed that a low cost LIDAR module can be utilized to make accurate distance measurements to produce {x,y,z} coordinate values of the surrounding environment. This year I wanted to incorporate the basic principle of autonomous mapping and remote sensing into my project.

Abstract

The purpose of this project is to generate a cost effective, 3-Dimensional (3D) representation of a surrounding spatial environment utilizing a Light Imaging Detection and Ranging (LIDAR) module that can ultimately be used by a variety of robotic-based systems to sense and interact with their environment. The use of LIDAR technology, as well as the ability to interface with a LIDAR module and make mathematical calculations with an Arduino microcontroller, were researched. For the project, a LIDAR laser ranging module was mounted to two servo motors to create the ability to scan a spatial environment. An Arduino microcontroller was used to interface with the LIDAR module and servos, and perform mathematical calculations. Based on the distance measurements read from the LIDAR module and commanded servo positions, spherical coordinates (rho, theta, phi) were calculated and then mathematically transformed to Cartesian coordinates (x,y,z) and serially communicated to a computer screen to create a 3D representation in the x, y and z planes of the sensed environment. My project demonstrated the potential of low cost LIDAR-based systems. The ability to accurately take distance measurements and process data in near real time opens capabilities for intelligent machines to effectively interface with their environment.

Experimental Progression

Last year, the Arduino program was designed to interface with servo motors to scan a surrounding area . Since the LIDAR module perceives itself in a spherical space, all calculations must be computed in terms of spherical coordinates {ρ, θ, φ}. However, in order for the point values to be plotted in the graph, the values must be converted into cartesian coordinates {x,y,z}.

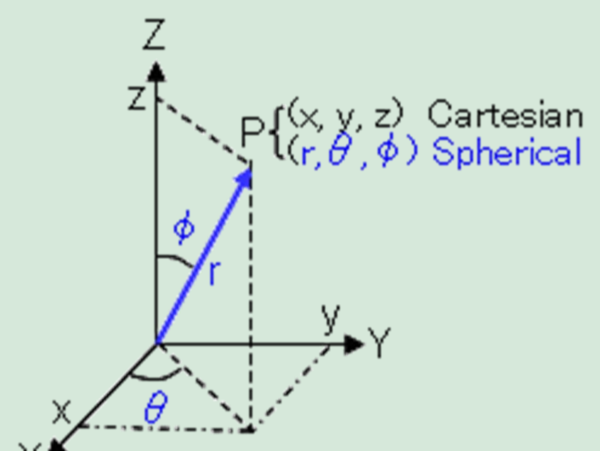

Diagram 1.1

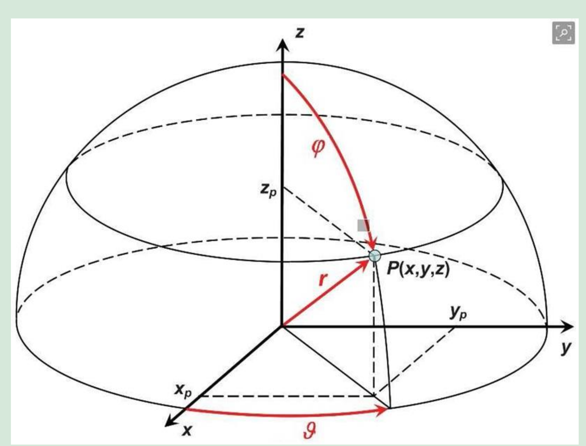

Diagram 1.2

Mathematical Conversions:

$$x = \rho \cdot \sin(\varphi) \cdot \cos(\theta)$$
$$y = \rho \cdot \sin(\varphi) \cdot \sin(\theta)$$
$$z = \rho \cdot \cos(\varphi)$$

ρ (rho), sometimes denoted as r, is commonly thought of as the radius. Rho is LIDAR’s distance measurement.

θ (theta) is calculated relative to the position of the servo in the x-y plane. It is calculated in terms, of radians and is called the polar angle. The plane on which theta operates is commonly referred to as the polar plane.

φ (phi) is calculated relative to the position of the servo in the z plane. It is made in terms of radians and is called the azimuthal angle. The plane on which phi operates is called the azimuthal plane.

The program is designed to display Cartesian coordinates on a computer screen via serial communication. The data is output in a linear fashion of {x,y,z,x,y,z…}.

Flowchart

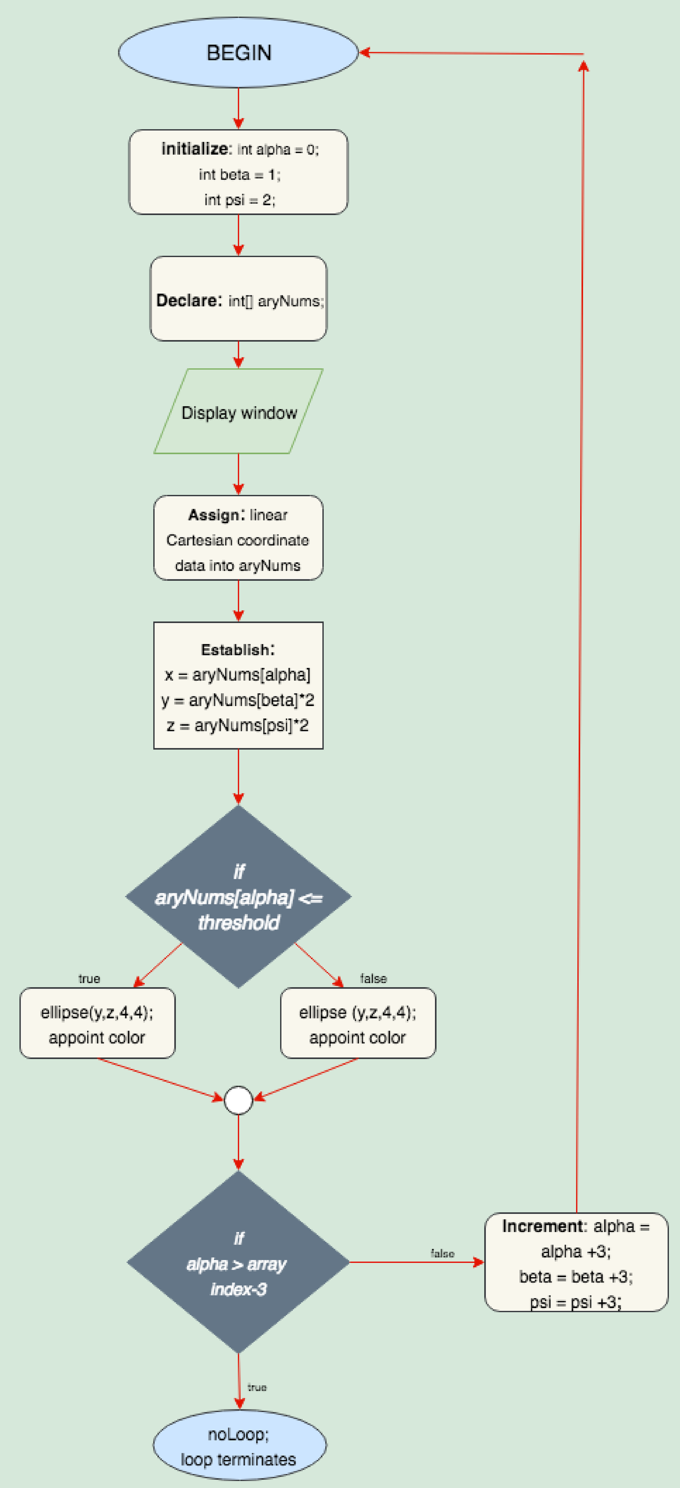

Diagram 1.3

Compare and Contrast

Humans can rapidly and effortlessly sense and identify everyday objects; however machines must use advanced image processing techniques and learning networks to recognize simple images. The flowchart is a model of the rudimentary code used to exploit the basic and foremost step that all vision-oriented machines use.

The code is designed to take the LIDAR distance measurements and plot the y and z values in a display window. The array of LIDAR measurements are transmitted out of a separate Arduino program in a linear series (x,y,z,x,y,z…). The processing code is programmed to extract the distinct values by incrementing the array position for every completed loop.

The x values are an integral part of the processing code. The processing code takes 3 dimensional coordinate values and plots the values in a 2 dimensional coordinate system. The x values are utilized to apply a topographical characteristic to the coordinate point. An *if-else* statement appoints a designated color to the coordinate point if the meets the parameters of the statement threshold. Similarly, modern day autonomous systems utilize a depth statement to remotely sense the positions relative to platform.

The processing code is designed to loop after one pass of code is complete. The code increments the alpha values so the next pass uses new data. Neural networks use similar methods of teaching the system to learn through trial and error, this is called back propagation. Although the processing code does not utilize neural net backpropagation, it uses the basic principle of continuous looping until a desired parameter is met.

Generated Plots- Image Processing and Analysis

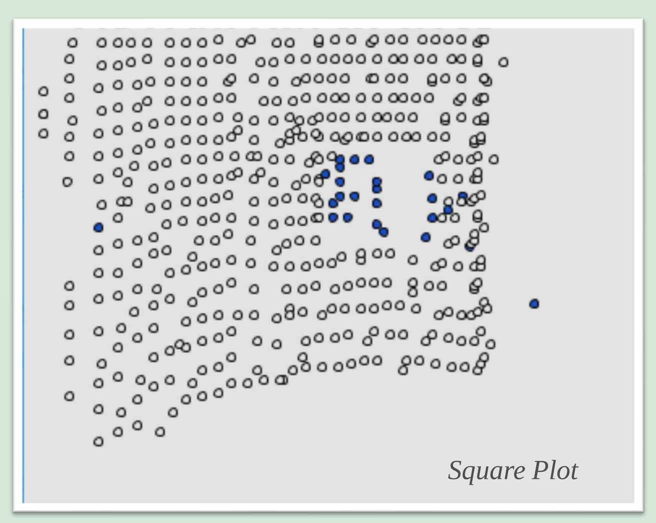

Diagram 1.4

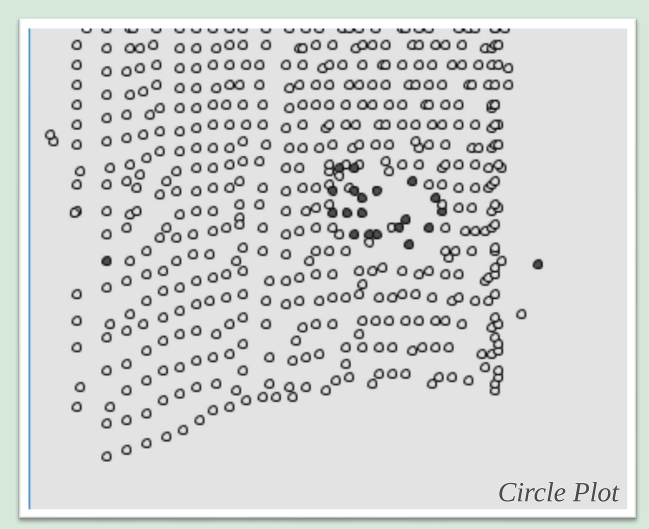

Diagram 1.5

The generated data are graphed in a 2-D plot and significant points are assigned a designated color. Diagram 1.4 illustrates the identity of the scanned square, however the outlier data makes the image appear noisy . The blue points of Diagram 1.4 are in a condensed region of the plane. The embedded empty space in the outline of the square is the “unseen” projection of the square behind the it. Diagram 1.5 displays a wider and more dispersed data set. Overall, the circle plot does appear more complete than the square plot, but the square more clearly gives insight into the identity of the shape from the unseen region.

Discussion

LIDAR is increasing in popularity due to its ultra-precise performance and sensitivity to minute distance changes. Similar LIDAR systems prove their novelty and significance to environment-sensing machines. The simple, rudimentary processing code generates impressive results; however, in order for machines and autonomous systems to advance in society, the systems and programs will need the following developments.

Advanced Topography

Modern day LIDAR surveying systems utilize multi-color plots containing millions of points. The processing code of the experiment uses only one layer of color, whereas advanced LIDAR systems uses as many as 7 different colors, these colors give the machine insight into depth characteristics of the surrounding area.

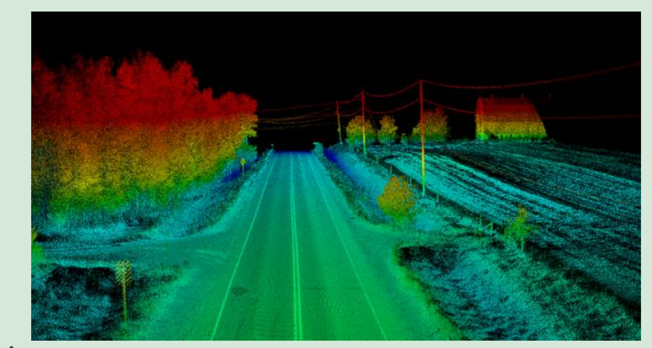

Diagram 1.6

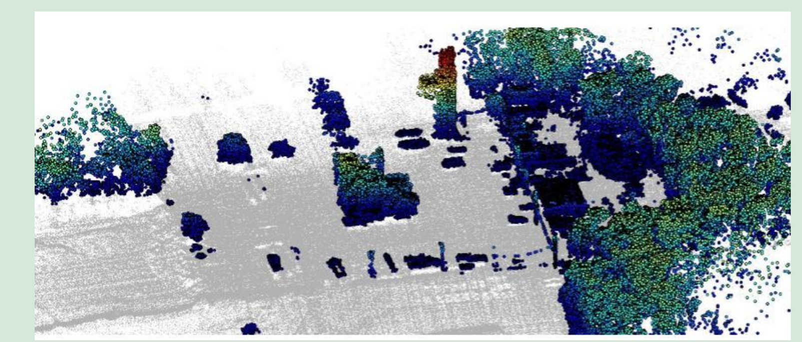

Diagram 1.7

Noisy Data

Noisy data is irrelevant and meaningless outlier data that lies beside desired information. The shapes graphed expressed noisy data in the fact that the shapes identity was surrounded by unwanted data. Noisy data is difficult for machines to understand and recognize. In order for machine intelligence to advance, computer systems must be able to read and interpret noisy data.

Diagram 1.8

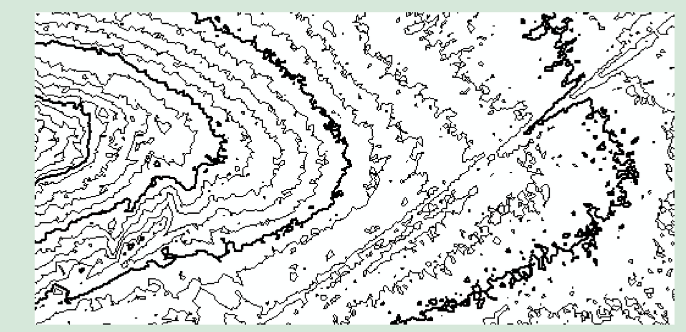

Diagram 1.9

Conclusion

A low-cost LIDAR module proved to be a novel instrument for constructing rudimentary LIDAR distance measurements. Although the LIDAR was able to render a valid plot of the scanned area, the shapes scanned by the LIDAR were noisy and unpredictable. The program was able to generate the topographical characteristics designated in the code and ultimately plot the shape with an appointed color.. The LIDAR technology has proven its ability to interface with an Arduino microcontroller and computer software. Overall, the processing code, in conjunction with Arduino and LIDAR, demonstrated the basic principle of modern day image processing and object recognition.

Applications

Because of LIDAR’s unparalleled ability to perceive its surroundings with such extreme accuracy, the instrument is ideal for remote sensing and machine vision. One of the most interesting applications of LIDAR is its use in autonomous rescue robots designed to operate in hazardous conditions that prove dangerous for humans. These robotic platforms are often designed with intricate dexterity and precise object recognition. Autonomous vehicles of the future will certainly be relying on LIDAR to aid in navigation. This is made possible through the collaboration with LIDAR technology. Other applications include self-driving cars, military aerial drones, forest mapping and bridge surveying.

References

Diagram 1.1 – By Dr. Rain Rueter
Diagram 1.2- by casio electronics
Diagram1.3 – 1.5 – by Andrew Trepagnier
Diagram 1.6 – by Ron Berg
Diagram 1.7- Ranjith Unnikrishnan
Diagram 1.8- by Adam Geitgey
Diagram 1.9- Environmental Systems Research Institute