Abstract

In the world of robotics, sensors serve the paramount function of connecting the robot to the environment around it. Sensors of all kinds provide the necessary information for the robot to conduct its specific task. In the field of autonomous robotics, navigation is one of the most interesting and researched problems. Robots that can navigate and move themselves through an environment are being used in countless applications, everything from autonomous vacuums to advanced military robots. Laser ranging sensors use laser light to determine distances and thus have a number of advantages. Laser rangefinders are more accurate, faster and more reliable than most other ranging systems. Lasers are suited to extremely high speed operation thus the sensor can provide a huge amount of information in relatively little time. Furthermore, laser light does not dissipate quickly thus laser range finders can measure very large distances. A rotating laser range finder allows a robot to scan an area and record readings about distance to objects in its field of view. Combining these sensor readings with processed image readings can provide a very powerful map for an autonomous robot or useful information for the robot user.

It is clear that this project relates to many of NASA’s enterprises. Autonomous robotics is a very advanced field and robots are increasingly being used in environments that are too harsh for humans, namely outer space. Furthermore, while the NASA design teams probably will not adapt this project, many technologies and important research comes from smaller robotics programs working independently. This project is intended to provide an advanced robotic sensor at a reduced price therefore making it more widely adapted.

My goal is to design and implement a low cost effective laser ranging system optimized for smaller robotics programs. Commercially available laser rangers such as the Hokuyo URG-04LX cost $2500 and more advanced sensors can cost much more than that. My intention is to create a low cost, low power, sturdy, reliable range finder that could easily be implemented by a robotics team. To reduce costs, I will make small concessions in accuracy and speed for greatly reduced price.
Narrative

Project Plan: My project is to design and build a laser range finder for robotic applications. Laser rangers are commercially available, but they are very expensive and are designed for very sophisticated robots. It is my intention to design a low cost rangefinder that is more geared to smaller robotic programs. Some commercially available range finders are accurate to within the millimeter and have a very wide range of functionality but this accuracy comes at a price. One of the more inexpensive rangefinders on the market, the Hokuyo URG-04LX, provides a 2 dimensional scan at very high speeds and accuracy but costs $2500. This price tag is out of the range of many robotics programs especially for a single sensor. The main design constraint for my range finder will be its total cost. The entire sensor should cost under $500 if possible and will be optimized for cost effectiveness. Small reductions in accuracy and functionality can greatly reduce the price of a ranging system.

As stated the primary design constraint for this project is the budget. The driving idea behind the project is to keep the cost low without sacrificing the basic functionality of the sensor. Many ranging applications do not require the measurements to be within a cm and some even less. The Hokuyo URG-04LX is accurate from 0.02 meters to 4 meters with a maximum error of 10mm. This level of accuracy, while needed for some applications, is not needed for basic navigation information. It is more important to know that there is an object in a certain area then know exactly how far away it is to the millimeter. Thus my goal is to measure distances from 1m to 4m with a maximum error of 5% of the distance, which correlates to an error of 5cm to 20cm. This error is acceptable for basic positioning and navigation algorithms.

Another important design constraint for two-dimensional range finders is the angular resolution or the amount of rotation in between distance readings. This is important because it defines the minimum size of an object that can be reliably found, the finer the angular resolution, the smaller the object that can be found. Again the Hokuyo URG-04LX has a resolution of 0.36 degrees per reading. This provides an extremely fine map of the surrounding. My design will again sacrifice as little of this accuracy as possible while reducing costs. My design will have a minimum resolution of two degrees per reading which will still provide a reliable map of the surroundings. With a reading every two degrees, the sensor will be guaranteed to pick up all objects larger then 13cm. The speed with which the sensor can obtain these readings is also taken into account. While commercial range finders can scan 360 degrees in 100ms, my design
will be significantly slower to optimize accuracy and correct angle alignment. The minimum speed will be a 180-degree scan in 3 seconds. This is still fast enough for robotic navigation. **Design Method:** The first step of the design and implementation of this project was to research current solutions and put together as much information as possible on all of the different aspects. Research was conducted by reading texts on general ranging as well as searching online for different solutions. Acroname and SICK were both contacted and requests were made for information on either the design of their sensor or general information on laser ranging. Acroname is a public friendly company that provides robotics information on a range of topics. SICK is one of the forerunners in the laser ranger market. Two main methods for ranging using lasers were found. The first measures the time of flight of a laser from when it leaves the sensor, is reflected off an object, and then is read by the sensor again. The method relies on very high-speed components and calculations. The second method relies on geometry. A laser is bounced off of an object and the angle with which it returns is measured. This information can then be correlated to distance through a trigonometric algorithm. As much information as possible was collected on both methods including prices and performance specifications on many different parts for the sensor. The information was then synthesized into four different cohesive designs that could be compared. It was decided that the angle measurement method was not only less expensive but was more flexible and receptive to different designs. Currently the method of angle detection is being tested and decided upon. A CMOS image sensor could be used to record information about the location of the laser point. Through image analysis, the laser spot could be found then its lateral position in the frame could be used to calculate its exact location. This method is especially attractive because of the low cost of image sensors in relation to laser sensors. Once the image sensor design has been verified as a viable approach to the problem, the image-processing algorithm will be designed and implemented. Once the components are functioning then it will be condensed to a self-contained sensor. Two-dimensional functionality will then be implemented so that the sensor will provide a full sweep of its surroundings returning 180 degrees of distance data. The design will be constantly iterated upon and optimized to provide the most functional and accurate sensor for the smallest cost. **Interdisciplinary Approach to the Problem:**

- Electrical: This project is a primarily electrical engineering problem as building and connecting the different components of the sensor is main design goal.
- Mechanical: Design and implementation of the sensor housing as well as the rotating mechanism provides the mechanical aspect of this design
- Software: The sensor will be based on an 8051 processor that will require programming. The programming will take the image data and translate the laser position into a distance reading that can be transferred to the robot.
- Image Processing: The image sensor will take an image, then an image processing program will be used to determine the pixel address of the laser spot.

**Expected Outcomes:** There are three major milestones in the completion of this project. 1.) Prove that this image sensor based method of range finding is viable and will produce distance data. Using the image sensor and a laser, this method will be proven in the lab before the system is condensed to a single item.

2.) Add two-dimensional functionality to the sensor. Mounting the sensor on a turning mechanism and adding software that will provide a robot with a full sweep of data will make the sensor much more powerful and useful to a robot.

3.) The cohesion of the whole system into a self-contained sensor that can be easily interfaced with most robots. Ideally the sensor could be utilized by the Trinity Robotics Team as a fully functional ranging sensor.

   Optimally, I will be able to complete the design and implementation of the sensor in an innovative way. The solutions that are currently possibilities are unique and different from the current commercial laser rangers available. Furthermore, designing a low cost and simple sensor could promote the use of the technology in more robotics programs.

**Career Potential:** This project has given me and continues to give me a unique view into what it means to design a product from start to finish. My projects has forced me to use skills form every part of my engineering education as well as learn new skill and research new information. As I move on into the engineering work force the skills that I have obtained and sharpened with this project will prove invaluable. Furthermore, electrical engineering is certainly a field that interests me and a field that I hope to work in. This project is an extension of my education into an actual design.