

ECE 480 Team 4
Distance Sensor Application Note

By Yakov Kochubievsky 4/3/2015

Purpose

Team 4's project is to design a "Smart Walker". A walker (figure 1) is 2 or 4 wheeled frame that disabled or elderly people use as walking aid. A walker increases balance and stress put on the body. The Smart Walker is a walker modified with a device that will sound an alert to a visually impaired user when stairs or sudden changes in elevation are ahead. Ideally the device should be compatible with a variety of walkers. The Smart Walker uses distance sensors, microcontrollers, a power supply, and piezo speakers to alert the user to dangerous changes in elevation and stairs. This application note will focus on the implementation of distance sensors in the Smart Walker. Our experiments show that LiDAR sensors are most effective for the purpose of detecting stairs or elevation changes.

Figure 1 (Walker)



Components/ Equipment

The components and equipment pertaining to the distance sensor include:

- 2 LiDAR Lite Range Sensors

- 1 Arduino nano (ATMEGA328)
- 1 Smart Walker Housing Mount (custom made)
- Computer capable of usb communication

LiDAR Lite Range Sensors

Figure 2 shows the LiDAR Lite distance sensor designed by Pulsed Light 3D. This distance sensor's key components are: a transmitting laser, a receiving PIN diode, 2 lenses, and a microcontroller. The transmitting laser sends a pulse of concentrated light to a target while the receiver reads the transmitted signal. The Lidar Lite uses a process called "signature correlation" to determine the distance to a target.

The desired characteristics for a distance sensor for the purposes of designing a smart walker are: portability, long range, high accuracy, and low power consumption. Some of the features that make the LiDAR Lite a good option for the Smart Walker design:

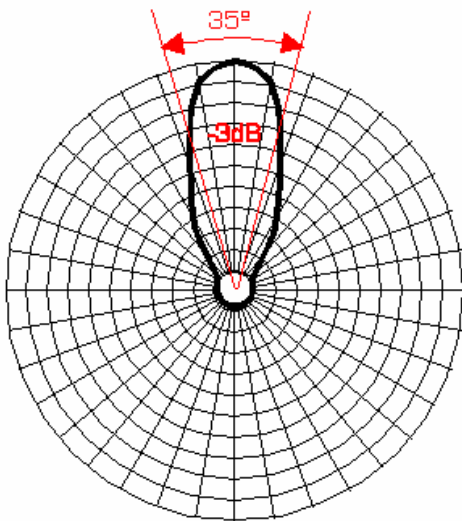
- Dimensions: 21 X 48.3 X 35.5 mm
- Performance: 0-40m Laser Emitter
- Accuracy: +/- 0.025 m
- Power: 5vdc, <100ma
- Rep Rate: 1 - 100Hz rep rate
- 0.5 degree beamwidth

Beamwidth is a critical concept in distance sensing. Beamwidth is the angle of the window that the sensor can detect. The beamwidth concept is illustrated in figure 3. A very broad beamwidth results in undesired objects being detected by the sensor while a very narrow beamwidth might not detect a drop off if a walker isn't aimed directly at the stairs. A solution to this problem is to use two sensors with narrow beamwidth placed on opposite sides of the walker.

Figure 2 (LiDAR Lite distance sensor)



Figure 3 (Beamwidth Illustration)



Another option for a distance sensor is the PING))) ultrasonic sensor by parallax. This option has been widely explored by our design team with mixed results. While the PING))) was able to detect distance accurately, it had trouble getting a signal at low angles of depression and wasn't able to perform adequately in detecting far enough ahead of the walker.

ARDUINO Nano

The Microcontroller is the device that will read distance data from the sensor and send the signal to activate the piezo speakers in order to sound the drop off alert once a specific change in elevation is detected. There is another app note that covers the specifics of programming the microcontroller and the algorithm that detects a drop off. This application note will discuss the interface between the microcontroller and the distance sensors.

Because there are 2 distance sensors and a piezo electric circuit that needs to communicate with the microcontroller, a microcontroller with a sufficient amount of pins is required. Each distance sensor needs 2 I/O pins, 1 5V pin, and 1 GND Pin, and the piezo circuit needs 1 I/O pin. A sufficient clock speed is required in order to make measurements quickly enough so that the user has enough time to stop before a drop off. The microcontroller should also be compact in order to fit inside of the Smart Walker housing mount. Most Arduino microcontrollers will meet these requirements, the documentation provided by Pulsed Light 3D is specific to the Arduino Uno but the sensors can easily be operated by most microcontroller.

- Operating Voltage: 5 V
- Input Voltage: 7-12 V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 8
- DC Current per I/O pins: 40 mA
- Flash Memory: 32 KB
- SRAM: 2 KB
- EEPROM: 1KB
- Clock Speed: 16 MHz
- Dimensions: 45 x 18mm

Smart Walker Housing Mount

The sensors, piezo speakers & circuit, and the microcontroller all need to be contained in a protective enclosure which will include windows for the sensor's transmitters and receivers, a service access point, and a gap through which a power

conductor can be routed through. The enclosure will be placed on the highest horizontal bar available on the walker (see figure 1) and will need to be able to pivot around the horizontal bar in order to choose the angle of depression (The angle of which the sensors are aimed at the floor, see figure 4). Figure 5 is an example of an early prototype of the Smart Walker Housing Mount.

Figure 4

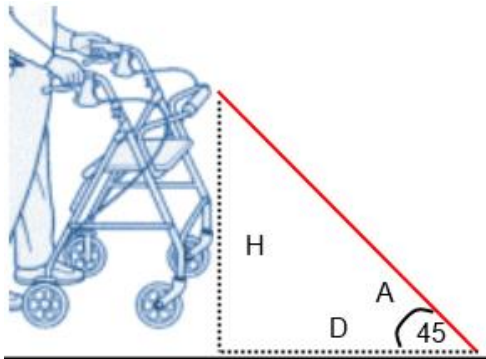


Figure 5 (Housing Sensor Mount)



Implementation

Determining Stopping Distance

It is important to determine the alert time required for the user. The required alert distance was determined by instructing the client to move regularly along a path with distance markers and stop as soon as the client heard the alert. The alert was sounded at a distance marker known to Team 4 but not the client. The position at which the client stops is then subtracted from the distance marker at which the client was alerted to determine the stopping distance. Team 4's client consistently had a stopping distance of about 3'6" which was rounded up to 4'.

Connecting the Sensor to the Microcontroller

The sensor can be tested by making the connections that can be observed on figure 7. The sensor comes with a connector cable which can be soldered or connected to various pins on the microcontroller. Figure 8 illustrates a pinout of the Lidar Lite distance sensor. Pin 1 is the 5V input pin and should be soldered to the "Vin" pin of the microcontroller. Pin 6 is the ground pin of the sensor and should be soldered or connected to GND pin of the microcontroller. Pins 4 and 5 need to be connected to the "ICSP2" pins on the microcontroller. The microcontroller will be powered through a mini usb port which will also power the sensor.

Uploading the code to the Arduino Controller

The software to communicate with the arduino can be downloaded on the arduino website <http://arduino.cc/en/Main/Software>. The arduino software needs to be installed on the machine as per the instructions on the arduino website. There is sample code posted on github by Pulsed Light 3D that can be obtained at

https://github.com/PulsedLight3D/LIDARLite_Basics. Upload and run this software on the arduino with the sensor connections detailed in the previous section. A window should appear that constantly updates the distance read by the sensor. It is a good idea to confirm the accuracy of the readings with a tape measure. Updates to the sensor sensor software will be discussed in detail in the microcontroller app note.

Detecting Sudden Changes of Elevation

The sensor should be placed in the Smart Walker housing mount once the sensor is working and is reading distances accurately. The height at which the sensor is placed should be measured, this height will be referred to as “H”. The distance at which drop offs, stairs, and sudden changes of elevation is the stopping distance determined earlier in this section, this distance will be referred to as “D”. The distance that sensor reads is a diagonal line from the position of the sensor to the floor a distance “D” away from the walker, this distance will be referred to as “L”. H, D, and L form a triangle, knowing this we can use the pythagorean theorem to determine what distance “L” the sensor should read in order to obtain a desired distance “D”. L should be calculated as $L = \sqrt{H^2 + D^2}$. Adjust the housing mount until the sensor is reading a distance L calculated by the previous equation. Once this distance is set, experiments on various drop offs should be done in order to establish a pattern for elevation change.

Figure 7 (Arduino to LiDAR connection)

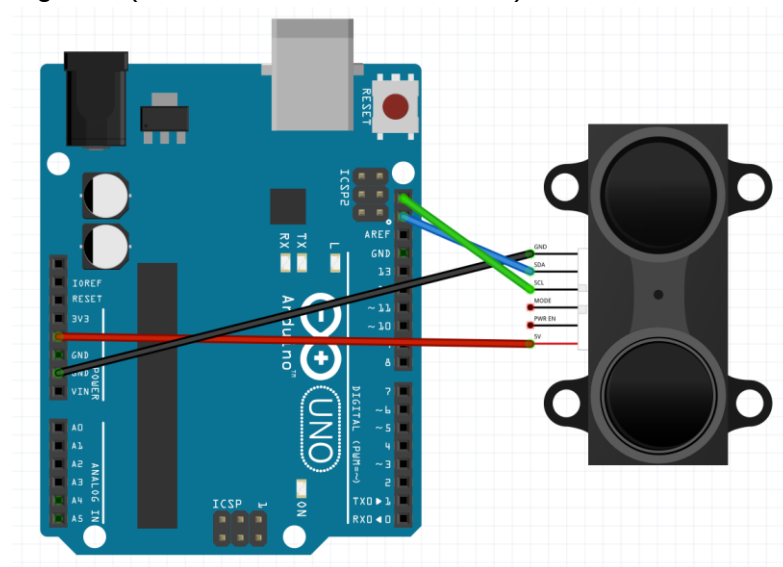
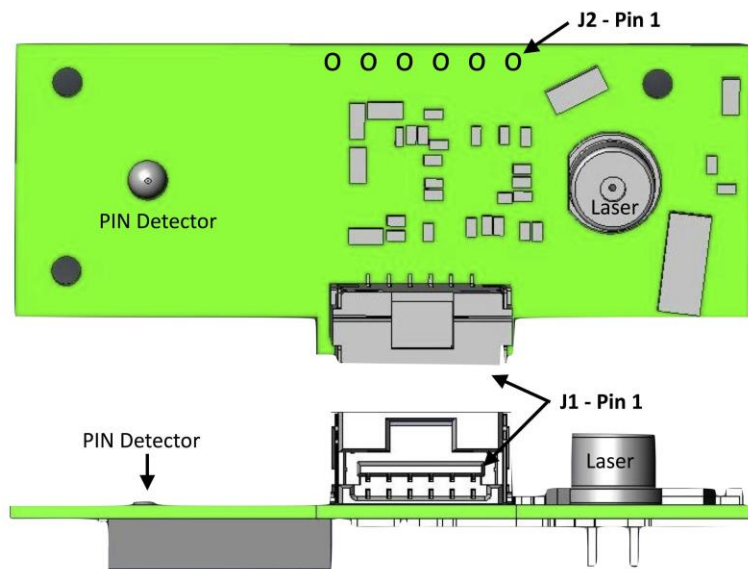


Figure 8



Results and Recommendations

Team 4 is in the process of connecting and doing experiments with the LiDAR Lite sensor. Previous experiments were done using the Parallax PING))) sensor. Those experiments were determined to be a failure by Team 4 as the maximum distance that the ultrasonic sensor could detect 2' ahead of the walker. Likely reasons for this underperformance include:

- Shallow angle of incoming signal to the floor is caused by limited height at which the sensor can be placed
- Shallow angle of incoming signal causes insufficient reflection to the detector
- Wide beamwidth causing false distance readings caused by objects in the user's periphery

Pulsed Light 3D has confirmed that these issues should be fixed with the LiDAR sensor. The reasons while the LiDAR Lite will overcome the underperformance issues are:

- Shallow angle of incoming signal will affect targets at very far distance (40 m). The power of the outgoing signal and the signal correlation technology will enable the sensor to detect the signal at desired distances with shallow incoming signals.
- Narrow beamwidth will make testing easier as the distances measured will be less susceptible to objects in the periphery.

References

Information and specs about the LiDAR Lite obtained from <http://www.pulsedlight3d.com>

Information and specs about Arduino products obtained from <http://arduino.cc/>