DYNAMIC OBSTACLE DETECTION

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Certificate

This is to certify that the thesis entitled "**Dynamic Obstacle Detection**" submitted by Mr. Sunil Manohar in partial fulfillment for the requirements for the award of Bachelor of Technology Degree in Electronics and Communication Engineering at National Institute of Technology, Rourkela is an authentic work carried out by him under the supervision of the undersigned.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date: 11th May, 2015 Prof. Manish Okade

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Abbreviations

RADAR – Radio Detection and Ranging

LIDAR – Light Detection and Ranging

PWM – Power Width Modulation

UK – United Kingdom

BBC – British Broadcasting Corporation

IR – Infrared

ETA – Electronic Travel Aid

GPS – Global Positioning System

Abstract

The Smart Cane was designed as an enhancement for the traditional white cane used by the visually impaired for navigation. While the traditional white cane is effective in navigating ground level obstacles such as pits, stairs and so on and so forth, it is significantly inefficient in detecting obstacles above knee height, such as trucks, cars and so on. To solve this shortcoming, a group of students under their post-doctoral guide in Indian Institute of Technology, Delhi created Smart Cane, an add-on for the existing white cane that used ultrasonic ranging to determine the nearest threats to the user and set up an advance warning system for the same. It uses a tactile feedback system to warn the user of approaching obstacles with an effective range of 0.5 – 1.8 / 3 m. It has two modes: short range and long range which correspond to the variable maximum ranges, respectively. It is also significantly cheaper than the alternative walking aid enhancements offered by a variety of companies and boasts of a long battery life (Preliminary tests claim that the aid can last for up to a week with only a single charge of three to four hours). However, the Smart Cane has its own drawback in the sense that it is unable to warn its user of moving vehicles, such as cars, bikes and the like which possess a significant threat to the visually impaired given that they are unable to detect them and are hence at constant danger while navigating crowded roads.

The goal of this project is to supplant the existing Smart Cane with an additional IR sensor that makes it capable of detecting moving vehicles coming towards the user and warn the user if it is a threat to the wellbeing of the user. It functions in the "toward" mode, i.e. it only detects the objects coming towards the user and has an effective range of 250 m in optimum conditions. It uses the existing tactile feedback system to warn the user of approaching dangers. It relies on battery slightly more intensively than the ultrasonic sensor, but the usage can be optimized to minimize the battery drain.

Keywords: Smart Cane, Ultrasonic sensor, IR Sensor, Visually impaired, Navigation

Chapter 1

Introduction

According to World Health Organization, around 285 million people are afflicted with visual impairment worldwide, 39 million of whom are actually visually impaired, and 246 million have low vision. 90% of those reside in low income areas. 80% of visual impairment cases can be prevented or cured [1]. Visual impairment is a severe disability that restricts an individual's ability to integrate into the society and as early as a century ago, visual impairment simply led to institutionalization and discrimination from the society. The very nature of the disability is such that it forces the disabled person to depend upon external help even for basic actions. While there are rehabilitation programs that target the visually impaired, they have had limited success as of late.

The preferred walking aid for the visually impaired is the traditional white cane which was invented in 1921 by James Biggs of Bristol and later popularized by Guilly d'Herbemont in France in 1931. From there it was popularized in UK by BBC, and the white cane was recognized as the standard gear for the visually impaired. The Lion's Club International in North America holds similar claims regarding the origins of the cane and was probably instrumental in its proliferation across the continent [2].

The most recognizable version, however, appeared in the post-World War II era, when the wounded visually impaired veterans needed support and a reliable aid for navigation. Dr. Richard Hoover modified the existing white cane to what it is now in an attempt to further ameliorate the plight of the veterans, and the traditional white cane was born. It was called as the "Hoover" cane and the navigational method was renamed as "Hoover's mode of travel". It is a foldable, easy to carry design, painted white to provide maximum visibility to the pedestrians and drivers and serves as an easy identifier for the visually impaired.

Despite its widespread popularity, the traditional white cane has its own set of problems. It is unable to detect obstacles over knee height, it cannot provide information of the geographical surroundings, and it is only useful only over a limited geographical area. Thus the visually impaired have been forced to supplant the white cane with other aids such as guide dogs. This has spurred research in this area, and researchers have sought to bridge the difference between the abled and the disabled via Electronic Travel Aids, or ETAs. However, the cost of these is prohibitively high and is hence, generally speaking, unavailable to the larger visually impaired population.

The Smart Cane, developed by a team of students at Indian Institute of Technology, Delhi, tried to remedy that by introducing a cheap, effective alternative ETA for the visually impaired. It uses ultrasonic ranging to detect obstacles as far as 3 m away. This project seeks to enhance the Cane by adding another IR sensor to make it capable of detecting moving objects as well.

1.1 Ultrasound

Ultrasound is a sound wave with a frequency higher than the human audible limit, i.e. about 20 kHz. It has a variety of applications: it is used to detect objects and measure distances, ultrasonic imaging or sonography is used in both human and veterinary medicine, it is used to accelerate certain processes and also cleaning and mixing, and it is also used to find flaws in structures. Ultrasonic is the application of ultrasound for various purposes. The various applications are:

- **Tracing**

    - **Long range sensor:** An ultrasonic sensor does not require direct physical contact. For some methodologies in various businesses this is a favourable element over inline sensors that may pollute the fluids inside a vessel or tube or that may be stopped up by the item. The concept behind the usage of a pulsed ultrasonic wave is that the transmit signal comprises of short bursts of energy. After every burst, the hardware searches for an arrival flag inside a time interval directly proportional to the time it takes the energy to go through the vessel. The signal during this time interval is studied.
    - **Motion sensors:** A typical ultrasound application is a programmed entryway opener, where an ultrasonic sensor identifies an individual's methodology and opens the door. Ultrasonic sensors are likewise used to distinguish gate crashers; the ultrasound can cover a wide region from a solitary point.
    - **Long distance testing:** Ultrasonic testing is a kind of non-destructive testing regularly used to discover blemishes in materials and to quantify the thickness of items. Frequencies of 2 to 10 MHz are basic. However, for uncommon purposes, different frequencies are utilized. Investigation may be manual or

mechanized and is a crucial piece of present day assembling methodologies. Most metals can be investigated and in addition plastics and aviation composites as well. Lower frequencies (50–500 kHz) can be used to review less thick materials. Ultrasonic examination disposes of the utilization of ionizing radiation, with wellbeing and money saving advantages. Ultrasonic examination is largely computerized now. An ultrasonic test of a joint can recognize the presence of defects, measure their size, and distinguish their area.

- **Location detector:** A typical usage of ultrasound is called Sonar. An ultrasonic pulse is produced, and if there is an obstacle in the way, part or majority of the pulse will be reflected back to the transmitter as a reflection and can be recognized. By noting the time interval, it is possible to calculate the distance of the object from the observer. The speed of Sonar pulses in water depends on the temperature and the saltiness of the water. Despite the fact that discovering is performed at both sub-capable of being heard and perceptible frequencies for extraordinary separations (1 to a few kilometres), ultrasonic reach finding is amazingly accurate.

- **Imaging**

Ultrasonic imaging uses waves of frequencies of 2 MHz and higher; the shorter wavelength permits determination of little interior subtle elements in structures and tissues. The force thickness is by and large under 1 watt/cm^2, to prevent warming and cavitation impacts of the item. Ultrasound waves are also utilized as acoustic microscopy, with frequencies up to 4 GHz. Ultrasonic imaging applications incorporate modern non-ruinous testing, quality control and therapeutic uses [3].

- **Acoustic microscopy:** Acoustic microscopy uses sound waves to picture structures. Frequencies up to a few GHz are used.
- **Human medicine:** Therapeutic sonography (ultrasonography) is an ultrasound-based analytic restorative imaging system used to envision muscles, tendons, and numerous inside organs, to determine their size, structure and other injuries with ongoing tomographic pictures. Ultrasound has been utilized by radiologists and sonographers to picture the human body for more than 50 years. The innovation is moderately cheap and convenient, particularly when contrasted and different systems, for example, Magnetic Resonance Imaging (MRI) and Computed Tomography (CT). As presently connected in the medicinal field,

appropriately performed ultrasound represents no known dangers to the patient. Sonography does not utilize ionizing radiation, and the force levels utilized for imaging are so low it would be impossible reason antagonistic warming or weight impacts in tissue. Although the long haul impacts because of ultrasound presentation at analytic power are still unknown, right now most specialists feel that the advantages to patients exceed the risks [4]. As indicated by Radiology Info [5], ultrasounds are valuable in the discovery of pelvic irregularities and can include procedures known as stomach (transabdominal) ultrasound, vaginal (transvaginal or endovaginal) ultrasound in ladies, and furthermore rectal (transrectal) ultrasound in men.

1.2 Infrared

Infrared (IR) is invisible radiant energy, electromagnetic radiation with longer wavelengths than those of visible light, extending from 700 nanometres (frequency 430 THz) to 1 mm (300 GHz) [9] (in spite of the fact that individuals can see infrared up to no less than 1050 nm in experiments [10] [11] [12] [13]). The greater part of the warm radiation discharged by articles close to room temperature is infrared.

Infrared energy is discharged or consumed by particles when they change their rotational-vibrational developments. Infrared energy energizes vibrational modes in a particle through an adjustment in the dipole minute, making it a helpful frequency range for investigation of these vitality states for atoms of the best possible symmetry. Infrared spectroscopy inspects ingestion and transmission of photons in the infrared energy range [15].

Warm infrared imaging is utilized widely for military and regular citizen purposes. Military applications incorporate target securing, reconnaissance, night vision, homing and following. People at typical body temperature emanate essentially at wavelengths around 10 µm (micrometres). Non-military uses incorporate warm productivity examination, natural checking, and modern office examinations, remote temperature detecting, short-ran remote correspondence, spectroscopy, and climate anticipation.

Chapter 2

Literature Review

There is a huge amount of ongoing research to create cheap and effective navigational aids for the visually impaired. The traditional white cane is being constantly upgraded with new technology to make it more effective. While it is sufficient to deal with ground level obstacles such as pits, stairs, puddles, etc. it is singularly unequipped to deal with obstacles above knee height, such as trees, trucks, cars, etc. While the traditional white cane is easy to make and cheap and easily identifiable, it requires the user to become accustomed to it to become useful. A recent estimate put the number of hours required before the user could walk safely and comfortably with the cane was 100 hours [17]. However, a lot of effort has been made in the area of enhancing the traditional white cane.

2.1 C-5 Laser Cane

The C-5 Laser cane was introduced by Benjamin et al in 1973. It uses three laser diodes and three silicon photodiodes acting as receivers to perform optical triangulation of obstacles. It can detect practically any obstacle in front of the user and has an effective range of 1.5 – 3.5 m [18]. There were several disadvantages in this model; particularly regarding safety and health issues for the user if proper precautions were not taken. The eyes were particularly susceptible. The receivers were also prone to malfunction as they tended to respond to ambient light sources such as the sun, street lights, etc. The accuracy was also drastically affected in hot and smoky areas [19].

2.2 The Motwat Sensor and the Nottingham Obstacle Detector

Both the Motwat sensor and the Nottingham obstacle detector (NOD) are handheld devices used for obstacle detection. While the Motwat sensor used ultrasonic ranging to calculate the distance of objects, the NOD used SONAR. The Motwat sensor required engagement of both hands of the user to function effectively.

2.3 Binaural Sonic Aid

The Bianaural sonic aid (Sonicguide) looks similar to a pair of spectacle frames. The transmitter is fitted in the middle of the frame, while the receivers are fixed on either sides. It uses the phenomenon of frequency shift to calculate distances and hence the users have an interaural amplitude difference to indicate the position and distance of the obstacle [20]

2.4 Kaspa

It is a very complex system configured to detect distances towards multiple obstacles. It consists of a sweep FM ultrasound emitter and three sensors which are purposefully displaced to get an accurate idea of the location of the obstacle. Hence the echo signal is rich in data which can be extracted easily to gain valuable information. Here, the obtained frequency is inversely proportional to the distance of the obstacle [21].

2.5 Radar gun

Radar guns have been classically used by the law enforcement departments to flag down speeding drivers. They use radio frequencies (RF) to calculate the speed of moving vehicles and warn police officers of speeding vehicles. They generate a focussed beam, wait for it to bounce back and then evaluate the time interval to calculate the speed of the moving objects. They were eventually replaced by the more accurate LIDAR guns (Light Detection and Ranging) [22].

Chapter 3

Materials

The given project was simulated using a variety of software packages. The microcontroller of choice was Arduino Uno, hence the project was implemented on the same.

3.1 Arduino Uno

The Arduino Uno is a microcontroller board based on ATmega328, containing 14 digital I/O

Figure 1: Arduino Uno

pins (6 of which can be used for PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 1: Arduino Uno specifications

3.2 Arduino 1.6.4

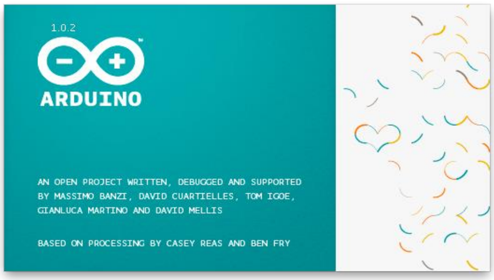

Figure 2: Arduino IDE

The Arduino development environment contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. It is a cross platform software that can run on Windows, Linux and Mac OS. It is published as open source tools, available for extension by experienced programmers. The language can be expanded through C++ libraries, and people wanting to understand the technical details can make the leap from Arduino to the AVR C programming language on which it's based. The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment. The environment is written in Java and based on Processing and other open-source software.

3.3 Processing

Figure 3: Processing logo

Processing is an open source programming language and integrated development environment (IDE) constructed for the electronic expressions, new media craftsmanship, and visual configuration groups with the motivation behind showing the essentials of PC programming in a visual setting, and to serve as the establishment for electronic sketchbooks. The venture was started in 2001 by Casey Reas and Benjamin Fry, both previously of the Esthetics and Computation Group at the MIT Media Lab. One of the expressed points of Processing is to go about as a device to get non-software engineers began with programming, through the moment satisfaction of visual input. The dialect expands on the Java language, however utilizes a rearranged linguistic structure and design programming model.

3.4 Simulator for Arduino

Simulator for Arduino is a simulation software created by Virtronics to simulate Arduino sketches. It is a licensed software that can show us the results of using the Arduino code before burning it into the Arduino board.

3.5 Ultrasonic sensor

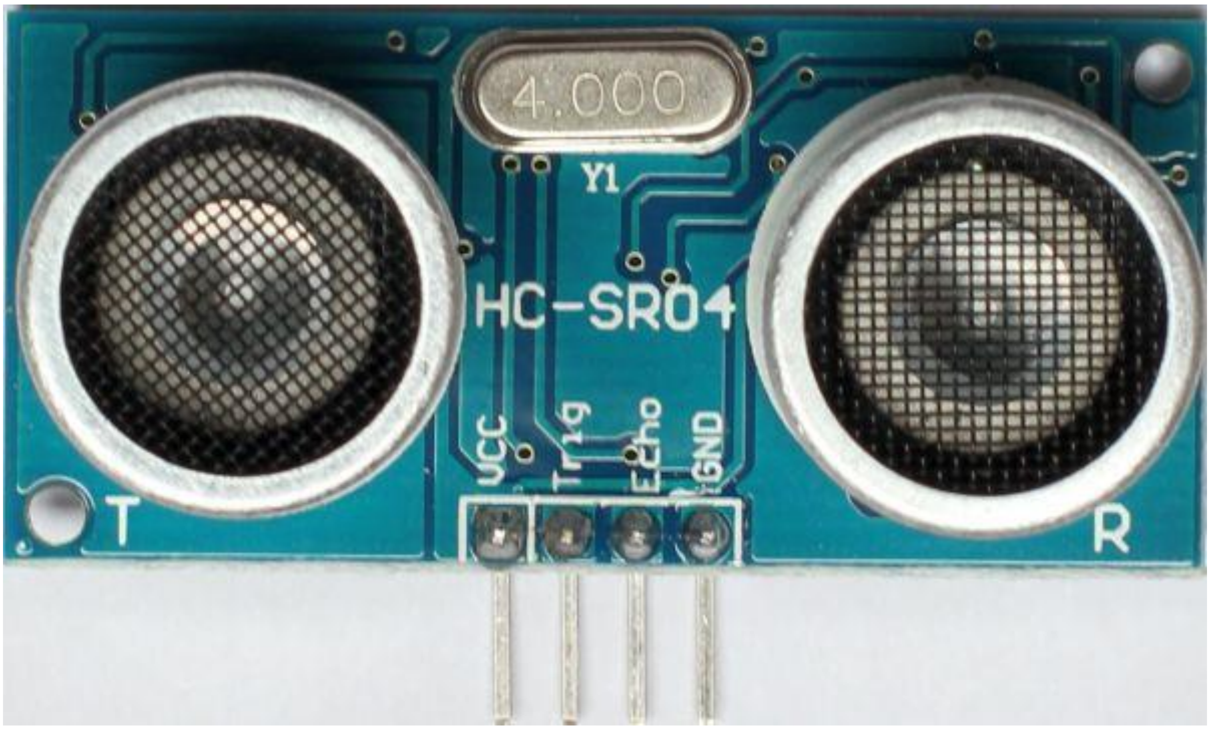

Figure 4: Ultrasonic sensor (HC-SR04)

HC-SR04 is an ultrasonic ranging module that provides 2 cm to 400 cm non-contact measurement function. The ranging accuracy can reach to 3mm and effectual angle is < 15°. It can be powered from a 5V power supply. The modules includes ultrasonic transmitters, receiver and control circuit. It has a pulse high of 10 us and operates at 40 kHz. It offers a stable performance, accurate distance measurement, has a high density and a small blind. It is used in robotics barriers, object distance measurements, level detection, public detection and parking detection.

Electrical Parameters	HC-SR04 Ultrasonic Module
Operating Voltage	DC - 5V
Operating Current	15 mA
Operating Frequency	40 kHz
Farthest Range	4 m
Nearest Range	2 cm
Measuring Angle	15 Degree
Input Trigger Signal	10us TTL pulse
Output Echo Signal	Output TTL level signal, proportional with range
Dimensions	45*20*15 mm

Table 2: Electrical parameters for HC-SR04

3.6 Proteus Professional

Figure 5: Proteus Design Suite

The Proteus Design Suite is wholly unique in offering the ability to co-simulate both high and low-level micro-controller code in the context of a mixed-mode SPICE circuit simulation. With this Virtual System Modelling facility, it is possible transform the product design cycle, reaping huge rewards in terms of reduced time to market and lower costs of development. Proteus Virtual System Modelling (VSM) combines mixed mode SPICE circuit simulation, animated components and microprocessor models to facilitate co-simulation of complete microcontroller based designs. It is now possible to develop and test such designs before a physical prototype is constructed. It is useful to test the simulations of the Arduino code before implementing it on an Arduino Uno board.

3.7 Radar gun

Figure 6: Radar gun

Figure 7: Radar gun

This contains a radar unit that uses the principle of Doppler to calculate the speed of a moving object. It was used by the law enforcement department a few decades ago when it was replaced by the more efficient LIDAR gun.

Chapter 4

Methods

4.1 Ultrasonic detection

HC-SR04 sends out 8 pulses at a frequency of 40 kHz with an input trigger signal of 10 us. The processing is then put on hold until the pulses are received. Upon their receipt, the distance is calculated by the formula:

$$D = T/58.2$$

Where D = Distance in centimetres

T = Time taken by the pulse to return

The algorithm of distance detection using ultrasonic sensor is:

Step 1: Send a predetermined number of pulses at a predetermined frequency.

Step 2: Wait for all the pulses to return without a significant change in frequency.

Step 3: Record the time taken as T.

Step 4: Determine the distance D between the user and the object using the given formula.

Step 5: Provide warning if necessary.

The coding was initially done in Processing but later carried out in Arduino IDE for convenience. The programming employed a simple ping test to determine the distance between the observer and the obstacle

4.2 IR detection

The radar gun employs a train of 10 pulses operating at a frequency of 38642 Hz or approximately 38.6 MHz to calculate the distance and speed of the moving object. The microcontroller looks out for noise by only permitting pulses that are similar to the characteristics of the original pulses to register on the counter while receiving the train and then calculating the altered frequency depending on the time taken by the pulse train to fully arrive.

4.2.1 Doppler effect

The apparent shift in the frequency of a sound source due to relative motion between the source and the observer is termed as Doppler Effect. This occurs due to the difference in time periods it takes the wave to arrive at the observer's position and hence leading to the impression that the wave has a different frequency. In case of radio waves, the altered frequency is provided by the formula:

$$\Delta f = 2fv/c$$

Where Δf = Apparent change in frequency

f = Original frequency

v = Speed of object

c = Speed of light

The assumption here is that the observer is at rest w.r.t. source.

As we can see, the velocity of the moving object can be calculated using the above formula as well, which is our goal in this project.

The pulses were sent at the rate of 38.6 MHz and were carefully filtered and received. The rate of the return pulse train determines the altered frequency. Using this information, the apparent change in frequency can be calculated. Using the data gained, the speed of the object can now be obtained.

The algorithm for distance and speed detection using radar is;

Step 1: Generate a pulse train at a predetermined frequency.

Step 2: Carefully filter out the noise from the incoming train

Step 3: Store the average time lag between the transmission and return of the pulse train.

Step 4: Calculate the apparent frequency and hence, the apparent change in frequency.

Step 5: Calculate the velocity of the approaching vehicle.

Step 6: Use the time interval recorded to calculate the distance of the vehicle from the user.

Step 7: Warn the user if necessary.

The coding was carried out in Arduino IDE, tested in Simulator for Arduino and the bugs were then fixed.

4.3 Code integration

With both the modules working correctly separately, the next job was to integrate both of the codes into one seamless program so that they could perform together. The code was then optimized for fastest results.

The algorithm for the integrated code is:

Step 1: If ultrasonic mode is required go to Step 2 else go to Step 7

Step 2: If short range mode is required go to Step 3 else go to Step 5

Step 3: Concentrate the wave pattern so that only close objects are detected (Use the ultrasonic detection algorithm).

Step 4: Go to Step 1.

Step 5: Diffuse the wave pattern so that objects reasonably far away are also detected (Use the ultrasonic detection algorithm).

Step 6: Go to Step 1.

Step 7: Determine the location of nearest threats using IR detection algorithm.

Step 8: Go to Step 1.

Thus the code constantly remains on the alert for threats.

Chapter 5

Results

5.1 Ultrasonic detection

The code was written in Processing, later in Arduino and successfully simulated in Simulator for Arduino.

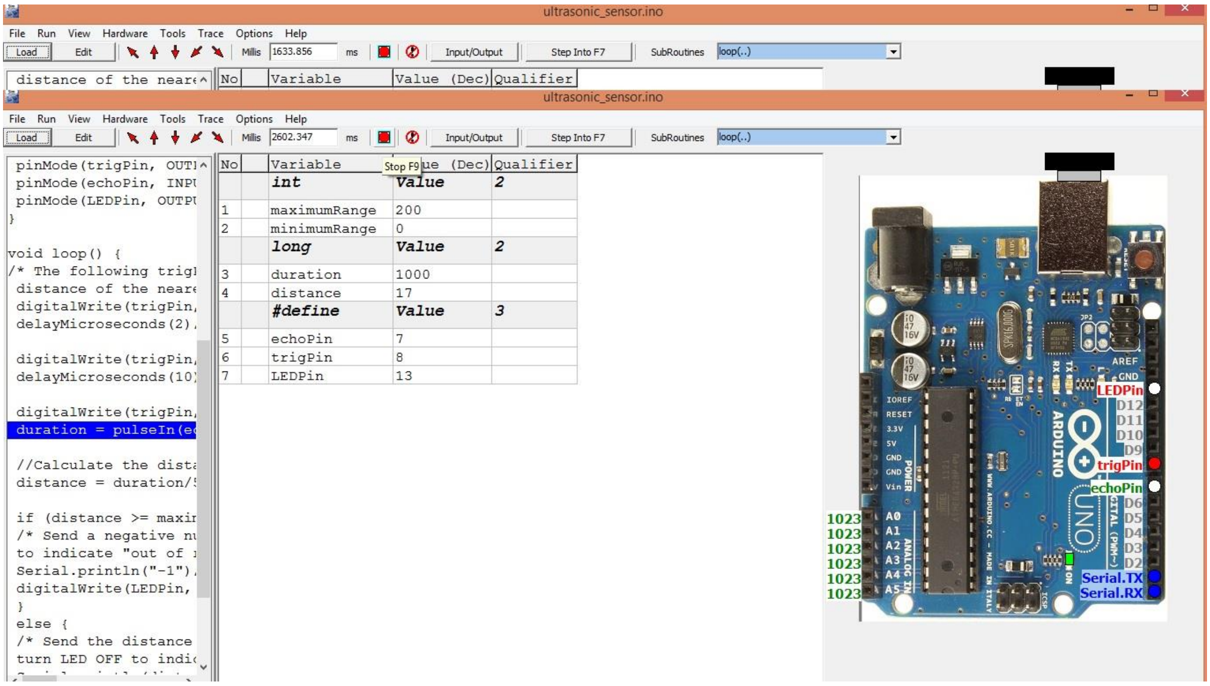

Figure 8: Ultrasonic detection

The Trig Pin engaged when the code was run, indicating that the code was working successfully. Here pin 7 was assigned as Echo pin, whose job was to listen for the return ping. The Trig pin was pin 13, whose job was to generate the pulse train. Once the pulse was triggered, the microcontroller stayed passive until it recovered the returning pulse train. Once the pulse train was recovered, the time interval was noted and the distance of the object from the observer was noted and stored.

5.2 Radar detection

The code was written in Arduino, and simulated in Proteus successfully. It uses frequency detection to determine the moving object's speed and location.

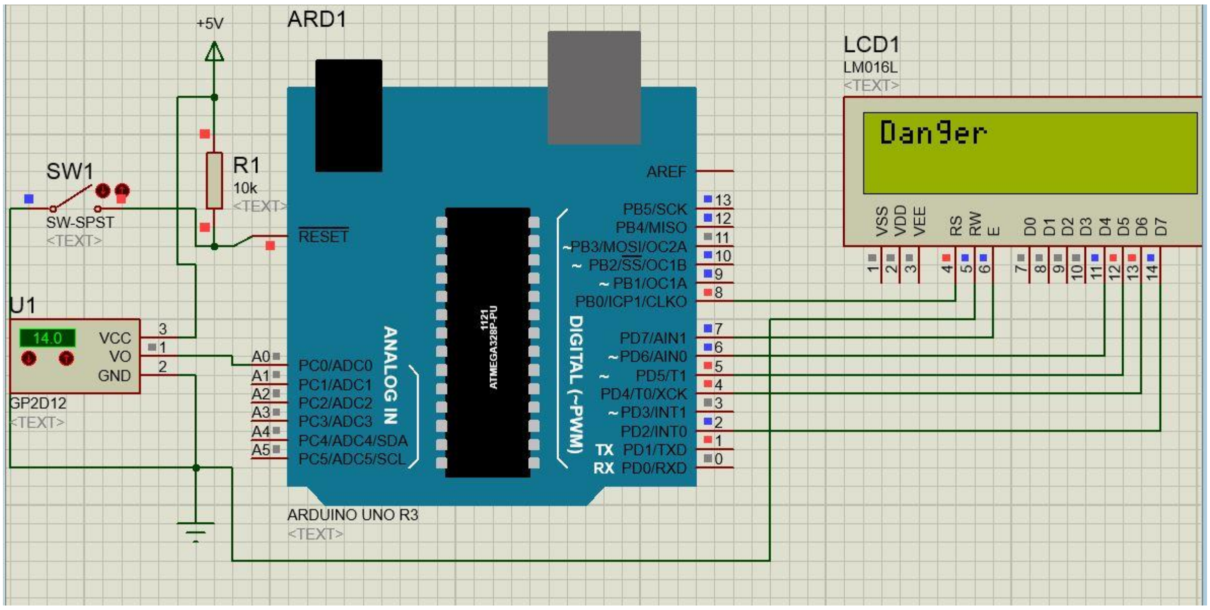

Figure 9: Radar detection

The code was found to be working successfully and issued warning the user if danger was in the vicinity.

5.3 Code integration

The modules were found to be working fine separately and hence they were now integrated into a single program for efficient functioning.

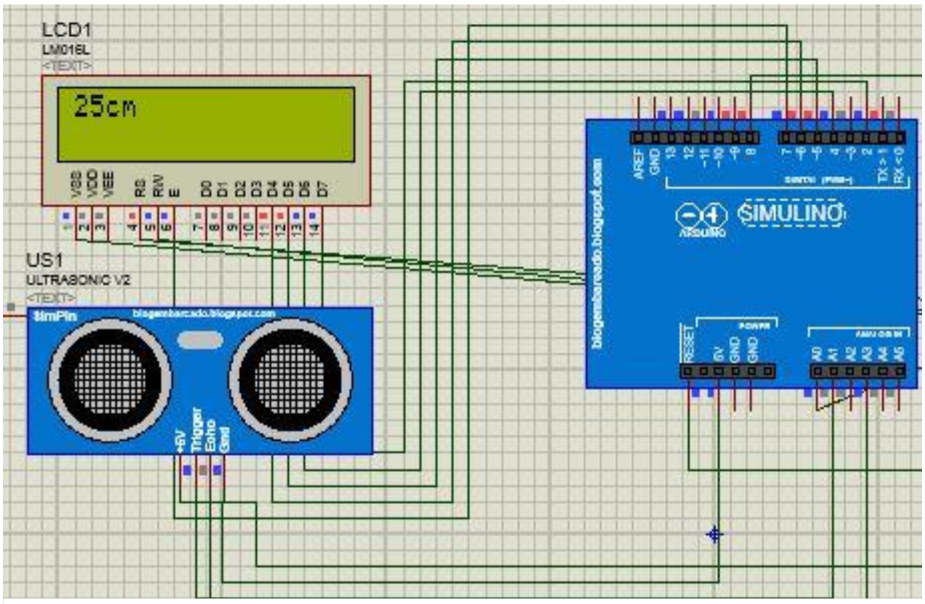

Figure 10: Ultrasonic ranging

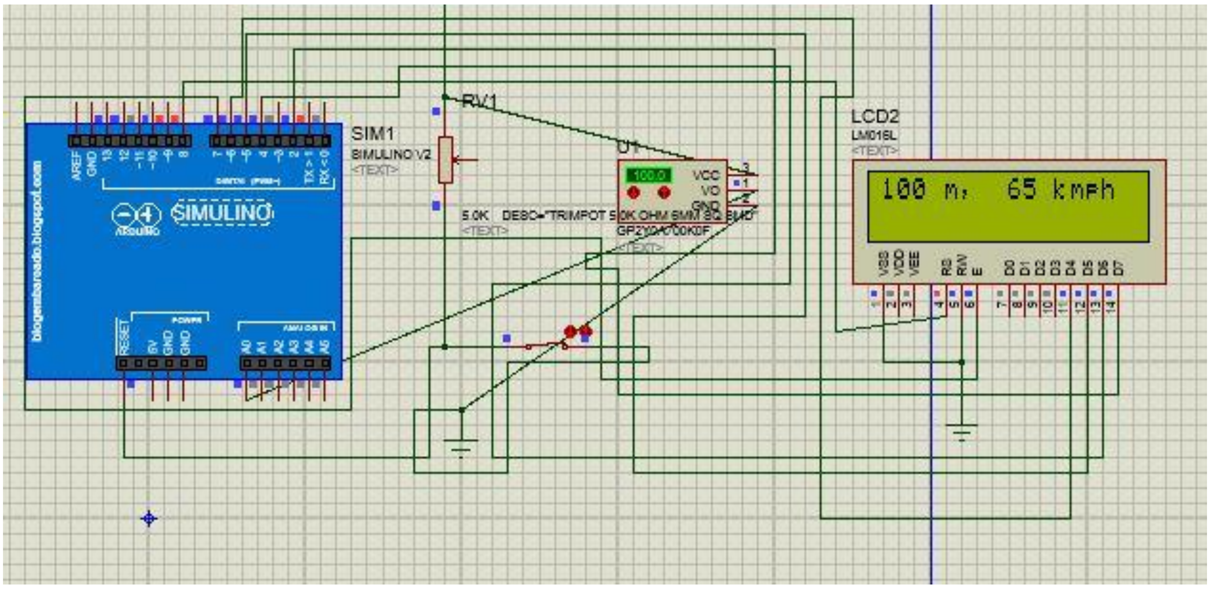

Figure 11: Radar ranging

Hence both codes were integrated into a single code, refined, optimized, made more sensitive to distance fluctuations and needs of the user.

Thus the project was completed successfully.

Chapter 6

Conclusion

The study of the device was comprised of a thorough study of an ultrasonic sensor and a radar unit. The designed device should be capable of detecting both ground and aerial obstacles, both static and dynamic. The efficient range for the device is 3 m in short range mode and 250 m in long range mode under optimum conditions. In this range, the simulations worked perfectly. The device flashed danger whenever there was anything risky in the vicinity of the user. The simulations were accurate and relevant to the ultimate goal of the project.

Hence the aim to enhance the existing Smart Cane to detect moving high speed objects was realized successfully.

Chapter 7

Future Work

Due to time and technical constraints, the project could not be properly implemented on an Arduino board with the appropriate hardware. Also, the radar gun used in the project is tougher to procure now that it has become obsolete. The next goal of this project would be to construct a working model, and find alternatives, if any, if the difficulties prove to be insurmountable. While the core idea can be validated, the project can be further enhanced by GPS and recognition software, which would tend to do away the unnecessary new processing for familiar places.

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