Abstract

The collision detection device is able to detect obstacles near the user and report how close the obstacle is using the LEDs, LCD display, speaker, and an eccentric motor. As an individual approaches a wall/locker/pedestrian, they are able to identify that there is an obstacle in his/her way and readjust their position until their path is clear. For real-time usage, the software must be modified in day mode to notify the user to maneuver out of the obstacles path while there is still sufficient distance between them. For night mode, the resistance of the pull-down resistor must be adjusted so it becomes more sensitive to light and gives the user a warning when a car is sufficiently away from them. In the future, a smartphone will be used in place of the active electromechanical components that alert the wearer and pedestrians.

Introduction

There are many distractions that people encounter throughout the day with the increase reliance on technology. There are constantly news stories about pedestrians getting into accidents because they are not paying attention to what is going on around them but rather looking at their cellphones. Therefore, the proposed project concept will be an obstacle sensor that can notify distracted users when they are walking close to an obstacle so that they do not collide with it whether it is a person, vehicle or building. The design can also be used to help the visually impaired such that they no longer need to rely on carrying canes.

Theory

Various passive and active electrical components were used for the collision detection device. The most basic passive element that was used for this project was the resistor. A schematic diagram of the resistor can be seen in Figure 1 below. The voltage-current relationship for a resistor follows Ohm’s law which is $V = IR$ where $V$ is voltage in volts, $I$ is current in amperes, and $R$ is resistance in ohms.

![Resistor Schematic](image)

**Figure 1.** Schematic symbol for a resistor

A variable resistor was used in this product as well. Variable resistors, also called potentiometers, consist of 3 leads. Two of the leads are connected to the ends of a resistive
material while the third is connected to a wiper which can be rotated to contact at different points of the resistive material. By sweeping the wiper across the resistive material, the resistance between the wiper lead and stationary lead varies. The schematic symbol for a potentiometer can be seen below in Figure 2.

![Schematic symbol for a potentiometer](image)

**Figure 2. Schematic symbol for a potentiometer**

Another passive element that was used was the push button. For this product, a normally open, single-pull, single-throw push button was used. The schematic symbol to represent a button can be seen in Figure 3 below. A button consists of a pole and a throw. The pole is the mechanical part that shorts with the throw. There are two categories of switches: normally open and normally closed buttons. As the name suggests, the normally open buttons remain open when they are not pushed and vice versa for normally closed buttons. The amount of pulls and throws are not limited to one each. There are also multiple pole multiple throw buttons. For this product a normally open, single-pole, single-throw button was used.

![Schematic symbol for a button](image)

**Figure 3. Schematic symbol for a button**

Light emitting diodes (LEDs) were also used. The LED, like all diodes, are one-directional meaning that current can only flow in one direction. This is similar to a one way valve in piping systems. The LED has an anode, which connects to the positive voltage and a cathode which connects to the negative terminal. The schematic symbol of the LED can be seen in Figure 4 below.

![Schematic symbol for a LED](image)

**Figure 4. Schematic symbol for a LED**
When connected to an output pin of a microcontroller, the LED is connected to a resistor in series. This resistor is present to limit the amount of current that the LED can draw thereby protecting them. For the Arduino Pro Mini that was used in this project, the maximum current draw was 40mA per I/O pin. However, the LED has an operating current of about 10mA. Since the LED operating current is lower than that of the I/O pin, the LED current was used to determine the approximate resistance. This was calculated to be about 360Ω, however, 470Ω resistor was picked because it was the closest available resistor above the minimum required.

\[ R = \frac{V}{I} = \frac{3.6V}{10 \times 10^{-3}} = 360\Omega \]

A photoresistor was also used. This is an element whose resistance changes based on the amount of light that is exposed to its surface. Specifically, as the amount of light increases, its resistance decreases. It should be noted that the photoresistor’s resistance-to-lumen relationship is not linear. The schematic symbol for this element can be seen below in Figure 5 below.

![Figure 5. Schematic symbol for a photoresistor](image)

A NPN transistor was used in this product as well. The transistor is simply an electronic switch. It consists of three leads: the base, emitter, and collector. For an NPN transistor, when the voltage at the base is larger than at its emitter, current will be allowed to flow from the collector to the emitter. These are useful when an actuator requires more current than the output pin of a microcontroller can provide. Therefore, a signal is sent to the base which triggers the current flow from an external power source such as a battery. The schematic symbol for the transistor can be seen below in Figure 6.

![Figure 6. Schematic symbol for a NPN transistor](image)

Lastly, an ultrasonic sensor was used as a distance sensor for the product. An ultrasonic sensor determines the distance of an object in front of it by first sending out a 40kHz pulse.
Then, it counts the amount of time between when the pulse was sent and when the echo signal reflected off the object in front of it. By knowing the speed of sound, the distance can be determined by the time it took for the sound to travel back and forth. The calculation for distance as a function of $T$, the round trip time, for the speed of sound at $72^\circ F$ can be seen below.

$$D = \frac{1}{2} VT$$

where $V = 344.8 \frac{m}{s}$ and $D$ is the distance of the object from the sensor.

The sensor can not only detect objects directly in front of it, but also objects at an angle from it. According the PING ultrasonic sensor data sheet, the sensor can detect objects within a $40^\circ$ cone in front of it. A diagram of this can be seen in Figure 7 below.

![Figure 7. Area of detection for the PING ultrasonic sensor](image)

**Mechanical Design**

The external housing of the device was modeled in SolidWorks. All associated electronics such as the ultrasonic sensor, LCD with speaker, LEDs, photoresistor, and eccentric motor were also modeled to ensure that each component is able to fit inside the housing. All circuitry was concealed from the environment.

The three LEDs (red, yellow, and green) were mounted on the upper left corner of the front cover in the prescribed order. This placement would mimic a traffic light that has been turned counterclockwise by 90 degrees. The photoresistor was mounted directly under the yellow
LED. All four elements were clustered on the upper left corner as they were configured and soldered onto the same perfboard.

The ultrasonic sensor was positioned at the upper center portion of the cover. This gave the ultrasonic sensor enough height to pick up the obstacles directly in front of the wearer and minimizes the chance that it would pick up erroneous readings from the floor.

Initially, the entire housing was to be produced using a 3D printer. The material of choice would have been acrylonitrile butadiene styrene (ABS) plastic. Due to an unexpected error, only the front cover of the device was printed. The rest of the housing was made using a small electronics component box. The box had similar dimensions as the original housing, so minimal modifications were required.

![Figure 8. Front view of the device obtained from SolidWorks](image)

**Electrical Design**

**Microcontroller**

The entirety of the project is based around use with an Arduino Pro Mini. This microcontroller has 14 I/O pins and has a maximum current of 40 mA per pin, or 150mA drawn from the entire chip. It runs off of a 5V power source, but has an internal voltage regulator to allow it to be powered by a source of up to 15V when connected through the raw input pin. A single 9V battery was used to power the entire device. This chip was chosen because of it is compact size compared to the traditional Arduino.

**User Interfaces**

In both modes of use, the user is notified using four main interfaces: the LCD screen with piezospeaker, the LED indicators, the tactile pushbutton, and an eccentric motor. The LCD
screen requires three pins for function. The first two are power from the regulated 5V (Vcc) output pin and ground. The final pin is connected to one of the I/O pins set to output to transmit the necessary signal to the LCD and speaker to perform. The maximum current draw of the LCD and piezospeaker is 25mA according to its data sheet. The LED indicators use a red, yellow and green LEDs each connected to an individual pin and placed in series with a 470Ω resistors to limit the maximum current draw to less than 10mA each.

The pushbutton is used to allow for switching between the two modes of use of the device. The pushbutton is normally open (NO), meaning that the circuit is disconnected. The button is connected in a pull down resistor as shown in Figure 9. Schematic diagram for a NO active high button connection with pull down resistor, below. There is a resistor connected to an input pin such that when the button is pressed, the pin won’t short with Vcc potentially damaging the pin. When the button is open the pin signal is pulled low to ground through a 10kΩ resistor.

![Figure 9. Schematic diagram for a NO active high button connection with pull down resistor](image)

The eccentric motor is used to create a vibration in the device to signal obstacles to a user without the ability to see the LEDs or LCD panel. The total current draw from the components mentioned above, as well as the sensors for the two modes described below, the Arduino is close to 100mA. This is close to the maximum rating for the entire Arduino board, therefore, the motor will be powered on a separate, parallel circuit, to remove any possibility of damaging the board. This is done using a NPN 2N3904 Transistor. The collector and emitter pins are connected to the raw 9 V battery power and ground respectively, and will supply current when a signal is sent through the Arduino pin connected to the base of the transistor.

*Day Mode*
In day mode, the product is collecting data to determine if the user is coming close to any obstacles. This is done using the Ping ultrasonic sensor, which is programmed to provide serial data about the distance between the sensor and any approaching objects. This sensor, has three pins, one connected to the regulated 5V \( (V_{cc}) \) pin, one ground, and one signal pin which is connected to an I/O pin on the Arduino.

**Night Mode**

In night mode, a photoresistor is used in a pull down resistor circuit to signify a car approaching the user by sensing light intensity from the headlights. The circuit is similar to the pushbutton schematic shown in Figure 10, however, the pushbutton is replaced with a photoresistor, and the connection to ground contains both a resistor and a potentiometer, so the light sensitivity can be calibrated. When there is no light, the photoresistors resistance will be higher than the combination of the resistor and potentiometer in the connection to ground and so the I/O pin will be pulled low. If there is a light that is bright enough to cause the resistance of the photoresistor to be lower than that connected to ground, current to flow from \( V_{cc} \) changing the state of the pin to high.

![Figure 10. Schematic diagram for a photoresistor connection with pull down resistor](image)
Software Design

The software design began by determining all of the inputs and outputs that would be monitored and controlled by the microcontroller. There were a total of 5 outputs and 2 inputs to be controlled. These pins were then defined and assigned.

Other constants were assigned such as the threshold distances for the product to alert the used. The low and high threshold values were defined as 2’ and 6’. Other variables were also defined as well. One of the significant variables that were defined was those for the button debounce. A button debounce was placed in the code so that the user could toggle between night and day mode safely without having to worry about the button fluctuations. This ensured that when the button was pressed, it wouldn’t register more than once in a short period of time.

Conditional statements were used to switch back and forth between the day and night modes of the product. Within each of the day and night modes, more conditional statements were
used to switch between the modes for each scenario. In day mode, these statements were used to
determine the distance of the object in front of the user and to control the LEDs and motor in the
appropriate way. For the yellow mode, when the object is between 2’ and 6’ of the user, code
was written so that the motor would pulse at an increasing frequency as the distance decreased.
To control these pulses, a command to determine time difference was used instead of the delay
command. Using the delay command would have decreased the sampling rate of the ultrasonic
sensor which was not desired.

For the night mode, conditional statements were used to switch between two modes. The
first indicated that there were no cars in front of the user which provided no user feedback and is
defined as a low pin input. The second indicated a car approaching and was notified to the user
by the vibrating motor and all 3 LEDs. In the night mode, the product vibration was constant
rather than pulsed. This is because if a car was approaching, the user needs to move out of the
way as soon as possible.

Finally, at the end of the code, there were user defined functions to convert the round trip
travel time of the ultrasonic pulses to distances based on the theory above. In the case of this
product, a function was defined to convert the time to distance in the units of inches. The
Arduino code that was written for this product is attached.
### Bill of Materials and Cost Estimate

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**Figure 12.** Prototype bill of materials

The LCD screen and ultrasonic sensor contribute over 50% of the total cost of the prototype. The price for them may be slightly reduced when purchased in bulk. The cost of the remaining electronics can potentially be reduced again as bulk orders will be cheaper. The
jumper cables and perfboard can be replaced with a manufacture board with surface mount components to further reduce the size.

Testing

Day Mode

Test subjects were first blindfolded to ensure that they do not know where they are going. The collision detection device was held at the individual’s chest to mimic how the device would be mounted. Starting from a predetermined location, the individual moved into the hallway. The green LED lit and the LCD displayed the message “All Clear” which indicated that there were no obstacles within six feet from the individual. As they moved around the area and toward potential obstacles such as lockers, walls, and pedestrians, the eccentric motor mounted within the device activated and alerted them of potential obstacles and approximately how close they were from them. The yellow LED flashed at different frequencies based on proximity and the message “Object Coming” indicated that an obstacle was in the way. As soon as they were approximately two feet from the wall or locker, the red LED lit. The eccentric motor spun continuously until they moved away from the obstacle. A “Get Out” message displayed on the LCD and the speakers sounded to warn nearby pedestrians to change their paths. They navigated approximately 100 feet from the starting location using only the device as guidance. As obstacles were detected, they would stop and readjust their position until the device no longer indicated an obstacle.
**Figure 13.** Day mode with green LED lit and “All Clear” message

**Figure 14.** Day mode with yellow LED lit and “Object Coming” message
**Night Mode**

To activate night mode, the pushbutton on the circuit was toggled. An indicator on the LCD displayed the message “Night Mode” to show that it is engaged. A “No Cars” message was indicated that there were no vehicles in front of the device with their headlights on. Another individual holding an LED mimicked a car’s headlight and pointed it at the device from a far distance. The light moved towards the device until the light intensity has reached the design threshold of the device. The device starts beeping and the eccentric motor activated. A “Get Out” message displayed on the LCD screen, warning the wearer to step out of the path of the car. All three LEDs lit as a measure to warn the driver.
**Figure 16.** Night mode displaying the “No Cars” message before the light intensity threshold is reached

**Figure 17.** Night mode displaying the “Get Out” message when light intensity threshold is reached
Advantages and Disadvantages

For the visually impaired, the current design allows for the user to avoid stationary and moving objects directly in front of the person near waist level. The vibration from the eccentric motor pulses at different frequencies to allow the visually impaired person to determine how far away the object is in front of them. The sampling rate of the ultrasonic sensor is currently set to 10Hz which is responsive enough to detect when objects get in the way. The night mode allows early detection of any cars that are coming directly in front of the user allowing and signals the user that a car is coming until the car passes.

For people who are not as aware while they are texting while writing, the day mode provides the same features those of which can be transmitted to the eccentric motor in the phone that they are texting on as well as using push notifications on the screen itself. In the case of the current prototype, an LCD screen was used as an analog for a phone screen that could potential be used.

One of the disadvantages of the current design would be its ability to detect objects at different elevations. This is important for obstacles such as the sidewalk curve or if a stranger
wants to play a practical joke on the user by placing their hand in front of the ultrasonic sensor simulating an object right in front of the user which is dangers and not humane. The ability to detect the elevation of the floor you or walking on or the height of the object that is approaching would solve this issue.

Another, disadvantage of the current design is the ability to detect the distance at which the car is during night mode. A photoresistor was used to detect the car light which is not accurate enough for distance measuring. Even though a potentiometer was used to adjust the sensitivity of the photoresistor, a more accurate photosensitive element would be used if the distance was to be used.

Currently, only one photoresistor is used in the design and is directed forward to detect oncoming cars, however, ideally photosensitive elements would be placed on the sides of the product as well to detect cares that might pass in front of the user. In fact, detecting cars that pass in front of you is more important than those that are coming head on since this situation is more common such as when one crosses the street.

**Conclusion**

The collision detection device was performed successfully according to design specifications for day and night usage. In day mode, the distance between the wearer and the obstacle where the yellow and red LED modes are engaged can be adjusted by code. The distances used in the tests were six and two feet for the yellow and red LED, respectively. When used in a real-life scenario, the distances where both warnings are activated should be greatly increased to give the wearer enough time to maneuver out of the obstacle’s path and vice versa. Factors such as reaction time and available space are highly unpredictable and vary between individuals and environments.

In night mode, the light intensity threshold can be adjusted by using by using different resistors depending on the level of sensitivity the device is trying to achieve. The device was able to respond to a bright LED flashlight that was five to six feet away. In a real-life scenario, a car would be moving much faster when compared to our test scenario. The photoresistor would need to be able to respond to a car at least 100 to 150 feet away and warn the user before it is too late.

In the future, most of the electromechanical parts used in the collision detection device will be provided through a smartphone. Modern smartphones have all of the required components for vibration, message display, etc. The smartphone is essentially the complete
package with a smaller footprint. Additional components such as the gyroscope and accelerometer that was not used in the device can be incorporated as part of the device through programming. The ultrasonic sensor and photoresistor will not be bundled with the smartphone. It will be an independent device that is used solely to monitor the wearer’s surroundings. As a result, communication between the smartphone and the sensors will be mediated through Bluetooth. Most smartphones, if not all, have Bluetooth functionality.

It is also anticipated that the collision detection device with be integrated with the smartphone GPS with audio guidance. This allows the wearer to determine their current location using GPS data and help them navigate the area. Data libraries of local stores, restaurants, and attractions would be available to the wearer and the smartphone can guide them to their destination. If there are locations that have not been explored, the wearer can explore it themselves and add their GPS data to the database.

References
