Senior Design Proposal

Trailer Towing Assistance System

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Introduction

In this project we will seek to design and construct a trailer monitoring system to provide the operator with useful safety related information about the trailer and its surroundings.

Problem Description

The purpose of this system is to mitigate a number of safety risks associated with towing a trailer as well as to provide some convenient features for the operator. First, when a vehicle is towing a trailer its blind spots are significantly increased. As a result, normal driving maneuvers, such as changing lanes, become much more difficult and risky. Secondly, any situation that requires the operator to back up can prove hazardous because the operator has a large blind spot directly behind the trailer. If these blind spots could be eliminated or reduced, the safety risks associated with towing a trailer would also be reduced.

Other safety concerns when towing a trailer include the status of the trailer door as well as the temperature inside and outside of the trailer. The system will monitor the trailer door and alert the operator if the door is open at any time. This will deter the operator from accidentally driving away with an open trailer. Also, the system will display the temperature both inside the trailer and outside so that the operator can avoid overheating the contents of the trailer and adjust his driving for icy road conditions.

Finally, the trailer towing assistance system is intended to make towing a trailer easier. Currently, the operator must connect cables from the truck to the trailer to run the trailer's brake lights and turn signals. This system will send this information wirelessly from the truck to the trailer, thereby eliminating the need to physically connect wires to the trailer. Hitch the trailer to the truck and go!

Proposed Solution

To help reduce the risk associated with these blind spots we propose a system comprised of several sensors to provide the operator with information about potential hazards in those blind zones. The main function of our system would be a blind spot warning system that would monitor the blind spots of the vehicle towing a trailer and inform the operator when another vehicle moves into one of the blind spots. This system could be implemented in several ways, some of the possibilities are: Cameras mounted on the trailer linked to a display in the vehicle, a laser ranging system mounted on the trailer, or an ultrasonic ranging system mounted on the trailer. As an auxiliary function our system would use its blind spot detection system to assist the operator while the trailer is being backed up. This would help prevent accidents involving objects in the blind spot directly behind the trailer.

Demonstrated Features

Primary Features

- Blind Spot Detection
- Backup Ranging
- Wireless Brake Lights and Turn Signals
- Wireless Display Console for Operator

Auxiliary Features

- Indoor & Outdoor Temperature Sensors
- Door Position Sensor (Open/Closed)

Available Technologies

Blind Spot Detection

To solve the presented issue, we need a device that will help us determine if a vehicle resides in any of the two closest neighboring lanes. Our solution must be reliable and accurate, such that the driver can switch lanes with confidence. It must also be able to function at anytime of the day, meaning that light conditions should not affect its operation. Taking these factors into account, the best way to solve the problem would be to use a proximity sensor. The device should be able to read the distance to the nearest object, and return the value. Based on these readings, the apparatus should then determine if there is a car on the nearest lane. Finally, it should tell the user which lanes are occupied.

Other requirements include low power consumption and low cost. The device must be active as long as the vehicle is on, so we must use low power technologies. To minimize cost, we should avoid distance sensors that return very accurate readings, since these are usually very expensive. The user is not interested in knowing the exact position of an adjacent vehicle to ten significant digits. Also, we do not need a sensor that with long range capabilities. For our purposes, a range of 3 meters would be sufficient.

There are many classes of proximity sensors, each with distinct advantages and disadvantages:

Light sensors: Determine the distance based on changes in light intensity. As an object approaches the sensor, the intensity of light at the receiver is diminished, and the device concludes that the distance to the object has been reduced. This technology is not very reliable because it assumes that the luminosity of the place stays the same. Since our blind spot detector should be able to function during the nighttime, we cannot utilize this type of sensor.

Capacitive sensors: Determine the distance based on changes in capacitance. These do not require light, so they present an advantage over light sensors for our purposes. However, they are highly dependent on the dielectric constant of the material. Also, capacitive sensors are not very directional, so they would not be suitable for our project.

Laser sensors: Use laser technology to get very accurate distance readings. However, they are extremely expensive. For instance, the Hokuyo URG-04LX Laser Sensor is listed as $2695.00.[1] Since it is advertised as a "reasonably sized, reasonably priced, high performance laser," we can conclude that lasers are exorbitant for our low budget.

Acoustic sensors: Devices that utilize this technology send out an ultrasonic signal. When the signal reaches the object, it echoes back to the receiver. Distance is determined by measuring the total time taken for the acoustic signal to return. Since the time is proportional to the distance, the distance to the object can be easily found using this technology. This type of sensor requires a device with a digital clock (e.g. microcontroller) to keep track of time intervals.

Concerning specific acoustic sensors, the Parallax Ping Ultrasonic Range Finder[2] seems to be suitable for our needs:

It only costs $29.95[3] and it has a maximum range of 3 meters, which is sufficient for our needs. The device has a total of three pins: 5 V, Ground, and Signal. The signal pin is I/O, and it is used to communicate with the microcontroller. According to its specifications, the microcontroller triggers the Parallax device by using a pulse, which in turn sensor sends an ultrasonic signal and waits until it is echoed back. After this occurs, the Parallax device notifies the microcontroller. In this fashion, the microcontroller can then compute the distance of the nearest object.

Although the Parallax sensor seems like a good option, we could also build our own device. We could purchase an ultrasonic transducer ($9.99)[4] along with a 40 kHz crystal ($1.95)[5], and then use these parts to design our own sensor. Although the complexity of our project would significantly increase, the learning experience would be unique.

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[1] http://www.acroname.com/robotics/parts/R283-HOKUYO-LASER1.html
[2] http://www.hobbyengineering.com/H2951.html
[3] http://www.hobbyengineering.com/H2951.html
[4] http://www.hobbyengineering.com/H1324.html
[5] http://www.hobbyengineering.com/H1629.html

Backup Ranging

There are several available technologies available to sense distance to an object. Ultrasonic, IR, and laser are the primary candidates that can be considered. Each has advantages and disadvantages based on a number of criteria.

*Lasers: L*aser proximity sensors are a very good way to accurately measure a distance. Many lasers are able to measure down to the thousandth of an inch with no problem. For this project this kind of accuracy is not needed. Another down side to lasers is the power consumption and packaging size, neither is good for a trailer backup sensor. The final criterion for the sensor is price. Lasers are substantially more costly than their IR and ultrasonic counter parts making them a poor value.

Ultrasonics: Ultrasonic sensors use very high frequency pressure waves and their reflections to detect distance. The ultrasonic sensors have a very good range and enough accuracy for the application. The pricing is much below lasers as well as being packaged in a reasonable size. The interface signal to the microcontroller is based on pulse width. This means that a certain amount of processing power would be needed to decipher the pulse width.

IR: IR technology is the least expensive solution for the application, being about half the cost of ultrasonic. The effective range of IR is much shorter than the other solutions, but has the range required for the application. The accuracy of IR devices is not as good as laser, but meets the requirements for this particular application. The interface to the microcontroller is a simple analog signal that is proportional to the distance to a given object. This would require an A/D converter , but little processing time in the main program.
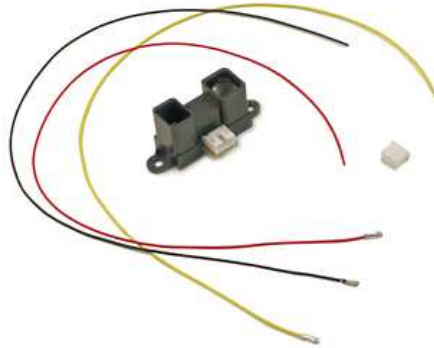
      The best solution for a backup trailer sensor is IR. With enough range for our application, IR is a cheap simple solution for what we would like to accomplish. This also opens up the possibility of adding multiple sensors for the same cost as a single ultrasonic or laser device.

Wireless Communications (Brake Lights, Turn Signals, and Display Console)

      One of the main conveniences this product offers is wireless monitoring of the trailer from the cab; the operator will not have to connect any cables to the trailer. With this wireless capability, the system modules would only need to be connected to a power source in order to communicate the status of the system to the driver. In order to provide this functionality, we need a wireless communication capability that can synchronize and transfer data between several different devices. There are many wireless RF media available to meet this specification, but the types we are considering are those classified as personal-area-network (PAN) wireless media. This is because we need a relatively short range (distance from front of trailer to cab of vehicle) in order to avoid extra RF pollution of the surrounding spectrum, and to save power, as the system may likely be running on some sort of battery. There are several different PAN standards, and each has its relative advantages and disadvantages.

      One technology that is quickly becoming very widespread and commonplace is Bluetooth. Bluetooth can communicate over a very wide range, depending on what class of transmission power is used. Class 1 is common in most Bluetooth devices, such as wireless peripherals for computers or headsets for cell phones. This transmits at 1mW with a range of less than 10 m. Class 2 transmits at 10mW, and has a slightly extended range, reliable at 10m. Class 3 is uncommon, with a power of 100mW and a range of up to 100m. Bluetooth operates in the 2.402 – 2.480 GHz range, which is in one of the FCC ISM bands. These devices can communicate with up to 8 other Bluetooth devices within its transmission radius at once, which could potentially be very useful for synchronizing multiple modules

of our system. Also, Bluetooth communicates by using thousands of different frequencies in its transmission every second in order to reduce the probability of interference with other devices operating in the same bands. Finally, Bluetooth can establish communication within its transmission radius regardless of physical obstructions, due to the low transmission power, which may be useful to facilitate communications that will have to travel through the surfaces of a trailer and towing vehicle.

Another wireless technology that is similar to Bluetooth is Wibree. It has the same transmission range as class 2 Bluetooth (10m), and is designed to be very compatible with Bluetooth applications. However, it was developed for use in extremely low power applications, particularly for use with extremely small cell batteries. It was also designed to be a lower-price alternative to Bluetooth. Low power consumption and low price are very favorable for our application; however, Wibree is still experimental and is not available for general use, which makes it a non-viable option for our project.

A second possibility for our system is ZigBee. It is designed for low data transfer rate applications, which theoretically give devices an extended battery life. ZigBee can operate in either the 2.4GHz or 915MHz ISM band. An advantage that this may hold for us over Bluetooth is that ostensibly it is both a cheaper and simpler alternative, especially because it requires less software to operate than Bluetooth. One of the foci of the development of ZigBee is for use in mesh networks for embedded sensor networks and building automation. It is designed to consume little power, sometimes with devices running over a year on one battery. This may provide another advantage of ZigBee over Bluetooth for our purposes.

Finally, the Ultra-wideband (UWB) standard provides interesting considerations because it uses a very wide transmission spectrum that theoretically can share bandwidth with other narrowband devices without producing interference. It runs in a 3.1-10.6GHz band that the FCC authorizes for unlicensed use. UWB enables short-distance high data rate connectivity that would likely work well within the ranges we need, but could possibly provide some data rate overhead that is not necessary for our uses. Another feature of UWB is that the wide transmission spectrum leads to short transmission pulses, which prevents overlapping of the original pulse by possible reflections, which can destructively interfere with and fade the signal. However, due to our short range needs, this likely would not be applicable enough for us to use the technology over either Bluetooth or ZigBee.

Cost is a crucial factor in determining which wireless standard to use.   A typical Bluetooth transceiver that could be used in our project is about $10-30 on Digikey. Zigbee transceivers were in the range of $2.50 - $25 depending on features and packaging. We were unable to find parts for the Wibree standard; it seems to be an emerging standard that it not yet fully deployed.

Therefore, due to the constraints of cost, power consumption, and range we are leaning towards using the Zigbee standard.

Temperature Sensing

We would like to provide the driver with the temperature inside the trailer as well as outside. The most cost-efficient way to measure temperature is to use a thermistor; a resistor who's resistance is temperature dependant. The temperature measurement does not need to be extremely accurate; we can accept the relatively large errors associated with thermistors in exchange for their low cost. We could either design a circuit, using the thermistor and an A/D converter on the microcontroller to measure the temperature or we could purchase an IC to perform this function. On digikey, thermistors were typically much less than $1 and IC's cost approximately $3.

Door Position Sensing

One of the safety features of our device will be the ability to detect if the trailer's door is open or closed. There are a number of sensors that could provide this information; they are most easily broken down into two categories: 1) Contact sensors and 2) Non-contact sensors. As the name implies, contact sensors have a physical connection that is either broken or connected. Non-contact sensors, such as lasers, infrared, or magnetic devices do not have any physical contacts. Non-contact sensors are typically more expensive but they do not have moving parts that could wear out over time. We are leaning towards using a non-contact sensor as they will last longer, and would be easier to retrofit into an existing trailer. Again, we have the choice of designing our own sensor or purchasing an IC to perform this task. Amazon lists a similar device intended to alarm windows for approximately $5.

Engineering Content

The trailer towing assistance system is essentially a small network of sensors that will provide data to the operator. The engineering content can be broken down into three sections: 1) Sensors, 2) Interfacing with sensors, and 3) Displaying information.

Each function of the system requires the use of a different type of sensor. A great deal of complexity can be added to this project by deciding to design each sensor from the ground up. Conversely, a great deal of complexity can be removed by purchasing pre-fabricated sensors. In our system we propose to purchase some sensors and design others:

Components to design:

- Blind Spot Detection
- Indoor & Outdoor Temperature Sensors
- Wireless Brake Lights and Turn Signals (purchase 'wireless' component)
- Wireless Display Console for Operator (purchase 'wireless' component)

Components to purchase:

- Backup Ranging
- Door Position Sensor (Open/Closed)

The second area of engineering content will be designing a board to interface with all of the sensors. It will need to poll each sensor, record the data and send this information to the wireless display. Also, this board will need to receive signals from the truck and control the brake lights and turn signals. This board will be the "brains" of the system. It will be located on the trailer and will run off a battery.

The third source of engineering content will be designing the wireless display unit. This piece of the system must communicate with the "brains" on the trailer. All of the data, including blind spot status, backup range, blinkers, brake lights, temperature, and door position must be relayed to this unit. This part of the system will provide the operator with the information the system is meant to gather.

Conclusion

After more closely examining the trailer towing assistance system, and breaking it down into functional blocks, we now have a good understanding of how to approach this project. Each feature the system will perform was examined and the relevant technologies that could be used to solve each problem were listed. Specific technologies for each functional block will be decided upon in a later assignment. We are very excited to begin working on this project and look forward to picking out specific parts for the system.