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HITCHING A TRAILER USING ULTRASOUND: INNOVATIVE AND PRACTICAL?

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HITCHING A TRAILER USING ULTRASOUND: INNOVATIVE AND PRACTICAL?

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Abstract

Sensors are essential in countless systems worldwide, extending the capabilities of human senses in ways that were once unimaginable. Imagine amplifying our perception a thousandfold — this is achieved with technologies like motion amplification, X-ray imaging, or the sonar used by submarines. At the core of many of these technologies is a simple concept: a signal is emitted, reflected, and received, with the distance calculated based on the signal's travel time. While these systems can be highly accurate, their costs often make them impractical for some applications. Ultrasonic sensors offer a compelling alternative, balancing affordability with functionality. Widely used for automotive blind-spot detection, motion tracking, and other short-range applications, ultrasonic sensors can also assist with precision tasks like trailer hitching. This report explores the use of ultrasonic technology to align a truck with a trailer, eliminating the need for multiple attempts or an assistant. A prototype was developed using an Arduino-based system that provides real-time feedback through visual and auditory cues to guide the driver. While limitations in range and environmental interference were noted, the system proved to be a cost-effective solution for improving the hitching process. Further refinements, such as integrating multiple sensors or infrared technology, could enhance its performance and resilience.

Keywords: Ultrasonic Sensors, Trailer Hitching, Sensor Calibration, Proximity Detection, Autonomous Parking, Arduino

Nomenclature

LiDAR – Light Detection and Ranging
TOF – Time of Flight
IR – Infrared
Ultrasonic – High-Frequency Sound Waves

INTRODUCTION

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Sensors perform many vital functions in various systems around the world, lending powerful capabilities to our creations. With the use of sensors, we extend our abilities beyond what was once imaginable. Imagine amplifying our senses a thousandfold—this is precisely what we do today with technologies such as motion amplification, X-ray scans, and even the sonar used by submarines. At the heart of many of these technologies lies a fundamental concept: a signal is emitted, reflected, and returned to a receiver. The distance is calculated based on the time it takes for the signal to travel, whether the signal is light, sound, or X-ray. The simple formula of speed multiplied by time, divided by two to account for the return journey, allows us to determine the one-way distance.

These technologies can be extremely accurate, but they often come with a significant price tag. The balance between functionality and cost is always a crucial consideration in design, leading engineers to seek trade-offs or combinations of sensors that can achieve the desired effect while reducing overall expenses. Ultrasonic sensors provide an excellent solution in this regard, offering high functionality at a fraction of the cost of other technologies. Used across various industries, ultrasonic sensors shine in applications such as automotive blind-spot detection, motion tracking, and other short-range, object-detection tasks. They can also be highly effective in precision applications like trailer hitching.

In this report, we will explore the application of ultrasonic sensing technology to assist in parking a truck with the goal of aligning it accurately with a trailer. By using an ultrasonic sensor, the system will guide the driver to park the truck properly, enabling them to hook up to the trailer on the first attempt without the need for human assistance or a backup camera. This solution eliminates the time-consuming process of getting in and out of the vehicle multiple times—an effort many drivers undertake to correctly align with the trailer.

MATERIALS AND METHODS

MATERIALS

The following materials and components were used to design and develop the proximity detection and alignment system for trailer hitching:

Arduino Uno R3 Kit

The Arduino Uno R3 kit was used to prototype circuits for the ultrasonic sensor, servo motor, an active buzzer, a passive buzzer, and a simple on button. All of these components were included inside the kit.

Ultrasonic Sensor

The ultrasonic sensor was used to measure the distance between the truck and the trailer. It emitted sound waves, which were reflected back to the sensor, allowing it to calculate the distance to the trailer.

Servo Motor

A servo motor was used to control the movement of the ultrasonic sensor, ensuring that it could be positioned correctly for accurate distance measurements.

Active and Passive Buzzers

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The active buzzer provided an audible tone when the truck came within 3 feet of the trailer's receiver. The passive buzzer played "Santa Claus is Comin' to Town" once the truck and trailer were properly aligned.

On Button

A simple on button was included in the kit to activate the system.

3D-Printed Mounting Bracket

A custom mounting bracket was designed and 3D-printed at the Kao Innovation & Collaboration Studio to secure the ultrasonic sensor to the servo motor.

Laptop and Processing4 Software

A laptop in the vehicle was used to run Processing4 software, which displayed the radar interface to visualize the truck's proximity to the trailer during the parking process.

METHODS

The following methods describe the assembly and operation of the proximity detection and alignment system:

Prototype Assembly

The components from the Arduino Uno R3 kit were assembled to create the prototype. The ultrasonic sensor was mounted on top of the truck's hitch using the 3D-printed bracket. The servo motor was used to control the sensor's position for accurate distance detection.

Sensor Placement

The ultrasonic sensor was positioned at a height that allowed it to overlook the ball of the hitch. This ensured that the sensor's sound waves would not be obstructed by other parts of the truck. The trailer was raised so that the receiver was positioned above the hitch ball, ensuring it would be detected by the sensor.

Software Programming

The Arduino IDE was used to program the Arduino Uno to control the ultrasonic sensor, servo motor, and buzzers. The code was designed to trigger the active buzzer when the truck came within 3 feet of the trailer and to adjust the servo motor based on sensor readings.

Radar Display Setup

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The Processing4 software was used to create a radar display on the laptop. The radar displayed a line that shortened as the truck approached the trailer. When the ultrasonic sensor detected an object, the line turned red, indicating proximity.

Proximity Alert Visual Indication

As the truck backed up, the ultrasonic sensor provided distance data that triggered the active buzzer when the truck came within 3 feet of the trailer's receiver. A solid circle representing the truck's hitch was also displayed on the radar, sized at 2 inches.

Alignment and Audio Feedback

Once the truck's hitch was aligned with the trailer's receiver, the passive buzzer played "Santa Claus is Comin' to Town," signaling to the driver that it was safe to exit the vehicle and connect the trailer to the hitch.

The Arduino Uno R3 kit was used to prototype circuits for the ultrasonic sensor, servo motor, an active buzzer, a passive buzzer, and a simple on button, which were all included inside the kit. A mounting bracket was 3D-printed at the Kao Innovation & Collaboration Studio for the purpose of securing the ultrasonic sensor to the servo motor. The Arduino IDE programming application was used to write the code for the physical functions of these components, and the Processing4 software was utilized to provide the radar display to a laptop in the cabin of the vehicle. The prototype was mounted atop the hitch attached to the truck and set at a height that would overlook the ball of the hitch, ensuring the ultrasonic sound waves emitted by the sensor wouldn't be blocked by other parts of the truck. Ideally, the trailer was raised to a height where the receiver was positioned vertically above the hitch ball to prevent collision and ensure it was within the sensor's horizontal plane for detection. With the system powered on and the driver backing up to the trailer at a controlled speed, the radar displayed the visual indicator of a line that turned red when the sensor detected and locked onto an object. As the driver continued to back, they could hear the audible tone from the active buzzer on the Arduino prototype, indicating they were within 3 feet of the trailer's receiver. A solid circle representing the truck's hitch, sized at 2 inches, was also displayed at the end of the line in the radar display. As the line shortened in response to the truck's proximity to the trailer, the driver could visually see the measurements and angle within the radar display. Once the hitch and receiver were aligned, the passive buzzer played "Santa Claus is Comin' to Town," signaling the driver that they could confidently step out of the vehicle and connect the trailer to the truck.

RESULTS AND DISCUSSION

Figures

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Figure 4: Prototype Setup with Components Mounted on the Hitch

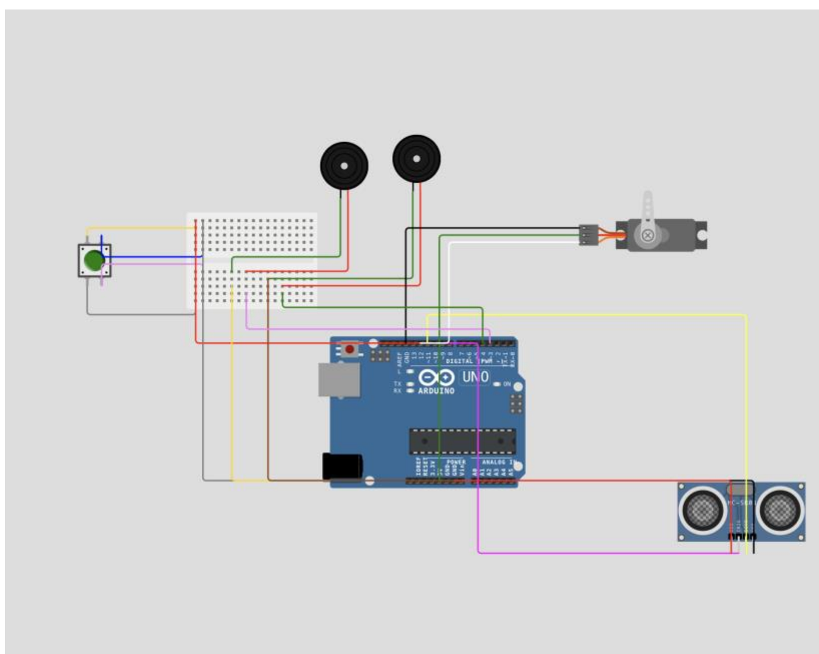

Figure 5: Circuit Diagram of the Prototype

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Figure 6: 3D-Printed Mounting Bracket for Ultrasonic Sensor

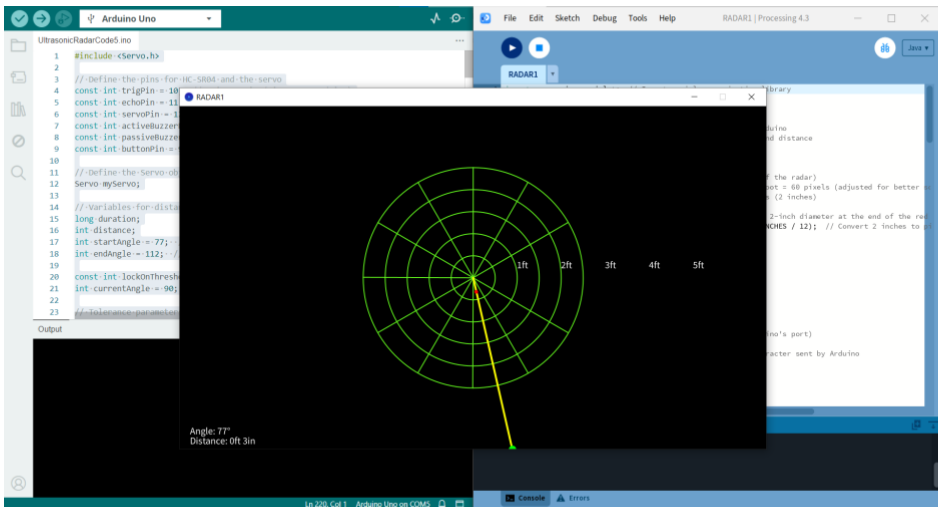

Figure 7: Overview of Radar Display in Processing4 Software

Equations

$Dist. = \frac{speed \cdot time}{2}$ for active sensors. For passive, you will only detect the presence or absence and not the distance.

CONCLUSION

There is a time and place for ultrasonic sensors and my observations when testing the prototype for hitching the trailer lent a comprehensive of its weaknesses. With this single sensor only capturing the horizontal plane errors could occur if for example the object you are expecting to see on the radar is too low or too high and dirt and debris was an immediate problem in the clogging of the protective screens in front the sensors, which blocked any readings more than 0. In my experience, this system's functionality and practicality would be further increased with the addition of more ultrasonic sensors and in combination with other forms of detection such as IR. Nonetheless, this is an innovative solution for someone lacking those resources and it resulted in more success than having no indicator at all.

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