Sensor Integration for Low Cost Truck Collision Avoidance

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Abstract

An average of 42,000 vehicle related fatalities occur per year in the United States. 4,500 of these fatalities involve a heavy truck. Current crash avoidance systems for commercial trucking have the potential to reduce these fatalities, but are usually too much of a financial burden due to the high cost of sensor technologies. This project focuses on developing a low-cost crash avoidance system for large trucks by integrating several different low-cost sensors. Three sensors have been selected for testing and development for this system: ultrasonic sensor, short range radar, and magneto-resistive sensor. These sensors have shortcomings that don't allow them to work in a standalone system, however, an integration algorithm is presented that uses the strengths of each sensor type to overcome the limitations of the others. These sensors have been selected to monitor the rear and lateral blind spots of a Class 8 truck. In addition, the information from different sensors can be utilized to determine object type, track targets, and assign target threat levels.

Objectives

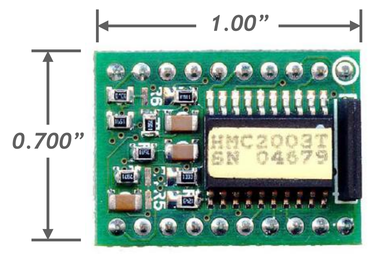
- Identify low-cost alternative sensors and model their behavior
- Develop an algorithm that combines sensor strengths and limits sensor shortcomings
- Greatly minimize the possibilities of false positives and report few false negatives
- Ensure the system responds in real-time
- Monitor the rear and lateral blind spot regions of a Class 8 truck
- Identify objects that are potential threats
- Build and test a full scale prototype

Sensors

A thorough literature review was completed to identify the state-of-the-art sensors and their applications in today's crash avoidance systems. Instead of focusing on a single sensor type, the literature search was aimed at reviewing all sensor types being studied for crash avoidance and similar applications. The following sensors were selected as low cost alternative sensors for this project.

Magneto-resistive Sensor

- Honeywell HMC2003 three-axis magnetic sensor
- Three permalloy magneto-resistive sensing elements
- Magnetic field range: ±2 Gauss
- Resolution 40 µGauss
- Unaffected by adverse weather



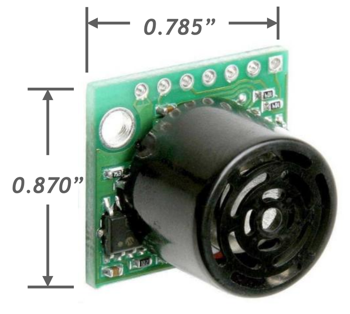
Honeywell HMC2003 Magnetic Sensor

Ultrasonic Sensor

- MaxBotix LV-MaxSonar®-EZ series ultrasonic sensors
- Generates 42 kHz sound waves
- Sample time: 50 ms
- Range: 20 ft

Radar

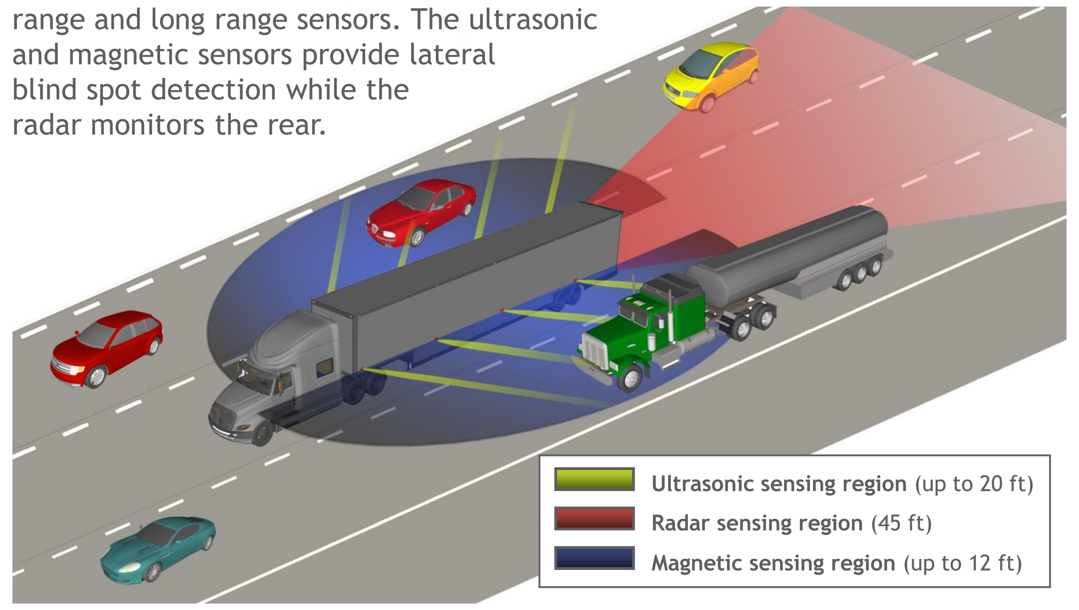
- 24 GHz radar
- CAN bus communication
- Range: 15m and 30m



MaxBotix LV-MaxSonar®-EZ Ultrasonic Sensor

Sensor Coverage Area

The focus of this sensing system is to prevent rear impact and sideswipe crashes. A system that provides coverage for these crash modes requires to use of both short range and long range sensors. The ultrasonic and magnetic sensors provide lateral blind spot detection while the radar monitors the rear.



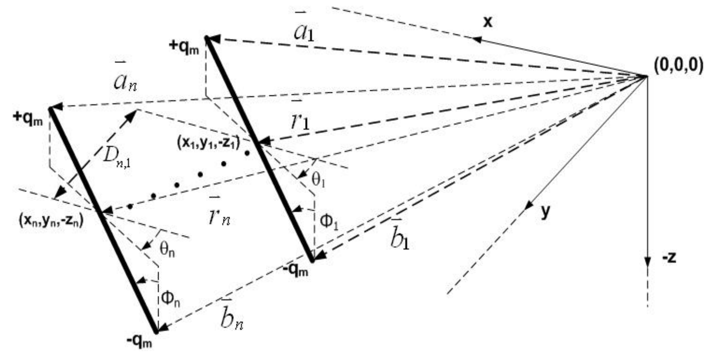
Sensor Analysis

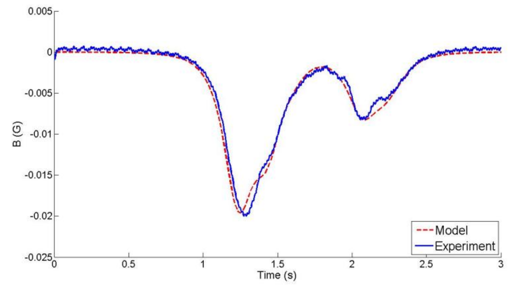
A thorough test plan was carried out to validate that magnetic sensors can provide an active role in this crash avoidance system. A single magnetic sensor was set up on the lateral side of a test vehicle and vehicle magnetic signatures were collected.

Magnetic Sensor 3D Modeling

A mathematical model was created to understand the behavior of the magnetic signal as a vehicle passes the sensor. This model includes the effects of magnetic field strength, vehicle dimensions, and number of acting dipoles. The model can be used to set numeric values for various object types.

The figure on the right is the model used to derive the equations that describe the magnetic behavior of a passing vehicle. The sensor is located at the origin and the bars represent vehicle dipoles (axles)

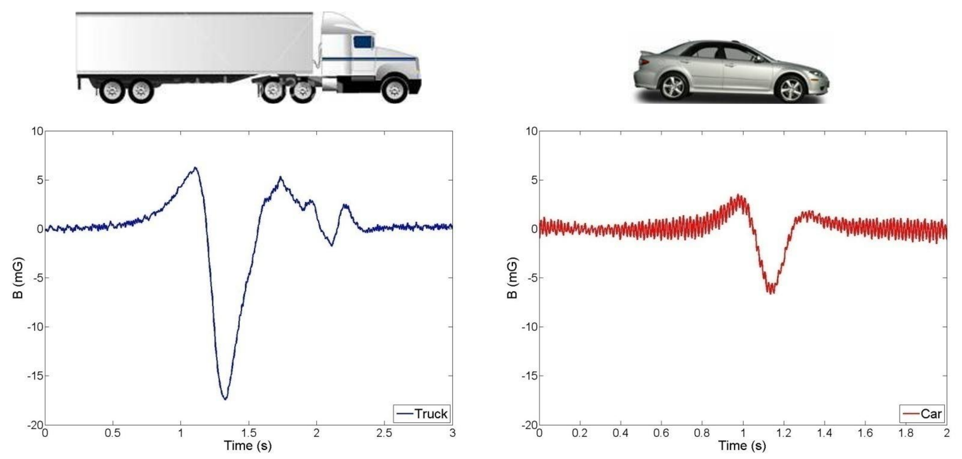




The graph on the right shows the magnetic signature of an heavy truck obtained experimentally, which is also compared to the analytical model.

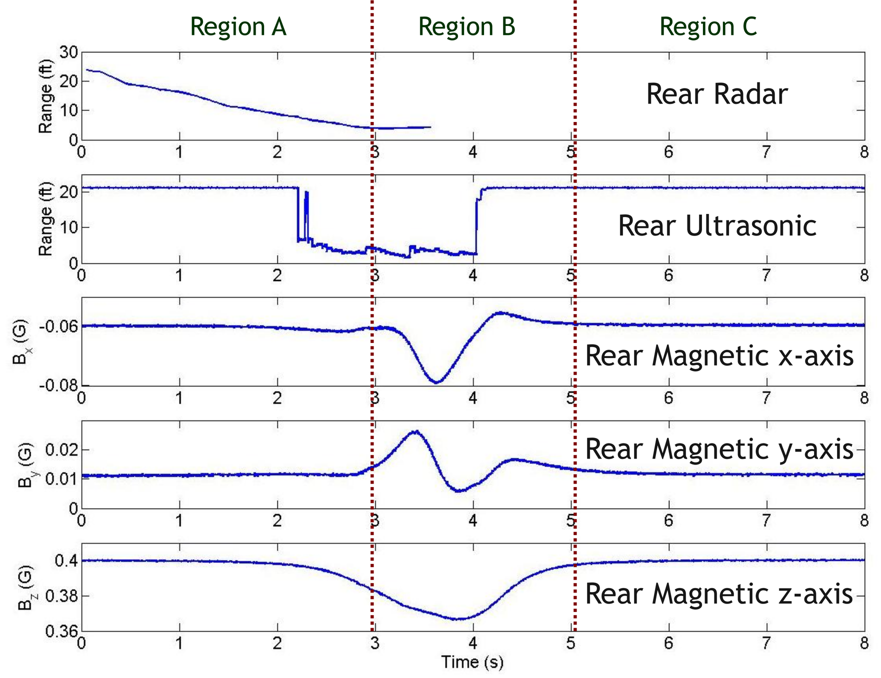
Magnetic Sensor Results

All vehicles possess some remanent magnetism that can cause localized changes in magnetic field. As a vehicle passes a magnetic sensor, a distinct magnetic signature or footprint is produced. All vehicles have their own magnetic signature based on their size, mass, number of wheels, and so on. Although no magnetic signature will be the same, trends in signal amplitude and frequency allow for positive detection of moving vehicles and even determination of vehicle type. Below are the magnetic signatures for a typical heavy truck and a typical car.



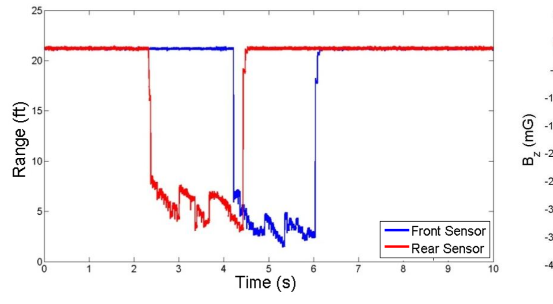
Preliminary Combined Sensor Data

The following graphs show the combined sensor signals produced when a passenger car passes the equipped test vehicle.

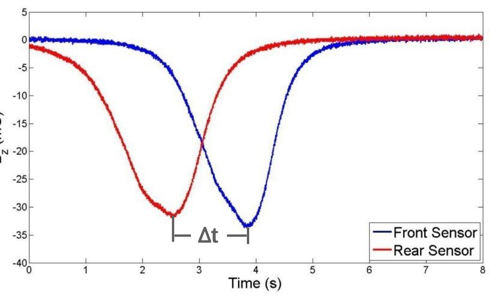


Region A: Car in adjacent lane approaching rear sensors of test vehicle
Region B: Car in adjacent lane beside sensors of test vehicle
Region C: Car in adjacent land ahead of sensors

The graphs shown above represent the capabilities of individual sensors. Multiple ultrasonic sensors allow for region detection and vehicle tracking while multiple magnetic sensors placed a fixed distance can allow for relative velocity calculations. Such a sensor fusion becomes possible with the use of an intelligent algorithm



Two Successive Ultrasonic Sensors



Two Successive Magnetic Sensors

Full Scale Testing

A full scale tests were conducted to collect realistic data sets from heavy trucks. This heavy truck seen to the right was equipped with two lateral facing ultrasonic sensors, magnetic sensors, camera, and a rear facing radar. The data acquisition system is self contained and is equipped with CAN bus communication, 16 channel analog input, Firewire, and serial communication.

Data Acquisition System

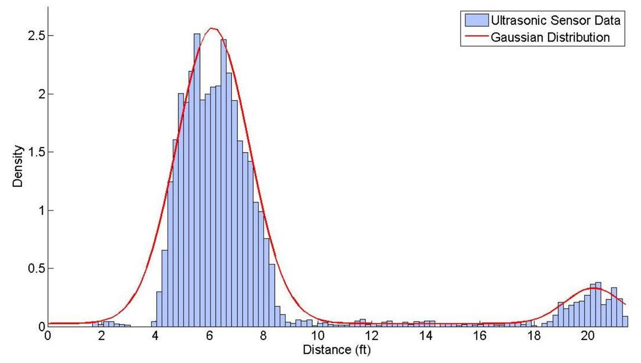
Rear Radar

Ultrasonic and Magnetic Sensors

Firewire Camera with Ultrasonic and Magnetic Sensors

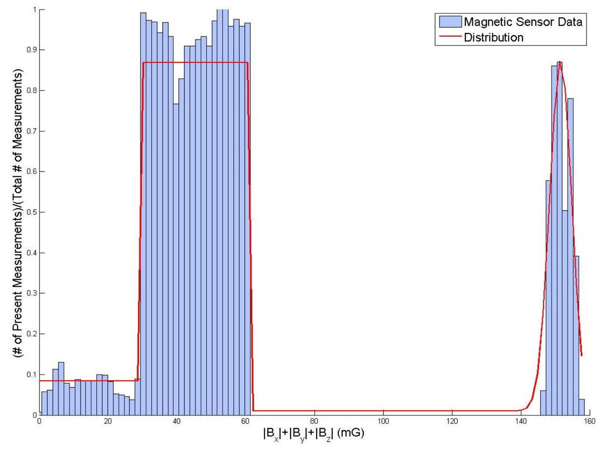
Sensor Statistical Modeling

Statistical profiling was completed for the ultrasonic and magnetic sensors. The figures below represent the average behavior of the two sensors when vehicles are passing the heavy truck from the driver side rear. This statistical modeling takes account for uncertainties created by environment and process noise.



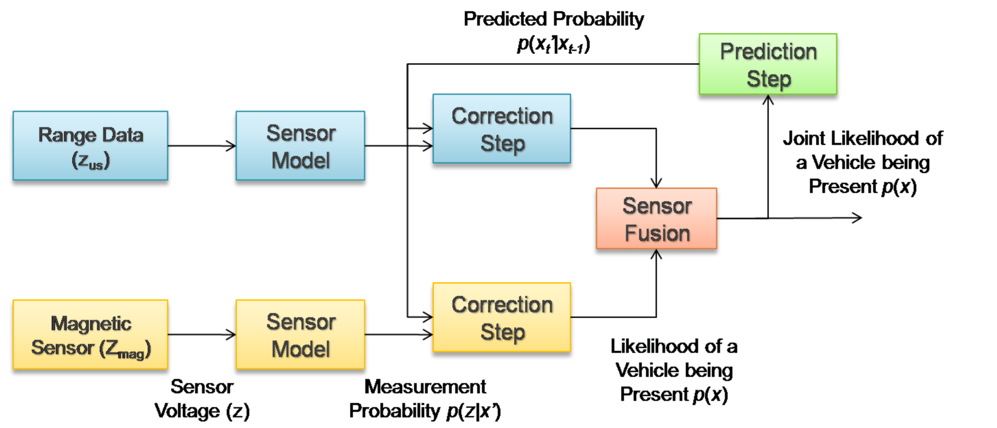
Typical ultrasonic sensor behavior as vehicles pass the heavy truck. The sensor behavior can be modeled using Gaussian distributions.

Typical magnetic sensor behavior as vehicles pass the heavy truck. The sensor behavior can be modeled using box functions and Gaussian distributions.

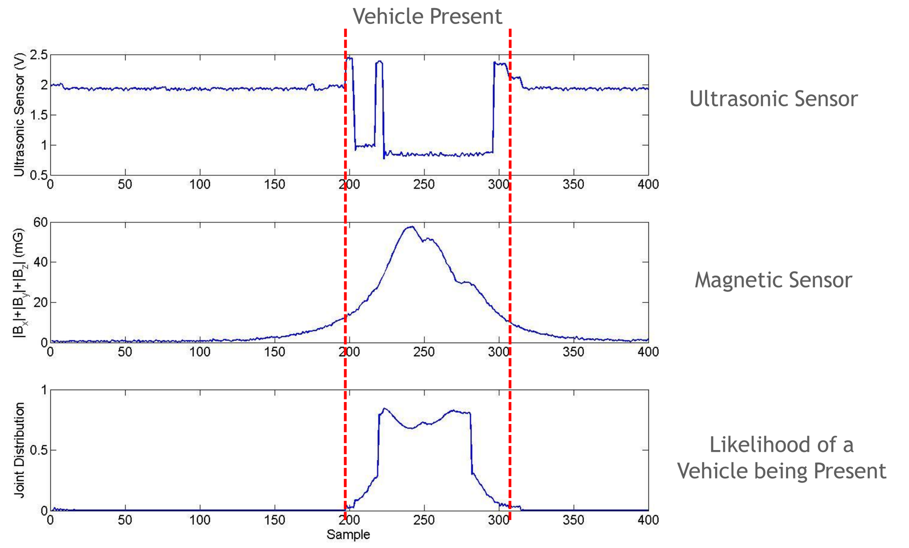


Bayesian Filter Algorithm

A Bayesian recursive model was created to convey the likelihood of a vehicle being present in the lateral blind zones of a large truck. The algorithm helps integrate the multiple sensors. By knowing the advantages and limitations of each sensor the algorithm can help alleviate false positives that may arise with the use of standalone sensors.



The below figure shows the likelihood of a vehicle being present as a typical vehicle passes the large truck. Noise is rejected and positive presence of a vehicle can be inferred from the sensor data.



Future Work

- Investigate threat level assessment
- Perform studies to quantify threshold values
- Optimize sensor integration
- Incorporate wireless capabilities
- Initiate countermeasures (active braking/steering)

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