**SENSORS**

We used two different sensors in this project. This approach was based on sensor fusion that fused the measurements from the two sensors. The sensors utilized in this project are the MPU9250 Magnetometer and the VL53L0X TOF (Time of Flight) Integrated Circuits sensor, they operate at different sampling rates.

**Magnetometer Sensor:**

Most vehicles are still based on internal combustion engines, which do not generate a significant magnetic field of their own. Detection of vehicles by magnetometers is based on the effect of ferromagnetic materials contained in vehicles on the Earth’s magnetic field. As the magnitude of the Earth’s magnetic field is approximately 50 μT (Micro Tesla), it is necessary to focus on sensors with the highest possible sensitivity. Sensitivity is usually expressed in terms of the number of quantization steps per μT.

**Operating principle of Magnetometer:**

The earth’s field provides a uniform magnetic field over a wide area. The image below shows how a ferrous object, a car, creates a local disturbance in this field whether it is moving or standing still. Magnetic sensors can detect the change in the earth’s field due to the vehicle disturbance.

A drawing of a car

Description automatically generated with medium confidence

The net result is a characteristic distortion, or anomaly, to the earth’s magnetic field that is unique to the shape of the car. These distortions are also referred to as hard iron effects, or distortion of the vehicle. The image below shows before and after a ferrous object is introduced to earth’s magnetic field.

A picture containing diagram

Description automatically generated

**Time of Flight Sensor (TOF):**

A ToF camera uses infrared light (lasers invisible to human eyes) to determine depth information. The sensor emits a light signal, which hits the subject and returns to the sensor. The time it takes to bounce back is then measured and provides depth-mapping capabilities. This provides a huge advantage as it can accurately measure distances with a single laser pulse. Infrared (IR), sometimes called infrared light, is electromagnetic radiation (EMR) with wavelengths longer than those of visible light. Below is an image showing the wavelength of infrared next to the visible light. Human eyes can’t see this light, but we can feel it as heat.

Diagram, timeline

Description automatically generated

**Operating principle of Time of Flight:**

The image below show how time of flight sensor uses infrared light to accurately measure object distance. The sensor uses the time that it takes for photons to travel between two points to calculate the distance between the points.

A picture containing text, antenna

Description automatically generated

**Sensors Data Capture:**

The Magnetometer Z-axis field, component in the up direction, can be used to indicate the vehicle presence. This curve peaks when the vehicle is directly in line with the sensor axis. For the case of approximately one-foot distance to the sensor the graph below can be used to indicate presence. Threshold levels can be established to eliminate false sensing from neighboring lots of traffic and vehicles at a distance. Same case applies with time-of-flight sensor, The distance is measured from the vehicle parked on top and both sensor data is collected and analyzed to determine the presence of a vehicle.

**Vehicle Not Present:**

The graph below shows data from the magnetometer and time of flight sensor before the presence of the vehicle:

Graphical user interface

Description automatically generated

The image above complements the raw data captured through Arduino board interface and is displayed below. Both the magnetometer and time of flight sensor data threshold were set to allow minor fluctuations without triggering a false positive. For the Magnetometer was set to ± 10 using the base as a reference point and time of flight sensor was set such that it won’t trigger for a measurement below 80 mm.

![Graphical user interface, text, application

Description automatically generated]()

**Vehicle Passing Through:**

These two sensors were able to detect when a vehicle was passing through a parking lot as shown the image below. The spikes in the graph shows a vehicle being detected while passing through the sensors.

Graphical user interface, histogram

Description automatically generated

**Vehicle Present:**

The graph below is very interesting because it shows all the three stages. When the Vehicle is not present, when the vehicle movement has been detected and when the vehicle is present.

Diagram

Description automatically generated

Below is the raw data when the vehicle is present.

![Graphical user interface, application

Description automatically generated]()

**Problems/Challenges encountered:**

**Magnetometer Challenges:**

Magnetometer sensor had two main challenges that needed to be solved for it to effectively work and increase the accuracy of the data.

1. Basic Algorithm
2. Engine Effect

**Basic Algorithm:**

The basic algorithm originally simulated a vehicle for which the magnetic field variation exceeds the threshold (magnetometer base) in any part, like a standard sized car. However, there were vehicles such as SUV and lifted trucks for which the magnetic field variation was lower than the threshold in some parts and the graphs are shaped different with respect to the type of vehicle. Therefore, there was the problem that there were types of vehicles which could not be detected by this algorithm. This algorithm was achieved by using Arduino ide program code. A more robust algorithm was needed to increase the percentage of accuracy.

**Engine Effect:**

As stated above, the “magnetic field variation amount” varies depending on the vehicle type, However, the engine section shows a magnetic field variation amount that far exceeds the set magnetometer base. This base point is calculated based of the position of the sensor relative to the earths magnetic field. This engine effect dictated the approximation of the sensor position in the parking lot.

The image below shows the engine effect when entering and exiting the parking lot.

Diagram

Description automatically generated