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Driver Assist System (DAS)

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***Abstract*— The advancement in Driver Assistance Systems (DAS) heralds a new era in vehicular safety and efficiency, particularly through the automation of critical driving functions. This paper proposes a system that uses TOF sensors to maintain a safe inter-vehicle distance to avoid collisions in the event of emergency braking. It can also help maintain a dynamic safe distance while driving, making the system viable for an adaptive cruise control system. This system uses a Time of Flight (TOF) sensor as a primary distance-ranging sensor and a Microwave Radar Sensor as a secondary distance-ranging sensor. This module will also employ a microcontroller as its brain. The decision to throttle or brake will be made by the controller and then be passed to the throttle and brake actuators through the Controlled Area Bus (CAN). This system will be much cheaper than the existing ones hence can be retrofitted into vehicles not equipped with a factory-installed driver assistance system.**

Keywords—Inter-vehicle Distance Maintenance, Time of Flight (TOF) sensors, Microwave Radar Sensor, Adaptive Cruise Control, Cheap.

I. INTRODUCTION

As of year 2022, the NCRB says that a total of 4, 72,467 'Traffic Accidents' were reported of which 4, 46,768 were road accidents. These traffic accidents resulted in injuries to 4, 25,727 persons and 1, 94,347 deaths. Majority (62.6%) of road accidents occur due to over speeding and 24.7% of road accidents are caused due to dangerous/careless driving or overtake and 2.2% due to poor weather conditions. Over speeding and careless driving have caused 1, 45,887 deaths and 3, 72,562 injuries. National highways contribute around 30.5% and state highways contribute 23.8% of road accidents. 20.3% of road accidents were reported during night. These maybe caused due to distracted driver or sleepy driver or driving under influence.

To tackle these issues the automotive industry has made significant advancements in Driver Assistance Systems aimed at enhancing vehicle safety and improving overall driving experience. Among these systems, Automated Inter-Vehicle Distance Maintenance (AIVDM) has emerged as a critical technology, particularly in the context of traffic congestion and highway driving. The AIVDM system enable vehicles to autonomously adjust their speed to maintain safe distances from preceding vehicles, thereby reducing the likelihood of collisions and improving traffic flow[1].

Traditional AIVDM systems mainly rely on Adaptive Cruise Control (ACC), which modulates the vehicle's speed through throttle and brake control to maintain a set distance from the leading vehicle. While ACC systems have proven effective in many scenarios, they often exhibit limitations [2], especially in complex traffic environments or during abrupt changes in driving conditions. The ACC system combines the cruise control at constant speed and the control of vehicle distance keeping, adopting vehicle-borne radar for environmental perception, thus assists the driver to drive the car safely and comfortably. [3]-[5]. At present, the ACC and AIVDM system is configured on some brands' high-end cars, and its functions are also expanding.

To address these challenges and enhance the precision and reliability of AIVDM, our research focuses on integrating Time-of-Flight (1D LiDAR) (TOF) sensors and Microwave Radar sensor (μWR) into the driver assistance architecture. TOF sensors offer distinct advantages over traditional sensors by providing accurate distance measurements based on the time taken for light or sound waves to travel to and from the target object. μWR using Electromagnetic waves can be used during poor weather conditions. By leveraging TOF and μWR sensor technology, our proposed system aims to achieve real-time, high-fidelity perception of surrounding vehicles and obstacles, enabling more responsive and adaptive inter-vehicle distance maintenance. The main contributions of this study are as follows:

1) Our work lays emphasis on usage of TOF sensors as the primary distance sensing sensor for the AIVDM. As a TOF sensor provides measurements by reflection of light waves, and is much cheaper compared to other distance sensors.

2) Usage of Microwave Radar Sensor as failsafe in case the TOF fails and to increase the range of our detection.

3) Usage of Controlled Area Network (CAN) to make adjustments in existing CAN bus network to control the throttling and braking of the vehicle.

4) Making a cheaper option for retrofit into older cars or lower end cars which do not have factory fitted Driver Assist System.

II. MILLIMETER WAVE RADAR VERSUS TIME OF FLIGHT SENSORS

A traditional ACC uses a Millimeter Wave Radar (mmWR) sensor as a primary distance sensing sensor. A radar employs radio waves to pinpoint targets, their angle, and velocity at comparatively greater distances. But in mmWR, millimeter waves are used which are smaller than radio waves and when they spread through the atmosphere, they have less effect on natural light and heat radiation sources. Because they can travel so unobstructed over great distances, they are perfect for use in communication networks. The atmosphere's millimeter wave frequency enables ground relay or high-capacity satellite-ground communication. Precision tracking and imaging radar at low elevation angles is also possible.

Whereas a TOF sensor emits infrared light from a small laser, which bounces off any object before returning to the sensor. This sensor calculates the distance between an object and itself based on the time delay between the light's emission and its return to the sensor after being reflected by the item. Since TOF projects light onto the scene rather of using ambient light like stereo vision does, it is a dynamic approach. As a result, even in low light, a TOF sensors are simple to use. Hence TOF's are capable of processing at greater distances.

TOF and mmWR both aim to detect the presence and size of distant objects, but both use completely different approaches to achieve it. Millimeter-wave radar uses electromagnetic waves with a wavelength between 1 and 10 millimeters, and frequencies between 30 and 300 GHz to detect objects. Whereas TOF emits light pulses and measure the time it takes for the light pulses to bounce back from an object.

Some advantages of TOF sensors:

- TOF provides a higher precision, higher frame rates, high field of view, greater sensor resolution and superior object classification.
- Compared to structured light and stereo vision, it offers a quick response time.
- TOF method is less dependent on mechanical alignment.

III. Inter Vehicle Distance Maintenance System

A. *Using Time of Flight (TOF) sensor*

Our reason to choose TOF (1D) over the mmWR sensor is because it is a cheaper alternative, and it has higher refresh rate than the mmWR. It has a compact design hence it can be easily incorporated into the existing body panels of the vehicle. The simplest TOF uses light pulse or pulses, and the illumination is switched on for a very small time, resulting in the pulse illuminating the scene. The pulse is reflected by the objects in sensor's field of view (FOV). The lens gathers the reflected light pulses and sends them as electric signal.

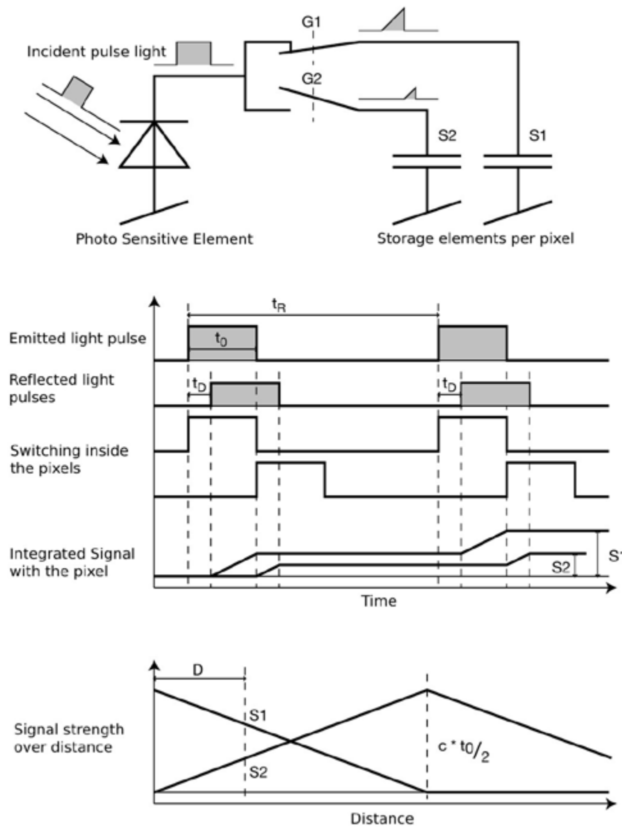

Figure 1. Working of TOF (1D LiDAR) sensor [6]

Depending on the distance, reflected light experiences a delay e.g. if the distance is 2.5m away the time delay is given by: here, c = approximate speed of light i.e. 3,000,000

$$t_d = 2 \times \frac{D}{c} = 2 \times \frac{2.5\ m}{300\ 000\ 000\ \frac{m}{s}} = 0.000\ 000\ 016 = 16.66\ ns$$

Hence for a distance of 2.5m, the time delay is 16.66 ns.From the above we can say that time delay for a TOF is quite small, almost immediate which is crucial for any possible collision avoidance.

Working of our module:

Working of our AIVDM module is quite simple we will mount our TOF sensor on the front grill of the vehicle. Our location for fitting the sensor is such because the front grill is frontmost part of the vehicle.

Light from the TOF is reflected by objects in its FOV. After the lens collects all these light pulses, it constantly sends electric signals to the microcontroller. The microcontroller computes the data according to calibration and then sends corrections to the throttle and brake actuators the car's existing CAN bus. These actuators will increase/decrease the throttle/brake according to the incoming signals.

B. *Using Microwave Radar sensor.*

We are using the Microwave radar sensor (μWR) along with our TOF module as a fail-safe as well as it can be used to

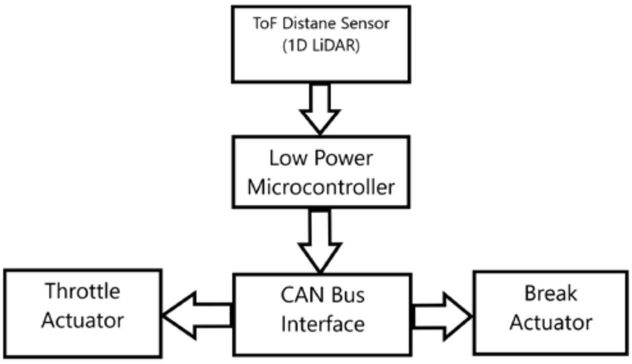

Figure 2. Basic working of our TOF module.

monitor vehicles from a larger distances. In case of any error/malfunctioning of the TOF sensor, the module will switch over to the µWR sensor bus. Also as the µWR uses Electromagnetic Waves (EMW), they can also be used in foggy or hazy conditions. Hence our module can prevent accident/collisions due to poor weather conditions.

Working of the module:

The µWR sensor will be mounted along with our TOF module. µWR uses the principle of Doppler Effect i.e. the frequency or wavelength of the wave appears to change from the perspective of an observer as the source of the wave moves relative to the observer.

Data from µWR sensor will be compared with the data of the TOF signal. Incase of any abnormalities in the data TOF module, µWR will take over the communication channel between the sensors and microcontroller. Then the communication will be done by the µWR sensor and the actuator via the existing CAN bus. This process will repeat unless stable data comes from the TOF sensor.

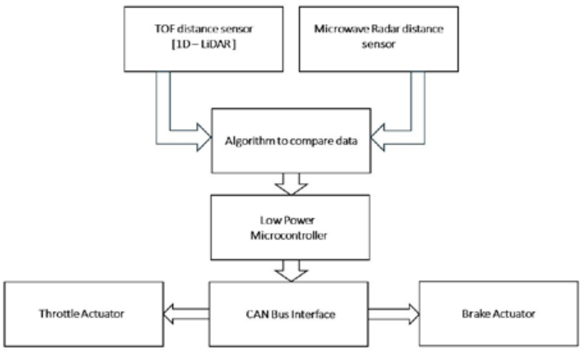

Figure 3. Basic working of µWR module

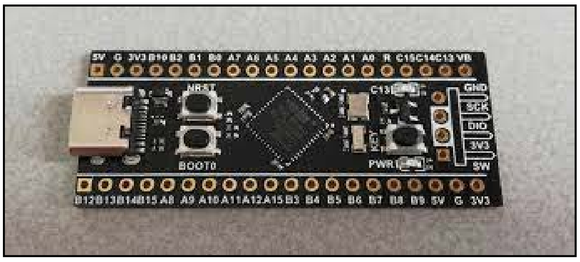

Figure 4. STM32F401 microcontroller

IV. Component List

As stated earlier we are using TOF sensors and the µWR sensor, the following are the exact component we will be using in our module.

A) STM32F401 microcontroller:

The Microcontroller we will be using is the 32 bit STM32F401microcontroller (mc). It has the ARM® 32-bit Cortex®-M4 CPU with FPU, Adaptive real-time accelerator and frequency up to 84 MHz. The peripherals are connected to 2 Advanced Peripheral Bus (APB) and 2 Advanced High Performance Bus (AHB). It also has a 32 bit AHB Matrix. It has a 12 bit Analog to Digital Converter (ADC) that can reach up to 2.4 Mega Samples per Seconds (MSPs). It provides up to 256 Kbyte Flash memory and 64 Kbyte SRAM. The package we are using has 36 I/O ports which are 5V tolerant. It also has 3 I2C ports and 1 USB 2.0 OTG port.

STM32F401 has a high computing speed and high refresh rates along with many GPIO port hence multiple senors can be intrerface with our MC.[7][8]

B) VL35L0X

The VL53L0X is a Time-of-Flight (ToF) laser-ranging module. It provides accurate distance measurement whatever the target reflectance unlike conventional technologies. It can measure accurately up to 2m. It has 940 nm Vertical Cavity Surface Emitting Laser (VSEL) emitter. It is totally invisible to the naked human eye.

The VL35L0X coupled with internal physical infrared filter enables longer ranging distances, higher immunity to ambient light and better robustness to glass optical cross talk. It uses I2C interface for device control and data transfer. It also has programmable I2C addresses. [9]

C) HB100 Microwave Radar Sensor

The HB100 Microwave Radar Sensor is an X-Band Mono-Static Doppler Trans receiver module. It has a built-in Dielectric Resonator Oscillator and a pair of microwave mixer and patch antenna. X band refers to operating frequency of 10.5 GHz. It has a detection range of 20m. Its operating voltage is 4.5v to 5.2V but only requires 30mA of current. [10]

D) I2C CAN Bus Module

As our MC does not support CAN bus protocol, we will be using the I2C CAN Bus module. This module uses the I2C protocol for communication and is built with a small, flexible design that makes it easy to integrate into any system that has an I2C interface. It is based on the high-performanceMCP-2515 CAN Bus controller and MCP-2551 CAN Bus transceiver, allowing for communication at speeds up to 1 Mb/s.

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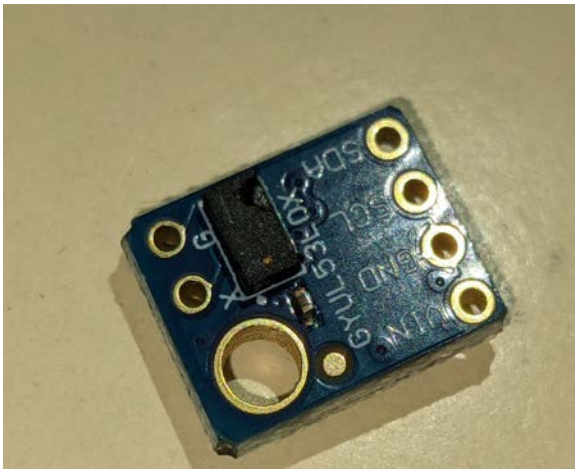

Figure 4. VL35L0X TOF module

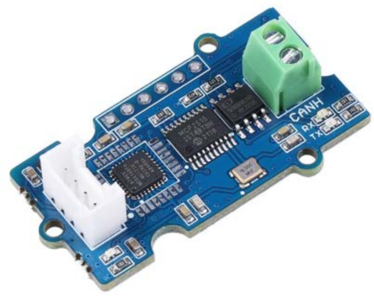

Figure 6. I2C to CAN Module showing MCP-2551 and MCP-2515.

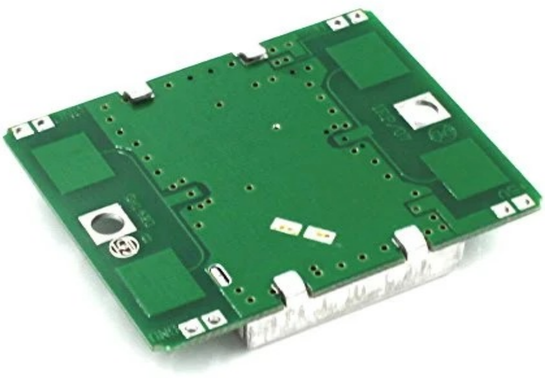

Figure 5.1 Antenna side of HB100

Figure 6. MCP-2551 CAN Transreceiver

Figure 5.2 Rear side of HB100

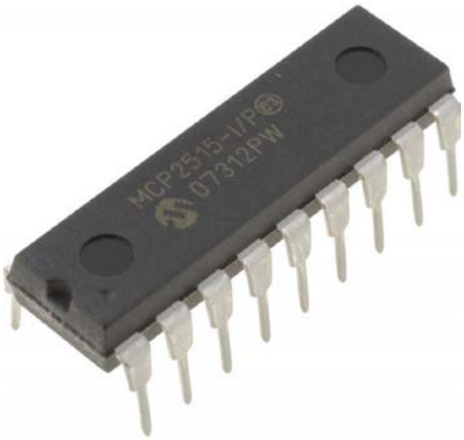

Figure 7 MCP-2515 CAN bus Controller

V. Acknowledgment

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