A CAN Protocol Based Embedded System to Avoid Rear-End Collision of Vehicles

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Abstract— **Driver and passenger safety is one of the prime concerns in modern day vehicle. Alarming statistics of accidents and increased number of vehicles on road demands for an intelligent safety mechanism that helps the driver in handling immediate precarious situations like sudden probability of a rear- end collision.**

The work proposes a mechanism that not only computes the deceleration of vehicle due to braking and displays the braking intensity through an array of LED but also involves monitoring the braking intensity levels and communicate it to the vehicles that are following it in lambertian range of IR transmitter module to avoid any collision pre-hand, due to any situation that may arise and cause immediate deceleration of the vehicle ahead.

An ARM Cortex M0 microcontroller will be interfaced with an accelerometer that senses the deceleration levels, a LED array to display the braking intensity and an IR transceiver module for inter-vehicle communication that would transmit pulses whose frequency is modulated proportional to the braking intensity level. To take decision and automatically control the motion of the following vehicle, a collision avoidance system consisting of CortexM0 microcontroller is implemented that warns the driver using a buzzer and messages the active and passive safety mechanisms to be activated using CAN protocol and takes control decisions according to an algorithm designed to handle the situation.

Keywords— **Accelerometer, Embedded System, Rear-end Collision, IR communication, Collision Warning and Avoidance System.**

I. INTRODUCTION

As per a report submitted by National Institute of Disaster Management, in India every 80 seconds there is a road accident i.e 1080 accidents per day. Human errors amount to 93 % of all accidents and according to police, rear-end collision constitute 30% of all fatal accidents [1].

An accident in which the rear of a vehicle is hit by a trailing car, due to immediate change in car's speed as a result of emergency or hard brake applied is termed as rear end collision.

STRADA (Swedish Traffic Accident Data Acquisition) performed an analysis that shows 91% of all rear-end collisions involve trucks. The most common rear-end collision is a collision where a car's rear is rammed by a heavy truck. Also more collisions that involve rear end crash do occur in broad daylight with good visibility conditions on a straight road and in good weather condition but nonetheless bad weather or bad visibility could also lead to rear end collision [2].

Reducing traffic accidents is one of the main objectives of any transportation system. Accidents due to rear-end collisions very common and it does become one of the research soughed topic in the automotive sector. As the Driver's ability to keep attention has a key role to play in prevention of such collisions, an automated system that assists the driver would prove to be of great help in reducing these accidents significantly.

II. EXISTING WORK AND SYSTEM

To decrease the present high statistics of accidents caused by rear-end collisions, many ideas have been proposed for essential advancement in developing system meant for collision warning. A system based on vision and image processing was proposed that could employ a camera to take video images and extract features from behaviour of the vehicles in front and draw conclusion to avoid collisions. A similar collision avoidance system was modelled using laser scanner and collision prediction algorithm using Kamm's circle [6]. Global positioning system (GPS) was also used to locate the vehicles in front and evaluate their relative velocity to find a solution to avoid collision [9]. Instead of vehicle to vehicle communication, an external infrastructure to vehicle based system is also proposed that maintains a network of all vehicles in coverage area and informs the vehicle of any situation which can lead to collision, pre-hand, so that they can take necessary action [7]. Systems enabled with WiFi to receive surround cars information and Zigbee to receive infrastructure information was also propose to mitigate collisions. Fuzzy logy based controllers have been deployed to develop and implement Collision Warning System (CWS) and Collision Avoidance System (CAS) [3].

All the aforementioned works are costly in terms of system infrastructure and also algorithmic computations. The systems need to either rely on external infrastructure or network to gather information about surrounding vehicles. These drawbacks make it necessary to build a stand-alone system that can be integrated within the vehicle itself to avoid rear-end collision with efficient response time. Hence systems based on microcontroller would just be the right solution to overcome all the limitations.

The paper proposes an ARM Cortex-M0 controller based design to implement collision warning system (CWS) and

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collision avoidance system (CAS). It uses an accelerometer to detect the deceleration of leading car and infrared communication to communicate with the trailing vehicle to warn the driver and take proper control action to avoid a rear-end collision.

III. PROPOSED SYSTEM

The system constitutes of two microcontroller. One for Collision Warning System and other for Collision Avoidance System as shown in Fig 1.

Fig. 1 Block Diagram of Proposed System

The alert warning system mounted on the leading vehicle is responsible for alerting the Collision Avoidance System of following vehicle to warn its driver and mitigate a crash that may be due to an impending rear-end collision. The desired mode of communication required is straight optical lambertian range of communication to notify only the vehicles following the leading vehicle.

A. *The Alert Collision Warning System*

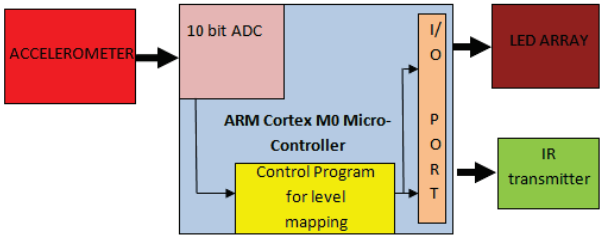

Fig.2 Block Diagram of the Collision Warning System

The warning system (Fig 2) measures the deceleration produced due to braking using an interfaced accelerometer and evaluates the threshold levels of deceleration.

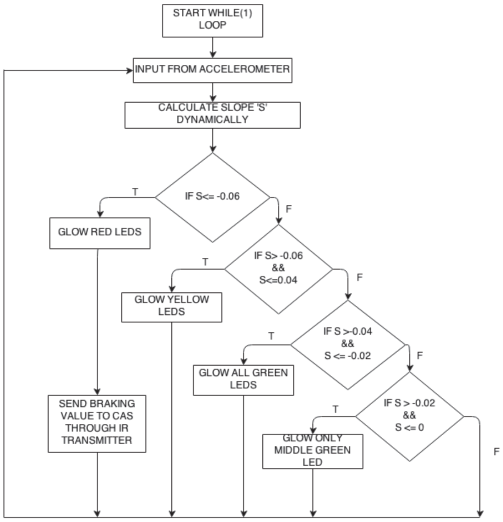

Fig.3 Flow Chart of the Collision Warning System

Fig 3 represents the control flow chart of the Collision Warning system. The algorithm calculates the slope of the response of Accelerometer dynamically. The system then displays the level of deceleration using an array of LED as shown in Fig 4(a),(b),(c) and transmits the levels of deceleration corresponding to a sudden brake to the Collision Avoidance System to generate the necessary control action as can be seen in the functional block diagram in Fig 2

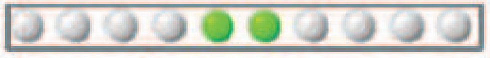

Fig.4 (a) Green led representing low braking intensity

Fig.4 (b) Yellow pair of penultimate led representing gradual braking

Fig.4 (c) RED led at ends representing sudden high braking intensity

1) Accelerometer: It is an electromechanical device that measures static and dynamic acceleration due to moving of the vehicle measured in terms of g force.

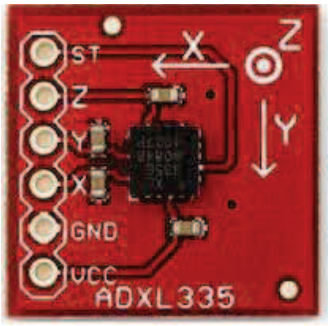

Fig.5 An ADXL335 accelerometer

An ADXL335 (Fig 5) accelerometer is interfaced to the microcontroller's analogue input to measure the vehicle's acceleration. The ADXL335 module is a low power, small, complete 3-axis accelerometer which can measure acceleration with a minimum full scale range of ±3g. [8]

The accelerometer was used in actual trials on a vehicle to measure different levels of braking and the corresponding voltage produced was plotted as shown in Fig 6.

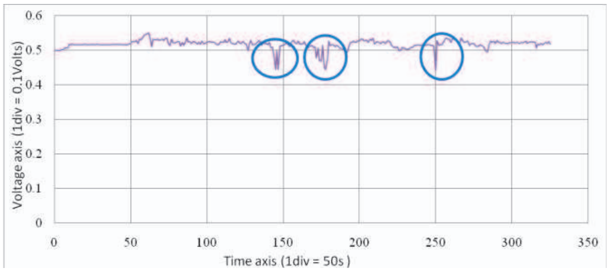

Fig. 6 Accelerometer response graph for braking intensity of a vehicle.

The graph represents real-time response of an accelerometer to acceleration produced by a vehicle on test. The dips indicated by blue circles in Fig 6 represent response from Brakes applied i.e deceleration of the vehicle. The slope of these dips gives the intensity of Brakes differentiating gradual braking from sudden brake. Gradual braking has gradual slope as seen around time-sample 175 and hard braking show steep slope as observed around time-sample 250(refer Fig 7(a),(b)).

(a) Gradual slope (b) Steep Slope

Fig.7 Snippet from response of accelerometer differentiating gradual and high braking intensity respectively

2) *Evaluation of Deceleration levels:* The deceleration level represents the type of braking applied. As discussed before, sharp slope represents hard breaking, categorising the slope will help in categorising the Braking Levels. The slope needs to be calculated on real-time basis using the microcontroller program.

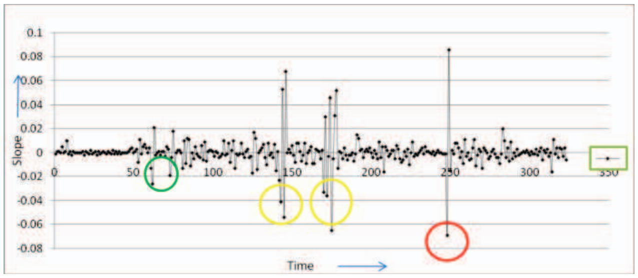

Fig.8 Plot of slope against time

The plot shows that during safe braking the value of slope is less than or around -0.04 represented inside green circle while values more than it correspond to further levels of gradual and sudden hard brake as seen for the time-sample 175 and 250 represented by yellow and green circle respectively in Fig 8. The value represented by red circle is the information that needs to be communicated to avoid rear-end collision.

3) *Braking Display LED Array:*

The LED arrays represent the tail light of leading vehicle that gives information about the vehicle's braking levels. The slope level especially the negative slopes have been divided into windows of 0.01 width where value bellow -0.04 represent normal braking intensity glowing the green centre LEDs (refer Fig 9) while braking intensity level that correspond to window from -0.0.4 to -0.06 representing gradual braking would glow yellow LEDS besides the green (refer Fig 10). The next window corresponding to slope values less than -0.06 represent sudden brakes and glow the red LEDS at extreme of array as shown in Fig 11.

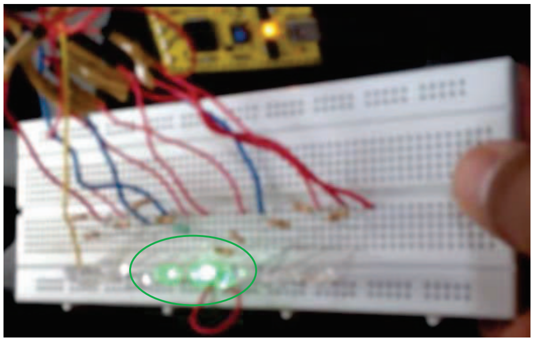

Fig.9 Centre LEDs (Green) in the array glowing indicating safe or low intensity of braking.

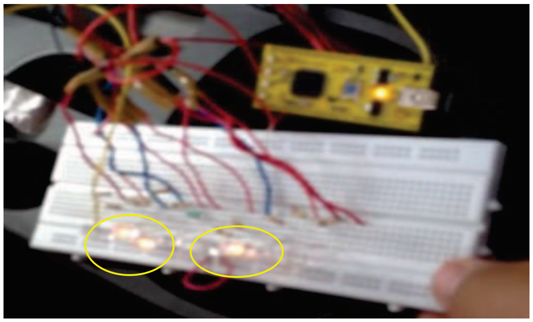

Fig.10 Penultimate LED (Yellow) in the array glowing indicating Gradual Braking Levels.

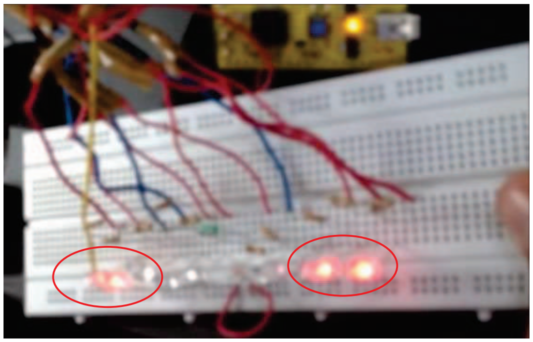

Fig.11 Extreme LEDs (Red) in the array glowing indicating high intensity of braking.

4) *Infrared Communication*:

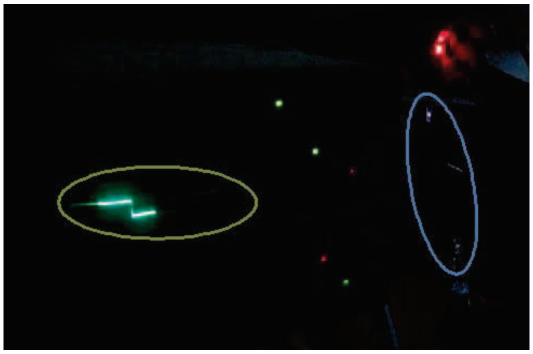

Fig.12 IR LEDs (Blue) communicating via pulse width modulated wave (Green) seen in a CRO.

After the evaluation of deceleration level and defining window levels, levels corresponding to last window which indicate dangerous sudden braking need to be communicated to the following vehicle. The mode of communication chosen is IR communication considering the range of communication. Pulse width modulated (PWM) signal is generated as a control signal if the braking intensity level is in either the last window period or just toward the end of second last window. Both PWM of different duty cycle represent the slope levels of -0.05 to -0.06 and -0.06 and bellow. This PWM is transmitted using IR LED which is to be read by a photodiode on the Collision Avoidance system. Fig.12 shows the pulse of the IR signal in a Cathode Ray Oscilloscope in a dark room to make the IR led's (blue colour in Fig 12) visible.

B. *The Alert Collision Avoidance System*

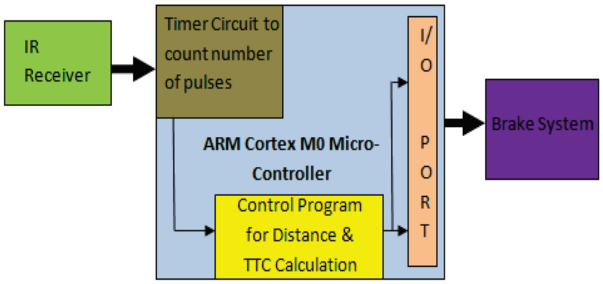

Fig. 13 Block Diagram of the Collision Avoidance System

The Collision avoidance system receives the IR signal transmitted by the CWS and draws proper control action based on the time to collision that it calculates. The following is the control flow chart of the Collision Avoidance system.

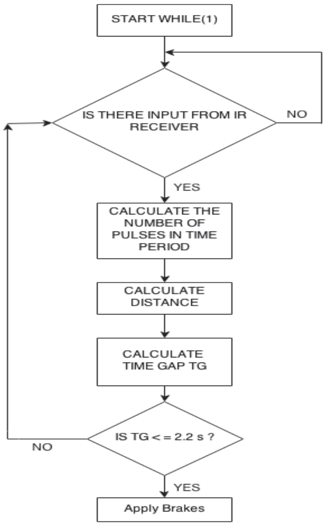

Fig. 14 Flow Chart of the Collision Avoidance system.

1) IR receiver: An IR receiver is a photo diode that generates electrical signal proportional to the intensity of IR rays incident on it. The signal is demodulated to receive the information signal. This information is the input to the collision avoidance system to start with control algorithm.

2) Time gap calculation: The IR transmission uses pulse width modulation to communicate the breaking intensity. This signal is nothing but rectangular pulses with frequency around 40KHz. The detected signal can be measured for the change in frequency to measure the distance between the two vehicles. The concept of Doppler effect is used to measure the distance. Basically, the number of pulses can be counted in specified duration of time. The change in number of pulses will be proportional to the distance the signal travels as seen in Fig 12.

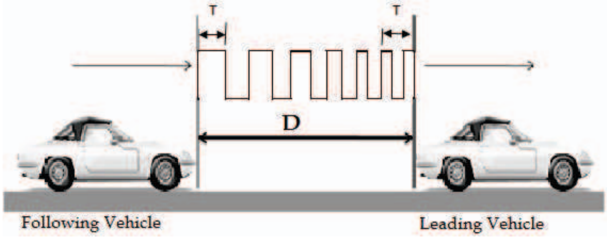

Fig. 15 Spread in pulse width proportional to distance

3) Control System: The IR receiver input triggers the timer circuit of microcontroller to count the number of pulses in a fixed duration of time T. The value of number of pulses in time period is compared with the value obtained at the frequency used for transmission which is fixed. The distance is estimated by the time obtained from difference of the above number of pulses. The distance and the velocity of car is used to calculate the Time Gap (TG).

$$TG = \frac{Distance}{Velocity\ of\ Following\ car} \quad \text{.... (1)}$$

According to Honda Algorithm if the time gap TG is less than 2.2 sec, it is a critical and appropriate braking need to be applied to stop the following vehicle [4]. Thus an appropriate control signal need to be generated to activate the Antilock Braking System (ABS) of Car. The driver is alerted by generating a buzzer. In the prototype we use a pulse width modulated control signal to control DC motor and to depict the situation. The DC motor depicting the wheel is made to stop if the TG value obtained is less than 2.2 seconds.

5) CAS-ECU CAN communication:

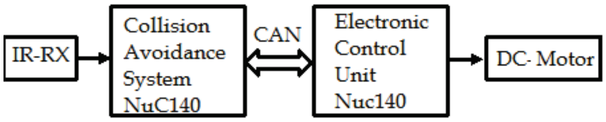

Fig. 16 Flow Chart of the Collision Avoidance system.

The collision avoidance system is to communicate as a device to the Electronic control unit (ECU) of the vehicle that controls the brakes of the vehicle i.e the Antilock braking system and the Electronic Stability Program control system. We use a Nuvoton Nuc140 development Board which has an inbuilt CAN2.0B controller as the CAS and the ECU of the vehicle to simulate an environment that generates messages to control DC motor attached to the ECU.

The interrupt driven architecture of the CAS sends CAN messages as a part of the Interrupt subroutine for various duty cycles of the pulse width wave representing levels of braking. Received messages are stored in their appropriate Message Objects if they pass the Message Handler's acceptance filtering of the CAN protocol. These messages are stored in the Message RAM of the Controller. The Message Handler FSM controls the handling of data in TX/RX register of CAN controller. The message is read and appropriate response mechanism is adopted according to the control program.

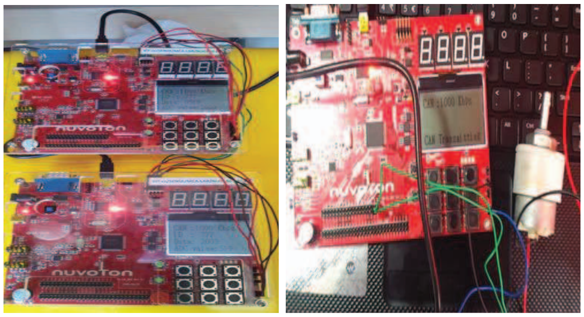

Fig. 17 CAS-ECU CAN communication and ECU controlled DC motor.

As in the case here, CAS generates the message only when the braking intensity is of highest level. The ECU on correct reception of the message stops the DC motor which is representation of a control action generated in response to the collision avoidance system.

IV. CONCLUSIONS AND FUTURE SCOPE

The proposed system uses an ARM Cortex M0 processor which is known for its efficient control and response time. The system is quick in response when compared with the available GPS based system in terms of response time. It is independent of any external infrastructure and network to calculate all its parameters which again increases efficiency. It is lower in cost as all its components are cheaply available and the processor is known for its cost effectiveness among its peer processors.

The system does not intend to notify other running vehicles except the ones that are following it or is in the lambertian line of sight of the array of IR transmitter lined in the rear bumper. These following vehicle are the most probable cause of rear end collision. Hence IR was chosen over other radiation technologies like RF, ZigBee and Bluetooth for its straight line of sight capabilities. Omnidirectional broadcasting of message was found to be undesirable in rear end collision avoidance of vehicles.

The system is integrated with the CAN controller for effective control of Collision avoidance parameters. Other control actions involving algorithms to steer the vehicle to change lane can also be involved and implemented. A system capable of providing driver safety is proposed and it can be further sophisticated by testing and improving its parameters to suit on-road conditions.

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