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AVOID COLLISION BETWEEN SMARTCARS USING Li-Fi AND ULTRASONIC SENSOR

Ms. B. Nantheni Devi[1], P. Amudhaganeshwaran[2],S. Babu[3]

Assistant Professor, Department of ECE, Krishnasamy College of Engineering and Technology, Cuddalore[1]

Student, Department of ECE, Krishnasamy College of Engineering and Technology, Cuddalore[2,3]

Abstract: With drastic increase in population, automation is becoming the need of the hour in order to make life more comfortable and easy. Due to the advancement and development in the field of automation and embedded system, the notion of smart car has become very popular. Smart cars are modernizing trends in the traditional automobile industry. Companies across the globe have been investing a huge amount of resources on the production and design of smart cars. Every technological development needs to overcome certain obstacles, and hence, in this paper, a design of a collision detection system for smart car using light fidelity (Li-Fi) and ultrasonic sensor on the Microcontroller platform is proposed. This design consists of an ultrasonic sensor and a Li-Fi circuit. The ultrasonic is used for measurement of distance between vehicles, and Microcontroller processes the data and makes de collision accordingly. Data transmission between vehicles is ensued using a Li-Fi transmitter circuit and a Li-Fi receiver circuit. The transmitter circuit is mounted on the tail lights of the leading car and the receiver circuit is mounted on the front side of the car that follows. Using visible light communication, the transmitter circuit transmits the calculated speed and the information is received by the receiver circuit of the second car. On the basis of the information received, the speed of the second car is changed in order to avoid collision. In this paper, a system that can detect and thus avoid collision between vehicles and prevent accidents is proposed and studied.

Index Terms: Li-Fi, smart car, collision detection, visible light communication, vehicle to vehicle communication.

INTRODUCTION

There has been a rapid growth in Automobile industry across the globe. With ever rising population, more and more people move to the cities, leading to faster urbanization.With rise in automation and Internet of Things (IoT), technology has increased the standard of living. Every year there is an increase in automobile sales of about 25% and the major reason is private transportation is becoming cheaper and affordable. One can conclude that in today’s lifestyle each individual has its own private vehicle. Sole ownership of vehicles leads to certain disadvantages in terms of the harmful effects on the environment due to emission of CO_2, CO etc.. Not only does the environment get affected by vehicles but one also cannot deny the fact that with increase in vehicular population across cities there has been an extreme rise in traffic and as traffic raises the roads, the highways, etc., start becoming unsafe for the citizens. Road accidents have become very common over the past few years and it is predicted to increase by 2% every passing year. The cars are totally dependent on human assisted driving rather than the pre-defined software of driving. But as human intervention is involved in the operation of these types of cars we can say that the entire efficiency of the car depends upon the efficiency of the driving skills of the per- son driving the car. And this makes them more liable to collision and accidents. But in today’s world almost all transportation is dependent upon on these cars but times are changing and we can say that the invention of smart cars with their perfectly de- signed software for driving with features like data gathering and automatic collision detection are not less than the revolution in transport industry. In order to count the problems associated with manual driving or in other words human assisted driving several automobile companies and tech companies are proposing the notion of smart cars or what we usually refer to as “Smart Cars”, i.e., automobiles with advanced electronics. These cars can park themselves, avoid collisions and even phone home when they need maintenance. Smart car comes with the feature of data monitoring. That means these car can gather data automatically based on the traffic conditions and the condition of the roads and as they are self-driven the automatically change their route based on the data collected The present smart car companies use Light Detection and Ranging (Li DAR) technology to detect the obstacles and gather the data. Li DAR consists of Laser transmitter which emits laser pulses and receiver captures the reflected laser pulse in order to measure the distance. The proposed system in this paper uses Ultrasonic range sensor instead of Li DAR. Unlike Li DAR, ultrasonic sensor transmits ultrasonic waves to detect the obstacle in front of it. Both the technologies have several advantages and disadvantages over each other. Several

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different parameters are considered to form the comparison such as cost of the technology, Detection range, Computation overhead etc. Apart from these comparisons, there are many more differences like Ultrasonic sensor can work in any weather condition but Li DAR only works in clear weather. Ultrasonic sensor is industrially acceptable while, on the other hand, Li DAR is not acceptable because of its high cost.

Smartness can be truly achieved when there exists a proper communication methodology between the cars. As a Smart Car is a totally autonomous body, the communication forms the heart of the design of any smart car; it requires transmission and receiving of data. Transmission and reception of data plays a very crucial role in the day to day activity. As more devices get connected to the internet chances of slower data rates and communication becomes vital. As bandwidth is fixed with in- crease in number of devices, security concerns increase. In light of the problems stated above a solution that one can adopt is the use of LI-Fi Technology or better known as advanced version of Visible Light Communication (VLC). Li-Fi or Light Fidelity is a communication scheme based on VLC and it is a fast and in-expensive form of optical wireless communication system, . It can be viewed as optical version of Wi-Fi which uses visible light for data transmission instead of radio waves. Li-Fi allows us to use a much larger frequency bandwidth of about 300 THz i.e., visible spectrum which is unused and unutilized than traditional Radio Frequency band (RF) with bandwidth of 300 GHz which is limited and decreasing day by day. Moreover the visible spectrum is free and does not require licensing . Li-Fi is proposed by H. Hass, and he referred it as “Data through Illumination”. According to Hass, Li-Fi can produce data speed of over 3 Gb/s for optical wireless communication. Li-Fi consists of 2 sections, mainly transmitter section and receiver section. At the transmission side Light Emitting Diode (LED) are used for transmission of data and at the receiving end silicon photodiodes are used to receive the data. The data to be transmitted is encoded in digital form i.e., “0” and “1” and the LED flickers to produce the corresponding digital signal. The flickering or switching “ON” or “OFF” of LEDs cannot be seen by naked eye as it is done rapidly in nanoseconds . The LEDs comes in different colors and the frequency of operation of the system depends only on the color. Mostly the preferred color for LED is white as its intensity is more compared to other colored LEDs and the transmission depends on the intensity and wave- length of light used . Thus, Li-Fi can truly be concluded as the technology of future for the transmission of data using light as a medium. This technology serves as a motivation to work and create different applications using Li-Fi which will be cheaper, safer and secure than the traditional Radio wave transmission system. Recently, various algorithms are developed for signal processing and Vehicle to Vehicle (V2V) communications. A nonlinear model of Partially-observed Boolean dynamical systems (POBDS) is developed with application in estimation and control of Boolean processes based on noisy and incomplete measurements. the author proposed a novel uncertainty propagation approach for multidisciplinary systems with feedback couplings, model discrepancy, and parametric uncertainty. The simultaneous estimation of state and parameters of POBDS is studied in .
In this work I have used the Li-Fi technology and ultrasonic range sensor to create a system which can detect and avoid the collision between two cars. The two cars can communicate using Li-Fi. The V2V communication ensures safety and prevents accidents. The cars designed using the proposed systems

TABLE I
ANNOTATIONS USED

S. No	Symbol	Definition
1	V2V	Vehicle to Vehicle
2	LCD	Liquid Crystal Display
3	C_i	Set of number of cars
4	d_{th}	Threshold distance
5	V_t	Velocity of sound at temperature
6	V_0	Velocity of sound at 0 degree C
7	a	Attenuation coefficient
8	T	Temperature
9	C	Rate of change of velocity with per

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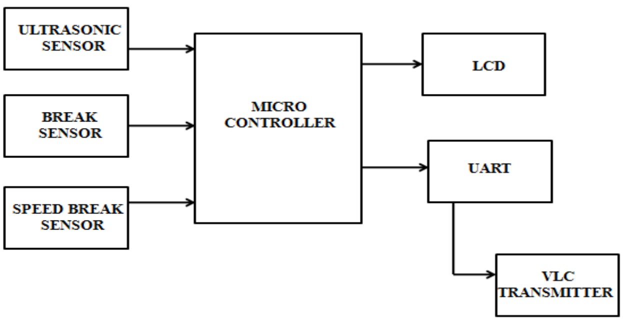
		degree rise in Temperature
10	S	Calculated speed in Km/hr
11	D	Distance measured using range sensor between two cars C_1 and C_2 in cm.
12	DOR	Degree of rotations
13	L_{TX}	Li-Fi transmitter
14	L_{RX}	Li-Fi receiver
15	L_{POS}	Last position of speedometer needle
16	S_{MAX}	Maximum speed of the car
17	DOR_{MAX}	Maximum Degree of Rotation
18	DOR_{MIN}	Minimum Degree of Rotation
19	C_{POS}	Current position of speedometer needle
20	V	Final velocity of car
21	U	Initial velocity of car
22	A	Deceleration of car (-ve value)
23	T	Stopping time of car
24	S_D	Stopping distance of car

Are known as smart cars because they can communicate and are capable to detect the problems and avoid collisions. The remainder of this manuscript is organized as follows: Section II deals with the proposed system's design for collision detection including hardware details and flow charts, Section III comprises of the algorithm of the system design. In Section IV results and system hardware design is shown and the paper concludes with Section V.

I. PROPOSED SYSTEM FOR COLLISION DETECTION

The Smart Car unlike any traditional car consists of number of sensors and complex circuitry to process real time data in order to make V2V communication more efficient and to ensure the passengers' safety. The proposed system uses Li-Fi technology to transfer the real time data between two vehicles. The annotations used in paper are shown in Table I.



Transmitter block diagram.

The Li-Fi transmitter circuitry and receiver circuitry are in- stalled in the Car represented by C_i where $i = 1, 2, \ldots, N$, for N cars. In the proposed system which will be investigated in this work, I consider the case with $N = 2$. The tail light of C_1 is equipped with Li-Fi transmitter and the front side of C_2 is equipped with Li-Fi receiver. The proposed system

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model is shown in Fig. 1. The devices and sensors which are used in the Li-Fi transmitter and receiver sections are described as follows.

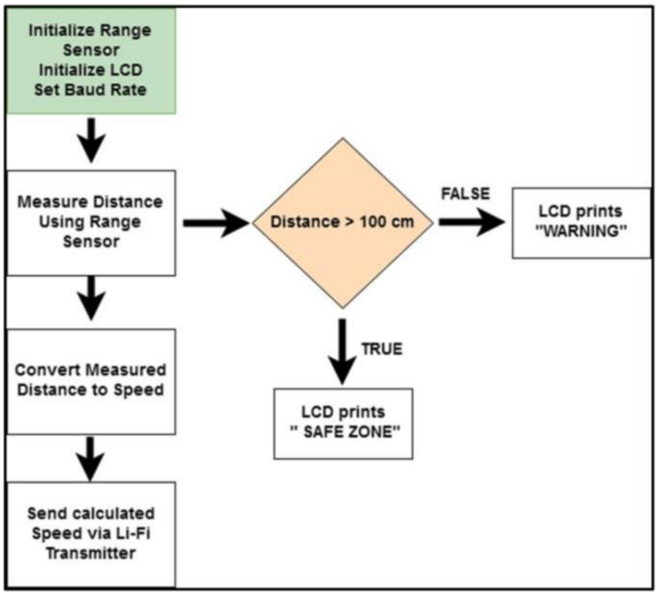
i) **Li-Fi transmitter module:** To transmit the calculated information from C_1 to C_2
ii) **Li-Fi receiver module:** To receive the information from C_1
iii) **Ultrasound range Sensor:** To measure the distance be- tween C_1 and C_2.
iv) **Servo motor:** To act as a speedometer, this will show the variation in speed.

Apart from the modules and sensor elaborated above, the sys- tem also uses LCDs, 12V Power Supply Board for the proper functioning. For the computational and data processing purposes, the microcontroller board is used. The board fetches the real time data from sensors and processes them according to the system requirements and thus acts as a central processing unit of system or the backbone of the proposed system.
The proposed system is categorized in two sub sections, namely "Transmitter" and "Receiver". The former deals with the circuitry related to the transmitter side while the latter deals with the circuitry related to the receiver side. The elaborated explanations of both the sections are described below.

The Transmitter Module

This module is equipped with Li-Fi Transmitter module, Ultra-Sonic Range sensor and microcontroller Board which in turn helps the leading car C_1 to transmit the information to following car C_2 to detect and avoid collision. The block diagram of transmitter section and its real time module is shown in Figs. 2 and 3, while the work flow diagram of transmitter section is shown in Fig. 4. When a following car C_2 approaches the leading car C_1, the range sensor installed in Car C_1 gets initialized and measure the distance between two cars. If the measured distance between two cars is less than the threshold distance (d_{th}) then the LCD display attached to the transmitter section will appear the indication "WARNING"

Transmitter module



Transmitter flowchart.

the LCD display will inform "SAFE ZONE". Threshold de- pends on several different parameters like the relative velocity between two cars and distance between two vehicles, braking safety distance, "two seconds" rule . In this work has been considered one meter as the threshold distance or safety margin between two cars due to limitation of measuring range of an ultrasonic range sensor. In this prototype, the ultrasonic sensors used to measure distance in range of 10 cm–100 cm. the measured distance values shown in Table II. The graph between the actual and measured distance is illustrated in Fig. 5. From the graph, it can be observed that the accuracy of measured distance is good as compared to the actual distance and it is almost linear.

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TABLE II

ACTUAL AND MEASURED DISTANCE

Actual Distance (cm)	Measured Distance (cm)	Accuracy (%)
10	11.23	89.04
20	21.04	95.05
30	30.96	96.89
40	40.77	98.11
50	50.65	98.71
60	60.51	99.15
70	70.36	99.48
80	80.19	99.76
90	90.14	99.84
100	100.11	99.89

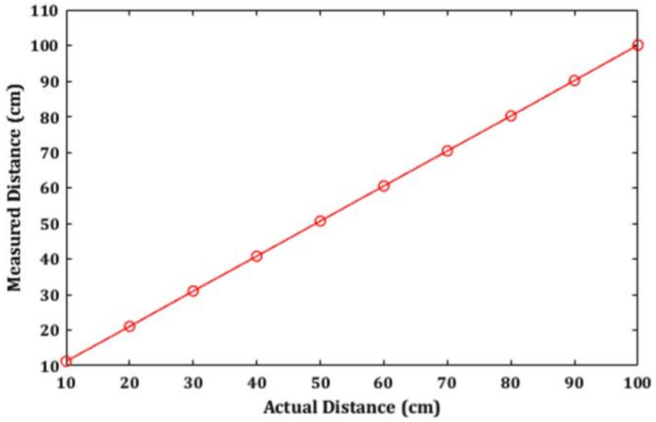

Fig. 5. Graph between actual and measured distance.

The measured distance between two cars (D) is used to calculate the speed of second car C_2 (S) by which it should move in order to avoid the collision. The calculated speed of car C_2 is transmitted to it using Li-Fi transmitter. The calculation involving the conversion of distance measured to the speed of car C_2 is shown below:

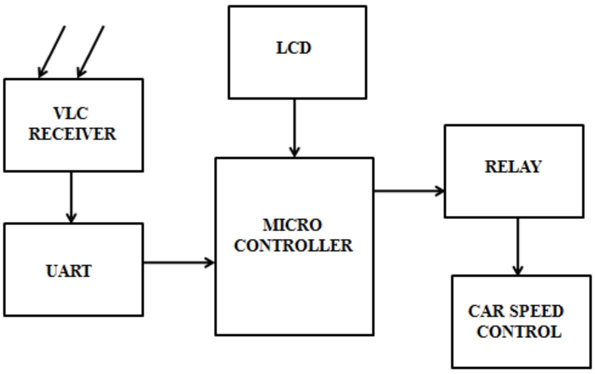

Fig. 6. Receiver block diagram.

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$$V_t = V_o\, e^{-aD} + CT \qquad (1)$$

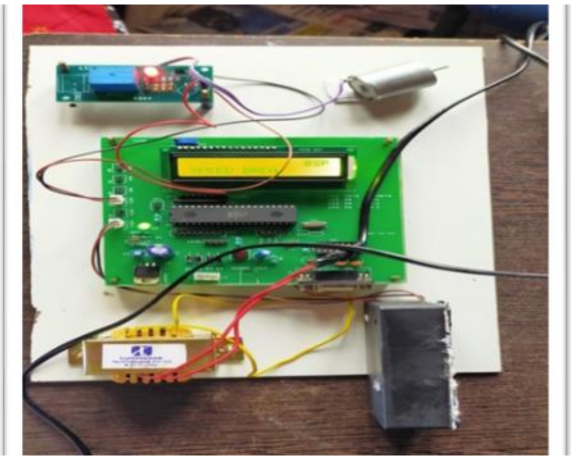
where, "Time" is the ping time from sensor

The equation which relates the conversion of distance mea- sure to the speed depends on certain factors like the maximum speed of the car allowed (In this paper it is 90 Km/hr), the safety margin between the cars C_1 and C_2 (In this paper it is 1 m or 100 cm), the precision and exactness of range sensor used. So, the equation becomes as follows.

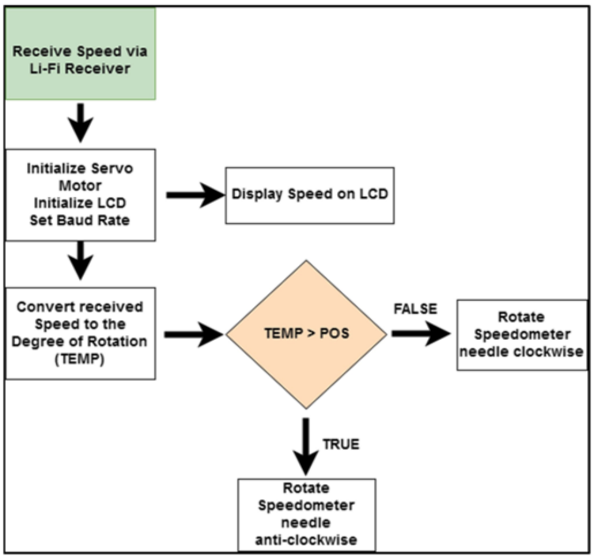
$$S = 0.9 \times D \qquad (2)$$

A. The Receiver Module

The receiver section receives the information transmitted from leading car C_1 and is installed in C_2, it is equipped with Li-Fi receiver module, LCD display and microcontroller. Servomotor act as a speedometer. The block diagram of receiver section and its real time module is shown in Figs. 6 and 7. The work flow diagram of receiver section is shown in Fig. 8. The receiver module will receive the speed transmitted by car C_1 with help of Li-Fi receiver. The servomotor, LCD display will be initialized. The received speed will be displayed on the LCD display. The speed will be converted to the degrees of rotation of servo motor using set of equations. One might ask why the speed is converted to the degrees of rotation. The answer is obvious since the servo motor is used to depict the speedometer, the needle of servo motor needs to be rotated clockwise or anti- clockwise in order to show the change in speed so that is why the speed is converted to the degrees of rotation. If the speed received is greater than the current speed of car C_2 then needle is rotated clockwise and vice-versa.



Receiver moudule



Receiver flowchart.

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The equation can be modified as per the need of the user. There are certain factors on which the equation depends like the maximum speed of the car (in this paper its 90 Km/hr), the quality and precision of servomotor used to design the speedometer. So, the equation becomes as follows:

$$DOR = 160 - (1.5 \times S) \qquad (3)$$

ALGORITHM DESIGN

This algorithm is designed to control the speed of the following car C_2. The algorithm is divided into two parts namely for Transmitter Side and Receiver Side. Depending upon the threshold distance, the calculated speed from the transmitter side is transmitted to the receiver side and according to it the speed of following car C_2 changes.

A. The Transmitter Section

Step 1: Start execution of instruction and calculate the distance using range sensor
Step 2: Check **If distance** < d_{th}
Step 3: **If Step 2 is TRUE,** Display "WARNING" on LCD **Step 4**: **If Step2 is FALSE,** Display "SAFE ZONE!" on LCD
Step 5: Convert measured distance to the speed
Step 6: Transmit calculated speed to receiver via L_{TX}

In car C_1 (transmitter side), the distance between the two cars C_1 and C_2 (D) is measured using range sensor. The measured distance value is compared with the threshold distance (d_{th}). If the measured distance is lesser than the threshold distance, the LCD displays "WARNING" else, it displays "SAFE ZONE".

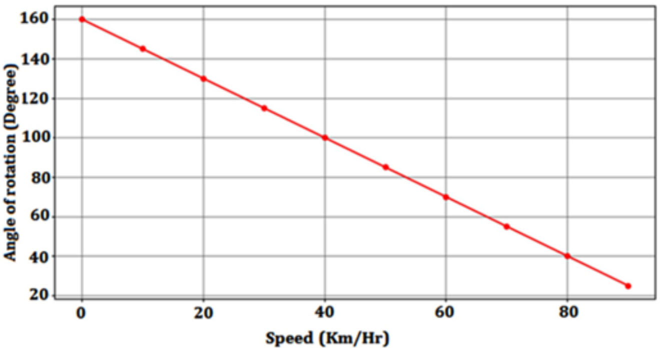
At the same time the measured distance is converted to speed using Eq. (4) and it can be transmitted to the car C_2 (receiver side). That is the speed of the car C_2 (S) will vary automatically based on the distance between the two cars.

Initializations: Set LCD, Servo motor, Baud Rate, L_{POS}, C_{POS}.
Step 1: Receive speed from transmitter via L_{RX}
Step 2: Display speed on LCD
Step 3: Convert speed to DOR
Step 4: **If C_{POS} > L_{POS} , is TRUE,** rotate pointer anti- clockwise
Step 5: **If Step 4 FALSE,** rotate pointer clockwise

The car C_2 (receiver side), receives the transmitted speed and display the value in its LCD. In the proposed prototype, the received speed is converted in to DOR to indicate the speed of car C_2. If C_{POS} is grater then the L_{POS} , the speedometer needle rotates in anticlockwise direction (that means speed of car C_2 is decreasing to avoid the collision), else the speedometer needle rotates in clockwise direction (that means speed of car C_2 is increasing since the collision chance is less).

III RESULTS AND DISCUSSIONS

The developed prototype is tested and analyzed with respect to speed versus distance and the angle of rotation versus speed using eqn. 4 and 6 respectively. Fig. 9 represents the speed of the car is controlled with the distance between the cars. From the figure, it can be observed that the speed of the car is decreases as the distance between the cars is decreasing. With respect to the developed prototype, the threshold distance between the cars is 40 cm means that the second car can maintain the speed of 35 km. That is, if the distance is equal or greater than the threshold distance then the speed changes to the maximum speed (i.e., 90 km/hr) and if the distance is less than the threshold distance then the speed will decrease linearly.



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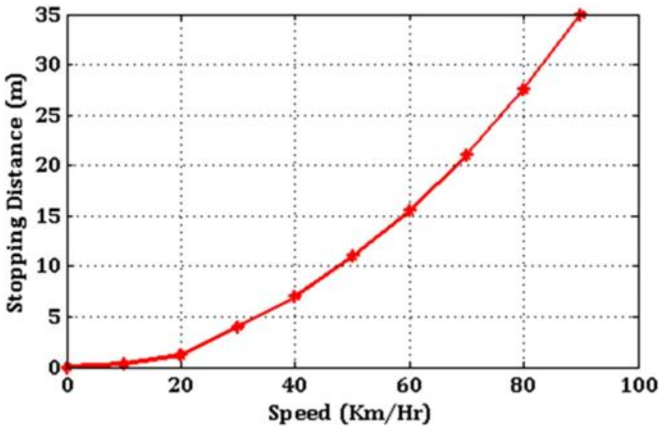
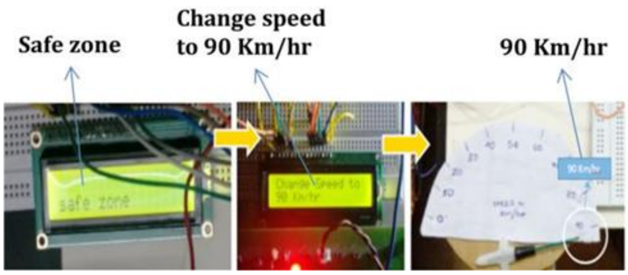
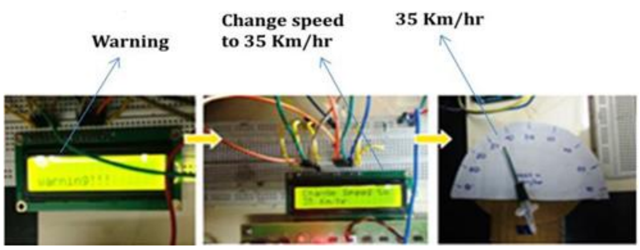




The relationship between the angle of rotation and the speed is illustrated in Fig. 10. In the proposed and developed prototype, the speed of the second car is controlled with the help of stepper motor angle of rotation. From the graph, when the speed is increased, the angle of rotation required is decreased. That is if the speed of the car is reduced from 80 to 40 Km/ hr. the angle of rotation to be increased from 40° to 100°. That is the speed is inversely proportional to the angle of rotation, when the speed is maximum the angle of rotation needs to be minimum and vice-versa. For example, when the Speed is 90 Km/hr.

The two scenarios of collision avoidance (warning and safe zone) of the proposed and developed prototype are illustrated in Figs. 11 and 12. From the Fig. 11, it can be inferred that when the cars are in danger zone i.e., the distance between the cars is less than the threshold distance (the minimum distance to keep between the cars to avoid collision) 100 cm or 1 m, then the LCD at transmitter side will show "warning" and the LCD and speedometer at receiver side will show change in speed. That is if the car C_2 is running at the speed of 90 Km/hr and the distance between the cars is reduced to lesser than the threshold distance then the speed of car C_2 is automatically reduced to avoid the collision depends on to maintain at least the threshold distance between the cars. The reduced speed of car C_2 35 Km/hr is the sample value.



Another scenario 'safe zone' of collision avoidance is illustrated in Fig. 12. From the Figure, if the distance between the cars is greater than the threshold distance, the chance of collision is very less and the cars will be in safe zone. And, the LCD at transmitter side will show "Safe zone" and the LCD and speedometer at receiver side will show change speed to 90 km/hr. That is the distance between the cars is lesser than its threshold value, the speed of car C_2 can be increased. The increased speed of car C_2 90 Km/hr is the sample value showed in Fig. 12.

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4. Theoretical Analysis

Collision avoidance plays a vital part for any collision detection system. In order to successfully avoid collision, it is necessary to know how much time a car takes to stop after detection of obstacle and the distance it travels during that time interval. These two parameters when integrated together helps in successful design of a system that is capable of not only detecting collision but at the same time avoiding it.

According to experimental evidence, it has been observed that the maximum deceleration of a car is 9 m/s^2 provided the car has an ABS system installed.

The mathematical relationship between speed and deceleration is as follows:

$$v^2 - u^2 = 2 \times a \times s\,d \quad (4)$$

Using the above relationship a graphical plot of speed vs stopping distance of a car is shown in Fig. 13. In a similar way, the mathematical relationship between speed and time can be expressed as:

$$v = u + a \times t \qquad (5)$$

Using the above relationship a graphical plot of speed vs stopping time of a car is shown in Fig. 14. As per the results obtained from Fig. 13 and Fig. 14, it can be concluded that the average stopping distance is in the range of 1 to 35 m and average stopping time of car travelling at different speeds varies in the range of 0 to 3 seconds. However the safety margin proposed in the paper is 1 meter.

IV CONCLUSION

About 1.25 million people are affected each year due to road accidents. The safety of the driver, the passengers and the public should be of primary concern in regard to various road safety measures that are being adopted by governments. Adopting a solution to prevent such fatal accidents due to inefficiency of human assisted driving is of utmost importance. With rise in technology and automation it has become possible to propose a plan to mitigate the adverse effects of Human assisted Driving. This paper presents a new and innovative collision detection system to prevent collision of cars, thereby reducing the probability of fatal road accidents. The proposed method in this paper relies on Li-Fi transmitter and receiver systems. This paper would encourage and motivate others to further explore the notion of Smart Cars and the use of Li-Fi Technology and hence, develop more efficient strategy to enhance the transmit- ting range of the Li-Fi system and propose innovative solutions to overcome the challenges due to line of sight (LOS) Communication and white light interference i.e., associated with the Li-Fi. Apart from that, the ultrasonic range sensor can be modified to increase its detection range. The proposed system can be extended to detect the Side impact collision, Lane-Change assistance or Blind-Spot detection. With proper assistance from the concerned authorities it is highly possible to implement the proposed system in the Smart Cars of the future.

REFERENCES

[1] C. Zhu, V. C. M. Leung, L. Shu, and E. C.-H. Ngai, "Green Internet of things for smart world," *IEEE Access*, vol. 3, pp. 2151–2162, 2015.
[2] H. Mahadevappa, "A study on air pollution by automobiles in Bangalore city," *Manage. Res. Pract.*, vol. 4, no. 3, pp. 2536, 2012.
[3] P. Shruthi *et al.*, "Analysis of fatal road traffic accidents in a metropolitan city of South India," *J. Indian Acad. Forensic Med.*, vol. 35, no. 4, pp. 317– 320, Oct.–Dec. 2013.
[4] T. Jiang, U. Ayyer, A. Tolani, and S. Hussain, "Self-driving cars: Dis- ruptive or incremental?" *Appl. Innov. Rev.*, vol. 1, no. 1, pp. 3–22, Jun. 2015.
[5] J. Carlin, C. Birdsong, P. Schuster, W. Thompson, and D. Kawano, "Eval- uation of cost effective sensor combinations for a vehicle precrash detec- tion system," SAE Int., Warrendale, PA, USA, Tech. Paper 2005-01-3578, 2005.
[6] S. Kulkarni, A. Darekar, and P. Joshi, "A survey on Li-Fi technology," in *Proc. Int. Conf. Wireless Commun., Signal Process. Netw.*, 2016, pp. 1624–1625.
[7] H. Haas, "LiFi: Conceptions, misconceptions and opportunities," in *Proc. IEEE Photon. Conf.*, 2016, pp. 680–681.
[8] H. Haas, L. Yin, Y. Wang, and C. Chen, "What is LiFi?" *J. Lightw. Technol.*, vol. 34, no. 6, pp. 1533–1544, Mar. 2016.
[9] C. Quintana, V. Guerra, J. Rufo, J. Rabadan, and R. Perez-Jimenez, "Read- ing lamp-based visible light communication system for in-flight enter- tainment," *IEEE Trans. Consum. Electron.*, vol. 59, no. 1, pp. 31–37, Feb. 2013.
[10] M. Imani and U. M. Braga-Neto, "Particle filters for partially-observed Boolean dynamical systems," *Automatica*, vol. 87, pp. 238–250, 2018.
[11] S. F. Ghoreishi and D. L. Allaire, "Adaptive uncertainty propagation for coupled multidisciplinary systems," *AIAA J.*, vol. 55, no. 11, pp. 1–11, 2017.
[12] [12] M. Imani and U. M. Braga-Neto, "Maximum-likelihood adaptive filter for partially observed Boolean dynamical systems," IEEE Trans. Signal Process., vol. 65, no. 2, pp. 359–371, Jan. 2017.
[13] [13] P. Bhateley and R. Mohindra, "Smart vehicular communication system using Li Fi technology," in Proc. Int. Conf. Comput. Power, Energy Inf. Commun., 2016, pp. 222–226.
[14] [14] X. Yang, J. Liu, F. Zhao, and N. H. Vaidya, "A vehicle-to-vehicle com- munication protocol for cooperative collision warning," in Proc. IEEE 1st Annu. Int. Conf. Mobile Ubiquitous *Syst., Netw. Services*, 2004, pp. 114–123.
[15] R. R. Sharma, Raunak, and A. Sanganal, "Li-Fi technology transmission of data through light," *Int. J. Comput. Technol. Appl.*, vol. 5, no. 1, pp.