Hardware implementation of fire detection, control and automatic door unlocking system for automobiles

J. Joy Mathavan
Department of Engineering Technology
Faculty of Technology, University of Jaffna
Kilinochchi, Sri Lanka
joymathavan1991@gmail.com

A.W. Faslan
Department of Engineering Technology
Faculty of Technology, University of Jaffna
Kilinochchi, Sri Lanka

N. U. A. Basith
Department of Engineering Technology
Faculty of Technology, University of Jaffna
Kilinochchi, Sri Lanka

W.V.S.D. Wanigasinghe
Department of Engineering Technology
Faculty of Technology, University of Jaffna
Kilinochchi, Sri Lanka

Abstract— **During automobile fire accidents, the lives couldn't be saved because of the failure in opening the vehicle doors. There are systems available for the detection and control of fire accidents in automobiles but those systems are designed to detect the fire, warn the drivers and operate the fire extinguishers to control the fire. The system designed in this research work tends to unlock the vehicle door automatically along with alerting the driver with an alarm and supply fire extinguishers during automobile fire. Temperature sensor and smoke sensor are used to detect the fire and different motors are used to open the door and supply the fire extinguisher. The system works even if the battery fails or the electrical system fails or the door locked manually. Since separate system is installed for each door, in case if the system of a particular door fails, the passenger can be saved by the other door.**

Keywords—automatic door unlock; accident; automobile; DHT11 temperature sensor; MQ-2 sensor for combustible gas

I. INTRODUCTION

The researchers are constantly working on fire protection in automobiles to prevent the injuries and deaths. In 2019 February, Dr. Omar Awan a 48-year-old anesthesiologist and father of five children was died when his Tesla model S car was crushed and got fire near Fort Lauderdale, Florida [1]. A police officer arrived almost immediately after the crush. This officer and another person tried to open the door of the car and save the person but failed because of the door lock design of the Tesla. They could not get him out of the car. He died because of fire and inhaling smoke/toxic gases emitted from bonnet.

In 2019 November two children were killed during a fire in Mercedes Benz G class (4x4) at Abu Dhabi. Two children left in a parked vehicle. A sudden fire incident occurred during that time [2]. Since the mother locks the door and left the car in the park, the people who saw the fire incident couldn't open the door of the car. Those children were trapped in the vehicle

and burned. Three years old and one and half years old children died in that fire accident. There are so many other fire accidents happening all over the world; but these two are the mentionable and latest fire accidents occurred. Airbags can prevent the accidents by collision; in the similar way a permanent mechanism is necessary to stop the life loss by fire accidents.

A system which can detect and control fire is necessary in such situations. That system should be able to worn the driver, operates the fire extinguisher and unlock the door automatically. During an automobile fire, if there is a system to detect the fire and alerts the driver, then, the driver and passengers have chance to save their life from the fire. Also, there must be systems to operate the fire extinguishers automatically during automobile fire incidents.

Most of the automobiles have used fire resistant material to protect the passenger compartment from engine compartment, if there is any fire accident in the engine compartment. The fire in the engine compartment emits toxic gases which can cause breathing problems and sometimes even to fatal death. If the fire is to be prevented, then likelihood direction of propagation of fire and fire-resistant material in the location has to be identified. It can also be done by dividing the car into compartments like chassis, transmission and engine. To identify the right place of fire, the system has to be programmed separately for each compartment where fire can be expected. Because normally the engine compartment temperature is very high; so the temperature detection has to be programmed for every compartment separately.

Even though the door of the vehicle can be opened manually, a person who trapped inside the vehicle fire, especially babies may not be able to open the door from inside. Because of inhaling toxic gases emitted from fire accidents, the driver or the passenger may be unconscious, and he too can't open the door sometimes. Breaking the window is also not possible all the times or it will take some time. So, a system to

automatically unlock the door during a fire in automobile is suggested in this paper.

II. LITERATURE REVIEW

Three ways are considered in past researches while dealing with the fire hazards in automobiles. Fire prevention, fire minimization and fire suppression are those three ways [3]. There are four classes of fire named class A, B, C and D. Water is the extinguisher for Class A fire. Oil-based fire is classified as Class B fire and fire occurred due to electricity is categorised as class C fire. Automobile fire can be of class B, class C or both and is extinguished by the supply of right quantity of carbon dioxide to the fire source. Fuel leakages are the top most cause and electrical system failures are the second most common cause of automobile fires [4]. If there is fire initiate in the engine, it takes an average of 4 minutes to reach the passenger compartment. Fire from rear end of vehicle reaches the passenger compartment in 2 minutes and it takes around 10 to 15 minutes for fire brigade to arrive at the scene [5]. In [6], the author showed that it took an average of 12 min to cause appreciable damage if a fire hazard occurred in a vehicle.

Every day more than 2,000 vehicles are damaged by fire accidents. Two out of every 1,000 registered cars in the UK catch fire every year. Fuzzy logic control systems along with an Arduino microcontroller system is used to address this issue [7]. Robert et al. used a system using Arduino microcontroller and fuzzy logic technology to detect fire in automobiles and to reduce the damages due to fire. Sensors like smoke sensor, temperature sensor and flame sensor were used in their research [8]. Traditionally, fire detection in automobiles are based only on heat detection [9]. But at later stage fire detectors like gas, smoke, flames and heat sensors are used to detect a fire hazard [10]. A combination of two important technologies fuzzy logic and artificial neural network (Ann) called the adaptive neural fuzzy interface system (ANFIS) is used by Barera Sarwar et al to design a fire detection control system and to reduce false alarms. It is further mentioned in their research, since the traditional fire detection systems generate false alarms, the London fire brigade has to attend a false alarm for every 10 minutes and losing around £37 million per year [11]. U.S. fire departments reacted to an average of 287,000 vehicle fire accidents every year between 2003 and 2007. An average of 480 deaths, 1525 injuries and a direct property damage of US $1.3 billion caused annually because of these fire accidents [12].

There can be several reasons for a vehicle to catch fire. High temperature of the engine, leaking fluids, a broken battery, malfunctioning fuel tank, abnormal wear of the engine or battery and high temperature of exhaust manifolds are few reasons for it. Chances of fire increase by accidents of vehicles with each other [13].

III. METHODOLOGY

This research paper is focusing on three main operations. First is detection of fire, second is alerting the driver and third is

TABLE 1. SPECIFICATIONS OF DHT11 TEMPERATURE SENSOR

Parameters	Conditions
Temperature Accuracy	±2°C
Response Time (Seconds)	6 sec – 15 sec
Power Supply	3V – 5.5V DC
Measurement Range	20-90%RH 0-50
Humidity Accuracy	±5%RH

operating the fire extinguishers and unlock the door. To the fire detection, smoke sensor and the temperature sensor is used. The specifications of temperature sensor and smoke sensor used in this research work are shown in table 1 and in table 2 respectively. Fire can be detected through the signals of these sensors. A temperature sensor and a smoke sensor are fixed on each door. MQ2 Smoke sensor is capable of sensing LPG, Smoke, Alcohol, Propene, Hydrogen, Methane and Carbon Monoxide in the air. MQ2 Smoke sensor is a Metal Oxide Semiconductor type gas sensor. When smoke comes into contact with the sensor, the sensor changes its resistance. From these values, the concentration of the gases in the air can be detected by using voltage divider network.

Specifications of SG90 9g motor is mentioned in table 3 and the picture of it is shown in Fig. 2. SG90 9g Micro Servo motor which can rotate from 0 to 180 degree is fixed on the door and it is programed to rotate for 90 degree in this research work. This plastic gear type servo motor is used as the car door lock. A metal gear type servo motor of MG996R High Torque Metal Gear Dual Ball Bearing Servo motor works on 5V is used to operate the CO_2 extinguishers. Specifications of MG996R servo is shown in table 4 and the picture of the same is shown in fig. 3. Arduino UNO is a microcontroller, connected to the laptop by type B USB cable and can be programmed. The Arduino board used here has 14 digital input and output pins and 6 analog pins. Digital I/O pins are used to light up the LED for alarm signal and analog pins are used to read the signals from temperature and smoke sensors. The Arduino programmed to get the signals from sensors and operate the servo motors. The Arduino is programmed to rotate both SG90 and MG996R servo motors when the temperature sensor reads a temperature greater than

TABLE 2. SPECIFICATIONS OF MQ-2 SEMICONDUCTOR SENSOR FOR COMBUSTIBLE GAS

Parameters	Conditions
Gas detection	Combustible gas and smoke
Concentration	300 – 10000ppm (Combustible gas)
Heater Resistance	$31\Omega \pm 3\Omega$ (Room Tem.)
Heater Consumption	≤900mW
Sensing Resistance	2KΩ-20KΩ (in 2000ppm C3H8)
Sensitivity	Rs (in air) / Rs (1000ppm isobutane) ≥ 5

TABLE 3.   SPECIFICATIONS OF   SG90 9G MICRO SERVO

Parameters	Conditions
Dimension	22.2 x 11.8 x 31 mm approx.
Operating speed	0.1 s/60 degree
Operating voltage	4.8 V (~5V)
Temperature range	0 ℃ – 55^0C

Fig. 2. SG90 9G Micro servo motor

Fig. 3. MG996R servo motor

38^0 Celsius and the smoke sensor read a reading of smoke concentration more than 400ppm. The system works only if both the conditions are fulfilled. The temperature and smoke limit values can be set according to the desire of the user. In this case, 38^0 Celsius and 400 ppm values are default values. Based on country and even within the country from region to region this value may be varied, since road side temperature of Sri Lanka, Canada and Somalia is not the same.

TABLE 4.   SPECIFICATIONS OF MG996R HIGH TORQUE METAL GEAR DUAL BALL BEARING SERVO

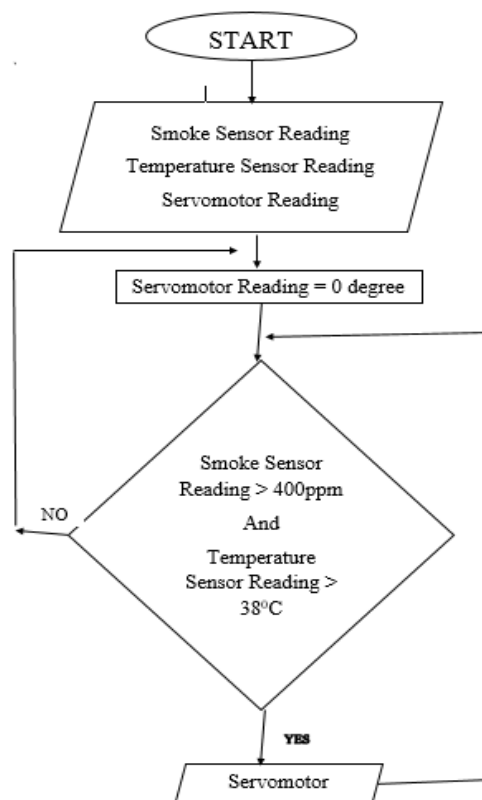| Parameters	Conditions
Dimension:	40.7 x 19.7 x 42.9 mm approx.
Operating speed	0.17 s/60º (4.8 V), 0.14 s/60º (6 V)
Operating voltage	4.8 V - 7.2 V
Running Current	500 mA – 900 mA (6V)
Temperature range	0 ℃ – 55^0C
Stall torque	9.4 kgf·cm (4.8 V), 11 kgf·cm (6 V)

Fig. 4. Flow chart of the working model

In the similar way the smoke concentration of Mumbai, Goa and Delhi is not the same. So according to the regions, based on a reference value, the limit values for temperature sensor and smoke sensor are to be set.

If fire enters the passenger compartment, the temperature and smoke concentration in the passenger compartment increases and it is felt by DHT11 temperature sensor and MQ2 smoke sensor respectively. According to the commands send by Aurdino, SG90 servo motor unlock the door and MG996R servo motor operates the fire extinguishers and the system work automatically to perform these tasks. At the same time the driver is alerted by a fire alarm; which has a sound signal and light notification at the dashboard. Since the door is unlocked and alarm is sounding, anyone around the accident spot can grab the door and open it from outside. Even the passenger inside can open it easily. This system is designed only to unlock the door automatically, and not to open the door completely. In order to achieve maximum efficiency in safety, separate systems are fixed in each door. If it is a two-door vehicle, there will be two separate fire unlocking systems. If it is four doors vehicle, there will be four separate fire unlocking systems. For most of the automobiles, the control of all doors is with the driver. If the driver is the first person to face the fire risk, he can't do anything to save others by unlocking the doors. In such case separate door unlocking systems are useful in saving the lives as fast as possible.

IV. RESULTS AND DISCUSSION

TABLE 5.   RESPONSE OF SERVOMOTORS ACCORDING TO SENSOR CONTROL

DHT11 temperature sensor	MQ2 Smoke sensor	Door Unlocking (SG90 Servo)	CO$_2$ Extinguisher (MG996R Servo)
$38^0C <$	$400ppm <$	Work	Work
$38^0C <$	$400ppm >$	Not Work	Not Work
$38^0C >$	$400ppm <$	Not Work	Not Work
$38^0C >$	$400ppm >$	Not Work	Not Work

A major problem of automobile fire accident is discussed in this paper. Very recently, a terrific accident of Bus vs Jeep occurred in Omanthai, Sri Lanka. 5 people killed and 21 got injured. It is mentioned in the news that the bus and jeep got fire after the accident and all who travelled in the Jeep were dead. It is claimed that the fire after the accident is the reason for the huge count of dead and injured people [14]. This type of hazards can be solved by attaching the new system called automatic door unlocking system to the automobiles. A servo motor is attached on the door to open it based on required commands and another servo motor is attached to supply the fire extinguisher to the fire zone. There can be babies or even people who inhale the toxic gases due to fire and felt unconscious, trapped inside the vehicle. In such situation an external person can open the door comfortably from outside and rescue their life. Since this system has individual mechanism to unlock each door, there will not be any issue in opening the doors. The conditions to unlock the door and initiate the fire extinguishing mechanism are shown in table 5. Both the systems will work only if the temperature and smoke value are above the prescribed level. If only one condition fulfilled, the systems will not work. For example, the temperature alone may increase, if the vehicle is parked so long in sun light. The smoke concentration alone may increase if passengers inside the vehicle smoke cigarettes. But these two are not fire hazardous situations. This is why conditions are designed in a way that, both the sensors should show above prescribed values in order to operate the door unlocking and fire extinguishing systems.

V. CONCLUSION

At current scenario, the above mentioned system could be one of best fire emergency door unlocking system. It can be noticed from research papers that, there is no any mechanisms available so far to unlock the door during an automobile fire situation. In current scenario, a light shows an indication in dashboard, if any door is not closed properly in automobiles. Once all the doors closed properly the system will be locked by the driver before starting the vehicle. This is to prevent the exit of passengers without the knowledge of driver in any situation. At the same time it has a negative side also. If the driver didn't unlock the system under any hazardous situation, a passenger cannot open the door to escape. In case if the driver is the first person to die or to get unconscious, the life of all the passengers is in high risk. The above mentioned system is designed to address these issues. Even if the battery fails or the electrical system fails or the door locked manually, we can have a chance to rescue those who trapped in a fire. Since separate system is installed for each door, in case if the system of a particular door fails, the passenger can be saved by the other door.

VI. FUTURE SCOPE

This system has separate battery to supply power to the proposed system and the battery has to be changed with time. When the battery voltage is low, we have to replace it with a new one. In the future, solar powered rechargeable batteries can be used for this purpose, since the hybrid technology can be used in this aspect. Or else the proposed door unlocking system can be modified to work on the power obtained from the normal car battery and not from a separate power source. But in that case, if the fire occurred from the car battery, the door unlocking system will also not work. So in such case a separate battery is necessary to open the door which is not connected with normal car battery. Flame sensor could be added in the future to increase the accuracy of the system. With little advancement, in the future, a similar system can be installed to houses and all the working places where there is susceptibility of fire hazard.

References

[1] https://www.ndtv.com/world-news/us-doctor-omar-awan-dies-in-burning-tesla-as-futuristic-doors-didnt-open-after-crash-in-florida-alle-2121767

[2] http://gulfnews.com/uae/two-children-killed-in-burning-vehicle-in-abu-dhabi-1.1573627497076

[3] N. Navet and F. Simonot-Lion, eds., Automotive Embedded Systems Handbook (industrial information technology series). boca raton, fL: CrC, 2008

[4] I. S. Wichman, "Material flammability, combustion, toxicity and fire hazard in transportation," Prog. Energy Combustion Sci., vol. 29, no. 3, pp. 247–299, 2003.

[5] Ms. Vidhy Khule, Ms. Divya Dhagate, Ms. Rajashree Kadam, ''Design and implementation of a fire detection and control system for automobiles using fuzzy logic'', International Journal of Engineering Sciences & Research Technology, April, 2017, pp 112 -119.

[6] L. halada, P. Weisenpacher, and J. Glasa, "Computer modelling of automobile fires," in Advances in Modeling of Fluid Dynamics. London: intechopen publishers, 2012, pp. 203–228.

[7] Robert Sowah, Kwame O. Ampadu, Abdul R. Ofoli, Koudjo Koumadi, Godfrey A. Mills, and Joseph Nortey, ''A Fire-Detection and Control System in Automobiles'', IEEE Industry Applications Magazine, March/April 2019, pp 57-67.

[8] Sowah R., Ampadu K.O., Ofoli A., Koumadi K., Mills G.A., and Nortey J. ''Design and Implementation of a Fire Detection and Control System for Automobiles using Fuzzy logic'', Proceedings of the IEEE Industry Applications Society Annual Meeting; Portland, OR, USA. 2– 6 October 2016

[9] Vehicle fire protection at a new level, VULCAN Project, Dafo brand AB, Swedan

[10] Ola Willstr, Peter Karlsson and Jonas Brandt, "Fire detection & fire alarm systems in heavy vehicles", SP Sveriges Tekniska Forsknings institut AB.

[11] Barera Sarwar, Imran Sarwar Bajwa, Noreen Jamil, Shabana Ramzan, and Nadeem Sarwa, "An Intelligent Fire Warning Application Using IoT and an Adaptive Neuro-Fuzzy Inference System". 2019 Jul 17.

[12] M. Ahrens, "U.S. vehicle fire trends and patterns," national fire protection Assoc., Quincy, mA, nfpA no. Uss27-01, 2010

[13] Macam S. Dattathreya, Harpreet Singh, and Omas Meitzle, "Detection and Elimination of a Potential Fire in Engine and Battery Compartments of Hybrid Electric Vehicles". Advances in Fuzzy Systems Volume 2012, Article ID 687652, 13 October 2012.

[14] http://www.hirunews.lk/235074/5-killed-in-an-accident-in-omanthai-21-injured