Smart IoT In-Car Life Detector System to Prevent Car Deaths

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Abstract. Unfortunately, many deaths are reported every year during the summer for infants, kids and pets who were left in cars and suffered from heatstroke. This paper is proposing a simple smart IoT system for in car detection of a living subject and taking the necessary actions to prevent their life loss. The system has a wide range of sensors including microwave sensors to collect a large set of data inside the car. The system will analyze the data and make the appropriate actions to prevent any death. These actions include sending an alert message to the parents and the emergency department, rolling down the windows, or starting the engine and turning on the air conditioner.

Keywords: Internet of Things (IoT) · Tree decision algorithm · Microwave · Passive infrared

1 Introduction

To prevent the number of deaths due to children being trapped in hot vehicles, an IoT life detector system is proposed in this paper. Since 1998, 37 children were killed by heatstroke per year in the United States [1]. An infant could experience un- compensable heat within 20 min, heatstroke within 105 min, and death in 125 min [2]. The heating rates of the interior of an economy car and a minivan under the sun are approximately 0.42 °C per minute and 0.30 °C per minute, respectively [3]. By detecting lives in a dangerous environment, alerting the parent and nearby emergency departments for rescue and/or acting on the vehicle, lives could be saved.

In literature, many papers discussed the detection of human lives in different situations. For example the authors in [4] used microwave sensors at 1150 MHz (L band, 1–2 GHz) to search for live people under earthquake rubble by detecting their heartbeats using the Doppler Effect. Another paper [5] discussed how they used microwaves to detect living beings by considering the movement of the rescue team around the disaster field, their microwave generator and antenna set up are similar, but they compare the feedback signals from two antennas by cross-correlation in frequency domain to eliminate the error made by the movement of the rescue team. A dynamic comprehensive model was developed in [6] to predict the rate of change in cabin temperature. They considered three main parameters; air temperature, global radiation, and wind velocity.

In this paper, rather than relying on a single sensor or situation, we will discuss how to enhance the accuracy of detecting a living being in a car. First, to detect a human life

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trapped in a car we can't use cameras inside the car to protect the privacy of the driver. Therefore, we need an alternative method. We can utilize carbon dioxide sensor, temperature sensor, microwave and passive infrared sensors to detect if the subject in the back seat is a life. Second, we can utilize smart devices and the cloud to alert parents and rescuing departments if there is a life in danger. Third, we can integrate our proposed system with the car controlling system or the Engine Control Unit (ECU) of the vehicle to take any life-saving actions such as rolling down the windows, starting the engine or turning on the air conditioner. The paper will introduce the overall idea of the smart system using microwave and passive infrared sensors and it will introduce the tree decision algorithm to send the data to the cloud. The paper will introduce the event engine system in the cloud platform that will send the alerts to the parents and the emergency department.

2 Overall System

As shown in Fig. 1 the smart IoT life detector will be implemented with four sensors: temperature sensor, CO2 sensor and two motion sensors. The sensors will monitor the atmosphere inside the car and the presence of a person inside the car. An algorithm will link between the threshold value and the human presence. We first conducted the experiment by testing each individual sensor. We then simulate an enclosed room with volume of 3000 L to replicate an enclosed car cabin. We tested our system by ourselves. If any reading went off, the system will send an alert through the cloud server and will contact the ECU unit of the vehicle to roll down the windows if necessary.

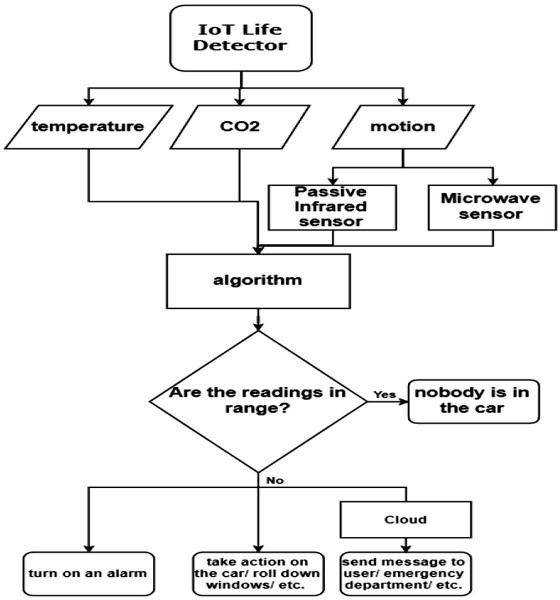

Fig. 1. Flowchart of the system

The Main system that will control the sensors will be a low power Microcontroller (MC) atmega328 that will be monitoring the readings of only one sensor and when one has an active situation it will set up an interrupt service to operate the other sensors. The sensors will be a PIR, Integrated Microwave Sensor, Temperature sensors, and SprintIR wide range low power CO2 Sensor.

A FLORA GPRS module will be receiving the emergency data and send it to the cloud application to alert the parents of a child detection in the car and a possible dangerous situation.

3 Critical Life Indicator

To distinguish between a life child and any other object placed on the backseat; we utilize sensors to make the classification. The device will have an algorithm with combination of data set that includes temperature, carbon dioxide, sound, and motion. If any reading went off, plus a life was detected, that life was in danger. Since some infants can stay silent for a long time, a combination of sensors is used to determine if there is an infant placed in the backseat. A simple algorithm can be set as if all data are in range, no life is trapped. For more accuracy of life detection, a combination of different sensor readings should be considered such as CO2, sound, and motion sensors. A temperature sensor is important too for an alert of critical temperature levels.

3.1 Temperature

An infant could experience un-compensable heat within 20 min, heat stroke within 105 min, and death in 125 min [2]. The heating rate, P of the interior of an economy car and a minivan under the sun are approximately 0.42 °C per minute and 0.30 °C per minute respectively [5].

$$T_{interior} = T_{initial} + P * t\,(^{\circ}\mathrm{C}) \tag{1}$$

Assuming room temperature is 25 °C, using Eq. 1 if an infant is placed in the backseat of a sedan, it would take 29 min to heat up the interior temperature of the car to the normal body temperature (37 °C). This means that heat will start flowing into the body in 29 min.

3.2 Carbon Dioxide

According to [6], above 1,000 ppm CO2 in air is associated with complaints of drowsiness and poor air. Between 2000 ppm to 5000 ppm, human will experience headache, sleepiness, stagnant, stale, and stuffy air. Above 5,000 ppm, toxicity or oxygen deprivation could occur. In our research, we assume the rate of carbon dioxide emission is constant, every breath out contains 4.0–5.3% of volume of carbon dioxide [7]. The average size of sedan has about 2800 L air and the Tidal volume (which is defined as the quantity of gas delivered with each breath) of a child is approximately 6 mL/kg and the respiratory rate of an infant is 30–60 breath per minute [8–10].

$$V_{CO2} = \frac{V_{tidal} * W_{infant} * R_{respiratory} * V_{\%,CO2emission}}{V_{vehicle}} * 10^6 (ppm) \quad (2)$$

From Eq. 2, assuming tidal volume of an infant is 6 mL/kg, weighs 10 kg, s/he breathes 30 times per minute, 5% carbon dioxide every exhale volume, and vehicle volume is 2800 L, the infant is adding 32.1 ppm of carbon dioxide. It would take about 31 min for the child to feel drowsy and 62 min to experience headache and sleepiness.

4 Motion Detection

Human motion could be detected by passive infrared sensor and microwave sensor. To ensure a moving object or a life is monitored, an algorithm of combination of sensors could be used. The PIR senor will be monitoring the car atmosphere at all times and will be sending to the Microcontroller unit (MC) the date to detect the presence of a human body inside the car. If the threshold of danger zone is reached the microwave sensor will be reading the body motion inside the car, as the microwave sensor has a high sensitivity of motion sensing to make sure that a human being is detected in the backseat of the car.

4.1 Passive Infrared Sensor

An integrated circuit is used to detect any object that emits infrared radiation, its algorithm returns a value of high voltage if there is an object moving. The sensor will be taking readings at a rate of 10 Hz. If it has an active reading of human presence it will operate the other three sensors to recheck the danger zone of the threshold.

4.2 Microwave Sensor

We will be using a sensor called HB100 microwave module, which is using Doppler Effect to determine the speed of an object. It emits a constant 10.525 GHz microwave, then receives a reflected signal and analyzes its frequency to determine the speed of an object. This microwave sensor is operated with a low-pass amplifier circuit. From the sensor response, we can calculate the respiratory rate of a life, it detects a movement of a surface, in our case, the chest skin.

5 Internet of Things (IoT) System IoT System

The IoT system is handling the safety control which connects between the embedded system in the car and the Internet application services that alert the parents and the police department. The system is using the GPRS module to transmit data sent through the transmitter and receiver serial cable from the main system. The Module is transmitting data using the MQTT protocol to the cloud. The module is using a simple tree decision algorithm with two integers. Integer 1 represents a critical condition is detected and the system must be triggered/activated and an integer 0 represents a normal situation with all sensor values being less than the threshold values. The integer values are updated periodically and sent to the cloud server.

The algorithm makes a decision of activating the system by using Iterative Dichotomiser 3 (ID3) which uses entropy function and information gain as metrics. In Eq. 3, the entropy H(s) is the amount of the uncertainty in the data, s is the current set for which entropy is calculated and c is the set of classes we are choosing which is yes and no. If the values are under the threshold, the entropy will equal zero and if it is high it will equal 1. In Eq. 4, the E(Y, N) is the information gain which will be measuring the difference in the entropy H(s) before and after the set N is split with the set Y. As shown, N is the subsets created from splitting N by Y.

The algorithm will compute the entropy for the sensors values. For every attribute, the entropy is calculated, then we take the average of the information entropy, calculate the gain for the current attribute and pick the highest gain and then repeat. Based on the highest gain it will give a decision of yes or no and convert it to the integer values 0 and 1, respectively. The integer values are sent to the cloud server.

$$H(s) = \sum_{i=1}^{c} -T_i log_2 T_i \tag{3}$$

$$E(Y, N) = H(s) - \sum_{i \in N} T(i) H(i) \tag{4}$$

Figure 2 shows the cloud server has an event engine trigger with an active event window, the developer can set a threshold line to that window and if the value data exceeds the threshold it will send an alert.

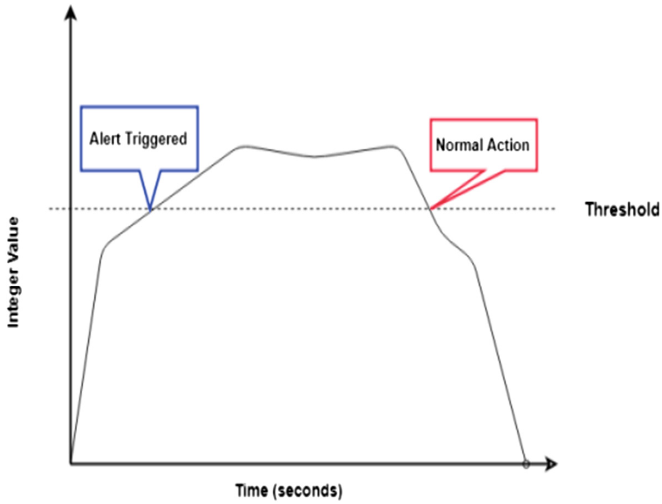

Fig. 2. Engine trigger events

The type of alert will depend on the time it took the value to cut the threshold, during the first 10 min it will send a text Message to the parents. After that period, it will send a recorded call to the emergency. To setup an automatic alert text message to be sent by the smart system for an alert, we designed an application with an action using a HTTP context value and assigned the context, device label and the variable ID, then a text message will be sent as shown in Fig. 3.

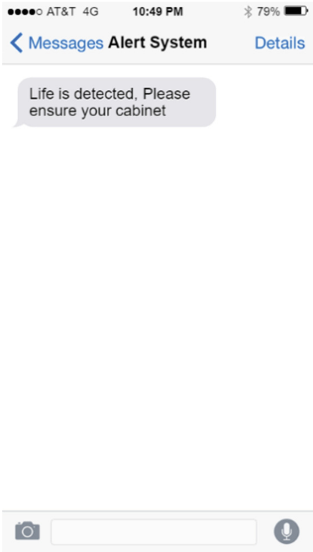

Fig. 3. Alert message system

6 Results

The designed system was tested partially and it was successful in detecting a human presence using the PIR sensor as shown in Fig. 4. Once a motion was detected, the system was activated to start checking all the sensor data and analyze them for any possible life threatening situation inside the car.

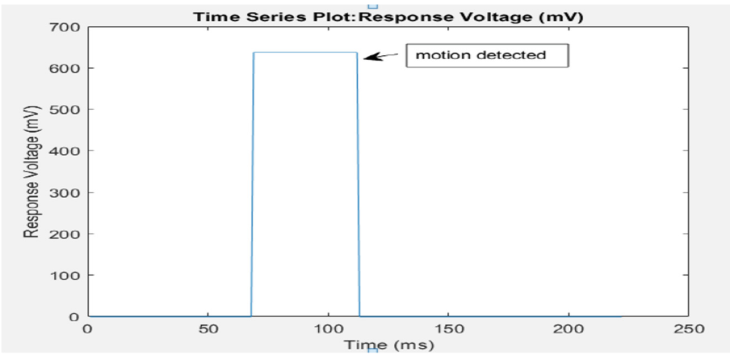

Fig. 4. PIR sensor results

The microwave sensor will be detecting the human motion in the car and insure the presence of a child before sending an alert message to the emergency department. Figure 5 shows a motion is detected within a range of time and thus the system will react to this movement inside the car. We processed the raw signal, then analyzed it with Fourier Transform. We can get the Respiratory rate at 0.22 Hz, i.e. 13.2 breathe per minute. The algorithm will send an alert after detecting motion for 30 s, an integer of a byte value of 1 will be sent over the wireless serial communication. The Server system will use the trigger engine to make an action event and send an alert through a text message to the parents and then the emergency department through a recorded voice call.

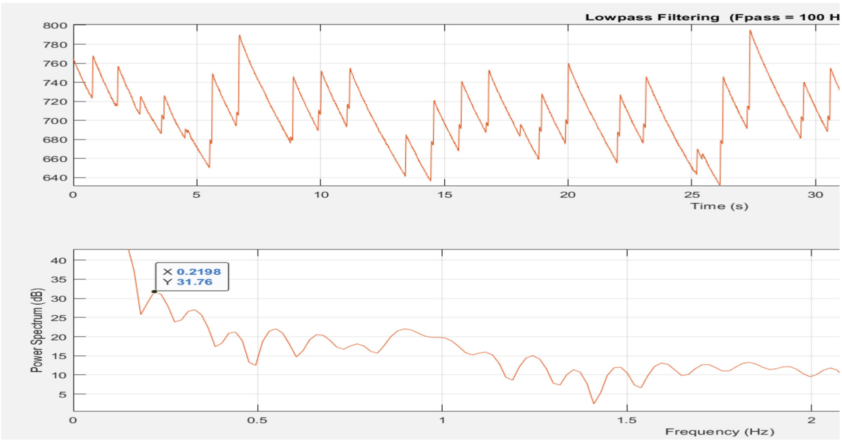

Fig. 5. Microwave Sensor results

7 Conclusion

The Smart device is designed to save children lives and make parents aware of the possible dangerous situations. The system is designed with a minimum cost and designed to be portable. The system can be integrated in any car if it is going to be used for alert purposes only and it can be built into the car system to take more actions such as controlling the AC unit and rolling down the windows to save children trapped in heated cars.

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