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IoT-Based Driver Distraction Prevention System

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Abstract. Each year, many people pass away in car accidents. Drunk driving, distracted driving, and fatigued driving are the leading causes of car accidents. Some studies have noted that the features relevant to drunk driving and fatigued driving are driver's alcohol consumption, smoking, and carbon monoxide (CO) concentration in the car. Hence, it is important and necessary to detect these factors during driving to avoid driver drowsiness and prevent car collisions. In this paper, we develop an IoT-based preventative system to monitor in-vehicle air quality and check for driver head bending. To ensure users can easily deploy the proposed system, we used low-cost sensors and tiny IoT devices to run the system. The suggested system uses low-cost gas sensors including MQ-2, MQ-3, and MQ-7 to track air quality in the car using Arduino D1. Additionally, we developed a Banana Pi camera setup to run a customized Teachable Machine model to ascertain whether or not the driver is paying attention to the road. We showcase the proposed system on the ThingSpeak cloud platform. Finally, in the proposed system, the buzzer and speaker will sound alarm warnings to the driver and occupants if the gas concentration in the car exceeds a specified value or driver distraction is detected.

Keywords. IoT, distracted driving, ThingSpeak, in-vehicle air quality

1. Introduction

Driver inattention while driving or fatigue driving often causes car collisions. Some studies have reported that when drivers use a mobile phone while driving, they are unable to immediately respond to unexpected traffic changes. Strayer et al. [10] indicated that when drivers use a cell phone while driving, reaction time to hit the brakes will be reduced. Their paper noted that 1 second of head-down mobile phone use while driving at 60 km/h is comparable to 16 meters of blind driving. Consequently, using a phone while driving increases the likelihood of traffic accidents. Other than using a phone while driving, alcohol-related influence may induce change in driving behavior making it more aggressive. In this scenario, it may be impossible for a driver to maintain a safe following distance to prevent car collisions.

On the other hand, some studies have indicated that toxic gas in a car may lead to drowsy driving. Wright et al. [11], for example, noted that low-level exposure to carbon monoxide (CO) has a severe negative impact on driver response time and driving performance. In [12], their study reported that when the driver was exposed to 100 ppm

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of CO for two hours, blood carboxyhemoglobin (COHb) levels of the driver increased by 3.4% adversely affecting driving ability. In addition, McFarland's [5] experimental results indicated that when the COHb level in the driver's blood reaches 11%, the driver's peripheral vision to avoid car collisions is reduced. In [6; 9], these studies reported that when the driver is exposed to CO concentration at 200 ppm for two hours, a driver will become fatigued and dizzy. In addition to the impact of harmful gas in the vehicle, some studies have addressed smoking while driving is inappropriate and dangerous behavior which is one leading cause of driver mortality [1].

In order to prevent car collisions, some studies have suggested driver distraction detection systems to monitor air quality in the car using gas sensors and to detect driver behavior using Internet of Things (IoT) devices. The advantage of these suggested systems is that low-cost sensors and tiny devices can be simply deployed in automotive applications. Bhardwaj et al. [3], for example, proposed a collision prevention system using MQ-3 sensors to detect drivers' alcohol consumption. If a driver is intoxicated while driving, the buzzer in their system will generate a sound until the driver stops the vehicle. Dong and Lin [4] proposed driving fatigue and distraction detection system using a convolutional neural network (CNN) to determine whether or not the driver is distracted or fatigued. In their paper, the CNN model was deployed over Nvidia Jetson TX2 for real-time driver distraction detection. While the Nvidia Jetson TX2 can be used to deal with numerous computations, it is relatively expensive for taxi or truck drivers. To cope with this problem, in this paper, we developed a driver distraction and fatigue detection system to monitor drivers' head bowing behavior and air quality in the vehicle using a variety of low-cost gas sensors and tiny IoT devices. In the proposed system, we use a MQ-7 sensor to measure concentration values of in-vehicle CO levels. Additionally, MQ-2 and MQ-3 sensors were used to detect drivers' smoking and alcohol consumption, respectively. Furthermore, we designed a web-based Teachable Machine (TM) model, proposed by Google, to recognize drivers' head bowing, and it is deployed over a low-cost device Banana Pi M+2 with a web camera. When the in-vehicle toxic gas exceeds a specified concentration value or the driver is bowing their head, a buzzer and speaker are utilized to alert the driver in our system. For better data visualization, we chose the ThingSpeak platform to monitor in-vehicle air quality and to analyze drivers' head bowing behavior. The ThingSpeak platform, a free open platform, has been applied in various IoT-related studies [2; 7; 8].

The rest of this essay is structured as follows: The suggested IoT system is described in Chapter 2, the experimental results are shown in Chapter 3, and the conclusion and future work are discussed in Chapter 4.

2. The proposed IoT-based system

In this section, we illustrate the suggested IoT system design, which includes gas sensors to monitor in-vehicle air quality and edge device Banana Pi for recognizing driver's head gestures while driving, as shown in Figure 1.

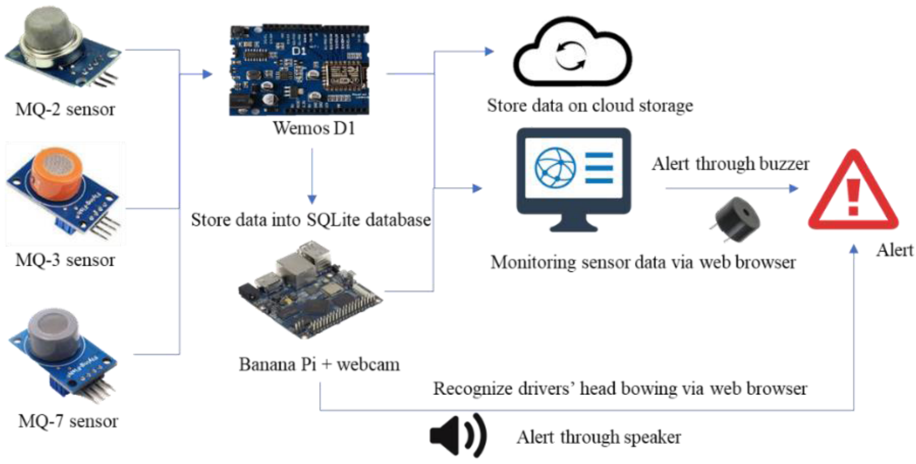


Figure 1. Proposed IoT architecture.

2.1. Sensors and IoT devices

In Table 1, we summarize the gas sensors' and IoT devices' specifications. The MQ-2 is a smoke sensor, the MQ-3 was used for alcohol detection, and the MQ-7 was used for CO detection. These gas sensors are attached to Wemos D1 microcontroller board, and the sensor data is pass to Wemos D1 through analog signal. The Wemos D1 microcontroller board uploads air quality data to the ThingSpeak cloud platform and stores into SQLite database on Banana Pi M2+. The driver's face image is passed to the TM model for real-time driver distraction detection by Banana Pi. The actual operation of the proposed system is illustrated in Figure 2.

Table 1. Sensors and IoT devices.

Sensors/IoT	Feature	Specification (units)
MQ-2	Smoke detection	Concentration range: 300 ~ 10000 (ppm)
MQ-3	Alcohol detection	Concentration range: 0.05~10 (mg/L)
MQ-7	CO detection	Concentration range: 10 ~ 1000 (ppm)
Arduino Wemos D1	Open-source platform to operate sensor and capture sensor data via analog and digital pins	Arduino UNO microcontroller; ESP-8266EX WiFi; Digital I/O pins: 11; Analog input pins:1; Input voltage: 3.3V, 5V; Current: 1A
Banana Pi M2+	A microcomputer based on ARM 32-bit processor	GPU: Mali400MP2 GPU @600 MHz, Supports OpenGL ES 2.0; CPU: H3 Quad-core Cortex-A7 H.265/HEVC 4K; Memory: 1GB DDR3; I/O pins: 40

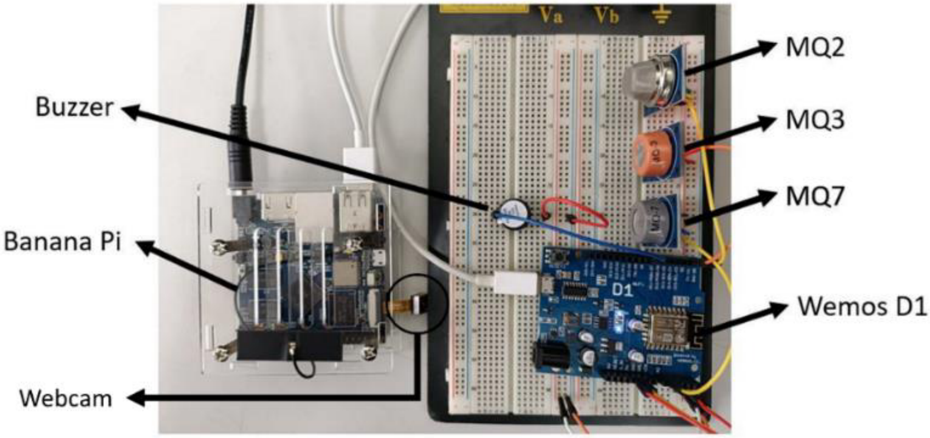


Figure 2. Actual driver distraction prevention system.

2.2. Detection of driver's head bowing

A car accident may occur when a motorist bows their head while using a cell phone or momentarily dozing off. With the help of the camera on Banana Pi, we trained the Google TM model to detect head bowing behavior in the proposed monitoring system. We used 200 head bowing (focus) examples and 200 not head bowing (not focus) examples as a training dataset to train TM model as shown in Figure 3. The TM model was iteratively trained through 50 epochs with batch size at 16 and learning rate at 0.0001. Our device emits a signal to alert the driver to maintain concentration while driving if it detects head bowing behavior.

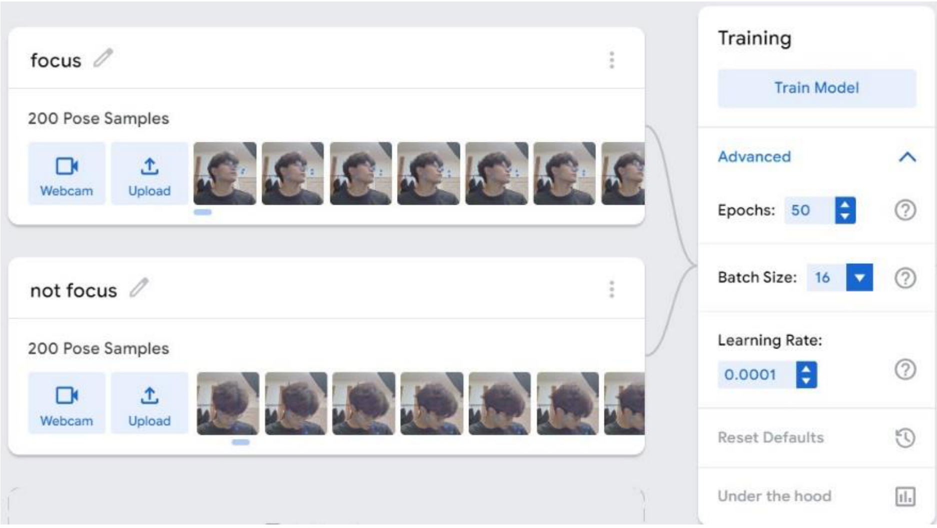


Figure 3. Training TM model.

2.3. ThingSpeak platform

The sensor data in our system was uploaded to the ThingSpeak platform and saved in a SQLite database. The sensor data was transformed into SQLite database through the serial port of Wemos D1, in which sensor data is saved in "int64" format. The ThingSpeak website created for our system features head-gesture recognition and air quality monitoring in the automobile interior. The website's monitoring of air pollutants and detection results using the TM model to identify driver's head is bowing are explained in Section 3.2.

2.4. The alarm settings

According to [6; 9], people exposed to 200 ppm of CO concentration for two hours will feel sleepy and dizzy. As a result, in the proposed system, we set the maximum CO concentration to be 200 ppm. On the other hand, when the driver is bowing their head, it represents that the driver may be using a mobile phone or dozing off. Regarding this work, when the focus or not focus score reaches 1, it indicates the driver's head is or is not bowing, respectively, in our system as depicted in Figure 4. When CO concentration in the car is larger than 200 ppm or driver's head is bowing, our system will issue a warning alert to the driver. In the future, we will collect more drivers' face images at multiple angles to retrain the TM model for side viewing detection.

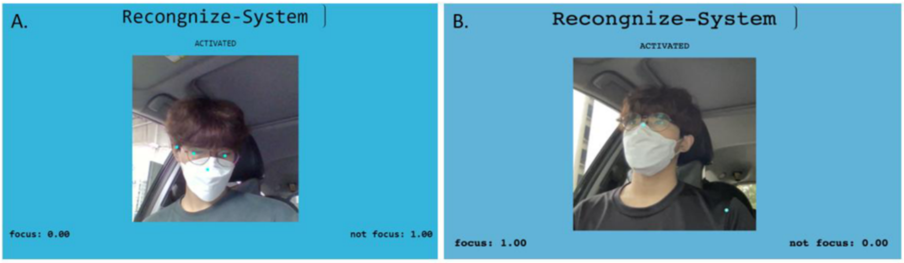


Figure 4. Driver head gesture recognition system.

3. Data acquisition and results

This section illustrates and discusses the data description and experimental findings.

3.1. Data acquisition

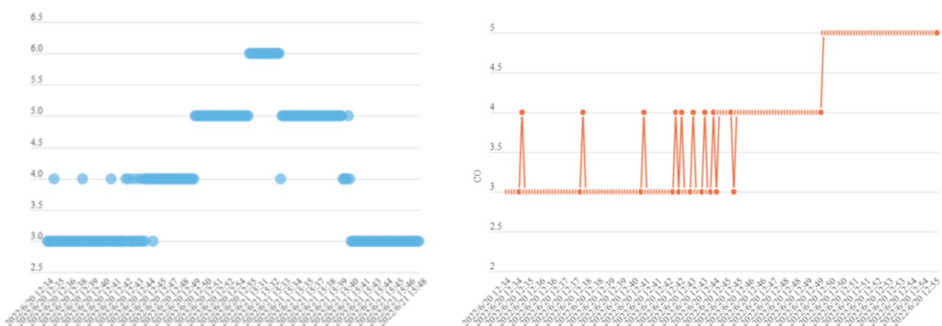
In this paper, we saved values on the sensors and head bowing times into a SQLite database as shown in Table 2. A total of 275 data between June 20, 2022 and June 21, 2022 using the suggested system was collected. The SQLite database has 275 rows and 6 columns. The columns are CO, Smoke, Alcohol, and head bowing times, respectively. The concentrations of CO and Smoke are per unit part per million (ppm). The "Alcohol" column is defined as binary classes: alcohol-negative class is labeled as class 0 and alcohol-positive is labeled as class 1 (Concentration > 0.05 mg/L). The "head bowing times" column represents the amount of head bowing behaviors.

Table 2. SQLite database data.

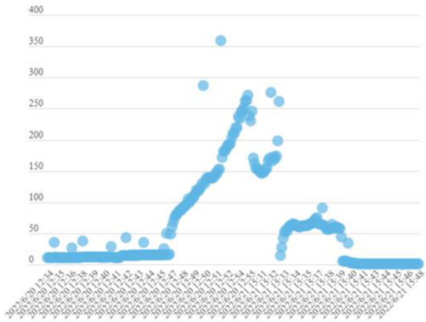
No.	Timestamp	CO	Smoke	Alcohol	Head bowing times
1	2022/6/20 12:34:19	3	11	1	5
2	2022/6/20 12:34:28	3	11	1	5
3	2022/6/20 12:34:37	3	11	1	5
4	2022/6/20 12:34:45	3	11	1	5
5	2022/6/20 12:34:53	3	11	1	5
6	2022/6/20 12:35:03	4	35	1	5
7	2022/6/20 12:35:12	3	12	1	5
8	2022/6/20 12:35:20	3	11	1	5
9	2022/6/20 12:35:29	3	11	1	5
10	2022/6/20 12:35:37	3	11	1	5
…		…	…	…	…
106	2022/6/20 12:49:17	4	100	1	10
107	2022/6/20 12:49:26	4	104	1	10
108	2022/6/20 12:49:35	4	109	1	14
109	2022/6/20 12:49:43	4	107	1	14
110	2022/6/20 12:49:51	5	113	1	14
…		…	…	…	…
271	2022/6/21 15:48:39	3	1	1	6
272	2022/6/21 15:48:48	3	1	1	6
273	2022/6/21 15:48:57	3	1	1	6
274	2022/6/21 15:49:06	3	1	1	6
275	2022/6/21 15:49:15	3	1	1	6

3.2. Results and discussion

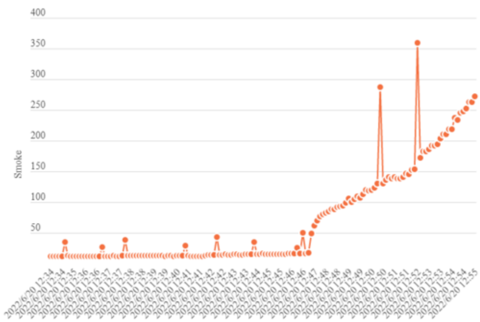
Based on the collected data, we depicted distributions of CO, Smoke, and head bowing times as shown in Figure 5 (a), (c), and (e). In Figure 5 (b) and (d), our vehicle passes through busy traffic between 2022/06/20 12:47 and 2022/06/20 12:55, and the concentration values of CO and Smoke steadily rise. Simultaneously, we tested the TM model for driver's head bowing detection. The distribution of the driver's head bowing times is illustrated in Figure 5 (e) and (f).



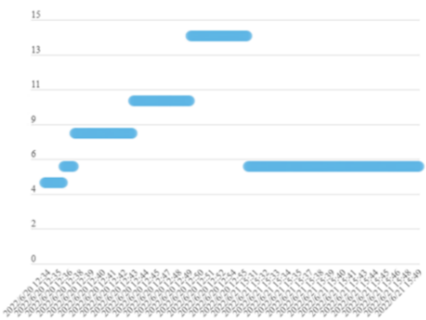
(a) CO concentration distribution (b) Rising CO concentration



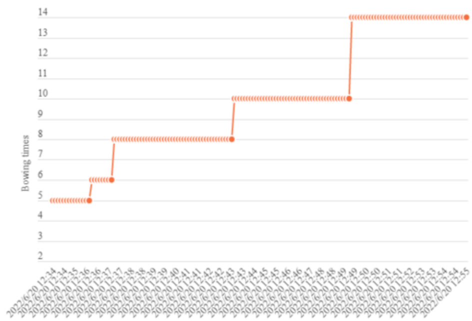
(c) Smoke concentration distribution



(d) Rising Smoke concentration



(e) Head bowing times distribution



(f) Rising head bowing times

Figure 5. Experimental results.

4. Conclusion and future work

The IoT prevention system for distracted driving we presented in this research uses MQ-2, MQ-3, and MQ-7 gas sensors to detect smoking, alcohol use, and CO, respectively. We trained a Google TM model to recognize the driving head bow motion and correctly identify and classify whether the driver is focusing attention on the road or not. Additionally, in our system, the speaker is additionally employed to provide the "o" voice warning sound, as the buzzer can only produce a sound. As for limitations of the suggested system, the designed TM model for driver distraction detection can be performed by the Internet, but when the Internet is not accessible or working, the TM model is inactive. In our future research, we consider two directions: One is using a GPS sensor to evaluate car speed to remind the driver for preventing car collisions. The other is expanding deployment of more various sensors connected to Arduino Mega and Raspberry Pi. In actual applications, the suggested system can be installed in one cab to monitor drivers' driving behavior and air quality in the car. Furthermore, those findings could be provided to governments as a reference in formulating traffic regulations.

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