Interior Vehicle Temperature and Carbon Monoxide Detector for Humans and Pets

Beatrice Smetana
BS in Electrical Engineering
Central Michigan University

Loti Ibrahimi
BSc (Hons) in the Internet of Things
Waterford Institute of Technology

Justin Lizotte
BS in Electrical Engineering
Central Michigan University

I. Introduction

On average 38 child fatalities occur in the United States from a heat stroke every year, which is about 1 every 9 days [1]. Statistics show that before 1990 there were 17 child fatalities from vehicular heatstroke [1]. Since 1990 there have been 836 [1]. In just 10 minutes after leaving a vehicle, the temperature can raise about 20 degrees [2]. Two-thirds of the heat come within the first 20 minutes after leaving the vehicle [2]. Statistics show that this is a rising concern in the United States.

To help lower the rates of child vehicular fatalities a year the team came up with the IoT device that will notify a guardian as well as take steps to help prevent the vehicle from reaching dangerous temperatures. The concept is to use heat signature sensors to detect if there is a living subject left behind in the vehicle, as well as temperature sensors to monitor the interior temperature of the vehicle.

With this data, the plan is to alert the guardian if they are a certain radius from the car and that there is a living subject detected. Also, if the vehicle is approaching dangerous temperatures, hot or cold, the car will automatically start and run the air conditioning or heat in order to correct the inside temperature. If the guardian is away from the vehicle for a substantial amount of time the authorities will be notified.

II. Concept

A. *Research*

The proper research was performed to find concepts or systems that incorporate similar design aspects. After finding relative articles, the team moved towards finalizing the concept idea and the design of the system. This process started when the team met and laid out what the system would need to do. The main goals for this project include detect a living subject, alert guardian, and take action in an emergency. After the main goals were developed the process of how the system would operate was next to be determined. This involved choosing different sensors, a way of data transmission, and how the data would be used.

From the research and data statistics, the team found out that among the 836 child vehicular fatalities 88% of the children are under the age of 3 [1]. Also in the same research article 55% of the 836 were unknowingly left behind [1]. The data and statistics for the age, and the certain circumstances that the child was left behind in the team narrow down the proper actions and features required for the system.

B. *Concept Idea*

The idea behind the development is to use the IoT device to sense a living subject that has been left in a parked car. To monitor if there is a living subject inside the vehicle, heat signature sensors will be placed strategically throughout. The heat signature sensors located throughout the cabin working in coordination with pressure sensors located in the seats will be the method to detect a living subject. By sensing body heat from the surrounding temperature and using pressure sensors to detect weight on a seat this data can be used in conjunction with each other to identify possible living subjects. Once the guardian has left the vehicle and moves outside of a 5-meter radius the guardian will be notified.

The use of a temperature sensor will verify the internal temperature of the vehicle. With that data, the system will determine if the temperature outside of a safe range for living subjects. The determined safe range for the system will be between the internal temperature of 4-24 degrees Celsius. This becomes an issue in the summer months due to the warm weather conditions. There is also a concern in opposite circumstances, with low temperatures which is why the device will correct for both.

Under normal operating conditions, the system will alert the authorities if the guardian does not re-enter the 5-meter radius outside the vehicle in an hour. If the system malfunctions or cannot protect the living subject from extreme conditions, action will be taken sooner. These cases would involve the car failing to start, running out of fuel, or simply could not reasonably correct the temperature (This could require a secondary range of temperatures to define extreme cases).

Extreme cases would be defined as the vehicles internal temperature fell below 0 degrees Celsius or rose higher than 29-degree Celsius. If any of these extreme cases occurred and the guardian failed to return, the authorities would be notified 5 minutes after the case is first detected.

The other features of the system would also monitor the interior of the vehicle for carbon monoxide. This will be monitored for cases where the vehicle is on and in an enclosed area, such as a garage. In an extreme case scenario, if unsafe levels are reached this will sound a buzzer in the vehicle and send a notification. If a living subject is detected, then action will be automatically taken by contacting authorities to send an ambulance in concern of the health of the passenger(s).

The goal for this development is to lower the amount of child vehicular fatalities each year and to prevent serious injury due to heat stroke, hypothermia, or carbon monoxide. This is being developed to allow guardians to not only react but to have the car take certain measures to correct the situation.

Estimated Vehicle Interior Air Temperature v. Elapsed Time

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Elapsed time	Outside Air Temperature (F)					
	70	75	80	85	90	95
0 minutes	70	75	80	85	90	95
10 minutes	89	94	99	104	109	114
20 minutes	99	104	109	114	119	124
30 minutes	104	109	114	119	124	129
40 minutes	108	113	118	123	128	133
50 minutes	111	116	121	126	131	136
60 minutes	113	118	123	128	133	138
> 1 hour	115	120	125	130	135	140

Courtesy Jan Null, CCM; Department of Geosciences, San Francisco State University

Fig. 1. Estimated Vehicle Interior Air Temperature v. Elapsed Time

III. Project Materials

Materials needed for this project will be:

- LEDs
- Buzzer
- Jumper Wires
- BME680 Temperature/Gas sensor
- Force sensor(s)
- AMG8833 Thermal Camera sensor(s) (to detect passengers)
- Raspberry Pi (for control)

IV. Related Work

Over the past few years, systems have been researched and developed to monitor vehicle conditions and relay that information in an attempt to solve problems of heat stroke and other hazards regarding individuals trapped inside [3-4]. These hazards are explained in more depth above. In conducting research, multiple systems have been found that monitor and correct these hazards in a few different ways. Many of these systems, especially more recently, have incorporated IoT in conjunction with sensors to send alerts to either vehicle owners or law enforcement [3-4].

After consulting these articles, the team found many similar ways of gathering and monitoring the conditions inside of the vehicle. However, these systems differ in how the gathered information is used and sent from these sensors.

In one system proposed in 2017 by Jetendra J. and other researchers [3]. IoT was used to monitor the conditions of the interior and exterior as well as the location of a vehicle. These conditions and location were then sent to a cloud database and alerts were then sent to a G.R.P.S. app relaying the data on the cloud [3]. This flow of the system is very useful for storing data of the conditions as well as alerting the proper recipients. Sending the data to a cloud first allows tracking of the conditions over time rather than just alerting only when there is an undesirable condition. This can also allow the tracking of previous events where undesirable conditions were met or instances of neglect of alerts sent. For the team's system, this information is very valuable to keep track of to identify possible repeat offenders when leaving children or pets unattended in vehicles.

Another benefit from this type of system is having the ability to send alerts to multiple recipients like the mother, father, babysitter, law enforcement, etc. This system utilizes the use of GPS to provide the location of the vehicle being monitored [3]. This information being collected is important when alerting emergency personnel so they can locate the vehicle. However, this system did not incorporate actions to be taken other than notifications being sent to determine recipients. In certain cases, alerts may not be enough and immediate actions must take place.

One other system proposed by Shyma S. [4] addresses actions to be taken in the vehicle to counteract conditions being monitored. This system used O2, humidity, temperature, PIR sensors to monitor conditions and check for passengers inside of the vehicle [4]. The data collected is then run through a flow of checks to verify if conditions are safe or unsafe and if there are passengers inside. If unsafe conditions and a passenger are detected the system activates a buzzer to alert that there is a problem and motors to roll down the windows to introduce fresh air into the vehicle [4].

This system is useful because it takes immediate action in case of unsafe conditions and passengers are detected. This, however, does not address the issue of alerting guardians or law enforcement in case of possible injury resulting from the extreme conditions. Statistics show that cracking of a car window has little effect on the overall temperature of the car approximately it only changes the temperature by 3 degrees [2]. The passenger would still be exposed to very dangerous temperatures which may result in death.

A further issue is with rolling down the windows of the car. It is a step in the right direction to take immediate action but this action leaves the vehicle and passengers vulnerable to possible theft or other implications regarding security and safety of the passengers inside of the vehicle.

V. DESIGN AND IMPLEMENTATION

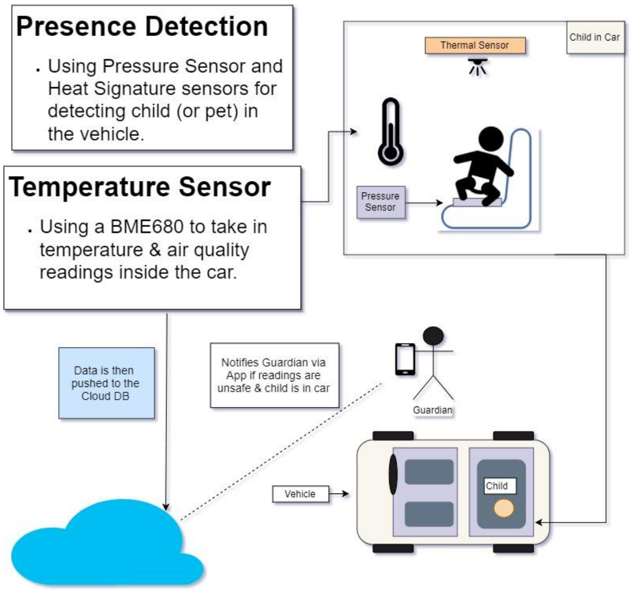

Fig. 2. Visual representations of sensors and system.

Figure 2 shows the visual representation of the setup of sensors inside the vehicle. The force sensor located in the seat. When a living subject is placed into the car the weight on the sensor will be detected. This will be the first criterion used by the system to determine if a living subject is inside of the vehicle. The second criterion is the thermal heat signature sensor. This will be strategically placed in the cabin to monitor the area in which the force sensor is located. The heat signature sensor will determine through thermal imaging if a living subject is present. If there is an area with a large cluster of high temperature or a huge temperature difference both of these things will indicate if a living subject is present.

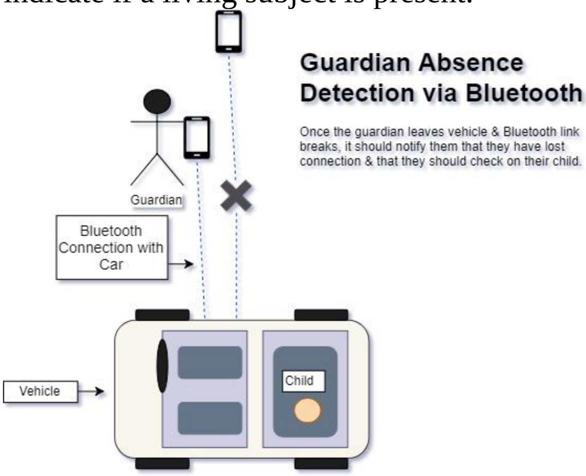

Fig. 3. Visual representation of the range detection for the guardian.

In Figure 3, the visual representation shows the connection between the monitoring system and the guardian's phone. If the guardian were to walk out of range of the Bluetooth connection, the guardian would be notified that the connection was lost and that the child or pet is still inside the vehicle.

The overall design for the monitoring system is shown in Figure 4, the connection diagram. The connection diagram gives a visual on the overall connection of the system. The four sensors that are involved in the design are all connected to the head microcontroller, the Raspberry Pi, which is connected to the car. The data transmission travel from the Raspberry Pi to the cloud, which is where the data will be stored for further instruction. The data will be used to notify the guardian that the living subject is in the vehicle, but will also store previous data to look for repeated cases. In the case that the living subject has been left multiple times will be sent to the authorities where corrective measures will be taken.

Figure 5 shows the criteria the overall system will go through in order to take the correct action to the situation. First, the indication of a living subject will be detected. The test will then go through multiple separate stages to detect the exact situation. The multiple stages are to help prevent false alarms.

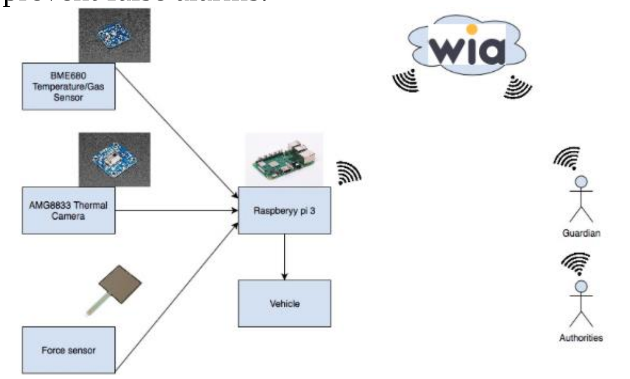

Fig. 4. Visual of parts used and connection of system.

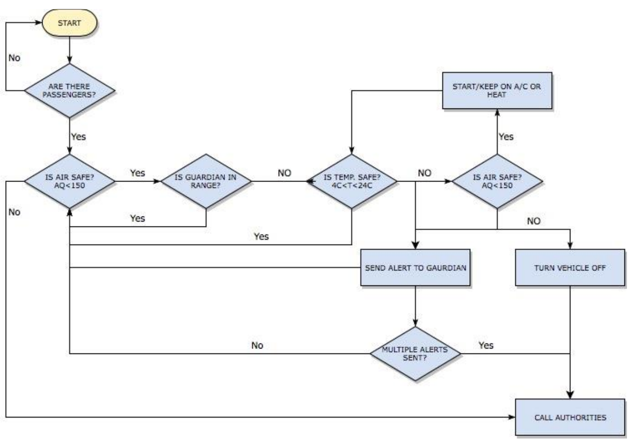

Fig. 5. Flow of the systems sensors, monitoring and emergency situations.

VI. Cloud, Notifications & Bluetooth

Wia will be utilized to post data and send notifications. Wia is an open software that allows device to communicate with one another via the cloud.

The Raspberry Pi will be registered as a device on Wia, along with a few events (data) that will also be used in order to send notifications. For the time being, notifications will be sent either via email or twitter (possibly twitter). This is all made possible using Wia.

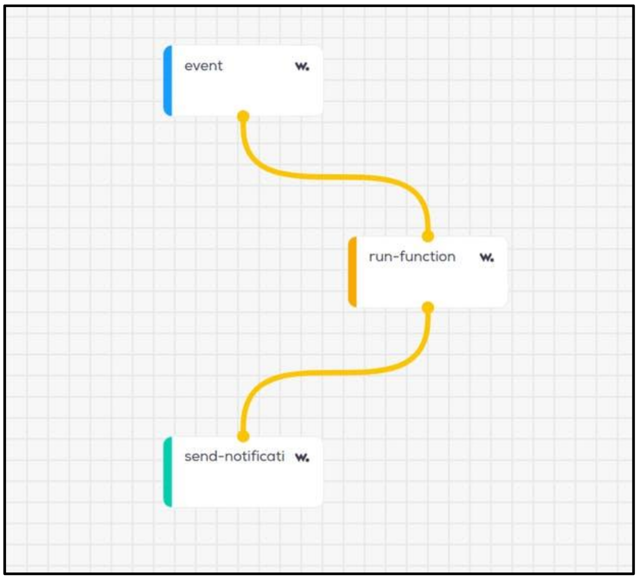

Fig 6. Wia Flow-Builder.

Wia flow builder makes the process of bringing everything together a whole lot easier. Data readings are called in as events (temperature, pressure, heat sensor etc.) which can then be passed through functions that can be tailored to carry out certain actions, actions whereby if certain events are met - e.g. if event1 (temp is above a certain value) & event2 (child detected - heat sensor/pressure sensor i.e. certain values are met) send a notification to guardian.

With regard to the bluetooth connection (proximity of guardian) & Wia, a script can be created on the Raspberry Pi itself which would have a MAC address table of known devices. This would mean if any of those devices are in range the bluetooth link would automatically be established (in other words, the guardian is 'present' & his/her phone is connected to the car). This basically means that the RPi would act as the trigger for data being sent to Wia which would ultimately lead to the parent being notified - based on the situation.

Breakdown of BLE link & Wia integration:

- ➔ Guardian in range (bluetooth link established between phone and RPi):
    - All under control.
- ➔ Parent out of range (bluetooth link not established between phone and RPi):
    - Send data up to Wia (events).
    - Data is then processed by function (to determine if child presence & if temperature is too high).
    - If 'TRUE' send notification to guardian via twitter.

VII. Testing, Results, and Evaluation

The first sensor hooked up and running for the project was the BME680. This sensor was used to measure the cabin temperature as well as monitor the air quality for carbon monoxide. This sensor was previously set up to measure temperature, humidity, and pressure. After altering some of the python code the sensor was able to calculate an air quality score as well. The air quality score uses gas detection measured by the sensor in ohms multiplied by the humidity. To accurately measure gasses in the air the sensor requires a burn-in time. During this period that can be specified in the code, the sensor takes in values of the surrounding air and calculates an average quality score. Tests for accuracy worked well for detecting an air temperature reading in the room. However, testing gas detection for carbon monoxide is fairly difficult because carbon monoxide is a gas that is dangerous for the team to introduce to the sensor without risking health problems. To overcome this a match was lit and blown out to create smoke. This smoke was detected by the sensor however this was tough to consistently test. However, this test worked well for determining if the sensor is accurately working and could pick up unclean air. The BME680 detects other gasses than just carbon monoxide, so when performing final tests smoke will be used. Overall this sensor performed well for collecting the cabin temperature and air quality and reporting it to Wia.

The AMG8833 thermal sensor was the next to be tested. The schematic and example code were easily found online. After adding lines of code to report the maximum and minimum values detected by the camera, this data could be sent to Wia. This was very successful at detecting temperature changes in the field of vision. A heated potato was used to simulate a baby or living subject. The thermal camera easily detected the potato from the background. Cold temperatures were identifiable as well. Ice and cold carrots were used during testing to simulate something with mass but not living. These values were successfully uploaded to Wia to be used in conjunction with force sensor data.

The force sensor was the last of the components to be wired to the raspberry pi. This sensor was a simple circuit where when pressure is applied to the force sensor lowers the resistance. This allowed the use of resistance values to measure if there is weight on the seat or not. The force sensor used did not fit into the bread board or wire connections. This made getting a signal sent back to the pi was difficult at times. The sensor was also not sensitive enough to lighter forces being applied. This caused a problem when trying to demonstrate the function of the device. These issues regarding this sensor and others unfortunately were heavily caused by faulty components and wiring.

Wia was a very useful platform to upload, store, and control the data that was collected to from the sensors mentioned above. Uploading the data as 'Events' and creating a 'Widget' were very user friendly ways to upload, store, and display the data being collected. Temperature, humidity, gas, air quality score, maximum detected temperature, minimum detected temperature, and force was all of the data that was sent to Wia and stored. Wia flows was more difficult to understand. Wia flows is a design platform used to build flow charts using data uploaded as events to Wia. These flows designed were triggered by the events of the thermal maximum, force sensor, air quality score, and cabin temperature. These triggers would then run commands, functions, or send alerts. The flow used for this project used a combination of the thermal maximum and force to detect a person. This was more difficult to perform than planned because the flows do not have complete design ability. The air quality score and cabin temperature were used to determine if the cabin was safe. The combination of a person and the safety of the cabin was used to determine is an email alert was sent or not.

VIII. CONCLUSION

This document covers an introduction to a problem and solution, materials used, research, related work, design, testing, and results used when designing and building an IoT device. The particular device built was a vehicle cabin monitoring and person detecting system. As stated in the introduction the main goal of this project was to design and build a device to help lower the rates of child vehicular fatalities a year. The IoT device designed notifies a guardian as well as take steps to help prevent the vehicle from reaching dangerous temperatures. The concept is to use heat signature sensors in combinations with force sensors in the seat to detect if there is a living subject left behind in the vehicle. Also a temperature and gas sensor to monitor the safety of the interior of the vehicle. The results obtained from the prototype provided insight to what issues could arise when implementing the components into a vehicle setting. They also proved that the cabin of a vehicle could be monitored and its data could be used to identify problems and create alerts. The use of IoT devices in automotive and everyday life has proved to be very beneficial. Possible devices like the one created for this project could be used in many of applications to help save lives and reduce injuries. With minor modifications and different sensors the possibilities are ever growing.

IX. RELATED WORK LITERATURE

[1]. KidsandCars [Online] www.kidsandcars.org

[2]. noheatstroke [Online] https://www.noheatstroke.org/original/

[3]. J. Joshi, V. Gujral, S. Dwivedi, & S. Devarasetty "Vehicle and passenger protection through cooperative sensor based vehicular networking." Proc. of the 2017 IEEE 4th ICSIMA, Nov. 2017

[4]. S. Sasidharan, V. Kanagarajan "Vehicle Cabin Safety Alert System" ICCCI , Jan. 2015