# Automatic Detection System for Vehicular Heatstroke Prevention

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**Abstract:**

Many children and animals had died from Vehicular Heatstroke every year. According to the "Not Heatstroke organization," 882 children have died due to pediatric Vehicular Heatstroke since 1998 in just in the US. Vehicle manufacturers have not given this tragic problem the needed attention despite the massive development of the technology of vehicles. Nowadays, the technology of vehicles has been improved by different types of systems such as Anti-Lock Brakes, Electronic Stability Control, Adaptive cruise control, Lane-departure warning system, and Self-parking which assist and protect the driver›s life during the trip. In this paper, a comparison between this system and other vehicular heatstroke detection systems will be executed. An automatic vehicular heatstroke detection system will be designed based on an Infrared Array Sensor. This system will detect any child inside the vehicle by using the Infrared Array Sensor "Grid EYE" as soon as the driver leaves the vehicle. After that, the system will activate the light and horn of the vehicle as an alarm. And then, the system will send an SMS to the driver by GSM signal. Finally, the system will send a signal to turn the air condition on only in case there is no response from the driver.

**Keywords:** Grid Eye sensor, Arduino Uno, PIR sensor, Lm35 sensor, SIM800l GSM.


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# نظام اوتوماتيكي لحماية الاطفال من الاختناق الحراري داخل المركبات

## الملخص:

**العديـــد من الاطفال والحيوانات المنزلية ماتوا نتيجة الاحتباس الحراري المتولد داخل المركبات. وفقـــا لمنظمـــة 'Not heat stroke' فانه توفي 882 طفلا نتيجة هـــذا الاحتباس خلال الفترة مـــن عام 1998 فقط في الولايات المتحـــدة الامريكية. حيث ان الشـــركات المصنعة للمركبات لم يعيروا هذه المشـــكلة الاهتمـــام اللازم بالرغم مـــن التقدم التكنولوجي الهائـــل في مجال صناعة المركبات. زودت المركبات الحديثه بالعديد من أنظمة السلامة والامان للحفاظ على حياة السائق والـــركاب ومن اهم هذا الانظمـــة (Anti-Lock Brakes , Electronic Stability Control , Self-parking , Lane-departure warning system , Adaptive cruise control) وهذا الانظمة قد تســـاعد وتحمي حياة السائق والركاب أثناء الرحلة. في هذه الورقة البحثية, قمنـــا بتصميم نظام آلي (اوتوماتيكي) لاستشـــعار الاحتباس الحراري داخل المركبات بواســـطة حساس بالاشـــعة تحت الحمراء (Infrared Array Sensor). عند اغلاق ابواب السيارة يقوم هذا النظام باستشعار وجود اي طفل داخل المركبة باستخدام حساس الاشعة تحت الحمراء, وفي حال كانت درجة حرارة داخل المركبة عالية فان النظام يصدر إنذار الســـيارة فاذا لم يكن هناك تجاوب خلال فترة زمنية محددة يقوم بارسال رسالة نصية الى السائق. وفي الاخير اذا لم هناك تجاب يقوم الجهاز بتشغيل المكيفات الهوائية للسيارة وفتح نوافذ السيارة.**

**الكلمات المفتاحية: مستشعر الاجسام الحرارية، مستشعر حركة الاجسام، متحكم Arduino، حساس درجة الحرارة lm35، وحدة الإرسال والاستقبال SIM800.**

## 1. Introduction:

Vehicular heatstroke is considered a major cause of vehicle-related deaths and these fatalities happened for children after being left in enclosed vehicles. An average of 38 death cases per year during 1998-2020. In 2019, the number increased to 53 death cases[1]. According to KidsAndCars.org over 940 children have died since 1990[2]. However, children who survived suffer different degrees of heat illnesses and degrees of permanent damages 6,4. All these stats are just in the US and certainly, this is a worldwide problem.

Heatstroke is clinically when the core body temperature reaches above 40°C and this condition is associated with central system dysfunctions such as delirium and convulsions or coma [3],[4]. It is essential that the core body temperature must maintain at 37°C and this situation is achieved by a physiological process called thermoregulation. Our bodies get their heat by metabolic process and from the surrounding environment. When the body reaches the excessive temperature (more than 37°C) this leads to a thermoregulation response. Thermoregulation response occurs in many ways mainly by sweating and water intake. 1.7 mL of sweat can dissipate 1 kcal of heat[4],[5]. This response also involves some behavioral changes such as clothes removing[5].

When the air in the enclosed vehicle reaches uncompensable heating, this leads to thermoregulation failure. The natural ability to dissipate extra heat becomes inefficient and the body core temperature begins to rise. And then heatstroke occurs when the core temperature reaches over 40°C.Heatstroke is the last level and most severe of heat illness and it is reached after few heat levels. The high temperature of the enclosed vehicle causes heat stress which is a feeling of discomfort. After that comes heat exhaustion when there is not sufficient dehydration, this is at core temperature between 37°C and 40°C. This hot temperature leads to heat stroke that causes central nervous system dysfunction, coma, and death[5],[6].

The physics behind this heat rise in an enclosed vehicle is due to a greenhouse effect. When the vehicle is exposed to solar radiation, the window glasses allow light radiation to enter the cabin. This radiation is absorbed and converted into heat by the seats and floor. Since glasses are opaque to thermal radiation, this generated heat is then trapped inside the cabin that causes this heat to rise [7].

The temperature rise rates are dependent on weather changes as well as different seasons. Cabin temperatures are maximum in the clear days (with direct radiation from the sun) and especially in summer. The maximum cabin temperatures range between 41°C and 76°C, with an average of 20°C over the starting ambient temperature with rising rate of 3.4°F per 5 minutes for closed windows and 3.1°F per 5 minutes for cracked windows(few centimeters); The studies showed that 80% of that temperature rise occurred in the first 30 mins and took 60 mins to reach the maximum temperature[4].

Infants and young children are more vulnerable to heat stroke since they have immature or less effective thermoregulationso they have lower sweat rates[5].


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They have a higher heat production rate because they have a higher surface area to body mass[3]. In addition, they do not have the capability for behavioral reaction to the change of temperature such as removing clothes, avoiding direct sunlight, or opening the windows.

Most of these cases happened when children were left in an enclosed vehicle by adults in the vehicle. According to an analysis of 171 fatalities in the US, 73% of them were children who were left by adults [8]. KidsAndCars organization demonstrated the circumstances of child vehicular heatstroke fatalities as 56% of them were unknowingly left in the vehicle and 26% got in the vehicle on their own [2].

Despite all public education and laws against leaving children alone in cars, the death rate is still the same as in previous years. This can happen to any parents because of the daily distractions, change in sleep routine, change in the way we transport children. In addition, all these can cause memory to fail at time[2]. So, we see that this problem needs to be solved using technology by designing a device that reminds the parents if they left their child or pet in the vehicle. This technology will ensure the safety of children.

## 2. Related work:

In paper [9], the author implemented a smart sear which used to prevent children from heatstroke risk. The author decided to detect the child by inserting a device inside the seat of the child. The author utilized two types of sensors which are temperature sensors and a weight sensor. The NTC temperature sensor was used to measure the temperature of the child. Also, the weight sensor is a tough switch that was integrated with the seat to detect if there is a child in the seat. A PIC microcontroller was selected as the main process unit because of its powerful features and connected with a Bluetooth module to indicate the driver or parents about the child inside the vehicle. This project was not tested in the real environment of vehicles. Also, the author did not mention how the alarm was designed.

The author in [10]represented a new method of detection for a child in a vehicle within less than 20 minutes. The author used a 24Ghz RF ISM band which has less power of transmission about 4mW. This type of wave does not affect by sunshades or clothing. The receiver sensor analyzed the reflected signals and filter only the heart rate of human pulses by specific algorithms. The breathing movements of the sleeping baby were also filtered. According to the author, this process may take around 1 – 2 to notice the unattached child only in case the observation of a significant level of motion. The author classified the detection into two methods which are Global motion recognition and discrimination small breathing patterns. The first method operates when the child is awake and moves its body. The second method works when the child is asleep. As mentioned, the reflected signals in both methods may contain noises that may lag the response time 8 – 10 seconds. In this paper, the author stated that the alarm signal may be wrong and there was no way to avoid this condition. Also,

one of the problems in this system is that the system can detect the people beside the vehicle and send a false alarm even if there is nobody inside the vehicle.

In paper[11], the authors showed a method to develop an automatic system to reduce the risk of child death in vehicular heatstroke. The authors sorted many devices which are already on the market and they presented the disadvantages of these devices. A comparison was utilized by authors between different type of sensors which are used in Vehicular Heatstroke Detection System. The comparison listed the advantage and disadvantages of these sensors (Thermal sensor, Carbon dioxide sensor, PIR sensor, Ultrasonic sensor, Pressure sensor). In the methodology of this paper, the authors highlighted criteria to select the appropriate sensor to detect a child in a vehicle on four points which are range, response time, false alarm, and cost. Each point was explained in the point of view of the authors and then the authors decided to implement PIR and ultrasonic sensors in their project. They demonstrated their project in various situations such as a child moving inside the vehicle and a child while asleep. The authors used RF as the transmitter and receiver for the alarm. In our opinion, the authors considered the cost as the first priority instead of the life of humans. Also, the used sensors are not accurate, and they may detect anybody even if it is not a human and may cause a false alarm.

## 3. Methodology:

In this section, the main components of our system will be explained in detail. We have used in our project these components: Arduino UNO microcontroller, Infrared Array grid eye sensor, PIR (A passive infrared sensor), SIM800L GSM/GPRS module, and LM35 temperature sensor.

### 3.1 Grid eye sensor:

The Grid eye sensor is based on MEMS (micro electromechanically systems), it consists of 64 MEMS thermopile elements arranged in an 8x8 grid on a single detector chip, see figure (1). Each thermopile element provides one temperature value, so we get 64 temperature output values in range (0°C - 80°C). The Grid eye sensor is capable to detect temperature and temperature gradients contactless over the entire specified area with viewing angle of 60 degrees on two-dimensional area on both horizontal and vertical directions and 7 meters maximum distance [12],[13], see figure (2).


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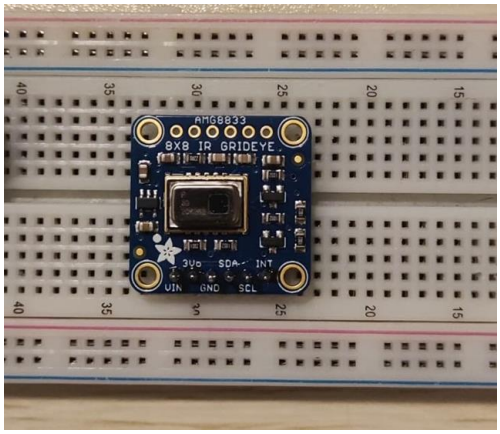


**Figure 1:Grid Eye sensor**

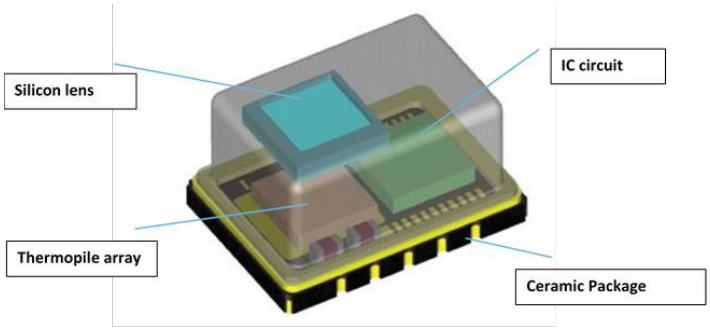


**Figure 2:Grid eye package [12]**

The thermopile array is housed in a reflow compatible Surface Mount (SMD) package consisting of an RF-shielded metal cover, ceramic base. This cover has an integrated silicon lens, that allows the infrared radiation to pass to the sensing elements (thermopile array)[12].

Grid eye absorbs the emitted thermal energy (infrared radiation) that passes through the silicon lens to the thermopile sensing elements which converts this thermal energy into a proportional output analog signals. The integrated circuit ( IC ) converts these analog signals into digital temperature values to be sent to a microprocessor [12],[13].

The microprocessor task is to format a map of the individual thermopile temperature value to obtain a binary image or thermal of 8x8 pixels, see figure (3).

Grid eye sensor can be used for human presence detection by detecting the temperature distribution. It can detect human presence in both stationery and motion positions. When a human enters the view field, the sensor absorbs the infrared radiation emitted by the human body and generates a thermal map

of it. This thermal map can be processed using some algorithms to get higher resolution [14][15].

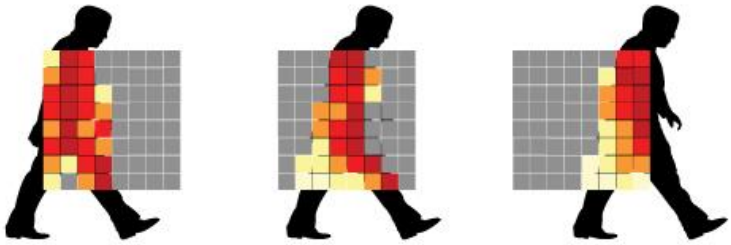

**Figure 3:Grid-EYE 8×8 Array [15]**

### 3.2 PIR sensor:

The PIR sensor is used to detect human motion when passing the sensor's view range by detecting the emitted infrared radiation from the body. It is called passive since it does not emit energy, it just detects the emitted infrared radiation from the bodies. It is small and inexpensive device that make commonly used in many applications, see figure (4).

It is basically consisting of pyroelectric sensor that generates signal when it is exposed to infrared radiation and this is the core of PIR sensor. It is covered by Fresnel lens that focuses infrared radiations into the pyroelectric sensor and expand the view range of the sensor.

In operation, the PIR sensor uses pair of pyroelectric sensors beside each other and sense the emitted radiation in the view range. When a worm body passes, it first intersects one half of the

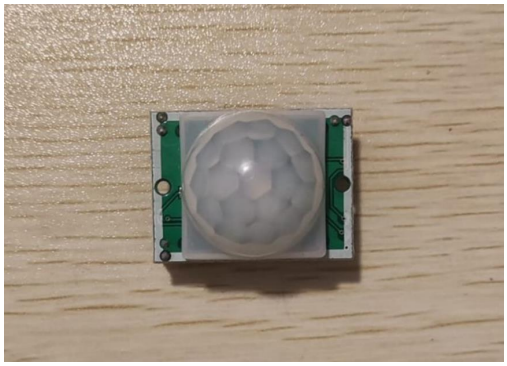

**Figure 4:PIR (passive infrared sensor)**


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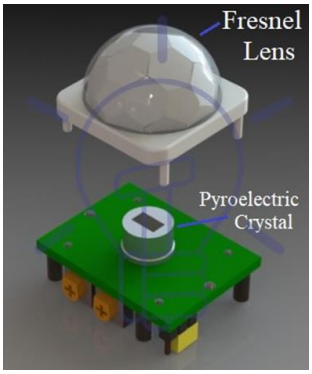


**Figure 5:PIR construction [17]**

PIR sensor (one pyroelectric sensor) that generates positive signal in one half of the PIR sensor that causes differential change between the two halves. This differential change causes the detection of moving body [16],[17], see figure (5).

### 3.3 LM35 temperature sensor:

The LM35 is a temperature sensor that can sense air temperature and provides an analog temperature value calibrated directly in Celsius. It is small and inexpensive. It can measure temperature of range between -55°C and 150°C with accuracy of 0.5°C (at 25°C). It can operate by input voltage range from 4V to 30V with recommended 5V input. It has many features such as low impedance output (0.1 Ω for 1-mA Load), low drain current less than 60-$\mu$A and low self-heating. M35 works with linear (proportional) scale factor of 10mV per 1°C. The output voltage varies by this scale to indicate the detected temperature, a change by 10mV in the output voltage pin of the LM35 sensor corresponds to a change by 1°C. We connect the output pin to analog to digital converter to get a digital voltage value. This scale will be explained in the function of thissensor[18],[19],see figure (6).

**Figure 6: LM35 Temperature sensor[19]**

### 3.4 Arduino Uno microcontroller:

The Arduino is considered as one of the most popular microcontrollers which have an open-source platform for building and developing electronics project. The Arduino Uno is categorized as a part of the Arduino series which supported

with ATmage 328 microcontroller. This board also is suitable for education and training purposes because it has IDE (integrated development environment) and it is easy to write and edit the software through a USB cable. The Arduino board can be implemented in communication projects in both wire-connection by (SPI, CAN, I2C) or wireless- connection by (Wi-Fi, Bluetooth, FM). Also, this board can be integrated into controlling processes at homes, industries, or hospitals because it can deal with different analog signals such as (heat, light, sound, pressure, humidity) and to control the output for instance (motor, light, sound). The Arduino Uno has 14 digital pins and 6 of them support PWM signals as an output. It also has 6 analog pins that are used to receive an analog signal with a range of voltage (0 - 5) DC Volt. In addition, these analog pins can be used as digital pins. This board is integrated with 16 MHz a ceramic oscillator. Finally, this board can be powered through a USB port or power port with a range of DC voltage (0 - 18) Volt [20], see figure (7).

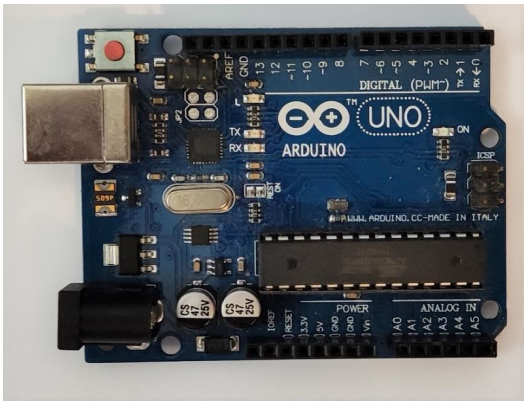


**Figure 7: Arduino Uno microcontroller**

### 3.5 SIM800L GSM/GPRS module:

The SIM800L module is a mini-GSM modem that can be used for sending and receiving SMS, making, and receiving voice calls as well as connecting to internet through GPRS, TCP/IP. It is commonly used in projects that need long range connectivity.

The SIM800L module is constructed of SIM800L GSM cellular chip (from SimCom company) with operating voltage between 3.4V and 4.4V. It supports the four major GSM frequencies bands (quad-band GSM/GPRS) that enables it to work anywhere in the world. It usually includes antenna to connect it to a network. It can connect to any global GSM card with 2G SIM 18.

It has a LED on the right top of it that shows the state of the cellular network. The LED has three blinking states that indicate to the SIM800L module status. If it blinks 1blink/second means the module is running but has not connected to the network, 2blinks/second means the module is connected to the network and 3blinks/second means that the module contacts the network and it ready to send and receive SMS and calls[21], see figure (8).


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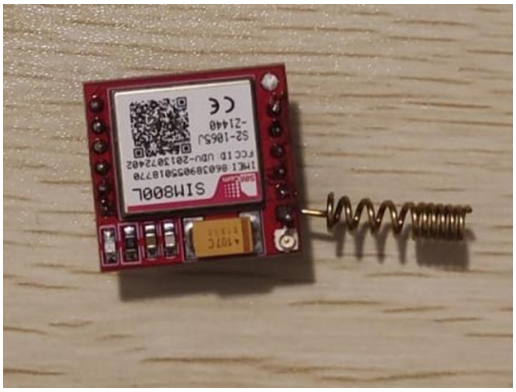


**Figure 8:GSM module**

## 4. System hardware design:

In this section, functionality of the hardware parts will be explained. The block diagram of the system will be shown and how the different parts in the system relates to each other. Finally, the circuit diagram and wiring of the system will be attached at the final of this section.

### 4.1 Block diagram of the hardware design:

In our project, we used four different types of sensors which are (Grid eye sensor, PIR sensor, LM35 temperature sensor, and door and engine sensor) as input for our project. Each sensor has its own functionality in the system for example gird eye sensor is responsible for detecting a stationary body by its thermal image such as a sleeping child has a lower probability to make a noticeable move that can be detected by motion sensor. So, the child can be detected by grid eye sensor. The PIR sensor is used to notice any motion body inside the vehicle just in case only if the grid eye cannot find the thermal image of that unattained body. The temperature sensor has an important rule which measures the temperature of the air inside the vehicle and indicates whether the child is in danger or not. Finally, (door) sensor is not a real sensor, but it is a signal which can be taken from the main CPU inside the vehicle through CAN bus. On other hand, the output of our system is an alarm. The Alarm parts are sound, light, and SIM800l GSM/GPRS module. Sound and light induction are implemented by LEDs and buzzers. The SIM800l GSM/GPRS module is integrated into our project to send an SMS alarm to the driver to remind him that a child is in the vehicle. At the end, the Arduino Uno is the main microcontroller in this system. The block diagram of the system is shown in figure (9).

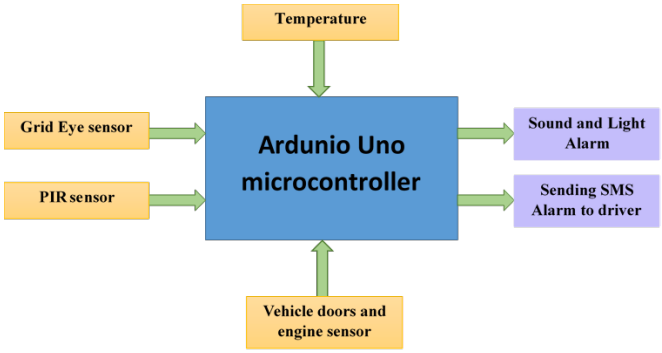


**Figure 9:Block diagram of the hardware design**

## 4.2 Circuit diagram of the hardware design

In figure (10), the circuit diagram of our system is presented. We used fritzing software to construct the circuit and the wiring. This software is an open source to build or develop design electronics hardware by CAD software. This software was explored at the University of Applied Sciences Potsdam[22]. As shown in our circuit diagram, The LCD was used only for monitoring the operation of the system.

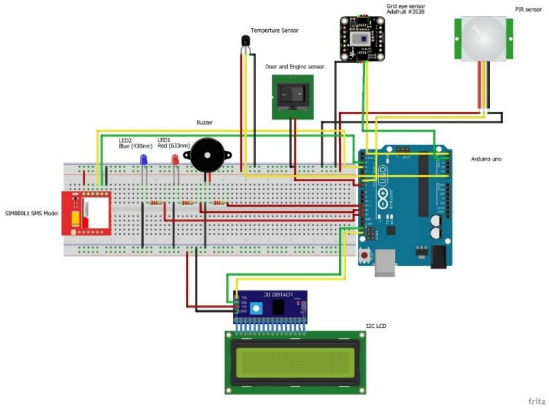

**Figure 10:Circuit diagram of the hardware design**

## 5. System software design:

In this section, the software of our system will be stated. Our system is operating based on four main parts which are: the system algorithm, Grid Eye sensor algorithm, PIR sensor algorithm, and LM 35 algorithm. Each part of our system has its algorithm which will be explained in this section.

### 5.1 System algorithm

In the flowchart shown in figure (11), full operating system algorithm is presented. At starting point:


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- Grid eye sensor starts to scan for the thermal image and check whether this image for a human or other object.
- If the thermal image for a human, the system will start to measure the temperature inside the vehicle. If not the PIR will start to detect if there is any motion inside the vehicle.
- If the inside vehicleair temperature reaches 32 °C or more, the system will check the door and engine signal if it is on or off.
- If the door and engine are closed, the system will give an alarm and send SMS to the driver and not stop alarming until the door is open.

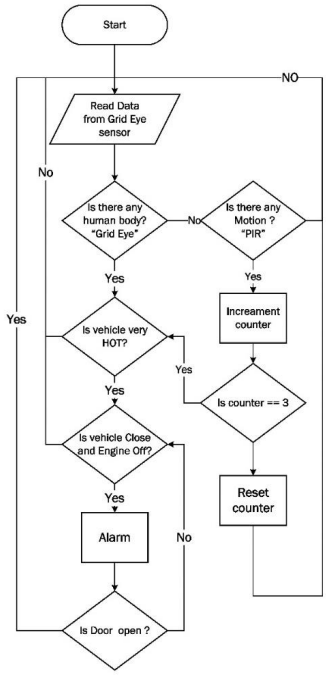


**Figure 11: Flow chart of System algorithm**

## 5.2 Grid Eye sensor algorithm:

In the flowchart shown in figure (12), Grid Eye sensor algorithm is showed. At beginning:

- Grid eye sensor begins to scan the thermal image for the area with a view range of 60 degrees and a length of 7 meters in the view.
- The sensor converts this thermal image into 8*8 pixels and sends this data to the microcontroller.

- The microcontroller processes the data. We will make a scale for the temperature values of range 0 Co - 80 Co of each pixel. The scale is 1:20 for each pixel. So, the temperature in range (0Co - 20Co) will be ranged (0-1), temperature range (20Co - 40Co) will be ranged (1-2) and temperature range (40Co - 80Co) will be ranged (2-4).
- The human body infrared radiation is in the scale range 1-2 (temperature range 20Co- 40 Co).
- The microcontroller counts the pixels within value range 1-2 if it counted more than 5 pixels in this range. The flag means more than 5 pixels in the thermal image with temperature range 20Co- 40Co.
- When the sensor detected a flag, we set a timer for 10s to check whether this flag will maintain within the temperature range 1-2 during this time.
- If the flag maintains in the temperature range during the time, we set an increment to repeat the same steps 10 times (the steps are to check the existence of the flag then check if the flag will maintain in the temperature range during the timing).
- If the counter counts 10 times, the algorithm will indicate there is a human body inside the vehicle.
- This step is to ensure that this flag is for the human body since the human body is always in this range over time. if this flag is for any other source of temperatures such as black bag (bags emits temperature just during hot days) and its temperature increases very fast during this weather that allow the sensor to differentiate these emitting bodies from human by the speed of temperature change.
- We set the flag to be more than 5 pixels of temperature range 20℃- 40 ℃ Since we determined that the human body is detected by more than 5 pixels according to our experiments. And this number can be changed by changing the distance of the sensor from the body position so we can set the number of pixels by trying it on a real vehicle.


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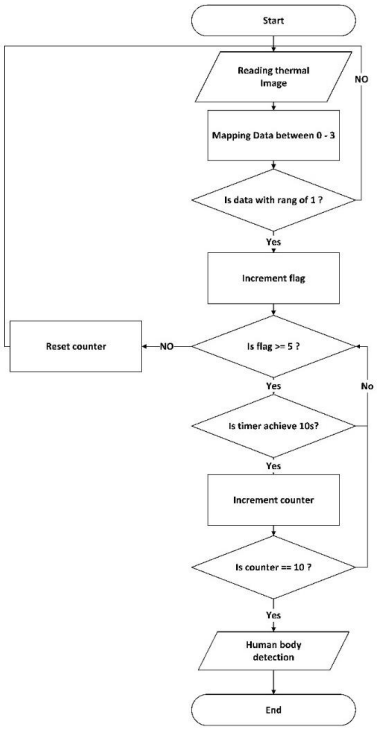


**Figure 12:Flow chart of Grid Eye sensor algorithm**

## 5.3 PIR sensor algorithm

In the flowchart shown in figure (13), PIR sensor algorithm is stated. At the beginning:

- PIR sensor detects any motion inside the vehicle.
- If there is a motion, the microcontroller starts to set a counter and start to count 3 times or more.
- If the counter reaches 3 times or more within a time of 60s, the algorithm will indicate of a human body inside vehicle.
- If counter counts 2 times or less within a time of 60s, the algorithm will reset the counter and start over.

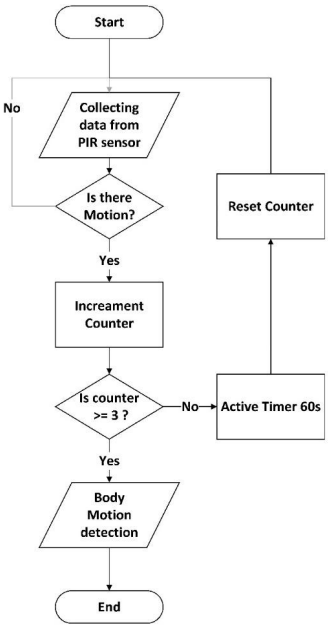


**Figure 13: Flow chart of PIR sensor algorithm**

## 5.4 LM35 temperature algorithm

In the flowchart given in figure (14), LM35 temperature sensor algorithm is shown and figure (15) shows Characteristics of LM35 Temperature [23]. At the beginning:

- LM35 temperature measures the air temperature inside the vehicle and sends data to the microcontroller as a voltage with amax output of 1.5 Volt see figure (14) [23].


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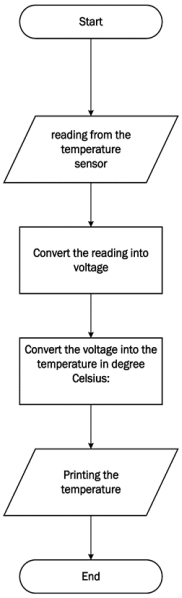


**Figure 14: Flowchart of LM35 temperature algorithm**

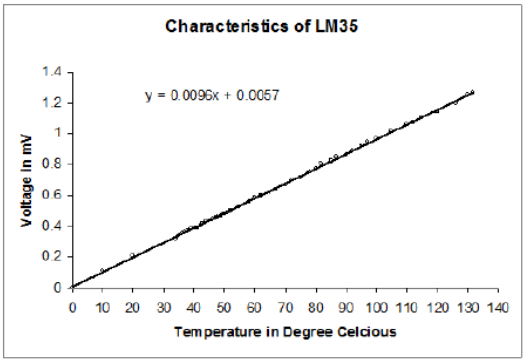


**Figure 15: Characteristics of LM35 Temperature [23]**

- The $2^{10}$ -bit ADC register coverts the sensor voltage to a value by equation (1) which is around 307 when voltage is 1.5 Volt.

$$\text{Arduino analog pin} = \frac{\text{sensor voltage}}{5} * 1023$$

**Equation 1: Converts sensor to ADC value**

- The microcontroller converts the value 307 to temperature in Celsius by equation (2).

$$\text{Celsius temperature of LM35} = \frac{\text{ADC value}}{307} * 150$$

**Equation 2: Converts ADC value to temperature in Celsius**

## 6. Main functionality of the system:

In this section, we will explain the functions after testing our system. This system has different functions which are:

6.1 No human inside a vehicle:

In this state as seen in figure (16), we tested our system and no human in front of the sensor. As seen on the LCD,

- The air temperature is 27 Co
- Grid eye is OFF.
- PIR is OFF.
- Doors of vehicle are ON (which means is OPENED)
- In this case the system will not activate the alarm since the conditions are false.

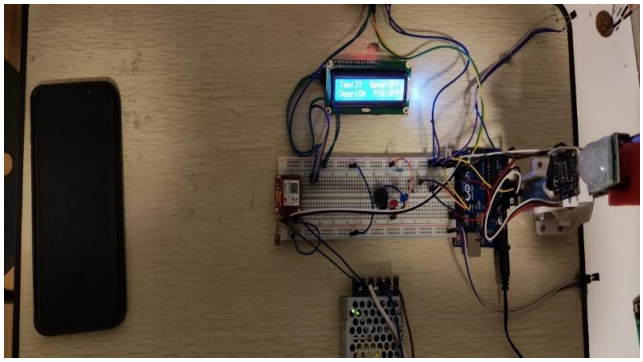

**Figure 16: System with no human inside a vehicle**

### 6.2 Human inside a vehicle but not moving:

In this state as seen in figure (17), we tested our system and human but in a stationary condition. As seen on the LCD,

- The air temperature is 32 Co
- Grid eye is ON.
- PIR is OFF.
- Doors of vehicle are OFF (which means is CLOSED)


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- In this case the system will activate the alarm since the conditions are true.

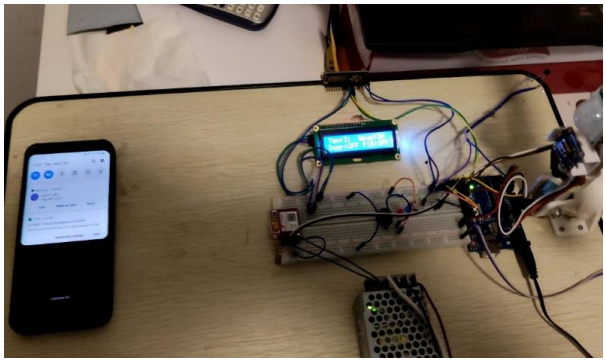

**Figure 17: System with Human inside a vehicle but not moving**

### 6.3 Human inside a vehicle but moving:

In this state as seen in figure (18), we tested our system and human moving in the vehicle. As seen on the LCD,

- The air temperature is 32 Co
- Grid eye is OFF (this can be on with time since grid eye sensor can detect moving and constant body).
- PIR is ON.
- Doors of vehicle are OFF (which means is CLOSED)
- In this case the system will activate the alarm since the conditions are true.

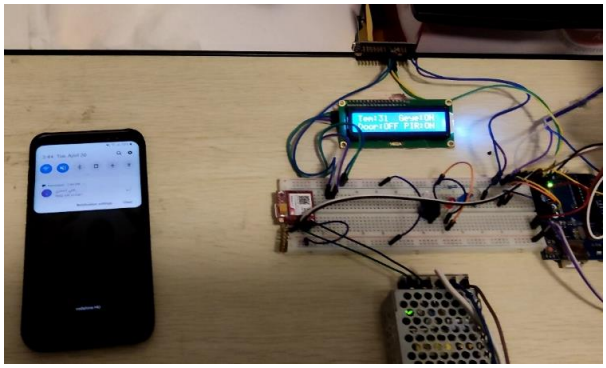

**Figure 18: System with Human inside a vehicle but moving**

### 6.4 Doors of the vehicle opened:

In this state as seen in figure (19), we tested our system and human but in a stationary condition. As seen on the LCD,

- The air temperature is 32 Co

- Grid eye is OFF.
- PIR is OFF.
- Doors of vehicle are ON (which means is OPENED)
- In this case it will not activate the alarm since the doors are open.

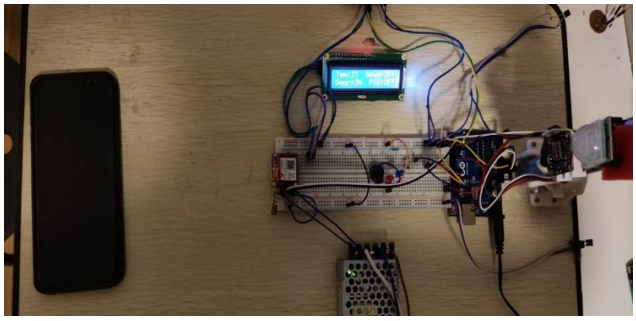

**Figure 19: System with Doors of the vehicle opened**

## 7. Conclusion:

In conclusion, this project is a system for the prevention of heatstroke in children. A Grid Eye sensor was applied to detect any human body inside a closed vehicle in a stationary state. Also, PIR (Passive infrared sensor) was used to notice motion that was not detected by the grid eye sensor. An alarm was designed to warn using sound and flashlight as well as send warning SMS to the driver.

## 8. Future work:

The future work is to covert this system into PCB (Printed Circuit Board) and to implement it in a real environment inside a vehicle. A machine learning algorithm will be added to the system to increase the efficiency of detection by the gird eye sensor. In the end, high-performance microcontrollers such as (raspberry pi 4, Nvidia jetson nano, or STM32F7) will be integrated to improve the response of the system.

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