Human Detection Sensors for Car Post-Locking Child Presence Detection System

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Abstract – This project presents the use of human detection sensors for Post-Locking Child Presence Detection system. The aim of this project is to detect the presence of humans, especially children left unattended in cars. The system is made up of a sensing unit which consist of human detection sensors such as Passive Infrared (PIR) motion sensor, MEMS thermal sensor, and a built-in microphone, that runs on an Arduino Uno microcontroller. The MEMS thermal sensor works through temperature differentiation, PIR sensor detects motion and the built-in microphone detects voice through frequency selection. The human detection sensors are the initial triggers for the Post-Locking Child Presence Detection System. The system is effective in detecting presence of humans in the car which can lead to the reduction of child left unattended cars.

Index Term – Passive Infrared (PIR) motion sensor, MEMS Thermal sensor, built-in microphone, Arduino Uno microcontroller, Field Programmable Gate Array, Human Detection Sensors, Monitoring Unit, Triggering Action, Alarm Mechanisms

I. INTRODUCTION

There has been a rise in the number cases of children being left unattended in cars. In January of 2014, a child was found dead after being left by his father inside their car. The child was left starving for nine hours [1]. In another reported incident in Subang Jaya, a three-year old child was left for five hours in a school park which resulted in her death [2]. A nonscientific media survey was done between 1998 and 2009 by Jan Null of San Francisco State University found out that fifty one percent of the incidents, parents or caretakers forgot the child was still in the back seat of the car and another 30%, the child was playing unobserved in a parked car and became trapped. Only 17% of the cases resulted from caretakers intentionally leaving behind their child in the car [3]. The interior temperature of a car parked facing the sun on a day in the low 80°F may reach 110°F within 45 min[4]. A child may suffer fatal hyperthermia (heatstroke) if left prolonged under these conditions. A child's body have less surface area relative to their volume, this means, there are less skin to dissipate heat [5]. The hot and sunny weather of Malaysia would add more towards the problem since it would speed up the process of suffocation. In addition to that, it is very unsafe to leave a child unattended due to the high number of kidnapping cases. Therefore, it is important to find a viable solution to overcome these problems.

At present, there are a few child reminder products like Baby Alert International, Inc's "ChildMinder® Smart Clip System car" that detects the presence of a child through a safety clip[6]. Another product from the same company, "ChildMinder Smart Pad System" that differentiates the pressure applied to the sensor [7]. These types of sensors work well but are only limited to children specifically babies that are small enough to seat on a baby seat. This would not solve the problem for children at higher age or without baby seats. Furthermore, these type of devices require considerable effort from the caretakers to ensure correct positioning and, even then, the devices are still inconvenient and unreliable [3].

The aim of this project is to design a sensing unit that uses human detection sensors which would detect these children automatically and alert fellow drivers from leaving the car. This report presents the implementation of human detection sensors, which includes a Passive Infrared (PIR) motion sensor, MEMS thermal sensor, and a built-in microphone. The human detection sensors will trigger a monitoring unit that would be incorporated with an alarm mechanism which consist of an automatic power-window, a notification through Short Message Service (SMS) and a-built in car alarm made up of a buzzer. This approach was taken to promote maximum security for children at any range of age without any hassle. Fig. 1 shows the general overview connection of the sensing unit to the whole system

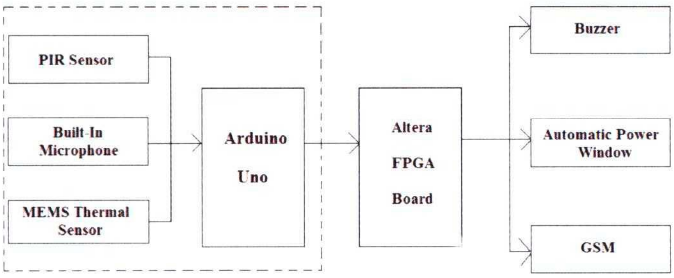

Figure 1. General overview connection between sensing unit for the Post-Locking Child Presence Detection System

The human detection sensors are considered as the sensing unit for the "Post-Locking Child Presence Detection System" is an interfacing between hardware and software. The human detection sensors are processed by an Arduino Uno microcontroller. The core language that is mainly being used by the Arduino is C computer programming language but may also read C++ languages as well[8]. A great advantage is to have the hardware platform set up within the Arduino already. This allows programming and serial communication over USB which is simple enough and easily maintained for future improvements [9]. Arduino Uno microcontroller was chosen mainly because it has an on-chip resource that can achieve a higher level of integration [10] and reliability at a lower cost. For such a project, costing is essential to promote usability by consumers. Built-in resources increase reliability because they do not require any external circuitry to be working for the resource to function. Microcontrollers generally can be classified into 8-bit, 16-bit, and 32-bit family based on the size of their arithmetic and index register. The ATmega328 chip found on the Uno has a Flash memory of 32k which although seems small, works well considering the human detection system does not take up much space. Microcontroller has a Central Processing Unit (CPU) [11], in addition with a fixed amount of RAM, ROM and other peripherals all embedded on a single chip. Today different manufacturers produce microcontrollers with a wide range of features available in different versions. This is a suitable base to implement alongside this system which requires a very powerful and fast microcontroller.

II. METHODOLOGY

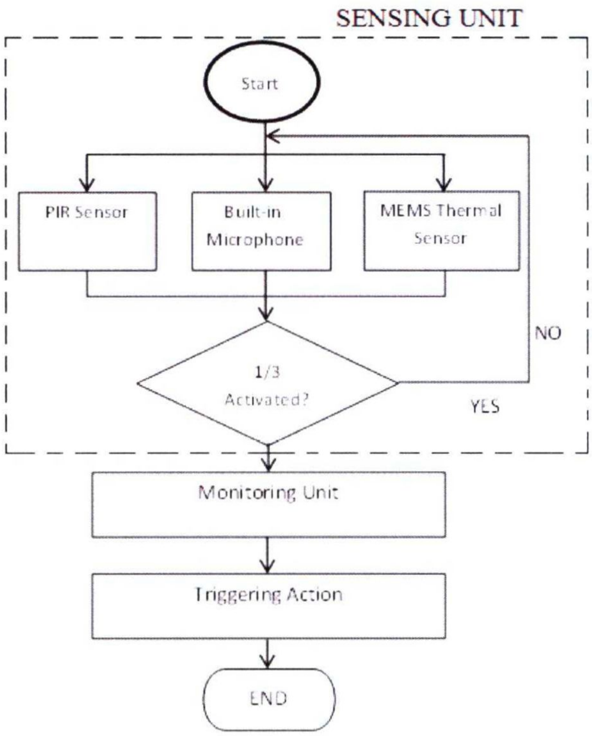

Figure 2. System flow chart

The system is divided into three parts; sensing, monitoring and triggering action. Sensing unit is responsible in detecting the child inside the car. The sensing elements consist of human detection sensors that are designed specifically to capture any stimulus that a child may give off. Three main stimulus that are put into considerations are motion, temperature and sound. Fig. 2 shows the system flow chart for the whole system. As seen from the system flow chart, the sensing unit works when one third of the sensor are activated, a signal is then sent to the monitoring unit for confirmation. The system would only work through human stimulation, this is to allow maximum efficiency of the system. Monitoring unit will not be activated and will be in standby mode throughout the time.

A. Sensing Unit

The sensing elements are responsible in the initial triggering of the system. The human detection sensors would be the first to run and is in charge of activating the monitoring unit. The sensing elements are triggered through possible reactions given off by a child. The human detection sensors are made up of a Passive Infrared Sensor, MEMS thermal sensor and a built-in microphone.

1) Passive Infrared Sensors

Passive infrared (PIR) sensor is made of a pyroelectric sensor which detect levels of infrared radiation. An object will emit low levels of radiation depending on the temperature. Unlike active infrared sensors, it does not transmit any infrared beam to a receiver, it is sensitive to any thermal energy given off by a body. When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. A child left would move under stress, therefore when a child is detected, it first intercepts one half of the PIR sensor, which causes a positive differential change between the two halves. This differential change would in real life application, would send a signal to the monitoring unit for image reference. In real live situation, when a baby is awake, it will surely move under pressure if the heat is too intense. PIR sensor is very sensitive to motion, and digitally reads or writes. Any sudden movement will spike a HIGH in digital output for the Arduino Uno microcontroller. The PIR sensor originally uses a Fresnel lens like in fig. 3(a) but was replaced with a cone-shaped lens like fig. 3(b) for sensitivity purposes. It is found out that the Fresnel lens are too sensitive and would not be applicable to be placed inside a car since external movements from outside the car would cause false readings. The cone-shaped lens was replaced for a better reading since it would be a lot more focused and centred inside the car.

Figure 3(a). Fresnel lens on PIR sensor

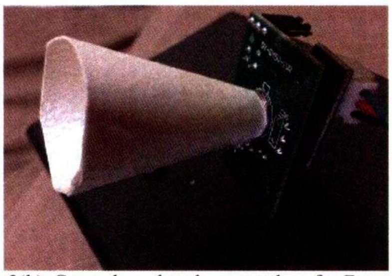

Figure 3(b). Cone-shaped replacement lens for Fresnel lens

2) Built-in Microphone

The sole purpose of the built-in microphone is to differentiate baby cries from other sounds by applying high-pass filter principle which would block every frequency below the cut-off frequency. Fig. 4(a) shows the high-pass filter and amplifier schematic diagram for the built-in microphone. This microphone is tuned to reject any frequency below 400Hz. The voiced speech of a typical adult male will have a fundamental frequency from 85 to 180 Hz, and that of a typical adult female from 165 to 255 Hz. An infant cries may vary between 450Hz and 520Hz [12]. Sudden peak in frequency (more than 500Hz) triggers the alarm. In real life application, any external noise from outside sources would not significantly affect the microphone because external noise would not produce high enough frequency or sudden peak in frequency mainly due to the enclosed space of the car. Sound would only be picked up within the car. It is impossible to make an absolute cut-off frequency, therefore this circuit was designed to filter away humming and the most of adult voices. When a child is crying or screaming the pitch will rise. Surrounding noise (taken for granted) will give off very high frequency, so this is not very much of importance. Fig. 4(b) shows the high-pass filter and amplifier schematic diagram implemented on a breadboard.

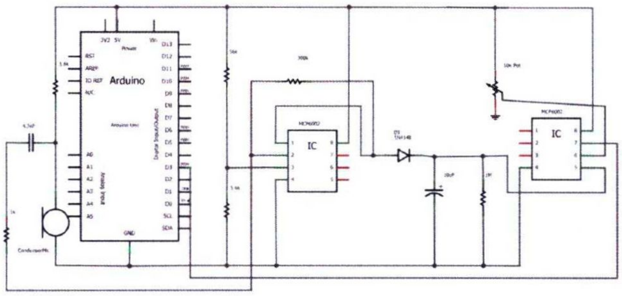

Figure 4(a). The high-pass filter and amplifier schematic diagram for the built-in microphone.

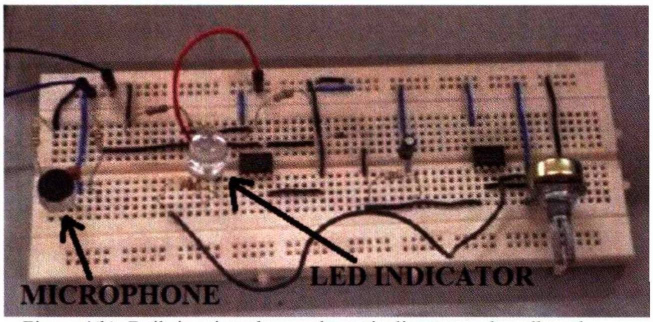

Figure 4(b). Built-in microphone schematic diagram on breadboard

3) MEMS Thermal Sensor

Thermal sensor can detect far-infrared ray of an object through the sensor chip of 8(1x8) channels. For this system, the thermal sensor will monitor any change between channels. The silicon lens collects radiated heat (far-infrared ray) emitted from an object onto the thermopile sensor in the module. Fig. 5(a) shows an overview of the thermal sensor. The radiated heat produces an electromotive force on the thermopile sensor. The analog circuit calculates the temperature of an object by using the electromotive force value and a measured temperature value inside the module. The MEMS thermal sensor consists of an eight channels that monitors and reads temperature on 8 separate sites. In addition, a separate channel was introduced to read the ambient temperature of the car. This added channel will be called channel 0. For this project, the thermal sensor is tuned to continuously monitor any spike in temperature inside a car. A non-living object will not radiate heat as high as a child would. Before setting the condition, a few precautions were taken into consideration first to prevent from false reading and high power consumption. The thermal sensor would continue to monitor under a certain condition which is, if the ambient temperature is below 25°C. Anytime the ambient temperature reaches more than 25°C, this sensor will stop and proceed with the other human detection sensors. This is purposely done because temperature inside a car would gradually increase, therefore will give off false reading. Therefore, inside a prior air conditioned car, the ambient temperature would be at a range between 23°C to 25°C. As long as the ambient temperature maintains below 25°C, the thermal sensor would still be activated, if the ambient temperature reaches more than 25°C, it will stop. Under the conditioned ambient temperature, there is also a range of temperature needed to trigger the monitoring unit of the whole system. Any spike in temperature more than 28°C read by the 8 channels of the thermal sensor, will trigger the alarm. The thermal sensor is used to detect any peak in temperature when the system is off. A child's temperature would exceed more than other non-living objects inside the car because a human body would radiate more heat. Sudden peak in temperature would activate the monitoring unit. Fig. 5(b) shows how the thermal sensor reads temperatures through their channels.

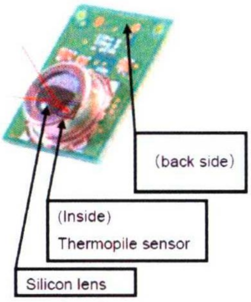

Figure 5(a). Overview of the MEMS thermal sensor

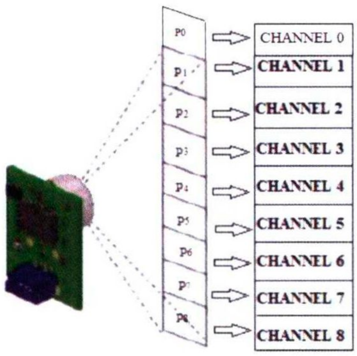

Figure 5(b). Thermal sensor measurement according to respective channels

4) *Interfacing with Arduino Uno microcontroller*

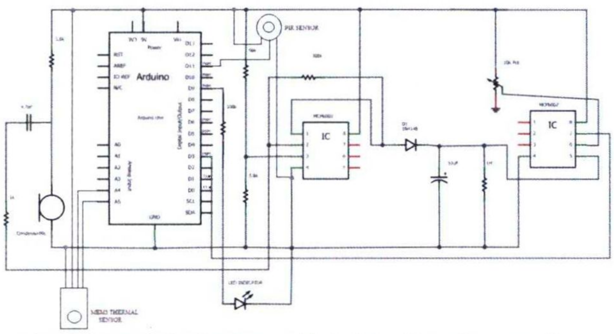

Figure 6. Interfacing hardware with Arduino Uno microcontroller

Fig. 6 shows the interfacing between hardware and the Arduino Uno microcontroller. The human detection sensor was conditioned using the microcontroller to detect a child inside a car. The Arduino Uno can overcome the limitations of the hardware used. The microcontroller is responsible for the calculation of the temperature produced for the MEMS Thermal sensor, the following equation (1) was used to calculate the temperature for each channels;

temp[i]=(rbuf[(i*2)]+(rbuf[(i*2+1)]<<8))*0.1; (1)

The thermal sensor takes in an analog input and reads the temperature. By using the microcontroller, we may set the condition in which it would trigger the output. The PIR Sensor is a digital-based sensor that would produce either HIGH or LOW output, therefore when a person moves, it would produce a HIGH signal in which was used to trigger the output. Lastly, the built-in microphone has a comparator IC chip that would produce either a HIGH or LOW output based on the reference voltage set. The frequency and amplitude of a sound might vary. The microphone is sensitive and would produce multiple HIGH outputs if fed with pro-longed high frequency. This was solved using the microcontroller by binary shifting the microphone output and producing only one output. This can prevent from power consumption and false reading. The Arduino Uno is fed with a 5 Volt power supply which is sufficient enough to run the human detection sensors.

III. Results and Discussion

A. *Technical Info graphic*

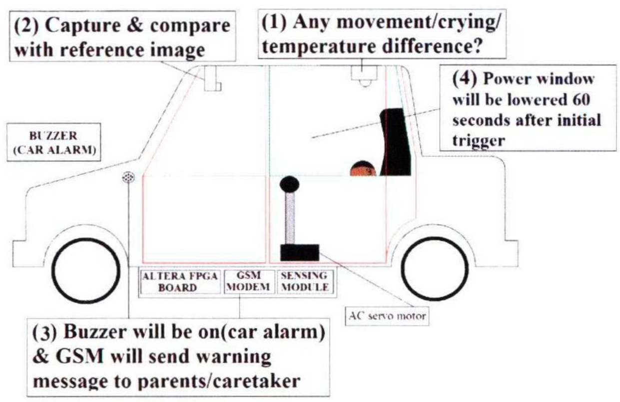

Figure 7. Individual modules interfacing on an FPGA board

For this system, the output will be the three alarm mechanisms that are set to trigger when the monitoring unit has been confirmed of any sight of the baby. However, the sensing unit is the initial input that must be activated to turn on the monitoring unit. Based on fig. 7, at (1) when there is a movement or crying or temperature difference detected within the car, if any one of these sensors are triggered the sensing module will send a message to the Terasic camera that is implemented with the Altera FPGA board. At (2), the camera will capture and compare the image with the reference image. If there is a difference with the reference image, the camera will trigger the initial alarm mechanism (3). Buzzer will be triggered and a warning SMS will be sent to the parents. On the final stage (4), the power window will be lowered 1 minute after the initial (GSM and buzzer) trigger.

B. Sensing Unit

For this system, the output will be the three alarm mechanisms that are set to trigger when the monitoring unit has been confirmed of any sight of the baby. However, the sensing unit are responsible in activating the monitoring unit in which triggers those alarms.

To display individual functions of each sensor, a separate set-up was implemented. A Light Emitting Diode (LED) was placed that acts as an indicator. If one sensor is triggered, a signal will activate the LED. In reality, the LED is replaced with a Terasic Camera of the monitoring unit. This was just to illustrate how each sensor work and how they will give an output signal.

Fig. 8 shows how a PIR sensor works and its operation. When an object (human hand) that gives off radiated heat, come into the frame of the PIR sensor, the PIR sensor will collect the infrared and triggers a temporary LED that acts as an indicator. When a hand is placed in front of the sensor, it will intercept the first half of the slot, producing a positive differential change, and when the hand leaves the sensor, the sensor will produce a negative differential change, the changes in pulses are what is used to send a signal to the monitoring unit, but for display purposes the LED.

The microphone was tested on two different sound sources. The microphone was tuned to reject any frequency below 400Hz. Fig. 9 (left) showed how a knocking sound does not affect the microphone, while fig. 9 (right) was tested with a sound recording of a baby crying.

A thermal sensor was placed inside an air conditioned room with an ambient temperature measured to be around 23°C to 25°C. Human skin temperature at average would give off 33°C [5]. Although the skin temperature may be lower, as ambient temperature rises, the body temperature should rise faster. The thermal was set to detect between a range of temperature which would trigger the alarm. Fig. 10 shows how the thermal sensor measure through their respective channels. In fig. 10, it shows how a hand is detected inside a laboratory with an ambient temperature of 23°C to 24°C. The thermal sensor has been set to activate under 25°C of ambient temperature. In real life situation, the temperature inside a car will increase more than 35°C depending on the location of the car. Therefore to activate the sensor, a condition must be set prior to the installation. The sensor would not be able to differentiate a baby from an object inside the car if the temperature is more than the set condition. This is the reason why ambient temperature was taken into consideration to maximize accuracy. Therefore below 25°C of ambient temperature (channel 0), channel 1 to 8 would continuously monitor for an object above the threshold range which is more than 28°C. Assuming a car that was air-conditioned prior before stopping, the ambient temperature would be between 23°C-24°C which is the reason the experiment was held inside an air-conditioned laboratory as in fig. 11. Therefore, as ambient temperature increases, the skin temperature of the child would increase as well. The child would have the highest temperature at first reading. The child would affect any of the channels based on where he or she is placed. Sudden peak in temperature (more than 28°C) in any of the channels would indicate a child is available.

Fig. 12 displays the readings obtained from the thermal sensor. The first reading displays the ambient temperature while the 8 others are the temperature values captured. The display reads from left to right however measurement is taken from top to bottom of the sensor. Therefore when a hand was placed at a higher angle, the second reading which is the first channel, from the right (after ambient temperature) changes value, as the hands move lower, the next channels will change as seen from the second reading.

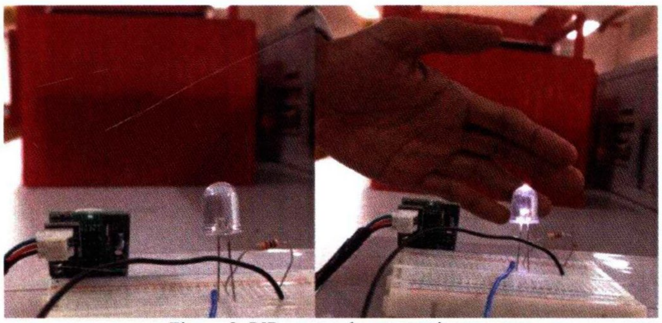

Figure 8. PIR sensor demonstration

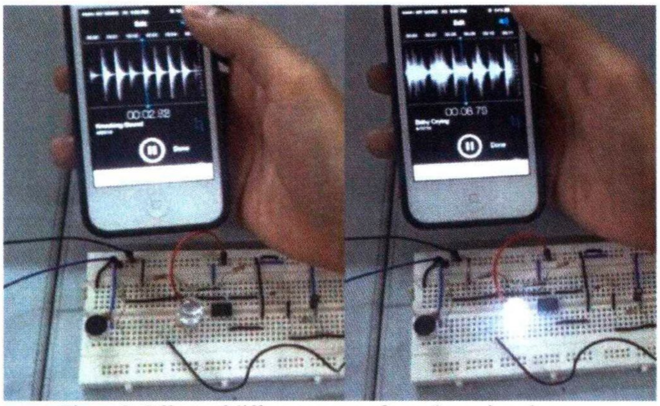

Figure 9. Effects of different source of sound on microphone

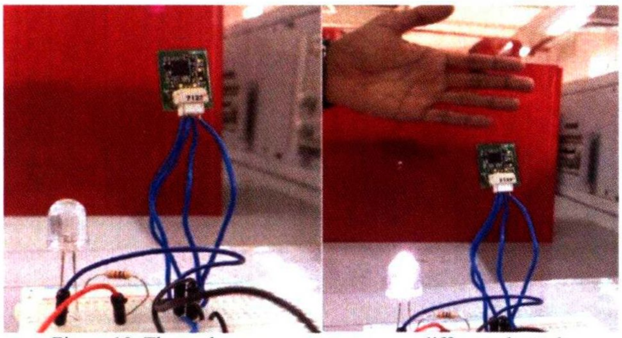

Figure 10. Thermal sensor measurement on different channels

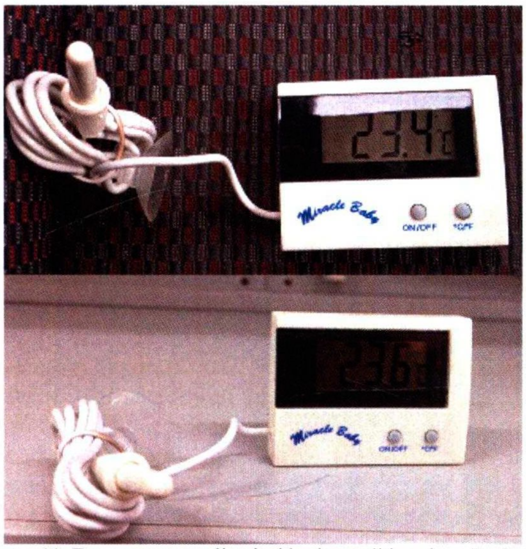

Figure 11. Temperature reading inside air-conditioned car (top) and inside laboratory (below)

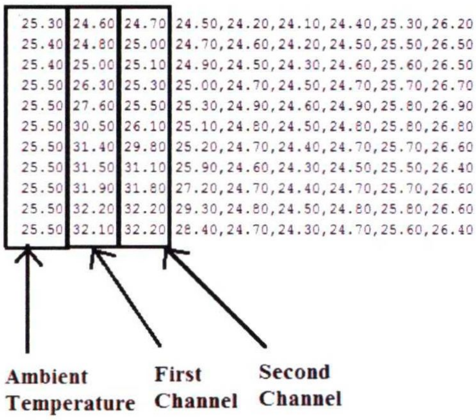

Figure 12. Temperature reading of the thermal sensor

C. *Monitoring Unit & Alarm Mechanisms*

In response to the sensing unit, there are the monitoring unit and the alarm mechanisms. Monitoring unit captures and compares the new image with a reference image through edge detection. If there is a difference between the two images, monitoring unit will turn on the alarm mechanisms consisting of a Buzzer (car alarm), Global System for Mobile Communication (GSM) module and an automatic power window. Fig. 13 shows a warning message sent to the parents' phone. The comparison between other products and the Human Detection Sensors for Post-Locking Child Presence Detection System is shown in table I. Table I show the comparison between assembling the product, how it detects, the requirement for the product to work and the detection rate.

This product has a bigger advantage compared to the other products.

Figure 13. Warning message through GSM

TABLE I. COMPARISON BETWEEN OTHER CHILD REMINDER PRODUCTS

Product	Assembly	Detection	Requirement	Detection Rate
ChildMinder ® Smart Clip System car	Manually Clipping the child on the baby seat	Unhooking the clipper	Baby seat	Low, only applicable for babies in baby seat and not for child aged higher
ChildMinder ® Smart Pad System	Manually placed below baby seat	Through weight difference	Baby seat	Low, only applicable for babies in baby seat for child aged higher
Human Detection Sensors for Post-Locking Child Presence Detection System	Automatically runs when engine is off	Motionless detection through child reaction	Low voltage power supply	Efficient, not influenced by external sources, may also detect elderlies or animals left.

IV. Benefits & Innovation

Currently, there are no known vehicles that are manufactured with these kinds of security in one whole system. Existing products are developed separately or must be bought individually. This product uses low cost sensors, which are developed to become a solution for detecting the presence of a child. Arduino Uno microcontroller is used for this project, because of its higher level of integration and reliability at a lower cost. A system like this requires a fast processing and response reaction. Pre-existing products requires manual handling and constant maintenance. This is step-forward to a better existing alarm system.

V. Conclusion

This system was created to detect the presence of children left unattended in cars. These results clearly substantiate the advantages of incorporating these sensor with the monitoring camera and the alarm mechanisms. The human detection sensors are automatic and does not require manual configuration. The human detection sensors are the most important part of the whole system since it is responsible for the initial triggering of the system. This system should be implemented within cars due to its fast-paced detection and hassle-free control. Other human detection sensors may be added to the system to further improve the quality of the sensing unit. Sensors such as MQ5 gas sensor that can detect different volumes of carbon dioxide and other gases inside the vehicle may be used to detect increased low levels of carbon dioxide inside vehicles. Other than that, sensors that can detect movements like piezoelectric sensors may also be added in case the movement of the child is very little that it does not get picked up by the human detection sensors. These are some of the improvements that can be added to improve the effectiveness of the system. With the results obtained and comparison made in table I, this proves that the system is by far the most efficient safety feature compared to other already existing products on the market.

Acknowledgement

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