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Applying Mechatronics to Improve the Safety of Children in Vehicles - What Can Be Done?

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Abstract. Nowadays, the media have reported an increasing number of cases where children are accidentally being trapped in vehicles while they parents and guardians are away attending to other matters. In this paper we discuss the feasibility of applying Mechatronics to improve the safety of children in vehicles with the ultimate goal of developing a means for parents,guardians and authorities to be informed if ever there is a child trapped in a vehicle and in need of urgent assistance. We have also presented some preliminary experiments we have carried out for a safety alert system which is currently being developed in our lab.

1. Introduction

Nowadays, cases regarding children trapped in vehicles can be observed through media frequently. Recently, Nurul Hidayah Bahaudin reported that a child as young as 6 years old had faced a deadly fate when his transporter forgot to send him to his evening school[1]. It was stated that the young boy was trapped inside the van for as long as 3 hours. The driver sent the boy to a nearby clinic but he was announced dead while receiving treatment. The doctor declared that the boy suffered heatstroke due to excessive exposure to heat.

Ishimine defined heatstroke as a situation where the core temperature of the body reaches 40℃ and usually comes with the failure of the nervous system as the side effect due to excessive high temperature exposure [2]. The heat management mechanism of a growing young child's body is still under development. Due to the weak heat management, the body temperature of a child has a higher rate of temperature increment compared to an adult. It can be observed that the public is still taking vehicular heat stroke lightly. Most of them see the mishap as something that will never happen to them. As reported by McLaren et al., leaving the window car down did not reduce the rate of the rising temperature and the maximum achievable temperature [3].

Due to the ignorance of parents and the negligence of responsibility, the child is doomed to a deadly fate. Parents and caregivers should be well aware of the deadly consequences. Mechatronics has a promising potential to be applied in the development of a safety alert system to warn parents and authorities about the possibility of a child being trapped inside a vehicle. Such an alert system would need to be comprehensive, robust and consists of multiple features such as presence sensing, temperature sensing and real time alert mechanisms to drivers and caregivers to alert them of the presence of their young ones. It is hoped that with the development and eventual usage of such a

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safety alert system the number of child deaths due to heatstroke in vehicles can be reduced or prevented all together.

2. Cases of Children Trapped in Vehicles

A number of research had been conducted to rule out some of the main causes of these accidents. Some of the main causes are as follows:

A) Parents negligence in leaving their child unintentionally
B) Dramatic change of routine
C) Stress or any form of mental fatigue

A hectic lifestyle contributes significantly to this problem. Looking at such cases that happened either in Malaysia or abroad, there are some common factors that causes parents to forget. Majority of these cases happen because the drivers claimed that they forgot due to the sudden change in their routine on a daily basis. Busy drivers usually rush to work every day but suddenly they have to break their routine to send their child to the nursery or school. The brain may not be able to comprehend such sudden changes to routine immediately. The driver may also place the child on the rear seat, causing the lack of interaction between the driver and the passenger, consequently resulting in the driver forgetting that there is indeed a child in the rear seat.

Considering a psychological aspect of the case, psychiatrists suggested that the element of stress was also as a common factor in the equation. Stress causes an unstable state of mind, thus making the driver less alert to surroundings. The stressful experience may occurred before or during the driving. In addition due to other problems such as lack of sleep, the brain may not able to process information such as detecting a sleeping child's presence inside the vehicle.

3. Hot Car Phenomenon

A study had been conducted by Jan Null from Department of Meteorology & Climate Science, San Jose State University to further understand the dynamics of a vehicle heating up due to surrounding conditions. According to the report, the interior and the windows of the car are said to be transparent to the sun's wave of radiation. Therefore, the wave heats up the object within the vehicle. With the increasing temperature of objects inside the vehicle such as dashboards, steering wheel and seats, these objects are capable to heat up the ambient air inside the car to conduction. These objects simultaneously release longwave radiation, making the interior of the car the most optimal "oven" due to lack of ventilation[4].

Some drivers deliberately leave their children inside the car with the intention to quickly perform a task and get back thinking that their children will indeed be safe during such a short duration. This however is a dangerous practice even if the windows of the vehicle are left open for ventilation. According to McLaren et al., winding down the windows of the car slightly do not decrease the rate of temperature increase inside the car or even decrease the limit of the temperature possibly achieved [3].

4. Existing Safety Empowering Technologies

Currently, the number of cases regarding child being trapped inside vehicles is still high. So far, there is no system that is being used by car manufacturers in Malaysia and abroad specifically to prevent such cases. There are however third-party products in the form of car accessories which are currently being marketed and commercialized especially in the United States. Augenbraun in his survey reported that a baby products manufacturer known as TOMY developed a product that may be one of the solutions to this predicament [5].

Produced in 2013, TOMY's Smart Car Seat was designed to communicate with the driver of the vehicle through a dedicated communication technology named iAlert. TOMY stated that the product features temperature, angle and motion sensor that will notify the driver if the condition of the car is not suitable or conducive to accommodate a child inside the car. Even though the system may sufficient to address the problem, users reported that the system failed to achieve the 0% percent failure rate.

Another currently commercialized product is the Baby Alert's ChildMinder SoftClip System Digital Wireless Technology Monitor [6]. This product was designed based on proximity sensing technology. The product comes in the form of a pair of sensors. One is supposed to be carried by the driver or the caregiver and the other pair will be attached to the baby car seat. As stated by Baby Alert, the pair carried by the caregiver will gives out an alert if the pairs are separated by a distance of more than 15 feet for approximately 6 minutes. Therefore, the caregiver will be reminded of the child's presence. Baby Alert also developed the alternate version of the product called ChildMinder Infant-Toddler ElitePad System. This product uses a pressure pad to detect the presence of the child instead of the proximity sensing principle. However, Augenbraun highlighted "…most deaths happen when there is a change in routine." He also stated the user is prone to forget the device because of its flaw in the design where the device needs to be handed over to the other caregiver if there is a change in role. Thus, the process will open up some room for errors [5].

Bologna reported in The Huffington Post that two fathers from Florida invented a device that can also be one of the gadgets that are capable to address this problem. Friedman and Shamma developed the idea and named it, Sense-A-Life. According to the article, the device was designed as a wireless and Bluetooth-capable and able to send inputs to the user through a smartphone app. With a pressure sensor installed inside the baby seat, the system is capable to read out the presence of a baby with a minimal weight of 0.9 kilograms. The system is also capable to sense if a driver is stepping out of the car while leaving the child inside the car without any supervision. If the situation occurs, the system will send an alert to the forgetful driver. A second driver can also be alerted if no response is being detected from the first driver [7].

The products described above are some options that were already commercialized. However, there are still room for improvements in the design of these products, especially those that may improve the reliability and the failure rate for long term use. There are still individuals or research teams working hard to innovate and invent foolproof systems to ensure that one day, the number of cases children trapped in vehicle can be reduced to 0%.

In 2014, Oshman Engineering Design Kitchen from Rice University developed an infant safety system called Infant SOS. The team of students had developed the system with the idea to keep the core temperature of the child's body below the life-threatening level. The fundamental aspect of this project that the system was developed to be attached or to be integrated with a normal baby seat. The system also produce alerts sufficient enough to tell the driver about the condition of the child. The system also features a relive system namely the cooling system where the system will ensure the temperature is maintained at a suitable level [8].

In 2003, a patent was granted to Bosch Robert Corp, Dulin and Seip in which they had developed a system to ensure prevention of passengers being trapped inside a vehicle [9].

In these existing systems, the parameters that are being measured and sensed inside the interior of a vehicle are a) if the temperature rise to a predetermined value, b) if the vehicle is in motion, and c) if the passenger is present. With these parameters, the mechanisms were to be executed based on the value of the measured parameters. Another feature that can be noted is that the system provides a "sleep mode" when there are no passengers that are being left behind the moment the driver leave the car. This feature was beneficial to reduce overall power consumption and longevity of the device.

Sasidharan and Kanagarajan reported that they had developed a safety alert system where their system monitors parameters such as oxygen concentration, temperature and humidity regularly. As mentioned by them, they took account the oxygen depletion rate with the accumulation percentage of poisonous gas such as carbon monoxide as gas suffocation is also considered as one of the causes of children's fatalities inside a car. Another aspect of their project that can be noted is that the system provides a form of a relief to the cabin of the vehicle. Basically, when the predetermined value of the temperature from the sensor achieved, the system will roll down one of the window of the car to a predetermined height of the window [10].

Another notable research is the work of Soto, Munoz-Sandoval, Ortiz, Nunez-Gozalez and Aguilar from Mexico. Their report entitled " A Multi-agente System to Avoid Heatstroke in Young Children Left in Baby Car Seats Inside Vehicles" divided the whole system into 2 subsystems namely User Agency and Monitoring Agency. The monitoring agency consists of a coordinator agent, a temperature sensor, a GPS module, a microphone and a motion sensor. As for the user agency, it works as the interface between the on-board system and the user. The user agency allows the system to directly communicate with the user and vice versa. In this particular work, Soto & et.al used the Arduino and Raspberry Pi to execute the written programs. With this configuration, the reported system uses Arduino to obtain value of designated parameters from sensors, initially connected to Arduino. The data then would be processed by the computing power of Raspberry Pi. Therefore, the Raspberry Pi acted as the brain of the system [11].

Lastly, a local team of researchers from Faculty of Computer Science and Information Technology, University Tun Hussein Onn, Malaysia developed a system to minimize heatstroke incidents among children. The proposed system utilized Bluetooth communication to transfer data to users and at the same time, the system used an Estimote beacon to approximate the distance of the driver from the car. As described in their publication, Hairulnizam et. al proposed an Android OS as their platform as because majority of OS users worldwide use Android OS [12].

5. Building a Safety Alert System Using a Mechatronics Approach

The foundation of the safety alert system which we are currently developing is made up of three core components. Firstly, the system will detect the voltage produced from the vibration from the engine of the vehicle. Any vibration which is detected indicates that the engine is still running, presumably the car is still in motion or the driver is still present in the car. Secondly, the system will also measure the temperature of the interior of the vehicle up to 40℃. Exceeding this temperature will put the child in a very dangerous situation. Lastly, the system will use a PIR motion sensor to sense any kind of presence in the car by detecting any motion inside the vehicle. Therefore, the circuit assembly of inputs will consist the circuit of vibration sensor, temperature sensor and PIR motion sensor. As for the programming of the software that will be uploaded into ATMega328p, the codes will be programmed in C language. When the codes had been written, with the developed algorithm, the system will process the inputs and produces the output in a form of text in the LCD display, LED to alert the presence of the child.

The monitoring unit for this proposed design will be consists of piezovibration sensor, temperature sensor, PIR sensor, reed switch and SKM53 GPS Module. As for the coordinating unit, the system will be solely be control by Arduino Uno running on the ATMega328p microprocessor. Lastly, the real-time output unit will be consisting on LCD display, LEDs and GPRS Shield V3.0.

The following section of this article describes the components which will be used in our proposed safety alert system. Figure 1 is a our system block diagram which describes our proposed method on how these components will work together to function as a complete safety alert system.

A) Vehicular Vibration Sensing

For this project, the vibration sensor will be one of the fundamental component in this system. During the initial phase of the execution of the program, the sensor will measure the vibration produced by the engine of the car. In the design, the sequential task of the system will be executed when the vibration sensor detects zero vibration from the engine. This indicates that the driver is ready to leave the vehicle. Due to the designated working environment for the vibration sensor, type of vibration that will be used is a piezo vibration sensor. Piezoelectric sensors can easily be adopted into the system due to its high temperature tolerance and flexibility in working with any type of force. This sensor can also be programmed to interface with any microcontroller such as Arduino Uno. Piezoelectric based sensors generate energy when they are put into pressured situations such as when the sensors are being pushed, pulled or pressed. This type of sensors also have the capability to produce AC voltage as high as 50V if it being configured correctly. Zener diodes are commonly used as a tool to scale down the voltage to a acceptable and safe levels. Piezoelectric sensors have the potential capability to produce high range of AC voltage when force are being applied.

B) Temperature Sensing

The second sensor that acts as a monitoring agent for this system is the DHT11 temperature and humidity sensor. For this sensor, the temperature measuring mechanism work with the NTC temperature sensor mounted inside. This sensor produces digital signal with auto calibration to ensure lower failure rate and prolonged performance for long term use. This sensor is highly compatible with Arduino Uno thus making it very flexible to be programmed for designated applications. Within the proposed system, this sensor will continuously measure the ambient temperature within the interior of the car. When the temperature reaches the maximum threshold value, the next sequential task will be executed.

C) Motion Sensing

Another sensor or input that forms the core function of the system is the PIR motion sensor. A PIR sensor can be affected positively and negatively by many uncertainties or variables. This motion sensor works with the principal of differential changes. This is because the output of this motion sensor is triggered by the change of pulses back and forth between positive and negative differential changes. The body of the sensor is made up of metal that can positively affect its performance. The detection range of this type of motion sensor can be widened by changing the refraction range of the lens. The commonly used lens are the Fresnel lenses that gives out large refraction of IR wave.

D) Magnetic Switching

To complement the system, one of the mechanism developed for the this project will be using the reed switch or also known as a magnetic switch. The reed switch is common among daily appliances such as mobile phones and laptops. The basic principle of this switch is that the switch is N/O or Normally Open type of switch within the circuit. Therefore, with this principle, the user can determine the time to make the circuit closed by ensuring that the pair of the switch come into contact with each other,

thus making the circuit closed. This switch is commonly made from ferromagnetic material to ensure a long shelf life.

E) Global Positioning Systems

In a life-threatening situation such as a child being trapped in a vehicle and the parents are not responding to initial alerts and notifications, the authorities need to dispatched to rescue the child as fast as possible. The authorities such as fire departments and police need to have the information regarding the exact location where the child is trapped. Therefore, they need any specific information about the location as fast as they can. Because of this reason, the development of this project will be including location tracking so that the location can be relayed to the authorities beforehand enabling efficient routes for the authorities to arrive.

For location tracking, a GPS module can be integrated together with the Arduino Uno, allowing the system to send specific locations (in term of latitude and longitude). GPS module also features real time clock tracking where the latitude and longitude of the location will be send together with real time stamp so that the authority can approximate their Estimated Time of Arrival (ETA) efficiently.

F) Coordinating Unit

In order to achieve the intended objective for this project, the “brain” of the system has been selected based on some of the features that must be taken into consideration such as size, number of GPIO pins, CPU clock speed, power consumption rate and mode of voltage input and also the programming flexibility. After an extensive research conducted among the common used microcontrollers and development boards, Arduino Uno has been chosen as the main controller of the system.
The Arduino Uno’s main processor unit is the ATmega328p microprocessor. With the combination of Arduino’s development board, the Arduino Uno features 14 digital GPIO pins. Within these pins, there are 6 of these pins can be used as PWM out pins. Analog sensors such as temperature sensors and light intensity sensors can be attached at one of the 6 analog pins on the board. The board also includes a 16 MHz crystal that can be used as clock for serial data transmission. With this, Pulse Width Modulation can be used to allow DC simulating AC with preferred parameters such as signal amplitude, frequency and duty cycles.

G) GSM Module

Developed in 1970, GSM became a widely used medium of communication worldwide. GSM provides a channel for digital cellular transmission such as voice messages and text messages using fixed frequency specially for GSM communications. Through TDMA method, GSM network convert the analog data into digital while compressing its size. Next, the digitized data is send to client data with rate from 64kbps to 120 Mbps. To use the GSM module with Arduino, the module needs to interfaced with a level shifter IC Max232. With a SIM card, the AT command can be transmit to the recipient of the command.

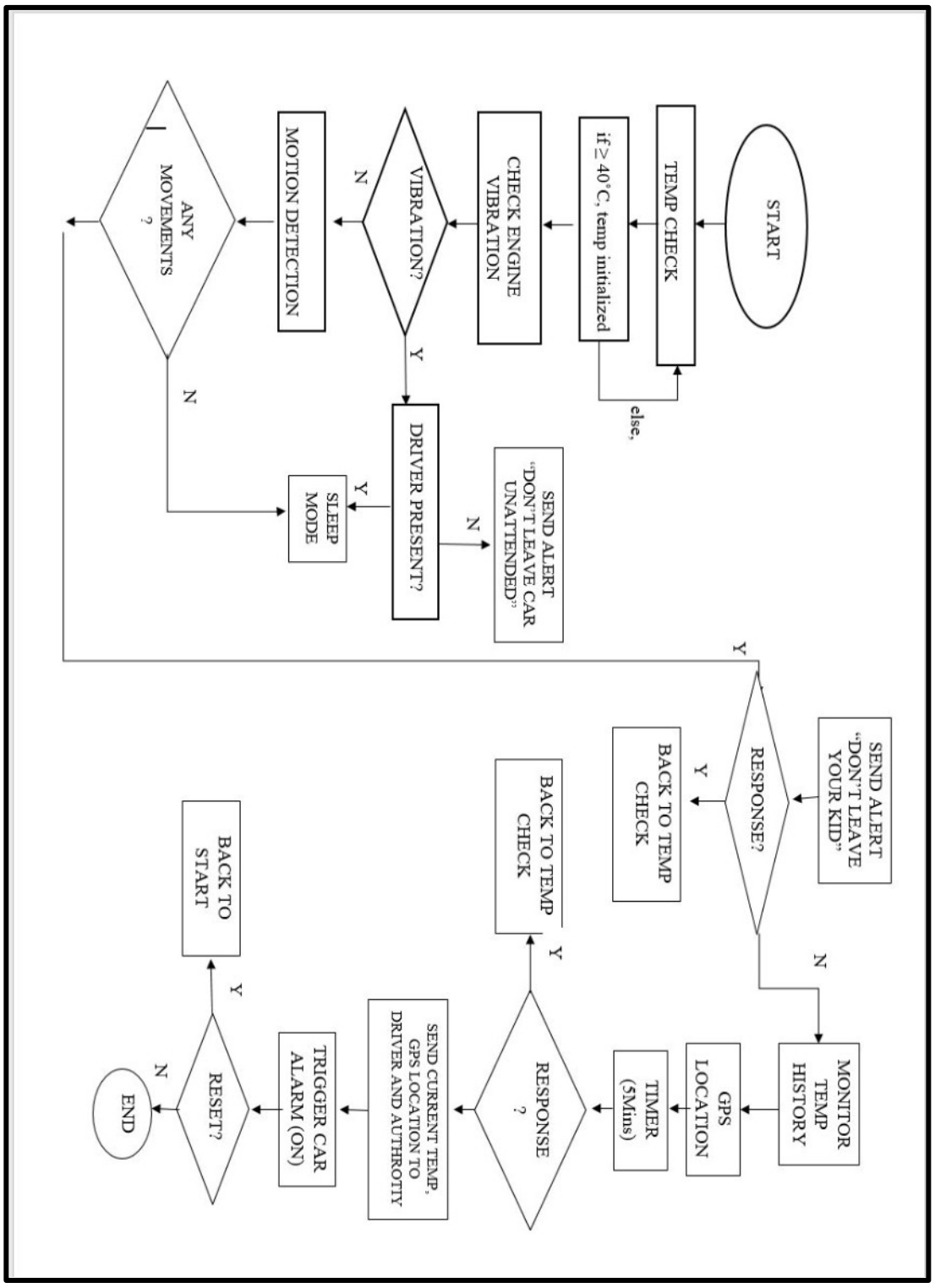

Figure 1: Proposed System Block Diagram.

6. Preliminary Experiments

To gain an insight on how temperature gradually increases inside the cabin of a vehicle, a preliminary experiment was conducted with the objective to observe the rate of temperature increase. With the collected data, further analysis can be done and crucial information will be noted to ensure that the developed system can effectively and efficiently handle the high temperature without facing any equipment failure while being continuously subjected to heat.

Another objective of this experimentation is that previous research by McLaren showed that the interior temperature of the vehicle quickly escalated 56℃ to 67℃ when the atmospheric temperature rises beyond 30℃[3]. This drastic increase in temperature occurs even though the surrounding temperature is constant. This result can be related closely with Malaysia's climate. According to the monthly report of temperature by Malaysian Meteorological Department, their latest report of March 2017 showed average morning temperature range of 22.1℃ to 34.2℃ [14]. This temperature range may result in drastic temperature escalation inside the cabin of the vehicle.

This experiment was conducted based on McLaren's work [3]. As mentioned, the objective of this experiment was to study the variation in temperature in the interior of the vehicle and the effect of the surrounding temperature to the variation of temperature inside the vehicle. At 1.00 PM, 6th May 2017, the experiment site was at IIUM Convest Hill, parking area. The vehicle, a Perodua Myvi, black in colour, was parked under full sunlight oriented at 45 degrees from the sunlight as shown in Figure 3to reduce the effect of direct sunlight through the windshield of the vehicle that may cause slight deviation from the actual value of temperature data. The duration for this experiment was 15 minutes with the interval data logging of 1 seconds per data. Before the apparatus were placed inside the vehicle, the door of the vehicle was opened to ensure that the initial temperature of the interior achieved the atmospheric temperature. The temperature data recorded shows continuously increasing temperature inside the vehicle as shown in Figure 4, although the atmospheric pressure at that time was constant. This is consistent with the fact stated by McLaren [3].

As for data logging, the configuration of the sensors and Arduino is showed in Figure 2. The configuration was integrated with PLX DAQ, a data logging software that can be integrated together with Microsoft Excel with real time data logging features. The setup was then placed inside the vehicle.

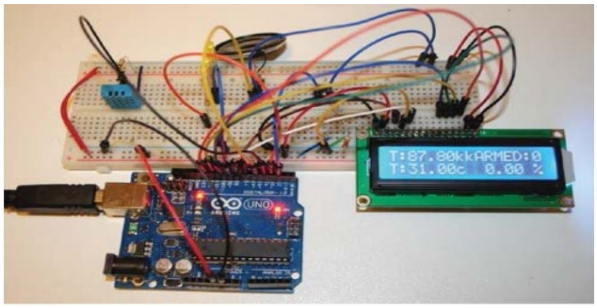

Figure 2: Configuration for preliminary experiment



Figure 3: Vehicle and Experiment Site.

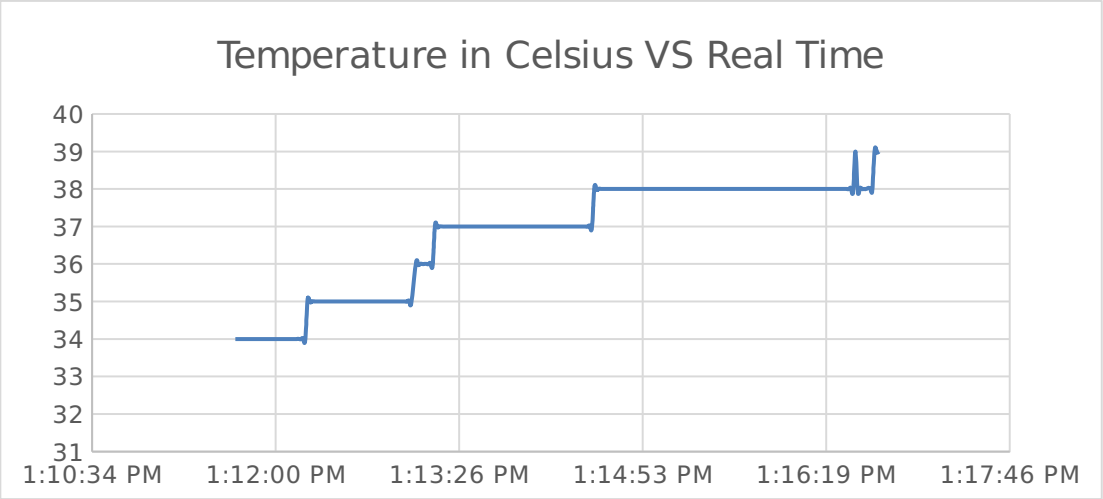

Figure 4: Variation of Temperature inside Vehicle with Respect to Time.

7. Conclusion

This paper presents a review of existing technology available to prevent children from being accidentally trapped inside vehicles. We have also presented a framework for developing our own safety alert system to address drawbacks in existing technologies. We have presented some preliminary results regarding temperature variations inside a vehicle. Further work is underway to develop a fully functional safety alert system embedded with communication abilities.

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