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Detection Systems for Airbag Deployment

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DETECTION SYSTEMS FOR AIRBAG DEPLOYMENT

By

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Dedicated to
Dr. Kenneth Johnson

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I would like to thank the Olivet Nazarene University Honors Council for providing the opportunity to complete my Honors Project and for funding. I would also like to thank the late Dr. Kenneth Johnson for encouraging me to pursue the honors project and for helping me find a project that would be exciting to conduct. I would also like to thank Dr. Johnson for his work in building the Engineering Technical Center where I was able to collect the data that I used for this project. I would like to thank Ryan Miller for providing the problem for the project and answering some of my questions along the way. Lastly, I would like to thank Professor Joe Makarewicz, my faculty mentor, for his advice and wealth of knowledge, and for encouraging me throughout my project.

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ABSTRACT

The airbag enablement system in today's automobiles is not ideal and may allow airbags to deploy when they should not. Weight sensors detect pressure when someone sits in a passenger seat, enabling the airbag to deploy if an accident occurs. This system is flawed. For example, if a heavy box is placed in a passenger seat, the airbag will be unnecessarily enabled. The goal of this research project was to determine if different sensors—not weight sensors or cameras—could be used to identify the occupant of an automobile seat.

Using a microchip programmed in C language, a circuit was designed with three sensors: ultrasonic range, passive infrared, and temperature. The temperature sensor was placed on an automobile seat to detect heat from occupant of the chair. The passive infrared sensor was positioned in front and above the seat to detect heat movement, and in order to detect the height of the occupant, the ultrasonic sensor was placed above the seat.

The sensors can conclusively determine whether the occupant is living or inanimate. The sensors cannot always determine if the occupant is specifically human or the age of the human.

Keywords: Smart airbag, ultrasonic, passive infrared, temperature

INTRODUCTION

Airbags are an essential and widely accepted safety aspect in any automobile [1]. Their use by the automobile industry is vital, and as their worth has been shown, the number of airbags in vehicles has increased substantially [1]. Unfortunately, airbags can also be dangerous. Because airbags are not tuned to the specifics of an occupant, minor injuries have increased since their implementation [2]. In general, airbags are designed for the average sized person, and so a person is more likely to sustain injury if their weight is further from the average person's weight [3]. With children, this is especially true, for the deployment of airbags has been known to seriously injure or kill children [4]. Additionally, when there is no safety threat against a human—as in the case of non-humans on an automobile seat—it would be safer for the airbags not to deploy at all. So when an object is placed on the seat, weight in itself is not enough to determine if an airbag should deploy or not. It cannot differentiate between humans, animals, and inanimate objects. Nevertheless, weight is one of the most commonly used systems in automobiles today [5].

Due to the inefficiencies with the weight system, research is being conducted to develop smart airbag systems [5]. A smart airbag system is one that can determine whether or not the occupant of an automobile seat is human, non-human living, or inanimate [5]. It also might determine the age and position of the human depending on how smart the system is.

For the above reasons, the goal of this honors project was to use different sensors to determine their combined potential usefulness in a smart airbag system. It was hypothesized that an ultrasonic range sensor, passive infrared sensor, and temperature sensor would be sufficient to determine the identity of an automobile occupant. The temperature sensor was chosen because of the apparent lack of experimentation with it and because living beings provide heat to the seat whereas most inanimate objects would not. The passive infrared sensor was chosen because of its ability to detect heat movement and ignore the movement of non-living occupants. The ultrasonic range sensor was chosen to determine the occupant's height as an estimation of age. The hypothesis was that the passive infrared and temperature sensors could determine if the occupant was living, the temperature sensor could determine if it was a child by the use of a booster seat, and the ultrasonic range sensor could determine an estimate of age.

REVIEW OF LITERATURE

Airbags are standard in automobiles today, and they are generally designed to deploy in frontal collisions [6]. Sensors in the automobiles measure sharp decelerations—caused by collisions—to know when it is time to deploy the airbags [6]. While this was the original method for deploying airbags, additions have been made to that system because it does not take passenger occupancy or position into account.

Occupancy is important for various reasons. One major reason is that if an airbag is deployed, it cannot be reused and must be replaced [6]. If an airbag deploys unnecessarily, an avoidable cost for replacement is incurred, and the car becomes unsafe for passengers until the airbag is replaced. Another reason the identity of an occupant is important is injuries. Airbags commonly cause minor injuries, but at times, greater injuries are sustained [6]. Airbags inflate at about 100 mph, and while seatbelts help prevent severe injuries, airbags can fatal to children [6]. That is why the government has set laws in place requiring airbags be tested for different ages of children [5]. Likewise, pets that are not restrained can also be killed by airbags [7]. Due to the laws in place, the airbag enablement system was designed with the average person in mind, not pets, inanimate objects, or even people not of near-average build [8]. Because airbags focus on the average human, it is important to develop smarter airbag systems to determine the identity of automobile occupants, and if they are human, to determine how forceful can the airbag deploy for them safely.

For occupant identification, weight sensors are standard in modern vehicles [5]. In fact, they have been mandated by law since 2004 to protect children [9]. These sensors are set in the passenger seats of automobiles to determine if the seat has an occupant, and if not or if the occupant is too light, the airbags do not deploy. For example, the system may use hydrostatic weight sensors to measure the pressure on the seat, and if the pressure is too little, the airbag is disabled [9, 10]. The weight system successfully removes the possibility of an airbag deploying for an empty seat, most young children, or for a seat with very light objects on it [10]. The weight system, however, does not recognize a difference between heavier inanimate objects compared to humans, nor does it attempt to detect pets or successful adjust to fit the size of any specific human heavy enough to turn on the sensor [10]. Therefore, a smarter system is still needed to reduce the number of airbag injuries.

Thousands of journal articles have been published regarding smart airbag systems. Potential solutions for airbags abound with varying degrees of complexity. Some intend to determine the class and identity of occupant [11, 12, 13]. Others desire to find the position of a human occupant [14, 15, 16], and a few do both [17, 18]. One of the greatest achievements for a smart airbag system would be attaining the ability to differentiate between the ages 12 months, 3 years, and 6 year and not just between a child and an adult [5]. Other questions smart airbags systems try to answer include: Is the occupant human? Is it an animal? Is it an inanimate object? If these questions can be answered, the strength with which the airbag is deployed—if it is deployed at all—can be altered, and therefore, the risk of injuries and fatalities would be substantially reduced [19]. This is especially true for children because they are sometimes improperly restrained, and when they are, the risk of death and injury is increased [20]. A weakened or non-deploying airbag has less risk of causing severe injuries or death [21].

According to Ryan Miller, an engineer in the automobile industry, a substantial amount of work has been done with a visual system of detection. Indeed, about twice as many articles seem to be available for visual smart airbag systems than for infrared smart airbag systems or ultrasonic smart airbag systems. The vision based smart airbag systems have been generated by a number of sources, including those in the automobile industry and professors at universities [12, 13, 17, 18]. Many of these systems are patented and tested, and they could feasibly be implemented in manufactured automobiles, and there are many different ways to go about utilizing a smart airbag system. For example, one way a vision based system can be used utilizes two cameras [11]. The cameras are placed in the center of the car and are spaced out about the width of human eyes. Both sensors then look towards the passenger and use each other to determine depth through a series of calculations, imitating how humans see depth. An algorithm then determines how and if an airbag should be deployed based on the information received. Another vision option involves placing a camera approximately above the driver to look down at the passenger [13]. In this system, the algorithm has pattern recognition capabilities, and it attempts to determine the age of the occupant—assuming the occupant is human—based on patterns for how the occupant looks in the car.

Despite the fact that vision systems are the most researched and developed smart airbags, those in the automobile industry consider them to not be ideal [5]. This is due, at least in part, to the fact that some people would not want to be watched by cameras while they are driving or riding in an automobile. Regardless, the fact that vision based systems have been in existence for years without the automobile industry accepting them proves that they are not the solution the automobile industry wishes to adopt.

Researching specifically ultrasonic sensors yields a number of results. Typically, multiple ultrasonic sensors are arranged around the occupant to build a picture of the occupant without actually using a visual lens. An example of this is a system that uses four ultrasonic sensors (along with other sensors) to determine how the occupant is positioned at the time of a crash [14]. The four ultrasonic sensors are placed in a roughly rectangular shape around the passenger and provide feedback on the occupant's position. One sensor is positioned by the automobile's radio controls, and the opposite corner of the rectangle is above the occupant's head. The other two are located above the driver and at the windshield, but this is problematic because the number of sensors is beginning to get excessive, considering other sensors are involved in addition to those four ultrasonic sensors. Another problem is that the purpose of the sensors is to determine the actual position of the occupant, but the system assumes the occupant is human.

Likewise, information for infrared sensors in smart airbag systems is available. Oftentimes, infrared sensors are integrated into a visual system. In one example, an infrared camera is used because it can focus on the heat of a human without the distraction of every item a regular camera would see [15]. The infrared camera identifies critical parts of an occupant—such as the head—and then uses the location to determine airbag deployment configurations. When specifically passive infrared sensors are used without cameras, they are used in multiple quantities like the ultrasonic sensors. For example, three rows of three infrared sensors are used in one design [16]. The farther forward the infrared sensors see the occupant lean, the less strength the airbag would use when deploying. Having each row be three sensors wide gives the system the ability to detect the occupant is leaning forward even if they are also leaning to the side. No sources utilizing a temperature sensor were found.

While the forms of smart airbag systems discussed above are the most common to find in research, other smart airbag systems exist. An example of a simpler smart airbag system can be found in the patent US 7401807 [22]. In this example, the smart airbag system looks at the position of the seat to make assumptions on the position of the occupant and the occupant's distance from the airbag. From the data on position it gathers, it determines how forcefully to deploy airbags, should an accident occur. In another example, Honda has begun to use a different type of smart airbag system [23]. Honda's system has sensors in the chair's back that detect the height of the occupant. If a child is in the seat or an adult is leaning forward, the height is detected as low and the airbag does not deploy. This system, while it accounts for age, fails to identify nonhuman versus human occupants.

Despite all of these examples, there appears to be a hole in the research. Most smart airbag systems use a camera, lens, or in some other way, a visual system [11, 12, 13, 15, 17, 18, 22]. Those systems that do not are either incomplete in their identification of the occupant [22, 23], or they use many sensors to attain data [14, 16]. There is not a system that uses only a few sensors while avoiding the use of visual sensors. That is why this experiment was conducted.

MATERIALS AND METHODS

To conduct this project, the initial task was to determine what sensors would be used. To remain economically feasible, using fewer sensors was a goal of the project, and three were chosen. To build the circuit (Figure 1), the project utilized a PIC 16F690 as a microcontroller. The microcontroller was programmed

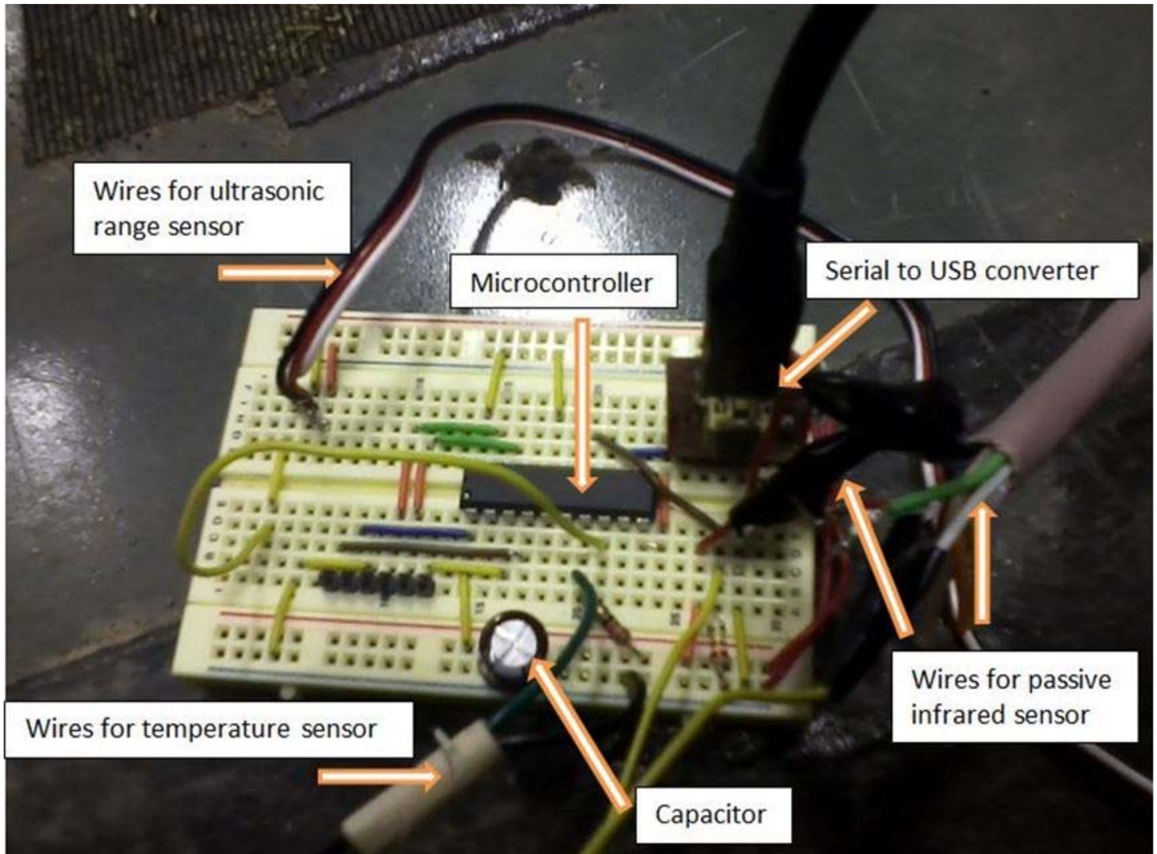

FIGURE 1: The fully operational circuit sits in the back of the automobile and is ready to begin logging data.

in C language using MikroC and the PICkit 2. The ultrasonic range sensor used was the Ping))) Ultrasonic Distance Sensor 28015 made by Parallax Inc. The passive infrared sensor was the AMN23111 Passive Infrared Motion Sensor made by Panasonic Electric Works. The heat sensor was an LM 335 temperature sensor. A capacitor was used to filter and balance the distribution of power from the power source to ground.

Initially the microcontroller was programmed to be used with a single sensor, and a MATLAB code was written to log data from a single sensor. Using this system, each sensor was tried one at a time to determine that it functioned correctly and that the circuit was being set up properly to gather data. Once all three sensors could function individually, the microcontroller was reprogrammed to function with all three sensors (see Appendix A for the code), and an addition was made to the MATLAB code in order to log data from all three sensors simultaneously (Appendix B).

Once all three sensors functioned together and the MATLAB code was debugged, the sensors—which were outputting numbers relative to each other but not of real world use—were calibrated so that the numbers they outputted were relevant. For the temperature sensor, a thermometer was used to

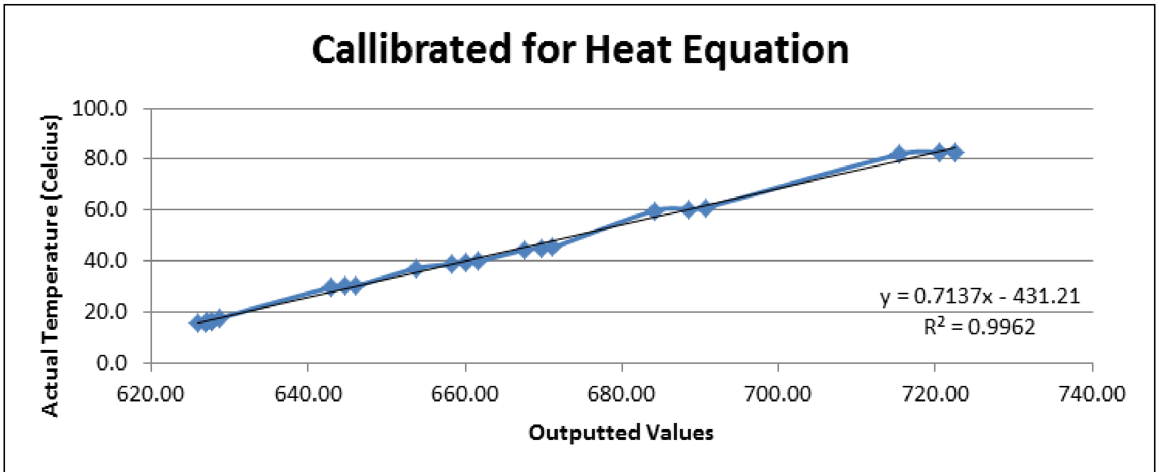

FIGURE 2: Values outputted from the heat sensor had to be calibrated into actual temperature values. To do this, the actual temperature was measured with a thermometer while logging data from the sensor, and then the results were graphed to determine the relationship.

determine the actual temperature, and values were logged by the sensor at a variety of temperatures. A heat gun was used to alter the temperature in order to obtain enough data points to effectively calibrate the temperature sensor. The values were inputted into Excel and graphed to determine the equation for the relationship (Figure 2). For the ultrasonic sensor, an object was placed at known distances from the sensor and the values outputted by the sensor were recorded from 10 cm to 100 cm at intervals of 10 cm. Three trials were run at each distance, and the average was taken to create a graph on Microsoft Excel. Using the equation from the graph, the ultrasonic sensor's numbers were converted to the actual distances in centimeters. The passive infrared sensor was not calibrated. Instead, it was observed that the sensor outputs a value ranging from 12 to 14 unless it detects heat movement. If heat movement is detected, the output dropped to 6 before stabilizing back at about 13.

FIGURE 3: The temperature sensor in position and taped to the top of the seat to detect body heat.

Using a Hummer as a test automobile, the sensors were set up in the controlled environment of an engineering workshop. The temperature sensor was taped to the top of the driver's seat (Figure 3), and the ultrasonic range sensor was positioned above the seat looking down at a slight angle as shown in Figure 4 on the next page. The passive infrared sensor was positioned in front and above the seat (Figure 5), slanted down towards an occupant. A diagram of three sensors in position can be viewed in Figure 6.

FIGURE 4: The ultrasonic range sensor mounted to the exposed frame of the Hummer as well. It was positioned above the seat at a slight angle to measure the height of any occupant.

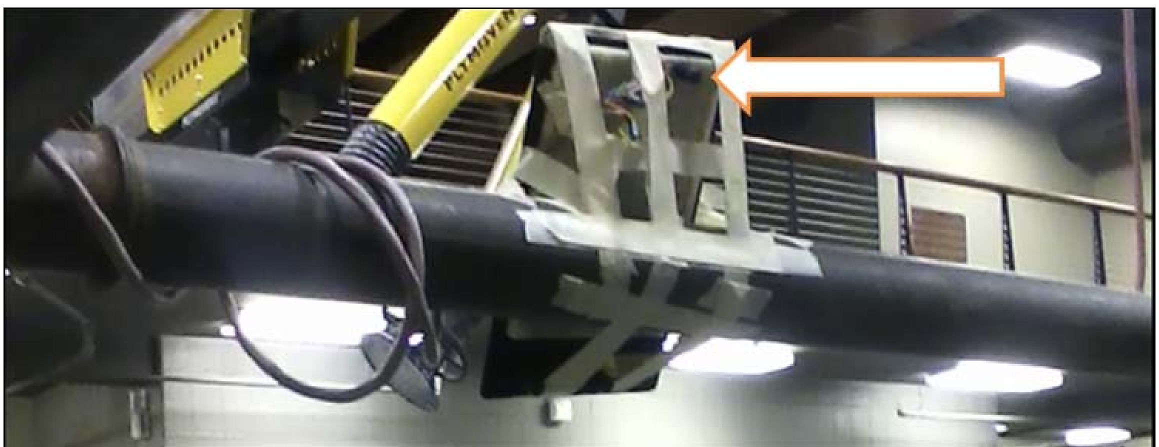

FIGURE 5: The passive infrared occupancy sensor was positioned in front of and above the seat, angled downward. It was mounted on the exposed frame of the Hummer. The arrow in the figure points to the actual sensor which is in a breadboard to make the position more stable.

As shown in the results section, data was logged at one sample per 100 milliseconds for 1000 samples per run. Occupants included female humans of ages 1, 4, 7, 13, and 57. Human male occupants were ages 2, 22, and 29. A small dog—both when sitting and when lying down—was used to represent animal occupants. A box was used to represent inanimate objects and was used a second time while being shaken to simulate the box's movement in a moving car. A hot crockpot was used to represent hot or warm inanimate objects.

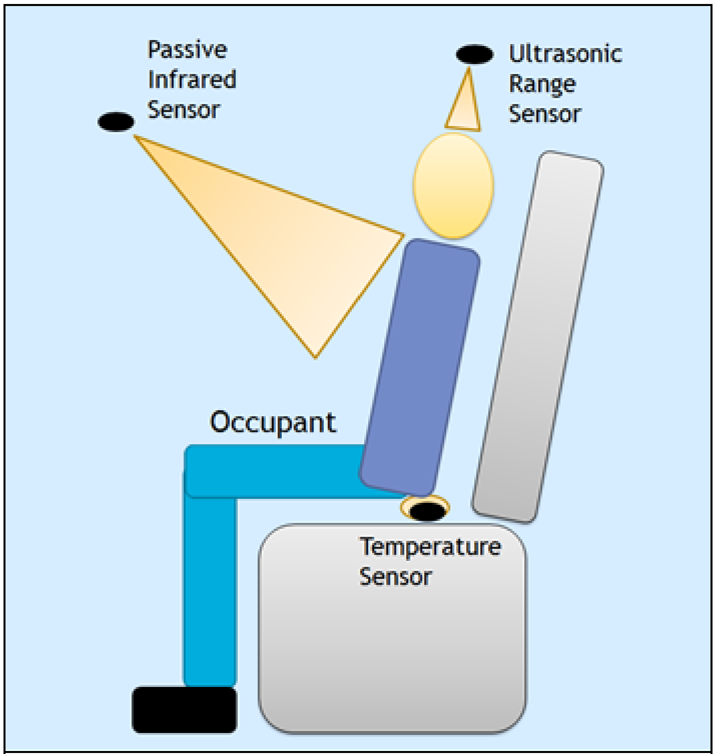

FIGURE 6: The picture shows how the sensors were positioned in relation to the automobile occupant. The orange zones indicate the direction and range of the sensors.

The data was collected by MATLAB and outputted to Microsoft Excel to be analyzed. After the analysis, an algorithm was written in MATLAB using half the samples to determine whether or not an airbag should be enabled in the case of an accident. Then the other half of the samples were run through the algorithm to determine if the algorithm was specific only to the first half of samples or if it applied to all of the samples and therefore, hopefully all possible samples.

RESULTS

The following graphs are split into two sections. The first section, dubbed "Algorithm Development", contains the graphs from logged data that were used when writing the algorithm to determine if the airbag should be enabled or not. The second section "Algorithm Check" contains the data in graph form that were used to verify that the algorithm functioned as it was supposed to function. All of the specific data values can be found in Appendix D.

Algorithm Development

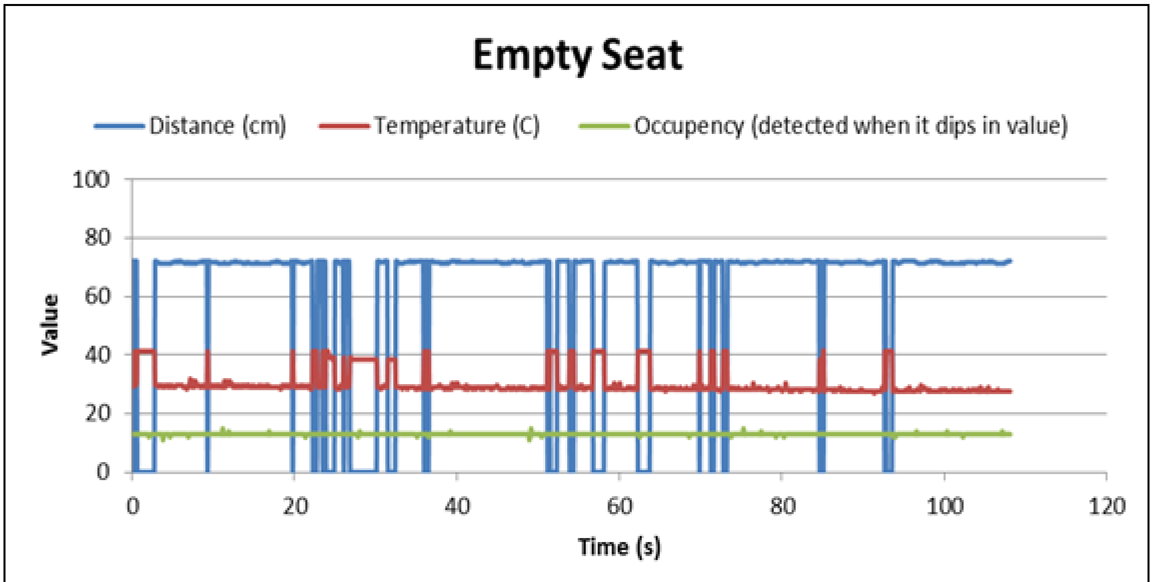

FIGURE 7: The data logged from the empty seat is an example of how the data sometimes corrupted itself, as seen in the relation of distance and temperature. Ignoring the corruption, it is clear that all the values are relatively stagnate.

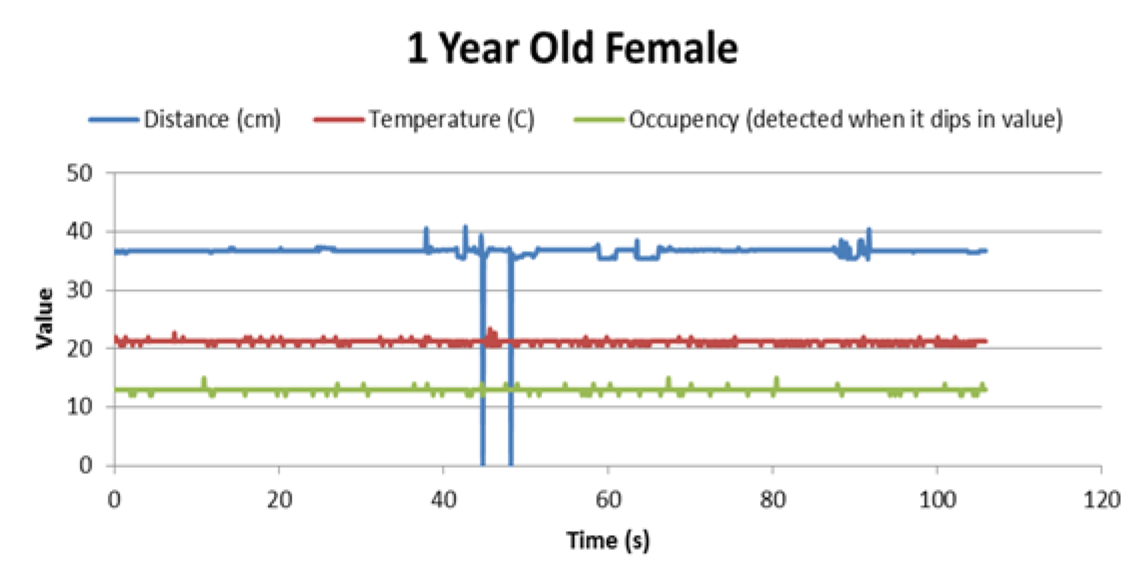

FIGURE 8: The one year old child did not have any occupancy detection. The other sensors did act as anticipated. This was probably due to the position of her car seat and the angle of the infrared sensor.

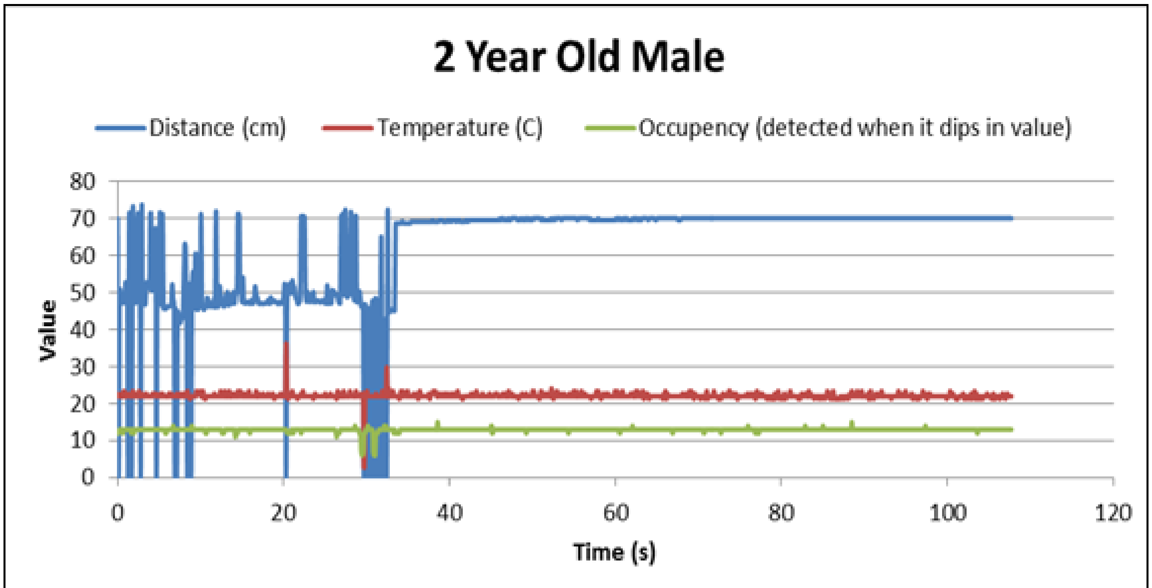

FIGURE 9: The child was removed early in the data run. When he was sitting, he was in a car seat.

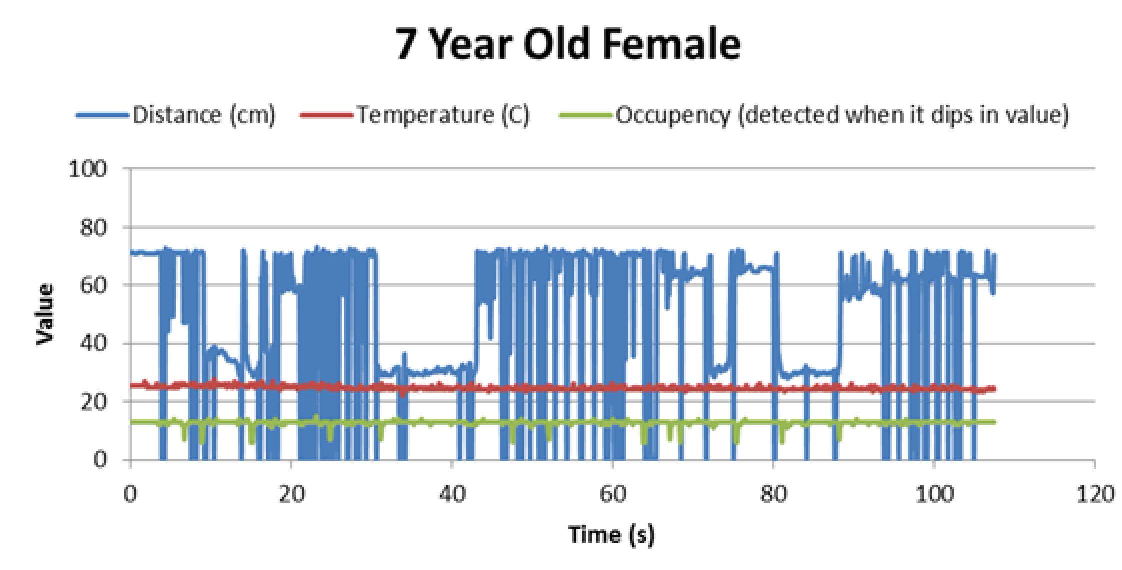

FIGURE 10: The graph of the seven year old child. She sat in a booster seat.

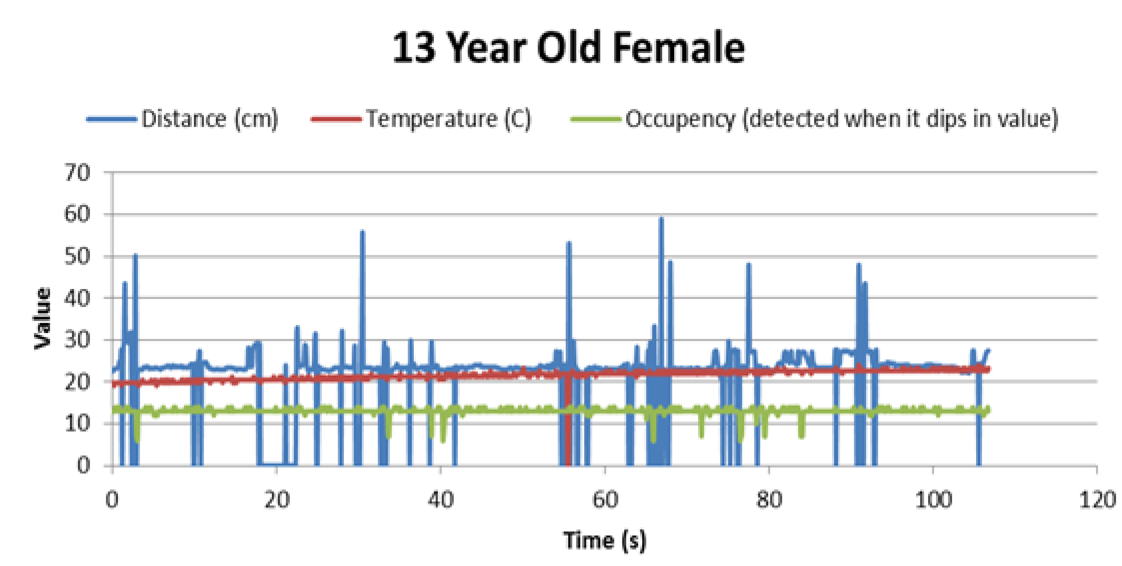

FIGURE 11: The data graph of the thirteen year old female exemplifies the rising temperature found when adults sit in the seat.

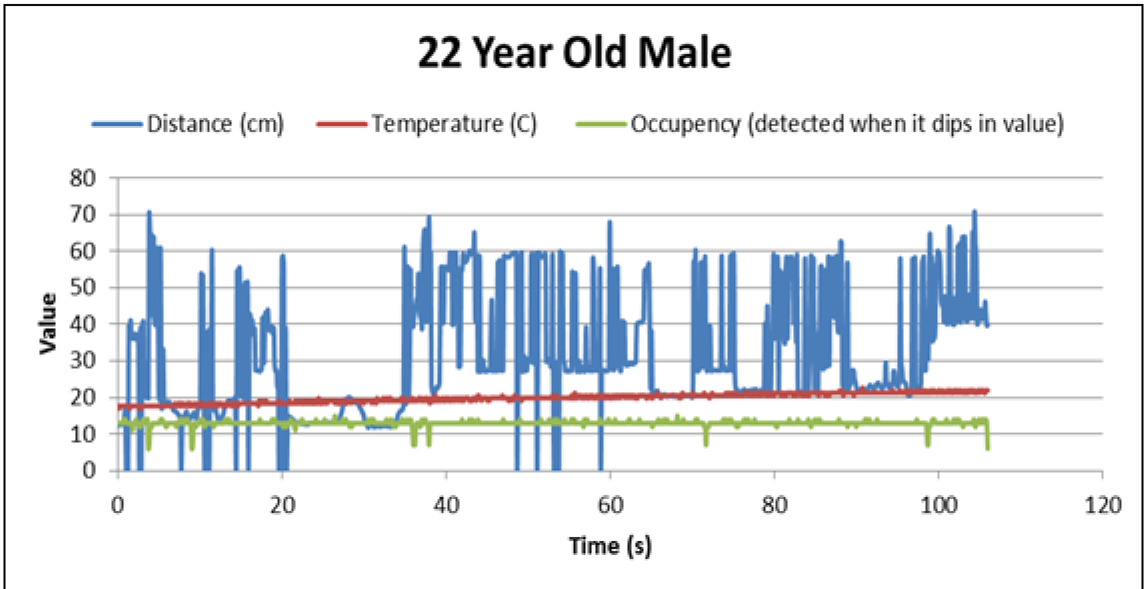

FIGURE 12: The data graph of the 22 year old male.

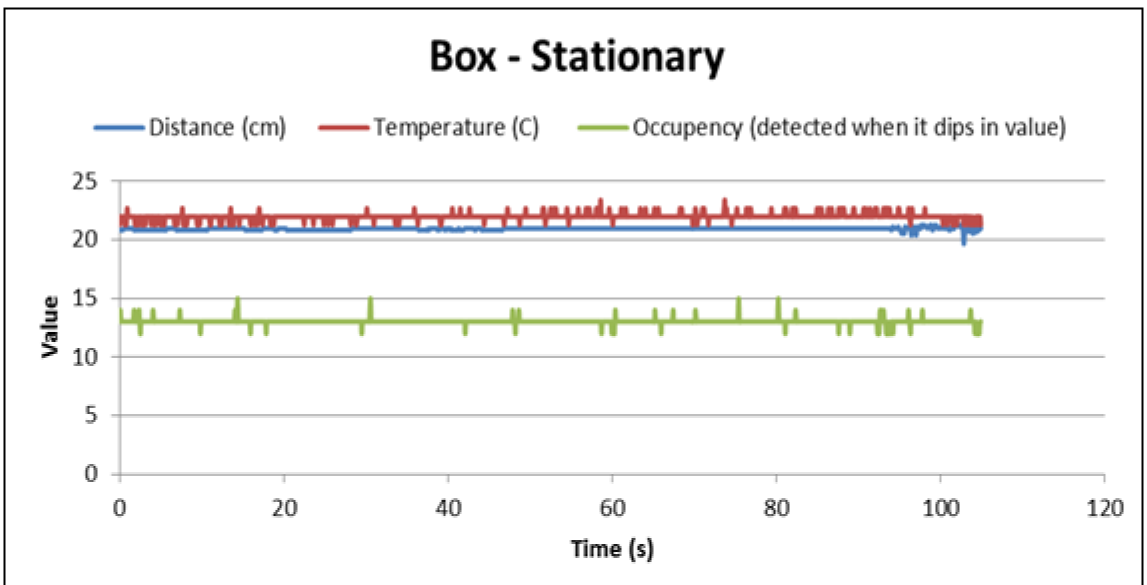

FIGURE 13: The box sat in the car seat and logged data as predicted.

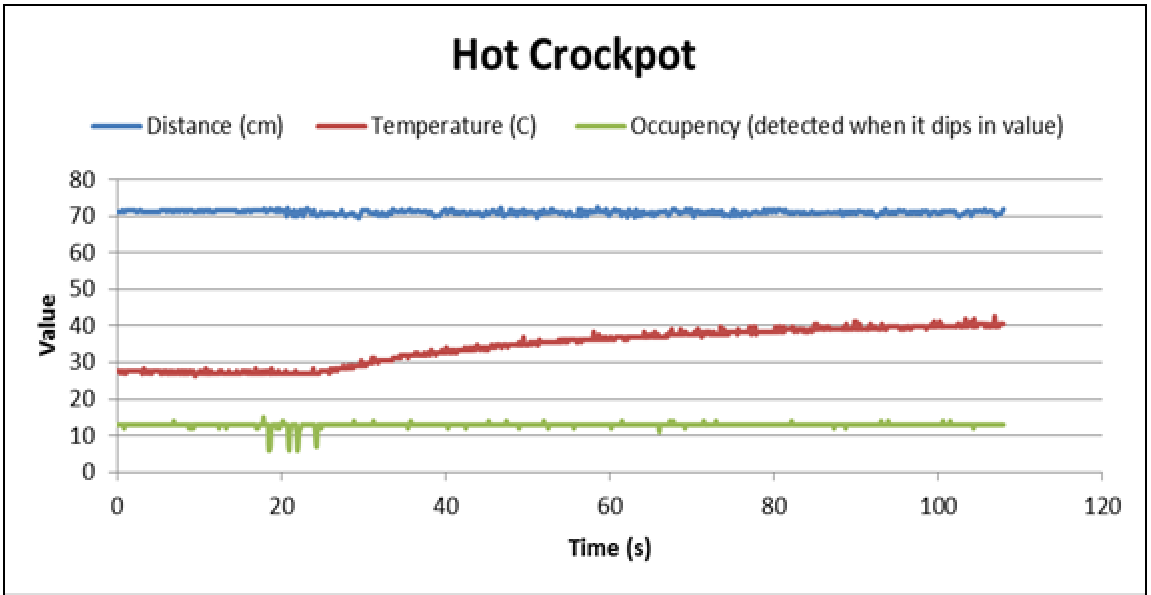

FIGURE 14: The data file for the heated crock pot detected occupancy when the pot was being set in the car, but not from the crockpot itself.

Algorithm Check

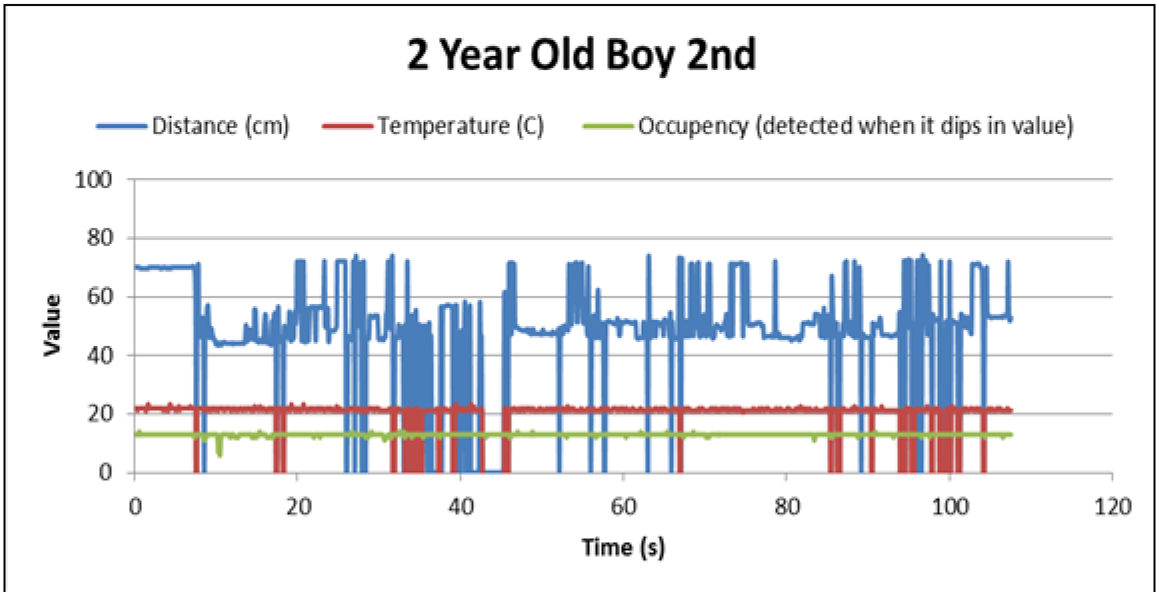

FIGURE 15: This was the second data run from the two year old male who sat in a car seat.

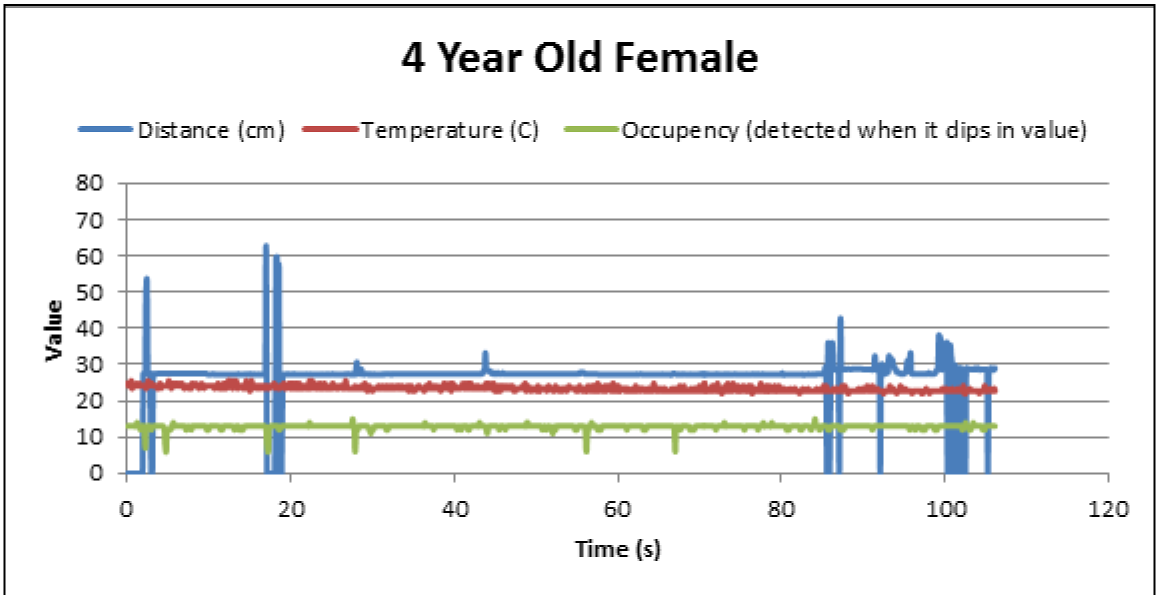

FIGURE 16: The data chart for the four year old female. She sat in a booster chair.

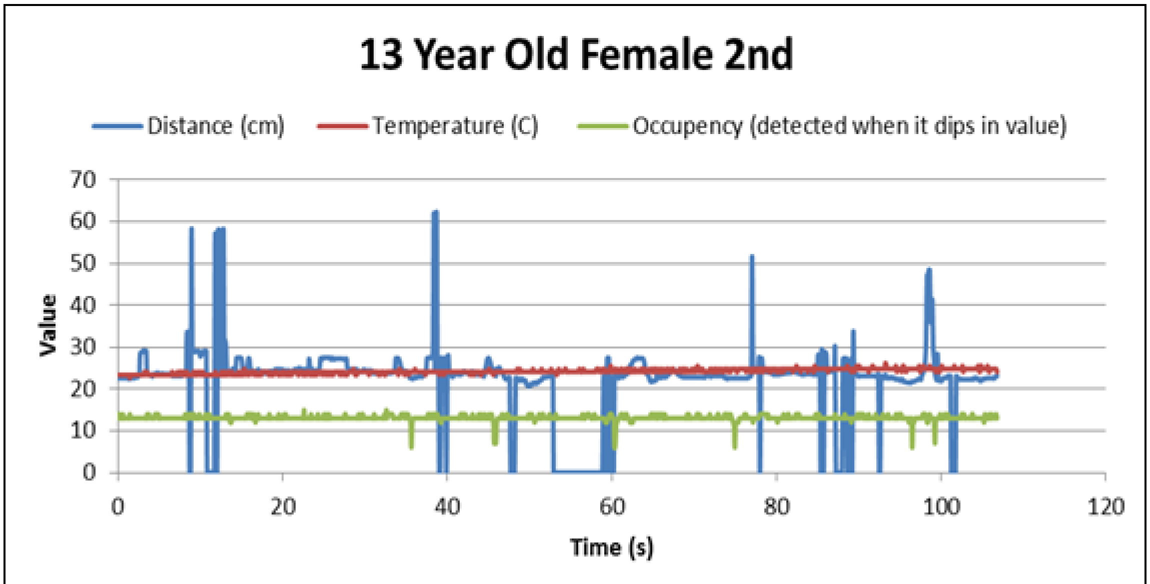

FIGURE 17: This was the second data run for the thirteen year old female.

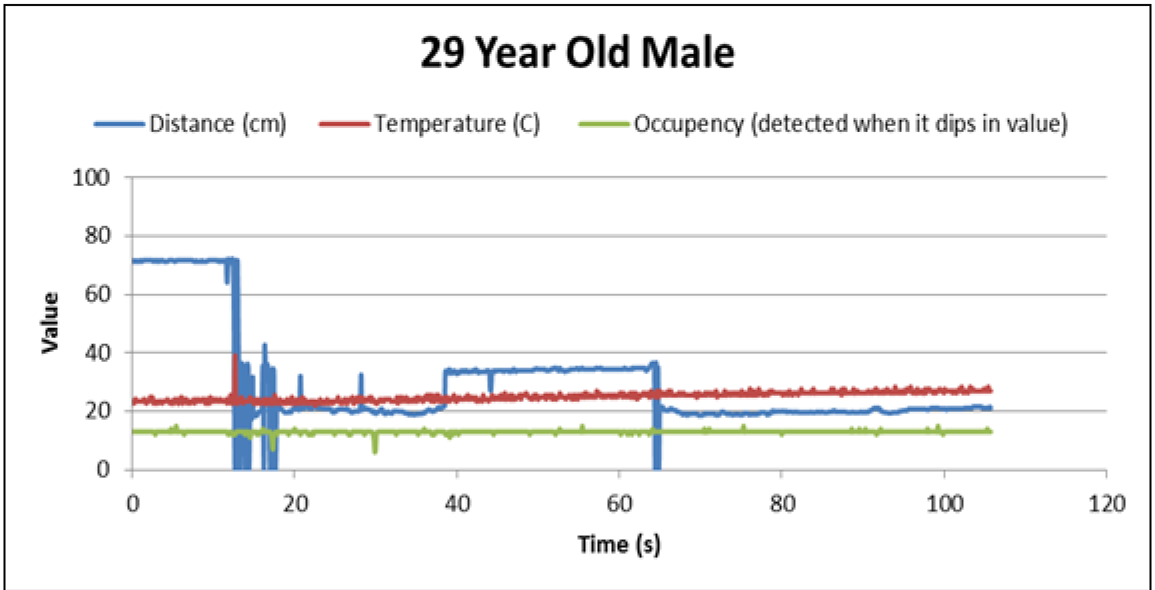

FIGURE 18: The data file for the 29 year old male.

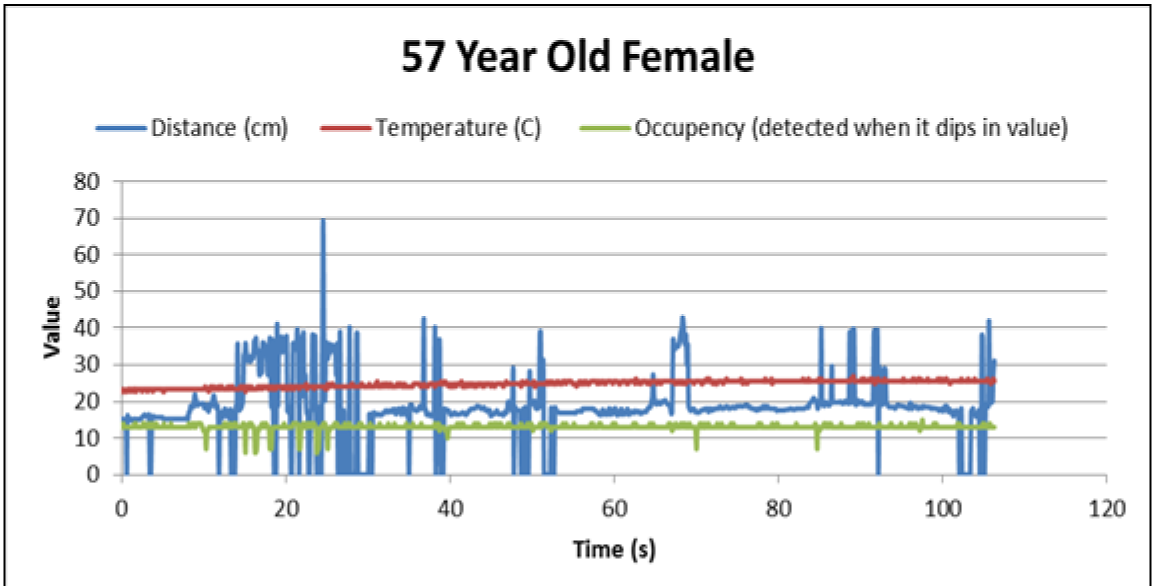

FIGURE 19: The data file for the 57 year old female.

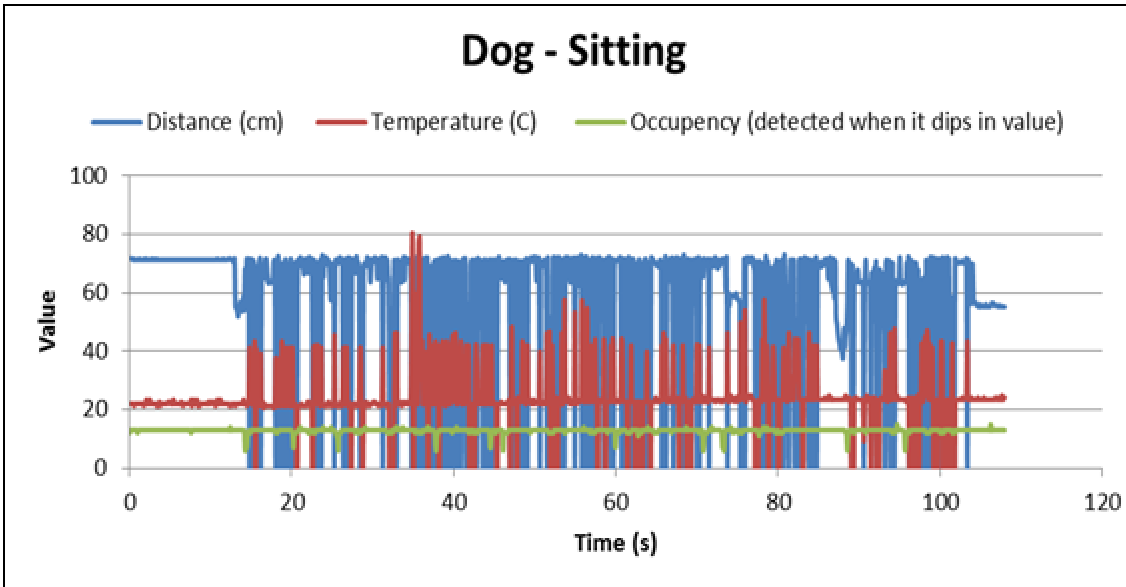

FIGURE 20: The data file for the dog when it was sitting was interesting. The lack of ability for the ultrasonic range sensor to find dog consistently resulted in extremely varying values for the distance.

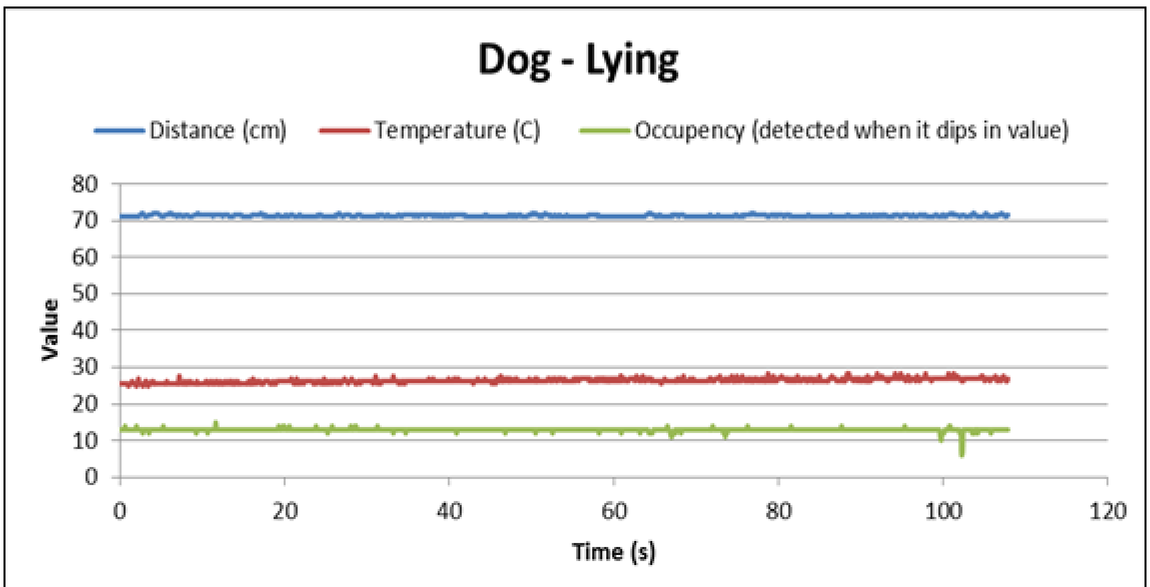

FIGURE 21: The dog, when it was lying down, was not detected.

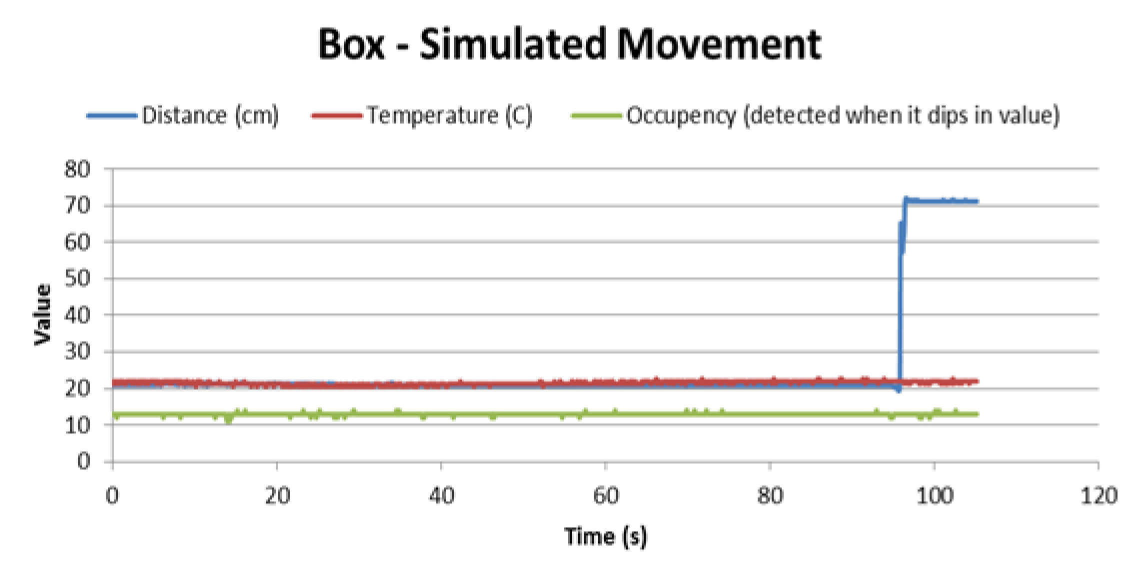

FIGURE 22: The box was run again while being shaking to simulate movement in the care. At the end of this run, the box was pushed forward and continued as if it fell over during a drive.

An odd phenomenon occurred while data was being logged that did not occur in the lab and was not seen until all data had been gathered: The ultrasonic range sensor sometimes read the value of approximately 72 cm (an empty seat) as 0. Therefore, both 0 and 72 refer to an empty seat, which is not an issue. However, a few times the jump between 0 and 72 caused interference with the heat sensor. This can be seen in the graphs for Empty Seat, 2 Year Old Boy – 2nd, and Dog – Sitting.

The data logged with the ultrasonic range, passive infrared, and temperature sensors provided interesting data as seen in the graphs on previous pages. Some of the results were expected, and some were not. For example, the temperature sensor functioned precisely as intended and hoped. When booster and car seats were used with children or when a non-heated inanimate object was placed on the seat, the temperature sensors provided a constant temperature value. When sat on or when the hot crockpot was placed on the seat, the temperature rose steadily.

The passive infrared sensor functioned almost completely as predicted with one variance. For the most part, the sensor had alterations from its near constant output only when it detected movement from a living occupant, signifying heat movement. However, the sensor did not report heat movement from the one year old child. The infrared sensor must have not been angled correctly to notice the one year old child, and that issue is addressed in the discussion.

The ultrasonic range sensor did not function as predicted in every aspect. As expected, it provided constant height values for inanimate objects, including the box when movement was being simulated. The ultrasonic sensor, however, did not report a consistent and near constant height value for living occupants. Instead, the ultrasonic sensor reported large spikes and sharp falls in height as the occupant moved in their seat. When developing the algorithm to make use of the data, the ultrasonic sensor was more useful for detecting movement than for reporting the height of the occupant.

DISCUSSION

Based on an analysis of the data, an algorithm was written to determine the identity of the occupant with as great a degree of accuracy as was feasible. The algorithm retrieves the data files originally logged and determines who or what is in the seat. Initially, it “cleans” the data. For example, where the ultrasonic range sensor logged 0 instead of 72 cm, the code recognizes this and enters the value of 72 in its place. After that, the code judges the number of infrared detections to see if someone is likely in the chair. If there are two detections, then it decides the chances are likely that someone or something living is in the chair. Then the system averages the temperature in portions of 250 samples and compares them to see if the average temperature is rising; however, for the temperature sensor to be useful outside of the laboratory, this would have to be rewritten for hotter environments. The temperature value would have to normalize to human temperature and not just detect rising temperature. This is addressed in greater detail later in the discussion. The algorithm then analyzed the height values from the ultrasonic sensor to determine how often the height changed. Once the algorithm finished the analysis and logged representative values for its judgments, it proceeds to make a decision for airbag enablement. If the infrared count is high enough to be considered living, it checks to see if the ultrasonic sensor detected movement. If so, it checks to see if the temperature is rising. If it as well, the algorithm decides that an adult is the occupant. If the temperature is not rising, then it is determined to be a child. If there is no height movement and not enough infrared detection, the airbag is disabled. If there is dynamic height but no infrared detection, then the system knows that the infant was the occupant.

When analyzing the data and developing the algorithm, it was found that the three sensors did not provide as much precision as hoped (see Table 1 for general results). The system is not flawless, and therefore, the data it provided has limitations. The written algorithm correctly identified adults (e.g. Figure 12)

Analysis of Sensor Results

Occupant	Infrared Detection	Dynamic Height	Temperature Rise
1 Year Old Female	No	Yes	No
2 Year Old Male	Yes	Yes	No
4 Year Old Female	Yes	Yes	No
7 Year Old Female	Yes	Yes	No
13 Year Old Female	Yes	Yes	Yes
22 Year Old Male	Yes	Yes	Yes
29 Year Old Male	Yes	Yes	Yes
57 Year Old Female	Yes	Yes	Yes
Box - Stationary	No	No	No
Box - Simulated Movement	No	No	No
Dog - Laying	No	No	Yes
Dog - Sitting	Yes	Yes	Yes
Hot Crockpot	No	No	Yes

TABLE 1: To help see patterns in the data, the graphs were analyzed to see if they met specific and simple parameters. The parameters used were infrared detection, changing height, and rising temperature. Except for the 1 year old child not being detected by the passive infrared sensor, both the infrared and temperature sensor functioned as expected. The ultrasonic range sensor had to be used to measure whether or not height was changing instead of the height of the occupant to be useful.

and can correctly identify children (e.g. Figure 10) who must use car seats or booster seats. However, because the range sensor did not provide actual heights consistently, the system could not estimate the ages of the children. The system incorrectly detected no occupancy for the one year old human occupant (Figure 8), though it still detected height movement. With the exception of the one year old, the infrared sensor alone can determine if the occupant is living or not. The ultrasonic range sensor is rendered almost completely unnecessary.

As far as non-humans go, the dog (Figure 20) could fool the system into believing that it is an adult human when sitting. Normal inanimate objects, represented by a box (Figure 13), are correctly identified as non-living. The result is true even when movement was simulated as if the vehicle were in motion (Figure 22). The algorithm successfully identifies the hot crockpot (Figure 14) as a non-human, despite the temperature rise. In fact, the algorithm written using half of the samples correctly identified the occupants of the other half of the samples, except for the dog. However, while the algorithm separates children from adults, in cannot determine an approximate age for children. More testing is required to see how exhaustive its ability is and how difficult it is to trick.

One limitation of the experiment was the temperature. Because the experiment was conducted in a laboratory setting, the temperature was constant. When an adult occupant is on the seat, the temperature sensor should eventually adjust to the internal temperature of the adult. Therefore, the experiment is likely valid for all temperatures. However, further testing would need to be done to ensure that at higher temperatures, the sensor adjusts towards human temperature, whether it is an increase or decrease in comparison to the ambient temperature. That is, the temperature sensor should read a falling temperature that stops at the internal temperature of the human if the car is hot in the middle of the summer. The algorithm would have to be altered to take this situation into account as well.

Another limitation of the project was in the failure of the infrared sensor to identify the one year old as living. As it is probably the result of the angle of the passive infrared sensor, it is probable that a steeper angle from the sensor to the seat would detect the child. To retain the integrity of the experiment, the position was not altered for this one test, but it would not be difficult to do further research in this area. Additionally, if one or two more of these sensors were used at different angles, they could potentially aid in determining age. For example, a passive infrared sensor directly above and facing down would have identified the one year old as living, and knowing that the original passive infrared sensor did not detect a living occupant, the assumption could be made that the child is very young and in a car seat. Another angle—possibly from the side—could determine if a child were in a car seat versus a booster seat, and therefore help determine age. Alternate positions of infrared sensors may potentially be of use in determining the difference between an adult and a dog.

Furthermore, if a weight sensor were added to this system—or perhaps if this system were used in conjunction with the weight sensors already commonly used—the weight sensor would be of great help determining the occupant. Light weight detected could reveal an animal or a child that is not in the proper car seat or booster seat, while heavier weights would indicate an adult. The weight sensor could act as a trigger for the system. When weight is detected, the other sensors activate to determine what exactly the occupant is, and once determined, the airbag remains off or on as determined for the duration of the drive.

CONCLUSION

The goal of this project was to determine the potential of the ultrasonic range, passive infrared, and temperature sensors in a smart airbag system. After designing a circuit with these sensors and logging data in a vehicle, the analysis of the data shows that the design within itself would be insufficient to determine the occupant of an automobile seat. Furthermore, a single range sensor from the top of the car will not reveal the height of the occupant to a respectable degree of certainty. The end results, however, provided useful data, and it is therefore likely that with a little more research and perhaps a couple adjustments to the sensors, a system could be developed to fully determine identity of the occupant of the automobile seat, creating a relatively inexpensive and effective smart airbag system.

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APPENDIX A – MICROCONTROLLER CODE

```
/*
 * Project name:
    Smart Airbag
 * Description:
    Get data from analog sensors and send to the computer.
 * Test configuration:
    MCU:            PIC16F690
    Oscillator:     INTRCIO, 08.0000 MHz
    SW:             mikroC PRO for PIC
 * NOTES:
    - Connect VDD (pin 1) to +5V and VSS (pin 20) to ground.
    - Connect AN7 (pin 7) to the analog infared sensor.
    - Connect RX  (pin 12) to a TX pin on another device.
    - Connect TX  (pin 10) to a RX pin on another device.
*/

 #define Lo(param) ((char *)&param)[0]
 #define Hi(param) ((char *)&param)[1]

 void InitMain()
{
 OSCCON = 0b01110001;           // Internal 8MHz Oscillator

 ANSEL  = 0b11000000;           // Configure AN pins as digital
 ANSELH = 0;
 C1ON_bit = 0;                  // Disable comparators
 C2ON_bit = 0;

 PORTA = 0;                     // set PORTA to 0
 TRISA = 0;                     // configure PORTA pins as output
 PORTB = 0;                     // set PORTB to 0
 TRISB = 0;                     // designate PORTB pins as output
 PORTC = 0;                     // set PORTC to 0
 TRISC = 0;                     // PORTC pins as output,

 ADC_Init();
 UART1_Init(9600);              // Initialize UART module at 9600 bps
                            //  max: 57600 for PIC16F690)
}

void main()
{
 unsigned int count;
```

```
  InitMain();

  while(1)
  {
    ADC_Get_Sample(6);
    UART1_Write(ADRESL);            // send command via UART
    UART1_Write(ADRESH);
    Delay_ms(33);

    ADC_Get_Sample(7);
    UART1_Write(ADRESL);            // send command via UART
    UART1_Write(ADRESH);
    Delay_ms(33);

    TRISC.B6=0;
    PORTC.B6=1;
    delay_us(5);
    PORTC.B6=0;
    TRISC.B6=1;
    count=0;
    while(PORTC.B6==0);
    while(PORTC.B6==1)
    {
    delay_us(5);
    count=count+1;
    }

    UART1_Write(Lo(Count));            // send command via UART
    UART1_Write(Hi(count));
    Delay_ms(34);
  }
}
```

APPENDIX B – MATLAB DATA LOGGING CODE

```
h = serial('COM11');
fopen(h);
infrared_array = [];
heat_array = [];
sonic_array = [];
time_array = [];
infrared_sum = 0;
heat_sum = 0;
sonic_sum = 0;
counter = 0;

t1 = clock;

for i=1:1000

    time_array = [time_array etime(clock,t1)];
    val1 = fread(h,1,'uint16');
    if(val1 > 500)
        if(val1 < 1000)
            heat_val = val1 * 0.7137 - 431.21;
            heat_array(i) = heat_val;
        end
    end
    if(val1 < 500)
        if(val1 > 16.5)
            sonic_val = 0.1462 * val1 - 0.5214;
            sonic_array(i)=sonic_val;
        end
        if(val1 < 16.5)
            infrared_val = val1;
            infrared_array(i)=infrared_val;
        end
    end

    val2 = fread(h,1,'uint16');
    if(val2 > 500)
        if(val2 < 1000)
            heat_val = val2 * 0.7137 - 431.21;
            heat_array(i) = heat_val;
        end
    end
    if(val2 < 500)
        if(val2 > 16.5)
```

```
            sonic_val = 0.1462 * val2 - 0.5214;
            sonic_array(i)=sonic_val;
        end
        if(val2 < 16.5)
            infrared_val = val2;
            infrared_array(i)=infrared_val;
        end
    end

    val3 = fread(h,1,'uint16');
    if(val3 > 500)
        if(val3 < 1000)
            heat_val = val3 * 0.7137 - 431.21;
            heat_array(i) = heat_val;
        end
        end
    if(val3 < 500)
        if(val3 > 16.5)
            sonic_val = 0.1462 * val3 - 0.5214;
            sonic_array(i)=sonic_val;
        end
        if(val3 < 16.5)
            infrared_val = val3;
            infrared_array(i)=infrared_val;
        end
    end

    i=i
end
fclose(h);

figure(1);
plot(infrared_array);
infrared_median=median(infrared_array);
display(infrared_median);
title('Occupency Change')

figure(2);
plot(heat_array);
heat_mean=mean(heat_array);
display(heat_mean);
title('Temperature (C)');

figure(3);
plot(sonic_array);
```

```
sonic_median=median(sonic_array);
display(sonic_median);
title('Distance (cm)')
datestring = [datestr(clock) '.csv'];

csvwrite([datestring(1:11) '-' datestring(13:14) '-' datestring(16:17)
'.csv'],[(time_array - time_array(1))' infrared_array' heat_array' sonic_array'])
```

APPENDIX C – MATLAB ALGORITHM

```
data = csvread('Data.File.Name');
time = data(:,1);
occupancy = data(:,2);
temp = data(:,3);
range = data(:,4);

figure(1)
plot(time, occupancy)
title('Infrared')
figure(2)
plot(time, temp)
title('Heat')
figure(3)
plot(time, range)
title('Range')

enabled = [];
enabled_times = [];

infrared_enabler = 0;
heat_count = 0;
heat_sum=0;
heat_enabler = 0;
sonic_enabler = 0;
sonic_disabler = 0;

for i=1:1:length(time)
    time_val = time(i);
    heat_val1 = temp(i);
    sonic_val1 = range(i);
    infrared_val = occupancy(i);


    % To clean the data
    if(i==1)
        heat_prev = heat_val1;
    end
    if(heat_prev > heat_val1 + 10)
        heat_val1 = heat_prev;
    end
    if(heat_prev < heat_val1 - 10)
        heat_val1 = heat_prev;
    end
```

```
    heat_prev = heat_val1;
    if(sonic_val1 == 0)
        sonic_val1 = 72;
    end

    % Enabling factors
    if(infrared_val < 7.1)
        infrared_enabler = infrared_enabler + 1;
    end

    heat_sum = heat_val1 + heat_sum;
    heat_count = heat_count + 1;
    if(heat_count > 249)
        if(i==250)
            heat_val2=heat_mean;
        end
        heat_mean = heat_sum / 250;
        if(heat_val2 < heat_mean)
            heat_enabler = heat_enabler + 1;
        end
        heat_val2 = heat_mean;
        heat_count = 0;
        heat_sum = 0;
        display(heat_mean);
    end


    if(i==1)
        sonic_val2 = sonic_val1;
    end
    if(sonic_val2 < sonic_val1 - 3)
        sonic_enabler = sonic_enabler + 1;
    end
    if(sonic_val2 > sonic_val1 + 3)
        sonic_enabler = sonic_enabler + 1;
    end
    sonic_val2 = sonic_val1;
end

if(infrared_enabler > 1.5)
    if(sonic_enabler > 10)
        if(heat_enabler < 2.9)
            display('Airbag Enabled - Child');
        else
            display('Airbag Enabled - Adult');
```

```
        end
    else
        display('Airbag Disabled - Infrared registered movement, but Sonic did not!')
    end
else
    if(sonic_enabler > 10)
        if(heat_enabler < 2.9)
            display('Airbag Disabled - Infant');
        else
            display('Airbad Disabled - Inanimate Object Moving Around')
        end
    else
        display('Airbag Disabled - Not Human')
    end
end
```

APPENDIX D – EXPERIMENTAL DATA FILES

The electronic folder "Appendix D – Experimental Data Files" is split into two folders. The first folder "Algorithm Development" contains the Microsoft Excel data files used when writing the algorithm to determine if the airbag should be enabled or not. The second folder "Algorithm Check" contains the files used to verify that the algorithm function as it was supposed to function. Each file contains all the logged data as well as graphs made from the data collected.

Algorithm Development contains eight data files:

1. 06-Mar-2014-16-45 Female 13 yr 1st: This file contains the data logged from a thirteen year old female. Two sets of data were logged with her in the automobile seat, and this was the first one taken.
2. 06-Mar-2014-17-13 Male 22 yr: This file contains the data logged from a twenty-two year old male.
3. 11-Mar-2014-16-08 Boy 2 yr 1st: This file contains the data logged from a two year old male. Two sets of data were logged with her in the automobile seat, and this was the first one taken. He was in a car seat.
4. 11-Mar-2014-16-31 Female 1 yr: This file contains the data logged from a one year old female. She was in a car seat.
5. 11-Mar-2014-16-35 Box: This file contains the data logged from a cardboard box.

6. 11-Mar-2014-19-33 Female 7 yr booster seat: This file contains the data logged from a seven year old female. She sat on a booster seat.
7. 11-Mar-2014-19-47 Empty Seat: This file contains the data logged when no one and nothing was occupying the automobile seat.
8. 11-Mar-2014-19-49 Hot Crockpot: This file contains the data logged from a crockpot that had been heated before being set on the seat.

Algorithm Check contains eight data files:

1. 06-Mar-2014-16-47 Female 13 yr 2nd: This file contains the data logged from a thirteen year old female. Two sets of data were logged with her in the automobile seat, and this was the second one taken.
2. 06-Mar-2014-16-51 Female 57 yr: This file contains the data logged from a fifty-seven year old female.
3. 11-Mar-2014-15-59 Male 29 yr: This file contains the data logged from a twenty-nine year old male.
4. 11-Mar-2014-16-10 Boy 2 yr 2nd: This file contains the data logged from a two year old male. Two sets of data were logged with her in the automobile seat, and this was the second one taken. He was in a car seat.
5. 11-Mar-2014-16-37 Box: This file contains the data logged from a cardboard box while it was being shaken to simulate traveling in a moving automobile.

6. 11-Mar-2014-16-39 Dog Sitting: This file contains the data logged from a small Boston Terrier while it was sitting in the automobile seat.
7. 11-Mar-2014-16-42 Dog Lying Down: This file contains the data logged from a small Boston Terrier while it was lying down in the automobile seat.
8. 11-Mar-2014-19-36 Female 4 yr booster chair: This file contains the data logged from a four year old female. She sat on a booster seat that had a back to it as well, but no sides.