PERFORMANCE ANALYSIS OF AUTOMATIC TEMPERATURE SCREENING & HAND SANITIZATION MACHINE

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Abstract - *This paper reviews the design development and performance analysis of an automated temperature screening & hand sanitization machine. This machine will be applicable in all areas of mass gathering to monitor the occupant body temperatures and hand sanitization. The need to automate such a system is of topmost importance keeping in view the current pandemic outbreak where the avoidance of physical touch is of great significance. This paper describes the process of designing the machine in various stages and analyzes the performance of the process of screening the temperature with hand sanitization in each stage for comparison. It also compares this solution to other market alternatives and explains the benefits thereof. This paper explores the detailed introduction about the current pandemic in chapter 1. Further in chapter 2, the block diagram of the entire system with its subcomponents is discussed. In chapter 3 the types of sensors used with their significance, connection in the system, and codes for execution are elaborated. The design of three different models is explained in chapter 4. The next chapter talks about the software used for the execution of the processes in the machine. Finally, it concludes with the comparison of all the models developed with the final model.*

Keywords: Automated Temperature Sensor, Automated Sanitizer Dispenser, Arduino, Covid-19 Pandemic, Microcontroller, Programmable Control, Robotics.

1. INTRODUCTION

The coronavirus pandemic also known as the COVID-19 Pandemic has now affected most of the world population and is still on a rise[8]. The virus causes acute organ failures primarily of LUNGS, blood clots, and chronic fatigue. Humans are found to be the majority of carriers of this virus. The virus is primarily transmitted via direct physical contact (e.g., from touch) or as an airborne particle coming out from breath or via sneezing which is ingested by another human being. After a complete lockdown for several months, most of the world is resuming the routine workflow. To avoid the spread of the COVID-19 virus during this unlock and for the times ahead certain guidelines are advised, to keep a check on the presence of the disease within an area of mass human presence [18][19].

The primary symptoms of this virus are fever, cough fatigue, loss of taste & smell, etc. Out of these the most prominent symptom that can be measured in the presence of fever. If we can check the human body temperature before a person enters the place which has a social subsistence, then the identification of the person having the symptoms can be segregate from the crowd and suggested for further related medical test for safety[22][13].

Keeping in mind this check is mandatory, there are numerous temperature guns available for screening the body temperature. But these perform only one job and require another human for operation. This process has a huge scope of automation wherein a machine can automatically detect the human temperature and also dispense the sanitizer without any contact to serve as an All-In-One alternative to complete both the task within a period. A machine like this would be capable of replacing all the existing tech like temperature guns, hand, and foot-operated sanitizer dispensers, and all other combinations that are based on manual operation. The purpose of this paper is to describe the design of such a machine based on multiple prototypes fabricated and compare the performance by considering the operating parameters and time requirement.[22][23].

2. SYSTEM DESIGN

2.1 Basic Block Diagram of the System.

The system has two primary functions, the first is to automatically sense the temperature from a certain distance and display it on a screen and the second one is to dispense the sanitizer once the hands are brought below the machine without touch [1].

To serve these basic functions the system requires synchronization of sensor and actuator with one closed-loop control system along with the basic components required in it. The system block diagram is shown in [Fig (1)].

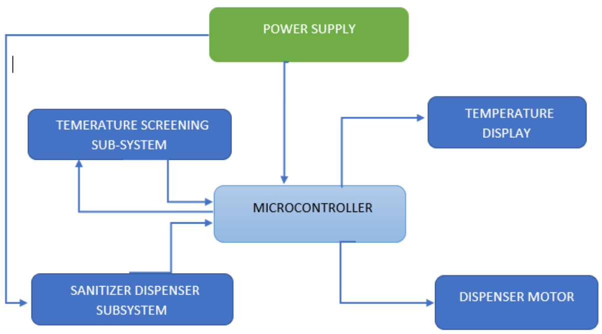


Fig. 1 - System block diagram

The system includes the following basic components with their unique purpose.

Power Supply – The machine is powered by a 12 V 2A DC adapter with an inbuilt surge protector.

Microcontroller – Arduino Mega with Atmega 2560 is chosen as the microcontroller for this system. Arduino Mega is a microcontroller that is a part of the AVR group. This is a universal programmable board used for developing prototypes. It has51 Digital input pins, including PWM, Rx, Tx pins, 6 analog input pins with inbuild ADC, a power jack, ICSP header, etc. This microcontroller uses Arduino software depends on C++. In Arduino, the program is divided into the void loop & void setup. Rest all the sensors are coupled with the code using built-in libraries.

2.2 Temperature Screening Sub-System – The components of this sub system are shown in [Fig. 2.] include the temperature sensor (MLX90614) an ultrasonic sensor and the display screen.

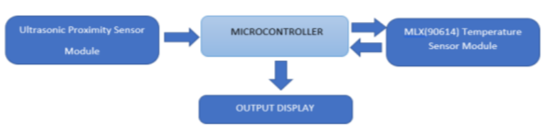


Fig. 2. – Temperature screening sub system

The actual components used in the temperature screening are,

Sensors – Proximity Sensor (Either IR or Ultrasonic), Temperature Sensor

Output Devices – 16x2 Lcd Display, 5V Active Buzzer.

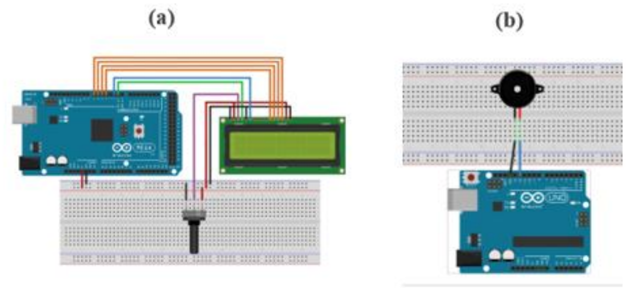


Fig. 3. – Components of temperature screening

Working

The basic working of this system begins with the Microcontroller initiating the ultrasonic sensor to send the ultrasonic waves at an interval of 10 milliseconds.

- On encountering an interruption, the sound waves reflect and are received by the receiver module.
- On reception of these waves, the module communicates the signal to the microcontroller which then initiates the Melexis Temperature sensor and asks it to sense the temperature of the object currently in its proximity.
- The analog voltage value of this sensor is then communicated serially to the microcontroller which performs the ADC operations and registers the corresponding sensor value.
- This value is displayed on the screen.

2.3 Sanitizer Dispenser Sub-System – The [Fig. 4.] shows this system, that with all the components works in unison with the microcontroller to dispense sanitizer to the users in a precise. The components of this system include an ultrasonic or an IR proximity sensor and an actuator mechanism for dispensing. The block diagram of this system is shown in figure 4[1][5].

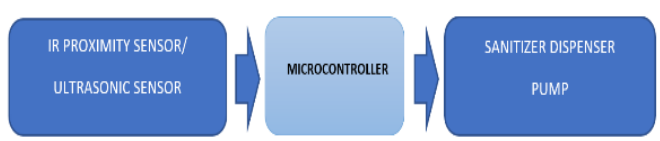


Fig. 4. – Sanitizer dispenser sub system

The components of this sub system include:

Sensors – IR/Ultrasonic Proximity Sensor

Output devices – 1 Channel 5V Relay Module, 12V DC Solenoid Valve

The following [Fig. 5(a)] shows the actual components used in the dispenser sub system

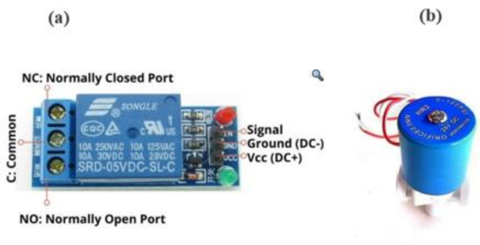


Fig. 5. (a) Relay module used for operating solenoid valve. (b) Solenoid Valve

3. SENSORS & SOFTWARE

3.1 Temperature Sensor: MLX 90614 – is a "Melexis" series infrared-based sensor with a field of view of 90 degrees [Fig. 6(a)]. It is an infrared thermometer for contactless measurement of temperature. Both the IR-sensitive thermopile detector chip and the signal conditioning ASIC are integrated into the same aluminium can. It has built-in low noise amplifiers, 17-bit ADC, and a strong DSP unit hence achieving very high accuracy and sensitivity for a thermometer[7][17].

This sensor gives access to a temperature range of 140 degrees with a resolution of 0.02°C.

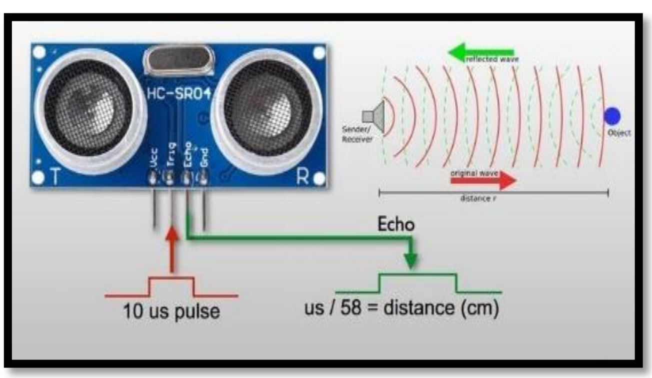


Fig. 6(a) – Melexis 90614 Temperature sensor (b) Block diagram of Melexis 90614 sensor

3.2 Proximity Sensor: For sensing the proximity of the subject from the machine we used two primary sensors.

1. **Ultrasonic Range Sensor**

2. **IR Proximity Sensor**

3.2.1 Ultrasonic Range Sensor - An ultrasonic sensor [Fig. 7] converts electrical energy into sound waves and vice versa. The acoustic wave signal is an ultrasonic sound wave that travels at a frequency over 18 kHz. It requires a microcontroller for attaching the sensor to the system[9].

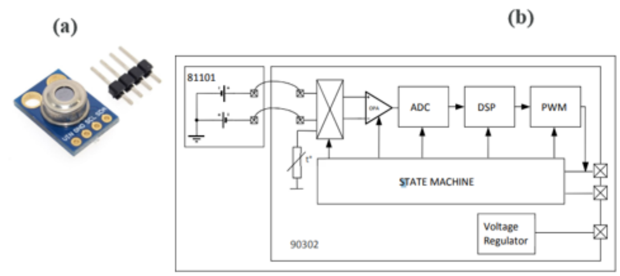


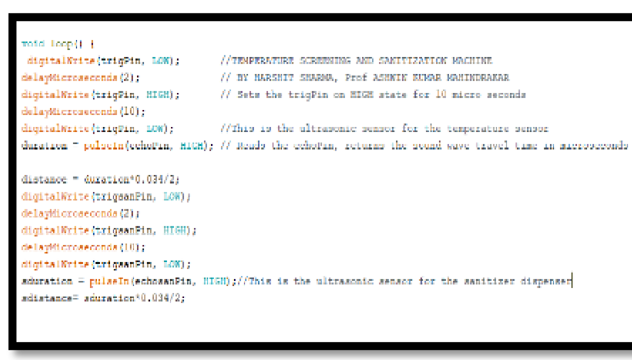
Fig. 7. – Ultrasonic range sensor

Connections

The ground and VCC pins are attached to the Arduino ground and 5V respectively. The trig pin is attached to any one of the PWM-enabled digital pins on the Arduino. The Echo pin is also attached to any one of the PWM-enabled digital pins on the Arduino.

Code

The code [Fig. 8] begins with defining the signal pin(s) that which the ultrasonic sensor is attached. The trig pin is set to LOW for 2 microseconds, and then HIGH for 5 microseconds, and then again LOW for a time of 2 microseconds. Then, the echo pin is declared as an INPUT and the time duration is captured using the (pulse in) method. Once the time elapsed is calculated the next step is to convert this to distance. The distance is calculated using the velocity of sound conversion factors in centimetres.



```
void loop() {
 digitalWrite(trigPin, LOW);       //TEMPERATURE SCREENING AND SANITIZATION MACHINE
delayMicroseconds(2);              // BY HARSHIT SHARMA, Prof ASHWIN KUMAR WAMINDRAKAR
digitalWrite(trigPin, HIGH);       // Sets the trigPin on HIGH state for 10 micro seconds
delayMicroseconds(10);
digitalWrite(trigPin, LOW);        //This is the ultrasonic sensor for the temperature sensor
duration = pulseIn(echoPin, HIGH); // Reads the echoPin, returns the sound wave travel time in microseconds

distance = duration*0.034/2;
digitalWrite(trigsanPin, LOW);
delayMicroseconds(2);
digitalWrite(trigsanPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigsanPin, LOW);
sduration = pulseIn(echosanPin, HIGH);//This is the ultrasonic sensor for the sanitizer dispenser
sdistance= sduration*0.034/2;
```

Fig. 8 – Program Code for initiating ultrasonic sensor.

3.2.2 IR Proximity Sensor –It works based on the electromagnetic beam reflection which is sensed by a receiver module and the generated pulse is sensed back to the microcontroller and is used for actuation.

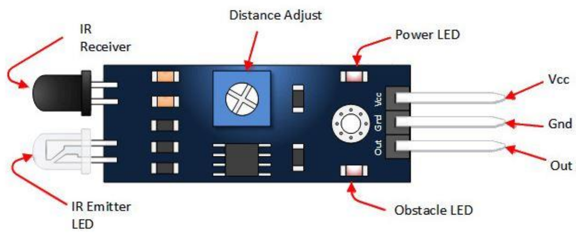


Fig. 9 – IR Proximity Sensor

Connections

The IR sensor [Fig. 9] uses the 3 pins to connect to the Arduino. The VCC and GND Pins are connected to the 5V and the ground pins respectively. The out pin is connected to the digital pin of the Arduino as an OUTPUT [15][16].

4. Design of prototypes

The prototype was made in three different stages. This model was designed in a total of three phases and each phase having a dedicated prototype. In this section, the details, as well as the key differences between the prototype design, have been explained using the various steps.

4.1 First Prototype

This prototype had the sensor arrangement as shown in the picture. For the Sanitizer dispenser, the sensor used was an IR proximity sensor that sends the pulse back to the microcontroller once the hands are inset range. The Dispenser mechanism uses a 5v nonpositive displacement pump which is actuated based upon the signal received from the IR sensor.

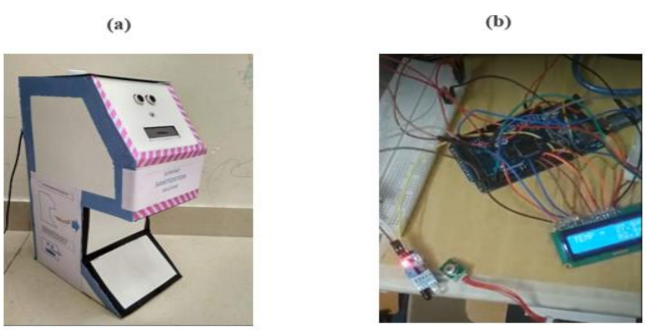


Fig. 10(a) – First model of machine (b) Internal connections

The first prototype had a body design made out of a cardboard container cut out to form a shape specially designed to accommodate hands below the nozzle. There is 15 degrees angle of approach towards the temperature sensor. This design although appeals visually to the user but has a major ergonomic drawback. The user has to tilt his/her head to approach the sensor which increases the chances of the user being in contact with the machine which ultimately results in breaching the main motive of contactless temperature measurement. The display used is an LCD 16x2 screen which has the benefits of space but the drawback is that there is an issue with screen contrast. Although the contrast is adjustable with a potentiometer under significant bright lights the display renders invisible white pixels difficult to notice. Apart from contrast issues, the incorporation of the LCD with the Arduino captures a total of 10 digital pins excluding the VCC & GND pins. This proves to be a major disadvantage when attaching the peripheral sensors for other operations.

To sense the proximity of the hands for dispensing the sanitizer, I used an Infra-Red-based proximity sensor, which although is much quicker and smaller in size but results in faulty detection at areas with a significant low ambient light. This ambiguous behavior resulted in random dispensing of the sanitizer leading to wastage. The initial model used a centrifugal pump type mechanism, actuated directly by the microcontroller on the reception of a pulse from the proximity sensor. The issue with this mechanism is that once the sanitizer is dispensed the non-positive displacement pump generates a negative pressure within the nozzle and draws the fluid back towards the tank along with atmospheric air and hence causes the dripping and uncertain quantity of fluid is dropped.

4.2 Second Prototype

To overcome all the drawbacks of the previous model I designed a new model with substantial changes in the hardware and electronic design.

Fig. 11 – Second model of machine

Physical
The angle of approach was removed resulting in a completely flat surface facing the user. This eliminated the issue of possible contact of the user with the machine surface [Fig. 11].

Electronic
All the issues addressed for the LCD 16x2 display were overcome with the 0.91-inch OLED display by ADAFRUIT. The contrast ratio of the display is much higher than the LCD and has 450 nits of brightness and hence provides excellent visibility in all types of lighting conditions. Also, the connections required to interface the OLED display with the microcontroller are four including the VCC and the GND connections.

The 1st prototype had issues with sensing the proximity for sanitization during the night. So, the IR proximity sensor was replaced by the ultrasonic distance sensor. The sensor uses sound waves to detect the distance of the object and that has no luminescence restrictions .and uses acoustic waves to sense the subject's proximity. This proves to be error-proof even in dark ambient lighting conditions. Also, the dispensing mechanism was replaced from the electronic pump to a relay-controlled solenoid valve actuated by the signal from the microcontroller-based upon the proximity of the hands. This ensured the optimum and desired quantity of sanitizer being dispensed without any leakage.

4.3 Third Prototype

All the improvements in the electronics and the physical design were finalized and the body was designed on the CAD software and was finally made with a foam body. An additional 4 character 7 segments display the TM1637 module for visibility at a further distance from the machine [Fig. 12(a)].

Fig. 12(a) – Third model of machine with an additional 7 segment display module on top.
(b) The attachment of solenoid valve below the sanitizer tank.

5. SOFTWARE

The development environment used for the operating code is the ARDUINO IDE. This is the text editor used for writing code to run the project module. The code was written keeping in mind the order of functionality required for the smooth running of the processes [14][10][11].

There are certain STEPS involved in the procedure for execution of the code.
The first step is to add all the libraries corresponding to all the modules and sensors used for the project.
· The temperature sensors require the Adafruit mlx. h library with the capability of enabling I2C communication with the processor.
· The 4-digit 7 segment display requires a dedicated library TM1637.h to interrupt the registers and bite into the sensor value of the MELEXIS MLX90614.
· The ultrasonic sensors for sensing the distance have their own set of libraries that enable the ping function every 0.01 seconds to transmit and receive the ultrasonic wave signal.

- The OLED display requires the Adafruit_GFX.h https://github.com/adafruit/Adafruit-GFX-Library
- Adafruit_SSD1306.h https://www.github.com/adafruit/Adafruit_SSD1306 Wire.h library to communicate with I2C protocol.

5.1 The SPI Library

Serial Peripheral Interface (SPI) is a synchronous serial data protocol undertaken by microcontrollers for talking with one or more ancillary pieces of equipment quickly over small distances. It can also be used for communication between two embedded systems. This library has been included to govern over all the serial communication between the OLED, The MLX temperature sensor, and the ultrasonic sensors included within the prototype. With an SPI connection, there is always one master device (usually a microcontroller) that controls the peripheral devices. Typically, there are three lines common to all the devices:

· miso (Master In Slave Out) - The Slave line that sends the data to the master,
· most (Master Out Slave In) - The Master line that sends the data to ancillaries
· sck (Serial Clock) - The clock pulses which harmonizes data transmission generated by the master
and one line specific for every device:
· ss (Slave Select) - the pin on every peripheral that is used to enable and disable peripheral devices.

Additional libraries that use SPI from interrupts, will be stopped from accessing SPI till SPI.endTransaction() is called. The SPI controls are applied to the start of the transaction and (SPI.endTransaction()) does not change SPI settings. The settings are left as it is unless the (beginTransaction) is called. For optimum compatibility, it is better to minimize the time before you call SPI.end transaction (), if the program is used together with other libraries which use SPI [20].

5.2 Tm1637.h LIBRARY

This is a i2c based driver library for the 7-segment display that includes function packets for

- Blinking each segment
- Writing Numbers and Alphabets
- Displaying colon
- And to scroll the numbers

We have included this library to display the 4 digits of the temperature value as read by the temperature sensor.

5.3 Adafruit_MLX90614.h LIBRARY

This is a special purpose library for the "melexis" temperature sensor that works on the I2C protocol. The basic function of the library is to convert the analog signals from the sensor pins to a digital output and then finally to a readable temperature unit either Degree Celsius or Fahrenheit. The temperature reading is calculated from the following relation:

- $T_{out} = [\ (2t2/T) \times (T_{o\_max} - T_{o\_min})] + T_{o\_min}$
- Where, Tmin and Tmax are the congruous resizing coefficients in EEPROM for the opted temperature output.
- T is the PWM period.
- Tout is TObj1, TObj2 or Ta are chosen depending upon the Register Configuration settings.

5.4 Adafruit_SSD1306.h & Adafruit_GFX.h

These are the graphic libraries that are interfaced with the Arduino IDE to display pixels in the range of 128x64 array. The wire library is used to communicate with the program and the gfx library is used to convert the data to the necessary graphics in terms of lit pixel arrangement. It is must to install these Arduino libraries to initiate the OLED. The SSD1306 driver library is used to initialize the OLED and give basic displaying functionality. The GFX library gives graphics abilities for imaging text, circles and drawing lines, etc. Both these libraries posted are on Adafruit site.

The second important step after defining the library is to execute the code. This execution involves following sub steps to meet the required step by step procedure.

5.5 Defining and initialising all the variables

The variables used for assigning and controlling several parameters of the programming sequence are initialized within the void setup in this step. The variables are interlinked with the corresponding digital output pins and this link is used to control the output.

5.6 Initializing the LOOP of the program.

The loop of the program begins with ultrasonic sensors sensing for any objects in close proximity, once they sense the proximity of a hand.
PHASE-I includes The loop enters the if-else step statements. In these statements, there are 3 separate conditions based on different body temperatures sensed by the sensor.
First Condition - If the body temperature is below or equal to the normal body temp i.e., 37.5 °C. Under this first circumstance once the program enters the if statement the loop goes through a series of commands to display the temperature onto the OLED screen with the title "NORMAL". Once the display command is executed then it beeps a buzzer twice to alert the user of the completion of the temperature sensing procedure.

The second Condition - If the body temperature is in the range of 38 °C to 40 °C. Under the second circumstance once the program enters the if statement the loop goes through a series of commands to display the temperature on to the OLED screen with the title "HIGH" since the body temperature above 38 °C to 40 °C is considered high and the user must be given an alert. Once the display command is executed then it beeps a buzzer twice to alert the user of the completion of the temperature sensing procedure.

The third Condition - If the body temperature is above 40 °C. Under the third circumstance once the program enters the if statement the loop goes through a series of commands to display the temperature on to the OLED screen with the title "VERY HIGH" since the body temperature above 40 °C is considered very high and the user must be given a warning regarding the potential feverish person. Once the display command is executed then it beeps a buzzer twice to alert the user of the completion of the temperature sensing procedure. But immediately after the buzzer the 'for loop' is placed to sound an "ALARM" for about 15 seconds. After the 15 second duration, the alarm gets switched off automatically resuming normal machine operations.

PHASE II explores that if during the run time once any one of these statements is executed, the code moves for a sanitization function block. This is also an else statement that works in unison with the first 3 conditions mentioned. If there is no proximity to the temperature sensor the code will always execute the else block containing the sanitization operation. This phase includes two conditions which are as follows,

The first condition - If there is a proximity to the ultrasonic sensor dedicated for dispensing the sanitizer, the code will prompt the controller to set a digital pin to high thereby switching a relay module to open the solenoid valve allowing the fluid to flow through the output nozzle. The opening and closing of this relay are pre-set to a specific time value to allow only 3-5 ml of fluid to come out. Once the time interval is complete the next step is to prompt the user to remove his/her hands. This is done by the message displayed on the OLED.

The second condition - If the loop is executing the temperature screening operation and if some user places the hand underneath the nozzle the program again prompts the user to remove hands. Once the loop is executed the program comes to an end. And again, starts the execution of a normal sequence of else statements until a new user places the hands before any one of the ultrasonic sensors.

5.7 Comparative Study of the Prototypes

Based on the pros and cons of each prototype here is the comparison between the 3 development stages:

The histogram [Fig. 13] shows how much better is prototype 3 as compared to the previous 2 designs in terms of overall performance.

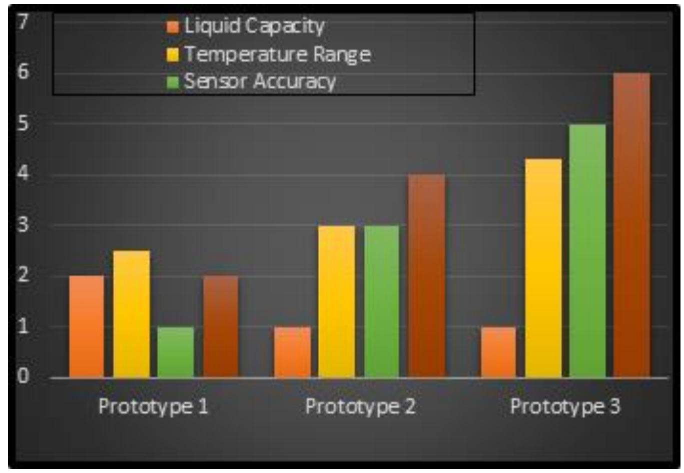


Fig. 13- This figure compares the 3 prototypes w.r.t four different parameters.

The temperature sensitivity and accuracy of all three models have been tested and the results are published below. The x-axis has the temperature in degree Celsius and the y axis has the number of readings [Fig. 15] taken. The graph [Fig. 14] shows the distribution of deviation from the mean reading for the same object whose true temperature as measured from a mercury thermometer was 36.7 **°C.**

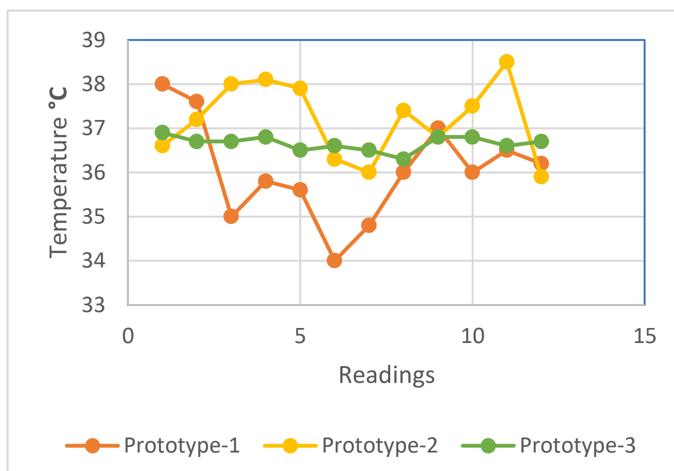


Fig. 14- The figure maps the temperature reads w.r.t the number of iterations to show the stability of each prototype.

Reading	Prototype - 1	Prototype 2	Prototype 3
1	38	36.6	36.9
2	37.6	37.2	36.7
3	35	38	36.7
4	35.8	38.1	36.8
5	35.6	37.9	36.5
6	34	36.3	36.6
7	34.8	36	36.5
8	36	37.4	36.3
9	37	36.8	36.8
10	36	37.5	36.8
11	36.5	38.5	36.6
12	36.2	35.9	36.7
SUM	**432.5**	**446.2**	**439.9**
AVERAGE	**36.04166667**	**37.18333333**	**36.65833333**
STD DEV	**1.146899642**	**0.864274087**	**0.167648622**

Fig 15- The figure shows the number of iterations with each prototype and their corresponding temperature readings in (deg. C).

The first 2 prototypes used the **MLX90614ESF-BAA** sensor which has lower accuracy and a higher field of view resulting in a higher standard deviation for temperature measurements of a single subject. The 3rd prototype uses the **MLX90614ESF-ABA** which has higher accuracy and a lower field of view resulting in a considerably low standard deviation for consecutive readings of a single subject. As seen in the Fig the standard deviation of the updated sensor is 8 times smaller than the previous sensor used in initial prototypes making it much more suitable for real-world applications [11].

The first two prototypes used **a LM-317 Linear Regulator** and the 3rd prototype uses a **LM2596 DC-DC Adjustable Buck convertor [11]**. The benefits of the later are shown below [**Fig. 16**].

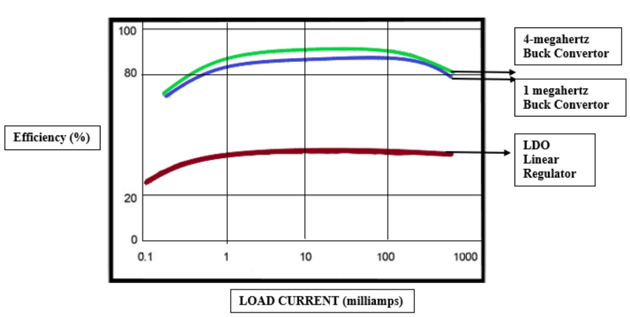


Fig. 16**-** The figure shows a map of efficiency against the load current for a Linear Regulator & a Buck Converter.

As seen from the graph the Linear Regulators are 30% less efficient as compared to buck converters and the heat generation is 200% more than adjustable buck converters. Thus, the inclusion of a buck converter to power the Arduino resulted in overall better performance and lower heat generation and hence reduced chances of system failures during operation.

6. Conclusion

By observing the performances of all the models, the third prototype was found to be more user-friendly and easier to operate at the entrance of all official premises where the crowded region is there. This will be used in public places also for taking the primary precautionary measures for avoiding the immediate spread of this pandemic Covid-19. The advanced version of this type of machine with the implementation of recent trends of robotics with IOT can have the scope for further research in the coming future.

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