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The Effect of Distance on Temperature Measurement Using an Infrared Thermal Imaging Camera

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Abstract *- the influence of the distance on the remote IR (infrared) sensor assisted measurement system of the temperature is analyzed. Using the MLX90640 Infrared Thermal Imaging Camera sensor, it displays the temperature of the object in a clear color corresponding to its temperature. Of course, this sensor allows us to see where the temperature is maximum and where it is minimum, depending on the image of the object. However, the result is affected by the distance between the object and the temperature sensor.*
We developed a small model project using ESP32 microcontroller, Infrared Thermal Imaging Camera MLX90640, with an array output of 24 × 32 pixels, TFT SPI 240x320 LCD monitor and HC-SR04 sensors. We analyzed the effect of object and infrared sensor distance on temperature.
Keyword- *ESP32 microcontroller, TFT SPI 240x320 LCD display, HC-SR04 ultrasonic sensor, mlx90640 Infrared Thermal Imaging Camera.*

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I. Introduction

In the last 10 years, the requirements for the use of various sensors in human living conditions, production, medicine, military, automotive, shipbuilding and several other fields have increased to the maximum. In this place, temperature sensors are used for various purposes [8]. Currently, remote temperature sensors are used in many fields [9]. Due to Covid-19, the demand for this has increased to the maximum. For this reason, various methods of remote temperature measurement were discovered. But the invention of mlx90640 Infrared Thermal Imaging Camera was a big news. Because, if we use this sensor, we can see the temperature of the object in different colors according to its shape.

Since the MLX90640 sensor works on the basis of infrared light, it measures the temperature of people and other objects that work in infrared light, and represents the image accordingly.

Besides humans, computers and many other objects indoors emit infrared radiation and hence can be captured by the infrared thermopile array sensor at the same time. But if we are only required to measure the temperature of people, we should separate it.The background of the infrared image of sensor is complex and dynamically changing, and we should remove the dynamic background, i.e. to remove non-human thermal disturbances first. Thermopile array sensor MLX90640, with an array output of 24 × 32 pixels [6].

II. Mlx90640 Thermal Camera, Hc-Sr04 And Esp32

Let's go over the origin of the MLX0640 sensor. MLX90640 sensor features and benefits:

- Small size, low cost 32x24 pixels IR array
- Easy to integrate
- Industry standard four lead TO39 package
- Factory calibrated
- Noise Equivalent Temperature Difference (NETD) 0.1K RMS @1Hz refresh rate
- I2C compatible digital interface
- Programmable refresh rate 0.5Hz…64Hz
- 3.3V supply voltage
- Current consumption less than 23mA
- 2 FOV options – 55°x35° and 110°x75°
- Operating temperature -40°C ÷ 85°C
- Target temperature -40°C ÷ 300°C
- Complies with RoHS regulations

MLX90640 application examples:

- High precision non-contact temperature measurements
- Intrusion / Movement detection
- Presence detection / Person localization
- Temperature sensing element for intelligent building air conditioning
- Thermal Comfort sensor in automotive Air Conditioning control system
- Microwave ovens
- Industrial temperature control of moving parts
- Visual IR thermometers

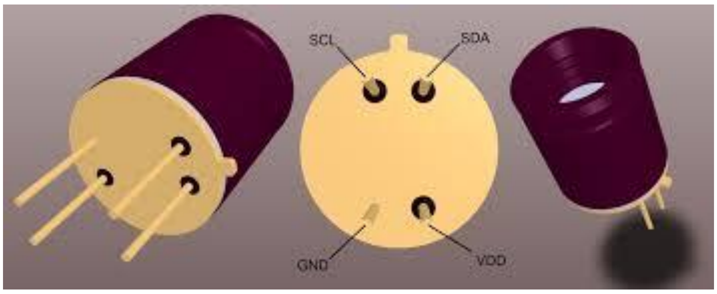


Fig. 1 MLX90640.

MLX90640 Description

The MLX90640 is a fully calibrated 32x24 pixels thermal IR array in an industry standard 4-lead TO39 package with digital interface [5], [7].

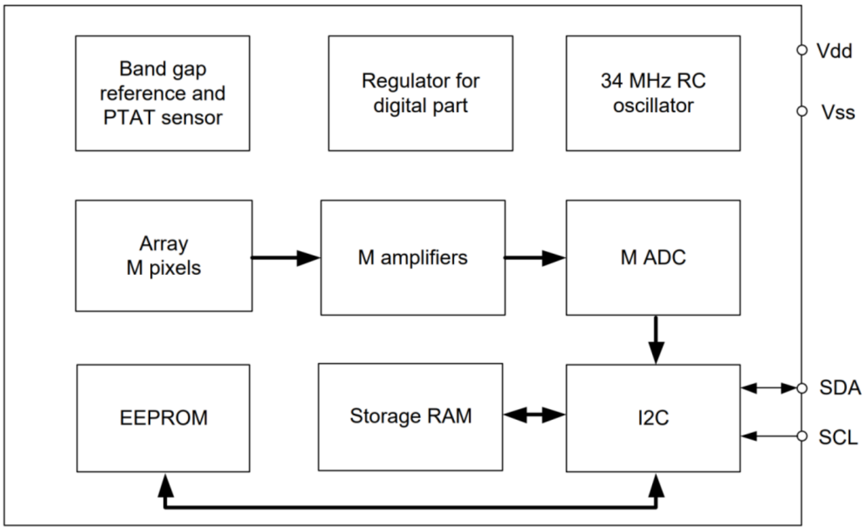


Fig. 2 Block diagram is MLX90640

The MLX90640 contains 768 FIR pixels. An ambient sensor is integrated to measure the ambient temperature of the chip and supply sensor to measure the VDD. The outputs of all sensors IR, Ta and VDD are stored in internal RAM and are accessible through I2C. [2]

The ultrasonic sensor HC-SR04 uses sonar to determine distance to an object. It offers excellent non-contact range detection with high accuracy and stable readings in an easy-to-use package. From 2cm to 400 cm or 1” to 13 feet. It operation is not affected by sunlight or black material like Sharp rangefinders are (although acoustically soft materials like cloth can be difficult to detect). It comes complete with ultrasonic transmitter and receiver module [3].

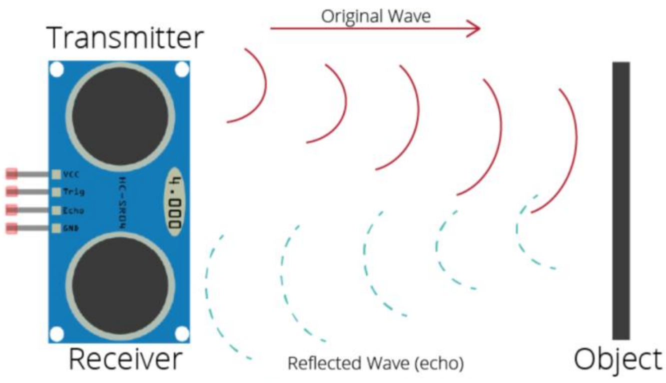


Fig. 3 Ultrasonic sensor HC-SR04

Features:
- PowerSupply :+5V DC
- QuiescentCurrent :<2mA
- WorkingCurrent: 15mA
- EffectualAngle: <15°
- RangingDistance : 2cm – 400 cm/1″ – 13ft
- Resolution : 0.3 cm
- MeasuringAngle: 30 degree
- TriggerInputPulsewidth: 10uS
- Triggerpulse (input)
- Echopulse (output)
- 0V (ground)
- Dimension: 45mm x 20mm x 15mm

Here is a brief description of our main controller, the ESP32 microcontroller:

ESP32 is a single 2.4 GHz Wi-Fi-and-Bluetooth combo chip designed with the TSMC ultra-low-power 40 nm technology. It is designed to achieve the best power and RF performance, showing robustness, versatility and reliability in a wide variety of applications and power scenarios [3].

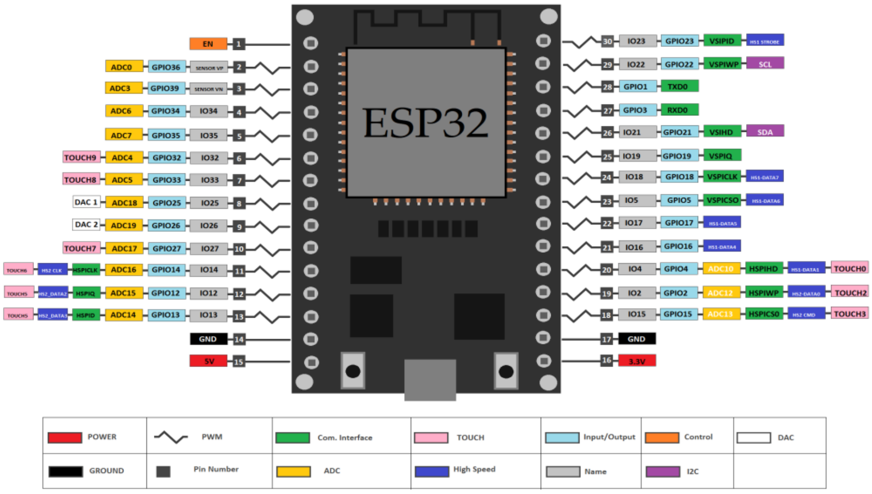


Fig. 4.ESP32 Pinout diagram (30 pin Devkit Development Board)

GPIO means General Input and Output. In the 30 pin ESP32 board, 25 GPIO pins are available to connect with external circuits. It also has some other GPIO pins that are connected internally with some ports and ICs. The GPIO pins are also used for other functions such as ADC, DAC, RTC, etc. But, only one function work at a time. So, we can configure the GPIO pin as an ADC or a UART in the program. You can see in the above diagram, the pin no 2 to 13 and pin no 18 to 30 have GPIO functions [1].

ADC means Analog to Digital Converter. The ADC pins help to connect external analog devices and components with this board. So, it can measure analog voltage, current. These ADC pins are also be used in the sleep mode for low power consumption. The pin no 2 to 13 and 18 to 20 have ADC functions.

DAC means Digital to Analog. Digital to Analog or DAC helps to convert the digital signal into an analog signal. These are used for analog output purposes. These pins are comes in the use for voltage control, PWM control, etc. The GPIO 25 and 26 or pin no 8 and 9 have DAC functions.

PWM means Pulse Width Modulated. There is a difference signal normal digital signal and pulse width modulated or PWM signal although they look like same. The digital signal has a constant or fixed time period and frequency whereas PWM signal has variable time period and frequency. The PWM function comes for very useful applications such as motor control or variable load controls. In the ESP32 board, almost all the pins are PWM enabled except pin no 1, 14, 15, 16, 17.

The 30 pin ESP32 board has 9 numbers touch sensor pins. The pin no 6, 7, 11, 12, 13, 18, 19, 20 the touch sensor pins. These pins are can be used to implement a capacitive touch sensor or touchpad without any external hardware [4].

III. Infrared thermal imaging camera with mlx90640 and esp32

Let's calculate a small circuit for connecting the MLX90640 sensor to the ESP32 controller. First of all, we need to connect the power source correctly. We connect VIN input voltage to VIN on ESP32 and GND to GND. We connect the SDA and SCL outputs to the 2 pins we want from the above sensor pins on the ESP32. We connect to pins D21 and D22.

Then, we need to connect ESP32 with ultrasonic sensor HC-SR04. We connect the Vcc and Gnd pins of the ultrasonic sensor to the 3v3 and Gnd pins of the ESP32, respectively. Connect the Trig pin to D5 and the Echo pin to D18.

After connecting the infrared thermal imaging camera and ultrasonic sensor to the microcontroller, we connect the TFT SPI 240x320 display to the controller. We will not need the TOUCH PINS of the LCD display. We can connect the remaining pins of the display to any digital pin except D5, D18, D21 and D22 pins on ESP32. Of course, we must connect the power supply to 3.3V and GND. We connect CS to D13, RESET to D26, DC to D2, SDI(MOSI) to D13, SCK to D14, LED to D27 and SDO(MISO) to D12. After that, we will write the Arduino codes.

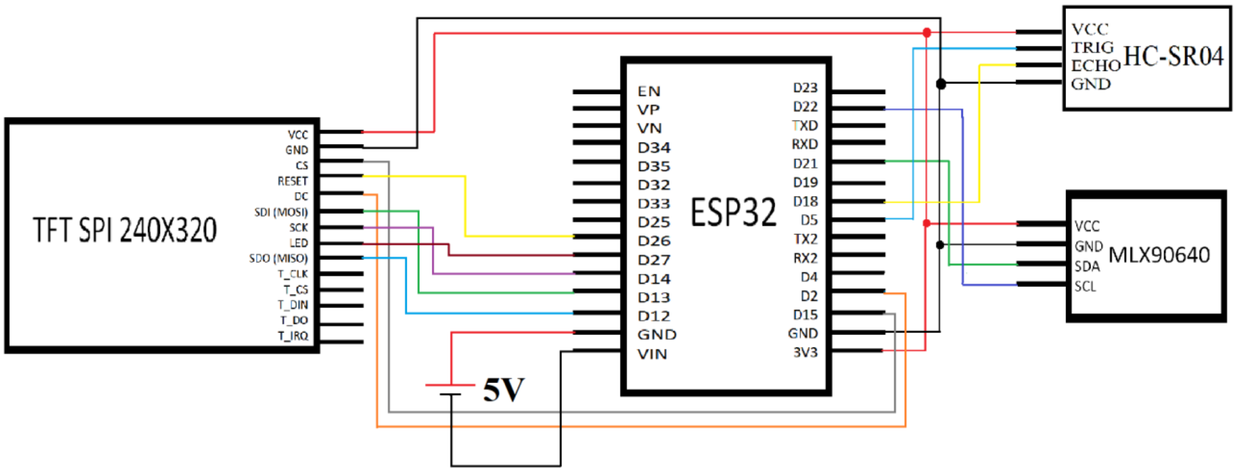


Fig. 5. Circuit Diagram of Thermal camera with distance project

We will write the Arduino codes.After writing the necessary files for Include, set the ultrasonic sensor to trigPin to D5 and echoPin to D18 with the "constint" command. Next, we write down the contacts of the TFT SPI 240x320 display connected to the controller. We implement it with define.

MLX90640_LCD_ESP32_HC-SR04 §

```
const int trigPin = 5;
const int echoPin = 18;

//define sound speed in sm/uS
#define SOUND_SPEED 0.034

long duration;
float distanceSm;

// For the ESP32, these are the default.
#define TFT_CS   15
#define TFT_DC    2
#define TFT_MOSI 13
#define TFT_CLK  14
#define TFT_RST  26
#define TFT_MISO 12
#define TFT_LED  27
```

Fig. 6. Coding in the Arduino IDE

A 2-byte "int" is written to display the corresponding temperature in red, yellow, and blue along the x and y axes, and we write the code in the SetUp section.

Select Board port 115200. Enter serial print on a new line. Next, we enter status in the int command. We associate the status with MLX90640 DumpEE. If the status is 0, the command to print "Failed to load system parameters" on a new line is written.

We specify the input and output with the "pinMode" command to input TFT_LED to output OUTPUT. We set TFT_LED and HIGH to the "digitalWrite" command. Then we enter commands for lcd display on tft.begin.

Our Infrared Thermal Imaging Camera has 24x32 pixels and our LCD monitor has 240x320 pixels. We need to place the signal received from the infrared thermal camera on a suitable monitor. If a pixel of our monitor does not produce a signal, then the problem is solved by adding the previous and next pixels of this pixel and dividing by 2 (ex. 13=(12+14)/2).

In turn, we select the colors corresponding to the temperature. Then we set the maximum, average and minimum values of the temperature according to the void loop commands. Then, he chooses colors accordingly.

MLX90640_LCD_ESP32_HC-SR04 §

```
T_min = mlx90640To[0];
T_max = mlx90640To[0];

for (i = 1; i < 768; i++)
    {
     if((mlx90640To[i] > -41) && (mlx90640To[i] < 301))
        {
         if(mlx90640To[i] < T_min)
            {
             T_min = mlx90640To[i];
            }

         if(mlx90640To[i] > T_max)
            {
             T_max = mlx90640To[i];
            }
        }
     else if(i > 0)   // temperature out of range
        {
         mlx90640To[i] = mlx90640To[i-1];
        }
```

MLX90640_LCD_ESP32_HC-SR04 §

```
             mlx90640To[i] = mlx90640To[i+1];
            }
        }


    // determine T_center

    T_center = mlx90640To[11* 32 + 15];

    // drawing the picture

    for (i = 0 ; i < 24 ; i++)
        {
         for (j = 0; j < 32; j++)
            {
             mlx90640To[i*32 + j] = 180.0 * (mlx90640To[i*32 + j] - T_mi

             getColour(mlx90640To[i*32 + j]);

             tft.fillRect(217 - j * 7, 35 + i * 7, 7, 7, tft.color565(R_
            }
        }
```

Fig. 7. Coding in the Arduino IDE

And by void getColour, we specify the color result corresponding to the temperature.

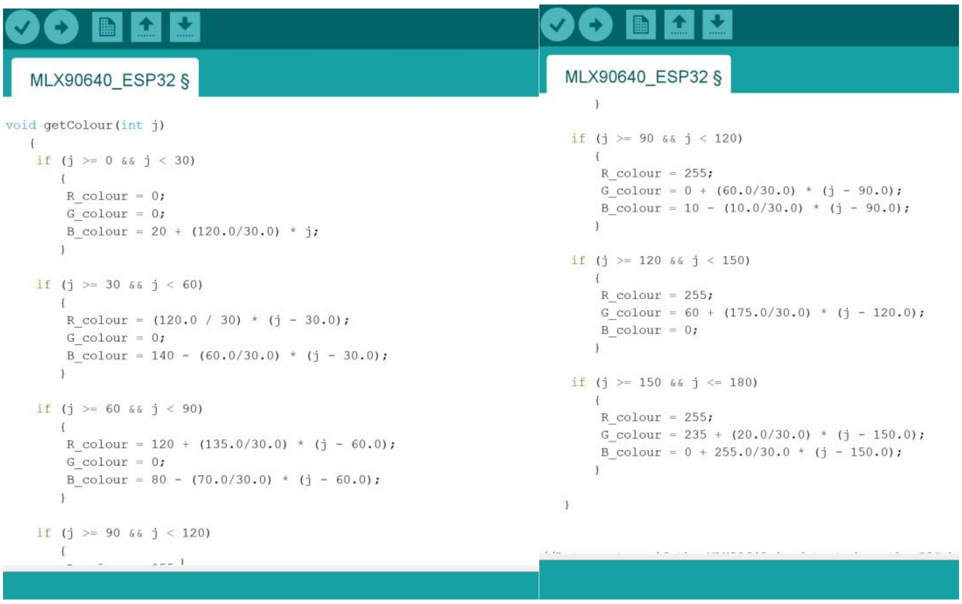
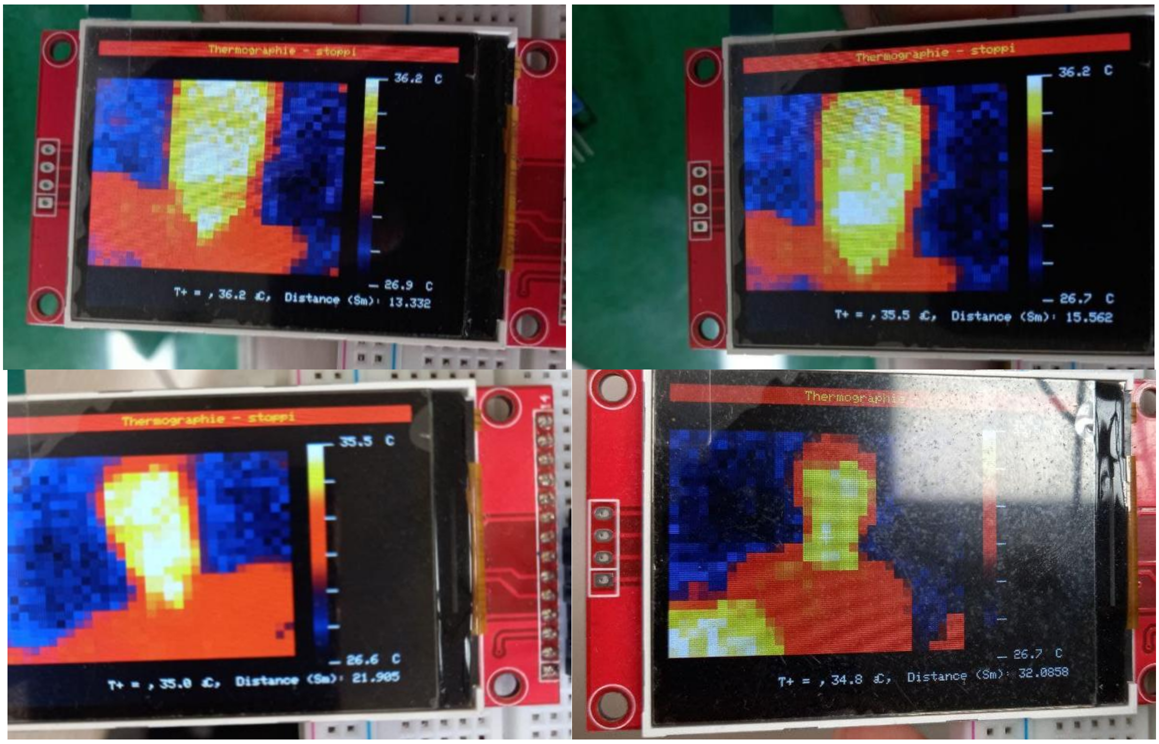


Fig. 8. Coding in the Arduino IDE

IV. Analysis of research results

After writing the codes, the power supply is given to the ESP32 microcontroller using a USB cable. And we load information about newly connected sensors and devices that are not available in the Arduino IDE library into the library in the form of an archive. Then, if there is no error message when we check the correctness of the codes, we upload the written codes to the ESP32 microcontroller. If there is an error message, we need to fix it. We didn't get an error message, so we don't have any errors. After the code is loaded into our controller, we can get the result.



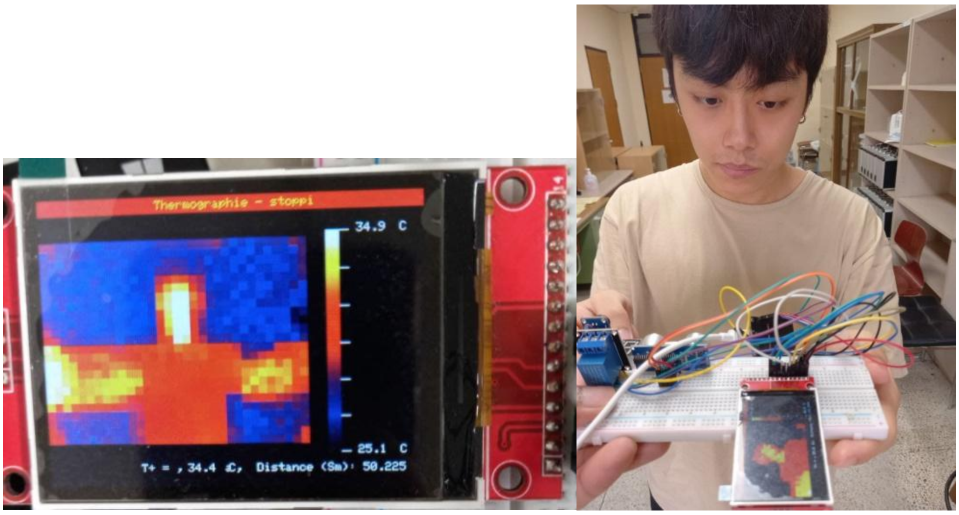


Fig. 9. Research result

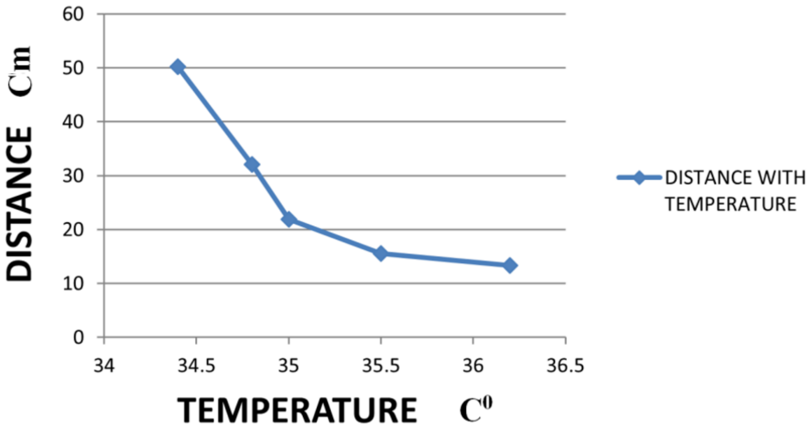


Fig. 10. Graphical representation of the research result

From the results of the above research, we can see that the high temperature of the object is expressed in yellow, and the low temperature is expressed in red. External influences are represented in blue. It allows you to see the shape of an object through colors. The LCD monitor also shows the overall temperature of the object. At the same time, it clearly shows the distance between the sensor and the object. We chose a person as an object. As the distance increases, the human temperature also decreases. We can see this in the graphic above.

V. Conclusion

In short, the object temperature measurement system was developed using the MLX90640 infrared thermal imaging camera sensor. The MLX90640 thermal camera determines the maximum and minimum values of the object's temperature and shows us its image in infrared form. As a result, it allows you to see the temperature of the object in a combination of different colors. Using the HC-SR04 Ultrasonic Sensor, we determined the distance between the object and the thermal camera. During the research, we saw that the distance has a great effect on the infrared thermal imaging camera sensor. So, we came to the conclusion that it is necessary to consider ways to eliminate the effect of distance.

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