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THERMAL SCANNING SYSTEM USING ARDUINO NANO

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Abstract. ***The paper presents the study and implementation of a thermal scanning system that collects and transmits in real time the thermal data of scanned objects for their constant monitoring using an infrared temperature sensor and an Arduino Nano board. The application is made with the Arduino IDE, with the help of which the control of the Arduino board, sensors, screen, and LEDs connected to the platform is conducted. The sensors create the overall image of the thermal scan and send it to the Liquid-Crystal Display Thin-Film Transistor (LCD TFT) screen, and if an anomaly occurs, the red LED lights up.***

Keywords: Arduino Nano, Arduino IDE, infrared temperature sensor, thermal scanning.

1. INTRODUCTION

During the pandemic, thermal scanning was mandatory, and many companies resorted to various thermal scanning techniques. The use of thermal scanning may vary. Any object that emits heat, no matter how little, even an inanimate body, can be scanned, thus knowing what temperature that body has reached and can be checked. This type of scan can be done with a thermometer-type device, which displays the temperature of the area it is aimed at, but it is not an accurate method because there are many factors that can increase the body temperature, and different areas of the body have different temperatures. Thus, more complex methods were used than a simple thermometer, and these are thermal scanning with the help of cameras; they scan the body, and together with a developed algorithm, they can identify if people have a temperature or if it is just a thermal anomaly due to certain factors. Thermal scanning works like an ordinary camera, which records the thermal radiation emitted by bodies and displays it as an image with different colours, from blue, which is cold, to red, which is very warm, making these colours an image of the thermal radiation of that body with heat zones and its heat intensity [1-3].

Temperature can be found by both direct and indirect methods. However, in order get a precise measurement, the subject of testing and sensor need to be thermally balanced, which might result in higher reaction times and reading incorrect information offset by the outside temperature. Also, non-contact infrared radiation monitoring delivers quick and reliable temperature readings with requiring contact with the skin. Non-contact measurement technologies have already been employed in a variety of applications in recent years, including healthcare, checking the environment, technology, electronic devices, automobiles, airplanes, and applications in the military [4–9].

Data acquisition, as shown in Figure 1, is a process that involves gathering information to understand electrical and physical phenomena using sensors, a measuring device, and a computer [5–6].

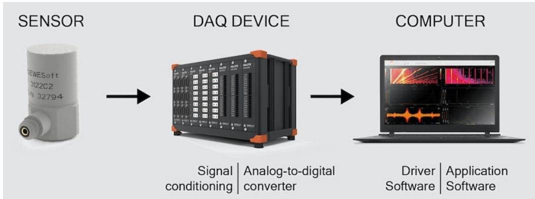

Figure 1. Structure of a data acquisition system.

With a data acquisition system, it is possible to find temperature, current, force, pressure, distance, movement, image, colours, etc [6, 8].

The sensors convert the physical values into electrical signals, which they send to the data acquisition system through a conditioning circuit in their transducer system for signal optimization. The data acquisition system is the system between the sensors and the computer, connected to the computer via the USB (Universal Serial Bus) port or the PCI-Express (Peripheral Component Interconnect) slot on the motherboard. Its function is to convert the analog signal received from the sensors into a digital format that computers can understand. A data acquisition system is a collection of electronic systems that perform the following tasks:

- Input: processes and converts analog data to digital data using analog-to-digital conversion.
- Processing: uses Digital to analog conversion to convert to analog format.
- Input of digital signals that have system or process information.
- Output of digital signal control [7].

2. DESCRIPTION OF THE EQUIPMENT USED IN THE IMPLEMENTATION OF THE SYSTEM

2.1 Arduino Nano board

The Arduino Nano platform shown in Figure 2 is easy to use and is based on the ATmega328 microprocessor. This platform can be powered via a USB Mini-B plug or externally via an unregulated 6-20V power supply (on platform pin 30) or a 5V regulated power supply (on platform pin 27). The power source selection mode is performed automatically by selecting the highest voltage source. The microprocessor of the platform has a capacity of 32 Kbytes (of which 2 Kbytes are used for loading the first instructions); it has a SRAM (Static Random-Access Memory) (with a capacity of 2 Kbytes) and an EEPROM (Electrically Erasable Programmable Read-Only Memory) (with a capacity of 1 Kbyte). The Arduino Nano has 14 digital pins that are capable of being used as inputs or outputs by using the functions pinMode(), digitalWrite(), and digitalRead(). The operating voltage is 5 volts. The platform connectors may supply or absorb a maximum current of 40 mA via an inbuilt resistor (by default unconnected) with a value ranging from 20 to 50k [10].

Figure 2. Arduino Nano board.

The Arduino Nano has 8 analog inputs, each with a 10-bit resolution (2^{10} = 1024 different values). Of the 8 analog pins, pins 6 and 7 cannot be used as digital pins, and some of them have special functions: pin A4 is for I2C (SDA) (Inter-Integrated Circuit, Serial Data) communication using the Wire library, and pin A5 is used for the clock pulse (SCL, Serial Clock).

The ATmega328 has the possibility of serial communication via UART TTL (Universal Asynchronous Receiver/Transmitter Transistor-Transistor Logic) (5V), which is provided by digital pins 0 and 1. The FTDI FT232RL (Future Technology Devices International) device implemented on the platform provides support for USB communication, and FTDI drivers (available in the Arduino software) provide a virtual communication port for the PC application. I2C (two-wire interface) and SPI (Serial Peripheral Interface) connection is supported as well by the ATmega328. The microprocessor has a bootloader that allows the code to run without using another external programmer. Communication is conducted through the STK500 protocol. In addition, the microcontroller may be programmed using Arduino ISP or other comparable software via the ICSP (in-circuit serial programming) header [11].

2.2 Infrared temperature sensor, MLX90614

The sensor is created as a non-contact thermometer by Melexis, with high accuracy and enhanced resolution, and the output data is delivered linearly, dependant on the temperature of the object. It enables easy customization for a wide variety of temperatures, power supplies, and update frequencies.

The signal processing chip of the MLX90614 has a low-noise amplifier and allows auto-calibration. The chip is an ADC (Analog Digital Converter) and DSP (Digital Signal Processing) device with a 17-bit resolution. The selected sensor has a field of view of 35^0 (Figure 3) [9, 12].

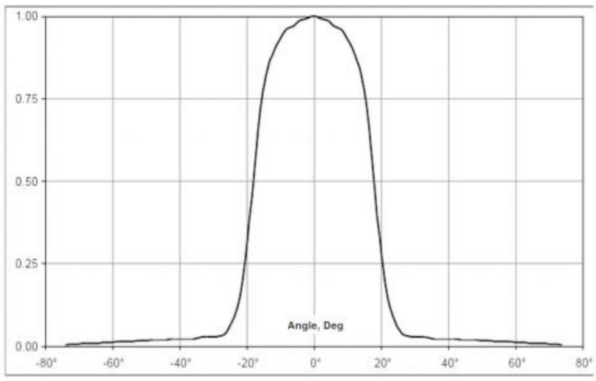

Figure 3. The sensor's region of view.

The MLX90614 can be considered an infrared thermometer used in remote temperature measurement (without having contact with the source). The IR thermopile detection module and ASSP (Application-specific standard parts) signal processing are both housed in the identical TO-39 package (Figures 4-5).

The temperature instrument is manufacturer calibrated and has a bidirectional PWM (Pulse Width Modulated) and SMBus (System Management BUS) digital ports (with a resolution of 0.02°C). Temperatures measured in the range -20°C to 120°C can be continuously transmitted on the 10-bit PWM input with a resolution of 0.14°C.

Figure 4. Infrared thermometer, MLX90614.

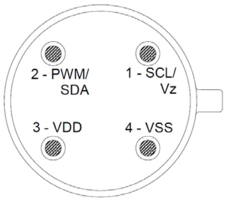

Figure 5. Description of the pins.

The sensor is manufacturer calibrated for a temperature spectrum ranging from -40°C to 125°C for the outside temperature and -70°C to 382.2°C for object temperature. The 10-bit PWM signal is set to convey the temperature of the determined item continuously throughout a temperature spectrum of -20°C to 120°C. By adjusting the data stored inside of two EEPROM cells without changing the sensor's manufacturer calibration, a PWM signal can be easily tailored to any spectrum wanted by the user. The PWM port can be adapted to serve as the heat relay, making it simple and inexpensive to use in thermostats or other temperature monitoring devices (the freezing or boil). The user finds the temperature limit. This function works as an instruction trigger in an SMBus arrangement, triggering it to cycle over all present slaves on the bus and set up their exact condition.

The MLX90614 comes standard with an element's emissivity of 1. It is readily adjustable by a consumer for any alternative emissivity in an area of 0.1-1.0 with any further calibration (e.g., using a black frame).

In terms of voltage of supply, the thermometer comes in two varieties: 5V usable and 3V (external power supply, rechargeable) compatibility. Using certain extra electronics, the 5V supply is simple to use to function at greater power voltages (e.g., 8-16V).

In addition, the sensor has an optical filter that blocks off visible and near-radiant energy to offer sun resistance.

The associated ambient temperature (Ta) and object temperature (To) are estimated based on the readings taken. The resolution for all estimated temperatures is 0.01°C. The information for both temperatures (Ta and To) can be accessed in the following manners: by accessing the RAM (Random Access Memory) cells devoted to this meaning, by using the 2-wire interface (with a resolution of 0.02°C at defined intervals), or by using the PWM digital signal.

The two recorded temperatures (Ta and To) get converted to the necessary PWM signal resolution in the final phase of the evaluation cycle, and the new data is placed into the PWM state machine registers, which will generate an equal frequency with a rate of duty showing the data performed. Because it offers low power consumption and has a sleep mode, this thermometer is ideal for portable mobile applications [13].

2.3 TFT LCD screen 240x240 1.3 inch, ST7789

Figure 6 shows a colour screen that can hold a lot of information on a 1.3-inch screen with 260 PPI (Pixels Per Inch), this screen being the 240x240 1.3-inch TFT LCD screen, ST7789. This monitor features an SPI interface for quick display upgrades. Because it is a write-only equipment, it requires only the SPI MISO line to be connected. Furthermore, the module does not connect the CS terminal to the interface, reducing the number of pins. The disadvantage is that it cannot be used concurrently with any other SPI modules on the identical bus.

The technical specifications of this screen are display resolution 240 x 240 pixels, RGB colours, SPI interface, input power DC 3.3V, operating current 30 mA (typical), screen controller SH1106 [14–16].

Figure 6. TFT LCD screen 240x240, 1.3"

The SH1106 is a single-chip OLED/PLED CMOS driver with a graphics controller and an organic/polymer light-emitting diode dot matrix display system. It has 132 lines and 64 columns, as well as brightness control, a screen RAM oscillator, and a powerful DC-DC converter, reducing the number of outside parts and power use. The SH1106 is right for a variety of small portable apps such as cell phone sub-displays, PCs, and so on [16].

2.4 PIR sensor, HC-SR501

The HC-SR501 sensor is based on infrared technology, features an automatic control mode, the German-made LHI778 probe technology is employed, and it has excellent sensitivity, accuracy, and a low voltage operating capability. It is extensively used in multiple electrical devices that require automatic identification, particularly battery-powered autos (Figure 7). The technical specifications of this sensor are supply voltages 5V–20V, consumption 65 mA, TTL output 0V-3.3V [17].

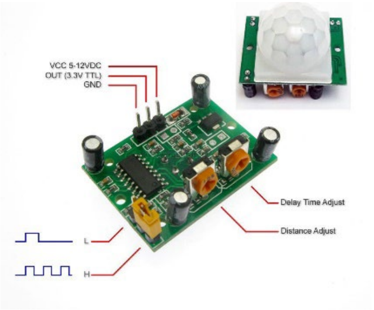

Figure 7. PIR sensor, HC-SR501.

2.5 Buzzer, MH-FMD

The Arduino Piezoelectric Buzzer MH-FMD module, like the one in Figure 8, can supply a variety of sounds depending on the frequency applied to the input. The module consists of a passive piezoelectric buzzer; it can generate various tones with frequencies between 1.5 and 2.5 kHz by switching it on and off at various frequencies, either using delays or PWM signals. Operating voltages are in the 3.3-5V range [18].

Figure 8. Buzzer

A buzzer or beeper can be described as a device that allows audio signalling; this signalling can be mechanical, electromechanical, or piezoelectric. Typical uses of these include alarm devices, timers, and notifying the user of their presence (e.g., a mouse click or a key press).

3. SYSTEM ANALYSIS AND SIMULATION USING PROTEUS SOFTWARE

Proteus is a Windows application for schematic analysis, simulation, and PCB design. Schematic analysis in Proteus Design Suite is used to simulate projects and design a PCB layout. Therefore, it is a core part and is available in all product configurations. Microcontroller simulation in Proteus is functional if a hex file or debug file is applied to it. It can be simulated with any electronic part, analog or digital, connected to it. Proteus software is used in various projects in areas such as motor control and temperature determination and offers the possibility of designing the user interface [19].

After connecting the components, I simulated the thermal scanning system using the Arduino Nano board (Figures 9–13).

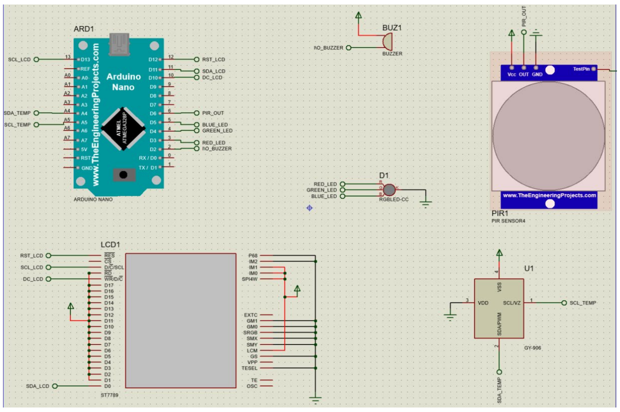

Figure 9. Simulation of the thermal scanning system in Proteus.

In Figure 10, the thermal scanning system was evaluated in Proteus in the phase of not detecting motion of the PIR sensor and switching to FreeDisplay mode in order not to constantly display temperature scanning values. This action resulted in the blue LED display of the RGB module and the LCD display of the FreeDisplay mode.

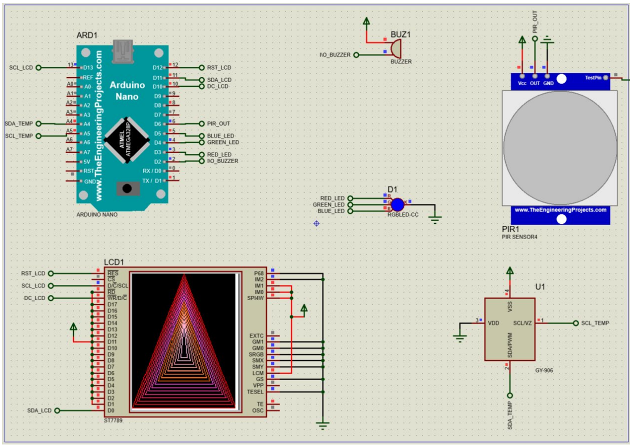

Figure 10. Evaluating two of the thermal scanning system using the Arduino Nano in Proteus.

The testing in Figure 11 in Proteus of the thermal scanning system was carried out by changing the code and providing static variables; more precisely, for the display of the Ambient value, the value 25.5°C was offered, and for the display of the Temperature value, the value 39.3°C was offered; these could not be provided by the temperature sensor in Proteus. Testing was done by pressing the button connected to the TestPin pin of the PIR sensor to display an increased temperature value; this action resulted in the display of the red LED of the RGB module. The values are displayed on the led screen, the values being Ambient 25.5°C and Temperature 39.3°C, this being written in red because it is above the limit provided in the source code of 38.5°C.

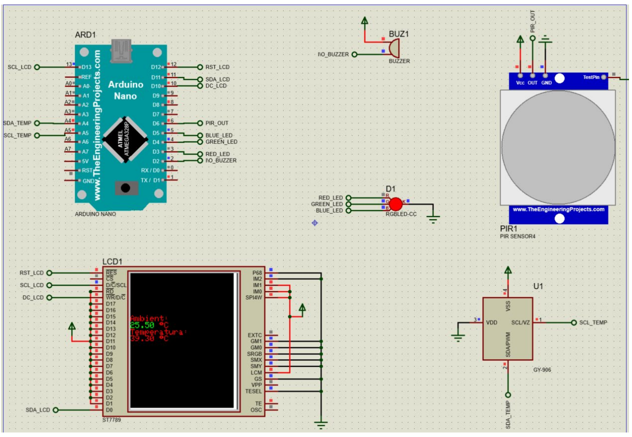

Figure 11. Evaluating three of the thermal scanning system using the Arduino Nano in Proteus.

The testing in Figure 12 in Proteus of the thermal scanning system was carried out by changing the code and providing static variables; more precisely, for the display of the Ambient value, the value 25.5°C was offered, and for the display of the Temperature value, the value 36.8°C was offered; these could not be provided by the temperature sensor in Proteus. Testing was done by pressing the button connected to the TestPin pin of the PIR sensor to display a normal temperature value; this action resulted in the display of the green LED of the RGB module. The values are displayed on the led screen, the values being Ambient 25.5°C and Temperature 39.3°C, this being written in green because it is within the limit provided in the source code between 30°C and 38.5°C.

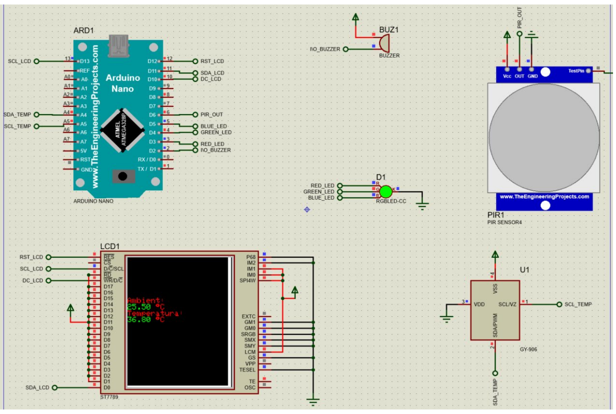

Figure 12. Evaluating four of the thermal scanning system using the Arduino Nano in Proteus.

The testing in Figure 13 in Proteus of the thermal scanning system was carried out by changing the code and providing static variables; more precisely, for the display of the Ambient value, the value 25.5°C was offered, and for the display of the Temperature value, the value 28.2°C was offered; these could not be provided by the temperature sensor in Proteus. The testing was done by pressing the button connected to the TestPin pin of the PIR sensor to display a low temperature value; this action resulted in the display of the yellow LED of the RGB module. The display of the values is done on the led screen, the values being Ambient 25.5°C, and Temperature 28.2°C, this being written in red because it is below the limit provided in the source code of 30°C and it displays the message "RETRY" because it is a value which cannot be considered as body temperature.

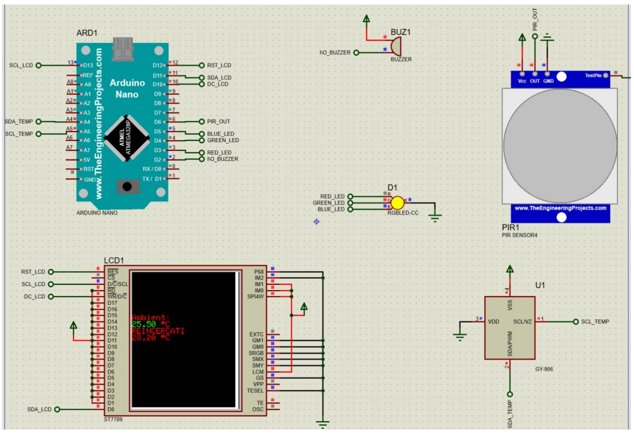

Figure 13. Evaluating five of the thermal scanning system using the Arduino Nano in Proteus.

Using the Arduino IDE, I made the code for the thermal scanning system using the Arduino Nano, which I uploaded to the Arduino Nano board and as a HEX file in the Proteus simulation. The open-source Arduino IDE software makes it easy to write and upload code to the board. This software can be used with any Arduino board. Arduino IDE software has a text editor that allows writing code, a field where messages appear, a text area, a toolbar with various buttons for functions, and various menus. It allows connecting to Arduino and Genuino hardware to run programs and communicate with them [20].

4. RESULTS

The work presents a system that allows thermal scanning of people using Arduino technology. The control is conducted with the help of the Arduino code, made in the Arduino IDE application, and the data is transmitted both to the screen and to the Arduino IDE application, if the system is physically connected to the computer (Figure 14).

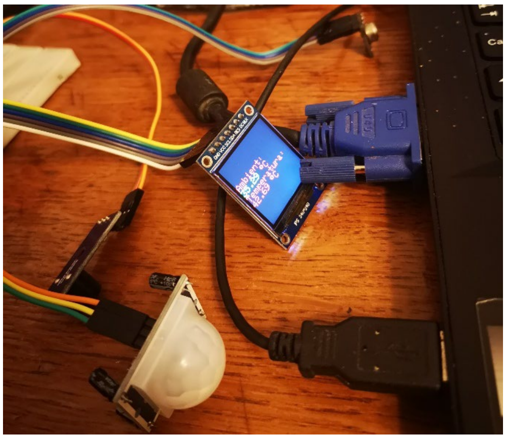

Figure 14. The original system measured the temperature of the laptop.

Figure 15 shows the first operation of the system using the laptop fan. It is seen that the temperature is 36-38°C ambient and 42-43°C Body, and the motion sensor does not detect the motion during the temperature check phase of the fan, as there is no movement in front of the ventilation, and the buzzer module is activated because the temperature is above the code limit of 38.5°C.

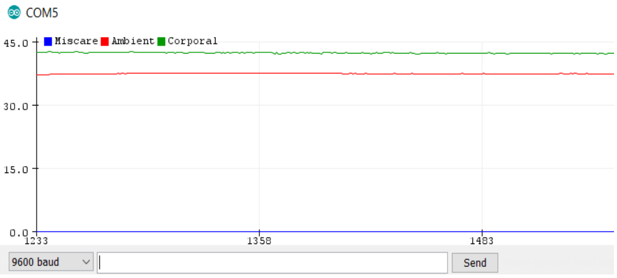

Figure 15. Constant recording of the laptop temperature.

In Figure 16, we obtained values close to those provided by the Argus Monitor computing system testing software used, where the CPU and video card temperatures are 52-54°C, temperatures that decrease at the vented outlet.

The temperature was also checked with the JIACOM FR850, where it showed a temperature of 38-39°C, which is extremely low compared to the temperature showed by the original system and the test software.

Figure 16. Constant recording of the laptop temperature with the Argus Monitor software

In Figures 17–18, we evaluated the first operation of the system using the refrigerator and freezer. It is seen that the temperature is -7…-9°C ambient and -2…-4°C Body, and the motion sensor does not detect motion during the freezer temperature check phase, as there is no motion in the freezer, and the buzzer module does not activate because the temperature is below the code limit of 38.5°C.

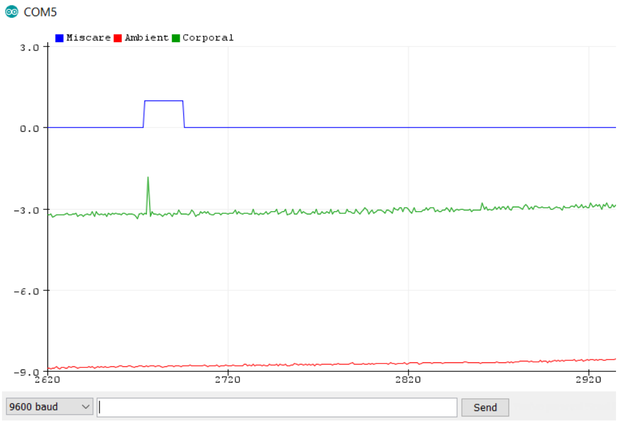

Figure 17. Constant recording of freezer temperature

Figure 18. The original system measured the temperature of the freezer.

The temperature was also checked with the JIACOM FR850 device, in which a temperature of 655.3 °C was shown to me, this value saying that the device cannot measure negative values.

In Figures 19-20, we evaluated the first operation of the system using people entering and exiting a store. It is observed that the temperature is 26-28°C ambient and 36-38°C Body, and the motion sensor detects movement in the phase of checking the temperature of people, being the presence of movement in front of the temperature sensor, and the module buzzer does not activate because the temperature is below the code limit of 38.5°C.

Figure 19. Recording temperature values in a store.

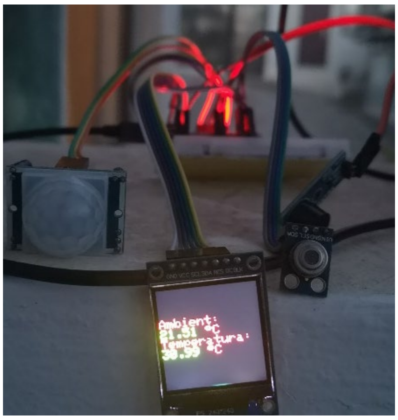

Figure 20. The original system for measuring the temperature in a store.

The temperature was also checked with the JIACOM FR850 device, where the indicated values were in the range of 35°C to 38°C.

In Figures 21-22, we evaluated the first operation of the system using people entering and exiting a park. It is seen that the temperature is 26-27°C ambient and 36-37°C Corporal, and the motion sensor detects the movement in the phase of checking the temperature of people, the movement being present in front of the temperature sensor, and the module buzzer does not activate because the temperature is below the code limit of 38.5°C.

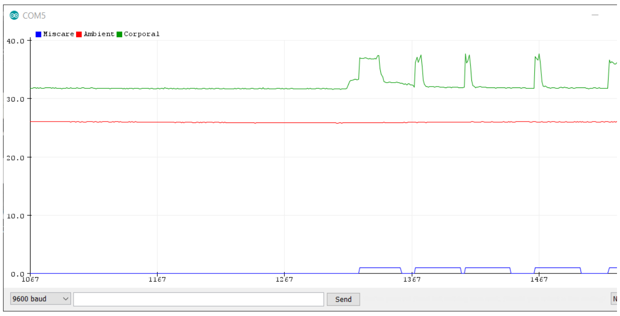

Figure 21. Recording temperature values in a park.

Figure 22. The original system measured the temperature in a park.

The temperature was also checked with the JIACOM FR850, where it showed a temperature of 35-37°C.

The program implemented for Arduino allows the constant reading of the temperature in the presence of movement with the help of the PIR sensor and displays on the screen both the ambient temperature value and the body temperature value if the person is at most 1 cm from the infrared temperature scanning sensor.

The temperature sensor can register both positive (Figure 15) and negative (Figure 17) values.

The motion sensor can be set in the temperature sensor actuation between 10 cm (Figures 19-20) and 7 m (Figures 21-22). The motion sensor can be set to trigger the temperature sensor for 0.3 seconds and 5 minutes until the next motion sensor reading.

The results obtained after evaluating the system are presented in Table 1 and compared with the Jiacom FR850 product, and in Table 2, the price of the realized system (by components) and the price offered by the Jiacom FR850 are given.

Table 1. Obtained results.

Cases analysed	Thermal scanning system (°C)	Jiacom FR850 (°C)	Motion detection and thermal scanning systems
Laptop fan	42.57	38.5	Not
	42.35	38.7	Not
	42.39	38.6	Not
	42.84	38.4	Not
	42.65	38.6	Not
	42.73	38.6	Not
	42.75	38.7	Not
	42.64	38.6	Not
Freezer	-2.32	655.3	Not
	-2.37	655.3	Not
	-2.48	655.3	Not
	-2.35	655.3	Not
	-2.51	655.3	Not
	-2.43	655.3	Not
Store	37.54	37.0	Yes
	37.63	36.8	Yes
	37.23	36.9	Yes
	36.91	36.5	Yes
	36.97	36.7	Yes
	36.63	36.2	Yes
	36.31	35.9	Yes
Park	36.73	36.2	Yes
	36.49	36.0	Yes
	36.84	36.1	Yes
	36.35	35.9	Yes
	36.15	35.8	Yes

After testing, the results in Table 1 show that:

- The thermal scanning system allows checking the temperature much closer to the truth than the Jiacom FR850 device.
- The Jiacom FR850 device does not have the possibility of scanning the negative temperature.

- The Jiacom FR850 device cannot continuously scan the temperature; there is a period of 1-4 seconds until it displays the scanned temperature.
- The Jiacom FR850 device also does not display the ambient temperature.
- The Jiacom FR850 device records a maximum of 30 scans in its memory, compared to the original thermal scanning system, which cannot store the values in the device's memory.
- The Jiacom FR850 device can only be used manually; it does not have an integrated system for scanning when detecting presence, like the original thermal scanning system.

Table 2. System Implementation Prices

Part name	Price
Arduino Nano	5,05 euro
Infrared temperature sensor MLX90614	12,12 euro
LCD TFT 240x240 1.3" ST7789	6,06 euro
Sensor PIR HC-SR501	2,63 euro
Buzzer MH-FMD	2,02 euro
RGB LED module	0,4 euro
TOTAL	28,28 euro
Jiacom FR850	60,58 euro

5. CONCLUSIONS

From the analysis of the results (Table 1), we can say that the system made is "efficient" and can be implemented in various access areas, and from the analysis made in Table 2, we can see a difference of almost 50% for the implementation of this system compared to the Jiacom FR850 device.

The thermal scanning system allows checking the temperature much closer to the truth than the Jiacom FR850 device. The Jiacom FR850 device does not have the possibility of scanning the negative temperature. The Jiacom FR850 device also does not display the ambient temperature.

The system can be improved by:
- Adding an ultrasonic sensor to check the distance between the object and the thermal scanning system and to check the temperature at any distance with the addition or subtraction of 0.14°C/mm.
- Adding a WiFi or Ethernet expansion board to connect to the local network, for example, the Arduino MKR Eth can be added to connect with an Ethernet cable or the Arduino MKR WiFi 1010 to connect wirelessly.
- Creating a database and communicating with it to keep the monitoring history.
- Adding a camera to capture and save the picture when the read temperature is increased.
- Addition of an SD memory card to keep on the device the history of scans performed by this system.

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