

Implementation of Internet of Things based solution of wireless infrared camera with MLX90621 sensor

Grisha Spasov¹, Vasil Tsvetkov¹, Galidiya Petrova²

Department of Computer Systems¹, Department of Electronics², Technical University of Sofia, Plovdiv branch, 25, TzankoDustabanov, 4000 Plovdiv, Bulgaria
 {vacc@abv.bg, gvs@tu-plovdiv.bg, gip@tu-plovdiv.bg}

Abstract – In this paper a low-cost solution applicable in the field of continuous monitoring of critical equipment in industry and smart homes is described. It employs a relatively new IR array sensor MLX90621 and implements the IoT concept and three-layer architecture. The implementation of this IoT solution is based on an open source hardware microcontroller development board PIC32-T795 and wireless MOD Wi-Fi ESP8266 module. It is considered to be with reasonable cost and affordable for the potential users. The paper demonstrates the benefits of having an inexpensive infrared sensor as a part of the developed solution for continuous monitoring of critical equipment for overheating.

Keywords– Internet of Things, Three layers architecture, IR array sensor, Wireless Infrared Camera.

I. INTRODUCTION

The development of Internet technologies, sensor networks, wireless and mobile networks, especially over the last decade, has led to the emergence of new technological solutions such as the Internet of Things (IoT), which are characterized by close integration between the virtual world and the real world. IoT represents a worldwide network of uniquely addressable interconnected objects [1]. IoT is an “interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework”[2]. Implementation of the IoT systems is linked to the following main paradigms: internet-oriented (middleware), things oriented (sensors) and semantic-oriented (knowledge) [1]. Due to their interdisciplinary nature, each specific implementation is detailed in the context of the particular application.

The purpose of this article is to present and demonstrate a low-cost wireless sensor solution applicable in the field of continuous monitoring of critical equipment in industry and smart home diagnostics and observation. It is based on a relatively new IR array sensor and is designed as an IoT solution.

This paper is organized as follows: section 2 presents the essentials of the concept for the Internet of Things architecture. The application of the Melexis MLX90621 IR array sensor in continuous monitoring of critical equipment and smart home are considered in section 3. The implementation of an IoT based solution of Wireless

Infrared Camera is described in section 4. The conclusions and the future work are presented in the last section.

II. ESSENTIALS OF THE CONCEPT FOR THE IoT ARCHITECTURE

The IoT has been introduced as the third wave of the web after static pages web (WWW) and social networking web. It is the worldwide network, which connects disparate types of objects anytime anywhere through the IP. Among many proposed architectures, the conventional IoT architecture has been divided into three layers, i.e. perception layer, network layer, and application layer as it shown on Figure 1 [3]. The perception layer is acting as the bottom layer of the architecture, which is responsible to extract information from things and to transform it into a digital format (the physical sensors of the IoT). Subsequently, the network layer transports the digital signals via the network (Ethernet, 3G, GSM, UMTS, WiFi, Bluetooth Low Energy, Infrared, ZigBee, etc.), while the application layer is liable for the application of transferred digital signals into different contexts [3].

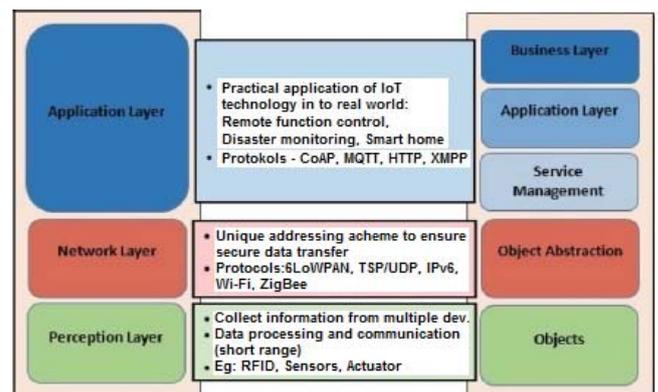


Fig. 1. The IoT Architecture [3].

In most cases, the three-layer architecture defines the basic idea of the Internet of Things, but this is not enough for the application layer research [4]. In this case, the five layer model is used, where the application layer is further extended with two additional layers - of service management and business layer. Often, in the five-layer model, the first two layers have some additional process formalization functions, and are referred to as Object Layer and Object Abstraction Layer. The three-layer IoT models have originated from the Wireless Sensor Network (WSN)

architectures where different types of communication media were necessary to be used. In the case of combining the first and second layer functions on a single device, the use of more powerful microcontrollers is required due to complex and massive computational needs. Many companies use Single Board Computers (SBCs), integrated with sensors, Embedded TCP / IP and security features to realize IoT products (e.g., Arduino Yun, Raspberry PI, BeagleBone Black, Intel Galileo, etc.) [4].

III. INFRARED CAMERA MLX90621

In many modern applications in industry, environmental monitoring, building automation and others, the infrared thermograph is used for monitoring specific manufacturing processes, HVAC systems, early warning in fire protection systems, security activities such as presence detectors, and so on. For some of these applications, the use of a low-resolution thermal-sensor array is relevant.

An appropriate candidate is MLX90621 IR array sensor, produced by Melexis, which internal block diagram, is shown on Figure 2. The sensor is small in size, with low power consumption and is easy to integrate [5]. Due to the factory calibrated temperature measurement with calibration parameters stored in the internal EEPROM it has high precision of measurement. All these features are a good reason for selection of this reliable sensor to be used in the developed solutions for smart home (Room Occupancy, Tracking Motion, Indoor Human Detection [6,7,8]), and continuous monitoring of critical equipment in industry [9]. In addition to 64 dedicated low noise chopper stabilized amplifier and integrated fast ADC, a Proportional To Absolute Temperature (PTAT) sensor is integrated to measure the ambient temperature of the sensor chip. The output data of both IR and PTAT sensors are stored in the internal RAM (16-bit result of IR measurement for each individual sensor (64 words) and 16-bit result of PTAT sensor) and are accessible through I2C digital interface that supports clock speed up to 1MHz. Depending on the application a microcontroller connected to the MLX90621 sensor can read the different RAM data and, based on the calibration data stored in the internal EEPROM memory (256x8) of the sensor, compensate for difference between sensors to build up a thermal image, or calculate the temperature at each spot of the imaged scene.

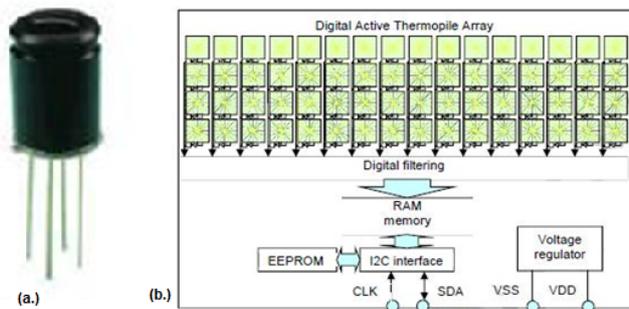


Fig. 2. MLX90621 IR array sensor (a.) Housing. (b.) Internal block diagram.

Each pixel measures the average temperature of its field of view. The MLX90621 operates at a power voltage in the

range of 2.6 to 3.3 volts (the device is calibrated and works best at 2.6 volts). The temperature ranges are as follows: -40 ... 85 C for the ambient temperature sensor; -50 ... 300 ° C for the observed object temperature.

After measurement the following sequence of calculations is performed:

- calculation of ambient temperature;
- pixel offset cancellation;
- pixel to pixel compensation of the difference in the sensitivity;
- compensation of the object's thermal radiation;
- calculating the object temperature (for each pixel)

IV. IMPLEMENTATION OF IoT BASED SOLUTION FOR WIRELESS INFRARED CAMERA

The developed solution is based on integration of open source hardware platforms and a MLX90621 IR array sensor. It is based on the three-layer IoT architecture depicted in Figure 1. The basic structure of the developed system is shown on Figure 3. It consists of 16x4 array infrared and temperature sensor MLX90621, microcontroller development board PIC32-T795 and wireless MOD Wi-Fi ESP8266 module. The Power supply could be external through a standard 2.5 mm jack (from 9 to 15 volts) or internal with a LiPo battery (3.7 volts).

The first layer is implemented by the MLX90621 and the programming modules for its initialization, data transfer from the infrared sensor and the measurement calculations. The microcontroller development board PIC32-T795, produced by Olimex, is equipped with a high performance 32-bits microcontroller (PIC32MX795F512H) [10]. It supports the needed communication protocols and the necessary ports and is easy for programming. MLX90621 is connected to PIC32-T795 via I2C interface (RD9 (SDA1) and RD10 (SCL1)). The microcontroller receives raw data from the IR sensor for every pixel and using equations provided from the manufacturer calculates the temperature of every individual pixel and assigns red, green and blue values to it. Those values are then presented to the client when requested. Other functionalities are possible to be added, like threshold values for some pixel areas and alerting the user when the values are beyond those thresholds.

The wireless module MOD-WIFI-ESP8266 [10] was used to realize the second layer. It provides the wireless WiFi communication to the PIC32-T795 via UART through the UEXT interface. The module contains: ESP8266 microcontroller, 2MB SPI flash memory, UEXT connector and PCB antenna. It has complete embedded TCP / IP stack (IPv4, TCP/UDP/HTTP/FTP).

The firmware that is built into ESP8266 allows wireless communication to be managed via Hayes commands (AT commands) through the serial port. When a command is sent, a response is received for the execution status of the command. Initially, the wireless module is restarted with the command: `v_USART_WriteStr (handle1, "AT + RST \ r \ n")`. Then should set the access point mode: `v_USART_WriteStr (handle1, "AT + CWMODE = 2 \ r \ n")`; then turning on the DHCP option in the TCP / IP stack of the module: `v_USART_WriteStr (handle1, "AT +`

CWDHCP = 0,1 \ r \ n"); and finally the SSID and password of the access point are set. They are stored in the

appropriate data arrays in the text form (postCnt1 = 0; newSsidStr [postCnt1]; postCnt1 ++).

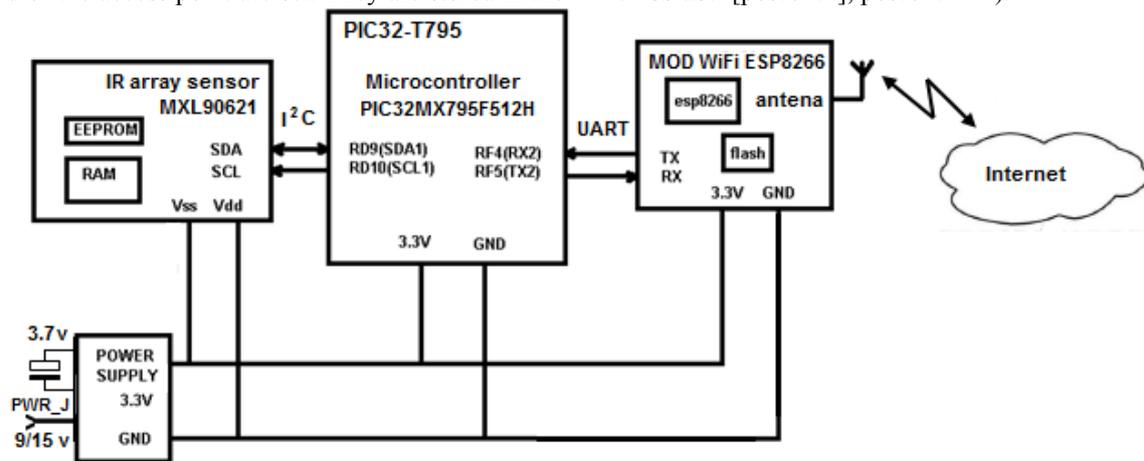


Fig. 3. The developed solution of IoT based Wireless Infrared Camera.

The third layer is implemented using a built-in HTTP server in the microcomputer of the ESP8266 module, which can read the sensor values and set the operating modes. It is started with: `v_USART_WriteStr (handle1, "AT + CIPSERVER = 1,80 \ r \ n");` by enabling a listener for requests on port 80. The built-in HTTP server has a simplified functionality. It maintains an HTML page displaying the parameters measured by sensor, and can change the device configuration (minimum embedded Web server) [11]. The web interface, by which the user can monitor and manage the sensor using a web browser, is shown in Figure 4. When the user makes HTTP requests to the IP address of the sensor (the default IP is 192.168.0.101), the Web server responds by returning the HTML file representing the client access interface. The user has opportunity to monitor the thermal picture from the sensor in real time, temperature values, refresh rate, and he has the opportunity to set temperature limits, refresh rate, data accuracy, calibration, and new SSID and password for connection to a wireless network. The refresh rate could be set from 0.5 to 16 frames per second, which drives the

cycle for requesting data from the sensor to be from 2000 to 62 milliseconds. AJAX (Asynchronous JavaScript And XML) is used to send commands as well to read periodically data from the sensor.

Our idea was to use the developed wireless infrared camera to illustrate a continuous monitoring of critical equipment for overheating. The image presented on Figure 5 shows the backside of the rack in the Data Center, situated in the Department of Computer systems and technologies at the Technical University - Sofia, Plovdiv branch. The infrared sensor creates a thermal picture, and one can easily distinguish the warmer zones presented in red, with maximum temperature of 40 C° and cooler zones presented in green with minimum temperature of 19 C°. The thermal picture is accessible through the web interface of the developed device. This thermal picture is superimposed on a photo on the backside of the observed area of the rack, where the cooling air flows. This helps us to analyze the critical for overheating components as CPU, memories, North and South bridges, etc.

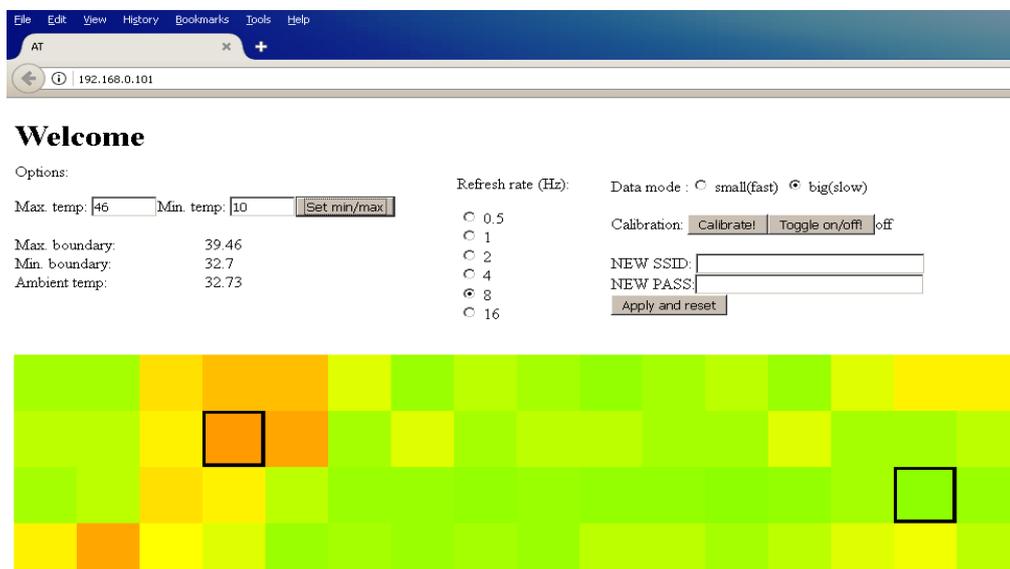


Fig. 4.The user web interface.

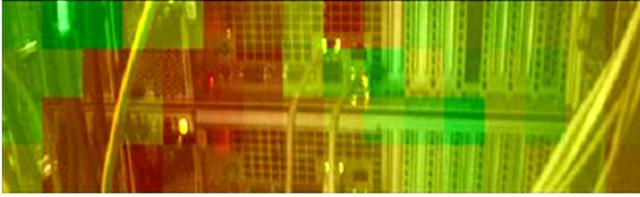


Fig. 5.A thermal picture superimposed on a photo of the backside of the rack in the Data center.

In this way the objects for which the increasing of the temperature is critical for normal work, and it is necessary quickly to take the corresponding actions to prevent overheating or even fire, could be continuously monitored. Further, a system for early warning for potential overloading, accidents and fires could be developed.

V. CONCLUSION

In this paper a low-cost solution applicable in the field of continuous monitoring of critical equipment in industry and smart homes is described. It employs a relatively new IR array sensor and implements the IoT concept and architecture. Based on an open source hardware microcontroller development board and WiFi module and an inexpensive IR sensor the developed solution is considered to be with reasonable cost and affordable for the potential users. The paper demonstrates the benefits of having an inexpensive infrared sensor as a part of the developed solution for continuous monitoring of critical equipment for overheating.

The option with internal battery power supply gives additional flexibility for monitoring of critical objects in difficult to reach places without the need of wires. The IoT based architecture facilitates the development of distributed systems for industrial and home monitoring.

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