Using IR array MLX90640 to build an IoT solution for ALL and security smart systems

Grisha Spasov[1], Vasil Tsvetkov[1], Galidiya Petrova[2]

Department of Computer Systems[1], Department of Electronics[2], Technical University of Sofia, Plovdiv branch,
25, TzankoDustabanov, 4000 Plovdiv, Bulgaria
{gvs@tu-plovdiv.bg,vaccc@abv.bg, gip@tu-plovdiv.bg}

Abstract – **In this paper we present and demonstrate a cost-effective alternative of infrared cameras - wireless sensor device that can be applied in the field of AAL, health care and security smart systems in home environment. It is designed as an IoT solution and it employs a new infrared array sensor MLX90640. For this purpose a Wi-Fi open source hardware board is used both for gathering the data from the sensor, processing the data and presenting it to Internet connected devices. The paper demonstrates the benefits of using relatively inexpensive sensor and open source hardware board for developing a solution with multiple applications and flexible connection to other smart devices via web interface.**

Keywords– **Internet of Things, Infrared array sensor, AAL, home security.**

I. INTRODUCTION

In the last decade with the development of new sensors and sensor networks the attention of many researches is focused on providing personalized services for users in their daily life, human localization or occupancy detection, activities recognition, and security issues. Vision-based human localization and actions recognition is under intensive research in the field of Ambient Assisted Leaving (AAL) and assistive technologies as the ageing population rapidly growing in a worldwide scale. However, the traditional cameras are not suitable for human localization and activities recognition in home environment mainly because of privacy concerns. This motivates the research groups to look for other suitable technologies and sensors and naturally lead to application of IR array sensors for indoor environment [1, 2]. As mention in [3] despite of increasing interest just a few manufacturer produce such devices and typically they have low resolution of 8x8, 16x4 or 16x16 pixels. There are many applications of these sensors in building automation, including fire detection, home observation, temperature monitoring [4], hazardous events and so on. Recently the attention is focused on application of IR array sensors for human localization and action recognition in AAL and smart home systems. The limited resolution of the employed IR arrays has initiated designs with multi-sensor systems [5, 6]. Additionally, different classification methods like: Random Forest, Support Vector Machine with Stochastic Gradient Descent training and k-Nearest Neighbours are applied. In [7] the authors reported 97% accuracy in human detection using low-resolution IR array sensor and complicated algorithms for noise removal, background estimation and probabilistic foreground detection. But they recognize that the main limitation of the proposed method is that it is hard to distinguish a human presence from other moving heat sources. In the same time, having a real time infrared array sensor for detection of human presence in a room, it is very convenient the same sensor to be used for monitoring the state of objects inside, thus being useful for the smart home automation and home security systems. For example, the image from a certain object (kitchen, home appliance, etc.) can be processed and evaluated in order to determine if there is a potential overheating, starting a fire or someone has forgotten to switch off the stove or iron. If such scenario has occurred the system will notify the user or the fire department, depending on the developed top applications.

In result of our review we came to the conclusions that: first, for human detection it is necessary to use IR sensor array with reasonably higher resolution still keeping the privacy, and second, to integrate this sensor with modules and services, based on smart home technologies, with the aim to detect critical conditions or predict them on early stage, to send alert to caregivers, relatives, etc. and take the corresponding actions.

The purpose of this article is to present and demonstrate a cost-effective wireless sensor device that can be applied in the field of health care, AAL and security smart systems in home environment. It is designed as an IoT solution and it employs a new infrared array sensor.

This paper is organized as follows: section 2 presents the new infrared array sensor and its main features and capabilities. The implementation of the IoT solution integrating Melexis MLX90640 infrared array sensor for monitoring of human presence and home appliances are considered in section 3. The conclusions and the future work are presented in the last section.

II. INFRARED ARRAY SENSOR MLX90640

The sensor that is selected for implementation of the IoT device is the MLX90640, produced by Melexis [8]. The MLX90640 is a fully calibrated 32x24 pixels thermal IR array in an industry standard 4-lead TO39 package with digital interface. 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 interface. The sensor is suitable for development of our IoT solution with its wide field of view (it has two options for field of view - 55°x35° and 110°x75°) and relatively good spatial resolution for low-cost infrared camera. Its current consumption is less than 23mA, which makes is suitable

even for battery powered solution. The refresh rate is between 0.5 and 64Hz, meaning that the sensor is capable of sensing very fast moving objects. The possible applications for the sensor are:

- 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;
- Industrial temperature control of moving parts.

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 sensor to be used in development of solutions for Indoor Human Detection, Room Occupancy, Tracking Motion, and continuous monitoring of critical electrical appliances in smart home.

III. IMPLEMENTATION OF IoT BASED SOLUTION WITH INFRARED SENSOR

The basic components of the developed IoT solution are the infrared array sensor MLX90640 and a Wi-Fi open source hardware development board ESP32-GATEWAY [9]. In this case three layer architecture is used [10], where the ESP32-GATEWAY acts as both collecting (perception) layer and network layer. The application layer is left open for the user to accomodate to the specific needs of each solution.

Functional diagram of the developed IoT based solution of wireless infrared array sensor is presented on Fig.1.

The MLX90640 (Fig. 1 a) serves as a sensing device that returns a 32x24 matrix of pixels with the raw data values. The ESP32-GATEWAY (Fig. 1 b) performs three main tasks:

- reading the data from the sensor using I2C interface (SDA is connected to ESP32-GATEWAY's GPIO18 and SCL to GPIO19) and calculating the temperature for each of the 768 pixels;
- interfacing with the user directly via web interface. It also connects to the MQTT broker (server) and can present the data to a user application;
- communicating with MQTT server.

The MQTT server or broker (Fig. 1 e) does the job of connecting the user to the IoT device. It waits for a connection from the nodes of the network and can present the data to every client that wants to access it.

We have chosen the MQTT protocol for data exchange between the IoT device, server and users. It works on top of the TCP/IP protocol. MQTT is a message oriented communicaion protocol that uses the publish-subscribe scheme for interaction between the clients [11]. The broker which can act as a server can effectively reduce the number of packets that fall into the internet and also the amount of processing the individual memory needed for the clients. MQTT defines three quality of services (QoS) that can be based on the importance of each message and the repeatability of messages in the environment. The use of

MQTT has several advantages, including more efficient dissemination of information, increased scalability; significant reduction of the network traffic and low overhead costs. In addition, using MQTT protocol reduces update rates to seconds and maximizes available bandwidth. It is suitable for remote monitoring and control and uses security based on permission. MQTT is designed to overcome the challenges of connecting the expanding physical world of sensors, actuators and phones with a software processing technologies [12].

We have taken into consideration that in the mobile environment the key design criteria are response times, throughput, lower battery use and lower bandwidth. Compared to HTTP, MQTT offers faster response and performance, and lower battery and bandwidth usage. This makes it very suitable for use cases where connectivity is intermittent and the applications should interact with each other and must send data securely without requiring duplication of logic.

Regarding the security, a username and password can be passed with an MQTT packet in the protocol. Encryption across the network can be handled with secure sockets layer, independently of the MQTT protocol itself. Additional security can be added by an application encrypting the data that is sent and received.

The Wi-Fi ESP32-GATEWAY board needs to be in the range of Internet enabled router (Fig. 1 c), so it can access the MQTT broker. At startup, an initialization of ESP32-GATEWAY module is performed, which includes initialization of non-volatile flash memory, where the Wi-Fi and MQTT configuration data is stored. The ESP32-GATEWAY reads the configuration data and extracts an Access Point (AP) SSID and password, which are previously stored.

If connection to the AP is successful, the user can use the SSID "ESP32-test-mqtt" and password "test1234" to connect temporarily to the ESP32-GATEWAY (working in AP mode) with a PC or phone. Then it is necessary to open HTML page of the ESP32's IP address (192.168.4.1) and use the web interface shown on Fig. 2. It allows the user to scan local APs and select the desired one. After a successful connection to the desired AP, the ESP32-GATEWAY stops the AP mode, and switches to station mode. Then it stores the SSID and password in flash memory for further use. The ESP32-GATEWAY's AP mode can also be invoked using a button on the board, and the web interface is also used to set MQTT configuration: broker, port, username, password, IDs, etc.

For each device there are three topics that are relevant to it: 'config', 'control' and 'readings' and together with the device ID the full topics are as follows (taking for example a device with ID: 00abcd):

- *device00abcd/config*: the device publishes to this topic a structure that represents the configuration of the sensor and ESP32-GATEWAY module;
- *device00abcd/control*: the device subscribes to this topic and waits for control and instruction messages;
- *device00abcd/readings*: the device publishes data from the sensor (infrared array values, PTAT value, timestamp, etc.).
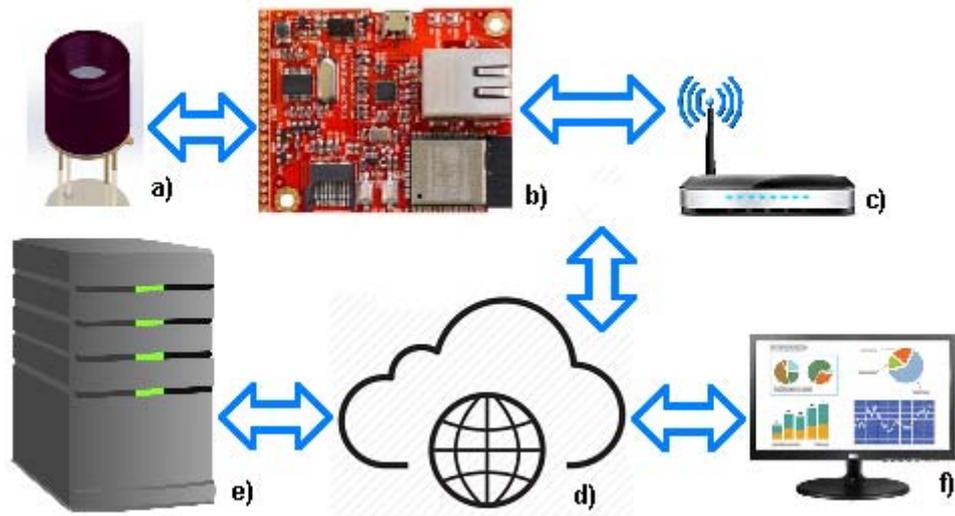
Fig.1. Functional diagram of the developed IoT based solution of wireless infrared array sensor.
a) MLX90640; b) ESP32-GATEWAY; c) router; d) internet connection; e) MQTT server; f) MQTT client

The data format for the messages is JSON. Using the MQTT server and the provided topics for each device it is possible to build a web application that can monitor and control in real time each infrared sensor.

When the application sends a 'stop' signal to the IoT device it stops sending data to the 'readings' topic. The device will stop sending data after one minute, unless the application tells it to continue. That way the unnecessary data will not be sent to the client, which is no longer connected.

The ESP32-GATEWAY uses secured web socket so the data is protected from intrusion. It also supports OTA from the 'config' topic which can be used to update the firmware of the device.

ESP32-GATEWAY board can get power from LiPo battery, or from adapter. It provides the 3.3V supply voltage to the infrared array sensor. The option with internal battery power supply gives additional flexibility for positioning of the device in difficult to reach places without the need of wires.

On Fig. 3 we have shown an example of detecting a potential fire hazard - the IR sensor is located in the kitchen and is directed towards the stove. If the sensor does not detect a presence of a person for a certain period of time and also the stove is switched on, then it can generate a warning message to the owner or some authority. Those specific details can be described in the business logic of the application layer of the solution.
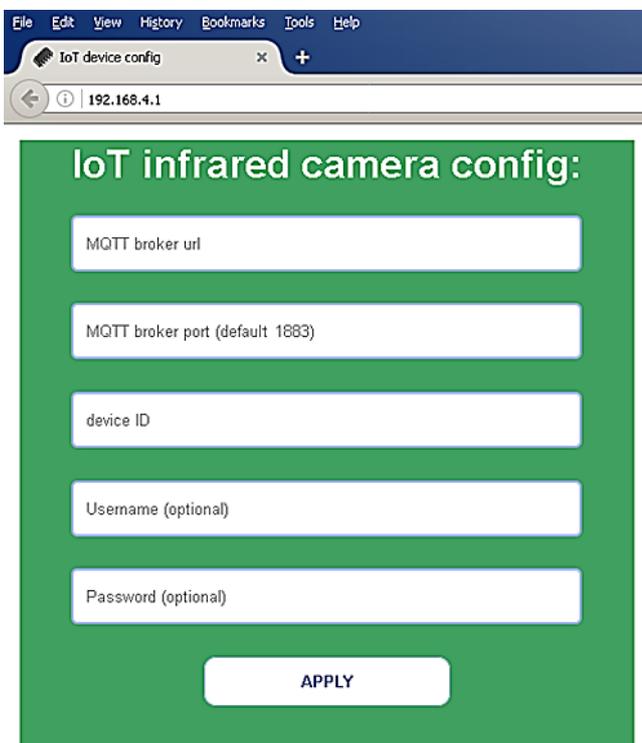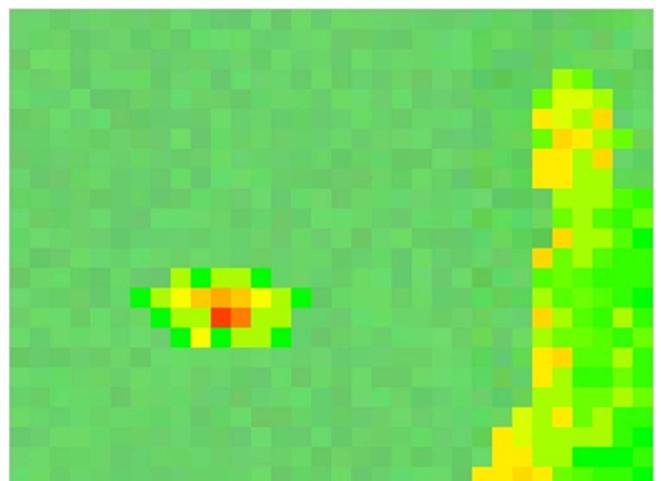

Fig.2. User web interface.

Fig.3. A raw thermal picture from infrared sensor with detected a human presence and a switched on stove in kitchen.

What sets the current solution apart from the previously mentioned is that this IoT device has better spatial resolution which allows to easily and more precisely observe temperature changes of the objects in the sensor' field of view.

IV. Conclusion

In this paper a cost-effective solution of wireless infrared sensor device that can be applied in the field of AAL, health care and security smart systems in home environment is described. It employs a new IR array sensor with higher resolution and implements the IoT concept and architecture. This architecture facilitates the development of smart home systems for human detection/localization and monitoring of the electrical appliances and equipment.

In smart homes and smart buildings the device could be tailored to detect specific temperature diviations on particular locations that could be used to avoid the risk of overheating and potential fire.

In the future, we aim to develop a network of IoT devices for physical parameters monitoring in smart home and healthcare and developed suitable applications for each case. Further, to develop a data center that will contain the data and these applications. This in particular, is very convenient when there is a need to track human presence, for exanple in a medical facility where the patients can be monitored even in the bathroom without invading their privacy.

Acknowledgment

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