IoT solution for monitoring of data in the visible and infrared spectrum

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

Abstract – **In this paper a cost-effective combination between infrared and visible camera for thermal imaging applicable in AAL and object monitoring in smart homes is presented and demonstrated. In recent years, we have witnessed a rapid surge in assisted living technologies. Internet of Things is a platform where every day devices become smarter, every day processing becomes intelligent, and every day communication becomes informative. Our implementation is based on four layers IoT architecture. The user interface provides an option for manual adjustment of the image alignment from infrared and visible cameras. Apart from manual procedure, a procedure for the automatic alignment of the images of the both cameras have been developed. The time necessary for the image data processing by the microcontroller which gathers data from the sensors or by the gateway device is estimated.**

Keywords – **Ambient Intelligence, Assisted Living, Internet of Things (IoT), Smart devices, Infrared imaging.**

I. Introduction

Globally, it is estimated that there will be an increase in age-related diseases, such as the Alzheimer's disease or Parkinson's disease. There will be rising of healthcare costs. Given the fact that almost 90% of the older adults prefer to stay in the comfort of their own homes, and given the costs of nursing home care, it is imperative to develop technologies that help older adults to age in place. Assisted living technologies based on ambient intelligence are called Ambient Assisted Living (AAL) tools. AAL can be used for preventing, curing, and improving wellness and health conditions of older adults. In the recent years there is a variety of sensors that have reached a lower cost and high accurate to be considered suitable candidate for the AAL field. There are many applications of these sensors in building automation, including presence detection, fire detection, home observation, temperature monitoring, hazardous events and so on [1]. The thermal imaging technology is fairly new in the fields of personal health and ambient assisted living systems, but with the recent success in development of low-cost solutions it became possible to introduce such smart devices in the lives of people that need special care and attention [2,3]. A special combination between data monitoring and data security must be achieved in order to guarantee the privacy of the individual while we still benefit from acquiring data from the surrounding world. As the resolution of the infrared sensors is not that great, they can be paired with a normal camera that can present a better representation of the image.

The purpose of this article is to present an IoT solution employing an infrared array sensor and high resolution camera, which can be applied in the field of health care, AAL and security smart systems in home environment. The implementation is based on four layers IoT architecture.

We would like to estimate the time necessary for two types of image processing, in particular pixel correction and image filtering, by the microcontroller which gathers data from the sensors or by the gateway device.

This paper is organized as follows: section 2 presents the pairing of an infrared array sensor Melexis MLX90640 with the OV2640 camera in a single PCB. The implementation of the IoT solution integrating infrared array sensor and the OV2640 camera for monitoring of human presence and home appliances and its architecture are described in section 3. The image data processing timing are considered in section 4. Finally, the conclusions and the future work are presented in the last section.

II. Pairing of Infrared Array Sensor MLX90640 and OV2640 Camera

The infrared sensor that is selected for implementation of the IoT device is the MLX90640, produced by Melexis [4]. The MLX90640 is a fully calibrated 32x24 pixels thermal IR array in an industry standard 4-lead TO39 package with digital I2C interface. The MLX90640 contains 768 FIR pixels. The sensor is suitable for development of our IoT solution with its wide Field of View (FoV - 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 OV2640 is a 2 megapixel camera with resolution of 1622X1200 pixels and 3.3V power supply. It supports the following output formats: YUV(422/420)/YCnCr422; RGB565/555; 8-bit compressed data [5].

The above mentioned features of both sensors are a good reason for selection of these cameras to be used in development of solutions for Indoor Human Detection and continuous object monitoring in the smart homes.

Since we intend to use two sensors to obtain the images, they need to be properly aligned. The infrared and visible light cameras are placed close together (one above the other) on the PCB. It is expected that the two sensors have the same field of view. However, there might be a slight misalignment if the field of view angles of the two cameras

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are different, so there is an option to re-adjust the image overlay. It could be done either manually or automatically.

The manual (hand adjustment) approach is quite straight forward: the user interface provides an option to re-position the two rectangles of the view in such a way that the infrared image and the visible light image are correctly aligned. This is done with the help of object that has a significantly different temperature than the background.

Apart from manual procedure, we have developed a second option (procedure) for the automatic alignment of the images of the both cameras. This approach also uses an object with different temperature, but it also needs to be with different color too, so that the edge-detection mechanism employed in the developed procedure can detect and position it inside the hotter pixels of the infrared image. The best results for the automatic alignment of the images of the both cameras are observed when two objects are used, for example two bright colored cups that are filled with hot liquid.

On figure 1 we demonstrate the results of applying the automatic alignment of the images of the both cameras using a cup filled with hot water and two ice cubes positioned on both sites of the cup. The positioning of the two overlaid images and how the different field of view angles are affecting the final image is shown.

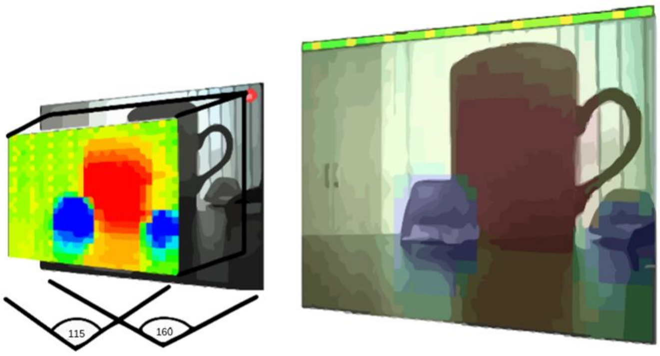

Figure 1: En example of the developed FoV angle correction procedure.

III. IMPLEMENTATION OF IoT BASED SOLUTION WITH 4-LAYER ARCHITECTURE

The implemented architecture is shown in Figure 2. It is based on four layers IoT architecture [6]. The transition to a four-layers architecture is due to the need to introduce middleware whose function is to store, analyze and process information on objects received from the gateway. In the proposed solution the perception layer is the closest to the object under monitoring. The sensors gather and perform minimal data processing before the result is passed to the upper layer. Here we use the ESP32-CAM module [5] for data processing on the first later. The second layer is taking care of organizing the data flow from each node and control the device discovery and addressing. The second layer device is a small Linux computer of the Raspberry Pi class, based on the A20 SoC: it is the free and open hardware board A20-OLinuXino [7] that is running a webserver and a database software. The third layer contains the business logic, security protocols and is the main data storage facility to which the gateway device is reporting. Finally, the user accesses the data through the fourth layer: the web and mobile application that is tasked with data representation.

We have chosen the MQTT protocol for data exchange between the IoT device, gateway and users. It is a message oriented communication protocol that uses the publish - subscribe scheme for interaction between the clients [8, 9]. MQTT works on top of the TCP/IP protocol.

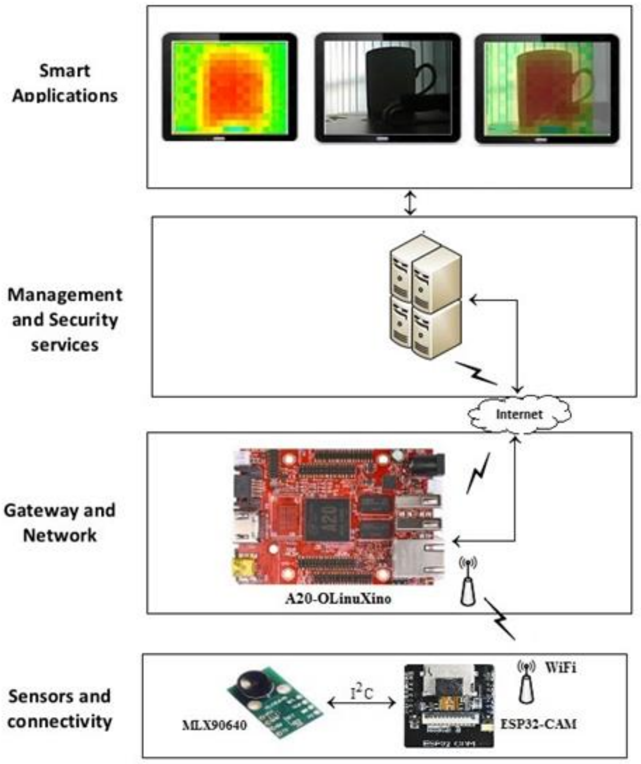

Figure 2: Four layers IoT architecture of the developed solution.

IV. IMAGE DATA PROCESSING TIME ESTIMATION

For some AAL applications the frame rate of the real-time image stream is also necessary to be taken into consideration. From the other side, the frame rate is dependent from the time necessary for image data processing. When the microcontroller gathers data from the sensors, it is necessary to perform some calculations with the raw data in order to get useful information for each pixel. Different approaches could be applied in that direction. We could either make the calculations on the microcontroller itself, or we could make them in the gateway device. The ESP32-CAM microcontroller is powerful enough to take care of the calculations that are needed in order to obtain the images from the sensors. The calculations comprise a variety of mathematical operations on pixels or groups of pixels aiming to achieve a better image quality. In order to estimate the image data processing times of the two approaches, we compare the time necessary to perform two types of processing – pixel correction and image filtering which are typical for the infrared sensors. The test calculations are performed on the data from each pixel from the infrared sensor.

In this timing analysis we have used the MLX90640_BadPixelsCorrection function provided from the Melexis developer notes for the MLX90640: https://github.com/melexis/mlx90640-library/blob/master/MLX90640%20driver.pdf section 3.5.1.

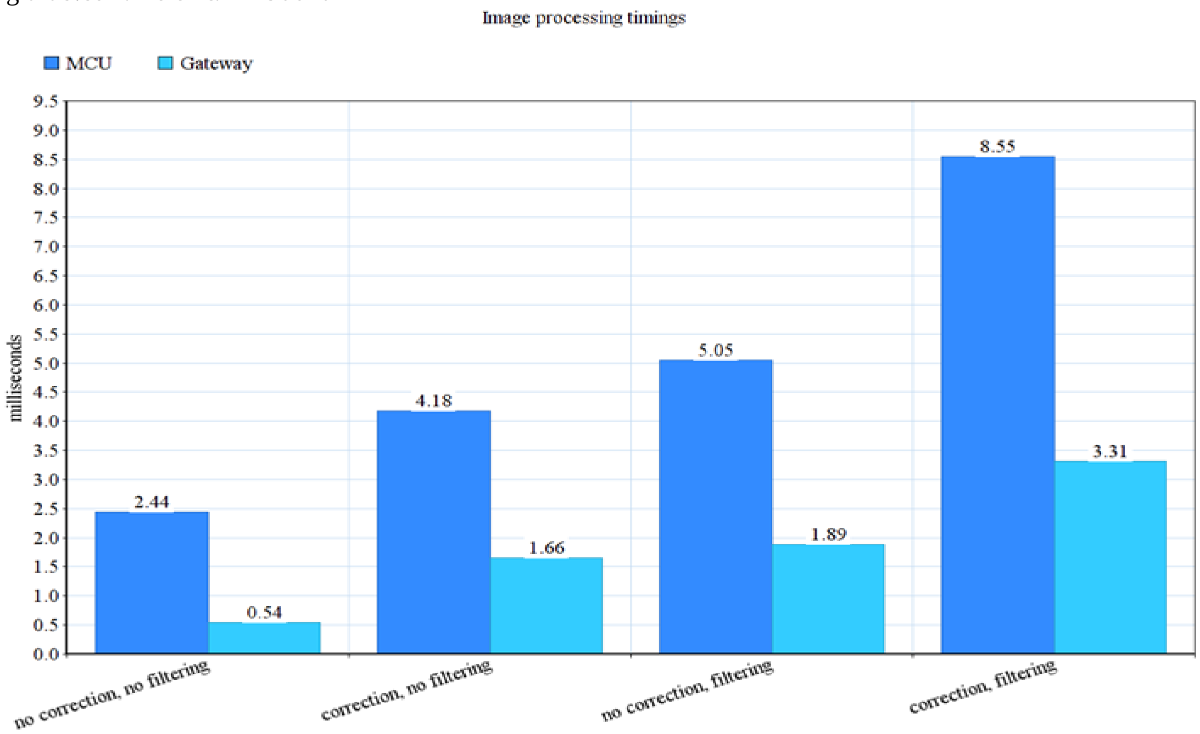

Figure 3: The data processing times for pixel correction and image filtering performed in the microcontroller or in the gateway.

The filtering consists of a 3x3 matrix that smoothen the pixels of the infrared image. The data set on which the calculations are performed is the 768 pixels from the 32x24 grid and each element of this data buffer is data type float. Every one of the timing values is extracted from the average of 10 consecutive samples performed on the ESP32-CAM microcontroller and the A20-OLinuXino based gateway device separately.

The results for the image processing times are visualized on Figure 3.

The results from this test show that using second approach the gateway (A20-OLinuXino) can speed up the data processing stage and thus we can obtain a better frame rate of the real-time image stream. Moreover, the user has the option to select at which stage the processing will be done and thus get different network workload, depending on the specific situation. More testing can be done to test this scenario in different network conditions.

In the end, we have shown the output from the developed user application – Figure 4. Here, the two images are overlaid and we get a combination of an infrared and visible light image. It can be seen how the water from the ice cubes is colored in blue and the hot cup is red. The user has the option to select to gather information from only one of the two sensors.

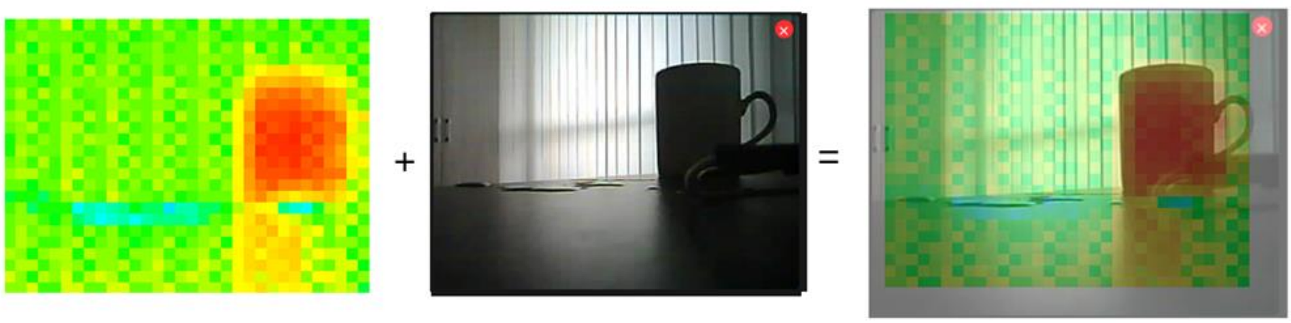

Figure 4: Application example output.

V. Conclusion

In this paper we have presented and demonstrated a cost-effective combination between infrared and visible camera for thermal imaging applicable in AAL and object monitoring in smart homes.

The implementation is based on four layers IoT architecture. The user interface provides an option for manual adjustment of the image overlay. Apart from manual procedure, a procedure for the automatic alignment of the images of the both cameras has been developed. The time necessary for the image data processing by the microcontroller which gathers data from the sensors or by the gateway device is estimated.

Future work involves test-bed experiments for image processing timing in scenario with more sensor notes and different network conditions.

With the increased demand on patient monitoring it is becoming more apparent that there will be a significant need for IoT solutions that will offload some of the responsibilities from the caregivers and the medical staff. In smart homes and smart buildings the device could be tailored to detect specific temperature deviations on particular locations that could be used to avoid the risk of overheating and potential fire.

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