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SKIN TEMPERATURE MEASUREMENT WITH THE LEPTON FLIR CAMERA

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RESUMEN

Debido a que actualmente no hay vacunas o terapias antivirales efectivas específicas para COVID-19, existe una necesidad global urgente de detección temprana de pacientes con Covid19 para detener la propagación del virus, una de estas formas es detectar si la gente tiene fiebre, tomando su temperatura, de tal manera que una temperatura superior a 37.5 ° C en la piel puede considerarse fiebre. Imágenes térmicas sin contacto (TI) es un método seguro y no invasivo para recopilar datos de temperatura de la piel, utiliza el fenómeno de que los objetos vivos emiten radiación infrarroja en cierta medida y la intensidad de la radiación infrarroja se puede utilizar para calcular la temperatura del objeto emisor. En este artículo, se presenta un sistema de visión de imagen térmica de bajo costo, que permite la inspección en lugares concurridos con personas que pueden tener fiebre, un síntoma de enfermedades infecciosas como Covid 19.

Palabras Clave: Covid 19, FLIR, Lepton, Qt.

ABSTRACT

Due to there are currently no vaccine or specific effective antiviral therapies for COVID-19, in general, there is an global urgent need for early detection of Covid19 patients, to stop the spread of the virus, one of these forms is to detect if the people has a fever, taking their temperature. Thus, a temperature higher than 37.5°C in the skin can be considered fever. Non-contact thermal imaging (TI) is a safe non-invasive method of collecting Skin Temperature data, it utilizes the phenomenon that living objects emit infrared radiation to some extent, and the intensity of infrared radiation can be used for calculation of the temperature of the emitting object. In this paper, a low-cost thermal imaging vision system is presented, it allows inspection of crowded places with people who may have a fever, a symptom of infectious diseases such as Covid 19.

Keywords: Covid 19, FLIR, Lepton, Qt.

1. INTRODUCTION

In December 2019, a pneumonia outbreak of unknown etiology took place in Wuhan, Hubei, China. Chinese Center for Disease Control and Prevention (CCDC) identified a novel beta/coronavirus called 2019-nCoV, based on phylogeny, taxonomy and established practice recognizes this virus related to severe acute respiratory syndrome coronaviruses (SARS-CoVs). Since February 22, officially known as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) denominated by the International committee of virus taxonomy [1], that is responsible for the pandemic. The World Health Organization (WHO) declared that the outbreak of COVID-19 constitutes a Public Health Emergency of International Concern (PHEIC) on January 30, 2020. As of 10 April 2020, the pandemic caused accumulated globally 1,524,161 confirmed cases with 92,941 deaths, affecting 213 countries and territories around the world [2].

Based on genome sequencing, 2019-nCoV is about 89% identical to bat SARs-like-CoVZXC21, 82% identical to human SARS-CoV and about 50% to MERS-CoV [3], the pandemic escalated exponentially at the beginning of 2020, which might only be the tip of the iceberg due to delayed case reporting and deficiency in testing kits [4].

Clinical manifestations resembled viral pneumonia. 81% of the cases are considered mild, whose symptoms were usually gone in two weeks. Severe patients progressed rapidly with acure respiratory distress syndrome (ARDS), eventually ended in multiple organ failure [5].

It was revealed that 98% of the patients in their study had a fever, of which 78% had a fever above 38°C. They also reported that 76% of patients had a cough, 44% had fatigue and muscle pain, and 55% had dyspnea [6].

Due to there are currently no vaccine or specific effective antiviral therapies for COVID-19 in general, there is an urgent need for global early detection of Covid19 patients to stop the spread of the virus one of these forms is to detect if the people has a fever, taking their temperature. The temperature of the human body is a complex, nonlinear variable subject to internal and external variations. The normal temperature of the human body depends on where the measurement is taken, the moment in the day and the level of activity of the person. This means that the temperature is subject to the circumstances of your intake. Different parts of the body have different temperatures. The generally accepted average temperature is 37°C. But a wide variety of ranges have been measured in the adult: from 33.2 to 38.2 in oral intake, from 34.4 to 37.8 in rectal intake, from 35.4 to 37.8 in the eardrum cavity and from 35.5 to 37°C in the armpit [7]. Thus, a temperature higher than 37.5°C in the skin can be considered fever.

Non-contact thermal imaging (TI) is a safe non-invasive method of collecting Skin Temperature data, used since the early 1960's utilizing the phenomenon that living objects emit infrared radiation to some extent, and the intensity of infrared radiation can be used for calculation of the temperature of the emitting object [8]. There have been developed different applications for compact thermal imagers such as non-contact thermometer, thermal enabled new user interfaces,

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spectroscopy, people counting, Internet of Things (IOT), Firefighting, Animal Care, and Electronic System Troubleshooting as stated in [9].

Nowadays several studies use low-cost infrared cameras to obtain thermal images with the objective to obtain corporal temperature [10]-[15].

It was concluded that low-cost infrared cameras like the FLIR ONE IR 2nd generation camera performance does not comply with the required standards for clinical use, recommending that the information provided by these imaging systems should only be taken into account for monitoring purposes and not as an input for diagnostic judgments [16].

FLiR Camera (Forward Looking InfraRed) Lepton 2.5 is a radiometric-capable LWIR camera solution that is smaller than a coin in weight and is one-tenth the cost of traditional IR cameras. Using an active 80x60 pixel focal plane array, Lepton integrates easily with native mobile devices and other electronic devices such as an IR sensor or thermal imager. Radiometric Lepton captures accurate, calibrated, non-contact temperature data at every pixel in every image. It has an effective frame rate of 8.6 Hz, a longwave infrared spectral range, 8 µm to 14 µm, also an automatic temperature compensation with a sensitivity of .05 °C, with video over SPI. The optimal temperature range is -10 °C to + 65 °C [17].

In this paper, a low-cost thermal imaging vision system is presented, it allows inspection of crowded places with people who may have a fever, a symptom of infectious diseases such as Covid 19.

2. FLIR LEPTON CAMERA & RASPBERRY PI

The FLIR Lepton thermal imager is compatible with standard communications interfaces SPI (Serial Peripheral Interface), I^2C (Inter Integrated Circuit) and MIPI (Mobile Industry Processor Interface). FLIR Lepton uses SPI and MIPI to send images, while I^2C is used to control camera settings. In this way, it is possible to modify its configuration without interrupting the taking of images by using two different protocols. See Figure 1.

Fig. 1 Lepton FLIR camera.

2.1 Raspberry Pi

Given the proliferation of smartphones, the idea of holding in one hand computers that are capable of performing billions of instructions per second is easy to take for granted, but the fact that you can modify the hardware and software of such small yet powerful devices and adapt them to suit your own needs and create your own inventions is very attractive. This is the success behind the low-cost system on chip (SoC) Raspberry Pi platform [18] [19]. Figure 2 shows RPi card.

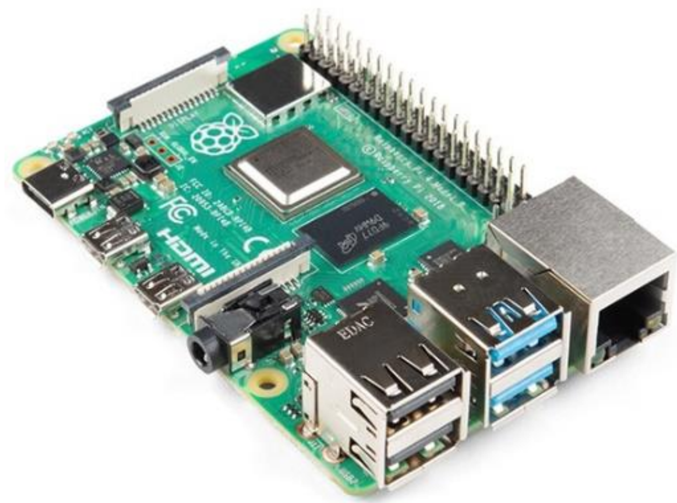

Fig. 2 Raspberry Pi.

2.2 Communication Interface

SPI is defined as a synchronous communications protocol, that is, the synchronization and transmission of data is regulated by a clock signal. In this protocol there is always a master device (in this case the Raspberry Pi board), which controls a series of slave devices. Typically, 4 lines or signals are defined in this protocol:

MISO (Master In Slave Out). The line through which the slave sends data to the master.

MOSI (Master Out Slave In). It is the line through which the master sends data to the slaves.

SCK (Serial Clock). It is the clock signal that synchronizes the data transmission and is generated by the master.

SS (Slave Select). It is the pin through which the master selects a slave to communicate with him. When the SS pin is in the LOW or "0" state, communication with the master occurs.

2.3 Connection

FLIR Lepton camera can be connected to the Raspberry Pi embedded system. For the connection of the FLIR Lepton 80x60 active pixels camera, LWIR sensor with wavelength of 8 to 14 µm, it will be done as shown in Figure 3.

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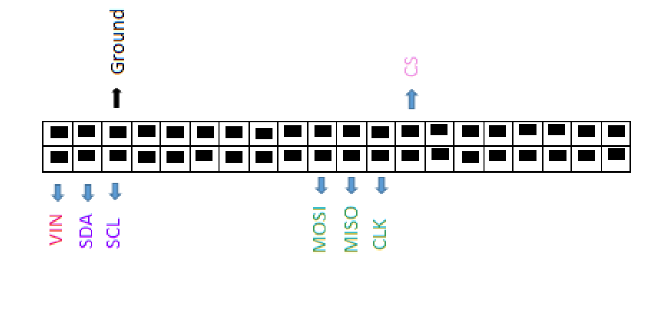

Fig. 3 Lepton & RPi Connection.

3. SOFTWARE DEVELOPMENT

The ability of Raspberry Pi to run a general-purpose embedded Linux operating system makes the platform accessible, adaptable, and powerful. One of the embedded Linux distribution is Raspbian, it contains a set of software programs and tools that makes the RPi works [18].

3.1 Qt

Qt is a powerful cross-platform development framework that uses standard C++. It provides libraries of C++ code for GUI application development and for database access, thread management, networking, and more. Importantly, code developed under this framework can be executed under Windows, Linux, Mac OS X, Android, IOS, and on embedded platforms, such as RPi. Qt can be used under open source or commercial terms and it is supported by freely available development tools, such as qmake and Qt Creator. The capability and flexibility of this framework make it an ideal candidate for GUI applications that are to run directly on the RPi, or on devices that control the RPi [18] [20].

The libraries of Qt are characterized by being independent of the platform where they are run and that allow graphical interfaces (GUIs) to be generated quickly and easily for many operating systems, including the embedded system Raspberry Pi. It has a multiplatform free software integrated development environment (IDE) called Qt Creator.

Its characteristics include:

a) It has an advanced C++ code editor.
b) It provides an integrated GUI and a form designer.
c) Tools for project management.
d) Context sensitive help.
e) Contains a visual debugger
f) Code highlighting and autocompletion.

Figure 4 shows Qt logo.

Fig. 4 Qt.

3.2 Signals and Slots

Qt has an event-driven programming model that enables events and state changes to be interconnected with reactions using a mechanism termed signal and slots. The slot, which is somewhat like a callback function, performs a user-defined function when it receives a signal. Importantly, the signals and slots mechanism can be applied to non-GUI objects; it can be used for intercommunication between any object that is in any way derived from the QObject class [18]. Signals and slots provide a powerful mechanism that is possibly the most unique feature of the Qt framework and used by Lepton camera software.

4. LEPTON MODULE

The FLIR Lepton camera requires the installation of a software module that contains the necessary libraries for its operation, it is written in the C++ programming language and contains the Qt framework, it is called LeptonModule [21].

4.1 Lepton Module Libraries

SPI. Enables the Peripheral Serial Interface where the mode, the number of bits per word and the data reading speed are already established.

Lepton_I2C. Communication with the FLIR Lepton camera requires the opening of a compatible communication port, this code allows the opening of the port where the interface is specified, the desired baud rate and returns a port descriptor to use with all the other APIs from the SDK library.

The Automatic Gain Control (AGC) algorithm converts the full-resolution (14-bit) thermal image into a contrast-enhanced image suitable for display is a histogram-based nonlinear mapping function.

LeptonThread. This source file contains the main algorithm of the project since here the image is built and the format is established for it, the SPI port is enabled, data obtained by the I²C interface is read so that they can be stored in an 80x60 digital matrix. To perform a new data reading, a waiting time must be established which is 750 msec.

Through the I²C interface the camera sends integer values from its 14-bit converter, these values are in the range 0 to 16384

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(2^{14}), these are stored in a variable called "value" to compare them with the variables "value1", "value2" and "value3" to subsequently obtain the 3 maximum temperature values in the scene.

For each of the 3 maximum values of the converter, its coordinates (X, Y) are obtained. In Equation (1) the coordinates (X_1, Y_1) for "value1" are shown.

$$(X_1, Y_1) \quad (1)$$

The Euclidean Distance (*ED*) between the 3 maximum values is obtained in Equation (2).

$$ED = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2} \quad (2)$$

At the end of the algorithm shown in Figure 5, the variables: "value1", "value2" and "value3" contain the 3 maximum conversions with a sufficiently separated threshold "*D*".

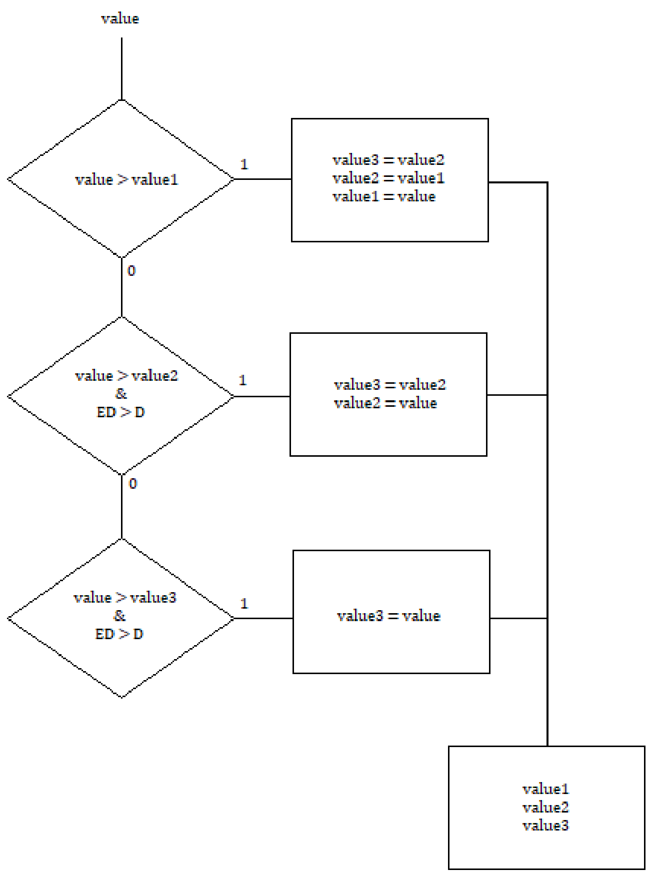

Fig. 5 Getting 3 hottest and separated temperatures.

The lepton_temperature() function returns the ambient temperature perceived by the Lepton camera. The values obtained from the converter are scaled by 100 in Kelvin degrees, so it is necessary to apply Equation (3) to obtain the ambient temperature in Kelvin.

$$TI = 0.01 * lepton\_temperature() \text{ °K} \quad (3)$$

The ambient temperature is assigned to the mid-range value of the 14-bit converter, that is, 8192 ($\frac{2^{14}}{2}$), the thermal scene average. In Equation (4) this assignment and the conversion to Centigrade degrees are made.

$$T1 = TI * \frac{value1}{\frac{2^{14}}{2}} - 273.15 \quad \text{°C} \quad (4)$$

The same is done for the other 2 objects (T2 and T3).

5. RESULTS

A Raspberry Pi-based embedded system with a 7" 800 x 600 pixels color LCD touch screen was integrated to host the FLIR Lepton camera. The system is small but sufficient to display thermal images.

The system contains the Raspberry Pi 4 Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC 1.5GHz, 4GB LPDDR4-3200 SDRAM, with Raspbian Buster operating system in 32GB MicroSD class 10 memory, with the Touch screen 7", 800 x 600 pixel resolution, 24-bit color, 70° viewing angle and capacitive touch, assembled in a cabinet (SmartiPi Touch) with space for the 7" screen and camera module for Raspberry Pi. See Figure 6.

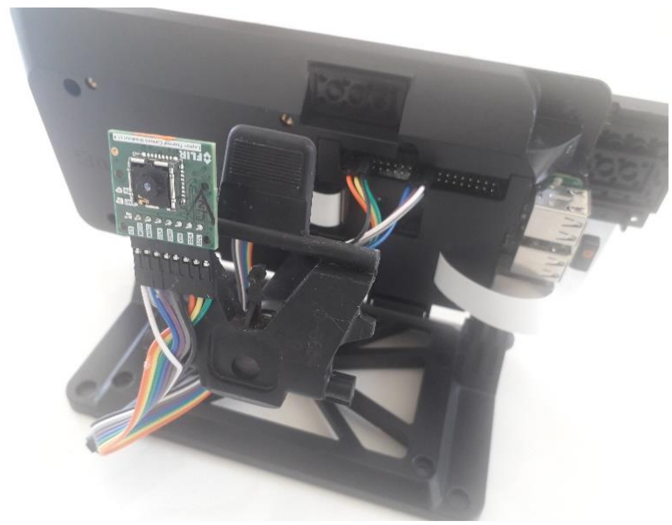

Fig. 6 Lepton + RPi + 7" Touchscreen + SmartiPi Touch.

The thermal image acquisition system is available to the community to monitor people with fever, a symptom of the disease caused by Covid 19. The system can be used in crowded places such as: hospital waiting rooms, classrooms, supermarkets, banks, offices of official and private agencies, etc.

Figure 7 and 8 show the system making its skin temperature measurement.

Figure 9 shows a two-target skin temperature measurement.

Fig. 7 Skin temperature measured with the system.

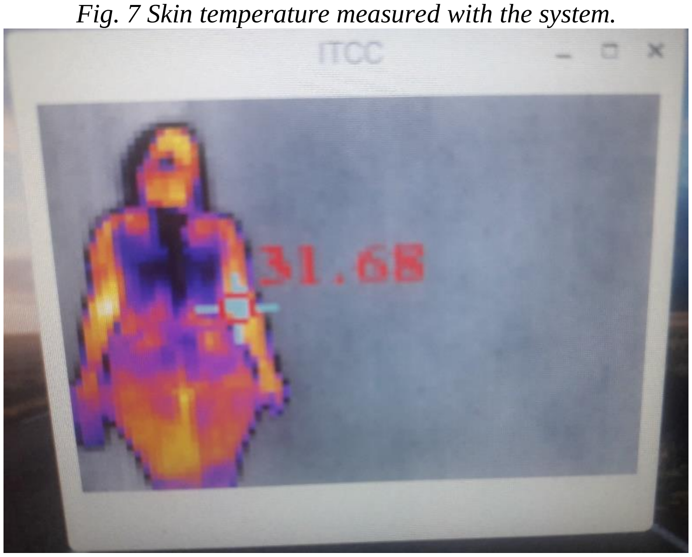

Fig. 8 Other skin temperature measurement.

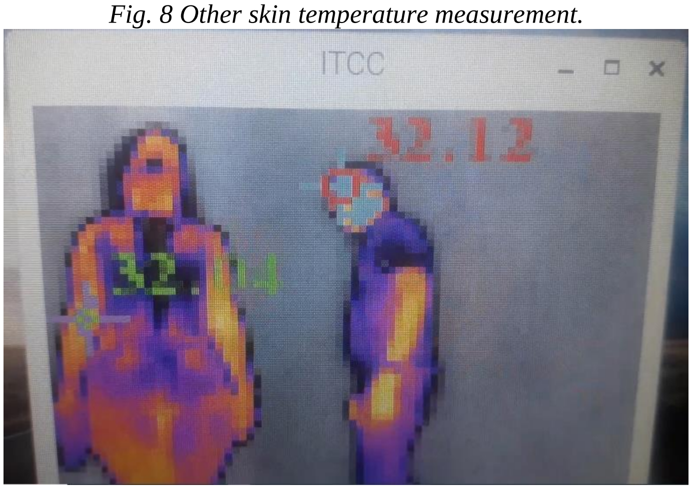

Fig. 9 Two-target skin temperature measurement.

6. CONCLUSIONS

The FLIR Lepton camera and Raspberry Pi 4 were selected as the main components of a system to detect an infrared radiation source and data processing.

By means of analysis and tests, the values of the Lepton temperature converter were obtained, these contain the emissivity factor of a real scene.

The use of the Raspberry Pi as the central processing unit in conjunction with the Qt programming environment allowed the implementation of a low-level artificial mink system facilitating communication between the components of the device.

The device was evaluated in different scenarios where possible applications in the industrial area could be seen, since, according to the needs of the users, adaptations can be made based on the images captured and the obtained temperature values.

The system has the ability to display the temperature of up to 3 people, the interest is those people who exceed 37.5 °C; this, in crowded places such as hospitals, schools, shopping malls, government institutions, etc., displaying the information obtained in real time on a 7” color screen.

Being a non-invasive prototype, it prevents operators from having direct contact with people, the measurement is made discreetly, thus the contagious agent is not spread. The prototype’s portability, easy handling, easy configuration, and low cost allows the detection of people who present body temperatures above the considered healthy standard, leading them to deeper medical examinations.

In addition, its functionality can be adapted to other activities that organizations require, when the contingency has ended, for example, clinical analysis, facility security, etc.

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