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Research paper

A Low Cost Thermal Imaging System for Medical Diagnostic Applications

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Abstract

This paper presents a low cost thermal imaging system for medical diagnostic applications. Available systems are expensive and are mostly meant for industrial applications. In this paper the existing system which is a basic system consisting of thermopile based sensor which produces thermal array is replaced with a "Thermal Imaging Camera" for medical diagnosis applications. The thermal camera scans the entire body of the individual to diagnose the diseases ie, infrared radiations from the human body part and then converts them to electronic signal. If there is any lump or any other unusual change inside the body, then the body temperature at that particular part will alone be high or low which indicates the "Hypo" or "Hyper" condition of the disease. Scene captured by the thermal camera is represented as a matrix. Each element of matrix represents a temperature value. Temperature values are divided into different ranges and each range is represented by an RGB value by the Raspberry Pi. Based on this thermal camera image we can detect the exact location in individual body part and further for that part alone we can take test and detect what kind of disease the individual is suffering. This system can be used in wide applications in the field of medicine such as detection of breast cancer, fever screening, thyroid disease detection, early detection of risk for diabetic peripheral neuropathy, Reynaud's phenomenon, orthopedics etc.

Keywords: *Thermography, thermogram, thermal imaging system, AMG8833 camera, raspberry pi, pseudo color image.*

1. Introduction

Thermal imaging is a non-destructive, non-contact and rapid system. It reports temperature through measuring infrared radiation emanated by an object. Automated thermal imaging system involves thermal camera equipped with infrared detectors, signal processing unit and image acquisition system supported by computer. It is elaborated in wide domains applications. In medical applications, Thermography is a imaging technique that is used to measure the temperature distribution in organs as well as tissues. The visual display of this temperature distribution is called a thermogram. Thermography can be used in several conditions as a diagnostic tool, for planning the treatment and to evaluate the effects of treatment. Thermography if used with other imaging modality, play a vital role in the conformation of many diseases.

All objects with temperature above 0K emit electromagnetic radiation, which is known as infrared radiation or thermal radiation which lies within a range of 0.75–1000 micrometer. For medical applications a very narrow wavelength band (8–12 micrometer), termed as body infrared rays is utilized. Blood circulation is the principle mechanism of heat transfer in human body. Heat emanating onto the skin surface and surrounding blood flow can be described by the following equation, which is known as Pennes bio-heat equation.

$$k\Delta^2 T - C_b W_b (T - T_a) + q_m = 0 \quad \text{--- (1)}$$

Here k is the thermal conductivity of tissue, q_m is the volumetric metabolic rate of the tissue, C_b W_b is the product of the specific heat capacity and the mass flow rate of blood per unit volume of tissue, T is unknown tissue temperature and T_a is arterial temperature. Infrared radiation from the skin or organ tissue reveals temperature variations by producing brightly colored patterns on a liquid crystal display. Interpretation of the colour patterns helps in the diagnosis of many disorders.

AMG8833 Camera (infrared thermal camera) is a non-contact device that detects infrared energy (heat) and converts it into an electronic signal that is processed to produce a thermal image on a video monitor. The signal can also be used to perform temperature calculations.

Figure 1: AMG8833 thermal IR sensors from Panasonic

The AMG8833 is the next generation of 8x8 thermal IR sensors from Panasonic, and offers higher performance than it's

predecessor the AMG8831.
The sensor only supports I2C, and has a configurable interrupt pin that can fire when any individual pixel goes above or below a threshold that you set. This sensor from Panasonic is an 8x8 array of IR thermal sensors. When connected to your microcontroller (or raspberry Pi) it will return an array of 64 individual infrared temperature readings over I2C. It's like those fancy thermal cameras, but compact and simple enough for easy integration. This part will measure temperatures ranging from 0°C to 80°C (32°F to 176°F) with an accuracy of +- 2.5°C (4.5°F). It can detect a human from a distance of up to 7 meters (23) feet with a maximum frame rate of 10Hz.
The paper presents a low cost thermal imaging system for diagnostic applications. The existing systems are really expensive (costs at least $5000) and meant for industrial applications. During certain disease conditions the body temperature goes above/below the normal value of 37^0C. This temperature variation can be detected using the system. The objective is to identify and diagnose diseases depending on the results obtained in the thermal image.

2. Existing System

The implementation of existing system begins with a basic system consisting of thermopile based sensor which produces thermal array. This detects the infrared radiations from the human body part and then converts them to electronic signal.
The scene captured by the sensor is represented as a matrix. Each element of matrix represents a temperature value. Temperature is calculated and a pseudo color image is developed with the help of a microcontroller.

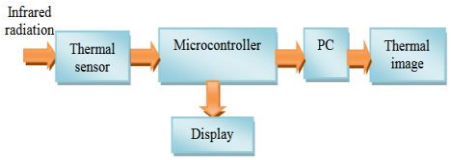

Figure 2: Basic block diagram

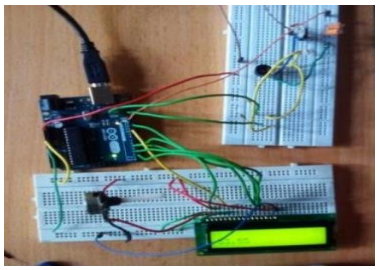

Figure 3: Experimental setup of existing system

3. Proposed Experimental Setup

The existing system which is a basic system consisting of thermopile based sensor which produces thermal array is replaced with a "Thermal Imaging Camera" for medical diagnosis applications. The thermal camera scans the entire body of the individual to diagnose the diseases. If there is any lump or any other unusual change inside the body then the body temperature at that particular part will alone be high or low which indicates the "Hypo" or "Hyper" condition of the disease. Temperature values are divided into different ranges and each range is represented by an RGB value. Based on the thermal camera image we can detect the exact location in individual body part. And for that part alone we can take test and detect what kind of disease the individual is suffering.

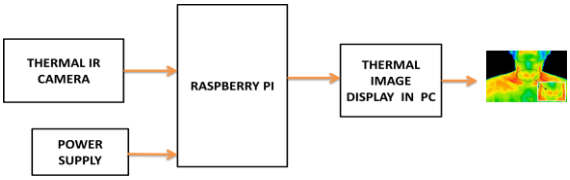

Figure 4 (a): Block diagram

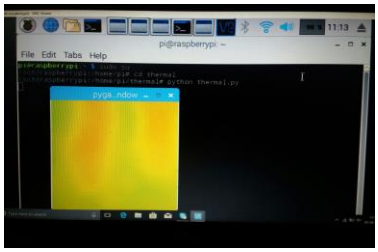

Figure 4 (b): Thermal image displayed on PC

Figure 4 (c): Experimental setup of proposed system

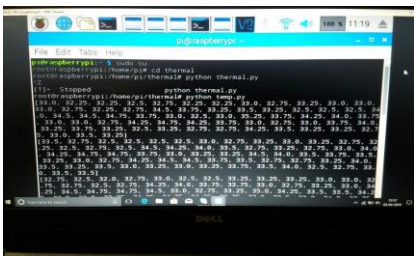

Figure 4 (d): Temperature values displayed on PC which are obtained from experiment shown in Figure 4 (b)

Detailed Description

The scene to be imaged is captured by the thermal imaging camera. Each element of the array is a pixel. The temperature value of each of these 240 x 240 pixels is calculated with the help of Raspberry Pi. The Thermal Camera and the Raspberry Pi communicate through the I2C bus. Then the result of Thermal IR camera measurement for each individual pixel and the result of PTAT (proportional to absolute temperature) sensor are read from the Thermal Camera RAM. PTAT sensor measures the ambient temperature of the chip and stores the value in the Thermal Camera RAM. The Camera and in-built sensor is by default in continuous mode i.e. it measures the temperature of the scene continuously. Calculation of object temperature includes ambient temperature calculation, pixel offset cancelling, pixel to pixel normalization and object emissivity compensation. The temperature of each pixel of the object in degree Celsius is obtained at the end of the calculations.
Serial data from the Raspberry Pi is read by the PC. Temperature values are divided into different ranges and each range is represented by an RGB value. The temperature values are represented by a pseudo colour depending on the range in which it belongs. A pseudo colour image for the scene is hence developed as shown in Fig 5.

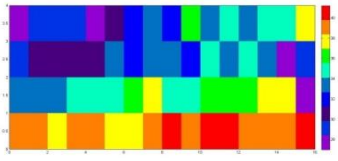

Figure 5: Sample pseudo color image (ceiling)

Analysis of Temperature Values

The real time temperature measurements were carried out several times. Measurements of various objects of known temperature showed likely accurate results within the Thermal Camera's capturing range.

4. Result

The system for diagnosis of medical diseases using thermal cameras presented in this paper and included in the digital image processing system of an thermal camera is fast and flexible. It is capable of real-time operation without introducing significant delays.

Experimental trial

The human hand was imaged at 30cm to obtain a temperature of 36.97^0C. A ceramic cup with hot water was also imaged at 30cm to obtain a temperature of 51^0C.
The human body was imaged at 30cm, 50 cm, 75cm and 1m. The results were obtained as given in Table 1.

Table 1: Human Body Imaged at Different Distances

Distance	Temperature
30 cm	36.97
50 cm	37.05
75 cm	37.13
1 m	37.25

Output Obtained from Proposed System Experiment

Patients with Diabetic Peripheral Neuropathy (DPN) had a higher foot temperature (32 – 35 °C) compared to patients without neuropathy (27 – 30 °C).

Figure 6: Thermal image of normal toe

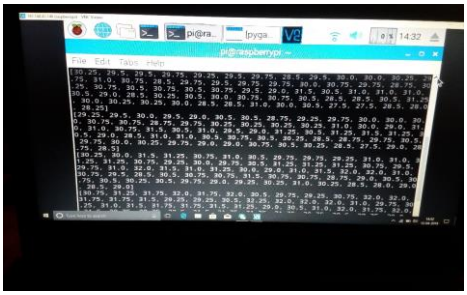

Figure 7: Temperature values of thermal image in figure (6) of normal toe

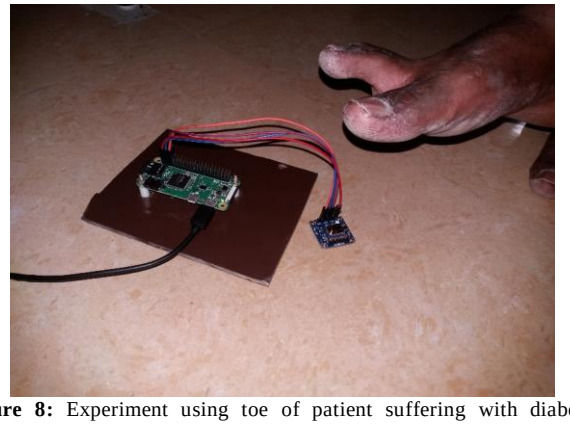

Figure 8: Experiment using toe of patient suffering with diabetic peripheral neuropathy (DPN)

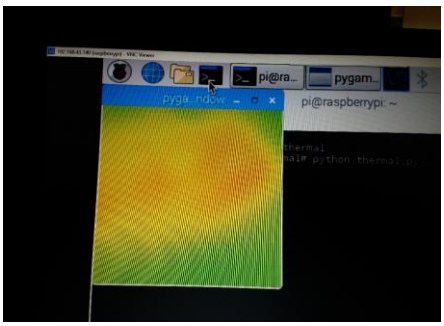

Figure 9: Thermal image of experiment in figure (8) using toe of patient suffering with diabetic peripheral neuropathy (DPN)

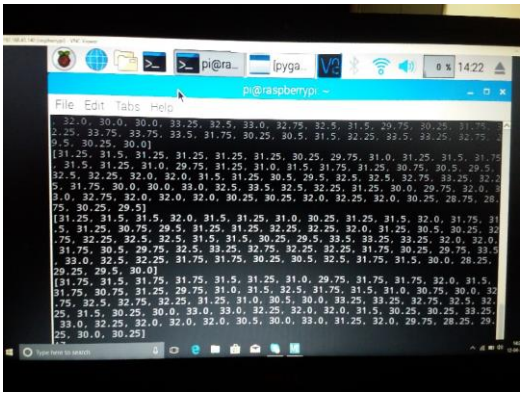

Figure 10: Temperature values of thermal image demonstrated in experiment in figure (9) using toe of patient suffering with diabetic peripheral neuropathy (DPN)

Research Study

Further the Research Study for experiment was performed for diagnosis of thyroid, diabetic peripheral neuropathy, vascular disorder, breast cancer, etc. and the analysis is as follows :

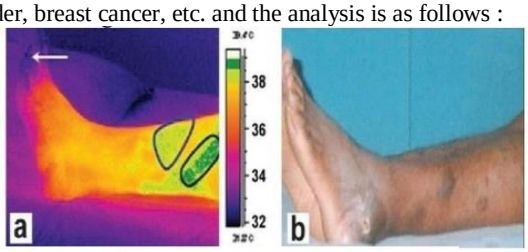

Figure 11: (a) Isothermal image and (b) Affected patient's leg photo

Figure 11 (a) illustrates the thermal image of the photograph of the affected patient's leg shown in Figure 11 (b). Figure 11(a) clearly indicated a lower temperature was noted at the distal portion along the toe tips due to sluggish blood circulation in the toes. A comparison between the abnormal area temperatures to the temperature of the surrounding normal area of the same patient's

leg indicated the differences in temperature. The temperature in the abnormal marked regions had an average temperature of 0.7 to 1°C above the normal regions.

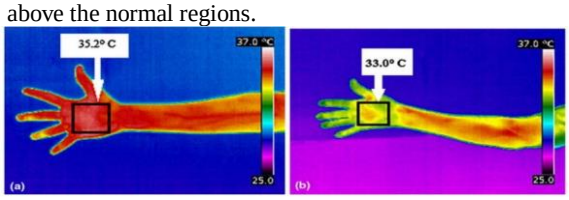

Figure 12: The thermogram of the palm region in: (a) control subject and (b) diabetic subject

Figure 12 (a, b) illustrates the thermogram of the palm region respectively. In a control subject, due to the normal metabolic function of the body and good perfusion of the blood, the skin temperature of the palm indicates 35.2 ° C. While in a diabetic subject, the palm temperature was lower the control subject due to poor blood perfusion and decreased metabolism. The skin temperature was 33.0° C in the diabetic subject.

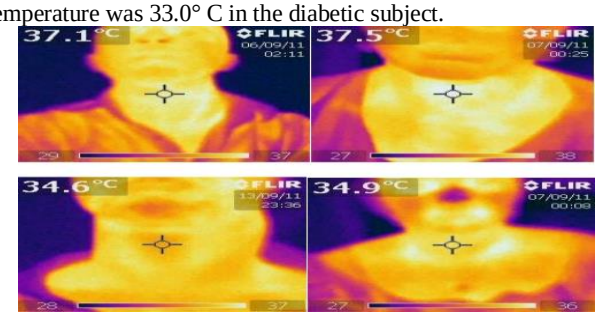

Figure 13: Typical thermographs of hyperthyroidic and hypothyroidic patients

Some sample thermographs for hyperthyroidic and hypothyroidic cases are shown in Figure (13). Figure (14) shows the variation of the patient skin temperature according to hyperthyroidic and hypothyroidic disease. The mean skin temperature of the former is 36.63 ± 0.56 °C while it was 34.92 ± 0.32 °C for the latter. The control had mean value of 35.76 ± 0.49 °C in between the two.

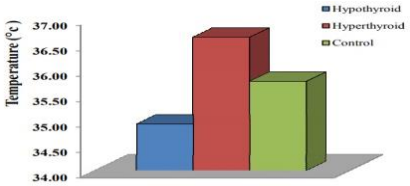

Figure 14: Variation of mean skin temperature with disease type

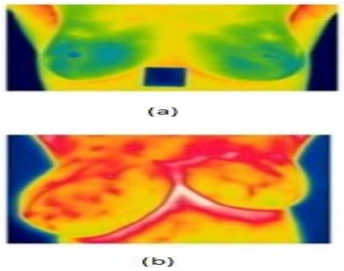

Figure 15: (a) A normal breast thermogram, (b) An abnormal breast thermogram

Figure 15 (a,b) depicts that the feature values of left and right breast of a normal breast thermogram were quite similar while, in an abnormal breast thermogram cases, there is a significant difference in the feature values of both breasts.[17]

5. Applications

Since the thermal imaging system is non invasive and non contact equipment, it can be used in diagnosing a number of healthcare conditions. Another advantage of the system is that its safe and uses no radiation. Some of the applications of the system are in Fever screening, Raynaud's phenomenon, Detection of breast cancer, [18]Orthopaedics, Diagnosis of Pain, Dental and maxillofacial applications, Thyroid disease detection and Early detection of risk for diabetic peripheral neuropathy.

6. Conclusion

A low cost, easy to use thermal imaging system was hence developed. The system requires no special training for using it. It needs lesser number of callibrations and resetting. The system is also very fast since the temperature values and thermal image is developed within 5 seconds. The generated thermal images can be stored and retrieved whenever necessary for future clarifications and references.

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