Innovative and Development of a High Fever Contagious Disease Detector

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***Abstract*—** Contagious diseases pose a serious threat to lives of people in our contemporary society and one of the predominant symptoms of contagious diseases is fever. Detection of fever is an essential step in identifying subjects who may be suffering from contagious diseases such as Ebola Virus, Avian Influenza, and Severe Acute Respiratory syndrome. This study developed a cost-effective device used to detect fever. TPA81 thermopile array, Arduino Uno, Adjustable stand and LabVIEW software was used to develop the fever screening system. We tested the device on 55 febrile and afebrile subjects using the inner canthi of the eyes as our region of interest and the temperature threshold of 38°C. we achieved the sensitivity of 100%, specificity of 96% and correlation coefficient of 0.97 when we compared our results with the clinical thermometer used for human body temperature measurement. It was also observed that the error difference between the actual temperature of the subjects and the measured temperature by the proposed device was only 0.45°C. In this study, we were able to demonstrate how a simple, cost effective TPA81 thermopile array was used to achieve an efficient non-invasive fever screening system which can be used to screen large number of people.

***Keywords*—** Contagious disease, thermopile array, Fever screening system, and temperature measurement.

I. Introduction

The need to identify high fever in our contemporary society can never be over emphasized; because several contagious diseases associated with high fever such as Covid-19, Ebola, Avian influenza, and SARs have emerged and are highly epidemic in nature and can easily be transmitted from one person to another [8]. Unfortunately, many health personals do fall victim of such diseases as they administered medical aid to affected persons [1]. The outbreak of these diseases caused large number of human deaths and is thought to have caused extensive economic damage [2]. The symptoms of these contagious diseases include fever, headache, bleeding, vomiting, sore throat, skin rashes, and cough but the predominant symptom is fever [3].

Fever is when a human's body temperature goes above the normal range of 36 - 37°C [6]. Fever screening in places of mass gathering of people can prevent the transmission of infection [8], and by isolating people with high fever the spread of contagious diseases can be mitigated. Fever screening is achieved through measuring human body temperature, which means that accurate measurement of body temperature is crucial [4]. The most reliable method of measuring core temperature is that of inserting a probe or catheter through a subject's nostril into the inner part of the body to measure the temperature of the vital organs such as the heart, lungs or the pulmonary artery [7]. This technique is highly invasive and associated with much risk even though it gives the most reliable result. Because of the risks associated with this kind of technique, other measurement site such as the forehead, armpit, rectal, tympanic, and oral which gives a better correlation to the core temperature were introduced and adopted. It was also observed that in order to minimize the rate of infection due to the contact nature of these measurement sites a suitable technique such as non-invasive, non-contact technique and live infrared thermography were proposed. It is paramount to measure human body temperature accurately because inaccurate results may influence diagnosis and treatment thereby compromising patient safety [5].

Several approaches to curtail the spread of contagious diseases via monitoring and detection of human elevated body temperature were proposed. Although these techniques have successfully demonstrated the ability of infrared thermography in detecting febrile subjects from a given population of people, yet these techniques are not portable [10], they are expensive to implement [8], special training is required to operate the systems and there is significant number of missed detection [9]. Therefore, there is a need to design a system which is portable, non-invasive, and cost effective which can accurately detect febrile person thereby reducing the spread of contagious diseases.

The purpose of this study is to develop a system which can detect febrile subjects with high confidence, relative ease and speed so that they can be sent for further medical diagnosis. To achieve this, a simple cost-effective thermopile array (TPA81 thermal sensor) was used in collaboration with Arduino Uno and LabVIEW software.

II. Methodology

This study was conducted from October 2018 to September 2019 at the prototyping Laboratory of the Department of Computer Engineering, University of Maiduguri. Verbal informed consent was obtained from the individual subject that went through the screening exercise.

In this study, TPA81 thermopile array was selected as the thermal sensor used to screen the suspected febrile subjects. It was selected due to its ability to measure the temperature of 8 adjacent points simultaneously. TPA81 is a thermopile array capable of detecting infrared in the 2um-22um range which is the wavelength of radiant heat.

A suitable interfaced was developed for TPA81 using two 1KΩ resistors, Vero board, and Arduino Uno as shown in figure 1. The Resistors served as a pull-up resistor, and the Arduino Uno served as an interface between the TPA81 and the PC.

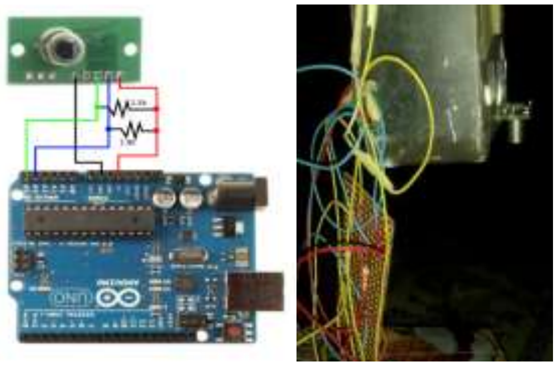

Figure 1: TPA81 interface

A sketch program was developed within the Arduino Uno IDE to enable a serial communication between TPA81 and the PC. Once the serial communication was established, a conducive environment with an average ambient temperature range of 18-25°C and objects of known temperatures were used to calibrate TPA81 for effective reading. Suspected febrile subjects are of different sizes and height, therefore, an adjustable moving mechanism that houses the thermal sensor (TPA81) was also developed using the principle of DC motor as shown in figure 2. switches were used to control the vertical upward and downward movement of the mechanism to easily locates Region of Interest (ROI). The inner canthi of the eyes were used as the ROI due to its proximity to the core body temperature and a set threshold of 38°C was used to identify a febrile subject.

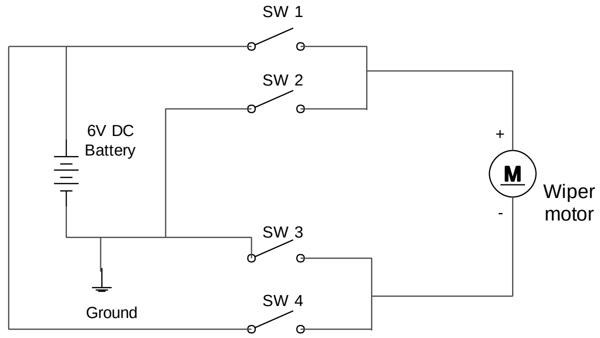

Figure 2: circuit diagram of vertical adjustable moving mechanism

After the sensor has been calibrated, an appropriate Field of View (FOV) has been selected and a suitable program has been developed in LabVIEW, the next objective achieved was the screening of different subject for the detection of elevated body temperature. The screening process is made up of four major sub sections as shown in figure 3. Consisting of detection, capture, processing and classification.

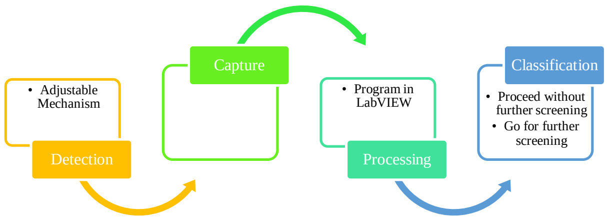

Figure 3: Screening Process

Detection section is the first part of the screening process in that a subject would stand and face the sensor while the vertical adjustable stand is being adjusted to the appropriate height until the region of interest (which in this study is the inner canthi of the eyes) is located.

The second section of the screening process is the capture of infrared energy emitted from the region of interest. the sensor captures the infrared energy and convert it into a string of digital data made up of nine adjacent pixel values as shown in figure 4. The leftmost pixel value is the ambient temperature while the remain eight adjacent pixel values is the digital representation of the temperature values of the subject. The pixel values are then read into LabVIEW for further processing in the capture section.

Figure 4: The String pixel values

Processing section is the sub-section in the program already developed in LabVIEW is used to read the temperature values generated from the capture section, process the values by scanning for the maximum value among the string of eight different temperature values captured from the inner canthi of the eyes of the subject. and compare the values with the set threshold value of 37.5°C. The reason why the maximum value of the string must be selected is because the pixels are the representation of heat signatures emitted from the ROI and the maximum value indicates the hottest spot of the ROI. Therefore, to compare the hottest spot with the already set threshold of 37.5°C easily identifies suspected febrile subject. Once the program has compared the selected temperature value with the already set threshold, it passes the outcome to the next level of the screening which is the classification.

This section is the decision-making stage and at the same time the output section of the program. It is further categorized into two main sections. Once the processing section has successfully passed on the result or outcome of the processing and comparison to the classification section, a conditional statement such as: $\forall\, x \leq 37.4, x = 0$ or $\forall\, x \geq 37.5, x = 1$ is used to classify the subject into one of the two major classes. x = 0 means that the subject body temperature is within the normal range while x = 1 means that the subject is having an elevated body temperature and should go for further screening. There are two Boolean indicators; one of which is green used to indicates a subject whose body temperature is within an acceptable range of 35 to 37.4°C and the other is red used to indicates a subject who has an elevated body temperature ranging from 37.5 to 41°C.

Once the system is power on, the system was allowed to initialized for about 5 minutes before any screening process commences. Most of the screening were performed in the morning hours between 8:00am to 10:30am and the average age of the subjects screened is 25 years.

Once the proposed system classified a subject as having an elevated body temperature that is the subject body temperature exceed the already set threshold and the subject has been flagged to go for further screening; such subject's body temperature is taken again by the conventional clinical thermometers to confirm and accertain that the subject actually has elevated body temperature.

III. Results and Discussion

Correlation plot of the inner canthi of the eyes measured by TPA81 and the Auxillary temperatures measured by the contact thermometers (both the Mercury-in-Glass and Digital Thermometer) for the subjects screened is shown in figure 5. The results obtained from TPA81 thermopile array shows a positive correlation with that of the contact thermometer but it was discovered that ambient temperature affects the accuracy of the correlation. Therefore an error correcting equation was used to filter out the effects of the ambient temperature giving a better correlation.

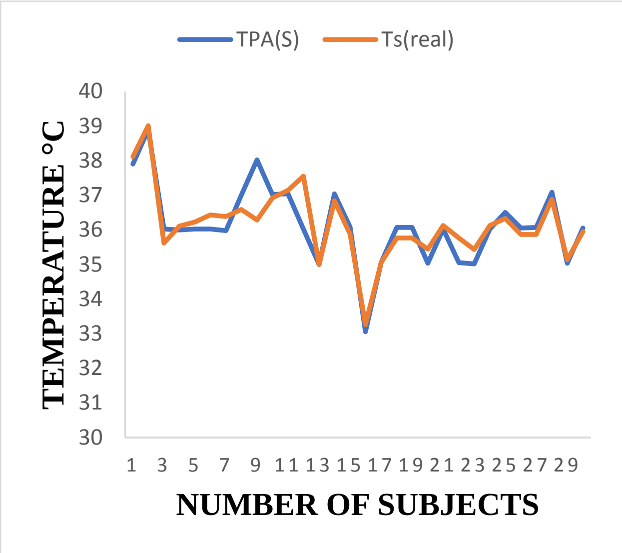

Figure 5: TPA81 (without correcting factor) Vs Ts(Contact thermometer)

The error correcting equation has four paramters which are: Surface temperature(Ts), Measured Temperature(Tm), Emissivity of the Object (ε) and Ambient Temperature (Ta). With the error correcting equation, the error generated by ambient temperature was reduced as shown in Figure 6 (error correcting equation).

$$T_s = \sqrt[4]{\frac{{T_m}^4 - (1-\varepsilon) * {T_a}^4}{\varepsilon}}$$

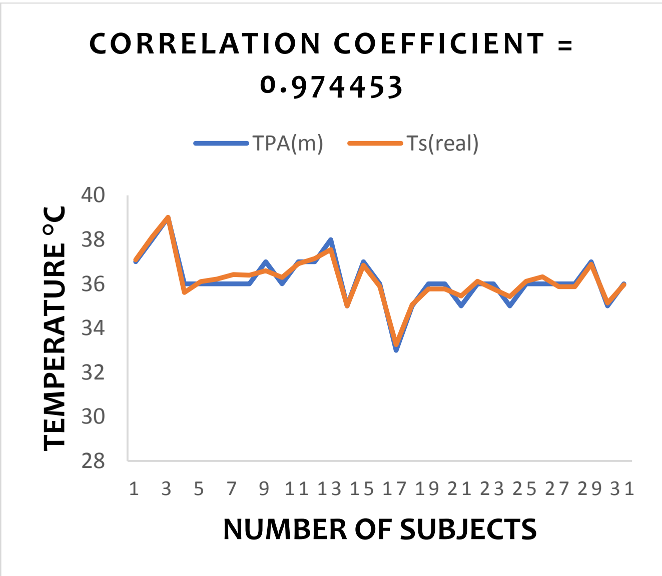

Figure 6: TPA81 (with correcting factor) Vs Ts (Contact thermometer)

There exist a linear relationship between increase in ambient temperature and error generation. Figure 7 shows the graphical representation of this relationship. It was noted that as the ambient temperature increases, the rate at which the sensor detects hot objects decreases and the more error is generated.

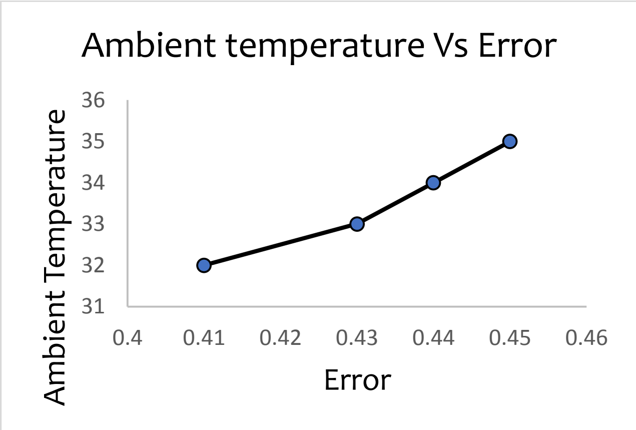

Figure 7: Ambient temperature against Error

The graph of figure 7 illustrated a linear relationship between ambient temperature and error generated during temperature measurement with the sensor. It has been justified that excessive increase in ambient temperature influences the accuracy of the system. It was observed that when there exist a significant temperature difference between the ambient temperatue and that of the subject, the error generated is less compared to when the temperature difference is neglible as demonstrated in figure 1.8. When the ambient temperature is 32°C the error is 0.41 and also when the ambient temperature is 35°C, the error becomes 0.45. For example, if the ambient temperature is 31°C and the subject's body temperature is 37°C, there exist a temperature difference of 6°C (37-31) which means that the heat energy in form of infrared radiation would be emitted faster and the sensor can easily detect the subject. But when for instance there is an increase in ambient temperature say from 31°C to 36°C while the subject still retained same body temperature of 37°C. The temperature difference in this case is 1°C (37-36) which means that though there would be heat transfer from the subject to the environment in form of infrared radiation and the sensor can detect the infrared radiation but with a little error as shown in figure 1.8.

It was observed that as the system powers on, it starts to dissipate heat, just as any electronic component. However, because these components were enclosed together with the sensor (TPA81), the heat builds up and affects the ambient temperature considerably. After several investigation and critical analysis, it was concluded that the sensor casing should be seperated from the general casing of the system and that was done efficiently.

IV. Conclusion

Several contagious diseases such as Covid-19, Ebola, SARs, Avian Influenza are emerging day by day posing great threat to human life and the economy of nations. One of the predominant symptom of these diseases is fever. Using thermal imaging techniques for fever screening has become a standard procedure in place of mass gathering of people. Therefore, to mitigate the spread of these diseases among the general public, a device capable of identifying febrile subject with reliable accuracy is needed. In this study, a cost-effective TPA81 thermopile array was used to effectively measure human body temperature in a close-range thermometry and can be used for fever screening at place of mass gathering of people.

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