International Journal on Emerging Technologies (Special Issue NCETST-2017) **8**(1): 557-560(2017)
(Published by Research Trend, Website: www.researchtrend.net*)*

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

IR Thermography- As Diagnostic and Adjunctive Tool For Maxillary Sinusitis

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ABSTRACT: Thermal imaging is a radiometric technique which is used to map the temperature distribution on objects' surface on the basis of emanating infrared energy. Due to its non-invasive and non-ionizing nature, this technique is quite useful in the medical field to diagnose the various abnormalities such as breast cancer, arthropathy, contusion, carcinoma, inflammation, ligament injury, etc. Principle of using thermal imaging in medical field is to diagnose the area of interest based on asymmetrical temperature distribution where the surface temperature is directly related to the flow of blood, and blood circulation. If there is any abnormality over the area of interest there is variation in temperature from nominal range. So, this technique is useful to diagnose the maxillary sinusitis. Thermogram of person who is suffering from sinusitis show the inflammation over the nose and maxillary region and give more variation in temperature profile as compared to control group.

Keywords: Thermalimaging, thermogram, inflammation, maxillary sinusitis.

I. INTRODUCTION

In 1800, Infrared (IR) radiation is accidentally discovered by SirFrederick William Herschel [1]. These infrared radiations are basically an invisible radiation and belong to the electromagnetic spectrum from 4µm to 1mm of wavelength.
The infrared region lies in between the microwave and visible region of the EM spectrum. Any object is placed above 0□K temperature emanates the IR radiation. The amount of Infrared energy is emitted from the surface of an object is directly depends upon the surface temperature and emissivity. More the temperature of the surface more infrared radiation is emanated.
These Infrared radiations are detected with the help of thermal imaging camera on the basis of temperature distribution over the object surface. The thermal imager is non-contact and non-ionizing based which gives the temperature profile of the surface field of view and called as thermogram, this technique is called as thermography [2]. These are the thermal imager is able to detect the radiation of medium (3-5µm) and long (7-14µm) wavelength of the EM spectrum. From the last few decades, thermal imaging has been used in several medical fields to diagnose the various abnormalities on the basis of temperature variation from the contralateral body parts. Is there any abnormalities in body region, there must be a temperature variation as compared with contralateral region. For the better evaluation in the result two types of thermal imaging are used

a) Passive Thermal Imaging: If the object is at higher or lower temperature than the background, then passive thermal imaging is used.

(a)

(b)

Fig. 1. (a) Visual image of human face (b) Thermal image of human face along with color pallet.

b) Active Thermal Imaging: an additional thermal source is used to differentiate the temperature profile of abnormal area and contralateral part.

These two images show the difference of visibility where each pixel of figure (a) shows true value and each pixel of figure (b) shows temperature dependent. Where, representation of thermal image is shown in distribution of color with respect to temperature over the temperature scale. This temperature scale is called as color palette.

II. HUMAN BODY THERMOGRAPHY

Infrared Radiations are divided into near-wave IR (0.75-1.4µm) short-wave IR (1.4-3µ) medium-wave IR (3-8µm) long-wave IR (8-15µm) and far IR (15-1000µm)[3-7]. For short wavelength, the peak wavelength and the absolute temperature are given by Wien's Displacement law:

$$\lambda_{max} = \frac{k}{T} \quad (1)$$

λ_{max}=peak wavelength(µm)
k=Wien's displacement constant
T=temperature in Kelvin

From equation (1), the relation of temperature and peak wavelength where, increase in temperature tends to decrease in peak wavelength. Normal human body surface emanate body temperature from 299.13 K-309.13 K. So, peak wavelength is

λ_{max} (Human body at 26-36 ºC) ≈ 9.71-9.34 µm

So, human body emanates radiations in long-wave IR spectrum, i.e.most of themedical thermal imager is designed over the mid-wave and long-wave band.

A. Physiopathological based understanding of thermograms of human body.

Variation in functional changes inthe human body like temperature, metabolism rate, and sweat gives the indication of any abnormalities in the body. Therefore, thermography might be an adjunctive tool to diagnose the abnormalities.Functional changes might be caused by the various abnormalities like skin burn, liver disease, paranasal sinusitis, fractures,breast cancer, arthropathy, contusion, carcinoma, inflammation, ligament injury, contusions, lymphomas, dermatological diseases, rheumatoid arthritis, orofacial pain, diabetic foot disease, liver disease, bacterial infections and inflammation. These abnormalities associated with surface temperature, which shows as hypothermia, hyperthermia, hyper-metabolism, and hyper-vascularization.

B. Thermal imagers in Medical field.

Human body emit radiation in a LWIR band (8-15µm) so, thermal camera for monitoring and diagnosing the human body is designed for LWIR band. This thermal camera is mounted over the stable platform which is moving smoothly in vertical and horizontal direction.

Fig. 2. Thermal Imaging Workstation.

For the better enhancement of Region of interest (ROI) in thermogram many of the color palette is available in the thermal imager like iron, rainbow, hot iron, gray,etc. From these entire various color palettes use only single color palette which is differentiated the maximum foreground from background inthe thermogram.

C. Standardization of thermogram Imaging in Medical fields.

In medical applications, some standards should be followed by thermographer to produce accurate and reliable temperature profile. Some papers were published by the European Association of Thermology in the last two decades of the twentieth century, which contained many elements of standardization in various thermographic clinical applications including: breast diseases, locomotor (or muscular) diseases and skin temperature measurements in drug trials.For the better result of Thermal imaging, data acquisition should be done in a temperature control environment, minimum temperature 18°C and maximum temperature 25C. To attain the thermal equillibration, the body parts to be diagnosed should be clothed and exposed to the desired temperature for 10-15 min before thermographic examination.Heavy meal and above average intake of tea, coffee,alcohol, smoking and supplements, use of ointments and cosmetics in all the relevant areas of the diagnosing part should also be avoided. These standards provide the correct and effective use of thermal camera in medicine and set out the minimal technical performances required for fever screening.

III. METHODOLOGY

In medical applications, thermal imaging is used only for monitoring the superficial organs which included the medical applications like:skin burns,fractures,breast cancer, contusion, inflammation, ligament injury, contusions, dermatological diseases, orofacial pain,musculoskeletal disorders, mass fever screening. For different applications, different body parts are to be monitored with thermography with respective consideration to environmental conditions and subject's posture. But in this study, the thermal images of human faces should be taken with a thermal imager thatshould be placed at 1 meter away from a subject. The thermal imager should beplaced on a tri-pod stand for stationary thermograms[8].The surface temperature is a function of various parameters including: blood flow, metabolic reactions, environmental conditions, and many more. If there is any abnormality in our body, then the rate of these parameters will be altered,which cause to change the body temperature. These parameters are very difficult to control intentionally. But the environmental conditions (room temperature, humidity and radiations) can be controlled according to our requirements. So, a great attention is required for considering these parameters while performing measurements on animates. In this experiment, theroom temperature should be maintained at 18-25°C[8].The room temperature below 18°C subject may be cause to shivering, which change the metabolism rate and results to alter the surface temperature. And temperature above 25°C subjects may be cause to sweat on the body surface which further results to change the surface temperature.The subjects should ask to be resting and sitting posture for 15 minutes in a controlled environment before acquiring the thermal images.

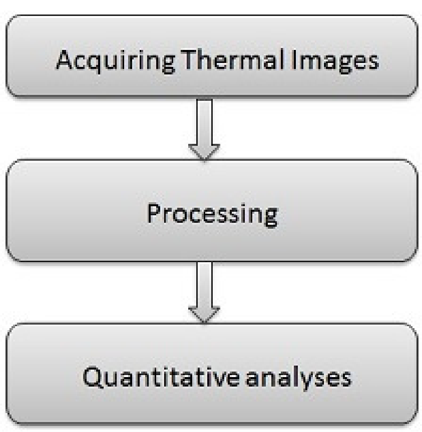

Fig. 3. Process Flow diagram.

Thermal imager should be placed directly 90^0 towards face with nearly 1 meter distance. There should not be placed any heat source which causes to change the temperature profile of thermograms.

IV. QUANTITATIVE ANALYSIS

From the thermograms, the diseased region contributes the different temperature profile as compared with contralateral region. Higher the variations of temperature from contralateral regions,easily to classify the abnormal and normal groups. A number of statistical analyses are present to evaluate the variation of temperature from closed group.

Variance: Variance is a measure of statistical dispersions about the mean of the distribution [9,11]. The variance σ^2 is the second central moment of a distribution and is defined as:

$$\sigma 2 = \frac{\sum f(x-\overline{x})^2}{n} \quad (2)$$

Median: In statistics, the median is the numerical value which separates the higher half of the probability distribution.Thus, more difference in the value of the median and more will be the asymmetric temperature distribution; whereas the value almost remains same for the normal thermograms[9-11].

Kurtosis: Kurtosis is any measure of the "Peakedness". Kurtosis, 'K' measures the flatness or peaks of a distribution relative to a normal distribution[9-10]. Kurtosis is also termed as the fourth standardized moment and is mathematically represented as,

$$K = \left\{ \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \left(\frac{P(i,j)-\mu}{\sigma} \right)^4 - 3 \right\} \quad (3)$$

Skewness: In statistics, Skewness is a measure of the asymmetric distribution. It can be positive ornegative, or even undefined. Skewness, 'S' characterizes the degree of asymmetric pixel distribution in thespecified window around its sample mean. Skewness is given as:

$$S = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} \left(\frac{P(i,j)-\mu}{\sigma} \right)^3 \quad (4)$$

Entropy: It is the measure of uncertainty in the temperaturevalues in the specified region of an image. It measures how much disorder is there in the system. Hence, entropy is a useful tool for detecting the asymmetries in the thermogram. For normal temperature distribution in the region, the value of entropy remains to be same. It is given as:

$$H(X) = -\sum_{k=0}^{L-1} P_{rk}(\log_2 P_{rk}) \quad (5)$$

Where P_{rk}= probability of the k-th grey level

L = total number of greylevels

V. CONCLUSION

This paper explores the various quantitative analyses for extracting the useful information from human body thermogram. Furthermore, thermal imaging is diagnosing and adjunctive tools for identifying the diseases related to superficial organs. The basic methodology for acquiring the thermal data from human subjects with the consideration of international standards is also presented in this paper. The given quantitative analyses help to identify the asymmetrical temperature distribution on the human face represented with large value of entropy and large regional temperature differences.

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