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CONDITION MONITORING OF ELECTRICAL EQUIPMENT USING THERMAL IMAGE PROCESSING

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ABSTRACT:

This is an Infrared thermography or thermal imaging which is a very convenient and non contact method which has been used for many types of physical asset such as electronic component, buildings surveys, and mechanical components and equipments. Excessive temperature rise will result into the majority of failures in electrical equipments. The condition monitoring plays an important role for identify the faults. This Infrared thermography was first used for military application but now a days cost effective , reliable and non contact type infrared thermographic system is being utilized in this identification as well as for fault diagnose .This paper presents a survey on different thermal imaging techniques for fault detection and diagnose based on the object temperature. In this paper, thermal images of some electrical equipments have been taken and converted into HSI colour model for the further processing unlike other techniques, instead of grey scale images, hue region has been taken into consideration and then different gradient based on the edge detection like Prewitt, Roberts and Sobel are used to find the hot region of the thermal images.

KEYWORD: 1**) HSI color model 2) Edge detection 3) Thermal monitoring 4) Image Segmentation 5) Infrared Thermography**

1) INTRODUCTION:

For maintenance of electrical equipment condition monitoring has become very important technology. The proposed technique gives better segmentation results for all images than the standard grey scale approaches. The state of electrical equipment is judged by comparing the hot spot temperature and with reference temperature. It uses mainly two approaches quantitative and qualitative. The qualitative measurement is widely used method by employing the ΔT criteria and But ΔT criterion does not say anything about whether the equipment's temperature limits are actually exceeded. In quantitative measurement, the observation is established by measuring the absolute temperature of electrical equipment under the same ambient conditions. Infrared thermograph is a non-contact and nonintrusive temperature measuring technique with an advantage of no alteration in the surface temperature and capable of displaying real time temperature distribution. Any object that has a temperature above absolute zero (-273oC) emits infrared radiation. Radiation that is emitted by any object does not need the presence of a medium. Thermal radiation, which is a type of radiation emitted by the bodies due to their temperature; it represents the difference between the amount of energy absorbed and transmitted by the body. Heat transfer through radiation is given by the Stefan- Boltzmann´s law. The equation is given by follow:

$$Q_{rad} = A \cdot \sigma \cdot \xi \cdot (T_s^4 - T_{refl}^4)$$

Where
Qrad = Radiated heat by object
A = Surface (m2)
σ = Stefan- Boltzmann´s constant
(5,67·10-8 W/m2/k4)
ξ = Emissivity (0, 95)
Ts = Surface temperature (K)
Trefl = Reflected temperature (K)

For thermal image analysis, special thermal camera is used called Infrared camera (IR). A thermal camera detects infrared radiation emitted from objects that have temperature above absolute zero or -273oC. An infrared camera detects infrared energy emitted from

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object, converts it to temperature, and displays image of temperature distribution.

2) METHODOLOGY:

HSI MODEL:

The HSI (Hue, Saturation, and Intensity) color model describes a color in terms of how the human eye senses colors. To obtain the HSI color model from RGB following formulas are taken into account:

$$H = \begin{cases} \theta & if \quad B \le G \\ 360 - \theta & if \quad B > G \end{cases}$$

With

$$\theta = \cos^{-1}\left\{ \frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{\frac{1}{2}}} \right\}$$

The saturation component is given by

$$S = 1 - \frac{3}{(R+G+B)}[\min(R,G,B)]$$

Finally the intensity component is given by

$$I = \frac{1}{3}(R+G+B)$$

In the HSI model, Hue is measured from red; saturation is given by distance from the axis. Hue component describes the color itself in the form of an angle between [0, 360] degrees. 0 degrees mean red, 120 means green, 240 means blue, 60 is yellow and 300 degrees is magenta.

B) EDGE BASED SEGMENTATION:

Different gradient based edge detection like Roberts, Prewitt, Sobel etc. is carried out for finding the specific hot region(s) from the thermal images.

SOBEL OPERATOR:

The gradient (Δ*f*) computed by Sobel operator is the difference between rows and columns of the 3×3 neighborhood as shown in following table where the center pixel in each row or column is weighted by 2.

TABLE I. IMAGE NEIGHBORHOOD

z_1	z_2	z_3
z_4	z_5	z_6
z_7	z_8	z_9

$$\nabla f = \sqrt{S_x^2 + S_y^2}$$

Where the partial derivatives s_x and s_y are computed by:

$$S_x = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3)$$

$$S_y = (z_3 + 2z_6 + z_9) - (z_1 + 2z_4 + z_7)$$

Where $z_1, z_2 ... z_9$ are intensities, f is input image.

S_x and S_y can be implemented using convolution masks:

TABLE II. MASKS FOR SOBEL OPERATOR (S_X)

-1	-2	-1
0	0	0
1	2	1

TABLE III. MASKS FOR SOBEL OPERATOR (S_Y)

-1	0	1
-2	0	2
-1	0	1

PREWITT OPERATOR:

The Prewitt operator uses the partial derivatives as follows:

$$Sx = (z7 + z8 + z9) - (z1 + z2 + z3)$$

$$Sy = (z3 + z6 + z9) - (z1 + z4 + z7)$$

TABLE IV. MASKS FOR PREWITT OPERATOR (S_X)

-1	-1	-1
0	0	0
1	1	1

TABLE V. MASKS FOR PREWITT OPERATOR (S_Y)

-1	0	1
-1	0	1
-1	0	1

ROBERT OPERATOR:

With 2×2 gradient operator, differences between adjacent pixels are calculated by Roberts's operator. Partial derivatives Sx and Sy are calculated using the following equations:

$Sx = (z9 - z5)$

$Sy = (z8 - z6)$

TABLE VI. MASKS FOR ROBERTS OPERATOR (S_X)

-1	0
0	1

TABLE VII. MASKS FOR ROBERTS OPERATOR (S_Y)

0	-1
1	0

C) OTSU THRESHOLD:

Otsu Threshold method can also be applied on thermal images for detection of hottest region in the image. Otsu method is used to automatically perform clustering-based image threshold. The image contained two classes of pixels; it then calculates the optimum threshold separating the two classes so that their intra-class variance is minimal. The algorithm for the Otsu method is given below:

1. Select initial estimate of threshold as average intensity value of an image.
2. Calculate mean gray values µ1 and µ2 of partitions R1 and R2.
3. Select a new threshold:

$$T = \frac{1}{2}(\mu_1 + \mu_2)$$

4. Repeat steps 2-4 until the new values µ1 and µ2 in successive iterations do not change.

D) STEPS INVOLVED IN THERMAL IMAGE PROCESSING:

- Some standard thermal images are taken for processing. At first, based on color, RGB image is converted into an HSI color model. Hue region is taken for further processing.
- Threshold using edge detection is done. Some gradient based edge detection techniques like Roberts, Prewitt, Sobel etc. are used for partitioning the hot region.
- Based on some image metrics like MSE, PSNR, best edge detection method is chosen which gives better results.
- In the next step, clustering based image threshold Otsu method is applied on thermal image which gives satisfactory results.
- Among these methods Otsu method is easily determined the hot region of thermal images.

E) IMAGE METRICS:

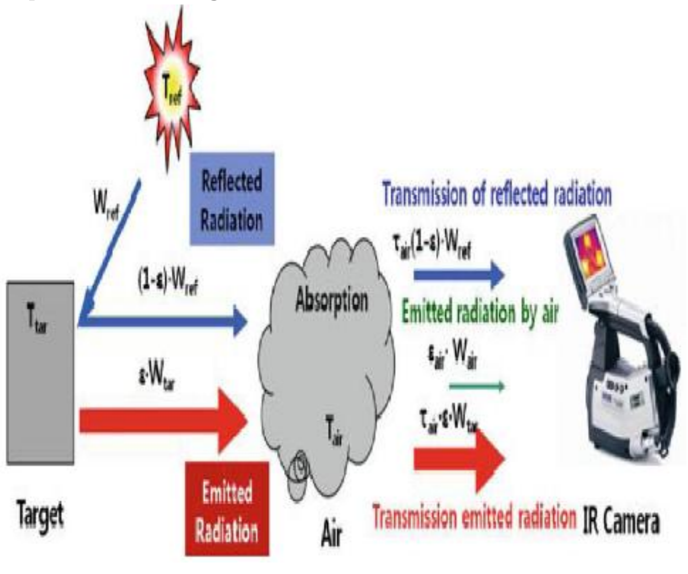
After performing different edge detection techniques on the thermal images, based on some image quality metric best method is selected. The simplest and most widely used full reference quality metric is mean squared error (MSE), which is computed by averaging the squared intensity differences of threshold image and the reference image (Hue region) pixels.Peak Signal-to-Noise Ratio (PSNR) is depends upon the value of MSE. Formulae for MSE and PSNR are given below:

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j) - y(i,j))^2$$

Where, x(i,j) represents the original image (Hue region), y(i,j) represent the threshold image, M and N are the height and width of the original image respectively.

3) IR THERMOGRAPHY FOR MACHINERY:

IR device can detect the thermal abnormality of machine when there is any rapidly overheating component on machinery. The total radiation that goes through the optics of infrared camera consists of the emitted radiation from the object itself and the reflected radiation from the surroundings. And that's why we need to set up the right emissivity and reflected apparent temperature, other air related parameters for temperature reading.



Block dig. Schematics of the total radiation go through the IR camera

4) RESULT AND DISCUSSION:

At first various segmentation techniques have been applied to the image-1 as in Fig. 1 by considering grayscale values. But it has not shown satisfactory results for segmenting the hottest region due to loss of information. In case of grayscale image almost entire heated region has been segmented rather than hot spot zone as shown in the following figure marked by red ellipse.

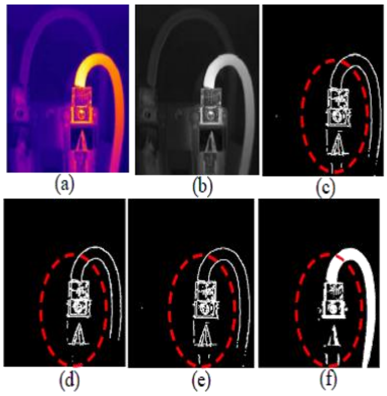


Figure 1. Hot region identification for image 1 considering grayscale image: (a) RGB image, (b) Grayscale image , (c) using Prewitt, (d) using Roberts, (e) using Sobel, (f) using Otsu.

To overcome the limitations of the above method, HIS model has been used, by taking the hue region. By taking hue region, heavy heated portion can easily segmented from the rest of the part of the image using Prewitt, Roberts, Sobel operators. The Otsu threshold method has also been applied to the same image. The results are shown in the Fig. 2 marked by red ellipse.

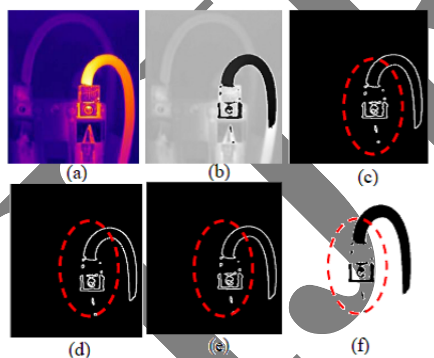


Figure 2. Hot region identification for image 1: (a) RGB image, (b) Hue region, (c) using Prewitt, (d) using Roberts, (e) using Sobel, (f) using Otsu.

The proposed method thermal images which has given better results as compared to standard grey scale technique. A few of them are furnished in Figs. 3, 4 & 5.

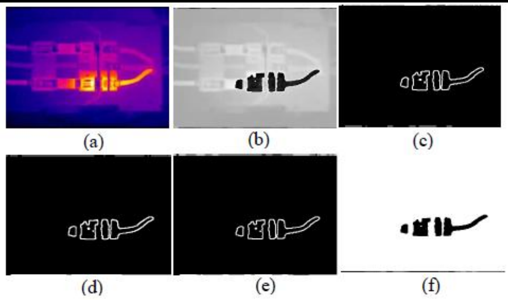


Figure 3. Hot region identification for image 2: (a) RGB image, (b) Hue region, (c) using Prewitt, (d) using Roberts, (e) using Sobel, (f) using Otsu.

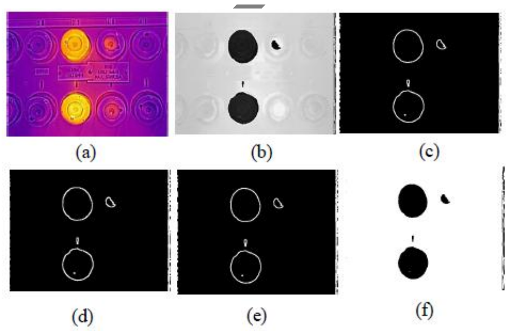


Figure 4. Hot region identification for image 3: (a) RGB image, (b) Hue region, (c) using Prewitt, (d) using Roberts, (e) using Sobel, (f) using Otsu.

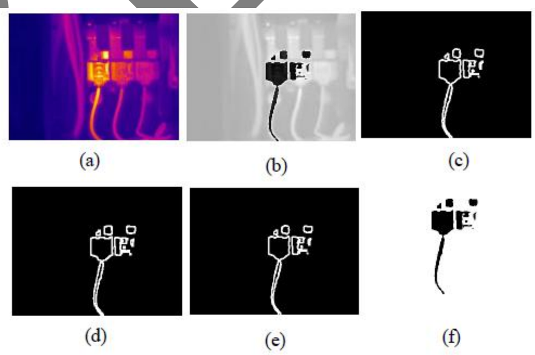


Figure 5. Hot region identification for image 4: (a) RGB image, (b) Hue region, (c) using Prewitt, (d) using Roberts, (e) using Sobel, (f) using Otsu.

Image metrics like MSE, PSNR are calculated for the thermal images. A Comparison is made between various hue regions, for example Fig. 4(b) and edge detected images, for example Fig. 4(c), Fig. 4(d), Fig. 4(e). Among these three edge detection techniques, Sobel operator gives better performance for thermal images. But in case of Otsu method, comparison is done among the hue region, for example Fig. 4(a) and threshold image for example Fig. 4(f). MSE is smaller and PSNR is greater for Otsu method as these images are to a certain extent similar. Therefore, Otsu method also gives satisfactory results for thermal images. The results are shown in the following table.

TABLE VIII. VALUES OF IMAGE METRICS FOR THERMAL IMAGES

Image name	Method used	MSE	PSNR (in dB)
image 1	Prewitt	0.52	51.0428392
	Roberts	0.51	51.0688629
	Sobel	**0.52**	**51.0422892**
	Otsu	0.07	59.7813554
image 2	Prewitt	0.53	50.9486356
	Roberts	0.53	50.9594493
	Sobel	**0.53**	**50.9485325**
	Otsu	0.07	59.6933703
image 3	Prewitt	0.62	50.2205710
	Roberts	0.62	50.2227856
	Sobel	**0.62**	**50.2197278**
	Otsu	0.03	63.1259878
image 4	Prewitt	0.55	50.7705405
	Roberts	0.55	50.7983384
	Sobel	**0.55**	**50.7690365**
	Otsu	0.06	60.0776692

5) CONCLUSION:

This paper presents a HSI color model based image segmentation technique for thermal images. The hue region has been considered to measures the main characteristics of a thermal image i.e. redness and yellowness Based on image metrics like MSE, PSNR values, Sobel and Otsu methods are found to be the best for them.

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