Infrared Thermal Image Segmentation for Fault Detection in Electrical Circuits Using Watershed Algorithm

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***Abstract*-- Infrared thermography is a non invasive technology that can be used in agriculture, construction, manufacturing and pharmaceutical industries for fault detection and to check the quality of an object. This helps to monitor temperature and analyze the high temperature zone so as to prevent the electrical assets from any catastrophe that may happen in future. The infrared camera generates a color image which needs to be segmented. We have developed a method by using the Watershed city block distance transform algorithm for the faulty image segmentation. The area of high temperature region obtained after segmentation was computed and is compared with that of the image area.**

***Index terms*-- Electric circuits, thermal imaging, pseudo colour images, Mathematical morphology, Watershed transform**

I. INTRODUCTION

Electrical power equipment and components play a vital role in human existence. They are found virtually in every home and manufacturing industry. When these equipments are operated at high currents it eventually The electrical equipment failure can be avoided if temperature leads to equipment break down and replacement. threshold is detected in order to take corrective action. The eyes, infrared imaging camera, ultrasonic sensors, and neon lamp methods. Infrared imaging has gained more recognition inspection of faulty insulators and transmission lines can be carried using several procedures such as human and acceptance due to its non contact and non destructive method of detection. It is very fast *[3]* and highly reliable

without disturbing the operation of equipment. *[2] [1].* Infrared thermal imaging has gained its popularity over past few decades since it is simple to interpret the thermal data, large area can be inspected, and there will be no emission of dangerous radiation. We have proposed a method to identify the problem early and avoid expensive equipment failure. Thermal images of faulty circuits are taken and segmented into different regions. Finding the areas of all those regions could detect the quality of object and locate the hotspots, if any.

II. BACKGROUND

A. A. Purpose in electrical fields

Thermal imaging can be used in various electrical applications such as cable boards, bus bar systems, overhead wires, electrical machines and drives, electrical equipment in mobile installations etc. A qualified evaluation of the images gives useful information to the operator such as early detection of weak points (damages) and avoids loss *[5]*.

1) Inspection of circuits:

1. Perform initial inspection on the new components installed in order to detect installation faults as potential malfunction sources.
2. Perform periodic inspection. The period interval depends on load on component, former thermo graphic results, and other environmental conditions.

B. Thermal imaging and its importance

Where E_b is total hemispherical emission of a black body ε is the emissivity (<1 for real objects and =1 for black body) σ is the Stefan-Boltzmann constant Any object above absolute zero emits IR (infrared radiation) proportional to its surface temperature, according to Stefan-Boltzmann law

$$E_b = \varepsilon\sigma T^4$$

T is the absolute temperature.

The thermo graphic scanning system can measure the surface temperature based on the radiation pattern without any physical contact between the test body and measuring system. Infrared camera receives this emitted radiation which is invisible to the human eye and converts into visible pictures by pseudocolour imaging. Each pixel is compared with that of predefined values for corresponding temperatures in the color palate. Thus a two dimensional image of the test object is obtained with different colour shades. We have proposed a method which uses colour image segmentation to obtain the area of all regions and thus comparing with a threshold area determines the life span of the test device. Modern IR imagers can resolve surface temperature differences of 0.1˚C or less *[4]*.

C. Various morphological techniques used

1) Pseudo color image processing: A pseudo color image is derived from the gray scale image by mapping each intensity value to a color according to a table or function. It is typically used when a single channel of data is available.

1) *Morphological operations:*

Erosion: The binary erosion of A by B is defined by the set object

$$A \ominus B = \{z|(B_z \subseteq A\}$$

That is, the set of pixel locations z, where the structuring element translated to location z overlaps only with foreground pixels in A. The mat lab function imerode () automatically decompose structuring element object (if a decomposition exists) *[8]*

Dilation: The binary dilation of A by B, denoted A⊕B, is defined as the set operation

$$A \oplus B= \{ z(\hat{}B)_Z \cap A \neq \emptyset\}$$

where ˆB is the reflection of the structuring element B *[8]*

Opening: Opening is the dilation of erosion of a set A by a structural element B defined as

$$A \square B=(A \ominus B) \oplus B$$

where ⊖and ⊕ denote erosion and dilation, respectively. Opening removes small objects from the foreground of an image, placing them in the background.

Closing: The closing of a set A by a structural element B is the erosion of the dilation of that set A which is given by

$$A \bullet B=(A \oplus B) \ominus B$$

where ⊕and ⊖ denote the dilation and erosion, respectively. Closing removes small holes in the foreground, changing small islands of background into foreground. In image processing, ***closing together with opening, removes noise*** *[9]*. Opening removes small objects, while closing removes small holes.

2) City block distance: Because of its simplicity while analysing the complex shapes, two dimensional digital images uses rectangular co ordinate system for computing the distance *[6]*. One such is the City block distance which uses L_1 norm. It is given by

$$||x,y||_{L1} = |x|+|y|$$

The distance from every pixel to its nearest neighbour is computed and is measured by number of horizontal and vertical steps taken to traverse (x,y). Diagonal distances are over estimated by this metric because diagonals are counted as two steps rather than √2

D. Watershed algorithm

Watershed algorithm is a mathematics morphological method for image segmentation that is based on region processing which results in global segmentation. The concept of watershed is based on visualizing a gray level image into its topographic representation.

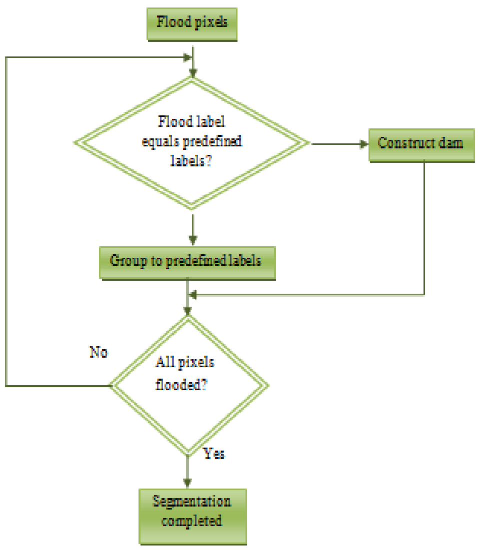

Fig1: Process flow of watershed algorithm

Three types of points are considered in watershed algorithm.

- Points belonging to the different minima
- Points at which water would fall with certainty to a single minimum (Catchment basin)
- Points at which water would be equally likely to fall to more than one minimum (watershed lines). The watershed transform has been widely used in many fields of image processing including medical image segmentation.

1) *Watershed transform for color image segmentation:* Extension of the concept of binary and grayscale morphology to color images is not straight forward .Such techniques are applied independently to each of the primary color components, R G and B of the image that applies morphological operations on color images directly and solves over segmentation problems. [7] Watershed algorithm can be implemented in any one of the three approaches

TABLE 1
VARIOUS METHODS OF WATERSHED ALGORITHM

Watershed algorithm approach	Description
Distance transform approach	Distance from every pixel to the nearest non zero valued pixel is computed.
Gradient method approach	Image has high pixel value along object edge and low pixel values everywhere else
Marker controlled approach	The boundaries of watershed are arranged along different ridges to avoid over segmentation

Here we used distant transform approach. Distance transform refers to the distance from every pixel to its nearest non zero valued pixels of that pixel [1]. The current distance assignment is compared to the current assignment of its neighbors plus the distance of that neighbor a_n from the current assignment. If the current distance assignment I(c) is greater then I(n) by a_n , then I(n)+a_n replaces I(c) which minimizes the distance from 'c'. Various distance transform approaches are as shown below. We employed the City block approach of distance transform for watershed algorithm.

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TABLE 2
APPROACHES IN DISTANCE TRANSFORM

Distance transform approach	Forward pass	Backward pass
1. City block	- 1 - 1 c - - - -	- - - c 1 - 1 -
2. Chessboard	1 1 1 1 c - - - -	- - - - c 1 1 1 1
3. Euclidian distance	√2 1 √2 1 c - - - -	- - - - c 1 √2 1 √2

III. PROPOSED ALGORITHM

The process flow of the offline monitoring system is shown in the flow chart fig2. It includes various stages as shown in the below algorithm. The flow of steps is in the algorithm below. The primary requirement to apply this method is an infrared thermal image of a faulty circuit.

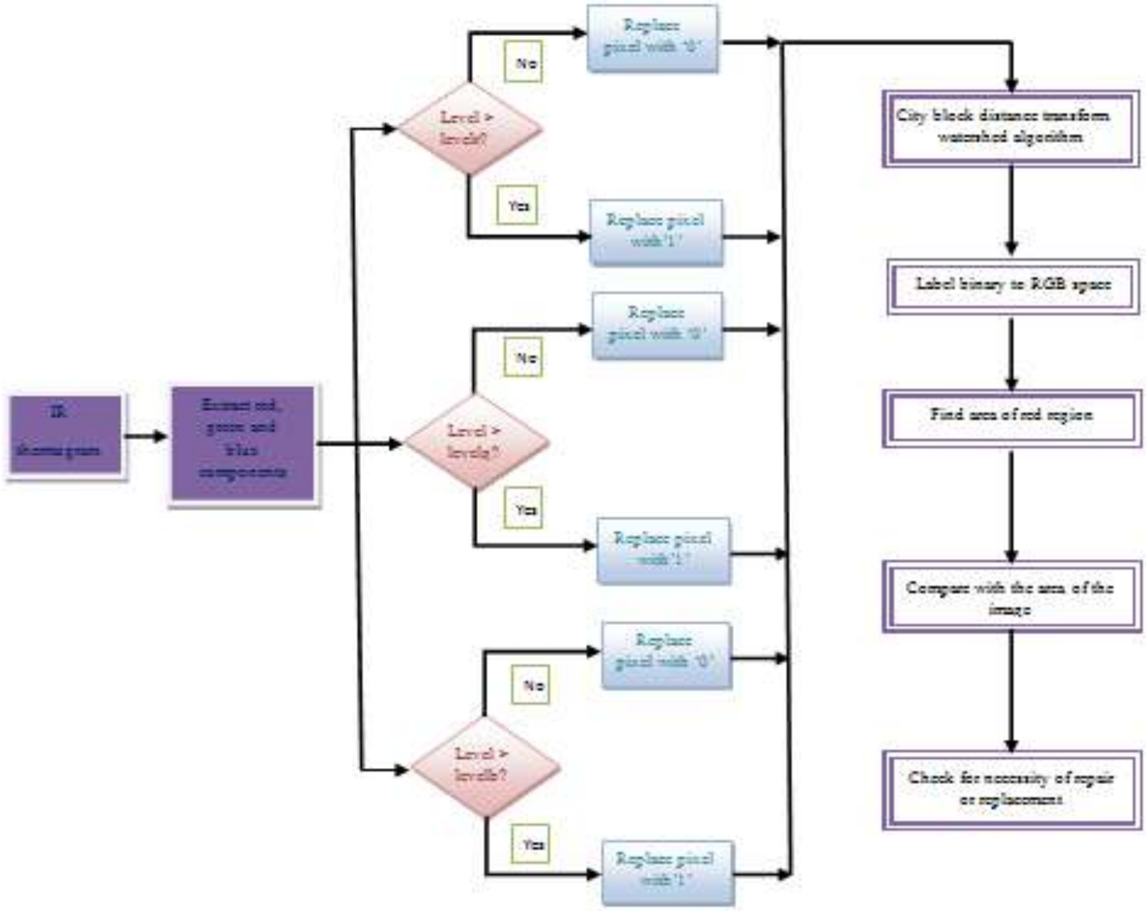


Fig2. Flow of proposed algorithm

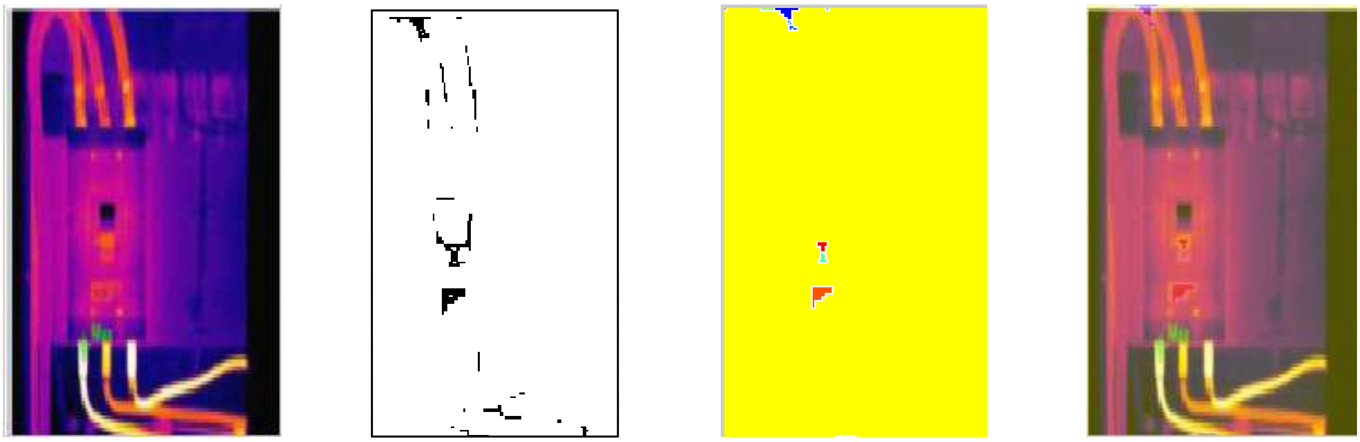
Proposed algorithm:

Since watershed algorithm can be applied only to a binary or gray scale image, we are converting the color IR image into binary by comparing with a threshold. Later the original image will be obtained by doing a vice-versa operation. The following are the steps involved in the above flowchart

- Obtain the red, green and blue components from the image chosen.
- For the Red component, if the pixel level is greater than the predefined level, replace the pixel with '1' otherwise replace it with '0'.
- For the green component, if the pixel level is greater than levelg replace the pixel with '1'; otherwise replace it with '0'.
- For the blue color component, if the pixel is greater than levelb replace the pixel '1'; otherwise replace it with '0'.
- Arrange the primary color component in sequential order to apply watershed algorithm.
- Segment the image obtained using the city block distance transform watershed algorithm.
- Convert the binary image to RGB color space.
- Find the area of more temperature region and compare it with that of the area of image.

IV. RESULTS AND DISCUSSIONS

After segmenting and applying pseudo colour imaging, the results are analyzed and the performances of various circuits were found. The different images taken are the images of transformers, electrical substation equipments and faulty fuse cabinet image. Figure 3 shows the thermogram of a transformer where small regions can be observed after segmentation which indicates the extent of damage.

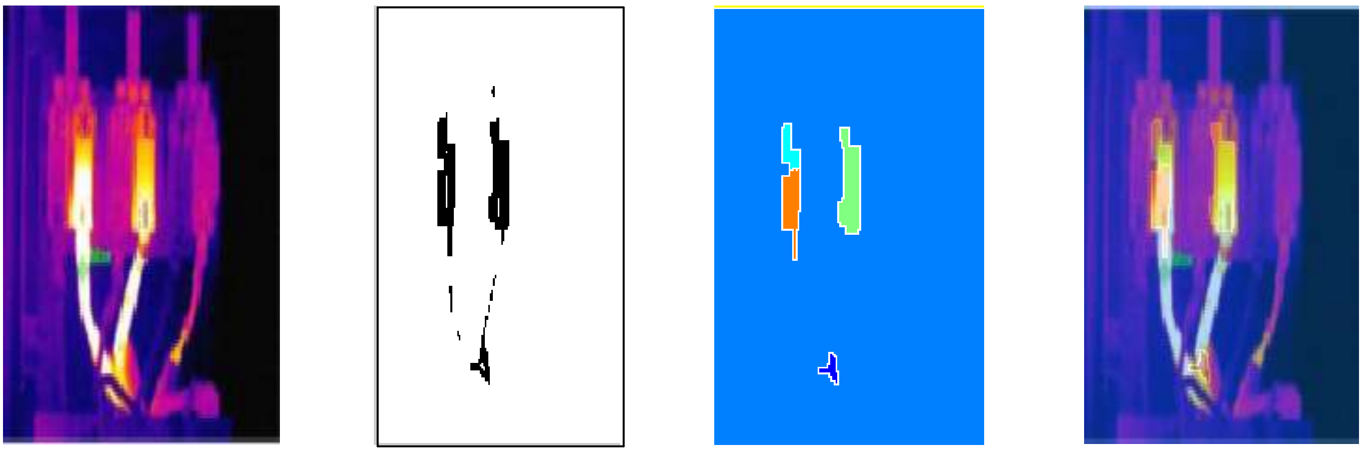


(a) Original image (b) Regional minima (c) Colour watershed transform (d)Label to RGB

Fig.3. Transformer thermo image with less damage [4]

The area of the damaged part is very less compared to that of the area of the image. The areas of damage in two regions detected were found to be 61 and 35 pixels. Thus the system needs repair and not replacement since it is lightly damaged.

Figure 4 shows the substation equipment of substation and the results obtained after various stages during segmentation

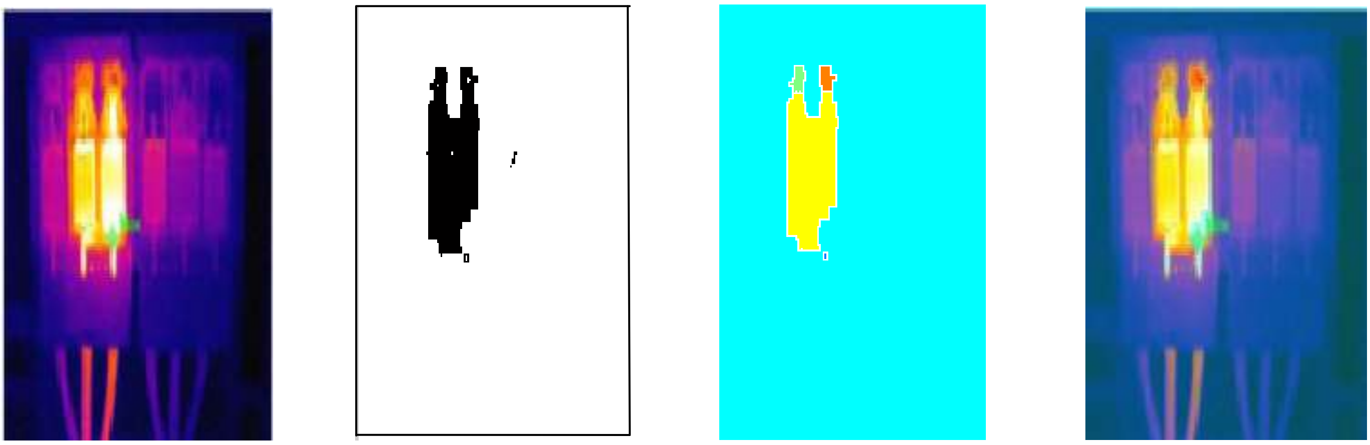


(a) Original image (b) Regional minima (c) Colour watershed transform (d)Label to RGB

Fig. 4 Distribution substation equipment heavily damaged [10]

The area of damage is very large. Hence the system needs replacement to prevent further damage. The areas of the two regions that are damaged are found to be 275 pixels and 434 pixels respectively.

Figure 5 shows the image of a transformer substation. The black region in the regional minima indicates the defect.

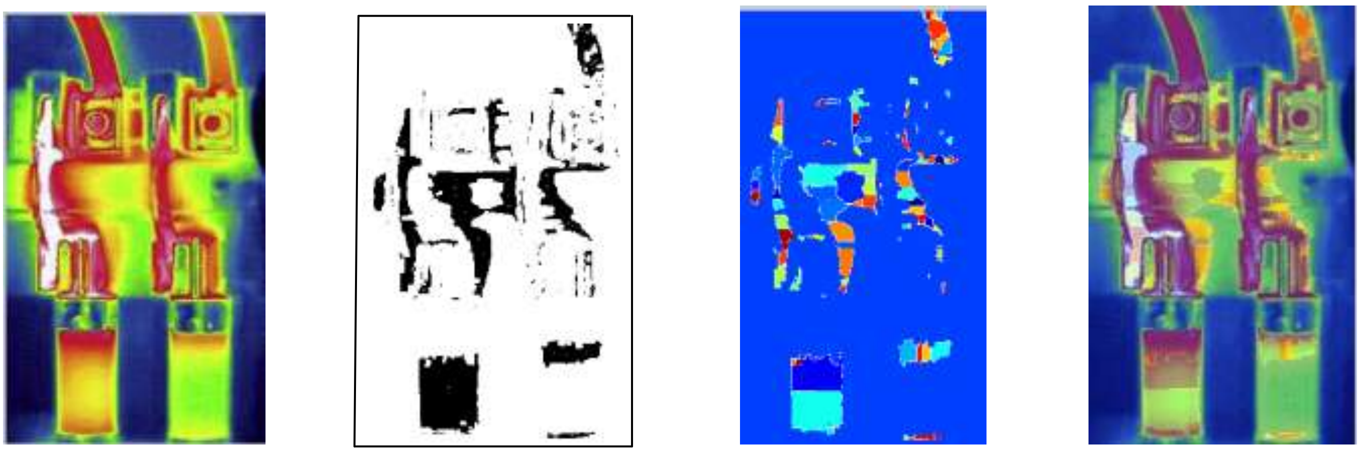


(a) Original image (b) Regional minima (c) Colour watershed transform (d)Label to RGB

Fig.5. Sample of substation equipment heavily damaged [10]

The area under the segmented part is very large and is found to be 1835 pixels which is very large compared to the image area. Hence the system is to be replaced immediately in order to protect the equipment from further damage

Figure 6 shows the thermogram of a faulty fuse cabinet



(a) Original image (b) Regional minima (c) Colour watershed transform (d) Label to RGB

Fig.6. Faulty image of a fuse cabinet [5]

The output of watershed algorithm resulted in a little over segmentation because of the complexity of image where the number of colour variations is very large. There are several regions in this segmented image and the areas are as 1531, 5910, 1742, 354, 756, 1142, 1286, 732, 335, 350, 588, 213 etc for the damaged parts. The equipment is totally damaged therefore it should be replaced immediately.

V. CONCLUSION

Our paper focuses on developing a non invasive monitoring and controlling system for detecting early faults in electrical assets. It has been developed to deal with offline monitoring and analysis of electrical assets such as: electrical contacts, capacitor banks, power supplies, switches, fuse cabinets etc. thus preventing the costly electrical circuits from any catastrophe that may happen in future. We have developed a colour image segmentation technique that employs city block direct transform watershed algorithm. The performance of this approach has been tested for 4 thermal images obtained from faulty circuits and the image outputs were shown. We are currently in process of applying this system to other repair procedures where traditional diagnostics have proven to be destructive.

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