American Journal of Sciences and Engineering Research
E-ISSN - 2348 -703X, Volume 4, Issue 3, 2021

Thermal Imaging Based on Thresholding Technique: A Novel Method of Fault Detection in Dynamic Environment

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Abstract- *Infrared thermography offers significant advantages in monitoring the temperature of objects over time, but crucial aspects need to be addressed which is the movements between the infrared camera and the inspected material seriously affect the accuracy of the calculated temperature. The key aspect of this work is Robust Moving Object Detection method using Visible Spectrum and Thermal Imaging. If we fuse visible spectrum and Thermal imaging together, more information about the moving object can be obtained as both are inherently complementary to each other. This paper proposes an initial approach to perform target detection as well as tracking for single and multiple moving objects in thermal video sequences. Thermal imaging is complimentary to visible imaging as it has capability to detect object in low light or dark conditions by detecting the infrared radiation of an object and creating an image which contains temperature information. The extracted regions are then used for performing the segmentation of targets in thermal videos. After segmentation of object, centroid based object tracking is performed to track the objects in thermal videos. The proposed method is evaluated on different thermal videos and found to be robust compared with standard background subtractionmethod.*

Key word: *Thermal imaging system, Infrared radiation, Thermography, Target region (Infected or Polluted region), Segmentation of images, Thresholding algorithm.*

I. Introduction

The discovery of infra radiation in early nineteenth century play an important role in production of major technological products dominated by related applications of infra radiation. There are different methods for measuring the radiations lead to the development of infrared systems **[1]**. Since that time infrared cameras have been extensively served in different applications. All objects in the environment have finite temperature emit energy in the form of electromagnetic radiation, which is arranged according to their wavelength or frequency. Depending on their wavelength, the electromagnetic spectrum can be divided into different regions which are ultraviolet, visible, infrared, and microwave.

Ultraviolet region: wavelength range of 0.1-0.4 µm, Visible region: wavelength range of 0.4-0.7 µm, Infrared region: wavelength range of 0.7-1000 microns (µm). Microwave region: wavelength range of 1000 µm -1 metre.

The radiation in all heated objects is in the infrared range. Infrared spectrum is in turn subdivided into four regions: *Shortwave region from 0.7-3 µm Mid wave region from 3-5 µm Long wave region from 8-14 µm, Far/Extreme IR from 14-1000 µm***[2]**

 Received- 13-03-2021, Accepted- 28-03-2021

Thermography: Temperature distribution on the surface of an object can be determined using a method called thermal imaging, often also referenced as thermography. Infrared energy is emitted by all materials above 0 ºKelvin (-273 ºCelsius). IR radiation is part of the electromagnetic spectrum and occupies frequencies between visible light and radio waves. This energy is converted into electrical signals by the imaging sensor in the camera and displayed on a monitor as a colour or monochrome thermal image that represents the variations of the temperature values.The main advantages of thermography are that it is non-invasive, noncontact, painless and not harmful either to the patients or the medical staff involved. Modern thermal imaging cameras provide high speed and high resolution. Furthermore, the stability of the earlier cameras has improved dramatically and calibration of the image against a stable temperature reference can be achieved to ensure reliability. This is of particular importance when repeated acquisitions are made with this technique.

Thermal Imaging Devices: Thermal imaging devices are combined of optics, detectors and a signal processing unit. Signal processing unit has the function of detecting the emitted thermal energy of the target and the background presented within the field of interest. Thermal imaging devices fulfill thermal maps construction process: **[3]**

1. The infrared radiations, which are received from the field of view, are collected, filtered spectrally, and concentrated onto a multi-element detector array using an opticallens.
2. Incident radiation heats the detector surface; heated surface of detector affects its material properties such as electrical conductivity, which in turn interprets into variation of the output signal.
3. Signal processing unit received output signal from the detectors and converts it to data for display.
4. Depending on infrared emission intensity, the data produced by the signal processing unit is displayed with different colors.

Different types of thermal imaging systems used for thermal imaging. **[4]** First type of thermal imaging system consists of a thermal imager and a thermal reference source. In this type of systems, the only temperature indication is the thermal reference source, which is set at a pre- defined threshold temperature. Type one systems use radiance difference sensing between a body temperature and the thermal reference source as measurement principle. The threshold temperature placed in Temperature reference source is used to classify the screened object as per requirement for fault detection. Second type of thermal imaging systems does not use any external temperature reference system. This system indicates the temperature of selected pixel (or group of pixels) within the image. The set constant temperature represents a threshold value. A constant colour scale can be set by the user for a demanded threshold temperature. This means when some object's temperature is more than the threshold temperature, the defined colour by the user is shown, then faulty object detected.

Screening Process: In public places such as hospitals and airports, objects pass through a specified direction past the temperature reference source, while an operator monitors the display. Thermal imager is adjusted to focus only on specified regions. The CPU processes radiation energy seized by the thermal imager constantly and display it on the monitor. The processor uses a color scale to map the temperature **[5]**. Usually the displayed colors depict the relative increase of temperature. The operator observes the display carefully and then decides if the subject needs extra check-up according the percentage and size of the red areas on the specified regions.

Infrared thermography efficiency in screening of moving objects: Infrared thermography in mass screening of moving objects can be achieved by temperature measurement accuracy and system automation. Automation here means capability of recognizing objects in infrared images automatically [6],[7],[8],[9]. If the device works in a self-administered way, the impact of the radiating heat sources in infection or fault screening can be fulfilled, because position of objects in infrared images is a vital factor to be addressed for rectifying the infrared thermography performance in mass screening of moving object for fault recognition. The standard procedure in infrared cameras is higher the temperature, the higher is the pixels intensity. In this case the location of objects specified regions in the infrared images can be determined by some simple image processing techniques such as temperature threshold and morphological processing which is the method for extracting requested image components.

One of the authors had done extensive work on thermal simulation, which had been performed by using" Ansys Multi-Physics-10" with constant temperature boundary conditions**[10],[11],[12]**.

II. Our Performance Evaluation

Identification of Target region: In thermography processing analysis we first define target region of different objects taken under tracking and detection. Present software uses regular prismatic shapes for the definition of these regions, such as, rectangles, squares, circles and ellipse that poorly identified certain anatomical regions. These regular geometric shapes present limitations when they do not fit with the anatomical shape of the area that is to be characterized, either by the exclusion of relevant data or the inclusion of irrelevant data in the evaluation of the thermal images. This can lead to the inclusion of errors or misunderstandings into the analysis of a certain thermal image. Our approach to overcome the geometric limitations of inclusion of irrelevant data in the evaluation, image segmentation algorithms may be applied to the selected target region.

Segmentation of Image: Segmentation is performed by demarcating an object on an image using pixel-level or object- level properties of the object. These properties can be edges, texture and pixel intensity variation inside the object, shape, size and orientation. The segmentation has two goals. The first is to decompose an image into regions for further analysis and the second is to perform a change of the representation of an image for faster analysis. Based on the application, a single or a combination of segmentation techniques can be applied to solve the problem effectively. The three types of segmentation techniques which is used for segmentation of image are Threshold based segmentation, Edge Detection segmentation and Region-based segmentation. Thresholding segmentation algorithms define the boundaries of the images that contain target objects on a contrast background. This technique gives a binary output from a gray scale image. This method of segmentation applies a single fixed criterion to all pixels in the image simultaneously. In this method we set an appropriate threshold value of temperature T, which is a converted binary image from a gray level image. The advantage of getting a binary image is that it simplifies both the complexity of the data and the process of recognition and classification. To describe it mathematically, a threshold image is defined with a pixel labelling where label 1 corresponds to the target object and 0 corresponds to the background. The thermal image can be defined as a function f(x, y) whereas the threshold image g(x, y) can be defined as follows:

$g(x,y) = 1$ if, $f(x,y)>T$ and $g(x,y) = 0$ if, $f(x,y)<T$

Our different approach of thermal pattern recognition for thermography: For specified objects face recognition neural networks and deep or supervised learning can be used to identify face regions in infrared images. Input layer for neural networks and input data for supervised classification are fed with averaged temperature data (pixel values) of the objects face regions and the shape factor values to help them with specified face regions recognition. For creating different segments of the object face recognition we use some functions like Bessel function. Template matching is a technique in signal processing for matching a template image with small sections of an image. This technique is used in many fields such as face recognition, biophysical data processing, and photogrammetric and remote sensing. Two main algorithms have been used for template matching are feature based matching and image based matching. Image based matching is used mostly when properties of the images are not fully distinct able or when the template image content constitutes the matching image. In this case, a template is scanned over the test image pixel by pixel and correlation between them is calculated at the same time. Final correlation score shows that the template is a match with the test image or not. However, image based matching is not widely used in face recognition because it is time consuming and has a high time complexity. In feature based matching, the edges or contours are principle matching criteria to find the best matching location of the template in the test image. The system should be designed in a way that makes it capable of searching a large database of images for objects with resembling traits specified by the user while developing an automatic image extraction system.

Strategy for automatic identification of object with fault: This strategy created to distinguish object shapes in the infrared pictures and tracking. It incorporates object selection, template matching, and decision making process and tracking objects. A block diagram of the algorithm is shown in the following figure-1.

Figure-1: Flow chart of working algorithm for object detection with fault

Thermal image modification (Thresholding)
First by adjusting the camera based on the normal object temperatures, objects with higher temperatures will appear in the image convection as mostly red as shown in figure-2 and isolated in target object. First step during object identification in any image is to convert it to binary image (black and white), this steps makes it easy to select the desired objects and to extract their contours**[13]**.

Figure-2: Human body with high temperature

Proposed Algorithm of Thresholding: In view of gray level (The **gray level** or **gray** value indicates the brightness of a pixel. The minimum **gray level** is 0. The maximum **gray level** depends on the digitisation depth of the image. For an 8-bit-deep image it is 255. In contrast, in a gray scale or colour image a pixel can take on any value between 0 and 255.) distribution in any image, we select the function of decision making which relies on pixel gray level.

We define two classes: first contain all pixels which are having gray levels 0 to T and similar to that and second comprise all pixels having gray level T+1 to N, where T is the threshold gray level and N is for the total number of gray levels in the image,
C1(g) =1 for g ≤T
=0 for g >T C2(g) =0 for g ≤T
=1 for g >T

Where Ci defined as the membership coefficient of the gray level g with respect to class i in the threshold image. The final image will obtained by transforming of the original image with two crisp pixel sets(A **set** defined using a characteristic function that assigns a value of either 0 or 1 to each element of the universe, thereby discriminating between members and non-members of the **crisp set** under consideration. In the context of fuzzy **sets** theory, we often refer to **crisp sets** as “classical” or “ordinary” **sets**.) and the membership value 1 or 0**[14]**.The purpose is to view the main image as also containing of two sets of pixels but having facial membership values. It means that the original image is viewed as to be created of two fuzzy sets. The pixels memberships (corresponding to a gray level) to a set is a measure of our uncertainty inassigning them to the specific class. Gray levels of both rightmost and the leftmost, for example, obviously would have maximum membership coefficients w.r.t class 1 and class 2 separately and, thus, minimum uncertainty associated in assigning them to their respective class. This membership coefficient is normalized to 1, like always. The uncertainty confident of categorization associated with a gray level w.r.t a specific class is then defined to be 1 (membership value of the gray level w.r.t that class). The process of thresholding or "defuzzification"(**[15]** Defuzzificationis the process of producing a quantifiable result in Crisplogic, given fuzzy sets and corresponding membership degrees. It is the process that maps a fuzzy set to a crisp set. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets.) involve with allotting a crisp set to the pixels. Subsequently, consolidates a decrease in the uncertainty associated in categorizing the pixels. Subsequently, it will lead to supply the "information" in transforming the original image comprising of two fuzzy sets to the final image comprising of two crisp sets. To determine the uncertainty degree of categorization of the pixels associated with any gray level, solely by and is equal to its probability occurrence within class 1 or class2. As for the independent of the distance from threshold which is chosen, the gathered information (equal to the priori uncertainty) for step of categorizing the pixels, black pixels will get equal value to obtained grayish category with also the so long as the possibility of existence of both theses gray levels, will assumed to be equal within class 1. This inevitability gives a false representation of the instinctive notion that if the amount of greater amount of assertiveness is greater, it would categorize in assigning class 1 to a black pixel rather than in putting in category of the same class to a gray pixel. Histogram is so modeled as an adjoin (zero memory) source and for the information gathered in classifying categorizing any gray level is nonaligned of the possibility of existence of the neighboring gray levels in class 1/class 2. Hence, according to this approach, great amount of information is classified and also by specifying the left-most gray level to class 1 and for right=most gray level to class 2.Besides, for an image with specific histogram, T1 will select for the threshold selected corresponding to maximum entropy. A theoretical stray shuffling of gray levels on the left of T1 will drive the final threshold T2 to 0 <T2 ≤ T1 while a collected of a threshold > T1 can lead to result in a superior severance of the modes for the histogram. Besides in **[16]** which threshold is selected as comparing to maximum information and next will be considering the problem of putting an "optimal" threshold only rely on the gray level distribution. So, it will be assumed exact features in the image so that it is a reasonably globally thresholdable one. For bilevel thresholding problem, list of axioms will be set and then obtain a criterion for the best threshold.

Assumption for this hypothesis of Thresholding:

1. Obtained information by setting class l (class 2) to pixels with minimum (maximum)gray level in the image iszero.
2. A hypothetical gray level *T′* is set between the fixed threshold gray level *T* and *T* + **l** so that a "pixel with this gray level" has membership coefficient of 1/2 of belonging to either class.
3. Gray level set to a class must imply the membership coefficient of *g* belonging to that class ≥1/2. also if gray level g2 is at a greater distance respecting the threshold *T* than the gray level g1, where g1 and g2 are on the same side of the threshold *T,* for the membership coefficient of g2 belonging to the corresponding class is greater than that of g1 and information transported is greater in classifying g1 than in classifying g2
4. The membership coefficient of a gray level w.r.t. a class rely on and grow up respecting to frequency of existence of the pixels with that gray level.

When axioms 1, 2 and 3 are apparent, the logic backing of axiom 4 is to get a higher membership for the pixels with gray levels at greater distances from the threshold (w.r.t. addresses to the number of pixels with intermediate gray levels) within a certain class. By assuming a linear relationship in axiom (4), from (2) and (4),

[14] it will result for the membership of the threshold, P1(T) =1/2+kp(T) (2)
where p(T) is chance of existence of pixels with gray level *T* and for *k,* it is about a constant which should be determined by applying axiom (1), and for the gray level *T* - 1 which is belong to class **l** and recline 2 strides on the left of the hypothetical gray level *T′* should mark that all of the pixels which their gray are level *T* – 1 additionally with those that their gray level are *T* would been categorized into class **1.** Of a whole a class, for ones with the gray level *T* – I to be member of class **1** and lie *i* + l strides on left of *T′* would specify that all of the pixels which their gray levels are *T* - i, *T* - i + 1, , *T* have been categorized into classl.
P1(T-1) =1/2+k(p(T-i)+p(T-i+1)+…..+p(T)) (3)

By applying axiom 3
We have

P1(0) = ½+ k(p(0)+p(1)+…….+p(T))
=½ +k(p(class1))________________________________(4)

From axiom1, it should be equal to 1 in that case the information gathered by categorizing and classifying the left-most gray level to class *1* is -log P(0) = 0
So, from equation 4 we get 1=1/2 +k (p (class1))

Or, k =(½)/p(class1) (5)

We then model the histogram as a "pseudo first order Markov source". We use "Pseudo" because the value of *k* relies on the accumulative distribution of the gray levels in class 1. Same for class 2 we couldhave:

P2(T+i) =1/2+k(p(T+i)+p(T+i-1)+…..+p(T+1)) (6)

The average information gathered by classifying and categorizing all its gray levels could be written now:
Information from 1:

I1= [-p (0)/p(class1)] logP1(0) - [p(1)/p(class1)]logP1(1)-_________________- [p(T)/p(class1)]logP1(T) (7)
Information from 2:

I2= [-p (N)/p(class2)] logP2(N) - [p(N-1)/p(class2)] logP1(N-1) [p(T+1)/p(class2)] logP1(T) (8)

Now we understand the histogram with equal average variability as to which class 1 is and which class 2. Hence preferably it should choose that threshold for which I1 = I2, the gray level is after then selected which minimizes |I1 – I2| is minimized.

III. Technical Approach

Application of this algorithm to thermal images:

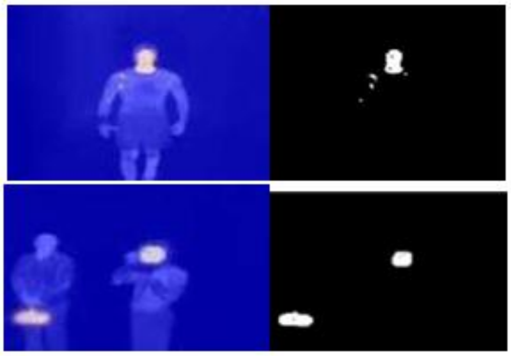

Figure-3: Images with one person with infection and one person with infected object

An example shows in Figure 3, after applying image thresholding on thermal images. The first image containg only one human with infection while second one contains one human with infection and one normal human carring an object with infection. The important part of this experiment is the detection of the object of interest which in our study, it is the body region. So far we were able to finds areas which their temperature are higher than threshold temperature (which will be nominated as infected body) after applying the threshold filter on them we may now have several white regions in a black background that all of them may presenting as an object with high temperature. Among them we would still have some small spots lefts in background after running the algorithm or there could be some objects with small areas like cups of coffee, so the first step might be filtering these irrelevant objects of from the image.

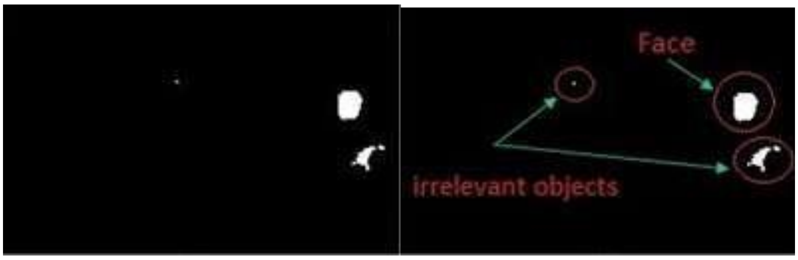

Figure-4: Detection of irrelevant object

As shown in figure-4, some small objects may result as errors in the automated image thresholding process. Automatic template matching process would be facilitated if the number of objects is smaller (as they will also count as target objects). The algorithm is going to propose pixel area and coordinate of all objects, such that in this step the small objects can be removed from their pixel area as it is obvious that the very small objects cannot be human faces **[17].** The algorithm successfully detects three objects as shown in Figure 4 By erasing this small irrelevant objects detected by considering their pixel area value the result will be an thresholded image consisting only objects with pixel area value like the face region and the next step will be the finding and detecting the face regions among the left objects and it would be done by applying the template matching algorithm**[18]**.

Template Matching:

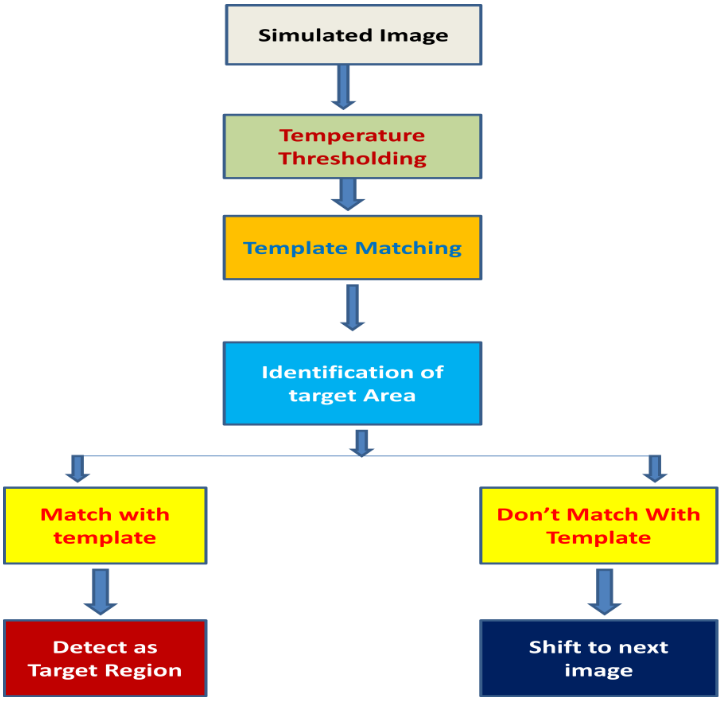

Fig: 5-Process of applying proposed algorithm to simulated image.

IV. Result and Discussion

The thermal camera that has adjusted to set the normal human body temperature as reference temperature is connected to program start taking thermal images of objects walking through the path. Shown in Figure 6 are first thermal images.

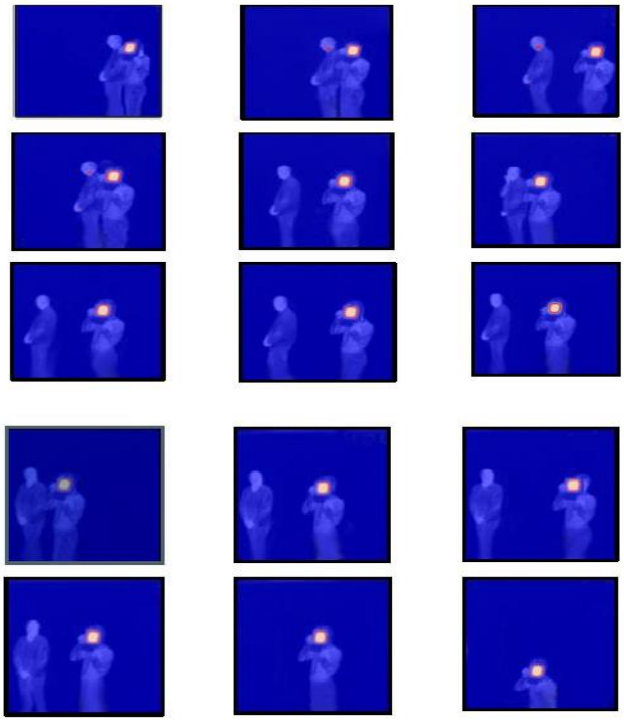

Fig-6 Images of objects in motion

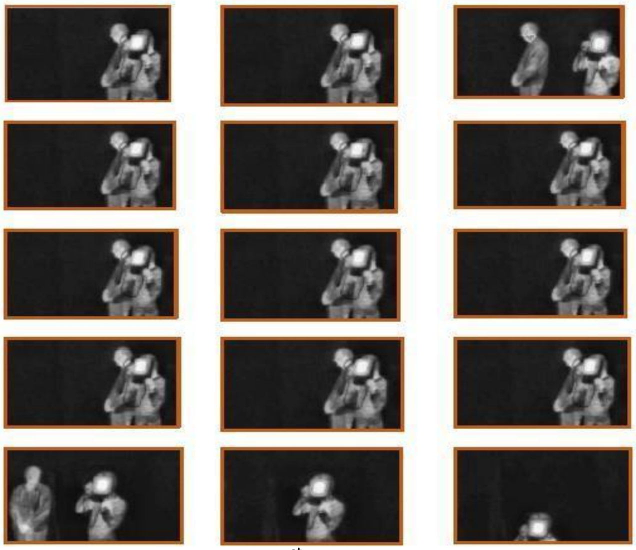

Fig: 7 After 1st image thresholding

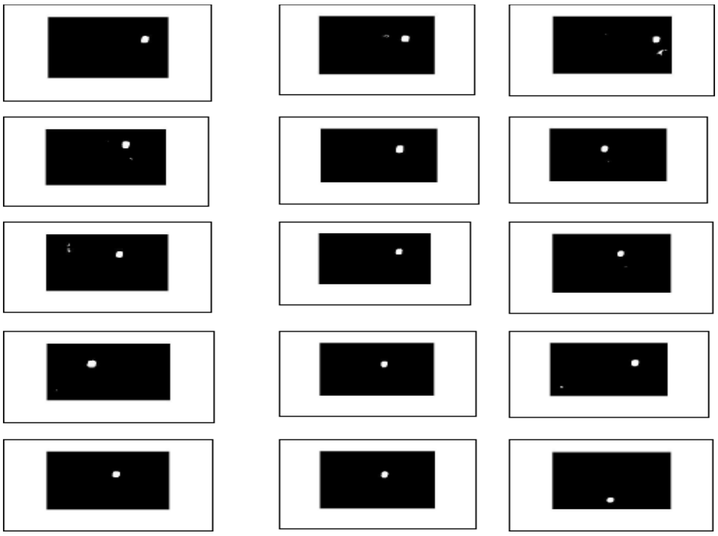

Fig: 8 After final thresholding

Algorithm finds

These objects with their pixel area value and coordinates were identified: Grain Areas: 200pxl, 80pxl, 3pxl.
The object with 200pxl is detected as target object.

After applying the image thermal thresholding there will be remained only the spots with higher temperature rather than a normal temperature. As it is seen the fig there some spots left, some has high temperature and some are only holes. For this step if these spot are very small they will be considered as hole and if they are bigger than holes, algorithm will find pixel area of all them including their coordinates. If the pixel area is much smaller than face pixel area defied in algorithm they willautomatically erased as shown in figure-4. Object with 3pxl area will considered as a hole and will be filled and abject 80pxl area as irrelevant object and will automatically erased.

Fig: 9 Final detection of object under threshold.

Method Used: We have described a template matching approach to achieve this function. Although template matching based method requires more computing power and time than traditional image processing methods, it can overcome uncontrolled and complex environments in practical applications. Template Matching is a high-level machine vision technique that identifies the parts on an image that match a predefined template. Advanced template matching algorithms allow finding occurrences of the template regardless of their orientation and local brightness. Template Matching techniques are flexible and relatively straightforward to use, which makes them one of the most popular methods of object localization. Their applicability is limited mostly by the available computational power, as identification of big and complex templates can be time-consuming.

Future Work

One of the important steps in the proposed algorithm is the image Thresholding that we could successfully detect high temperature objects from infrared images which obtained even without using a heat radiation source, it will help the automatic detection so easier. However the tracking section is very important too. In this study we propose an algorithm which can track the path of object traveling in 2-Dimensional, Hence the possible future work would be to examine and improve the algorithm in 3-Dimensonal and also by having a 3-D map of traveling path we would able to improve this work to automatic tracking the object with moving robots.

V. Conclusion

The use of IR thermal imaging for thermal facial biometrics has attracted recent research and commercial attention as an alternative to visual spectrum based security systems. Unlike the visible light cameras, IR thermal sensors could facilitate greater robustness to illumination changes and can operate in dark environments. Also, IR images can capture new anatomical and physiological face information, such as a structure of the blood vessels and facial vascular network and thermal face signature, that can be used as a unique biometric feature for each person. Due to the special features of the IR image, two research directions of developing facial recognition methods can be determined. The first relates to the use of physiological features (e.g. vascular networks), and the other to use of multi-modal fusion of complementary data types (e.g. visible and IR). Both research directions are still in their early stages, but the use of neural network and deep learning will further contribute to improving the results. Achieved an accuracy of thermal face recognition methods are rather high but the need for increased accuracy still exists since in security systems high accuracy is essential because even the smallest error can impact on national security, access control, and similar threats.

VI. Acknowledgements

One of the author Mr. Ratnesh Pathak would like to express special thanks of gratitude to his thesis guide Dr. Shuchitangshu Chaterjee as well as Registrar Dr. Amit Kumar Pandey and entire members of RKDF university, Ranchi, Jharkhand (INDIA) who gave the golden opportunity to do this wonderful project on the topic ***"Thermal Imaging based on thresholding technique: A Novel method of Fault detection in dynamic environment"***.

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