Applying CNN to Infrared Thermography for Preventive Maintenance of Electrical Equipment

S. Rokrakthong, T. Suesut and N.Tumrukwatthana

***Abstract*—This paper presents the new method to classify the condition of electrical equipment such as main circuit breaker, magnetic contactor, in term of thermal radiation effect using infrared thermography. The conventional neural network (CNN) is one of deep learning method which is widely used in pattern recognition and object detection. In this paper, the thermal image processing was used to determine the critical temperature on equipment and, the deep learning technology was applied to identify the type of equipment. Therefore, we can know the condition with the type of electrical equipment for maintenance purpose in real-time. An accuracy of our method is 91% for identifying type of equipment. This technique can be implemented to an automatic alarm annunciation system for other dangerous equipment with sensitive to thermal as well.**

***Index Terms*— Object detection, Infrared Thermography, Convolutional neural network**

I. Introduction

Infrared thermography is a tool to determine the temperature of any object by infrared thermal radiation wave. The object with temperature more than absolute zero, which can emit thermal energy by radiation. The higher temperature is impact to the failure of equipment such as loose connection, imbalance load, over load and improper installing. In addition, the failure can lead to many disasters like damage to equipment, injures or even death [1].

Infrared thermography is one of the non-contact testing that represent the surface temperature of object. Due to the temperature is parameter to identify the condition of equipment. Therefore, the temperature monitoring is good methodologies to analyze condition of equipment. Fuzhen Huang et al. present the novel fault diagnosis method with infrared thermography. Infrared thermography is key to classification the equipment combine with support vector machine. This work can classify condition of equipment to four condition [1]. In addition to classification it can also scheme to maintenance by priority of condition.

Instantly maintenance is also required identifying type of equipment to quick repair. The traditional method can classify priority for maintenance but cannot identify the fault equipment. Recently, the method to identify object are developed. Convolutional neural network is technique, that commonly applied to image processing. This technique has high performance classification when compared to the other method. The advantage of this method is fewer parameters to train data with very deep architecture. Shaukat Hayat et al. has applied deep learning to identify nine different class, that has effectively with 90.12% accuracy [2]. In addition, convolutional neural network can be identified class of object and can also localized position of object. Kai Han et al. propose a new method to detect defects on wheel hub surface. The faster R-CNN is used combine with ResNet 101 for detection. This method obtains the position of defects and type of defects [3]. So, object detection is used for identifying equipment.

In this paper has propose the method to analyze condition of equipment in MDB using by deep learning and infrared thermography. The equipment in main distributor board (MDB) to start three phase motor is no fuse breaker, breaker, magnetic contactor and overload relay. In rest of this paper are followed: Section 2 is principle; Experimental setup is shown in Section3; Section 4 and Section 5 are result of experimental and conclusion,

II. Relate work

A. Object detection

In field of object detection convolutional neural network become the leading method because the network can reduce parameter and complexity of network. Therefore, object detection by using convolutional is interesting to applied in this work. Faster R-CNN (Region-based Convolutional neural network) architecture is applied with RPN (Region Proposal Network) and fast R-CNN.

Region proposal network is the one of deep learning based on convolutional neural network. Which, the network can predict the area and score of objects at each position by the generated box also call anchor. Sliding window is used to extract the feature map. Shown in Figure 1. Fast R-CNN is applied with RPN to create architecture for object detection. From RPN, the region of interest is obtained, and fast R-CNN is used to classification. As shown in Figure2. [4]

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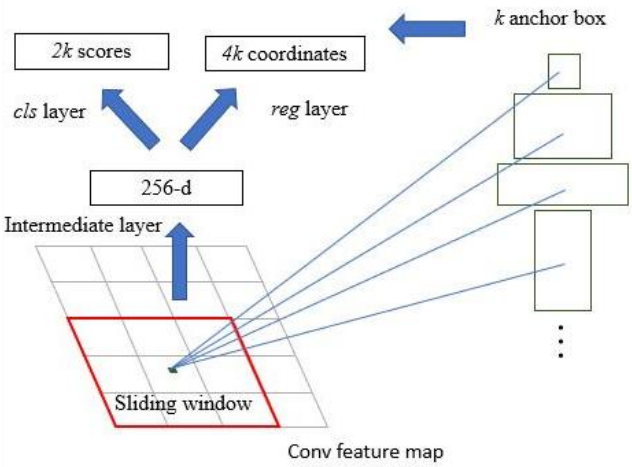


Figure 1. Region Proposal Network (RPN)

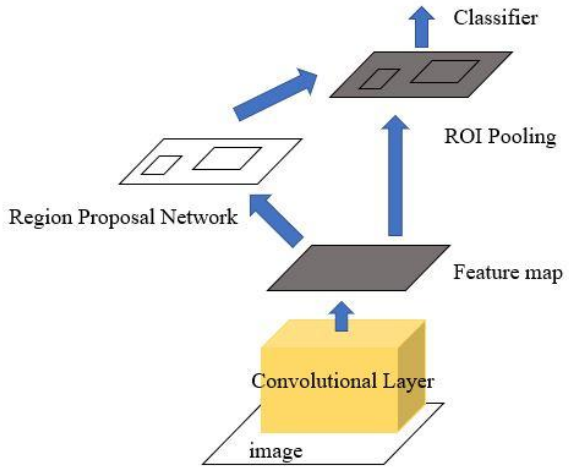


Figure 2. Faster R-CNN architecture

The model to detect object in figure 2, there are only one model but there are many models. The faster R-CNN was applied in this research because this model has efficiency to small object and has high speed training. [5]

B. Fault in electrical equipment

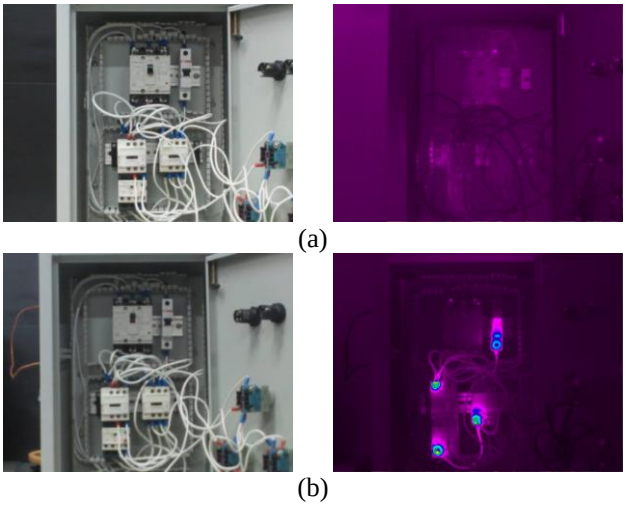
Avoiding fault in equipment is importance because fault in electrical equipment can affect to reliable of system and lead to catastrophic. Furthermore, the fault equipment requires a lot of budget to maintenance and manpower or in the worst case is casualties. The fault diagnosis by infrared thermography has divide to two type including internal fault and external fault. In this paper focus on external fault which, it can be directly observed on the surface of equipment. Normally, the high temperature on the surface occurs by high resistance from loose connection or any reason, the result is heat. [6] The criterions of condition of electrical equipment that detected by infrared of thermography using NETA standards for IRT base inspection of electrical equipment that define condition of equipment by differential of temperature to priority as shown in Table I [7].

C. Thermal imager

The temperature measured by thermal image camera is not only radiation emitted from the object but also radiation from ambient object and reflected on the object. Therefore, measuring temperature value to accurate need to control these conditions there are also many variants that affect to the measurement such as humility and ambient temperature in addition to the measurement of infrared imager must be align in line with the object. And the example images of fault equipment with both of visual image and thermal image as shown in Figure 3.

TABLE I
NETA STANDARDS FOR IRT BASE INSPECTION OF ELECTRICAL EQUIPMENT IN SIMILAR EQUIPMENT

(ΔT) with similar equipment (°C)	**(ΔT) with ambient temperature (°C)**	**Recommended Action**
1-3	1-10	Possible deficiency, warrants investigation (priority :4)
4-15	11-20	Indicate probable deficiency, repair as time permits (priority :3)
-	21-40	Monitor continuously until corrective measure can be accomplished (priority :2)
≥15	>40	Major discrepancy, repair intermediately (priority :1)



(a)

(b)

Figure 3. The example of image (a) visual image and thermal image with normal condition. (b) visual image and thermal image with abnormal condition

III. EXPERIMENT SETUP

The experiment setup consisted of infrared imager FLUKE TI-400 Portable imager (Table I), main distribution board and equipment to start motor three phase including no fuse breaker, breaker, two of magnetic contactor and overload relay. After that, both of visual image and thermal image are grabbed from fluke ti-400 at 120 cm of distance

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from MDB. The images are divided to 5 group including 1 fault objects, 2 fault objects, 3 fault objects, 4 fault objects and all of fault objects.

TABLE II
GENERAL SPECIFICATIONS OF FLUKE TI-400

IFOV	1.31 mRad
Detection resolution	320×240 pixels
Field of view	24 °H × 17 °V
Minimum Focus	15 cm
Optional Lens	Telephoto lens, wide angle lens
Measuring range	-20 to +1200°C (-4 to + 2192°F)
Thermal sensitivity	≤ 0.05°C at 30 °C target temp (50mK)
Built-in digital camera	5 megapixels
Fame rate	60 Hz

A. Training model to detection

The dataset containing 200 images were collected from MDB by FLUKE Ti-400 both thermal images and visual image. And randomly divide the visual image into two set by 140 images to training data and 60 images to test data to create model to identify and localize object. These images were same size but different environment such as one breaker in picture or four type of equipment in picture. After clustering group of data, the model was generated by faster R-CNN architecture.

Figure 4. The example of equipment in MDB to start three phase motor consisted of breaker, No fuse breaker, relay and magnetic contactor (from the left to right)

B. Pre-Processing Thermal images

The image is pre-processing using FLUKE software to adjust maximum and minimum temperature and convert to 8-bit gray scale image. The relative of gray level and temperature is depended on equation (1).

$$T_{(i,j)} = \frac{T_{max} - T_{min}}{255} \times g_{(i,j)} + T_{min} \quad (1)$$

where *T(i,j)* is Temperature at position (i,j). *Tmax* , *Tmin* is range of temperature after pre-processing procedure. g(i,j) is gray level at position (i,j)

C. Analyze and identify object

In this part, the program is developed by LABVIEW2018-64bit. The image both of thermal image and visual image is used to input of this program. And, the program is split in to two part. In part of visual image is used to detect type and localizing of object. In part of thermal image after the pre-processing the images were performed threshold segmentation and sent position of fault to analyze with position from visual image as illustrated in Figure 5.

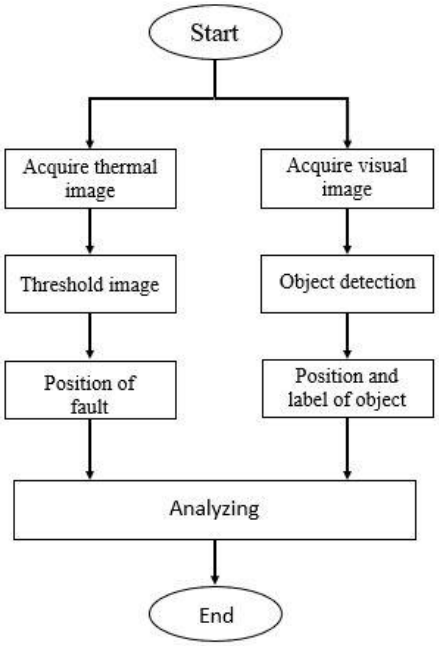

Figure 5. Procedure of the method

IV. RESULT AND DISCUSSION

In the experiment, the both of thermal image and visual image were collected to new data with different dataset of dataset to generate model to detect object. Then, the heat was simulated hot spot on each equipment that hot spot is random on each of connector (21 connector in 5 equipment). After that, the images will be randomized and used these to test data.

A. Object Detection

The dataset was rebuilt in previous step, it was randomized and used for accuracy testing of the model. The dataset to testing is divided into 5 group by each group has 20 images. the result of this step is shown in Figure 6.

B. Analyze and identify

After the object detection, the thermal image was used to diagnosis fault. The condition of equipment was considering by the different temperature of hotspot and temperature of equipment by using NETA standard for IRT inspection in electrical equipment which NETA standard has define condition of electrical equipment into 4 priority to maintenance. But, the action of priority 3 and 4 was monitoring until the equipment to be corrective processing and priority 1 and 2 the action recommends is maintenance. Therefore, in this work is divide the condition of equipment into 2 condition consisted by normal and abnormal. And the example of result as shown in Figure 5.

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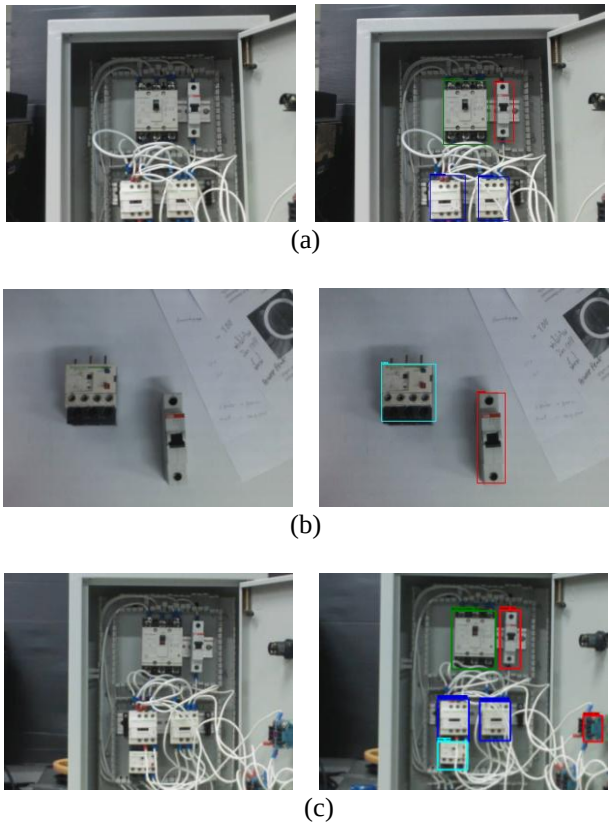

Figure 6. The example of result from object detection by generated model. (a) 4 equipment with 3 type in picture, (b) 2 equipment with 2 type in picture (c) 5 equipment with 4 type in picture but the system incorrect identify

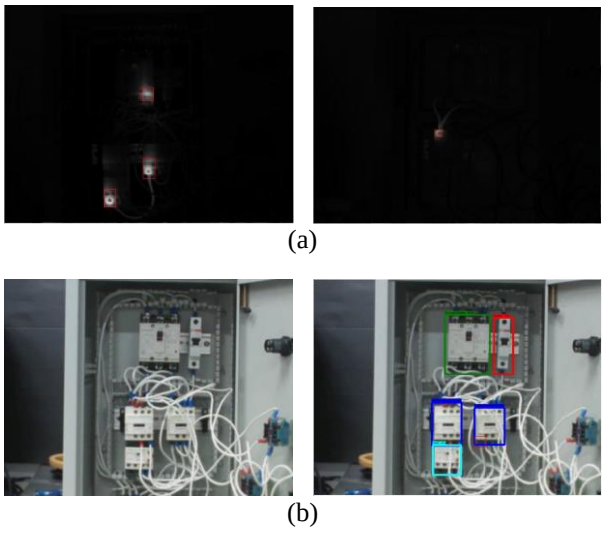

Figure 5. The result of temperature diagnosis with both of thermal image and visual image. (a) thermal image can detect hotspot on equipment. (b) When combine the result of thermal image with visual image is can classify and identify object to be failure.

TABLE III
RESULT OF THE METHOD

Number of fail objects	Accuracy (correct/total) %
1	(20/20) 100 %
2	(19/20) 95 %
3	(18/20) 90 %
4	(17/20) 85 %
5	(17/20) 85 %
Total	(91/100) 91%

TABLE III shows the result of combination of object detection and analyze fault with infrared thermography that can classify condition of each equipment by accuracy 91 %

The result is illustrating to some problem in object detection may be caused by size of object in image to retrain the model or caused by inaccurate temperature of measurement by thermal imager. Which, these problem affects to analyzing in section of analyze and identify that lead to cannot identify object to be failure or incorrect identify object to be failure.

V. Conclusion

In this work, the classification of condition in electrical equipment using application of deep learning and infrared thermography that illustrated to the temperature from fault is indicator to decide the equipment to be failure. So, the thermal image can be classified condition of equipment by different temperature. In addition, object detection by using convolutional neural network was applied in this work to identified type of object and location. When the combination of two section, our system can classify and identify the failure of object. However, this system still has some problems caused by thermal image and properties of visual image such as resolution and size of equipment in image. This technique can be applied to design the automatic alarm system for other dangerous equipment with sensitive to temperature changing as well.

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