XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6–11, 2009, Lisbon, Portugal

NEURAL NETWORK BASED CORRECTION OF INFRARED THERMAL IMAGER FOR SHORT DISTANCE MEASUREMENT

Sun Jian [1], *Zheng Enhui* [1], *Chen Le* [1], *Huang Yanyan* [1], *Fu Yaqiong* [1]

[1] College of Mechatronics Engineering, China Jiliang University, Hangzhou 310018, China,
email: sunjian@cjlu.edu.cn

Abstract – Based on the formula of image radiation, the influence of distance on the temperature measurement accuracy using IR thermal imager is analyzed in theory. Then an algorithm for correction based on neural network is proposed. The error caused by the difference between measuring distance and calibration distance is reduced.

Keywords: temperature measurement accuracy; distance; correction.

1. INTRODUCTION

By receiving incident radiation from the objects to the infrared focal plane array detector, the infrared thermal imager determines the temperature of objects. The infrared radiation received by the detector is not precisely equal to the incident radiation of object surface due to the effect of measuring distance, atmospheric transmittance, environmental temperature, and so on. Those cause the error between indication (apparent temperature) and actual temperature of the object. Currently, various factors that affect the accuracy of infrared temperature measurement are widely discussed and analyzed by many researchers [1-3].However, the error caused by the difference between actual measuring distance and calibrated distance is rarely concerned. In this paper, the error due to the distance is analyzed and is calibrated by the proposed algorithm for a measurement process in practice.

2. EFFECT OF DISTANCE ON THE ACCURACY OF TEMPERATURE MEASUREMENT

In the process of measuring, the effective radiation that can be received by infrared thermal imager includes radiation from the target, radiation of environment reflected by the target, radiation from environmental objects, atmospheric radiation and solar radiation. A blackbody is used as measured target and its emissivity is close to 1. It hardly reflects the radiation of environmental objects. In the experimental conditions, solar radiation can be ignored, and there are no surrounding high-temperature heating radiation sources. Measuring in a short distance, the influence of atmospheric radiation and attenuation is very little and can be ignored. Therefore, under conditions that environment radiation reflected by the target is ignored, the detector is always on the imaging plane and spherical aberration is corrected by the optical system. The radiation of detector focal plane can be expressed as the following equation [4]:

$$E^{'} = \pi\varepsilon\tau_0(\lambda)L(T_{obj},\lambda)\sin^2 u^{'} \quad (1)$$

Where ε is the emissivity of the target; $L(T_{obj,}\lambda)$ is the luminance of the target at the wavelength λ, temperature T_{obj}; $\tau_0(\lambda)$ is the transmissivity of the optical system at the wavelength λ; $\sin u^{'}$ is the numerical aperture in image space of optical system; and $u^{'}$ is the aperture angle in image space. When the measuring distance changes, the output signal of the detector is mainly related to the $\sin u^{'}$,as it is shown in figure 1. $f^{'}$ is the focal length of the optical system ; D is the diameter; and S is the object distance. According to Newton's formula and geometric relation:

$$\sin u^{'} = \frac{D/2}{\sqrt{\left(\frac{f^{'2}}{s-f^{'}}+f^{'}\right)^2+\left(\frac{D}{2}\right)^2}} \quad (2)$$

For the target in a long distance, the radiation luminance of image is:

$$E^{'} = \frac{\pi}{4}\varepsilon\tau(\lambda)\tau_0 L(T_{obj},\lambda)\frac{D^2}{f^{'2}+(D/2)^2} \quad (3)$$

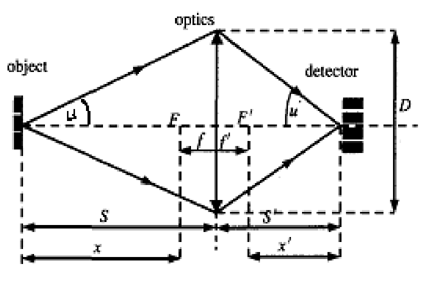

Fig.1. Schematic diagram of target imaging through optical system

ISBN 978-963-88410-0-1 © 2009 IMEKO

Therefore, from equation (1) and (3), the effect of distance on the accuracy of temperature measurement can be described in the following ways. On the one hand, when measuring in a short distance (less than 3m), with the increase in the distance, $\sin u'$ gets larger, namely the radiation intensity received by detector in formula（1）gets larger. On the other hand, when measuring in a long distance (more than 100m), the radiation intensity that received by the detector will be reduced due to the reduction of atmospheric transmittance. Therefore, the radiation intensity of the image as a whole will have a trend of increasing first and decreasing then.

Generally, the thermal imager is used in a long distance measurement, so they are calibrated in a long distance. The difference between the measuring distance and the calibration distance is not considered in public literature when the measuring distance is short. Therefore the error between the measurement result and reference temperature caused by the change of numerical aperture in image space is ignored when in a short distance measurement. To verify the conclusions mentioned above, we studied the relationship between the changes of measurement values and measuring distance when the temperature of black body is fixed at 120℃, as is shown in Fig.2.

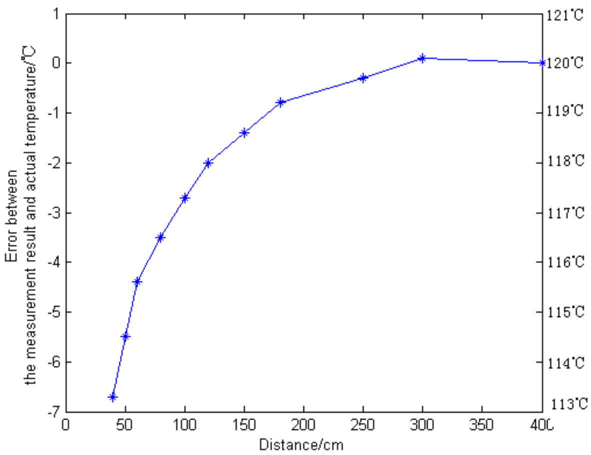

Fig.2. The deviation of measured values and reference temperature changes along with distance

When measuring in a short distance (less than 3m), the measurement result of temperature is lower than the reference temperature, which brings great deviation to measurement. Therefore a distance correction should be introduced when measuring actual targets in a short distance (less than 3m).

3. CORRECTION METHOD BASED ON NEURAL NETWORK

In this paper, we used the algorithm based on neural network to make correction-compensation to deviation between measured values and calibrated values .The deviation is caused from the change of aperture in image space. After compensation, the measured temperature values are close to the calibrated values so that the deviation is reduced and the measurement accuracy is improved at the same time when measuring in a short distance

Neural network can regulate the connection weights between neurons. It has the character of self-learning and the parallel processing ability of adaptive information, and is widely used in image processing, pattern recognition, signal processing, intelligent control and so on.

Many different neural network structures have been tried, some based on imitating what a biologist sees under the microscope, some based on a more mathematical analysis of the problem. The most commonly used structure is shown in Fig. 3.

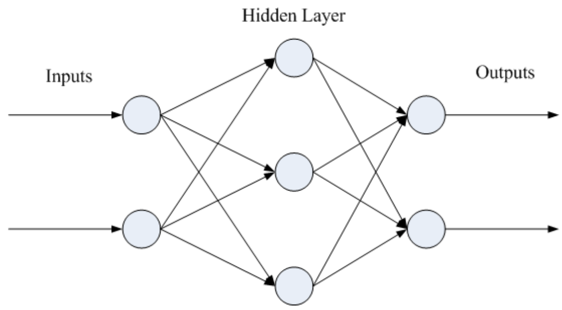

Fig. 3. A generalized network structure

This neural network is formed in three layers: input layer, hidden layer, and output layer. Each layer consists of one or more nodes, represented in this diagram by the small circles. The lines between the nodes indicate the flow of information from one node to the next. In this particular type of neural network, the information flows only from the input to the output (that is, from left-to-right).

The structure of BP neural network contains network layers and the number of neurons in each layer. Although the structure of network is relative to the algorithm, it can be adjusted and improved according to the practical application conditions. The operating efficiency is greatly affected by the improvement of the network structure due to the variables and their importance. A good network structure can improve the accuracy of algorithm and shorten the study time. Generally, the number of outputs and inputs variables determines the number of neurons in output and input layers. The number of neurons in hidden layer is relative to the number of neurons in output layers and input layers. The BP model runs best when the neurons in output layers, single hidden layer and output layers are almost the same or it has a pyramid structure.

Neural network is made of a great quantity of connecting neurons. It internal structure may be very complicated, but from the outside, the neural network can be seen as a black box which realizes the mapping between the inputs and outputs. Because of the mutual restriction and interaction among the neurons, the relationship between inputs and outputs is highly nonlinear. Therefore it can be used in function approximation and curve fitting. It has been proved that a network with a three layers nonlinear activation sigmoid function can be approached by nonlinear continuous function with any precision.

4. RESULTS

The temperature range of measurement of training sample set is from 50 to 130℃. We make a temperature training point every 20℃, and each temperature training point has nine different distance training points. The rest are used as test data. The temperature of test data is fixed at 120℃, and each test point also has nine distance inspection points. The inputs of training are distance and temperature while the outputs are the corrections. The fast Levenberg -Marquardt algorithm is used in the network [5].

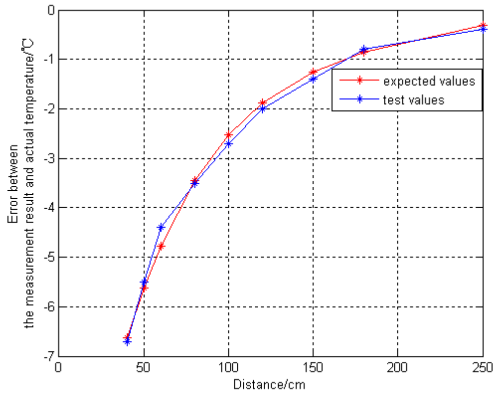

Fig.4. The relationship between test values and expected values (2-3-1)

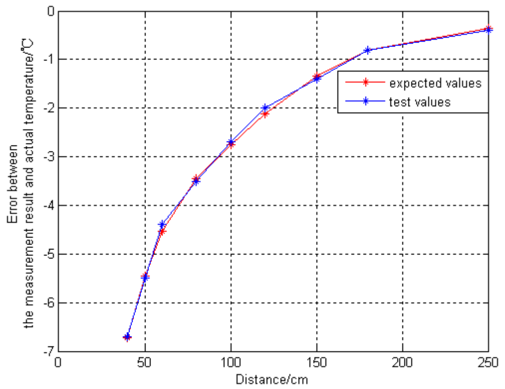

Fig.5. The relationship between test values and expected values (2-4-1)

In a number of measurements, the 3 largest variances are 0.09, 0.073 and 0.065.Corresponding standard deviations are 0.3, 0.27 and 0.25. When he topological structure of network for training is 2-3-1， the result for simulation is shown in Fig.4; and when the structure is 2-4-1，the result for simulation is shown in Fig.5. We can see the latter topological structure is a little better than the former in performance. After compensation to the deviation, the measurement results corrected by our method are close to the reference values, so that the measurement error is reduced when measuring in a short distance.

5. CONCLUSIONS

For the infrared thermal imager with a telescopic imaging system, deviation between measuring distance and calibration distance affects the accuracy of temperature measurement when measuring in a short distance; while the measuring distance has a little effect on the measurement when measuring in a long distance. Therefore the algorithm based on neural network is proposed to determine the correction. By this method, the accuracy of temperature measurement is improved efficiently.

ACKNOWLEDGMENTS

This work was supported by the National Special Research Programs for Non-Profit Trades (Quality Supervision, Inspection and Quarantine) (No. 2007GYJ016).

REFERENCES

[1] Zhang Jian, Yang Li, Liu Huikai. Effect of Environmental Object on Infrared Temperature Measurement[J]。Infrared Technology,2005，27(5)：419-422.

[3] Krzyszt of Chrzanowski, Joachim Fischer, Robert Matyszkiel. Testing and evaluation of thermal cameras for absolute temperature measurement[J]. Optical Engineering, 2000,39(9):2535～2544.

[3] Fan Chunli, Yang Li, Hua Shunfang. Effect of the Temperature of Thermal Detector on Temperature Measurement of Uncooled Infrared Imager[J]. Infrared Technology, 2002，24(5):22～25.

[4] Lu Zifeng, Pan Yulong, Wang Xuejing. Influence of Object System Distance on Accuracy of Temperature Measurement with IR System [J].Infrared Technology. 2008,30（5）:271-274.

[5] Dong Changhong. Matlab Neural Network and Application[M]. Defense Industry Press. 2005, 88-90.