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Software Design for Test & Diagnosis System of Universal Portable Infrared Thermal Imaging Equipment

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Abstract. This paper analyzes the current status and problems of ensuring the maintenance of the thermal imaging infrared equipment and proposes a software design scheme, algorithm and programming for the test and diagnosis system of universal portable thermal imaging infrared equipment, which provides expert guidance for the detection of comprehensive performance indexes, through the use of fault location, diagnosis and instrument maintenance.

Introduction

Currently, although massive thermal infrared imaging equipment has been developed and used before, the development of the corresponding portable detection and diagnosis equipment still lags significantly behind, putting the maintenance of the equipment in an extremely concerning position, mainly shown by:

(1) Traditional inspection of the comprehensive performance of thermal imaging infrared equipment can only be carried out by the manufacturer or repair facility;

(2) Since it is impossible to disassemble the thermal infrared imaging subsystem equipped in the weapon systems and send it for performance index testing, a portable testing equipment on site is required. However, maintenance for such platform thermal imaging infrared systems in the army is still missing at present;

(3) Traditional detecting instruments can only detect the performance indexes and cannot discover faults and give recommendations for diagnosis and maintenance, with particularly high requirements placed on the professional skill of the maintenance personnel. They can no longer meet the steadily increasing demands of the army on equipment usage and maintenance tasks.

Therefore, there is an urgent need to develop a system capable of conducting timely, rapid and reliable performance testing and diagnosis of the portable thermal imaging infrared equipment. Such a system shall be able to detect on-site the comprehensive performance indexes of the equipment and provide the necessary information references for fault location, diagnosis and maintenance so as to provide a strong assurance of fully-functioning performance of the equipment in battle.

The test & diagnosis system software is designed with the functions of testing performance indexes, circuit performance detection, fault diagnosis and maintenance guidance for the thermal infrared imager, as described below:

(1) It is able to test the performance indexes of the thermal imaging infrared system, such as MRTD, NETD, MDTD, SNR and Non-Uniformity;

(2) It is able to detect the single-sided board;

(3) It can conduct intelligent fault diagnosis to the functional component level and locate common faults to the component level;

(4) It provides repairing schemes in an intelligent manner and gives guidance for maintenance personnel to carry out troubleshooting.

Principles and Methods for Performance Indexes Testing

Testing of MRTD, NETD, MDTD, SNR and Non-Uniformity is completed in such a way that the simulated video signals of the thermal infrared imaging equipment are collected by the video capture card, which will then be transformed into digital signals and sent to the industrial personal computer (IPC), where testing of these performance indexes is completed in combination with the human-computer interaction interface and index testing algorithm.

Testing of MRTD

MRTD not only reflects the temperature sensitivity and spatial resolution of the thermal imager but also reflects the observation ability of the personnel, which plays an important role in judging whether the instrument is in good condition or not.

Testing method: use four-bar targets to observe the heat map and adjust the temperature until the resolution on the four-bar targets is less than 70% of the total area, and then calculate the average of the absolute value of the positive and negative temperature difference.

Testing of MDTD

Study the testing technology of minimum detectable temperature difference (MDTD) to acquire the critical value of the target and background temperature difference when the observer is able to distinguish the target under a given target size.

Testing method: adopt the hole-shaped target, conduct subject judgment through the output images and then draw the temperature curve.

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Testing of SNR

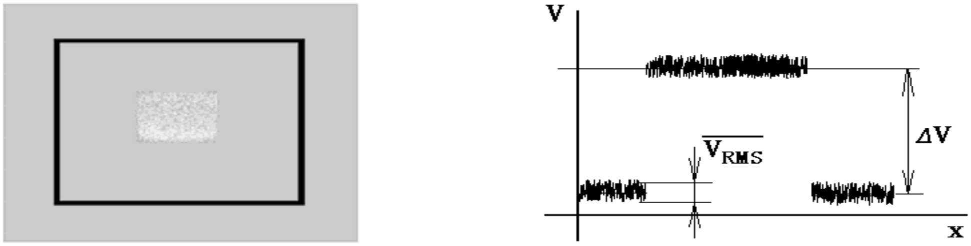
Set a testing area within the view field as shown in Fig. 1 (a). As is shown in Fig. 1 (b), under a uniform background, the fluctuation caused by any pixel in the testing area responding to V over time is called temporal noise, which is represented with VRMS - the standard deviation of V within a certain period. Its calculation formula is:

(a) Uniform background (b) Temporal noise

Figure 1. Pixel Temporal Noise

$$V_{RMS} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(V_i - \overline{V})^2} \tag{1}$$

Then calculate the average value $\overline{V_{RMS}}$ of temporal noise of all pixels in the testing area to include the effect of fluctuation over space caused by pixels responding to V (spatial noise).



(a) Thermal Image of Square Target (b) Signal and Noise

Figure 2. Testing of NETD

Set ΔT as the temperature difference between the square target surface and the background and make the square target form an image in the thermal imager as shown in Fig. 2 (a). Then the difference between the mean value of the square target thermal image and the mean value of the background thermal image is the image signal ΔV, as shown in Fig. 2 (b). Finally, SNR (signal to noise ratio) of the image when the temperature difference is ΔT is obtained, that is:

$$SNR = \frac{\Delta V}{\overline{V}_{RMS}} \tag{2}$$

Testing of Non-Uniformity

Measure the maximum value Vmax and the minimum value Vmin of pixel responding as shown in Fig. 2 (a), and the Non-Uniformity of infrared response of the focal plane detector is:

$$Non-Uniformity = 1 - \frac{V_{\max} - V_{\min}}{V_{\max} + V_{\min}} \tag{3}$$

Testing of NETD

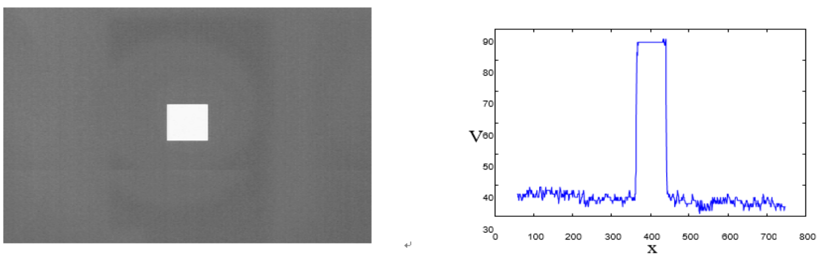
Establish a theoretical model for NETD to study the relationship between the output peak value signal of the thermal imager and the root-mean-square noise characteristics, the testing target and the background temperature so as to measure the temperature sensitivity of the instrument. According the testing principle of SNR, NETD is obtained through calculation of ΔT and SNR:

$$NETD = \frac{\Delta T}{SNR} = \frac{V_{RMS}}{\Delta V}\Delta T \tag{4}$$

To obtain NETD automatically, edge recognition on the infrared image of the square target must be carried out so as to correctly interpret different areas in the image. The horizontal edge of the square target is obtained by adopting the horizontal Sobel operator to conduct spatial filtering. And the horizontal Sobel operator is:

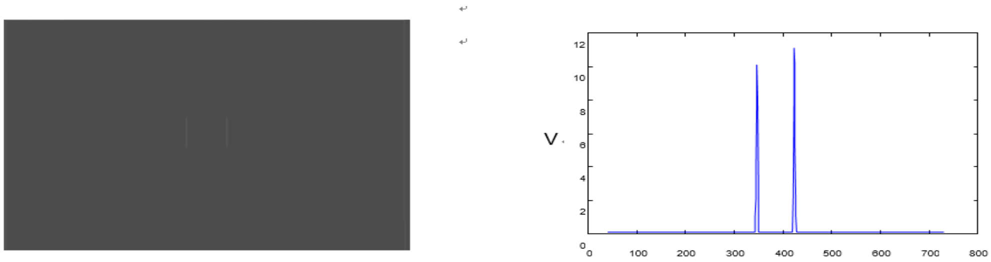
$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Thermal image of the square target is acquired first, as shown in Fig. 3. And then conduct edge recognition, as shown in Fig. 4.



(a) Overall Thermal Image (b) Section in Image

Figure 3. Thermal Image of Square Target



(a) Overall Thermal Image (b) Section in Image

Figure 4. Edge Recognition

The square target area and background area in the infrared image will be interpreted automatically by the software based on the edge obtained. Finally, calculate NETD according to the formula above.

Software Design and Realization

The testing & diagnosis system software includes testing software for industrial control computer and control software for DSP, of which the former can be further divided into the image capture & processing units, fault detection & diagnosis units and infrared system indexes-testing unit. The project team used Borland C++Builder software to carry out the programming and development since Windows XP systems are used for industrial control computers, but also to improve the compatibility and portability of the software system as well as the development convenience.

Fault diagnosis of the infrared equipment involves various knowledge of light, machinery, electricity and arithmetic fields. Due to the obscure and uncertain relationship between faults and symptoms and the simultaneous occurrence of multiple faults, it is difficult to adopt purely the symbol reasoning system or the neural network system. Therefore, a combination of the manual neural network system and the expert system is used to establish the expert system for fault diagnosis based on the former. The scheme design is shown in Fig. 5. And the user interface of the test and diagnosis system is shown in Fig. 6.

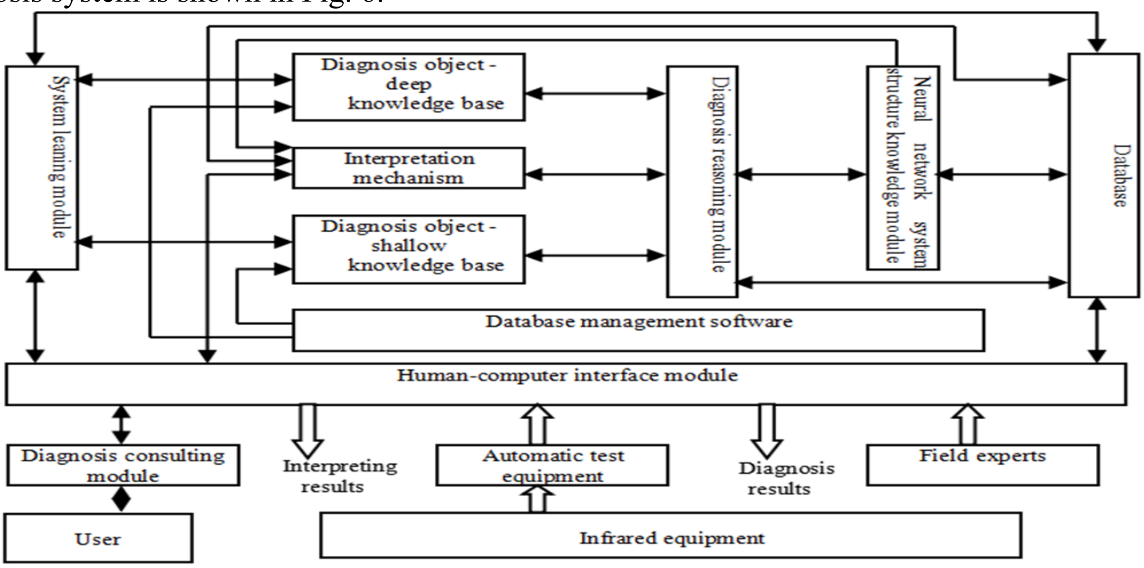


Figure 5. Design Scheme for Comprehensive Fault Diagnosis Expert System of Electro-Optical Equipment

Based on Neural Network System

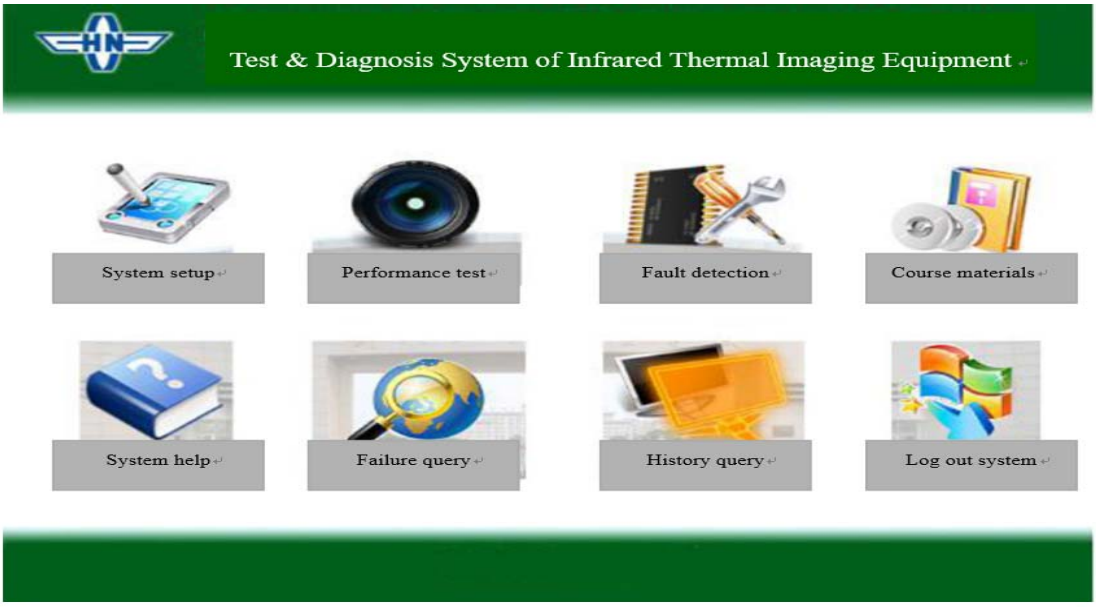


Figure 6. User Interface of the Test & Diagnosis System

Summary

This expert system has been put into practice, with the following listed effects: 1) Fault knowledge base on dendritical structure can help to avoid omitting diagnoses and make it easier to find faults; 2) Because the knowledge is stored in a relational database, the user is able to modify and browse the database as well as check and renew the knowledge in the database in a more convenient way. Furthermore, separation of the knowledge base, reasoning machine and application programs can be realized more easily, which is conducive to maintaining the whole expert system; 3) Complex reasoning function can be realized and the need to write procedure code greatly reduced with rules based on universal and flexible reasoning, as well as a concise reasoning process. Therefore, this system is able solve the problem of knowledge acquisition. While ensuring the completeness of the diagnosis knowledge, it can fully unlock the high-speed and high-efficiency advantages of the expert system.

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