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Study on the Measurement Technique of the Alignment Variation of Medical Infrared Thermal Imaging System

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Abstract

The change cause of the thermal imager alignment and its detection principle are analyzed in this paper. On this basis, an infrared thermal imaging is designed for the shortcomings of the traditional detection method, that alignment change detection system is based on CCD imaging technology. The cross pinhole target is used to establish the measurement space coordinate system for the digital image interpretation program in this system. The interpretation software is called about aiming at the baseline variation in the data processing system. According to the position relationship of the 5 pin hole in the field of the infrared thermal imager, the alignment change can be measured. The experimental results show that the system can effectively test the change in the baseline of the thermal imager, and the uncertainty of the test is better than 0.05mil.

***Keyword**: Alignment; Amount of change; Thermal imager; Infrared*

1. Introduction

With the development of infrared technology, infrared thermal imaging system plays an important role in medicine. The main use of medicine is to determine the patient's physical condition about the radiation wave. For example, the thermal imaging system can diagnose early breast tumor. Healthy women's breasts are symmetrical on both sides of the image. If there is an asymmetry, the patient is likely to develop breast disease. According to the radiation image of infrared thermal imaging system, the breast disease can be accurately determined. The alignment changes are a main parameter to reflect the performance of the infrared thermal imager. The development of modern equipment to test the changes of the infrared thermal imager is an important link to ensure the production quality of the infrared thermal imager.

2. Production of the Amount of Alignment Change

The amount of alignment change (also known as zero variation) of thermal imager (also known as infrared sights) refers to that the baseline of a thermal imager will produce a certain amount of change before and after it due to the impact of the use of the process, shock, *etc*. From Figure 2.1, the line OO_1 between the center of the objective lens of the infrared thermal imager and the sub center is alignment, the essence of the amount of change is the corresponding position changes to the alignment. The objective lens of an infrared thermal imager L_0, eyepiece L_e and the alignment OO_1 of dividing plate R_1 and the optical axis of thermal imager O_1O_2 are coincided, and the theory aimed is at baseline ll'. When the completion of thermal imager experiment, it lead to changes in the relative position.

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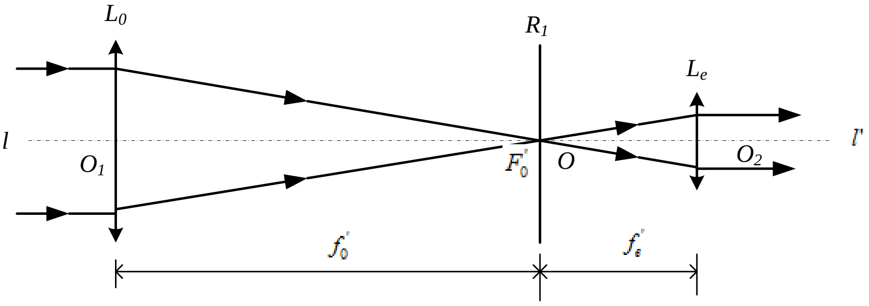

Figure 2.1. Ideal Working State of the Infrared Thermal Imager

As shown in Figure 2.2, because the sub center is offset after the experiment, there is a deviation angle β between baseline OO_1 and the theoretical optical axis ll'. At this time, the amount of alignment change of thermal imager relative to the baseline offset values is: $\theta = \beta$.

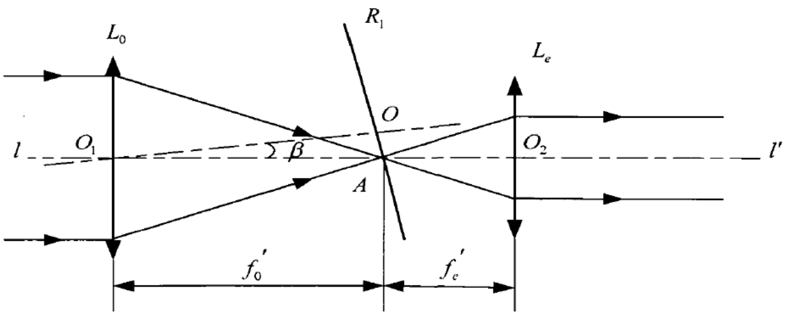

Figure 2.2. Changed Schematic of Alignment by Reticle

As shown in Figure 2.3, the thermal imager reticle board and the objective lens are offset in the process of test, There is a deviation angle α between the optical axis of thermal imager O_1O_2 and the theoretical optical axis ll', and there is a deviation angle β between alignment OO_1 and the theoretical optical axis ll'. The relations between the angle of figure shows that, the amount of alignment change of thermal imager relative to the baseline offset values is: $\theta = \alpha + \beta$.

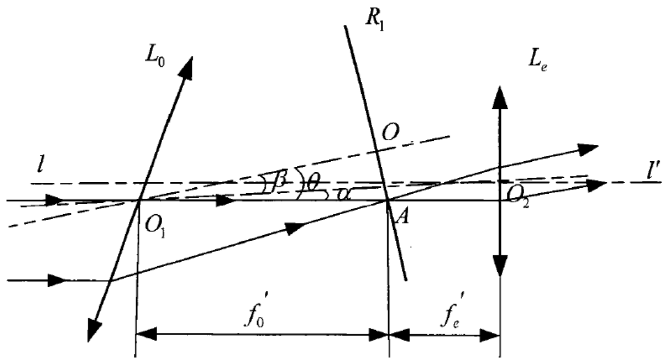

Figure 2.3. Changed Schematic of Alignment by Reticle Board and Objective Lens

As shown in Figure 2.4, after the experiment of infrared camera and the objective lens is completed, the reticle board and the eyepiece may shift due to the shock. According to the geometric relations of various angles in the figure, the amount of alignment change of thermal imager relative to the baseline offset values is: $\theta = \alpha + \beta$.

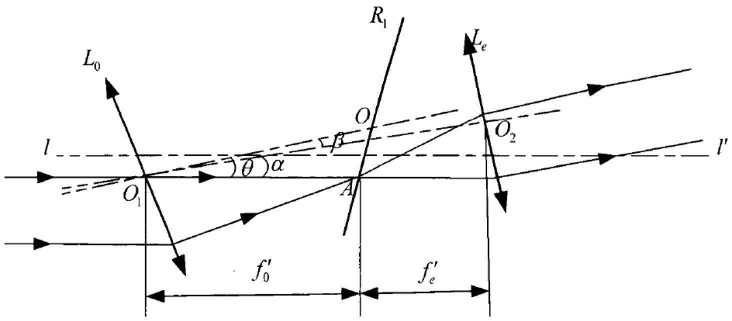

Figure 2.4. Changed Schematic of Alignment by Reticle Board, Objective Lens and Eyepiece

3. Alignment Variation Detection Principle

According to the causes of the amount of changes alignment above described, measuring the amount of alignment change of infrared camera needs a collimator to simulate infinity objectives. As shown in Figure 3.1, Le is the objective lens of parallel light tube, Re is dividing plate, reticle board center F'_e goes through parallel light tubes into the image point A, and the reticle board midpoint O of the thermal imager corresponding is to the reticle board point F'_O on collimator reticle board. In the figure, axis $F'_e O_e$ of the optical is reference axis ll' for the detection. According to the geometric relationship illustrated:

$$\theta = \angle F_e' O_e F_o'$$

$$\tan\theta = \frac{F'_E F'_O}{F'_e O_e} = \frac{F'_E F'_O}{f'_e}$$

$$\theta = \arctan(\frac{F'_e F'_O}{f'_e})$$

Since A is small, the above formula can be approximated as:

$$\theta = \frac{F'_e F'_O}{f'_e}$$

Wherein: $F'_e F'_O$ is offset that the image light pipe reticle board center formed on the reticle board of the thermal imager relative to the center of infrared reticle board, f'_e is the focal length of the light pipe.

In the actual testing process, the amount of alignment change θ can be obtained through direct measurement and indirect measurement method. As shown in Figure 3.1, the parallel light tube is rotated at a counter clockwise θ .The image point A that the collimator reticle board center formed on the thermal imager reticle board will coincide with the center *O* of the thermal imager reticle board, therefore, according to direct measurement, directly read out by the reading mechanism.

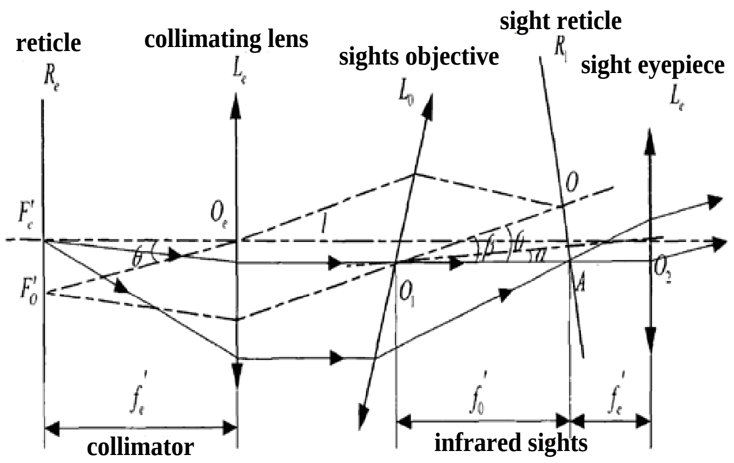

Figure 3.1. Aim Baseline Variation Detection Principle

When amount of alignment change is detected in practice, it usually does not take the turning collimator to obtain, so that not only affects the accuracy of the measurements, and this method is difficult to achieve. In the light of the above problem, a planar mirror is added in the light path of the parallel light tube to solve the problem, as shown in Figure 3.2.

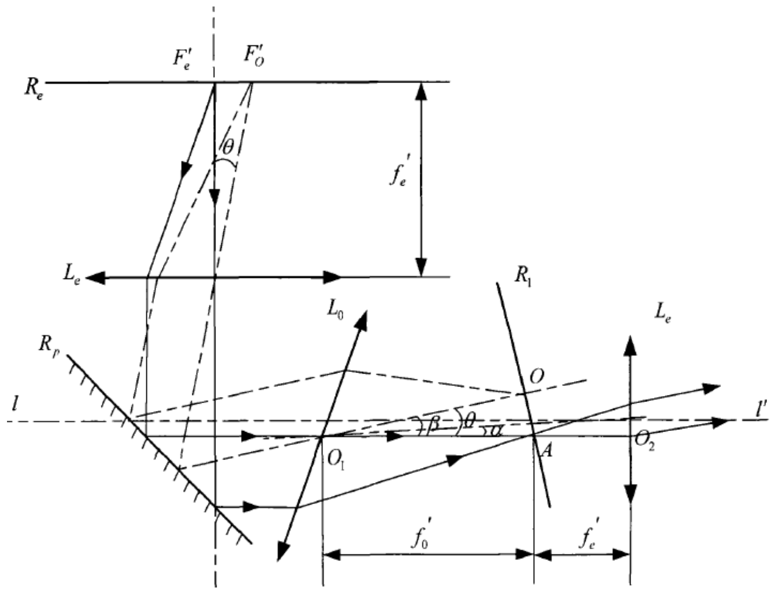

Figure 3.2 Reading Principle of Using Plane Mirror

If we want the image point A that the collimator reticle board center formed on the thermal imager reticle board coincide with the center O of the thermal imager reticle board, it is only necessary to rotate a plane mirror to a certain angle, which is known by the reflection principle, and it need to turn the mirror RP angle $\frac{\theta}{2}$

4. The Thermal Imager Alignment Variation Test System

4.1. Traditional Thermal Imager Alignment Variation Test System

Figure 4.1 The Alignment Variation of Traditional Thermal Imager Test Block Diagram

Traditional thermal imager alignment test variation is shown in Figure 4.1, the radiation temperature of surface blackbody is controlled by the control circuit, and its temperature accuracy determines the accuracy of the entire instrument. Traditional test equipment determines the amount of alignment change value by tester qualitative judging infrared target image effects by the thermal imager. Therefore, the test results from different testers will be different, there are some flaws.

4.2. Modern Thermal Imager Alignment Variation Test System

In this paper, "ten" pinhole integrated target, as shown in Figure 4.2, is used to establish measuring spatial coordinate system for the digital image interpretation program, and modern thermal imager alignment variation test method is shown in Figure 4.3.

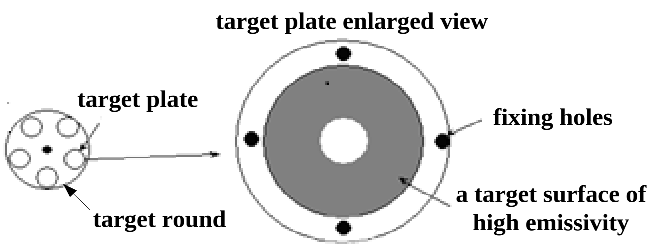

Figure 4.2 "Ten" Pinhole Integrated Target

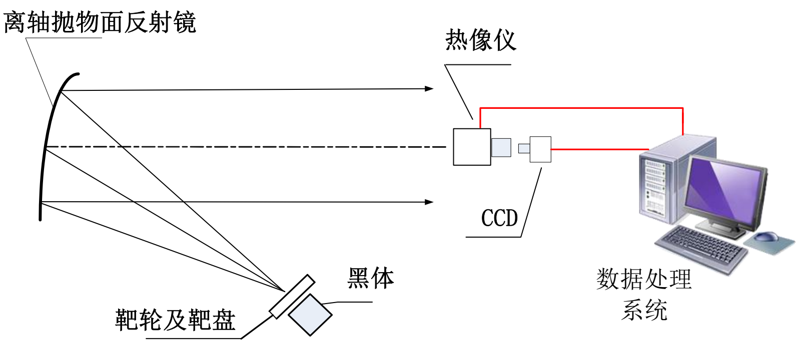

Figure 4.3 Modern Thermal Imager Alignment Variation Test Method

When the alignment variation interpretation software is called in data processing system, according to the five pinhole relative positional relationship of their division in the measured infrared camera field, its view give division position in the system angular measurement coordinates, and it is the zero position of alignment of the thermal imager. It needs to measure the zero momentum after the used thermal imager. The used imager on the same mounting base is installed, interpret the alignment zero value of the thermal imager. According to the amount of alignment change zero coordinate values before and after the test, walking zero amount of the thermal imager are get, that is the amount of alignment change.

5. The Measurement Results and Accuracy Analysis

Off-axis parabolic reflector is the body of the imager amount of alignment change test system. According to the functions and accuracy requirements, the design of its focal length is f = 1500mm, the diameter is D =Φ150mm, spectral range is: 8 ~ 14μm. In order to improve the precision, the resolution of the CCD is greater or equal to 1000×1000, and this experiment is indeed the Canadian Lumenera's Lu175m type camera. The differential temperature range of the surface blackbody is from －10℃ to 50℃, the effective radiation area is greater or equal to Φ30mm, the temperature resolution is 0.01 ℃, the temperature control accuracy is ± 0.3 ℃, the effective emissivity is greater or equal to 0.95.

Table 5.1 Zero Amount Walk Test Results (Unit: mil)

Frequency / Project	1	2	3	4	5	6
Measurements	3.418	3.417	3.423	3.424	3.421	3.420
Residuals	0.002	0.003	0.03	0.004	0.001	0.00

The test accuracy of the amount of alignment change of the thermal imager depends on the resolution of CCD camera. In this experiment, the camera resolution is more than 100 million pixels. The qualified indicators of the generally walking zero amount is not more than 0.7mil, that is, the angle is 151.2 per second. So the measuring range of the walking zero amount is little, can be set to ± 1 °. Thus, the selected resolution of the CCD is 1280 × 1024, so that each pixel corresponds to an angle of 4 °/ 1024 = 0.033mil, sub-pixel interpretation can be achieved by a certain weighted algorithm. So the accuracy of the infrared thermal imaging system at the zero position of the baseline is better than 0.05 mil. As it can be seen from Table 5.1, zero amount of walking test results is consistent with theoretical analysis results.

6. Conclusions

Since the infrared camera is with the advantages of fast response, wide measurement range, etc., it has been particular attention in the medical field. The amount of alignment change is main parameters to determine the infrared camera performance. In this paper CCD machine vision technology is implied, image interpretation techniques and infrared collimator technology is used to research the amount of alignment change of infrared measurement system deeply. Neither by moving the pinhole target nor by moving the reflector, the measurement of the amount of alignment change can be achieved. From the experimental results, the uncertainty of the system test is better than 0.05mil, higher than the current similar precision testing equipment.

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