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Research on accurate calibration method of screen plane equation of sky screen vertical target

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ABSTRACT

Aiming at the shortcomings of calibrating the screen plane equation by using traditional double theodolite intersection method, the optimization program of accurately calibrating the screen plane equation of the sky screen vertical target is proposed. The LED surface light source without off-axis phenomenon is designed as projection light source of light screen. The position and attitude of the reference ruler of the double theodolite measurement system are optimized. The technology of thickness center recognition of light screen are studied, which is designed a special light screen receiver with the functions of translation, rotation, lifting, fine adjustment, image capture and processing. The accurate calibration experiment of the screen plane equation of the sky screen vertical target has been completed. The feasibility and rationality of this scheme are verified through live fire experiments. Compared with the traditional double theodolite calibration method, the coordinate accuracy of the optimized calibration method is improved from 4 mm to 3 mm in an effective target surface of 1 m × 1 m.

1. Introduction

The intensity of vertical target is one of the main characteristic parameters for evaluating the performance of ballistic weapon system [1–3]. In the weapon range, the target coordinate of the projectile is usually measured by the sky screen vertical target measuring device [4,5]. The measuring principle is that the target coordinates of the projectile are calculated according to the plane equation of the light screen and the time of the projectile through the center of the light screen. The time can be accurately measured by the measuring instrument, and the measurement error is negligible. Therefore, the key to the accuracy of the measurement lies in the accuracy of the calibration of each light screen plane equation. The light screen projected by the sky screen vertical target is not visible, and the calibration [6] of the invisible light screen mainly adopts the double theodolite intersection method. The double theodolite intersection method has the advantages of simple orientation, easy realization of measurement method and high precision, etc. The coordinate value of points on the surface of light screen can be determined, and the plane equation of light screen can be obtained by fitting multiple points.

There are two methods to calibrate the screen surface by using the double theodolite intersection method: traditional calibration method [7] and non-disassembly calibration method [8,9]. The traditional calibration method comprises the following steps: arranging a double theodolite at a certain distance. Using the auxiliary baffle to receive the projected light screen, the center line of the screen strip is determined artificially, and the laser emitted from theodolite is aimed at three central points on the center surface in sequence, and the plane equation of the screen is obtained. Because of the human error, the screen plane can not be accurately

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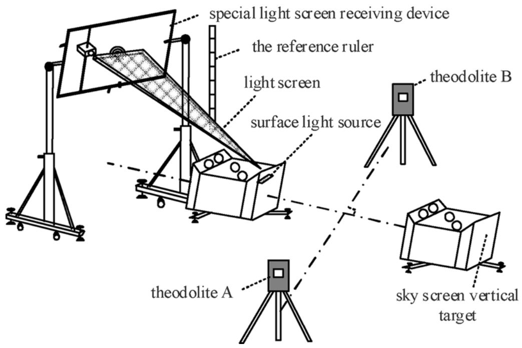

Fig. 1. Schematic diagram of calibration scheme.

calibrated. The basic principle of non-disassembly calibration method is as follows: According to the step change of the output signal of the sky screen vertical target acted by the small stroboscopic light source, the coordinates of three space points on the screen are obtained by using double theodolite, and the plane equation of the light screen is obtained. Due to the above two methods need to be optimized, the accuracy of the calibrated light screen plane equation is not high.

In this paper, the technique of calibrating the screen plane equation with double theodolite is studied, and the measuring system of double theodolite is optimized. The LED surface light source is designed to avoid the phenomenon of the sky screen off-axis. The measurement layout of double theodolite and the technology of thickness center recognition of sky screen are studied. The coordinate of the center point of the light screen is realized, so as to achieve the purpose of accurately calibrating the screen plane equation and to improve the accuracy of the existing calibration.

2. Overall scheme design and optimization

Based on the characteristics of the light screen, the existing methods for calibrating the light screen plane equation with the double theodolite are optimized, and the optimum design scheme is proposed. The overall schematic diagram is shown in Fig. 1.

The optimization scheme is mainly composed of theodolite A, theodolite B, the light screen receiving device, the surface light source, the sky screen vertical target and so on. The light source of projecting light screen, the accurate calibration of the double theodolite baseline and the technology of lght screen thickness center identification are optimized, respectively.

2.1. Optimal design of light source

The LED surface light source of projecting light screen can ensure that the width of projection screen is distributed symmetrically with the lens spindle as the center, and avoid the phenomenon that incandescent light source is easy to produce off-axis illumination after passing through slit and lens. The design principle of LED surface light source is shown in Fig. 2.

The circuit board with length of 65.2 mm and width of 42.8 mm is machined and welded.

2.2. Calibration optimization of double theodolite baseline

In this paper, the double theodolite intersection method is used. The baseline accuracy is related to the terminal coordinates of the datum. The center point of the reference ruler is taken as the space placement point. The optimization variable is used to find the proper position and pose of the reference ruler in order to achieve the goal of minimum baseline calibration error.

In order to be applied to practice, it is of engineering reference value to analyze the relationship between the baseline length and the optimal pose of the reference ruler. When the baseline length is determined, the position and attitude of the reference ruler corresponding to the minimum baseline error can be obtained by looking up the table, as shown in Table 1.

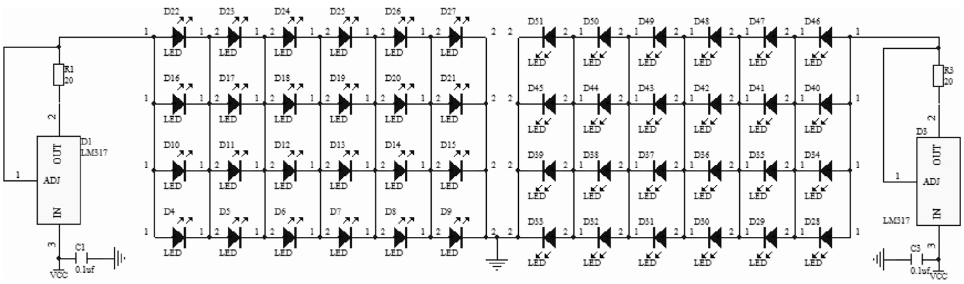

Fig. 2. Schematic design of surface light source.