Research on the Technology of Optical Motion Capture System for Robot Inspection

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ABSTRACK

Optical motion capture system has been widely used in measurement and control of biomechanics, medical treatment, UAV control and other fields. There have been experimental studies on the accuracy and accuracy of the optical motion system, but there is no study on the layout of the optical camera in the detection area to determine the detection volume boundary and calibrate the accuracy stability of the system within the detection volume. In this study, an optical motion capture system composed of eight OptiTrack Prime 13 cameras with equal spacing and single rings in the determined space was designed. According to the size of the detected object, the camera's angle of vision was adjusted through calculation to determine the maximum detection volume, and the system was calibrated within the detection volume to improve the calibration accuracy.The layout data of the optical motion capture system can be quantified to make the system test data stable and reproducible, and keep the consistency of the robot test parameters.

Keywords: Optical motion capture, Optirack Prime 13, Measurement error, Standard equation layout

1、Introduction

The research on mobile robots began in the late 1960s. Nils Nilssen and Charles Rosen et al. from Stanford Research Institute (SRI) developed a funded mobile robot named Shakey from 1966 to mid-1972. With the development of industrial technology, mobile robots can better adapt to complex working conditions, and the execution of large tasks even requires multi-robot cooperation and multi-robot coordination. In order to realize the above functions, the real-time navigation, positioning and motion parameters of the mobile robot need to be tested. In recent years, the optical motion capture system which uses vision to measure the target parameters and motion parameters has developed rapidly. The motion capture system has been widely used in robot control, UAV control, biomechanics and other fields[1-2]. Various experiments have been done in the past to evaluate the measurement accuracy of Optitrack [4-5]. When the camera of the motion capture system is arranged, the boundary of the capture volume of the motion capture system is not determined. When the motion capture system is calibrated, the boundary of the capture volume is sampled to provide poor calibration accuracy. If the capture volume is not sampled near the boundary, the accuracy of the system will be reduced [7].

Therefore, the purpose of this study is to improve the calibration accuracy and measuring stability of the optical motion capture system. Based on the height of the measured object, a standard equation is established to analyze and calculate the camera's angle of vision, determine the capture volume boundary, and determine the influence of calibration within the boundary on the calibration accuracy and test accuracy of the motion capture system.

2、materials and methods

The Optical motion capture system used in this study was composed of 8 Optitrack Prime 13 cameras and operated using Optitrack Motive software. Each camera is secured with a triangular stand. The calibration of Optical motion capture system was performed by hand using an Optitrak CW-500 calibration wand. Use CS-200 for calibration blocks that set the ground plane and the origin.The optical motion capture system was tested using the AUBO-I5, and the motion accuracy of the AUBO-I5 was ±0.02mm.The motion capture camera is arranged using a standard equation, and the panorama of the test area is shown in figure 1.

Figure 1 Panoramic view of a single ring layout of the test area

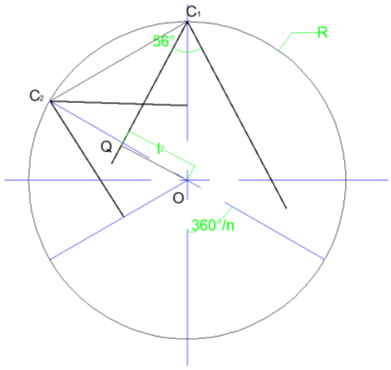

Figure 2 Horizontal viewing range of two synchronous cameras

To calculate the 3D mark position, there must be at least two synchronous cameras in the system simultaneously capturing and tracking the mark. Since the test room has a certain area, the layout area of the detection area is limited, so the maximum radius of the detection area can be determined. The height of the robot to be tested is determined according to the movement or execution of the robot during the detection process. Cameras are arranged at equal intervals around the detection area according to the standard equation, as shown in figure 2. The minimum horizontal distance between the overlapping boundary of two cameras' viewing angles from point O (origin) is line segment OQ, and a circle with line segment OQ as the radius is used as the safety detection area. The Opitrack Prime 13 camera has a horizontal viewing Angle of 56^0 [6]. According to the above conditions, the expression of the horizontal distance can be deduced as:

$$l_2 = \frac{Rsin28^0}{\cos\left(62^0 - \frac{360^0}{n}\right)} \quad (n \geq 6, n \in N) \tag{1}$$

Where, l_2 is the length of line segment OQ, ‘R’ is the distance between the tripod shaft and the center of the detection area, and ‘n’ is the number of cameras.

The height of the detection area shall meet the requirements of the detection height of the robot under test. The vertical Angle of the camera can be adjusted. As shown in figure 3, h_1 is the minimum height to meet the robot's detection requirements; h_2 is the installation height of the camera; R is the distance between the axis of the support frame and the origin of the detection area; l_1 is the effective detection radius of the camera. The Opitrack Prime 13 camera has a vertical view of 46^0 [6]. According to the above conditions, the formula of effective detection radius can be deduced as:

$$l_1 = R - h_2 \tan\left((90^0 - 46^0) - \tan^{-1}\left(\frac{h_2 - h_1}{R}\right)\right) \tag{2}$$

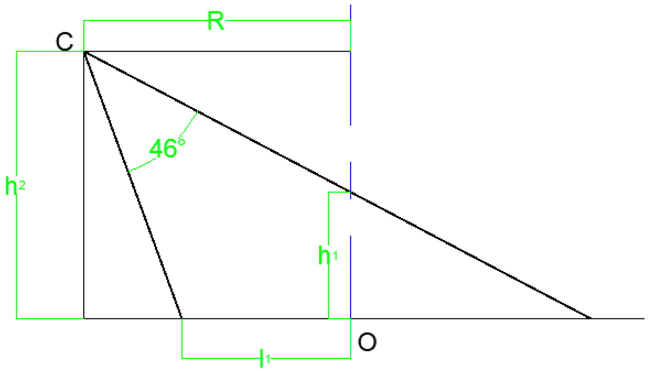

Figure 3 The camera's vertical perspective

According to the above standard equation and the size of the testing room, 8 cameras are arranged with equal spacing between rings, the distance (R) between the tripod axis and the center of the testing area is 3m, and the mounting height of the camera (h_2) is 2.5m. The value of (h_1) is 1.5m according to the robot testing needs. It can be calculated that l_2 is about 1.47m, l_1 is about 1.80m, and the radius of safe motion capture area is 1.47m, which is the smaller value of l_1 and l_2.In the calculation process, it is calculated that the vertical direction of the camera goes down horizontally 41.4^0 .

The optical motion capture system ensures a position error of less than 0.3mm and a steering error of less than 0.050, providing a high degree of accuracy for tracking with 6 degrees of freedom [6]. According to the camera's official website, the frame rate (FPS) of the camera is set at 240, and the default values of threshold, LED infrared value, exposure and other parameters are adopted.

The test verified that after the camera was preheated for 1 hour, the calibration rod CW-500 and calibration block CS-200 were used to calibrate the optical motion capture system arranged according to experience, and the calibration values were recorded. The robot was programmed to make the end-effector walk a circular arc at a height of 1m above the ground, and the optical motion capture system was used to record the moving trajectory data of the end-effector. After the data recording is stopped, the robot arm returns to the origin. The above operation is repeated 6 times [7].

After the camera is laid out and the calibration rod is used for calibration, the swinging range of the calibration rod shall not exceed 1.47m from the radius of the center and the height shall not exceed 1.5m.Repeat the data collection process for 6 times.

Through optimization, the two sets of data are synchronized [3]. 12 sets of data were evaluated, and the standard equation placement camera, calibration range, and measurement accuracy were analyzed [9-10].

3、RESULTS

The trajectory curve of the capture point data was fitted in Matlab. Figure 4 shows the trajectory curve of the capture point data of the optical motion capture system arranged empirically (Scheme 1). Figure 5 shows the trajectory curve of the capture point data of the optical motion capture system arranged according to the standard equation (Scheme 2).

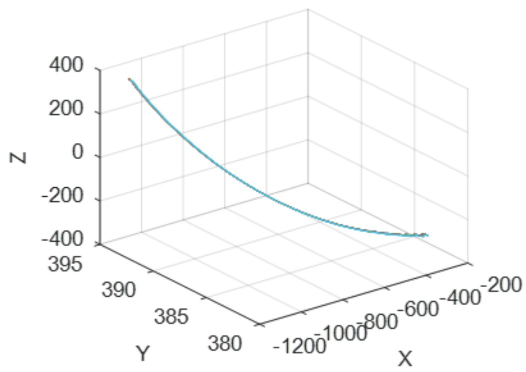

Figure 4 Fitting trajectory curve (Scheme 1)

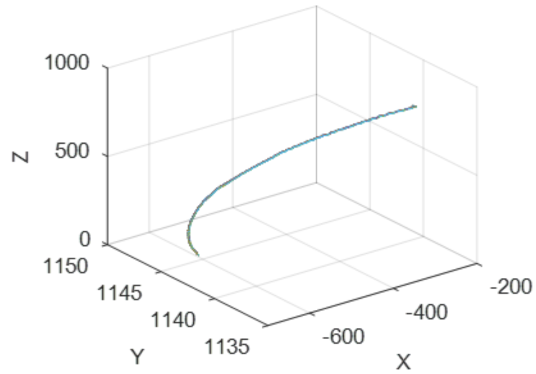

Figure 5 Fitting trajectory curve (Scheme 2)

Data analysis results are shown in Table 1. The test system of Scheme 1 has been calibrated for many times, and the calibration mean error is all greater than 0.180mm. The calibration mean error of the test data was 0.189mm, and the repetition error of the capture point was significantly different, and the test data fluctuated greatly. As expected, the calibration errors of the test systems deployed with the standard equations of scheme 2 were all less than 0.130mm. The calibration mean error of the test data was 0.126mm, and the repetition error of the capture point was narrowed. The reproducibility of the test data was high, and the stability of the test system was relatively improved.

Table 1 Test data error

Contrastive analysis	**Experience Calibration mean error:0.184mm**			**Normal equations Calibration mean error:0.126mm**		
	Maximum error	**Minimum error**	**Error mean**	**Maximum error**	**Minimum error**	**Error mean**
Curve 1-Curve 2	1.2373	0.0469	0.2213	0.6043	0.0796	0.4397
Curve 1-Curve 3	0.8742	0.0768	0.6259	0.3506	0.0374	0.1428
Curve 1-Curve 4	0.8392	0.0539	0.1550	0.5604	0.0700	0.3338
Curve 1-Curve 5	0.5805	0.0872	0.3569	0.3894	0.0539	0.1885
Curve 1-Curve 6	0.8246	0.1568	0.5040	0.6538	0.0819	0.4776
Curve 2-Curve 3	1.7605	0.0316	0.8354	0.4945	0.0819	0.3228
Curve 2-Curve 4	1.0900	0.0374	0.1848	0.7709	0.0088	0.3977
Curve 2-Curve 5	1.4859	0.0825	0.6259	0.5273	0.0355	0.3366
Curve 2-Curve 6	1.4859	0.1179	0.1550	0.8927	0.0324	0.2990
Curve 3-Curve 4	0.8351	0	0.6760	0.5870	0.0100	0.2898
Curve 3-Curve 5	0.4182	0.0539	0.3121	0.2936	0	0.1137
Curve 3-Curve 6	1.2593	0.0943	1.0932	0.6671	0.0374	0.3994
Curve 4-Curve 5	0.5255	0.0574	0.3978	0.8127	0.0100	0.3830
Curve 4-Curve 6	1.2326	0.0458	0.4219	0.3606	0.0141	0.2111
Curve 5-Curve 6	0.9530	0.0656	0.7897	0.8781	0	0.4807

4、DISCUSSION

The results of this study confirm that, according to the height of the object, the motion range needs, calculate the test area under the standard equation, adjust the height and view Angle of the camera, to meet the needs of different heights of moving objects, test system calibration mean error is small, improve the stability of optical motion capture system.

Under the above test conditions, the layout scheme of the optical motion capture system is quantified to improve the stability of the test system. The purpose of measurement is not only to give the value of the measurement results, but also to give the uncertainty of the measurement results. The stability of the test system is conducive to the quantification of the uncertainty. The maximum single point error of the empirically arranged measurement is 1.7605mm, and the average single point error is between 0.1550~1.0932mm. The maximum single-point error measured by the standard equation is 0.6mm, and the average single-point error is 0.1137~0.4807mm.Compared with the two, the error of the measurement results of the standard equation is greatly reduced.

The study had a number of limitations. The purpose of this study is to verify that the arrangement of the standard equations can improve the stability of the optical motion capture system and reduce the calibration error. Cameras are not optimized. All cameras are set to the same aperture, exposure, threshold, and LED brightness.The test results did not reach the test accuracy of the optical motion capture system [8].

The standard equation simplifies the complexity of the site layout scheme. The standard equation only supports the placement of the Opitrack Prime 13 camera and does not apply when using other models or a combination of models. For the small size of the object to be measured, the distance between the object to be measured and the camera can be reduced by arranging the camera according to the standard equation in a limited space, and the test results are relatively accurate. The layout of the standard equations has not yet been validated in other shaped test areas.

5、CONCLUSION

Under the standard equation arrangement, the calibration mean error of the measurement system is reduced and the stability of the optical motion capture system is improved.The above test results show that there are many error interference factors in the optical motion capture system, and it is necessary to further improve the accuracy of test data while ensuring the stability of the test system.

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7、ACKNOWLEDGMENT

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