Research on Stability and Accuracy of the OptiTrack System Based on Mean Error

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ABSTRACT

OptiTrack system was the most advanced optical motion capture system in recent years. Camera calibration was an indispensable part of optical motion capture. Its function was to convert 2D data obtained by each camera into spatial 3D data by multiple cameras. The mean error reflected the numerical relationship between the system coordinates and the world coordinates of the measurement area, so the mean error was related to the measurement accuracy of OptiTrack system directly. In this paper, the influence of average calibration error on measurement stability and accuracy was obtained by repeated calibration and sampling under control variables.

Keywords: OptiTrack System, mean error, measurement stability, Measurement accuracy

1. INTRODUCTION

Motion capture technology used in spatial pose detection is nothing new. Commonly used motion capture technology in principle can be divided into mechanical motion capture, acoustic motion capture, electromagnetic motion capture, optical motion capture[1]. These capture methods have their advantages and disadvantages in positioning accuracy, real-time control, convenience, price and cost, and multi-object capture performance, which complement each other. Due to the increasing demand for high precision data acquisition, space motion capture based on optics is becoming more and more popular. It has many advantages[2].(a)The activity range of the measured object is large, there is no cable, mechanical device restrictions, the use of more convenient.(b)High data collection frequency, more real reflection of the movement of the measured object.(c) The Markers are more economical and cost less.

OptiTrack system is an optical motion capture system developed by American Natural Point Company. The system is the industry's leading accurate motion capture and 3D tracking system, composed of infrared cameras and data processing software, etc., with ultra-high accuracy, minimalist workflow, ultra-low latency, high cost performance, open source SDK and other features. It is one of the most widely used motion capture systems in the world, which can track the motion state of the target in real time and display its three-dimensional coordinate information. This paper studies the relationship between the calibration accuracy, measurement accuracy and data stability of OptiTrack optical motion capture system.

2. OPTITRACK SYSTEM INTRODUCTION

Based on the principle of computer vision, OptiTrack system carries out coordinate measurement through the recognition and tracking of specific marks on the target. Cameras of the system are installed in a matrix, and the visual field overlap area of cameras is the effective measurement area. By receiving the light reflected from the mark points, the camera stores the information of the mark points as a grayscale image and obtains the position of the mark points in the two-dimensional image according to the grayscale information of the image [3]. For the same mark point, as long as it is seen by two cameras at the same time, the position of the point in space at that moment can be determined according to the images and camera parameters taken by two cameras at the same time and the principle of computer vision. The measurement process using OptiTrack system mainly includes system calibration, data acquisition and data processing [4].The purpose of system calibration is to determine the relative position relationship of the camera in space, as well as the position relationship of the world coordinate system, so it directly affects the accuracy of data collection.

The OptiTrack system in this paper is composed of eight cameras (6 Prime13 cameras and 2 Prime13W cameras). AS is shown in Figure 1.

(a) Prime13w cameras (b) Prime13 cameras

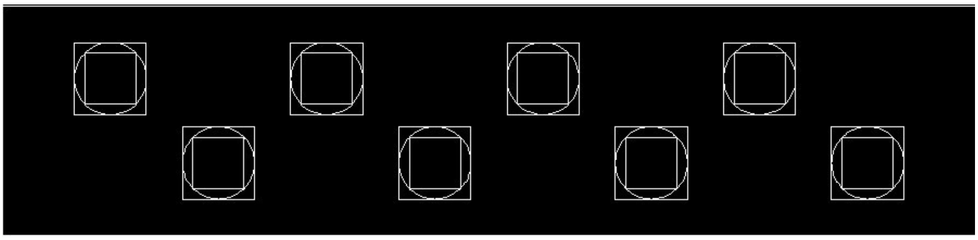
Figure 1.The OptiTrack system is composed of eight cameras

In the measurement process, if the position of a marker in the detection area is to be calculated, the marker must have at least two cameras in the system simultaneously capture the optical marker ball. When a mark is not seen by enough cameras (at least two) [5], the 3D mark will not appear in the captured data. Therefore, the visibility of the mark is very important for the whole process of motion capture, which requires the installation of optical motion capture cameras to be arranged properly [6]. Usually, optical cameras in the area are fixed in trusses or tripods and distributed evenly.

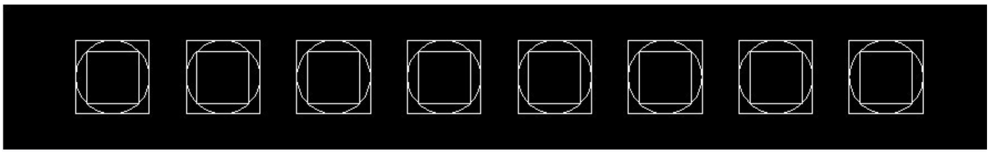
Each camera is mounted with facing the capture area. When installing an optical camera, we need to pay attention to the following points:

(1)The installation height of the optical motion capture camera should be higher than the maximum height of the measured object.

The camera height can be installed in the way of high and low, or in the way of the same height. The second installation method is adopted in this paper. AS is shown in the figure2 (b).



(a) High and low cross-mounted system cameras



(b) Uniform height mounted system cameras

Figure 2. Common installation method of system cameras

(2) In the capture area, the optical motion capture camera needs to be distributed equidistant.
(3) Adjust the Angle of the optical motion capture camera so that it looks at the subject under test.
In this paper, eight optical cameras are fixed on the tripods and distributed in a ring in the test area, as shown in the figure 3.

Figure 3 System placement scheme

3. OPTITRACK SYSTEM CALIBRATION PROCESS

At present, the calibration of the optical motion capture system requires the operator to calibrate it by waving the calibration ruler. However, in the process of manually waving the calibration ruler, the uniformity of the waving is difficult to be guaranteed, which directly affects the extraction of the mark points by the optical motion capture system and then affects the calibration results. In addition, with the calibration of randomness, such as moving track, speed, etc., can't guarantee in every calibration process, operating actions are completely consistent, lead to different even the same person after each calibration results have differences, but optical motion capture system is closely connected with calibration results and the system of the coordinate, it directly affects the calibration accuracy of optical motion capture system. This paper will illustrate the relationship between the calibration accuracy and the measurement results through experiments [5].

Before calibration, reflective spots in the test area need to be removed. OptiTrack calibration is performed by T-shaped calibration ruler, L-shaped calibration ruler and Motive running software. The function of T-shaped caliper is to feed back the sampling information to the camera to inform the camera of the spatial information. The L-shaped right-angle calibration ruler shall be placed on the center ground of the measurement area as the zero point of the spatial coordinate axis to inform the ground position of each camera and establish the system coordinate system. The long side of the T ruler is the negative direction of the Z-axis, and the short side is a square of the X-axis. The Y-axis is established according to the right hand coordinate criterion [8]. As is shown in the figure4 and figure 5.

Figure 4 T-shaped calibration ruler

Figure 5 L-shaped calibration ruler

Run the Motive System, and in the calibration page of OptiTrack, as shown in the figure 6, enter the model and size of the calibration ruler. It is very important to enter the matching ruler size here. If the wrong dimensions are provided for Motive, the calibrated 3D volume will be scaled incorrectly. Select "Complete Calibration" in the calibration type, and after confirming the calibration Settings, press START Wanding to begin the calibration.

Figure 6 Calibration setting interface

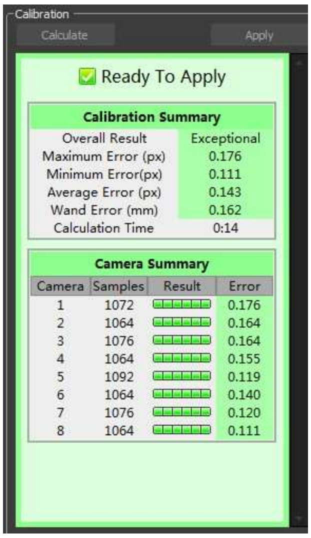


Figure 7 Number of samples from 8 cameras

The T-shaped calibration ruler is waved in the measurement area to collect spatial point samples continuously. The number of samples of each camera is shown in the figure 7.

At the same time, the sample in each camera in the plane coverage area will be shown accordingly. When each camera has collected a sufficient number of calibration samples, the software will calculate the collected samples by pressing the "Calculate" button on the calibration page. After the calculation is completed, a calibration result report will pop up and display detailed information about the calibration, as shown in the figure 8. Including maximum error, minimum error, average error, and calibration results are directly related to the average error, calibration results (in order from worst to best): poor, fair, good, excellent, excellent and special.Thus it can be seen that the quality of calibration has a great impact on the optical motion capture system.

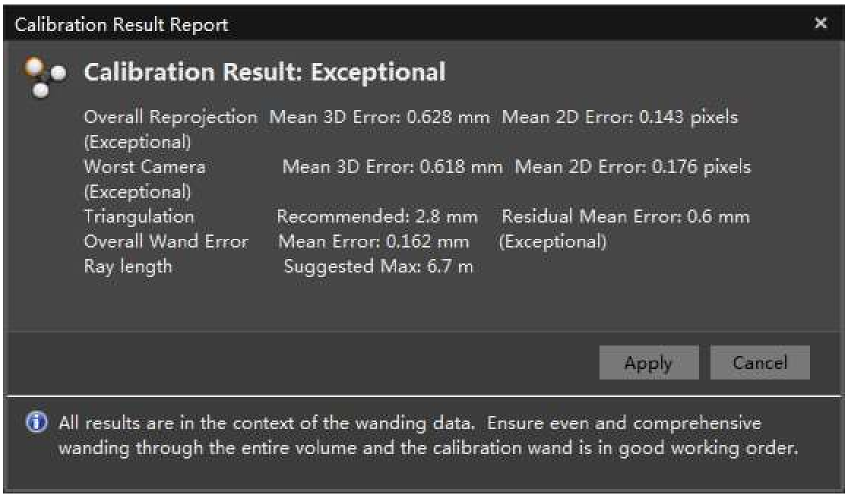


Figure 8 Display interface of calibration results

4. INFLUENCE TEST OF MEAN ERROR ON MEASUREMENT RESULTS

4.1 Influence of mean error on system data stability

As mentioned above, the test results may be affected by many factors, such as personnel and environment. Therefore, the test is carried out under the condition that many factors, such as illumination [9] and temperature [10] in the measurement area, physical location of the camera and the state of the tested object [11], are guaranteed to be quantitative. Under the same mean error value, the measured object is measured several times [12]. By comparing the continuously measured data x_i with the actual value x, the deviation value Δx_i can be obtained. By calculating the variance s^2 of a group of deviation values, the smaller the variance s^2 is, the more stable the system will be. Finally, the stability of the measuring system can be obtained under different mean errors [13].

$$s^2 = \frac{\left(\Delta x_1 - \overline{\Delta x}\right)^2 + \left(\Delta x_2 - \overline{\Delta x}\right)^2 + \cdots + \left(\Delta x_n - \overline{\Delta x}\right)^2}{n} \tag{1}$$

$$\Delta x_i = x_i - x \tag{2}$$

$$\overline{\Delta x} = \frac{\Delta x_1 + \Delta x_2 + \Delta x_3 + \cdots + \Delta x_n}{n} \tag{3}$$

For the purpose of the test, we used a moving track that could read out accurate data, the accuracy of the moving track can reach 0.001mm after metrological verification. As shown in figure 9. During the experiment, optical markers are installed on the moving track and driven forward or backward by the movement of the lead screw, the optical camera can obtain the position of the optical markers, and at the same time, the real data of the movement of the markers can be read out on the track.

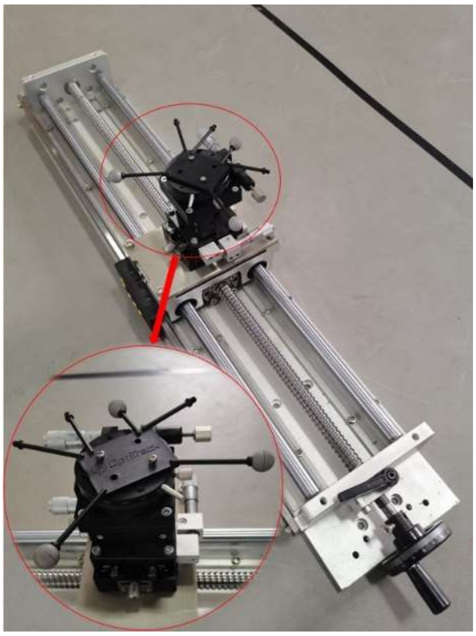


Figure 9 The moving track with optical markers.

The experimental results are shown in Table 1. In order to make the result more reasonable, the data measured by the system is accurate to the thousandth.

Table 1 . The deviation data when the system mean error is 0.162mm

Serial Number \ Mean Error 0.162mm	Absolute Displacement (mm)	True Value (mm)	Deviation (mm)
1	50.092	50.020	0.072
2	50.079	50.030	0.049
3	50.016	50.000	0.016
4	50.034	49.990	0.044
5	49.992	50.050	-0.058
6	50.110	50.010	0.100
7	50.051	50.000	0.051
8	50.127	50.010	0.118

9	49.842	50.000	-0.158
10	50.111	50.030	0.081

The above experimental steps were repeated and the system was calibrated for four times [12][14]. The measurement deviations under the four conditions of the mean error of 0.155mm, 0.144mm, 0.170mm, 0.099mm were obtained respectively, and the data were shown in Table 2, Table 3, and Table 4, Table 5.

Table 2 . The deviation data when the system mean error is 0.155mm

Serial number \ **Mean Error 0.155mm**	**Absolute Displacement (mm)**	**True Value (mm)**	**Deviation (mm)**
1	49.984	50.000	-0.016
2	49.981	50.010	-0.029
3	50.077	50.000	0.077
4	50.204	50.040	0.164
5	50.071	50.000	0.071
6	50.110	50.000	0.110
7	50.055	50.020	0.035
8	50.221	50.030	0.191
9	50.204	50.050	0.154
10	50.139	50.010	0.129

Table 3 . The deviation data when the system mean error is 0.144mm

Serial number \ **Mean Error 0.144mm**	**Absolute Displacement (mm)**	**True Value (mm)**	**Deviation (mm)**
1	50.026	50.000	0.026
2	50.054	50.030	0.024
3	50.118	50.000	0.118
4	50.159	50.000	0.159
5	49.955	50.000	-0.045
6	50.011	50.000	0.011
7	50.027	50.020	0.007
8	50.058	50.010	0.048
9	50.078	50.010	0.068

10	50.033	50.030	0.003

Table 4 . The deviation data when the system mean error is 0.170mm

Serial number \ Mean Error 0.170mm	Absolute Displacement (mm)	True Value (mm)	Deviation (mm)
1	50.076	50.030	0.046
2	50.163	50.010	0.153
3	50.010	50.030	-0.020
4	50.082	50.040	0.042
5	50.035	50.040	-0.005
6	50.072	50.000	0.072
7	50.083	50.010	0.073
8	50.092	50.000	0.092
9	50.026	50.040	-0.014
10	50.034	50.000	0.034

Table 5 . The deviation data when the system mean error is 0.099mm

Serial number \ Mean Error 0.099mm	Absolute Displacement (mm)	True Value (mm)	Deviation (mm)
1	50.049	50.090	-0.041
2	50.074	50.010	0.064
3	50.073	50.000	0.073
4	50.573	50.540	0.033
5	50.269	50.010	0.259
6	49.989	50.010	-0.021
7	50.088	50.000	0.088
8	50.008	50.000	0.008
9	50.063	50.010	0.053
10	50.008	50.010	-0.002

According to the test data in Table 1, the variance value of the measurement deviation can be calculated as 0.0061 mm^2

by the formula (1), when the mean error value of the OptiTrack system is 0.162 mm . In addition, when the mean error of the system is 0.155 mm , 0.144 mm , 0.170 mm and 0.099 mm , the variance value of the measurement deviation can be calculated, as shown in Table 6. In addition, when the mean error of the system is 0.155 mm , 0.144 mm , 0.170 mm and 0.099 mm , the variance value of the measurement deviation can be calculated, as shown in Table 6.

Table 6 . Measurement deviations corresponding to different mean errors of the system

The Serial Number	**Mean Error(** mm **)**	**Standard Deviation(** mm^2 **)**
1	0.162	0.0061
2	0.155	0.0050
3	0.144	0.0032
4	0.170	0.0026
5	0.099	0.0064

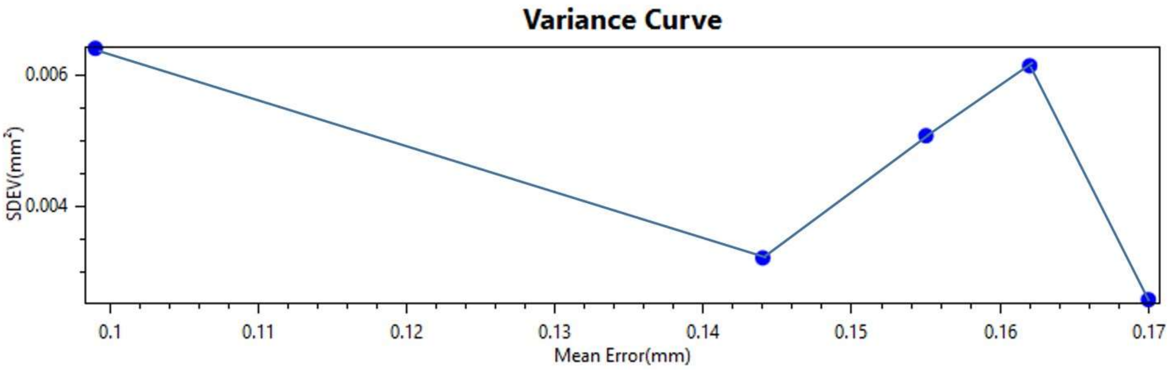


Figure 10 Variance corresponding to different mean errors of the system

As can be seen from Table 6, when the mean error of the system is 0.170 mm , the variance value is the smallest, which is 0.0026 mm^2 , and the test data at this time is the most stable. When the mean error of the system is in the other values and the variance of the measured data is all less than 0.007 mm^2 , it can be seen that the OptiTrack system has a high stability. However, there is no obvious linear relationship between the variance of the system mean error and the deviation data.

4.2 Influence of mean error of system on measurement accuracy

In order to test the measurement accuracy of OptiTrack system, error analysis was made on the experimental data obtained in this paper. Through multiple calibration of OptiTrack system, the different mean errors of systems in Table 6 were obtained. Ten sets of data were obtained under five different mean errors, which were compared with the true value, and five sets of error curves were obtained through data analysis. As shown in the figure 11 below.

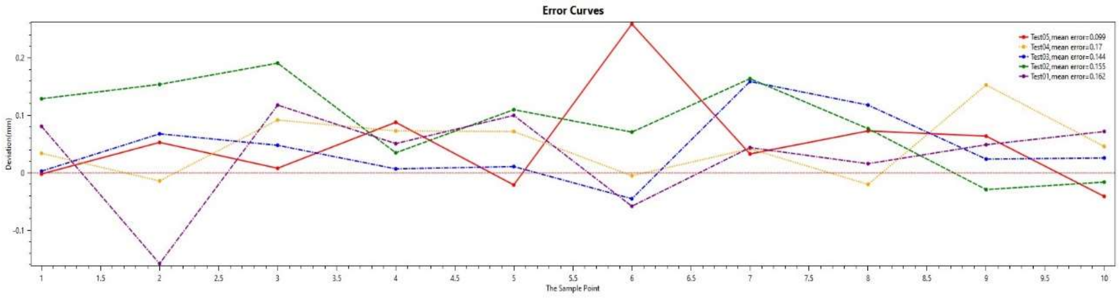


Figure 11 Error curves for several different mean errors of systems

It can be seen from the figure11 that the impact of average calibration error on the accuracy of measurement results is not linear. Therefore, when we use OptiTrack system for measurement, we should keep the mean error below 0.2 mm each time, so that the accuracy of measurement results can achieve the best.

5. CONCLUSIONS AND PROSPECTS

In this paper, the OptiTrack system was introduced, the effect of mean error of the system on the measurement stability and accuracy of the system was tested, and the data were analyzed. It was concluded that when the average calibration error of OptiTrack system was less than 0.2 mm, the standard variance of the measurement deviation of the system was better than 0.007 mm^2, which has high stability. Meanwhile, the accuracy of repeated measurement of data is better than 0.2 mm.

Through analysis above, it can be seen that OptiTrack system can meet the requirements of high-precision testing. Of course, the influence of other factors such as temperature, illumination and measurement area on the system accuracy needs to be further studied. Due to the idle conditions of the test, this test is not very comprehensive, but it can provide some reference for the follow-up research.

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