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Calibration Specification for Optical 3D Measuring Systems Based on Structured Light Scanning

基于结构光扫描的光学三维测量系统校准规范

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1 Scope

This calibration specification applies to the calibration of optical 3D measuring systems based on structured light scanning (hereinafter referred to as structured light measuring systems).

2 Terms and definitions

The following terms and definitions apply to this Specification.

2.1 point cloud [data]

A set of spatial coordinate points that are obtained by measurement to characterize contour features and are associated with each other.

2.2 ball bar, dumb bell

An etalon consisting of two spherical targets of the same diameter connected by a rigid structure.

2.3 ball plate

A standard measuring tool consisting of a series of standard balls with different diameters and a fixed bottom plate.

2.4 structured light

A beam of light with a defined pattern projected onto the profiled surface to be measured.

2.5 spherical form probe error; P_F

The range of statistical variation in the radial distance between the measured point and the fitted sphere.

2.6 size probe error; P_S

The difference between the standard ball diameter obtained by point cloud fitting and the reference value.

2.7 flat form probe error; F

In the vertical direction of the point cloud fitting plane, the maximum distance between all points in the point cloud.

2.8 sphere-spacing error; SD

The difference between the measured value and the reference value of the center distance between two balls.

3 Overview

The structured light measuring system is a non-contact measurement device. By projecting the structured light onto the surface of the measured object, and by collecting the point cloud of the structured light pattern on the surface of the measured object, the surface contour features of the measured object are calculated and obtained. The structured light measuring system is mainly composed of a camera (including a lens group), a structured light projection device, a calibration board, and measurement software. The composition of a typical structured light measuring system is shown in Figure 1.

Structured light measuring systems are divided into single-view system and multi-view system. A single-view system refers to a structured light measuring system that does not change the relative position of the structured light measuring system and the measured object during measurement. The multi-view system refers to structured light measurement in which point clouds are collected from different directions of the measured object by changing the relative position of the structured light measuring system and the measured object during measurement, and all point clouds are transformed into a unified coordinate system for data processing system. The multi-view system can be composed of multiple structured light measurement subsystems installed in different directions of the measured object. It can also be constructed by moving the single-view system to different directions of the measured object.

5 Calibration conditions

5.1 Operation modes and environmental conditions

Before calibration, the operation mode needs to be set, including the type and brightness of lighting, the measurement range, the type, quantity and distribution of sensors used in the system.

Environmental conditions, including environmental vibration, background light, ambient temperature and its uniformity, rate of change, shall be considered in the uncertainty assessment. At the same time, there shall be no other environmental factors affecting the measurement.

5.2 Calibration software

1) The matching (data acquisition and data processing) software of the equipment shall be used in the calibration process.

2) Set the point spacing, shutter time, sparse point cloud parameters, rejection rate, and fitting algorithm for image acquisition and processing.

NOTES:

1. When sparse point cloud is required, it shall be carried out according to the instruction manual. If these parameters are not specified by the manufacturer, no sparse point cloud is performed.

2. The rejection rate is set at 0.3%.

3. Unless otherwise specified by the manufacturer, the fitting algorithm is recommended to use the least squares method.

5.3 Etalons for calibration

Etalons for calibration shall be made of ceramic, steel, aluminum or other rigid material. It shall have a diffuse surface (non-volumetric scattering). The etalons used to calibrate

The sphere-spacing error SD shall be measured at 7 different positions in the entire measurement range. It is recommended to arrange and measure the etalon as shown in Figure 5.

For all measurement positions, use the fixed radius fitting method to fit all the center positions of the sphere. Each view takes a center coordinate in each ball bar.

When calculating the sphere-spacing of the ball bar at each position, the two ball center coordinates of the ball bar at each position shall be obtained from the measurement results of different viewing angles.

See 6.3.1 for the calculation method of the sphere-spacing error.

7 Processing of calibration results

Calibration certificate is issued to the calibrated structured light measuring system. The calibration certificate shall meet the requirements of 5.12 in JJF 1071-2010. Calibration results and their uncertainties list the calibration items and data. Indicate necessary information such as point spacing, shutter time, sparse point cloud parameters, proportion of deleted points, fitting algorithm, manufacturer and version number of the software used.

8 Recalibration interval

The user decides the recalibration interval according to the actual usage. It is recommended that the interval between recalibration shall not exceed 1 year.

Where,

$u(L_{ai})$ - the standard uncertainty component introduced by measurement repeatability;

$u(L_r)$ - the standard uncertainty component introduced by etalon.

A.4 Standard uncertainty components

A.4.1 Standard uncertainty component $u(L_r)$ introduced by etalon

A.4.1.1 Standard uncertainty component introduced by ball bar reference value

The measurement uncertainty of the reference value of the ball bar is 5.0μm, and the inclusion factor k=2, then

$$u_1(L_r)=\frac{5.0\ \mu\text{m}}{2}=2.5\ \mu\text{m}$$

A.4.1.2 Standard uncertainty component introduced by ball bar temperature variation

The coefficient of linear expansion of the ball bar is $(8\pm1)\times10^{-6}$°C^{-1}. The length is 99.984mm. The temperature measurement error is better than ±0.5°C. According to uniform distribution, then

$$u_2(L_r)=\frac{L\alpha\Delta t}{\sqrt{3}}=\frac{99.984\ \text{mm}\times8\times10^{-6}\ ℃^{-1}\times0.5\ ℃}{\sqrt{3}}\approx0.23\ \mu\text{m}$$

A.4.1.3 Standard uncertainty component introduced by measurement error of linear expansion coefficient of ball bar

The coefficient of linear expansion of the ball bar is $(8\pm1)\times10^{-6}$°C^{-1}. Obey uniform distribution in the half-width interval 1×10^{-6}°C^{-1}. The ambient temperature of the laboratory is estimated by an average deviation of 5°C, then:

$$u_3(L_r)=\frac{L(t-20)\Delta\alpha}{\sqrt{6}}=\frac{99.984\ \text{mm}\times5\ ℃\times1\times10^{-6}\ ℃^{-1}}{\sqrt{6}}\approx0.29\ \mu\text{m}$$

A.5 Composite standard uncertainty

See Table A.1 for a list of standard uncertainties.

------ The End ------