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Application Research of a Rear View Directional Registration Method in Indoor Scanning

Chuanli Kang[1,2], Tuanneng Lu[1,2*]

[1]Guangxi Key Laboratory of Spatial Information and Geomatics, Guilin, Guangxi, 541006, China

[2]Guilin University of technology, Guilin, Guangxi, 541006, China

[*] Corresponding author's e-mail: 1099857450@qq.com

Abstract. For indoor environments, laser scanners cannot receive satellite signals, and engineering needs to obtain indoor point cloud coordinates. This paper proposes a back sight directional registration method: sweep the scanning site at a known point, scatter the target site at another known point, and accurately scan the target to obtain the precise feature points of the back-sight point. The data of the scan site are converted to a known point coordinate system during data processing. Experimental results show: the method can not only register the two-site cloud data with high precision, but also have higher precision of the point cloud coordinates after converting the coordinates. To meet the actual engineering needs, it can provide reference for engineering applications such as indoor scanning and tunnel scanning.

1.Introduction

Since the ground 3D laser scanner is limited by the field of view of the scanner and the shadow between the objects when collecting the data, each station scan can only obtain the point cloud data in the current scanner coordinate system. To get the complete surface coordinates and attribute data of the scanned scene, the scene must be scanned from different angles of view. The 3D laser point cloud data acquired by multiple scanning stations are registered to convert the point cloud data in different coordinate systems into a unified coordinate system. However, in the indoor scanning, since the scanner cannot receive the satellite signal, the indoor point cloud coordinate data required for the project cannot be performed by the indoor scanning. For the registration and indoor scanning and positioning problems, domestic and foreign scholars have conducted relevant research and achieved progress. In [1], an improved two-dimensional laser scanning matching method is proposed. This method does not require a priori information to reduce the complexity of feature matching. The feature line screening method is used to reduce the computational complexity of the matching algorithm. Literature [2] proposed an indoor scanning matching SLAM method based on geometric feature correlation. The method is a complete endpoint definition and extraction method, which associates the line segment features with the complete endpoints, optimizes the geometric feature scan matching process, and then performs accurate convergence of the attitude angles, and the indoor positioning accuracy is high. In [3], an indoor flight positioning method based on laser ranging scanning is proposed. The ICP matching is performed by replacing the laser scanning data with the characteristic points of the indoor environment, which reduces the matching time and improves the rapidity of the SLAM algorithm. Literature [4] proposed a fast-spatial point cloud data registration method (PCA-ICP). For the improvement of ICP algorithm, domestic and foreign scholars have proposed

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different improvement methods, mainly in the determination of corresponding points and the robustness of the algorithm. For example, the literature [5] [6] [7] and other studies, proposed different ICP algorithm improvements, registration accuracy and registration efficiency have been significantly improved. The method uses principal component analysis to find the optimal spatial registration conversion parameters, which avoids the problem that the ICP algorithm falls into local optimum for finding the optimal solution. This method improves the registration speed. The methods proposed in the above studies can solve the registration and indoor positioning problems, but they are not easy to implement. To this end, this paper proposes an easy-to-understand and easy-to-implement indoor registration method: this method is similar to the total station rear view orientation principle, and realizes point cloud data registration through coordinate conversion, which is not only easy to operate but also easy to understand.

2.Coordinate conversion and evaluation method

Rear view orientation registration is performed by rotating, translating and scaling the original coordinate system *o-xyz* to coincide with the total station coordinate system *O-XYZ*. The three-dimensional coordinates (*X*, *Y*, *Z*) of the target are measured using a high-precision total station. Use the scanner to accurately scan the target and extract the coordinates (*x*, *y*, *z*) of the target in the scanner coordinate system. Use spatial similarity transformation formula:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = R \begin{pmatrix} x \\ y \\ z \end{pmatrix} + T \qquad (1)$$

Convert scanner coordinates to a total station coordinate system, where *R* is the rotation matrix between the two coordinate systems, and *T* is the translation matrix. If the coordinate system is rotated by α degrees around the *x*-axis, β degrees around the *y*-axis, and γ degrees around the *z*-axis, the rotation matrix in three directions of *x*, *y*, and *z* can be obtained: $R_x(\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix}$,

$$R_y(\beta) = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix},\ R_z(\gamma) = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad (2)$$

Thus, the rotation matrix of the coordinate transformation is:

$$R = \begin{bmatrix} cos\alpha cos\beta & cos\beta sin\gamma & sin\beta \\ -cos\alpha sin\gamma - sin\alpha sin\beta cos\gamma & cos\alpha cos\gamma - sin\alpha sin\beta sin\gamma & sin\alpha cos\beta \\ sin\alpha sin\gamma - cos\alpha sin\beta cos\gamma & -sin\alpha cos\gamma - cos\alpha sin\beta sin\gamma & cos\alpha cos\beta \end{bmatrix} \qquad (3)$$

The transformation parameters are used to convert the scan coordinates of the target point to the total station coordinate system, and compared with the measured coordinates of the total station, thereby determining the accuracy of the point cloud data conversion coordinates. The error of the scanning point in the three coordinate directions are:

$$\Delta x = X - x',\ \Delta y = Y - y',\ \Delta z = Z - z' \qquad (4)$$

In the formula, (x', y', z') is the coordinate of the scanning point in the total station coordinate system after the *R*, *T* conversion. If *n* points are measured, the error in each axial point and the error in the position are:

$$\sigma_x = \pm\sqrt{\frac{\sum_{i=1}^{n} \Delta x_i^2}{n}}\ ,\ \sigma_y = \pm\sqrt{\frac{\sum_{i=1}^{n} \Delta y_i^2}{n}}\ ,\ \sigma_z = \pm\sqrt{\frac{\sum_{i=1}^{n} \Delta z_i^2}{n}} \qquad (5)$$

$$\sigma_p = \pm\sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \qquad (6)$$

3.Data acquisition and data processing

This experiment first uses the GPS receiver to collect the outdoor control points using the RTK (Real Time Kinematic) measurement method, and then uses the total station instrument to adopt the "rear rendezvous" or "known back sight point" method. It is reasonable to arrange two control points indoors as scanning stations. These two points require mutual view, and then the target is deployed, and the coordinates of the target midpoint are measured using the total station. Next is the scanner installation and data acquisition. In this experiment, a room was scanned using a RIEGL-VZ 1000 3D laser scanner, a scanner was set up at one of the measured control points, the centering was leveled, and the other control point was used to erect the target for rear view orientation. Each target is cleaned during scanning to more accurately extract the position of the target center point. After the scan is finished, the scan data is opened using the online supporting software RISCAN_PRO. In order to reduce the influence of noise points on the accuracy of the data, the point cloud denoising is first performed. After denoising, the coordinates of the target center point are extracted by using software. The coordinates at this time are the coordinates defined by the scanner itself, and are listed in the table with the coordinates of the center point of the total station measurement target. The coordinate data is shown in Table 1.

Table 1. Target scan coordinates and total station coordinate data

Target label	Scanning coordinates			Total station coordinates		
	x	y	z	X	Y	Z
TP_001	-0.631	-1.587	0.232	xxx3613.521	xxx083.574	156.541
TP_002	-2.661	-3.268	-0.926	xxx3644.211	xxx074.366	156.845
TP_003	-8.040	-5.262	-0.933	xxx3632.326	xxx063.462	156.185
TP_004	-4.895	4.917	0.151	xxx3637.311	xxx093.361	157.101
TP_005	-4.913	4.895	-0.885	xxx3637.305	xxx093.315	157.053
TP_006	-1.980	7.038	-0.887	xxx3635.556	xxx093.785	156.681
TP_007	-1.562	7.393	-0.891	xxx3636.846	xxx093.478	157.036

Import the scan station control point coordinates into the scan data, then select the control point list, copy the control point coordinates to the scan coordinates, click "Backsighting orientation", and select the scan site corresponding to the control point list point. Then select the rear-view orientation point, select the target point on the tripod, and click Next to complete the scan coordinate transformation to the total station coordinates. Drag the two-site cloud data after coordinate transformation to the same window to open, you can see that the two stations scan data have been spliced together, and the splicing result is shown in Figure 1. From the outdoor view, the two-site cloud data has been completely spliced together, and the red dot cloud and the gray-white point cloud in the public area are interlaced to form a red and white area, indicating the fusion degree of the two-site cloud. Figure 2 shows the registration of the indoor point cloud. It can be easily seen that the two sites of cloud data complement each other in the scanning blind zone, making the indoor data completer and more accurate. Public scanning area building wall is intercepted and enlarged to see the degree of point cloud fusion. As shown in Figure 3, it can be seen that the gray point cloud and the red point cloud are merged together, indicating that the vertical direction point cloud data can be well stitched together. Intercepting the ground part of the public scanning area to enlarge the point cloud fusion degree is shown in Figure 4. It can be seen that the gray point cloud and the red point cloud can also be well integrated, indicating that the horizontal point cloud data can also be well stitched together

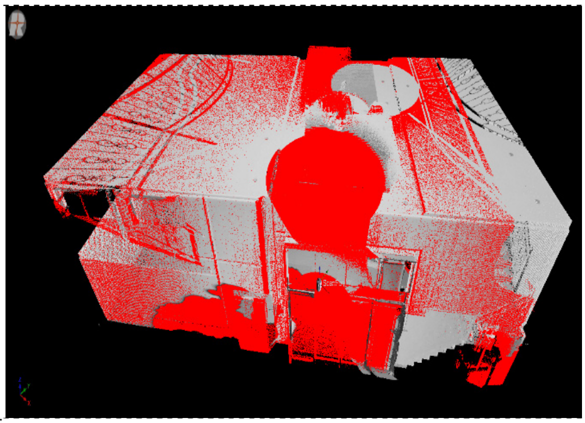

Figure 1. Registration result graph after coordinate transformation (indoor)

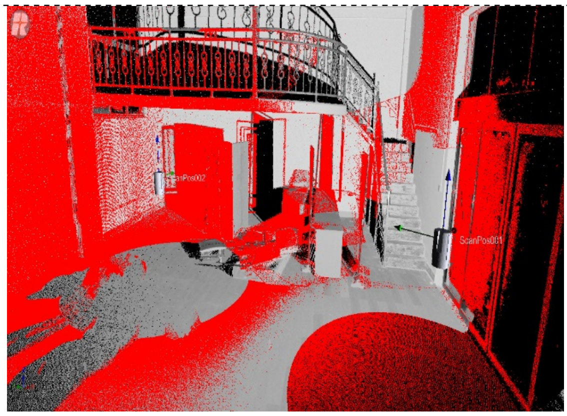

Figure 2. Registration result graph after coordinate transformation (outdoor)

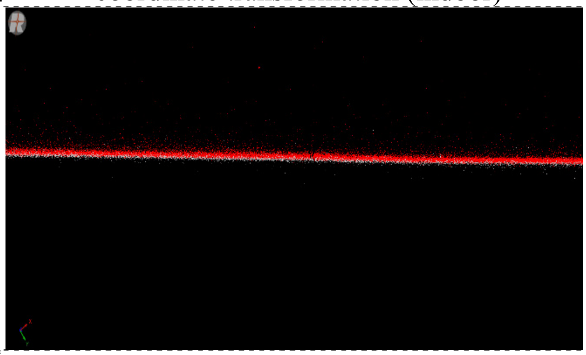

Figure 3. Partial enlargement of wall and ground point cloud fusion (Wall fusion effect)

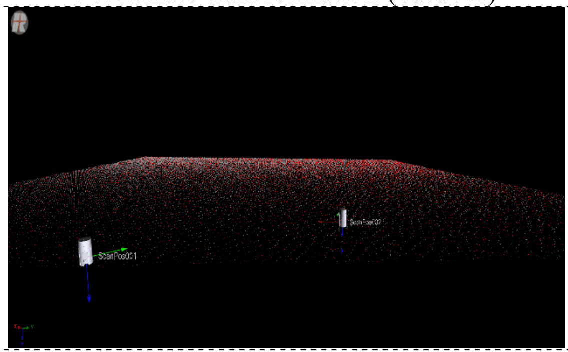

Figure 4. Partial enlargement of wall and ground point cloud fusion (Ground fusion effect)

In order to determine the accuracy of the coordinate data of the point cloud after the coordinate conversion, the point coordinate of the target measured by the total station is used as the detection point, and the coordinates of the target point in the point cloud data after coordinate conversion are compared. The difference between the scanned coordinates and the detected points is shown in Table 2.

Table 2. Scanning coordinates after conversion and total station coordinate difference

Target label	Scan coordinates after conversion			Coordinate difference(m)		
	X	*Y*	*Z*	*ΔX*	*ΔY*	*ΔZ*
TP_001	xxx3613.526	xxx083.580	156.542	0.005	0.006	0.001
TP_002	xxx3644.219	xxx074.376	156.848	0.008	0.010	0.003
TP_003	xxx3632.332	xxx063.471	156.184	0.006	0.009	-0.001
TP_004	xxx3637.315	xxx093.369	157.101	0.004	0.008	0
TP_005	xxx3637.314	xxx093.320	157.051	0.009	0.005	-0.002
TP_006	xxx3635.562	xxx093.790	156.685	0.006	0.005	0.004
TP_007	xxx3636.853	xxx093.484	157.036	0.007	0.006	0

By comparing the converted scan coordinates with the total station coordinates, it can be seen that the maximum coordinate difference in the *x*-axis direction is 0.009 meters, the maximum coordinate difference in the *y*-axis direction is 0.01 meters, and the maximum coordinate difference in the *z*-axis direction is 0.004 meters. From the formulas (5) and (6), the error in the axial point and the error in the point can be calculated as: $\sigma_x = \pm 0.007\text{m}$, $\sigma_y = \pm 0.007\text{m}$, $\sigma_z = \pm 0.002\text{m}$, $\sigma_p = \pm 0.01\text{m}$. This shows that, the coordinate precision after conversion in the plane coordinate *x* and *y* direction can be about 1 cm. Millimeter accuracy in the elevation direction. After the coordinate transformation, the coordinate precision meets the engineering requirements, and the rearview orientation registration can achieve the seamless splicing between the two sites.

4.Conclusion

For indoor environments, laser scanners cannot receive satellite signals, and engineering needs to obtain indoor point cloud coordinates. This paper proposes a back-view directional registration method to achieve multi-site cloud data registration. The method operation and basic principle are similar to the total station rear view orientation, which is not only easy to operate, but also easy to understand. The experiment verified that after the coordinate transformation, the two sites are well integrated. After conversion, the plane coordinates can reach 1 cm precision, and the elevation can reach millimeter precision, and meet the requirements of practical engineering applications. The method can be extended to tunnel engineering, basement engineering, topographic surveying, etc., and provides reference for practical engineering applications.

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