REGISTRATION OF TERRESTRIAL LASER SCANNER POINT CLOUDS BY ONE IMAGE

C. Altuntas[*], F. Yildiz

Selcuk University, Engineering and Architectural Faculty, Department of Geodesy and Photogrammetry, Konya/TURKEY - (caltuntas, fyildiz)@selcuk.edu.tr

Commission V, WG V/3

KEY WORDS: TLS, Point Cloud, Registration, Space Resection, Pose Determination

ABSTRACT:

Registration of point clouds in the same coordinate system is the most important step in processing of terrestrial laser scanner measurements. Used methods for registration of point clouds have required scanned overlap area between point clouds or adequate points for every scan in common coordinate system. These procedures are required time and labor more than necessary. In this study, a method has been explained for registration of point clouds in the same coordinate system by one image, which covers the scan area of each point clouds. Essentially, the method is performed in two steps. The first step for the process is calculated the exterior orientation (rotation angles and translation components) of each point clouds with respect to image coordinate system, and image and each scan axes is maked parallel for the other. Translation vector is determined by difference of projection center coordinates in each scan coordinate system. Evaluate of accuracy of the method used here is done by beforhand selected control points coordinates. Seen in the procedure, the method can be used for registration of laser scanner data but accuracy of registration of the method has yet sufficiently. The accuracies of the registration can be increased with removed distortion and other errors.

1. INTRODUCTION

The terrestrial laser scanner (TLS) is a time of flight instrument which can directly acquire very accuracy and dense 3D point clouds in a very short time. These instruments are used frequently in cultural heritage documentation, 3D modelling and acquire 3D data. Instrument's data is point cloud which has local cartesian coordinates. If too many scanning is required for 3D modelling of one object, every scanning must include overlaping surface with the other adjacent scan.

Too many different methods have been used for registration point clouds. The most popular method which is used to registration of point clouds is iterative closest point (ICP). ICP algorithm developed by Besl and McKay (1992), Chen and Medioni (1992). Althought the method required intensive computation and time expense, the most used method. The ICP assumes that one point set is a subset of the other. Point pairs of nearest points search in two point sets. Rigit transformation parameters estimated by the point pairs, then transformation is applied to the points of one set. Procedure is iterated until Euclidean distance is minimum between point pairs. The values of estimate transformation parameters of each iterations has used for approximate value of the next iteration. ICP algorithm is put on estimation a 6-parameter rigid body transformation with scale factor 1. ICP mathematical model is required initial values of unknowns. If first values of transformation parameters is good estimated, new values are estimated approximate after 5-10 iterations.

The negative sides of ICP registration methods are highly time consuming search for the nearest point and too much iterarions. To tackle the exhaustive search problem and improve of ICP, different techniques of the method have been application (Sharp et.al.,2002; Johnson and Kang, 1999). Different applications of ICP is named related with used technique and data, for example Color ICP (Johnson and Kang, 1999), Geometric ICP (Liu, 2006). There can be found too many ICP approaches in the literature (Rusinkiewicz and Levoy 2001; Chetverikov, 2002).

Another mothod used to point cloud registration or 3D surface matching is least sequare 3D (LS3D) matching technique. The method is developed by Gruen and Akca 2005. LS3D method is applied as least suquare matching of overlaping 3D surfaces, which are sampled point by point using a laser scanner device or other devices. Proposed method matches one or more 3D search surfaces with a 3D template surface, minimizing the sum of sequares of the Euclidean distances between the surfaces. The geometric relationship between the conjugate surface patches is defined as a 7-parameter 3D similarity transformation. As scale parameter is 1, 6-parameters is estimated, which have been needed for transformation of conjugate overlaping point clouds. LS3D matching is required initial approximate value of transformation parameters.

Also, registration of conjugate overlap point clouds can be done by 3D conformal transformation (Scaioni, 2002). A set of n models acquired by laser scanner have been transformed from intrinsic reference systems to a common reference system. It can be either select of reference coordinate system a one of the models or ground control point's (GCP) reference system. For each situations, a minimum of three points is required to compute the registration between two adjacent scans. Initial values for the transformation parameters must be provided to compute of conformal transformation. Transformation parameters between adjacent scans will be computed by least sequare adjustment. Place and count of points on an overlap

[*] Corresponding author.

scan have effected accuracy of computed orientation parameters. The method is useful when require tarnsformation of laser scans.

There are another kind of methods to compute transformation parameters and applay for adjacent overlap laser scans data related with survey instrument configuration, object surface and measurement area. Particularly, image based registration methods is used frequently (Dold and Brenner, 2006). To laser scanning while moving, the integration of the terrestrial laser and GPS/IMU sensors was done (Talaya, 2004). In this system, all the scanning data have been oriented correctly in reference frame directly. Independent model triangulation method is combined laser scanner data as similar method in aerial triangulation (Scaioni, 2002). In addition, there are too many different methods in literature for 3D modelling and combining of laser scanning data in reference coordinate system (Scaioni, 2005; Zhi and Tang, 2002).

In this study, combination of laser scanner data by one image was investigated. Image taken which cover adjacent laser scan area, and registration was performed by select point seen on the image and on the scans. This article has been organised form explain our work in section 2, experiments in section 3, conclusion and future work in section 4 and acknowledgement.

2. OUR WORK

In our work, it was investigated that registration of adjacent scans in common coordinate system by one image. The image has been taken form seen each adjacent scans. These scans have been registered by selected conjugate points on the scans and image. The steps of the our aproach are below;

- The projection center coordinate and rotation angels of the taken image related with scan1 (S1) and scan 2 (S2) were calculated.
- Rotation parameters are applied to the every scan (S1 and S2). In this way, coordinate axes of the each scan are parallel for image cordinate axes.
- Translation vector between the scans has calculated by differences projection center coordinates for the each scan.

This steps were explained in subsections.

2.1. Camera locate estimation

Camera locate estimation is defined of determining the position of calibrated camera from 3D references points and their images (Figure 1). It is also called space resection in the photogrammetry community and computer vision. The most part of the problem is determine of distances from image projection center to object reference points. The solve of the problem has required least 3 conjugate points on object and image. With any two points of the three points, equation (1) can be writen in below;

$$P_{ij}\,(x_i, x_j) = x_i^2 + x_j^2 + c_{ij}x_ix_j - d_{ij}^2 = 0 \qquad (1)$$
$$c_{ij} \equiv -2\cos\theta_{ij}$$

where, xi and xj is distance from i th and j th object points to image center, and they are not known. The other parameters in the equation is known. θ_{ij} is angle between i and j directions in the projection center C. d_{ij} is obtained with object coordinates of the points.

For two pairs of the three points is writed three polynom as below,

$$P_{12}\,(x_1, x_2) = x_1^2 + x_2^2 + c_{12}x_1x_2 - d_{12}^2 = 0$$
$$P_{13}\,(x_1, x_3) = x_1^2 + x_3^2 + c_{13}x_1x_3 - d_{13}^2 = 0$$
$$P_{23}\,(x_2, x_3) = x_2^2 + x_3^2 + c_{23}x_2x_3 - d_{23}^2 = 0 \qquad (2)$$

These equations are singuler, and if Sylvester method is applied for eleminate x_3 and x_2. Afterwards g_x is hand related x_1=x;

$$q_x = a_4x^4 + a_3x^3 + a_2x^2 + a_1x^1 + a_0 = 0 \qquad (3)$$

This equation is solved singular value decompositon method (SVD) (Zhi and Tang, 2002). There are indefinities solving poblem by three points. There are not indefinities for four points. Three g_x functions is obtained for four points and, SVD is applied by Maple software for these functions. After x_1, x_2,x_3 and x_4 was obtained, camera location (X_o,Y_o,Z_o) is calculated in object coordinate system.

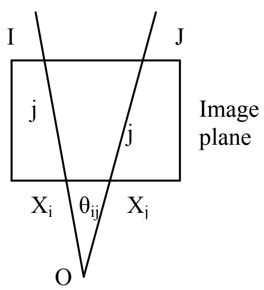

Figure 1. Image and object points.

2.2. Rotation angels between image and laser scanner data

Rotation angels between image and the each laser scanner data is calculated by collinearity equations (Equation 4). Number of the equation is selected point as much as the image and the each scans.

$$x = x_0 - c\frac{r_{11}(X - X_0) + r_{21}(Y - Y_0) + r_{31}(Z - Z_0)}{r_{13}(X - X_0) + r_{23}(Y - Y_0) + r_{33}(Z - Z_0)}$$
$$y = y_0 - c\frac{r_{12}(X - X_0) + r_{22}(Y - Y_0) + r_{32}(Z - Z_0)}{r_{13}(X - X_0) + r_{23}(Y - Y_0) + r_{33}(Z - Z_0)} \qquad (4)$$

where;
x,y : image point coordinates,
x_o,y_o: image pricipal point coordinates,
c : focal lenght,
r : elements of rotation matrix related ω,φ,κ.
X,Y,Z: obeject system coordinates,
X_o,Y_o,Z_o: coordinates of the projection center in object system.

The initial values of the unknowns (ω,φ,κ,X_o,Y_o,Z_o) in the equation 4 is reguire. Initial values of the X_o,Y_o,Z_o is accept projection center coordinates. Initial values of the rotation angels ω,φ,κ is estimated with similarity between image and scan.

3. EXPERIMENT

The laser scanning were obtained from two stations in the our labouratuary (Figure 2, Figure 3). Although our aim is registration of unoverlap laser scanner data, the laser scanning was performed overlap area on the each laser scans. Control points were selected in the overlap area and, the points were used for comparision of accuracy of the registration.

Aftwerwards, image taken form cover each adjacent scan (Figure 4), and registration of the laser scanning was done by one imege as if there are not overlap area between the adjacent scan (Figure 5). The process steps as in below:

1. 10 points were selected on the image and scan-1 (1,2,3,13,14,15,20,21,22,28). The points can be selected characteristic point of the object or used artifical point.
2. Projection centers (O_{S1}) coordinates (X_o,Y_o,Z_o) have been calculated related with scan 1 (as in section 2.1).
3. rotation angels have been calculated by collinearity equations between image and scan 1 (section 2.2).
4. scan 1 is rotated by angels in 3. Now, coordinate axes of scan 1 and image is parallel.
5. 10 points were selected in the image and scan 2 (6,8,11,17,18,19,24,25,26,27).
6. 2,3,4,5 is applied ordinary, and coordinate axes of scan 2 and image is parallel.
7. Translation vector is calculated by difference $O_{S1}(X_o,Y_o,Z_o)$ and $O_{S2}(X_o,Y_o,Z_o)$.
8. Registration has completed after sum of translation vector with scan 1 or scan 2.

Redundancies in control points, which is common for each scan, has been given in Table 1.

Figure 2. Laser scanning from station 1 (scan 1)

Figure 3. Laser scanning from station 2 (scan 2)

Figure 4. Image taken form cover scan 1 and scan 2.

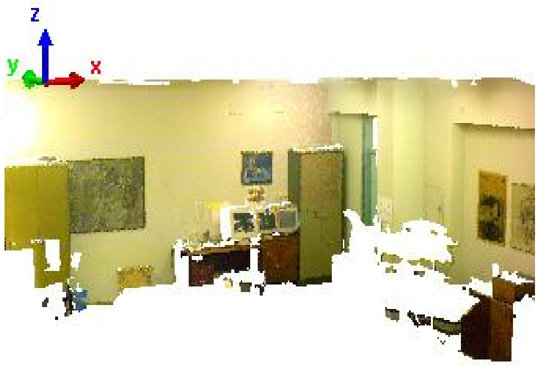

Figure 5. Combination of scan 1 and scan 2

Points	Translation vectors		
	tx (m)	ty (m)	tz (m)
O(proj.center)	-4.674	1.063	2.145
9	-5.068	1.251	2.249
10	-5.209	1.385	2.347
16	-5.023	1.370	2.311
4	-5.044	1.405	2.165

Table 1. Translation vector for control points and projection center.

4. CONCLUSION AND FUTURE WORK

The results of the registration is insufficient for combination of te laser scanner. If there are not overlap between adjacent point clouds, elements of the translation vector is estimated with difference of O_{S1}-O_{S2}. In this situation is not given enought accuracies result. If effect of the radial lens distortion is compute and remove of its, the accuracy of the registration can be increased. Also, If pixel size is enough small and increase of number of the points, accuracy of the registration can be increased. These situations will be investigated in the next study.

ACKNOWLEDGEMENT

The authors wish to acknowledge for the cooperation and the financial assistance given by the Scientific Research Found (BAP) of Selcuk University.

REFERENCES

Besl, P.J., McKay, N.D., 1992. A Method for resgistration of 3D shapes, IEEE Transaction on Pattern Analysis and Machine Intelligence 14(2), pp. 239-256.

Chen, Y., Medioni, G., 1992. Object modelling by registration of multiple range images, Image and Vision Computing, 10(3), pp. 145-155.

Sharp, G.C., Lee, S.W., Wehe, D.K., 2002. ICP registration using invariant features, IEEE Transsaction on Pattern Analysis and Machine Intelligence 24(1), pp. 90-102.

Johnson, A.E., Kang, S.B., 1999. Registration and integration of textured 3D data, Image & Vision Computing 17(2), pp. 135-147.

Liu, Y., 2006. Automatic registration of overlapping 3D point clouds using closest points, Image and Vision Computing 24 (2006), pp. 762–781.

Rusinkiewicz, S., Levoy, M., 2001. Efficient variants of the ICP algorithm, Proceedings of the 3DIM, pp. 145–152.

Chetverikov, D., Svirko, D., Stepanov, D., Krsek, P., 2002. The trimmed iterative closest point algorithm, Proceedings of 16 th International Conference on Pattern Recognition (ICPR'02), August 11-15, Quebec City, Canada, volume 3, pp.545-548.

Gruen, A., Akca, D., 2005. Least sequares 3D surface and curve matching, ISPRS Journal of Photogrammetry and Remote Sensing 59(2005) 151-174.

Scaioni, M., 2002. Independent model triangulation of terrestrial laser scanner data, The ISPRS Internatioanl Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 34(5/W12) (2002), pp. 308-313.

Dold, C., Brenner, C., 2006. Registration of terrestrial laser scanning data using planar patches and image data. The ISPRS Internatioanl Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 36(5), pp. 78-83.

Talaya J., Alamus R., Bosch E., Sera A., Kornuss W., Baron A., 2004. Integration of terrestrial laser scanner with GPS/IMU orientation sensors, XXth ISPRS Congress, 12-23 July, Istanbul/Turkey, pp.on CD.

Scaioni, M., 2005. Direct georeferencing of TLS in surveying of complex sites, Proceedings of ISPRS Working Group V/4 Workshop, 22-24 August, Mestre-Venice, Italy, ISSN 1682-1777.

Wenfeng, H., Wei, M., Hongbin, Z., 2005. Automatic registration of range images based on correspondence of complete plane patches. Proceedings of the fifth international conference on 3-D Digital Imaging and Modelling (3DIM'05), ISBN 1550-6185/05.

Zhi, L., Tang, J., 2002. A Complete linear 4-point algorithm for camera pose determination, MM Research Preprints, MMRC, AMSS, Academia, Sinica, Beijing, No. 21, December 2002, pp. 239–249.