Application Research of Earth Volume Calculation Based on 3D Laser Point Cloud Data

Yan Wang, Zixian Fan* and Yingchun You†

*College of traffic engineering, Shenyang Jianzhu University, Shenyang, Liaoning, 110168, China
†Corresponding author’s e-mail: 727698163@qq.com

Abstract. The accurate calculation of earth volume is a very important work in engineering construction. The traditional calculation of earth volume requires the use of RTK measurement to collect a large number of data, which makes the workload outside the page very large and seriously affects the efficiency. 3D laser scanning technology is now widely used in many areas. This paper uses a 3D laser scanner to collect data from a school experimental site and calculate the earth volume. Then compare with traditional RTK measurement methods. The results show that the three-dimensional laser scanning technology has a fast speed, high precision and good results. This technical method has achieved good results and is worth promoting.

1. Introduction

3D laser scanning technology is a 3D real scene reproduction method, which has been developed rapidly in recent years and is a new technological innovation in the field of surveying and mapping following the development of GPS [1]. Calculation of earth volume is a common and important work in the process of engineering construction, which is the premise of engineering construction and occupies an important position in construction, transportation, water conservancy, urban planning and other aspects [2]. In traditional earthwork calculation, total station instrument and RTK instruments are mainly used to obtain single-point elevation position data, and then section method, contour method, grid method and irregular triangle method are used to estimate earthwork in the region [3]. Traditional methods have many shortcomings, which mainly include two aspects. First, in the process of data acquisition on the outer page, the collection density of data points has a great impact on the accuracy of later calculation. If the data collection is intensive, it will be a waste of time and low efficiency. In the process of the second is on the inside pages of the method to select different also has great influence on the result of the later estimates, generally in the area relatively flat when using the method of DEM, the ups and downs is bigger but the changing law of slope area generally by contour method, in big ups and downs but the slope changes of irregular cross section method is used to [4]. For large projects, the terrain is often very complex, not a single kind of terrain, so it is difficult to choose the method. But 3 d laser scanner can be better to avoid these problems, as a kind of automatic, all-round, high precision, fast non-contact measurement technology, it can quickly a large number of obtaining 3 d coordinate information of the surface point, which can accurately response the change of surface relief, which can accurately estimate the earthwork quantity, so to explore using 3 d laser scanning technology to measure to estimate earthwork quantity has important actual significance [5-7].
2. Principle of 3D laser scanning technology
The principle of ground 3D laser scanner measurement is to measure the positional relationship between the center of the instrument and the target point by laser range finder. The 3D laser scanner is similar to the total station, which consists of the aiming axis, the horizontal axis and the vertical axis [8]. The coordinate system is selected using a custom coordinate system. The center of the instrument is the origin O, and the direction of the laser scanning is Y. The axis is then determined by the right-handed screw rule to determine the X-axis, which passes through the coordinate origin and is perpendicular to the horizontal axis. The determination of the coordinate points is mainly determined by three observation factors, including the slanting distance S from the center of the instrument to the observation target point and the angle θ in the horizontal plane and the angle φ in the vertical plane during the laser pulse scanning. As shown in figure 1. The calculation formula is as follows (1):

\[ X_p = S \cdot \cos \phi \cdot \cos \theta; \]
\[ Y_p = S \cdot \cos \phi \cdot \sin \theta; \]
\[ Z_p = S \cdot \cos \phi. \]  

(1)

3. Data collection

3.1. Survey area overview
This experimental site selected the lead stadium of Shenyang Jianzhu University, the surface covered with weeds, low shrubs, etc., and the view was good. There is a small slope in the site. The terrain of the site is conducive to obtaining accurate three-dimensional point cloud data, which meets the requirements of the experiment and can accurately calculate the earth volume. The test area is shown in figure 2.

3.2. Field survey
The 3D laser scanner scans quickly. The amount of spatial points collected is large. Therefore, in order to reduce the amount of data processing in the later stage, it is necessary to perform the survey on the site before the measurement. Selecting the appropriate measuring station and measuring route can not
only accurately cover the entire coverage but also reduce the amount of unnecessary data. Therefore, the station needs to have an open field of view, which can increase the effective angle of scanning. This experiment is selected according to the site. The four stations are the four corners of the site. The field measurement consists of three parts. The first part is the control measurement. The GPS-RTK is used to collect the position coordinates of the measurement station. The second part is to scan the measurement area. The third part is to use the traditional method to measure the survey area and then estimate the earthwork volume for comparative analysis.

First, four control points are set in the four corners of the survey area, and the GPS rover receiver is connected to the CORS to measure and record the four control points.

Then the 3D laser scanner is set up at the first control point. The 3D laser scanner does not need to be manually leveled because it has an automatic tilt compensator inside, and then the target tripod with the target point is placed on the next control point. A total of two scans are required on each station. The first time you set the appropriate horizontal and vertical angles by visual inspection, select the appropriate scanning resolution, and scan the measurement area after setting the parameters. After that, you need to scan the target points. Perform a second precise scan, which is to improve the accuracy of the results in order to facilitate the later point cloud stitching. After the end of a station scan, the scanner and the target point are transmitted to the next point as a whole until the end of the four stations.

Finally, the GPS-RTK is used to collect uniform points in the survey area. In order to improve the accuracy of the earthwork estimation, it is decided to make a point every 5 meters interval, and finally form a square grid of 5 meters square.

4. Data processing

4.1. Point cloud denoising and vegetation rejection

Due to external interference during the measurement process, the data contains a lot of useless redundant information. It includes people and vehicles moving around, the number of roadsides, and the vegetation covered by the surface, so they need to be removed. Because the scope of this experimental measurement area is small, it can be manually denoised by software. The information such as the vegetation point cloud is removed, and finally the filtered point cloud data is obtained.

4.2. Coordinate transformation

The point cloud data coordinates acquired by the laser scanner at each station are built in the scanner coordinate system. The splicing between each station is to convert the scanner coordinate system of each station to the same through a transformation matrix. In an engineering coordinate system. In this experiment, since each station is erected at four control points, the engineering coordinate system can be converted into a geodetic coordinate system through the backsight orientation function provided by the software. Specifically, the absolute coordinates and instrument height of the four station control points measured by the RTK are input into the software after calculation, and the coordinates of the corresponding measurement stations are modified, so that the data scanned by each scanning station are absolute geodetic coordinates.

4.3. Data thinning

The amount of data measured by each station of the 3D laser scanner is very large, which will greatly reduce the post-processing speed. Therefore, the data needs to be resampled. The size of the point cloud directly affects the processing difficulty. If it is too small, the processing speed will be very high. It is slow and requires high computer configuration. If the spacing is too large, it will affect the accuracy. Therefore, the point cloud thinning distance is set to 0.2m.

4.4. Point cloud stitching

Point cloud splicing is generally divided into two methods. One is based on the data measured by one station, and the other stations are spliced by the same name in the overlapping area between each station.
The software automatic splicing operation is simple, but due to the influence of the cumulative error, the accuracy is not high. Therefore, this experiment uses the second splicing method to unify the points after coordinate transformation to absolute coordinates, and then splicing, effectively improving the accuracy. The top view of the point cloud after the pre-processing is completed is shown in Figure 3:

![Figure 3. Point cloud top view after pre-processing.](image)

4.5. 3D modeling
After the pre-processing is completed, the data is exported in igs format and 3D modeled in Rhinoceros software.

5. Earth volume calculation
We need to analyze the point cloud and the actual terrain, and determine the shape characteristics of the grassland as a large plane and a small convex surface. According to the point cloud obtained by the pretreatment, the Rhinoceros software is used to construct the base surface to construct a triangulation network for the point cloud data, and the surface mesh density is set. According to the point cloud distribution, the adjacent surface nodes are adjusted so that the features of the surface are close to the characteristics of the point cloud, and finally the solid model is generated as shown in Figure 4. Then, according to the need to set the reference plane of the earthwork calculation, directly calculate the earth volume, as shown in Figure 5:

![Figure 4. Solid model.](image)  ![Figure 5. Design elevation.](image)

The GPS-RTK measurement data is imported into the CASS software. In the CASS software, the earthwork can be estimated by the elevation of the coordinate points, the elevation of the earthwork calculation surface is input, and the measurement area is circled by the set elevation plane and the composite curved surface, and then the calculation can be performed. Unearthed amount. Five sets of different elevations were selected to estimate the amount of earthwork in two ways. Table 1 gives the comparison results:

| Design elevation(m) | Rhinoceros   | CASS       | Difference |
|---------------------|--------------|------------|------------|
|                     | Earth volume(m³) |            |            |
| 40.0                | 14324.56     | 14267.66   | 56.90      |
| 39.5                | 13583.45     | 13526.02   | 57.43      |
| 39.0                | 12867.11     | 12831.63   | 35.48      |
| 38.5                | 12189.55     | 12143.12   | 46.43      |
| 38.0                | 11489.21     | 11434.89   | 54.32      |
As can be seen from Table 1, the earthwork measured by Rhinoceros software and CASS software has an error of 0.39% at a design elevation of 40 m, an error of 0.42% at a design elevation of 39.5 m, and an error of 0.28% at a design elevation of 39 m. At 38.5 m, the error is 0.37%. When the design elevation is 38 m, the error is 0.47%, and the error is less than 0.5%, which is in line with the engineering design standards.

6. Conclusion
Through this experiment, the 3D laser scanning technology is applied to the measurement of earthwork volume. The experimental results show that the earthwork quantity obtained by 3D laser scanning technology meets the engineering design standard, compared with the traditional GPS-RTK square grid measurement method. The obtained earthwork error is within 0.5%, and the 3D laser technology is suitable for earthwork measurement of more complex terrain and reduces the workload of the external page, reducing the difficulty of measurement and avoiding the limit of terrain. The amount of earthwork obtained by 3D laser scanning technology is more accurate, because the distance between the points obtained by the 3D laser scanner can reach centimeter level, which greatly increases the density of the points and more accurately expresses the surface shape. This is another. Traditional measurement methods cannot be achieved, so the application of 3D laser scanning technology in earthwork measurement is worthy of promotion.

References
[1] Huang Y, Zheng K, Liu X G. (2012) Application of 3D laser scanner in measuring ore volume. J. Science and Mapping Science., 37(03):90-92.
[2] Hu K. (2013) Application of 3D laser scanning in earthwork calculation. J. Mine Surveying., 2013(6):71-72.
[3] Li B, Ran L, Cheng C Q. (2012) Study on Application of 3D Laser Scanning Technology to Earthwork Engineering. J. Bulletin of Surveying and Mapping., 2012(10):62-64.
[4] Yang G L, Han F, Wang D Y. (2015) Research on Engineering Construction Measurement Application Based on 3D Laser Scanning Technology. J. China Hydropower & Electrification., 2015(02): 20-23.
[5] Liu Q, CUI X M, Liu W L, Li W J, Liu P F. (2015) Application of 3D Laser Scanning Technology in the Reclaiming of Coal Gangue. J. Surveying and Mapping Engineering., 24(10):67-70.
[6] Ou B, Huang C L. (2012) Application of 3D laser scanning technology in square measurement. J. Urban Survey., 2012(02): 123-125.
[7] Yuan F X, Qin Y B. (2016) An Jiariu. Application of 3D laser scanning technology in earthwork volume measurement. J. Surveying Engineering., 25(09):55-58.
[8] Jing W S, Wang J, Sun A Y. (2016) Study on Accuracy Evaluation Method of Ground 3D Laser Scanner. J. Surveying and Spatial Geography Information., 39(11):198-201+206.