Application of Terrestrial Laser Scanner in engineering survey

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Abstract: For evaluating the objective measured by the traditional measurement technology that is continuous and periodic single point observation method, it is one-sided and uncertainty. The 3D laser scanning technology called the real scene reproduction technology can provide the support for the 3D design of all kinds of tested objectives in the favorable data. It not only simplifies the construction project cost and improves the work efficiency, but also the results of its data evaluation are more reliable and comprehensive. In the past ten years, the terrestrial laser scanner as a physical representative of the three-dimensional laser scanning technology has been applied in some industries such as electric power, archaeology, factories, cities, Bridges, hotels, ships, criminal investigation to represent its immeasurable value. In this paper, these cases applied in the hotel, sculpture, landscape wall, karst cave are more representative to show a variety of terrestrial laser scanner applications.

1. Introduction

The traditional measurement means describe the measured object by continuous measurement and single point measurement. In some application scenarios, the measurement results can not fully meet the needs of customers, and in addition, they can not comprehensively and objectively evaluate the measured object. The 3D scanning measurement method can go deep into the complex field environment and space. By collecting a large number of point cloud data, it can quickly reconstruct the 3D entity model of the target and comprehensively evaluate the tested object. The data processed in the follow-up are used in metrology, mapping, stress analysis, finite element analysis, simulation analysis, virtual reality and other aspects. For nearly 10 years, the terrestrial laser scanner, as a representative of the 3d scanning measurement technology of material in nuclear power, cultural relics and archaeology, construction, aerospace, shipbuilding, petrochemical, energy, machinery, film and television, teaching, scientific research, automobile, public security, transportation, electricity and other fields, wide application, at the same time, the experts from all walks of life to draft some relevant regulations, standard, national standard and industry standard. For example, in the field of terrestrial laser scanner operation [1], oil industry [2], railway industry [3], construction [4][5], city [6][7][8], power [9], mining [10], shipping [11] and so on. At present, on the market the relevant terrestrial laser scanners as many as ten kinds of above. In this paper, we show the
2. Terrestrial laser scanner

2.1 The principle
The scanner is mainly composed of laser ranging system, laser scanning system, control system, power supply system and accessories, etc. It can quickly and extensively collect spatial point cloud information, establish point cloud model, and provide early services for the establishment of data model in the later stage. Scanner used in the process of measuring coordinate system, through the internal servo motor system, precise control of polyhedral reflecting prism of fast moving, the laser beam can carry on the linear array along the horizontal and vertical direction or plane array scan, by precision clock control encoder measurement of each laser beam transverse scan Angle and the vertical scanning Angle, and along the measuring axis distance measurements, after coordinates are finally converted into three-dimensional coordinates of the Cartesian coordinates.

2.2 Classification
There are many categories of terrestrial laser scanners. According to its scanning space, it can be roughly divided into terrestrial laser scanner, vehicle-mounted scanner and handheld scanner. In the process of 3D data collection, the general configuration is shown in Table 1. Different scanning equipment is required according to different conditions of the project. In most cases, terrestrial laser scanners are generally used at the building level.

| Device type                  | Practical accuracy class | Applicable scanning range             | Common accuracy range of equipment | Main instruments and equipment                     |
|------------------------------|--------------------------|---------------------------------------|-----------------------------------|--------------------------------------------------|
| Terrestrial laser scanning equipment | Building level           | Single buildings, courtyards, blocks, large buildings, etc | 1mm-6mm                           | Terrestrial laser scanner, etc                     |
| Mobile 3D laser scanning equipment | Building level           | Single buildings, courtyards, blocks, large buildings, etc | 10mm-50mm                          | Vehicle-mounted radar, recording radar, real-time positioning and mapping equipment, etc |
| Close range 3D scanning equipment | Component level          | Building components, detail nodes, part levels, decorations, etc | <1mm                              | Handheld scanner, portable scanning measuring arm, raster scanner, etc |
| Close-range photography equipment | Building level Component level | Individual buildings, courtyards, blocks, building components, detailed nodes, parts, decorations, etc | --                                 | UAV tilt camera equipment, video camera, camera, etc |

2.3 Measurement process
In the actual operation process of terrestrial laser scanner, different measurements need to be made according to different projects. Generally speaking, the scanning work is divided into two parts: field
work and internal work. Field operations are carried out using a terrestrial laser scanner. Sometimes targets are used, and sometimes color images of the site are collected. The internal work mainly includes stitching, modeling, measurement and achievement evaluation of the collected point cloud.

3. **Typical application cases**
Terrestrial laser scanner is an emerging in the field of survey and mapping measurement equipment, it can quickly and efficiently obtain the three-dimensional point cloud data of the object, it broke through the traditional way of measuring data, the current in the digital city, deformation monitoring, digital, cultural heritage protection, mining, engineering accident/have applied the scene of the crime, and other fields. Table 2 shows common application examples. In this paper, hotel, sculpture, landscape wall, karst cave as a typical case, to show a variety of terrestrial laser scanner applications.

| field                        | application          | example                                                                 |
|------------------------------|----------------------|------------------------------------------------------------------------|
| Digital city                 | 3D model             | Urban roads/buildings/facilities                                        |
| Deformation monitoring       | 3D model             | Seismic deformation, geological slopes, landslides, tunnels, Bridges,   |
|                              | 3D detection         | roads, DAMS                                                            |
|                              | 3D pipeline modeling | Offshore oil and gas platform,                                          |
|                              | Structure testing    | chemical/pharmaceutical/petroleum, smelting plant                      |
| The factory                  | Detection of spatial | Shipyard, car factory, aerospace industry                              |
|                              | position conflict    |                                                                         |
|                              | Volume inspection    | Nuclear/thermal power/substation                                       |
|                              | and verification     |                                                                         |
| Cultural Heritage Preservation| Two dimensional     | Ancient building interior and                                           |
|                              | engineering drawing  | exterior, statue, historic site survey                                  |
| mine                         | 3D model             |                                                                         |
|                              | Area/volume/virtual  | Open pit mine, mine tunnel, mine pile                                  |
| Accident/crime scene         | The virtual measuring| Accident analysis                                                       |
| Other                        | 3D modeling          | Crime scene analysis                                                    |
|                              |                      | Virtual reality/games/movies/TV                                         |

3.1 **Sculpture scanning**
Sculpture scanning belongs to the protection of cultural heritage, it has some differences with industrial modeling, industrial modeling needs a smooth surface, this smooth surface can be expressed by a function, as long as the measurement of some points on the surface can be calculated to the entire surface. However, the shape of the sculpture is relatively complex, and there are many blind spots to scan, such as thick hair wrinkles and curved inner ears. If the data is expressed by functions, it will be very large. In many cases, such relatively complex surfaces need to be outlined. From the accuracy above, the accuracy of industrial modeling is generally higher than the accuracy of sculpture. Figure 1 shows the site scan of the sculpture, and Figure 2 shows the modeled figure based on the point cloud of the sculpture.
3.2 The landscape wall
Digital landscape wall is a case of digital landscape. Digital landscape methods and technologies can help the whole process of landscape architecture research, design, construction and control, from data collection and analysis, digital modeling and modeling, virtual reality and expression, parametric design and construction, to Internet of Things sensing and digital measurement and control. The value of digital landscape is embodied in the whole process of landscape planning, design and construction. Research before the design stage, the development of 3D scanning technology such as data acquisition technology has changed the traditional way of investigation and data collection, data provides a more comprehensive, the guest officer, improved the precision of the research, present research traditional methods are difficult to collect environmental information, provides a new perspective for landscape design. Figure 3 shows the landscape wall scanned by a terrestrial-based laser scanner, and Figure 4 shows the modeling based on point cloud data. Data acquisition and modeling by terrestrial laser scanner in the early stage provide richer and more reasonable data support for the generation of landscape wall planning and design scheme.

3.3 Cave
The wide part of karst cave is like a square, while the narrow part is like a long corridor. Because of its particularity, the traditional measuring instrument can not meet the current requirements of karst cave detection. Because of its fast and efficient characteristics, terrestrial-based laser scanner has
remarkable advantages in 3D data and shape extraction of karst cave. The use of the devices, not only can improve the work of karst cave measurement precision and work efficiency, also for the inside of a cave landform and geological body form 3D visualization, virtual components inside the cave geographical scene building, cave geographical information system construction to provide data support, as the cave data construction, cave, cave landscape tourism development environment and landscape protection, cave archaeological and provide intuitive precision based data research and analysis, etc. Fig. 5 shows the site scanning map of the karst cave, and Fig. 6 shows the karst cave map after point cloud splicing.

3.4 Hotel scanning
In the final analysis, the business competition of the hotel is the cultural competition. Under this background, the online digital hotel system created by using virtual reality technology provides three-dimensional visualization management and online display support functions for the digitalization of the hotel. It can construct the whole hotel from the whole view to the part on the network. Through the network browser, the public can observe the external and internal environment of the hotel from any Angle, conduct independent roaming, and enter various rooms in the virtual room to experience the living environment of the hotel in an all-round way. Among them, the terrestrial-based laser scanner is a scientific instrument used to collect and analyze data showing the geometric structure and appearance of objects or environments in the world. The collected point cloud data is used for 3D reconstruction calculation to create digital models of actual objects in the virtual world. BaZhong TianMaShan Hotel is a five-star hotel in BaZhong area. Figure 7 shows the scanning image of the entrance of the hotel, and Figure 8 shows the color dot cloud image of the exterior of the hotel.
3.5 Other measurements
The terrestrial laser scanner can also be used as a standard for other measurement systems to carry out value transfer. Fig. 9 shows the two-dimensional line laser tunnel measurement system, whose measurement accuracy has always been a problem perplexing the railway system. The advent of terrestrial-based laser scanners has solved this precision problem. In this test, high precision 3D laser scanning technology and high precision coordinate positioning technology were used to check the positioning coordinates and the accuracy of visual resolution of the 2D linear laser tunnel measurement system, which ensured the accuracy requirements of the system for dynamic monitoring of the tunnel. Fig. 10 is a schematic diagram of field measurement.

Figure 9. Two-dimensional line laser tunneling measurement system.
Figure 10. Field operation diagram.

4. Summary
Terrestrial laser scanner as the real example of 3D laser scanning technology, it abandoned the traditional measurement shortcomings respectively and the two aspects of uncertainty, successful and effective to solve the traditional measuring way of small amount of data acquisition, data is not comprehensive, it can go deep into the complex scenario point cloud data collection, subsequent data modeling, data visualization degree is high, effect is clear. It is believed that with the development of information technology, 3D laser scanning technology will continue to improve, and the application of 3D terrestrial scanners will continue to deepen and extensive.

References
[1] CH/Z 3017 (2015) Technical specifications for terrestrial three-dimensional laser scanning.
[2] SY/T 7346 (2016) Code of terrestrial 3D laser scanning survey for oil and gas engineering.
[3] JIF 1719 (2018) Calibration Specification for 3D Laser Scanner for Volume Measurements of Rail Tankers and Tank Containers.
[4] WW/T 0082 (2017) Specification for digitalized surveying and mapping of wall painting in historic building.
[5] DB 11/T 1796 (2020) Technical specification of three-dimensional information acquisition of heritage buildings.
[6] DB 1310/T 232 (2020) Standard for warehousing urban 3D data.
[7] DB 50/T 393 (2011) Technical specification for three dimensional modeling of city.
[8] CJJ/T 157 (2010) Technical code for three dimensional city modelling.
[9] Q/GDW 11809 (2018) Interaction specification for the three-dimensional design model of power transmission and transformation project.
[10] DB 13/T 5148 (2019) Technical specification for three-dimensional modeling of iron ore deposits.
[11] CB 20022 (2011) The general requirements of 3D model for ship.