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Application of Terrestrial Laser Scanning in 3D Measurement and Control in Chemical Industry Park

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In order to satisfy the demand of delicacy management in chemical industry park for spatial data acquisition, this paper uses terrestrial 3D laser scanning technology to quickly obtain massive 3D spatial data for measurement in the chemical industry park. Taking one chemical industry park in Chengdu as an example, before 3D laser scanning, it’s necessary to firstly implement field exploration and understand general conditions and internal facilities in the park, especially key measurement and control areas, and prepare a detailed scanning plan. Pre-processing of internal data can be implemented to obtain panoramic 3D data of the chemical industry park, further extract the data and conduct 3D modelling and relevant analysis, so as to achieve 3D measurement and control of the park. Results show that this method is characterized in simple operation, quick measurement, high accuracy and strong practicability. So, 3D laser scanning technology can be used for 3D measurement and control in chemical industry park, so as to quickly obtain 3D spatial data in the park and measure more accurately.

1. Introduction

As one of major hazard sources, safety monitoring, maintenance and reconstruction and delicacy management in chemical industry park have been focuses and emphasized by all walks of life. But during supervision and management in chemical industry park, effective collection (Calders et al., 2017), processing and analysis of 3D spatial information are important links. Due to artificial contact, measurement safety is reduced by using traditional measurement technology (Chen et al., 2017). Meanwhile, due to numerical limit, single-point measurement is insufficient for satisfying demands of monitoring and management work for omni-bearing spatial information. With characteristics of fast speed, non-contact and true 3D etc., 3D laser scanning technology is used as an effective way for 3D measurement and control in chemical industry park. For 3D laser scanning technology (Fan, 2015), there is one laser pulse emitter in the 3D laser scanner. Two retroreflectors are quickly and orderly rotated to scan the narrow-beam laser pulse from the emitter through the measured area (Fang et al., 2015). Then, it’s necessary to measure the distance through the passing time of laser pulse from sending out to the surface of the tested objects and returning to the instrument (Huang et al., 2017). Meanwhile, encorder is used to measure the angle of each pulse, so as to get true 3D coordinate of the tested object. In foreign countries, 3D laser scanning technology has been widely used in the petrochemical (Kelbe et al., 2015), constructional engineering, and military science fields. But it’s just started in China, especially in reverse modelling of production facilities of petrochemical enterprise (Liang et al., 2014) s. Development and application of 3D laser scanning technology will be another advance in digital management, accident simulation (Liang et al., 2014), emergency drilling and evaluation in the chemical engineering field. In this paper, one chemical industry park in Chengdu is taken as an example and ground explosion-proof 3D laser scanner is used for 3D measurement and control in the park. What’s more, it details the research technical route, data acquisition (Liang et al., 2015), data processing, 3D modelling and tank deformation analysis, so as to provide reference for research and application in the related field (Liang et al., 2017).

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2. Design of 3D laser scanner control system

2.1 System plan and general block diagram

3D laser scanner is a high-precision measuring equipment (Puttonen et al., 2015). It involves mechanical engineering, electronic engineering and optics and other fields. According to project requirements and actual application demands (Starek et al., 2013), 3D laser scanner is mainly composed of the followings: control of master and slave computers; ranging for time of flight (TOF) of laser pulse (Sun et al., 2015); high-speed waveform acquisition of scanning echo; analysis and processing of echo through digital signal processing; 3D reconstruction, and processing and display software. General block diagram is shown in Figure 1.

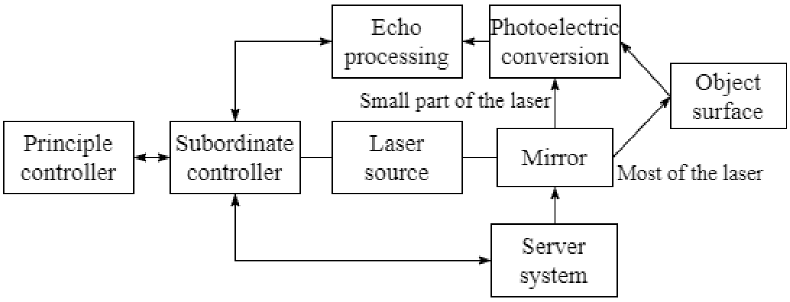

Figure 1: General Structure Block Diagram of 3D Laser Scanner

2.2 Driving of stepper motor

As 3D laser scanner has high requirements for accuracy (Wang et al., 2014), in order to overcome adverse effect of the gap(Wang et al., 2014), we omit meshed transfer parts in the design, and use operation (working) parts for rigid direct connection with motor shaft, i.e. the motor is directly connected with the load. Small displacement movement of actuating elements should be implemented through subdivided driving of stepper motor (Wang et al., 2015). Control equipment of stepper motor is composed of variable frequency (variable output frequency) signal source (Wang et al., 2017), loop pulse distributor and power amplifier (Yang et al., 2017). Drive circuit for each phase is shown in Figure 2.

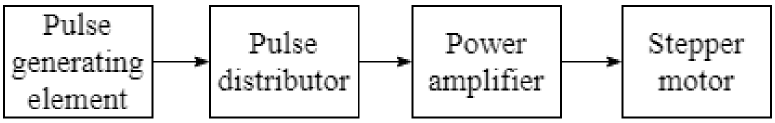

Figure 2: Block Diagram for Drive Circuit of Stepper Motor

Pulse generating element: one pulse frequency has a pulse signal generator continuously changing from several hertz to dozens of kilohertz (Zheng, 2012). It can be used to provide pulse signals (currently, singlechip and others are mainly used to generate digital signals and then transformed by D/A) with variable frequency; pulse distributor: a logic circuit which is composed of gate circuit and flip and flop generator (Zheng et al., 2013). It can be used to add the pulse signals to power amplifier in certain logic relationship according to the command, so that phase winding of the motor is guided through or cut off according to certain sequence and time, so as to achieve forward rolling (Zheng et al., 2016), backward rolling and stoppage etc.; power amplifier: in order to satisfy driving requirements, it’s necessary to amplify the output signals of loop pulse distributor, so as to provide rated current required for operation of the motor (Zhou et al., 2016).

2.3 System structure design

Through function demand analysis according to design objective of the system, 3D measuring system which is composed of 2D laser scanner and laser distance measuring sensor is used to obtain data information at characteristic pints in chemical industry park. The obtained data is joined up to wireless transmission communication module through serial ports of the sensor to realize wireless transmission. After data are obtained through wireless receiving module, test analysis software in the computer can be used for coordinate data processing, meshing, volume calculation, 3D display, history query and report output and others. Block diagram for system hardware is shown in Figure 3.

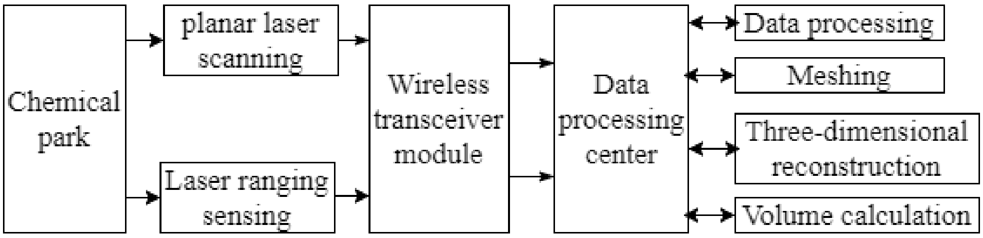

Figure 3: Block Diagram for System Hardware

Measuring system in chemical industry park is mainly composed of hardware and software. The hardware is mainly composed of 2D laser scanner, laser ranging sensor, wireless communication module, enhanced computer, and baffle board etc. Among them, data acquisition equipment which is composed of ranging equipment and wireless communication module is used to acquire 3D coordinate and transfer it for calculation and storage; system software is operated on the computer to control simultaneous operation of whole system hardware, store and process the measured data, and use meshing model to calculate material pile volume and mass in chemical industry park, and intuitionally show it through reconstructed 3D volume in chemical industry park.

2.4 Selection of ranging equipment

At present, main ranging methods of laser scanner include pulse ranging and continuous wave-related ranging methods. Pulse ranging method is characterized in narrow pulse and high power without setting cooperative target and its measuring distance is large. Ranging accuracy depends on timing clock frequency and echo threshold treatment method. General ranging error is centimetre-level and ranging frequency is low, such as 1Hz; based on laser pulse with sinusoidal modulation, its phase change during transmission can be measured to determine the distance to be measured, this is called continuous wave-related ranging method. It has high measuring accuracy, which is up to 0.1mm. As continuous laser has small power and requires cooperation objective and multi-scale measurement, this method is generally used for short-distance and high accuracy ranging. Correspondingly, the ranging data rate is also low. Schematic diagram for structure of laser scanner is shown in Figure 4.

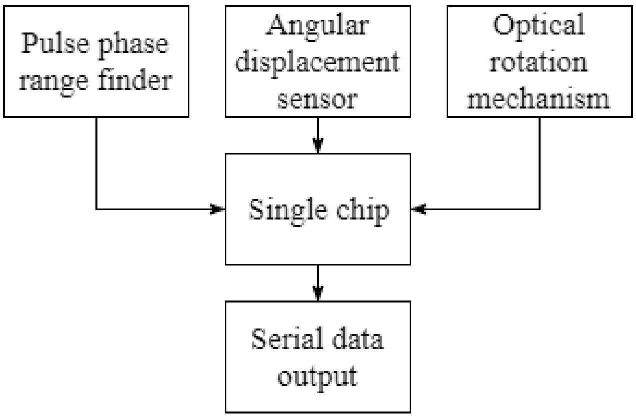

Figure 4: Schematic Diagram for Structure of Laser Scanner

Pulse phase ranging equipment is installed on the optics: in the slewing mechanism, angular displacement sensor is used to monitor real-time status of rotating mechanism. Scanning is used for continuous measurement. Measurement results are output through serial port RS232 or RS422 in digital signals.

3. Realization of data processing function

3.1 Volume calculation

Coordinates of 3D characteristic point cloud on the surface in chemical industry park are stored in the data documents in certain format. During volume calculation, the supplied document operating function is used to extract relevant data and store them in the memory variables; then, related pre-treatment algorithm should be used for denoising of acquired coordinate data, such as elimination of singularities, average value processing and boundary identification etc.; what's more, irregular triangular mesh is used to reconstruct the coordinate data and obtain multiple small triangular prisms for volume calculation after meshing of two adjacently scanned volume elements of section, and then add up the volume of all small triangular prisms to get the volume of the whole sectional volume element. Finally, it's necessary to add up all sectional volume to get the volume of the whole chemical industry park. Flowchart of volume calculation is shown in Figure 5.

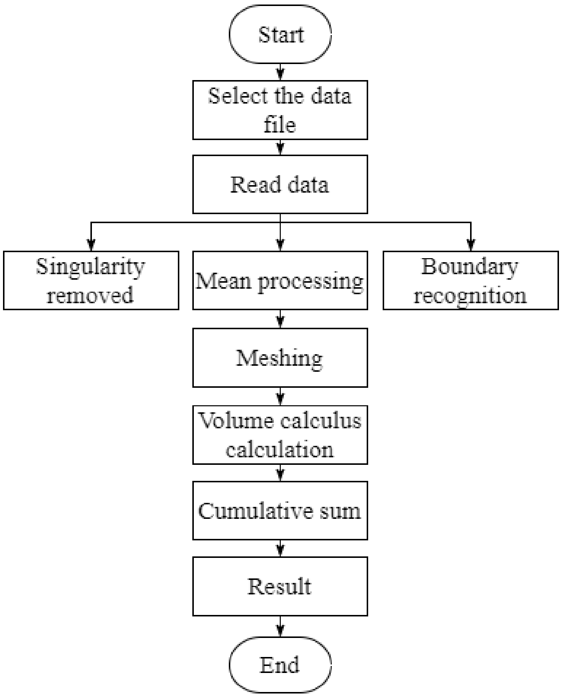

Figure 5: Flowchart of Volume Calculation

3.2 3D model reconstruction

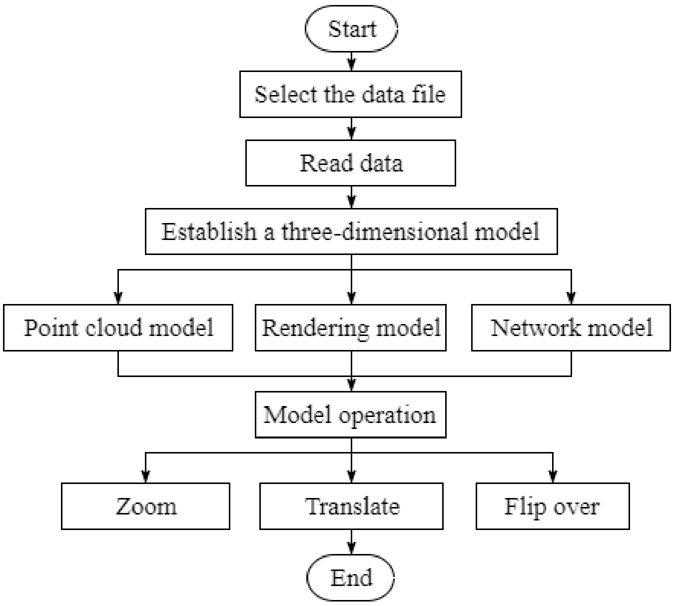

Figure 6: Model Reconstruction Flowchart

Dense point cloud data play an important role in showing surface information of the materials. But in case of requiring digital management system of chemical industry park, 3D point cloud data is inconvenient for attribute management due to its large volume. but, 3D model can be used to not only reflect spatial information of managed object, but also facilitate data storage, retrieval, edition and corresponding attribute connection. In this paper, LupoScan is used for 3D modelling for key pipes and tanks in chemical industry park. The built model is vector entity, convenient for browsing, management, single movement and edition, and used for providing a scientific basis for future maintenance, reconstruction and connection. Model reconstruction flowchart is shown in Figure 6.

4. Conclusions

3D laser scanning technology can be used for 3D measurement and control in chemical industry park, so as to quickly obtain 3D spatial data in the park. Through treatment, it can be used to measure and manger the buildings, pipes and tanks and other facilities and equipment in the park. Further 3D modelling and data analysis can be used for maintenance and reconstruction and safety monitoring and other delicacy management in chemical industry park, so as to provide a full and accurate spatial data support and scientific decision basis. But, there are still many problems worthing deep researches for that 3D laser scanning technology is used for monitoring and inspection in chemical industry park, such as real-time updating of 3D spatial information, establishing topological relation and implementing effective spatial analysis, integrating 3D model with production control to build an intelligent control, integrating 3D geometric field with other variables, such as temperature and humidity etc., to conduct further comprehensive data monitoring and analysis, which is also the key research topic in the future.

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