Study and application of lunar rover tracking measurement technology with laser radar and iGPS

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Abstract: The topographical data of movement environment and the real-time position and orientation of lunar rover must be accurately measured to test lunar rover’s ability of localization, path planning and mobile control. These data will be used to track the lunar rover’s movement in simulated lunar terrain in real time. Lunar rover tracking measurement technology with laser radar and iGPS is discussed in this paper, and a tracking measurement system is designed to measure and track accurately real-time position and orientation of lunar rover in the topographical data of movement environment. This system can provide some reference for the research of large-scale, high-precision and high-frequency tracking measurement of other rigid objects in specific environmental terrain.

1. Introduction

The lunar rover's navigation and control performance, especially the position determination ability, path planning ability and mobile control ability[1], need to be tested in the simulated environment of low gravity, lunar soil, terrain and illumination. The topographical data of the moving environment and the real-time position and orientation of lunar rover must be accurately measured. These data will be integrated to track the lunar rover’s movement in simulated lunar terrain in real time.

The Metris MV330 laser radar system[2], whose accuracy is better than 5mm, is applied to measure the 3D topographical data of the nonrigid simulated lunar terrain, which is larger than 90 square meters. The Metris iSpace iGPS system[3], whose accuracy is better than 1mm and sampling frequency is higher than 10 Hz, is applied to measure position and orientation of lunar rover. Lunar rover tracking measurement technology with laser radar and iGPS is discussed in this paper, and a tracking measurement system is designed to measure and track accurately the real-time position and orientation of lunar rover in the 3D topographical data of movement environment.

2. Design of tracking measurement system

In the tracking measurement system, the 3D topographical data of the simulated lunar terrain will be measured by the laser radar system, and the position and orientation of lunar rover will be measured by the iGPS system. Then the 3D topographical data will be converted into the DEM(Digital Elevation Mod) data. Finally, the position and orientation of lunar rover and the DEM data of the simulated lunar terrain will be integrated in an unified coordinate system to track the real-time position and orientation of lunar rover in the DEM data of movement environment.
The tracking measurement system consists of three subsystems: topographic measurement subsystem, position and orientation measurement subsystem, and data processing subsystem. The function of topographic measurement subsystem is to measure the terrain of the simulated lunar surface with laser radar system and obtain the 3D point cloud data of the terrain in the measurement coordinate system. The function of position and orientation measurement subsystem is to measure the position and orientation of lunar rover’s coordinate system, such as position, elevation angle, roll angle, and yaw angle, in the measurement coordinate system. The functions of the data processing subsystem are to transform the 3D topographical data into DEM data, integrate the lunar rover’s position and orientation data into the DEM data, and transmit these data to other devices in real time.

The hardware composition and software composition of tracking measurement system are shown in Figure 1. The overall measurement process of the tracking measurement system is shown in Figure 2.

3. **Topographic measurement subsystem**

The maximum measurement distance, the maximum measurement pitch angle, the scanning speed and scanning accuracy of laser radar system directly restrict its application in large-scale and high-precision terrain scanning. A study on large-size topography scan with Laser Radar was carried out to analyse and solve the problems\(^4\). In that paper, measure point planning, stitching method, scanning path design and optimized scanning parameters of Laser Radar were studied in detail to design an automatic scanning scheme of large-scale terrain. The topographic data obtained by the subsystem provides the discrete point cloud of the moving terrain of lunar rover for the tracking measurement system, and is the data source for generating topographic DEM maps.

4. **Position and orientation measurement subsystem**

The maximum measuring distance, the maximum transmitting pitch angle and the maximum receiving pitch angle of iGPS system will directly restrict its application in large-scale and high-precision dynamic measurement. A study on lunar rover position and orientation measurement with iGPS system was carried out to analyse and solve the problems\(^5\). In that paper, surveying point planning, network formation and calibration method of the transmitters, layout of the receivers, establishment and conversion of tracking coordinate system were studied in detail to design a dynamic position and orientation measurement scheme of lunar rover in large range. The dynamic data obtained by the
subsystem provides the real-time position and orientation of lunar rover for the tracking measurement system, is the data source for data processing subsystem, and is the key to realize the position and orientation tracking measurement of lunar rover.

5. Data processing subsystem
The data processing subsystem is composed of terrain data conversion module, data integration module, and data transmission module.

5.1. Terrain data conversion module
Terrain data conversion module converts the discrete point cloud data into DEM data of terrain. The position information recorded by the discrete point cloud data of the terrain, which is obtained by topographic measurement subsystem cannot visually display the topographic fluctuations. DEM data refers to the data set of plane coordinates and elevation of grid points in a certain range. It mainly describes the spatial distribution of regional topography. It is formed by data acquisition (including sampling and measurement) by contour or similar stereo model, and data interpolation. DEM data can visually and intuitively display the topographic morphology. The terrain data conversion module loads and processes the discrete point cloud data, and then builds DEM data. DEM data is generated by moving surface fitting and distance weighted average interpolation. Efficient spatial indexing mechanism algorithm is applied to ensure the rapid generation of DEM data.

5.2. Data integration module
Data integration module integrates and displays the real-time position and orientation of lunar rover in the DEM data of movement environment. Before data integration, it is necessary to ensure that the three-dimensional point cloud data of terrain and the position and orientation data of the lunar rover are in the same global measurement coordinate system to achieve effective overlay and integration of measurement data. The establishment of global measurement coordinate system needs to set up several reference spheres which can be recognized and measured by Laser Radar system and iGPS system in advance. Topographic measurement subsystem, position and orientation measurement subsystem measure the reference sphere respectively, and then establish the same global measurement coordinate system. After completing the data measurement, the real-time position and orientation data of lunar rover are superimposed on the terrain DEM data in the global coordinate system, and the position and orientation data of the lunar rover are updated and displayed on the terrain DEM data in real time. The effect diagram is shown in Figure 3.

![Figure 3. Effect of data integration](image-url)
5.3. **Data transmission module**

Data transmission module transmits the real-time position and orientation data of the lunar rover to the master computer and the driving source of sun sensors sensitive through TCP/IP protocol.

6. **Application of tracking measurement system**

In the simulation test of the lunar rover, according to the test environment and measurement accuracy requirements, a scanning scheme of simulated lunar surface and a measurement scheme of the lunar rover’s position and orientation are designed respectively.

According to the topographic characteristics of simulated lunar surface, a scanning scheme based on 3 survey stations and 14 common datum points is adopted (see Figure 4). The spatial layout of the scanning center group and scanning parameters (such as line spacing and point spacing) were designed according to different measuring stations and different measuring heights, and finally the topographic scanning of simulated lunar surface in the test field with size of $30 \times 30 \times 2m$ was completed. The accuracy of topographic position measurement is better than 0.5mm (3σ) and the accuracy of slope measurement is better than 0.1 degree (3σ).

![Figure 4. A scanning scheme based on 3 survey stations and 14 common datum points](image)

In the simulation test of the lunar rover, according to the lunar rover model, a dynamic position and orientation measurement scheme based on 4 laser emitters is adopted (see Figure 5). The measurement system is established by free networking method. The tracking coordinate system of the lunar rover is established by marking point conversion method based on 4 mini-vector bars (8 sensors). Finally, the real-time tracking measurement of the lunar rover’s position and orientation in the test field with size of $30 \times 30 \times 2m$ is completed. The position measurement accuracy of the lunar rover is better than 1 mm (3σ), and the orientation measurement accuracy is better than 0.1 degree (3σ).
Figure 5. A position and orientation measurement scheme based on 4 laser emitters and 4 mini-vector bars

The discrete point cloud data of simulated lunar surface obtained by the topographic measurement subsystem are shown in Figure 6. Terrain data conversion module converts the discrete point cloud data into DEM data of terrain. The data integration module integrates the position and orientation data of the lunar rover, which is obtained by position and orientation measurement subsystem, into the DEM data in real time. The final effect chart of the lunar rover real-time tracking measurement system is shown in Figure 7.

Figure 6. The discrete point cloud data of simulated lunar surface
Figure 7. The effect chart of the lunar rover real-time tracking measurement system

7. Summary
In this paper, a research of the lunar rover position and orientation tracking measurement technology based on Laser Radar system and iGPS system are carried out to test lunar rover’s ability of localization, path planning and mobile control. The lunar rover real-time tracking measurement system is designed and applied successfully in the ground test. In the test field with size of 30 × 30 × 2m, the accuracy of topographic position measurement is better than 0.5mm (3σ), the accuracy of slope measurement is better than 0.1 degree (3σ), the accuracy of lunar rover’s position measurement is better than 1 mm (3σ), and the accuracy of lunar rover’s orientation measurement is better than 0.1 degree (3σ). This tracking measurement system can provide some reference for the research of tracking measurement of other rigid objects in a wide range, high precision and high frequency in a specific terrain.

References
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