DIGITAL ELEVATION MODELS OF GREAT WALL BY A COMBINATION OF AIRBORNE AND TERRESTRIAL LIDAR

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ABSTRACT:

The Great Wall is one of the biggest man-made wonders of the world! The wall consists of bricks made by different dynasties and built on thousands of kilometers of steep mountain terrain. It has many different structures, irregular and inconsistent shapes. Therefore creating digital elevation models (DEMs) of the Great Wall through conventional satellite and photogrammetry stereo images has always been a challenge. . In this article, we will show that airborne laser scanning (LiDAR) can be used for the production of highly accurate DEMs of the Great Wall. In addition, a terrestrial laser scanner mounted on a tripod can also used to improve the terrain model, especially for the surfaces of the wall that are covered with dense vegetation. . The combined use of airborne and terrestrial laser scanners shows some exciting and promising advantages. The integration and fusion of data from both airborne and terrestrial laser scanners will be discussed. Highly accurate DEMs of the Great Wall with accuracies better than 10 cm have been produced. An evaluation of the accuracies achieved has been performed using either check points or trajectories obtained through kinematic GPS survey.

1. INTRODUCTION

1.1 The Project

Shanhaiguan Great Wall, which seat in Qinhuangdao city Hebei province, is the beginning of Great Wall. Although the wall are entire the circumvallation are destroyed heavily. So national finance bureau and Hebei province set special funds to repair them before 2008 Beijing Olympic game. The current situation investigation of Great Wall(including space location, destroy and texture etc.) is the inevitable step for repair.

This project aims at getting detailed map of shanhaiguan Great Wall(including guancheng, luocheng and wengcheng). So as to make highly accurate 3D model for the all. Which will give data support for Great Wall repair and construction.

Figure 1:Shanghaiguan Great Wall

1.2 LiDAR Technology

Use of LiDAR sensors and data has transitioned from the domain of research and development into the general marketplace primarily as a means of rapidly generating dense, accurate, digital models of the topography and vertical structure of a target surface. It can be said that the telecommunications boom in the 1990's brought the use of LiDAR into the more or less mainstream with the demand for mass production of high accuracy digital elevation models (DEMs), digital terrain models (DTMs) and triangulated irregular networks (TINs). LiDAR elevation data is ideally suited for mapping extensive areas where very high accuracy elevation data is required rapidly.

2. METHODS

According domestic aerial photography and Great Wall mapping situation we used abroad advanced LiDAR and digital photography technology to finish shanhaiguan Great Wall project. On this basis we want to do some study and research to make LiDAR technology more suitable to Chinese need and market.

For this project we will use airborne laser scanner, terrestrial laser scanner, high definition digital camera, GPS, IMU etc. to make highly accurate Great Wall models. We will acquire orthophoto and oblique texture so we can make the model more real.

When using LiDAR system we will use highly accurate digital camera to get orthophoto at the same time. We can tell the space location of LiDAR and camera through LiDAR GPS and ground GPS. The IMU can find every second airplane's pitch, roll and yaw changes. We can measure the Great Wall and height of Great Wall directly through Laser data. We use oblique camera to acquire Great Wall's side texture to realize exact measurement of point, line and area.

3. WORK PROCESS

3.1 Exact center of the wall located

Because the corridor is narrow we have to locate the wall's exact center so to cover every part of the wall. We use 1:50000 relief map and the historical photography data to get the basic location of the wall. At the same time we use GPS to get the corners' coordinates so as to locate the wall exactly.

3.2 Airborne laser system

In order to get enough laser points of the wall we design three lines for LiDAR system that are one just above the wall, each one for both sides they are 75m to 120m from the wall. Followings are the parameters:

- Altitude above ground ＝ 300m(average elevation is about 35m)
- Airplane speed ＝ 150 km/h
- Scanner angle ＝ 45degree
- Laser frequence ＝ 100,000hz
- Focal length ＝ 50mm

The point spacing is 10cm to 30cm. The pixel size on ground is about 7cm.

There are two synchronized ground GPS receiver when flying, which place at the control points of south-east corner of the wall and south to Big-Stone bridge respectively. For the definition of photo we choose clear day and check the picture quality when work. For the covered west parts we acquire the data when sun angle is wide enough and shadow is most small.

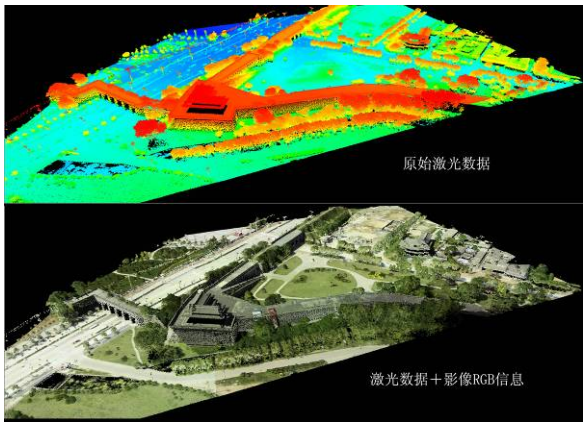

Figure 2: Laser data of the wall

3.3 Oblique picture taking

In order to get the side texture of the wall we design two lines which are 350m inside and outside of the center of the wall. For the west parts they are covered by mass trees we add one more line which is 225m to the west of the wall.

3.4 Terrestrial laser scan

The parts of wall which are covered by tress LiDAR and oblique camera cannot their ideal textures. Therefore we use terrestrial laser scanner to get them.

3.5 Data checking

After data acquiring we will do some preprocess work immediately to guarantee the quality. This work includes GPS and IMU data preprocess to get trajectory, laser and image coverage checking, image definition checking etc.

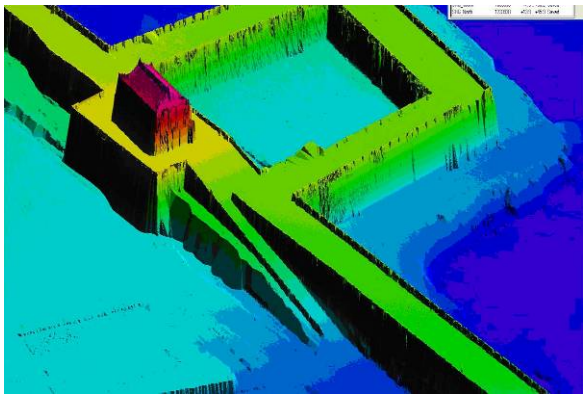

Figure 3: DEM of the wall

Figure 4: DOM (weng cheng)

3.6 DEM and DOM making

Firstly we classify laser data by LiDAR software and eliminate the points which are not belong to surface. Then we make DEM through surface laser points. The wall points are classify to surface.

On the base of classified laser data we micro rectify each pictures and mosaic them automatically then produce orthophotos. According to requirement we do some mix work to pictures' color to get high quality DOM.

Based on DEM and DOM data we can achieve 3D browse, distance, acreage and volume measurement, section cutting and making.

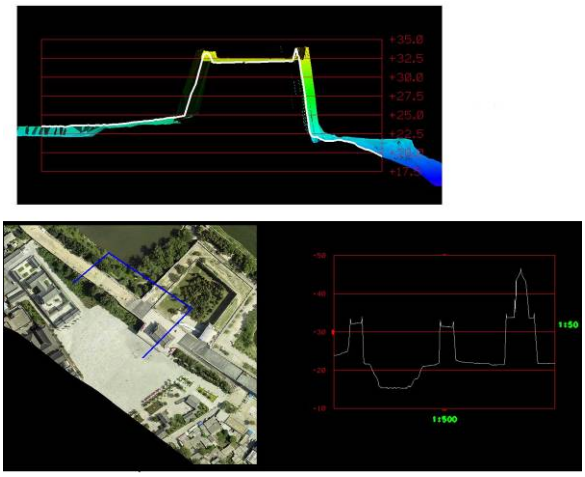

Figure 5: section

3.7 Real 3D model

We make TIN model for the wall through laser data. The orthophoto and oblique textures have exact space relationship. So we can create real 3D model for Shanhaiguan.

Figure 6: Real 3D model of Shanghaiguan Great Wall

4. IMPLEMENTATION

4.1 Equipments

1) Airborne Laser Scanner system
IGI LiteMapper 5600. full return waveform digitization,Maximum pulse rate up to 100,000 HZ，have a medium-format airborne digital camera system of 22 million effective pixels.

2) Terrestrial Laser Scanner system
Riegl LMS-Z420i. consists of a high performance long-range 3D laser scanner, associated operating and processing software RiSCAN PRO, and a calibrated and definitely orientated high-resolution digital camera that is Nokon D2X, 12.4 million effective pixels,focus length is 14mm.

3)GPS Receiver for base station
Trimble R8. 24-channel,double-frequency.

4.2 Implementation organization

It is the first time to make 3D photography for Great Wall. The geography of Shanhaiguan circumvallation is complex and trend is irregular. So if want to get the entire information of the wall we have separate them. Also we have to obey LiDAR system's requirement for turning, speed and safety(the north side of the wall is mountains). Which add difficulties for lines design, data input and flight.
This work creates a highly accurate 3D digital model for Great Wall. It is the first time in China and makes an example for Great Wall protection. The whole work is as follows:

- May.23.2006 to May.30，preparation
- Jun.1 to Jun.4，terrestrial laser scanner work
- Jun.5 to Jun.16，preparation for LiDAR system
- Jun.17 to Jun.18，LiDAR system work
- Jun.19 to Jul.5，DEM,DOM and 3D model making
- Jul.6 to Jul.9，production checking

5. ACCURACY

The checkpoint of Hebei mapping bureau checked our production's accuracy. Here are the outcomings:

1) For 44 points of 3D model, the average plane error is ±0.150m; the average elevation error is ±0.103m.

2) Checking 9 Jingbian tower elevation points using National Ⅳ Level, the average error is ±0.065m.
Checking 13 distance accuracy of 3D model, the average plane error is ±0.080m.

3) For 10 points of section elevation accuracy(only for characteristic points), the average error is ±0.131m.

6. CONCLUSION

1) The combination of low altitude high pixel photography and multi-sides measurement technology reproduce the Great Wall multi-angle textures.

2) The integration of new Digital waveform LiDAR technology and terrestrial laser scan system in digital Great Wall reflect the Great Wall's real 3D digital model.

3) The combination of high definition 2D pictures and 3D laser points data make big scale 3D shanhaiguan great wall, which make real 3D Great Wall model is visible in computer. That makes Great Wall reconstruction more easy.

4) It is the first time in China to combine LiDAR, terrestrial laser scanner, and other systems together. Which provides a new method for highly accurate and urgent project. It also offers a high technology way for digital city modeling.

REFERENCES

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