FAST RECONSTRUCTION OF THREE DIMENSIONAL CITY MODEL BASED ON AIRBORNE LIDAR

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ABSTRACT:

Three Dimensional City Model (3DCM) research becomes a hot area in GIS field in recent years. The 3DCM research also has great significance in traffic, land, mine, surveying and mapping, and other fields, especially in urban plan. The difficulty of acquiring 3D data is the key hamper for the development of 3DCM. Airborne LIDAR, which integrates GPS, INS and scanning laser rangefinder, can rapidly acquire the 3D position of ground using airplane. It is very economical, efficient and convenient to acquire 3D data. Traditional three-dimensional data acquisition method can't satisfied with the more and more fast development need of the city .airborne LIDAR technology is regarded as a convenience, swift, high-efficient three-dimensional data acquisition method, widely admitted progressively. LIDAR technology already has a history of more than ten years, major problem of hardware technology and system integration has already solved, had already developed successfully many business soft systems. But post-processing technology of LIDAR data still lag behind after practice, among them, the key problem is the data classification and extraction. A lot of commercial companies and some large institute are devoted to the research of this respect in the world, many kinds of filtration algorithm and extraction method have been introduced .in the future, more effective and more perfect algorithm will been used. Because of the complexity of the topography and surface feature of the objective world, at present, the research on data classification and extraction lay particular emphasis on different applications. As regards modeling of three-dimensional city, study mainly concentrate on the topography extraction and the building extraction etc. This paper has introduce post-processing procedure of airborne LIDAR data systematically, has realized the fast reconstruction of three-dimension urban model based on LIDAR data, enable this technology to serve the information construction of the city better.

1. INTRODUCTION

The construction of city informationization is gradually developing towards depth and width by the impetus of the national informationization tide. As an important technical support of the construction, GIS technology has already developed from two-dimension to three-dimension step by step. Three-dimension GIS can provide richer spatial information for city, give a more real expression of the objective world, enable the users to carry out browse, analysis and decision-making under the spatial and the three-dimension environment. Three-dimension city model is the foundation of establishing three-dimensional GIS, however ,for a long time, owing to the acquisition problem of three-dimension data, three-dimensional city model is difficult to establish fast and update timely, which impedes three-dimensional GIS's further development. The traditional methods of acquiring three-dimensional data include the topographic map with the architectural design blueprint, aerial photogrammetry, close-range photogrammetry, field surveying and etc, each of which has its own characteristics. but all have following limitation: complicated data acquisition procedure, long cycle, low efficiency and high cost. And worse still, regarding the complex building, the data acquisition is of low precision, and reconstruction model may be seriously distorted, such as Shanghai symbolic building -the oriental Pearl and Jinmao mansion.

In recent years, airborne LIDAR is gradually regarded as a new technology to acquire the three-dimension data precisely and fast. LIDAR is the initial letter abbreviation of Light Detection And Ranging (sometimes translated into laser radar),which is one kind of space surveying system integrating many advanced technologies such as laser ranging, digital aerial photogrammetry, global positioning system(GPS) and inertial navigation system(INS). Its operation principle is to use high-speed laser scanning survey to obtain fast three-dimension coordinate of the measured object surface in a large area with high resolution, subsequently, three-dimension data information of city may be collected quickly and massively .Compared with the traditional surveying methods, the airborne LIDAR technology has the following characteristics: high efficiency, high precision, automation, lower cost and rich information etc.

1) high efficiency: the airborne LIDAR can survey 1000 square kilometers within 12 hours. with the help of relevant software, the post-processing of LIDAR data may be conducted automatically or semi-automatically, transforming the LIDAR point cloud data into GIS or data formats received in other fields.

2) high precision: because laser pulse is not easily influenced by shadow and solar angle, the quality of acquired data is greatly improved, and especially the precision of elevation data is not limited by flight height. The precision of plane may reach 0.15 to 1.0 meter and the precision of elevation may reach 10

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centimeters. So compared with the traditional photogrammetry methods, it has superiority.

3) all-weather: except digital aerial photography, airborne LIDAR belongs to active remote sensing.

4) rich information: it may obtain not only three-dimension coordinates of the ground points, but also simultaneously three-dimension coordinates of the objects, such as trees, buildings and so on. And if LIDAR is loaded with the CCD, image information can be acquired.

At present, the research and application of LIDAR technology has been carried out gradually in our country. For example: Professor Li Shukai et al.of the Chinese Academy of Science has developed successfully the airborne three-dimension image forming system,and Professor Li Qingquan et al.of Wuhan University has developed the ground laser scaning surveying system, and Researcher You Hongjian et al.of Chinese Academy of Science has done research on buildings and topography extraction based on LIDAR data, and Dr.Zhang Xiaohong et al. of Wuhan University has done research on the LIDAR data filtering and objects extraction algorithm.These researches have achieved much in the theory aspect. Now, the more mature LIDAR commercial system includes ATLM and SHOALS (Optech company in Canadian), ALSSO(Leica company in America), TopoEye(TopoEyeAB company in Sweden), LiteMapper (IGI company in German), FalconII (TopoSys company in French). etc. and the more mature commercial softwares of LIDAR data processing include TerraModeler,TerraScan and TerraPhoto(Terrasolid company in Finland).

In 2006, Shanghai Institute of Surveying and Mapping acquired the airborne LIDAR data of 20 square kilometers in the central area of Shanghai using ALTM3100 airborne LIDAR system of the Optech company. This paper introduces the data processing procedure of the airborne LIDAR data and proposes a new method to reconstruct three-dimensional city model suitable for Shanghai with the help of relevant mature commercial software. It also explores a convenient, quick, highly efficient method of acquiring three-dimensional data and data processing, which solves an important bottleneck in three-dimensional GIS development, and which is of a crucial significance to the informationization construction of city.

2. THREE-DIMENSIONAL CITY MODEL

Three-dimensional city model, the foundation of establishing the three-dimensional GIS of city, decides the modes of organization, memory and management of the three-dimensional data, which directly influences the efficiency of browsing, distribution and inquiry analysis of three-dimensional GIS data. The three-dimensional city model is of application value and can be widely used, such as in the analysis of city noise、 thermal radiation diffusion、communication electronic wave coverage、city security and virtual reality of city and so on. This paper adopts object-oriented method, taking characteristics of Shanghai and application demand into account, and then, presents a new kind of the three-dimensional city model. According to the object-oriented thought, all kinds of things in the real world may be abstracted into one kind of objects with the public attributes. as for the city, the real world may be summarized for topography and object based on the terrain, so three-dimensional city model includes topography model and object model.

2.1 Topography model

Topography model usually expresses DHM(Digital Height Model) with digital elevation model, whose spatial distribution is described by the horizontal system of coordinate x, y, also may be described by the latitude and longitude ,whose altitude distribution is described by elevation Z. in practice, DEM can be expressed by two main methods :Regular grid model(Grid) and irregular triangular net model(TIN).they have their own merits and defects respectively, Grid model is simple and TIN may express undulation topography well. Considering topography is flat in Shanghai, the paper uses Grid to establish the topography model.

2.2 Object model

According to the characteristics of spatial distribution, object model in the city may be summarized into: artificial building model, horizontal element model, non-horizontal plane-shaped element model.

1) Artificial building model: in a city there are many artificial buildings including houses, viaducts and flyovers, bridges and so on, so the object models are in greatest need. We use 3DMax model tool to build up three-dimensional model for the artificial buildings, and realize the data exchange through 3ds document format .and 3ds divides the model into spatial triangular nets.

2) Horizontal element model: the horizontal element refers to the one with same elevation, such as lakes, reservoirs and so on .its characteristics are there being explicit conditions of boundary and there not being change in the elevation value in the area. The model is identical with the two-dimensional GIS with the only difference that it is three-dimensional coordinate point.

3) Non-horizontal element model: this kind of element mainly includes vegetation, green belt and the road. They generally covers the undulation ground, and the model may also be realized through the triangulation of the boundary polygon.

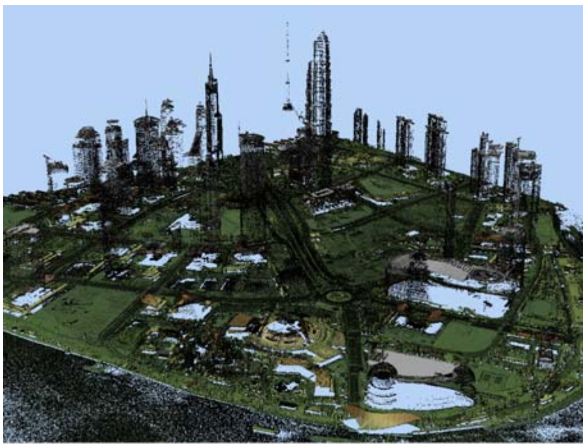

Figure 1. Point cloud of Lu Jiazui area of Shanghai

3. LIDAR DATA PROCESSING

LIDAR system uses random commercial software to process the data of plane tracking、plane attitude、 laser ranging and the swinging angle of laser scanning mirror, and finally, obtains the three-dimensional coordinates(X,Y,Z) data of various surveying points. The points, namely LIDAR original data, called “point cloud”, are three-dimensional discrete dot matrix data without attribute, suspending in the air as shown in Figure1,it is the point cloud data in Lu Jia zhui area overlapped ortho-image. The LIDAR original point cloud data have following characteristics:

1) Massive data: the data of 20 square kilometers acquired by Shanghai Institute of Surveying and Mapping is about 10G data (one point every 0.6m). at present, the software and hardware of an ordinary computer are unable to handle so magnanimous data once, therefore ,data must be blocked for the follow-up processing.

2) Insignificant discrete point: As the figure shows, point cloud reflects wholly the shape of buildings and the topography distribution characteristics, but in fact, single point cloud has no significance. Therefore, firstly, we must conduct the classification and recognition of original point cloud in order to realize the reconstruction of the three-dimensional city model through the operations of feature extraction and the constructed surface.

3)Rich information: the original point cloud information includes topography and objects, the latter comprise houses, trees, vehicles and power lines and so on. Now, The technology is unable to classify and recognize all the information one by one from the point cloud, therefore, the present research mainly focuses on how to extract interesting information, in the meanwhile, the emphasis is also different in different research fields. Regarding city, the key to research is the extraction of topography and buildings; and regarding forestry, the key is the extraction of trees.

LIDAR original data is pre-processed to produce digital surface model (DSM). Through classification and extraction, topography and object information related to model is acquired to prepare for three-dimensional city model .

3.1 Data preprocessing

Data preprocessing includes the deletion of abnormal point, coordinate transformation and flight strip combination.

1) Deletion of abnormal points: in the process of actual flight surveying, due to all kinds of factors such as mirror reflection, circuit problem of system and obstacle, there is abnormal value in LIDAR original data, so filtering the original data must be conducted in order to delete those abnormal points that are higher than the flight height or lower than the ground.

2) Coordinate transformation: original point cloud data of LIDAR belongs to WGS-84 coordinate system. As far as Shanghai is concerned, WGS-84 coordinate system of those points should be transformed into local coordinate system. for this purpose， firstly, WGS-84 coordinate system is transformed into Beijing 1954 coordinate system, and then transforms it into local coordinate system. Regarding elevation datum, what GPS provides is geodetic height based on the surface of ellipsoid. However, in practice, what we need is normal height based on the geoid. Elevation datum transformation can be achieved by establishing normal height model depending on some known control point fitting.

3) Flight strip combination: when LIDAR system works, due to the limitation of flight height and scanning FOV (field of view), the plane must fly the multi-strip route of zigzag in order to cover a certain area. Moreover, these routes must maintain certain degree of overlapping (10%-20%). Therefore the original LIDAR data of different flight strips must be merged, and put into order according to X direction or Y direction. And then the sorted LIDAR data is merged into a whole according to a certain order for block extraction and processing.

3.2 Data classification and extraction

LIDAR technology has enjoyed a development of more than ten years. The questions of hardware technology and system integration have been solved very well and now there are many mature commercial systems available. But the post-processing technology of LIDAR data lags relatively behind the demands, whose key problem is classification and extraction of data. Many international commercial companies and institutes of scientific research are devoted to this aspect and many kinds of filtering algorithms and extraction methods are already presented. At present, duo to the complexity of the object and topography in the objective world, the researches on the classification and the extraction of data lay different emphasis for different application. Speaking of three-dimensional city modeling, the research mainly concentrates on the extraction of topography and buildings.

In the aspect of topography extraction, Axelsson et al. in Sweden presented the gradual enhancement algorithm based on TIN (Triangular Irregular Network), which first chooses the initial ground point to construct the initial TIN, and second set parameter values such as the angle of iterative, the distance of iterative, the angle of tilt and so on, and third add the points of DSM to TIN step by step through iterative repeatedly, and finally, realize topography extraction; Franz Rottensteiner et al. in Austria used the lamination robust interpolation algorithm based on the non-uniform error distribution function to obtain DTM (Digital Terrain Model); Vosselman et al. in Delft University of Dutch presented morphology filtering method to separate the topography points from the non-topography points in DSM, which was improved and optimized later by many people and from which many other algorithms evolved; Wack and Wimmer in Austria presented a method based on grid grading to obtain DTM from DSM; Sithole et al.in Dutch compared all the algorithms mentioned above and chose many regions with different characteristics for experiment. Their results showed that these algorithms are effective for simple regions. But for the complex regions, especially the cities, the results aren’t very satisfactory and need manual intervention or further processing.

In the aspect of building extraction, Alhartthy et al. of Purdue University in America designed a evolution-filtering method to extract the three-dimensional information of a building; Vosselman et al .of Delft University in Dutch used the three-dimensional Hough transform to extract the roof information from DSM and the outline from the information of the plane. Regarding extremely crowded DSM point cloud, they also applied Delaunay triangle processing method to obtain the information of buildings; Michel et al. of Ohio University in America extracted the outside shape of buildings by the regiongrowth algorithm based on least square adjustment; Researcher You Hongjian of Chinese Academy of Science presented a method of automatically extracting the outside shape of buildings from sparse DSM point cloud. The difficulty in extracting buildings is the extraction of the shape of roofs. For the regular roofs (herringbone, flat top, oblique top), the algorithms mentioned above are very effective, However for the complex ones, manual intervention or further processing are needed.

At present, Shanghai Institute of Surveying and Mapping applies a more mature commercial software of Finland: TerraSolid to realize the classification and extraction of the data, which runs under the platform of MicroStation. The software was developed according to the classification and extraction algorithms presented by Axelsson et al. in Sweden, which comprises TerraScan, TerraModeler, TerraPhoto and many other modules. TerraScan is applied to data classification and extraction; TerraModeler is used in producing and processing each kind of surface; TerraPhoto is used in processing the original image. The topography model and building model established through the software need further repairing and processing if they are complex artificial buildings (Oriental Pearl, Viaduct and Flyover).

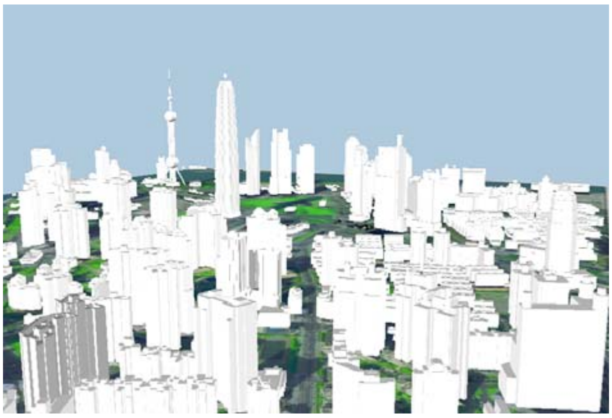

Figure 2.The three-dimensional model of Lu Jia zhui area of Shanghai without the texture

Figure 3. The three-dimensional model of Lu Jia zhui area of Shanghai with the texture

4. RESONSTRUCTION OF THE THREE-DIMENSIONAL CITY MODEL

Using TerraSolid module and assisted by a little manual intervention, a topography model and building model can be obtained from DSM. The topography mode is expressed by the triangular irregular net (TIN) and the building model by the 3ds format. Figure2 is the three-dimensional model of Lu Jia zhui area of Shanghai obtained from LIDAR data without the texture. In order to achieve a better effect of visualization, the topography model needs to superimpose the ortho-image and the building model need to paste the real texture. Figure 3 is the three-dimensional model of Lu Jia zhui area of Shanghai pasted with the picture of the texture.

Shanghai Institute of Surveying and Mapping possesses abundant two-dimensional data of Shanghai. Through integrating the data with the LIDAR topography data and using the corresponding tools developed by the author the reconstruction of models of other factors can be accomplished. After obtaining the elevation information from the topography data and the plane position from the two-dimensional data, the horizontal factor model can be constructed on the basis of the two-dimensional surface factor structure. The non-horizontal factor model can be reconstructed by using the superimposition operation of the two-dimensional data and the topography model TIN and the end model is also expressed by TIN.

5. CONCLUSION

The prospect of the airborne LIDAR technology's application is promising, and our country lags behind the developed countries relatively in the applied research of the technology. Shanghai Institute of Surveying and Mapping acquired the data of 20 square kilometers in the center of Shanghai with the airborne LIDAR technology. Through data processing, information extraction and reconstruction of the three-dimensional city model, the institute has accumulated the experience of LIDAR data processing and proved that the LIDAR technology is a convenient, rapid and highly efficient method for acquiring the three-dimensional data. It has extremely vital practical significance to guide comprehensively the applied research as well as the research of data processing of airborne LIDAR technology in our country.

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