WORKFLOW AND QUALITY CONTROL TO GENERATE DEM AND DSM BY AERIAL PHOTOGRAMMETRY

JIA Qiuying  CAO Haitang  JIANG Decai  ZHU Rong
Surveying and Mapping Engineering Branch of Aerophotogrammetry and Remote Sensing Bureau of China Coal (ARSC)  Xi’an, 710054 - jqy691107@163.com

WG IV/1-Spatial Data Infrastructure

KEY WORDS: Aerial Photogrammetry, DEM/DTM, Triangulation, Model Precision, CAD IKONOS

ABSTRACT:
DEM and DSM both are very important fundamental geographical information data. Along with the 3G technology unceasing development, DEM and DSM have been applied widely in the telecommunication industry. Since cooperating with Siradel France in 2004, ARSC has produced DEM and DSM data for Hong Kong, London, New York, Romanian entire boundary, and many French cities including Paris. Moreover, we first use IKONOS stereo pair imagery to produce DEM and DSM data for Morocco cities such as Rabat and Casablanca successfully. ARSC has provided high grade DEM and DSM data, already obtained France side's complete approval, also made the aerial photogrammetry method to generate DEM and DSM data applied in the data production widely. In this article, the authors mainly introduce the workflow to generate DEM and DSM data by the aerial photogrammetry method, the frequently asked questions and quality control method. This will lay a good foundation for us to provide the client with satisfied digital products.

1. INTRODUCTION
DEM (Digital Elevation Model) is the digital presentation of regional terrain. Its mostly reflects the nature landform characteristics in a local area. And DSM (Digital Surface Model) is the digital presentation of the earth surface features. They biggest difference lies in that DEM only express the hypsography, but DSM express not only the hypsography, but also includes each building surface and the vegetation coverage situation. It reflects the surface character of all object located in the ground.

Along with the rapid development of computer science and the aerial photogrammetry technology, the Chinese telecommunication industry also develops unceasingly following it, 3G mobile will enter Chinese market. 3G technology also will be applied widely. The aerial photogrammetry has become one of the most effective methods to provide high-resolution fundamental data for 3G technology. SIRADEL is a world leading provider of geographical databases, propagation models and radio expertise for planning and optimizing any radio networks worldwide, has lots of international cooperation partners. ARSC is one of them in Asia. In past several years, ARSC has provided about ten thousand square kilometers DEM and DSM basic data. In this article, the authors discuss the operation and quality control method combining with the practical problem appearing frequently in the production.

2. ESSENTIAL HARDWARE AND SOFTWARE

Hardware: SSK, ImageStation Z from Intergraph Corporation  
JX4 from Beijing Geo-Vision Tech.Co.,Ltd.
Software: Microstation J from Bentley Systems, Incorporated  
ISDM, ISSD, ISDC, ISFC from Intergraph Corporation  
CAD2000  
ARSCCHECK from Siradel France

3. TECHNICAL REQUIREMENTS

3.1. Data Capture Requirement to DEM
DEM data capture mainly includes road, hydrology, railroad and terrain feature lines, breaklines etc. various natural relief feature. The required accuracy of various elements to compose of DEM should be less than 1 meter. In order to avoid from affecting the precision caused by DEM's sudden change in the short distance, all breaklines must be cut down in intersection area. The elevation value in tie-in area of linear object should be only one.

3.2. Data Capture Requirement to DSM
DSM data capture mainly includes various building, industry and mining facility and vegetation etc.. The required accuracy of various elements to compose of DSM should also be less than 1 meter, and these elements must build a topology relationship, one corresponding elevation value should be labeled within each topological surface. If the height difference is more than 5 meters within the same clutter object, it should be cut into segmentation to form several topology relations. Similarly, if there is a dooryard within the building, or there is an open area within a forest, they also must be closed by using the independent polygon.

4. OPERATION METHOD
For DEM and DSM basic data capture, Siradel France has provided a set of detailed technical requirement. We have prepared the relevant operation plan after studying their requirements. Our workflow is as follows:

According to Siradel’s requirements to data, the captured data can be divided into three main parts: (See Figure 1. Three Categories of Digital Data)
To create a project by using ISPM

To restore Stereo Model

Data Capture

Captured Data Check

Data Editing

Edited Data Check

Data Submittal

Figure 1. Three Categories of Digital Data

- clutters (buildings, vegetation, water and bridges)
- altimetry (ground height)
- roads and railways

The client's general requirements: To describe the clutter objects with a closed polygon; the linear objects with a continuous line. Each clutter object should be completed with a 3D point located inside the polygon with a Z-value corresponding to the highest point of the object, and their height precision should be less than 1 meter.

According the above-mentioned requirements, we complete the work in two steps: data capture and data editing. Here first we would like to introduce the method for data capture.

4.1. Capture of Road Data

4.1.1. The classification of road data

It includes highways, main roads, secondary roads, local and urban routes, lanes and paths, railways.

4.1.2. Geometrical specifications

Because all the lines representing the roads networks contribute to the definition of digital terrain model, the density of the network can improve DEM. Therefore the 3D data component must be very accurate. The roads under and on the viaduct or river bridges must be captured in a continuous way; however they have to be interrupted in front of a tunnel entrance. The roads must intersect at common nodes, two intersecting roads must have the same z-value at intersection.

4.2. Capture of altimetry data

Altimetry is generally defined by the breaklines, but it can sometimes include 3D points and contour lines. The main purpose is to improve the digital terrain model outside the road network by giving all the terrain shapes and breaks. They include the tops of the embankments, the bottoms of the embankments, the thalweg lines, the crest lines, 3D mass points, contour lines. All these data should be captured with the same z-value at intersections.

4.3. Capture of clutter data

Clutter data are classified into four main categories: constructions, vegetation, water and bridges. At the end of capture, every kind of object must be described by a set of closed polygons whose height is given by a 3D point. This is performed in two main steps:

Step 1: 3D capture

3D capture, that means the exterior outlines of each object should be captured first and classified into different layer according to their height difference. A 3D point located within each clutter object should be captured at the maximal elevation of the object. It should be noticed that all the holes (yard, glade, or island) must be attached to the exterior contour using an interior limit. (See Figure 2)

Step 2: Creation of topology (Generation of closed polygon)

To transfer a set if 2D data from captured 3D data and all polygon objects will be picked up from 2D data to generate polygons by using GeoGraphics so as to reach an effect that each polygon must be associated to each 3D point. Please refer to Figure 3.
Once the topology is created, buildings, forest, bridge, river etc. are described by the closed polygons.

In consideration of the client’s requirement to data accuracy, what we must done during capturing data is that the object’s classification should be correct, the snap precision is up to grade, no omission and missing object. And that creating the topology to ensure z-value is the same at nodes of road and terrain data intersections, all those will be performed in data editing process. Hereinafter the operation method of data edit will be introduced.

4.4. The data editing

It can be completed in five steps: Step 1, Check layer and color, flying point and line; Step 2, Pick up DEM data and process data error; Step 3, Pick up all polygon features including tree hedge to create topology relations; Step 4, Pick up 3D point from 3D data and the polygon from 2D data separately and run ARSCCHECK to detect error, then modify them; Step 5, Transfer DXF format under the CAD 2000 according to the client’s requirement, then deliver the data to the client.

Step 1. Check layer and color, flying point and line: Its main purpose is to unify layer and color, to modify the wrong layer phenomenon probably appearing during capturing the data. Detect if there is flying point and line in data via front view.

Step 2. Pick up DEM data and process data error: Modify the dangling and make nodes to terrain (ground height), road and railway so as to ensure common nodes that should be shared at junctions of DEM data with same z-value.

Step 3. Pick up all polygon features including tree hedge to create topology relations. This is the key point in data editing process. First, modify dangling by using 2D data to the object elements in 3D data. Then, pick-up all polygon elements including tree hedges and transform them into 2D data. Make nodes to those 2D data, after that, modify dangling again. Because if the dangling is modified well or not will have relations with the veracity of creating topology. After completely dangling modification, the closed polygons can be created layer by layer under GeoGraphics.

Step 4. Run ARSCCHECK to detect the error and correct them. The topology should meet these requirements:

- A polygon cannot intersect itself or any other polygon. (See Figure 4)
- A polygon can touch another polygon. That means they share the same points. (See Figure 4)
- Tangential point between two polygons is not allowed. (See Figure 4)
- Polygon A can be fully inside another Polygon B. (See Figure 4)
- Holes cannot be totally located within another polygon. (See Figure 5)
- A polygon must not present sharp angle less than 5°. Refer to Figure 6.

Step 5. Transform the edited 2D and 3D data into DXF format under the CAD 2000, then deliver the data to the client.

5. FREQUENTLY ASKED QUESTIONS AND QUALITY CONTROL METHOD

In order to capture the high-resolution data, Siradel drafted a
detailed specification and supplied a check program to check the data quality. So during the actual operation, the operators should pay more attention to the consistency between the actual production and specification so as to ensure the data’s geometry precision and integrality. In the production process, the quality control will be completed in two steps. One is correct objects classification, strict snap, no missing information in data capture process; The other is strict match and overlap between 2D and 3D data, and correct topology in data editing process. The following is the frequent questions in the data production.

5.1. Orientation

The orientation precision will affect the precision of basic data directly. Therefore the orientation precision must accord with the design requirement. Usually, we adopt manual interior orientation, then import the aerial triangulation data directly, in this way, we can avoid from twice orientation error so as to ensure the orientation precision.

5.2. Altimetry (ground height)

Altimetry is the basic data to generate DEM, when its precision limits less than one meter, the following questions can appear frequently.

5.2.1. The embankment is not complete or missing.

Because the terrain (ground height) accuracy is required no more than one meter, only when the elevation difference between the top and bottom of embankment is less than one meter, the embankment can be ended. Even if sheltered from the construction, it should be described completely. Please refer to Figure 7.

5.2.2. The relation between the bridge and the embankment is illogical.

Please see Figure 8.

5.2.3. Lack of breaklines behind the buildings

This makes DEM data of part building falling under the ground. Please see Figure 9.

5.2.4. Breaklines are crossed

That the breaklines are crossed is also a common problem. This will cause DEM abnormal.

5.3. Road Capture

When capturing the road, often appear two common problems: one is easy to make road classification confused. So first, we must understand road classification criteria correctly in design requirement. And we also need to know the traffic situation in the surveyed areas within the various countries or regions. Secondly, it must be noticed to capture data at intersections by using 3D snapping so as to assure they have the same Z-value at intersection.

5.4. Clutters Data Capture

The clutters’ data are also an important part of basic data to generate DSM, it is requested to close the polygon and form certain topology relation, and no any intersection exists among polygons. Please see Figure 10.

5.5. Construction Classification

It’s also easy to create error when classifying building. This
requires us to understand construction classification criteria correctly in the design. Next is to understand the local architectural style, the natural conditions and social customs as well as the religious belief in the surveyed area of various countries and regions, then we can classify the construction accurately.

5.6. The Problem of Topology Relation

When editing the captured data, often meet the following problem: the topology relation is created incompletely, the 3D data capture and the 2D capture present the chaotic phenomenon. After merging the files, it presents the redundant or overlapping phenomenon. But such problems can be solved through checking repeatedly by running Siradel’s ARSC-CHECK programme.

6. CONCLUSION

Since cooperating with Siradel France in 2004, ARSC has produced DEM and DSM data for Hong Kong, London, New York, Romanian entire boundary, and many French cities including Paris. Moreover, it’s first time that we use IKONOS stereo pair imagery to produce DEM and DSM data for Morocco cities such as Rabat and Casablanca successfully. ARSC provides the high grade DEM and DSM data that have already obtained France side’s complete approval, also made the aerial photogrammetry method to generate DEM and DSM data applied in the data production widely. During working in the future, we will still make furtherer research for the approach to generate the DEM and DSM data by using the aerial photogrammetry method so that we can try to do better in improving the production efficiency and quality.

REFERENCE

High resolution data capture specification to DEM and DSM SIRADEL, 2005.


ACKNOWLEDGEMENTS

During writing this paper, Mr. Bai Zhigang and Mr. Chen Jingtian gave us the constructive support, and Ms. Cao Haitang made the translation for this article. Here we would like to express our heartfelt appreciation to them.