Oblique photogrammetry-based 3D GIS technology

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Abstract

Currently, 3D GIS has been widely applied in fields such as city planning, smart city, smart campus, 3D underground pipeline management, infrastructure management, water conservancy and environmental protection. In the development progress, the cost of 3D GIS collection and production is a key factor that restricts the development of GIS and application range of 3D GIS. Currently, model formats supported by SuperMap 3D GIS include 3DS, .X, OSGB, FLT. Manual modeling and oblique photogrammetry modeling are the two primary modeling methods for 3D GIS. For a long time, people have used 3D modeling software such as 3DMAX and MAYA to produce models manually. Though it has advantages, there are problems for manual modeling. As a good supplement to manual modeling, oblique photogrammetry modeling will develop constantly in 3D GIS applications. Though oblique photogrammetry modeling has obvious advantages in production cost, production cycle, and precision, challenges for applying oblique photogrammetry data still exist. SuperMap has implemented a number of technological innovations to overcome those challenges. Firstly, SuperMap GIS innovated the data processing method to realise the high-performance loading mechanism of the oblique photogrammetry data. Secondly, SuperMap GIS provided technology to recover the oblique photogrammetry to assist users in making the most use of the oblique photogrammetry data. Moreover, SuperMap GIS broken difficulties of the traditional analyses and researched GPU-based 3D spatial analysis methods for oblique photogrammetry models. Analyses methods provided by SuperMap GIS for oblique photogrammetry models include visibility analysis, viewshed analysis, skyline analysis, shadow ratio statistics analysis, and planning comparison analysis. Those analyses grant oblique photogrammetry modeling value and allow it to be more widely applied. Considering the prospects of oblique photogrammetry modeling, SuperMap will devote to innovations of applying oblique photogrammetry model data in 3D GIS constantly.

Key words:

oblique photogrammetry, 3D GIS technology, 3D spatial analysis

3D GIS technology progress in the era of oblique photogrammetry

Compared to 2D GIS, 3D GIS enables us to observe, understand, manage and plan our world in a more vivid and intuitive way. Currently, 3D GIS has been widely applied in fields such as city planning, architecture, water conservancy and environmental protection. In the development progress, the cost of 3D GIS collection and production is a key factor that restricts the development of GIS and application range of 3D GIS. For a long time, we used 3D modeling software such as 3DMAX and MAYA to produce models manually.

The effect of manual modeling depends on the technical level of the modeling staff. Manual modeling has some advantages as it is compact and does not have space-time constraints. However, manual modeling also has some restrictions and limitations, such as high cost, long production cycle, and difficulty in guaranteeing accuracy. Oblique photogrammetry data production, which is supplementary to manual modeling and even a subversion of manual modeling in some fields, provides better 3D data production and management.

Oblique photogrammetry modeling is a photogrammetric method, which combines conventional nadir images together with oblique images acquired at high angles to build 3D models with texture data obtained from oblique images.
Compared to manual modeling, oblique photogrammetry modeling has following advantages:

- **Automated production process**: Automated production process formed for oblique photogrammetry modeling reduces dependence on artificial skills.

- **High productivity**: Take a city area of 50 – 80 km² as an example. The flying and shooting can be finished in one day and the automated processing of data can be finished in two weeks. If parallel processing of multiple servers is employed, the production cycle will be shortened correspondingly. Therefore, oblique photogrammetry modeling can achieve data update of high frequency.

- **Low production cost**: Since the dependence on artificial skills has been reduced for oblique photogrammetry modeling, the production cost for oblique photogrammetry modeling is around 30 – 60% of that for manual modeling.

- **Data with high precision**: Currently, the error of oblique photogrammetry model data can be controlled under sub-metre level.

In summary, oblique photogrammetry modeling has obvious advantages in production cost, production cycle, precision, etc. As a good supplement to the manual modeling, oblique photogrammetry modeling will develop constantly in 3D GIS applications. Although there are still challenges for the application of oblique photogrammetry models in GIS, it has been widely used in multiple fields due to its advantages in efficiency and cost.

Considering that the oblique photogrammetry data has good prospect, SuperMap implemented a number of technological innovations in high-performance loading, object-oriented management, professional spatial analysis and so on, to enhance the application value and broaden the application range of oblique photogrammetry data considering challenges oblique photogrammetry data faced in the application.

**3D models supported by SuperMap GIS**

Data is the basis for GIS system construction. Strong and convenient data processing capability can provide powerful support for GIS system construction. SuperMap GIS supports mainstream 3D model data and batch import of textures. Model formats supported include 3DS, .X, OSGB, FLT and CityGML. Meanwhile, 3D Max model plugin has been provided for directly exporting 3D Max models and batch transformation of models.

Considering that the support of oblique photogrammetry models has significant meaning, SuperMap GIS has made great efforts in oblique photogrammetry model loading can bearing capabilities.

SuperMap GIS now supports the instant loading TB-level oblique photogrammetry data in full extent, with high panning frame rate, low CPU occupation, low memory resource occupation, and overall good user experience. A copy of oblique photogrammetry data for an area of 450 km² has been tested and the panning of the model is smooth and stable.

**Convenient and efficient oblique photogrammetry model loading mechanism**

Oblique photogrammetry data is often high in volume, and data transformation will be extremely time-consuming, sometimes costing months. SuperMap GIS can directly load original model format (.osgb format) of oblique photogrammetry data efficiently through a configuration file, without needed of importing and data transformation.
Besides, if oblique photogrammetry data needs to be overlaid with other vector data, generally projection transformation will be needed and this process is also time-consuming. SuperMap GIS allows the dynamic projection of the oblique photogrammetry data to the corresponding coordinate systems, which significantly reduces the data processing cost.

Strong oblique photogrammetry model bearing capability

SuperMap GIS provides some key built-in technologies. These technologies ensure the efficient loading and smooth display of TB-level oblique photogrammetry data. Meanwhile, long time stable running with relatively low hardware occupation is also ensured by the technologies. The key technologies include:

- **Making full use of LOD structure of oblique photogrammetry models**: SuperMap GIS made full use of the LOD hierarchical structure of oblique photogrammetry models to load data of different sophistication levels according to the position and importance level of features in the 3D scene. This will not only significantly enhance the browsing performance, but also achieve balance between effects and performance, therefore realising strong data loading capability with relatively few hardware resources.

- **Dynamic scheduling (out-of-core)**: Typically, to optimise performance, virtual reality or game software will load all data in the current scene into memory. Therefore, the amount of data loading is very limited. However, the GIS platform software often needs to manage, display massive oblique photogrammetry data of TB-level. It is impossible to place the data into the memory all at once and data needs dynamic scheduling based on the position of observation point to load data in current view into the memory and automatically release data out of current view. Data will be dynamically loaded from near to far according to the position of the observation point, with rough layer loaded before the loading of the fine layer. Data nearest from the observation point will be scheduled and rendered in highest priority scheduling and rendering. This technology does not only provide good visual experience, but also makes more efficient use of hardware resources.

- **Data and texture compression**: SuperMap GIS provides a compression tool, which firstly compresses the texture data of oblique photogrammetry data, then packages the compressed texture data into .osgb model file, and finally compresses the packaged .osgb file into zip file to ensure the compressed data is small enough and the compressed file is still in .osgb format. Through data compression, texture data and models can be downloaded and loaded into memory with one time, and texture data can be directly loaded into video memory without decompression. Models can be loaded faster, while video occupation is reduced. This technology increases the loading amount of model data and enhances the performance experience.

Oblique photogrammetry model recovery technology

As a technology that appears in recent years, oblique photogrammetry technology itself still has some flaws. For example, models may have holes, modeling effect for small-scale features may be not as good as expected, models may not match perfectly with the terrain. SuperMap GIS provides technology to recover the oblique photogrammetry to assist users to make the most use of the oblique photogrammetry data.

Model hole recovery technology

Oblique photogrammetry data may often have holes for water areas. This is because feature points of the same name will be automatically searched for an area at different angles during modeling process with oblique photogrammetry modeling software. Feature point in image is actually pixel point that possesses certain
parametric characteristics while has some differences with neighboring pixel. However, the water area in image generally has uniform color and it is hard to find such feature points. That is why holes may exist in water area, as indicated in Fig. 1.

Users can use a vector polygon filling with water symbol to fill the hole. Only four steps are needed with SuperMap GIS:

- **Step 1**: Create a 3D vector dataset to store the polygon for water area.
- **Step 2**: Draw a polygon for the hole.
- **Step 3**: Modify the vertices that do not match well with the boundary of the water area. New vertices can be added and redundant vertices can be removed.
- **Step 4**: Create a water symbol and set parameters such as shadow, wave, color, etc. Finally, assign the symbol to the water area to get the effect as shown below.
Small-scale feature optimisation

Small-scale features such as light poles and trees are not well represented with oblique photogrammetry technology. These features may exist as fragments, dangles, projections in oblique photogrammetry model, as indicated in Fig. 6.

To solve this problem, SuperMap GIS provides the flattening function to allow users to remove fragments and dangles, and then use 3D symbols to render them. The entire process is very simple – users only need to draw a region for flattening and modify the vertices of the region. Then the oblique photogrammetry model of the specified area will be flattened and users can use 3D symbols to render features in this area. As shown in Fig. 7, trees are rendered using 3D tree symbols.

Matching of oblique photogrammetry model with terrain

An oblique photogrammetry model is a digital terrain model, which contains realistic terrain information. Mismatching problems may exist while overlaying an oblique photogrammetry model with a terrain model, as
indicated in Fig. 8. This may be caused by the inconsistency of data acquisition time, acquisition accuracy of terrain data and oblique photogrammetry data.

To solve this problem, we can certainly replace or modify the original terrain data. But if we do not have the permission or ability to modify the terrain data, this will not work as we expect. SuperMap GIS provides a method to solve the mismatch problem at the display level, without modifying the original terrain data. We can modify the terrain to bring down the terrain of a specified area under the oblique photogrammetry model, which solves the mismatch problem and will not affect the terrain display for the area without oblique photogrammetry model. Vertices of area for terrain modification can also be modified in the scene, allowing users to modify the region precisely.

**Oblique photogrammetry-based 3D spatial analysis**

Oblique photogrammetry models are not individual models, and traditional 3D analysis methods cannot be implemented on oblique photogrammetry models. SuperMap GIS breaks difficulties of the traditional analyses and researched GPU based 3D spatial analysis methods for oblique photogrammetry models, not only realising 3D spatial analysis capabilities for oblique photogrammetry models, but also achieving real-time display of analysis results through GPU processing. Analyses methods provided by SuperMap GIS for oblique photogrammetry models include visibility analysis, viewshed analysis, skyline analysis, shadow ratio statistics analysis, and planning comparison analysis. Those analyses grant oblique photogrammetry modeling value and allow it to be more widely applied.

**Visibility analysis**

SuperMap GIS provides visibility analysis for oblique photogrammetry models to analyse whether two points or multiple points are visible to each other or not. As indicated in Fig. 10, an observation point and multiple target points have been selected in a scene, the visibility situation can be analysed through visibility analysis. Two colors can be used to represent visible segments and invisible segments, and the obstruction points will be returned.
Visibility analysis can be applied to evaluate tourism landscape, analyse line of line of building, monitor coverage rate, monitor communication signal coverage, monitor military facility distribution, monitor firepower coverage, etc.

![Visibility analysis](image10.jpg)

*Fig. 10: Visibility analysis.*

**Viewshed analysis**

SuperMap GIS provides viewshed analysis for oblique photogrammetry models to analyse the view range of specified position. As indicated in Fig. 11, an observation point has been selected and real-time result will be provided after setting viewing angles and viewing distances of horizontal and vertical directions. Two colors can be used to represent visible and invisible area respectively. Also, users can specify a route to get real-time dynamic viewshed effects for the route.

Viewshed analysis has great value in tourism route selection, forestry fire watchtower layout, maritime navigation, aviation, military, etc.

![Viewshed analysis](image11.jpg)

*Fig. 11: Viewshed analysis.*

**Skyline analysis**

SuperMap GIS provides skyline drawing and analysis function for oblique photogrammetry models. As indicated in Fig. 12, the skyline of the city from any angle can be acquired through adjusting the view angle of the camera and implementing skyline analysis. Meanwhile, the planning construction region data can be added to analyse the maximum height allowed with the condition that the current skyline is not destroyed.
The skyline can be used to assist the adjustment of positions and heights of planned buildings to save time and human power in city planning.

**Fig. 12: Skyline analysis.**

*Shadow ratio statistics analysis (illumination analysis)*

SuperMap GIS provides shadow ratio statistics analysis function to acquire illumination status of a specified area at certain time period. As indicated in Fig. 13, users can specify the time period, analysis area and sample distance in the scene, then discrete points will be inserted and shadow rate for each point will be calculated automatically. Colours will be assigned to points according to custom colour dictionary, intuitively displaying the illumination condition. Meanwhile, the shadow rate for each single point can be queried. Lighting rate is an important factor during planning construction. When the planning solution is finished, illumination analysis can be employed to check whether the lighting rate satisfies the needs or not. Shadow ratio statistics analysis can also be applied in building design and landscape design.

**Fig. 13: Shadow ratio statistics analysis.**

*Profile analysis*

SuperMap GIS provides profile analysis for oblique photogrammetry models to check the profile information of features. As indicated in Fig. 14, users can draw a cutting line from start point to end point, and then implement the profile analysis function to generate the profile. Meanwhile, measurement and position query can be implemented on profile analysis result. Profile analysis can be applied to deformation monitoring, land use planning, route selection, facility location selection, pipeline laying, coal mining, etc.

**Fig. 14: Profile analysis.**
Planning comparison analysis

SuperMap GIS provides flattening analysis for a certain area for oblique photogrammetry models. Users can specify to edit 3D region data, flatten a certain area of the oblique photogrammetry model, monitor the effect of demolishing of buildings, place newly designed models, and compare different design plans to satisfy the needs of the planning industry.

Oblique photogrammetry-based 3D GIS application

Currently, SuperMap 3D GIS has been successfully applied in fields such as smart city, digital park, smart campus, urban planning, 3D pipeline facilities, land, surveying, meteorology, ocean, military, petroleum and petrochemical, real estate, water conservation, and transportation.
After oblique photogrammetry model data has been introduced into 3D GIS, it has been applied in some fields. Some SuperMap 3D GIS applications based on oblique photogrammetry model data will be introduced in this chapter.

3D modeling project for China National Geopark

The project builds 3D models for a China national geopark with the support of high-tech including airborne lidar digital aerial photogrammetry, spatial database, geographic information system, and virtual reality. This project aims to provide an intuitive and vivid carrier for geological heritage protection, promotion of geological scientific knowledge, and presentation of natural beauty of the geopark.

This project features with high precision and massive data. The resolution of image acquired through oblique photogrammetry is around 0.05 m, the amount of original image data is around 18 T, and the oblique photogrammetry model data generated through Smart3D is around 600 GB, which requires high capability from 3D platform.

SuperMap GIS provides functions such as imaging survey, imaging navigation, imaging map management, route setting, browsing and presentation, etc., which builds a digital resort area for the geopark. The browsing speed is fast and the entire browsing process is stable, as indicated in the following figures.
Fig. 20: Oblique photogrammetry data for the entire geopark.

Fig. 21: Pepper peak of the geopark.

Fig. 22: Management office of the geopark.

Fig. 23: Pepper peak of the geopark (partial).

3D digital city geographic information system

The project developed a 3D digital city based on oblique photogrammetry data and SuperMap GIS. With imaging 3D, DEM, DSM, DLG, POI, regulatory plan data, administrative division data, and other basic data and thematic data integrated, the system provides functions such as city panning, data query, planning and analysis, emergency decision, data editing and flight management. Some functions are introduced below.

- **Planning solution design**: Designed data such as planned buildings and vegetation can be directly added to 3D scene to allow designers to form draft planning solution.
- **Multi-solution analysis**: Multiple solutions can be browsed and compared to assist decision makers in distinguishing whether the solutions match with the current city.
- **Height control analysis**: Compare the height control data with buildings in the city to mark buildings that exceed the controlled heights and display the property information of the buildings.
- **Flood analysis**: Analyse catchment area and flooded buildings according to water level data of monitoring points, with the combination of imaging 3D.

Future prospects

Oblique photogrammetry technology has brought revolutionary changes and makes it possible to objectively represent the real world. Oblique photogrammetry modeling not only keeps all features on the ground, but also guarantees more accurate position relation among models, creating a new era of 3D geographic information.
As a new and fast-growing 3D data acquisition method, oblique photogrammetry modeling technology will change the status that manual modeling is the primary source of 3D data. Oblique photogrammetry data has become a brand new data source of 3D GIS. SuperMap breaks bottlenecks of oblique photogrammetry model application, enhances the bearing capability of GIS platform software for oblique photogrammetry model data, and will devote to the performance enhancement constantly. Currently, SuperMap GIS has provided recovery technologies for three primary flaws of oblique photogrammetry model data, and will continue to provide tools for modifying model vertices, replacing textures for partial models to assist the use of oblique photogrammetry model data. SuperMap GIS has broken some bottlenecks of 3D GIS analysis based on oblique photogrammetry model data. Currently, 3D analysis functions such as visibility analysis, viewshed analysis, skyline analysis, shadow ratio analysis, profile analysis, and planning comparison analysis have been provided. SuperMap GIS will continue the research in contour analysis, slope and aspect analysis, cut/fill analysis, surface area and distance measurement to promote the application of oblique photogrammetry model data in fields such as city planning, landscape analysis, deformation monitoring, land use planning, route selection, facility location selection, coal mining, tourism, military, and others.

Acknowledgement

The 3D technologies covered in this paper are developed by the SuperMap R&D team. Because of their great work, we are able to show it here. The authors just provide a summary of the collective efforts and work from this team on behalf of them.

Reference


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