

The Application Research of Oblique Photogrammetry Technology in Road Planning

Zhihuang Zheng^{1,2}

¹ Managing Director, Fujian jingwei surveying and mapping information company, Fuzhou, China

² Vice Director, Big Data Institute of Digital Natural Disaster Monitoring in Fujian, Xiamen, China

E-mail: 273011974@qq.com

Abstract. This paper takes the planning and application of Ann Nine Railway as the demand, and adopting the multi-angle data information of the roads acquired by the oblique photogrammetry technology of UAV to realize the model reconstruction based on the Context Capture software. Then outputting data in kinds of formats to analyze. And based on Acute3D and LocaSpace to perform the viewing and measurement of the real 3D model, the model is repaired based on the Geomagic. The measurement and spatial analysis application of the 3D model based on LocaSpace. The application results show that the real 3D model was built could be applied to the railway planing based on the oblique photogrammetric data. And the measurement results can be used for various types of measurement and spatial analysis, which can provide the reference value of important data support for railway planning and design management, decision-making and construction operations and so on.

1. Introduction

With the development of the smart cities, the traditional two-dimensional road has been difficult to meet the demands of the road planning management and construction. The development and the application of oblique 3D modeling technology has brought about the major revolution to the project's planing design, management, examination and approval, construction and decision-making. In recent years, the rapid acquisition of ground information by low-altitude remote sensing technology has became more and more popular, so the UAV surveying and mapping technology has emerged as the times require. And the surveying and mapping personnel who use the oblique UAV to rapidly and efficiently perform the acquisition of surveying and mapping data are favored. Road is the skeleton of a city and it's also an important part of showing a city's style. The road planning develops with the development of social productivity. The road planning design is directly related to the living environment of human being, it's a comprehensive and complicated work [1]. With the development of science and technology, GIS technology is widely applied to the urban 3D modeling, which could greatly improves the efficiency and accuracy of road planning. However, the traditional orthophotography can only obtain the top information of the road, it could not obtain the side texture information of the buildings next to the road, but the oblique photogrammetry can break through the limitations of orthophotos.

As a new technical method, oblique photogrammetry has been widely used in 3D modeling, smart city construction and so forth [2]. For example, in foreign countries, San Jiang [3] et al. proposed the outdoor data acquisition based on UAV and an oblique photogrammetry measurement based on the off-line visual detection, and conducted an accuracy assessment test to explore the potential use of the



non-site inspection of the model construction based on the transmission lines. Kristian Svennevig [4] et al. proposed the 3D geological model construction of the opencast mine oblique photogrammetry measurement and applied it to the northern Greenland to better understand the evolution of structure. Grenzdörffer [5] et al. proposed that the oblique photogrammetry measurement is an effective tool of cadastral surveying, it could accurately draw the mapping of the cadastral activities in rural areas in three dimensional space. In China, Hao Zeng [6] discussed the application of the oblique photogrammetry measurement technology in smart cities from the perspective of smart city. Yang Yanmei [7] et al. proposed to build 3D model based on acquiring oblique photogrammetric image data, and based on the 3D models to realize the UAV digitalized large-scale mapping, as well as the result is good.

Three-dimensional modeling of oblique photogrammetry technology, smart city and other fields have been applied in some extent, but it is rarely used in engineering measurement. The three-dimensional model of oblique photogrammetry technology in road planning is mainly manifested in dynamic roaming effect display of 3D model, objects tagging, making thematic map, 3D model measurement and spatial analysis etc. [8] Among them, the oblique photogrammetric data in road planning design can assist the road planning design, construction measurement, Three-dimensional effect evaluation, assist in the completion and acceptance of roads, draw the thematic maps and assist in the old roads reconstruction, etc. The oblique photogrammetry has greatly improved the efficiency and accuracy of the road planning, and it could obtain the real 3D texture information of the ground objects. At the same time, UAV as a new low altitude remote sensing ground observation method, which has the characteristics of easy manipulation, short image acquisition period and strong maneuverability and so on [9]. It has the advantages of high performance-price ratio, limited monitoring area, fast acquisition of ground data and 3D modeling, and it is suitable for road design and measurement. Therefore, this research adopts the UAV oblique photogrammetry technology to obtain the road 3D model, which not only effectively avoids the low precision of traditional surveying and mapping industry, due to the large error to repeat round trip measurement, long acquisition cycle and high labor cost and so on. But also it provides the more abundant and intuitive data information for the road planning, design and completion acceptance in order to assist the road construction decision-making and administrative examination and approval department management decision.

2. Data acquisition

2.1. The oblique photogrammetry technology

The oblique photogrammetry, namely the oblique UAV measurement system. The oblique UAV measurement is performed by the aircraft carrying many oblique aerial cameras with rotating a certain oblique angle to obtain the image by taking photos from the air to the ground. In this research, the oblique image's data acquisition was carried out by Taiyi fixed wing oblique photogrammetry UAV and Dajiang Elf's four-rotor UAV. And the UAV aerial measurement of Taiyi PROPHET has the characteristics of easy to use, stable and reliable, high working efficiency, and it is suitable for the 1:1000 or 1:2000 aerial survey project in the area of 300 square kilometers. The Dajiang PHANTOM 4 UAV camera is equipped with a 1-inch 20 million pixel image sensor that could take the 4K/60fps video and take the static photos at a speed of 14/second. The Dajiang PHANTOM 4 has the five-eye machine vision and forward obstacle avoidance capabilities, which making it safer and more intelligent. The titanium material makes the machine body lighter and stronger, with 1 inch 20 million pixel sensor, 30 minutes battery's life, forward vision obstacle avoidance and intelligent manipulation, which can improve the efficiency value of data acquisition.

2.2. Acquisition of the oblique photogrammetry technology

The oblique photogrammetry data acquisition of this research mainly includes the flight route planning, the ground station preparation and the data acquisition. Taking the Dajiang Elf 4 flight route planning as the example, using the APP what is aimed for the Dajiang UAV planning route Altizure, the collected images could be uploaded to Altizure website to automatically generate the 3D models. Altizure APP could control the aircraft in real time on the flight path according to the pre-planned route, and set up the timing photo to take photos. The camera carried by the aircraft can automatically

collect the images of five angles downwards, after processing by the post-processing system, the 3D model of the real scene oblique could be generated. Meanwhile, the plane can be set up to take a positive photography downwards the plane in a vertical direction. The Altizure software planning route has the advantages of automatic route planning, intelligent continuous flight, full automation of data acquisition and intelligent task management. As shown in Fig.1 is the flight route planning interface of Altizure software.

Dajiang Elf 4 UAV collects data is based on the DJI GS PRO ground station, DJI GS Pro (Ground Station Pro) is an iPad application that can control the DJI aircraft to achieve the autonomous route planning and flight. The GS Pro has a simple and intuitive interactive design, and the application could manipulate the aircraft to achieve the automatic route flight and timing auto-photographing. Using the GS Pro to assist the field aircraft to collect data and apply it to all major fields where requiring aerial photography data collection, it will greatly improve the efficiency of the work. Before the UAV performs the mission, open the DJI GS PRO ground station and establish a connection with the aircraft.



Figure 1. Altizure flight route planning.

Before Altizure collects the data, at first we should install the DJIGO firmware and make sure the network is smooth before starting up the APP. After starting up, the software will connect to the DJI's background server for activation. After the first activation is completed, when it is reused after the first activation, it can be used offline directly. Next, making sure that a high speed SD card with sufficient capacity was inserted into the aircraft before taking off. Finally, making sure that the operators will correctly manipulate the Dajiang UAV to avoid the plane blasting. At the same time performing the preparation before taking off, firstly we should open the UAV and remote control power and set the UAV remote control to F level. Setting up the camera's parameters, such as the white balance, ISO sensitivity and exposure compensation and so on.

3. Data processing

3.1 Data preprocessing

After obtaining the field data of the oblique photographic images in this research area, the field data were preprocessed. The preprocessing work of the oblique data in this research area includes the classification and renaming of the oblique images and the processing of POS data. After the data acquisition of the Hubei province Huanggang section on the Ann Nine Railway was completed, the oblique images obtained by the oblique UAV were stored in the two cameras carried by the Taiyi fixed-wing UAV and the Dajiang Elf 4 UAV, respectively. The images in the two cameras were renamed and classified, so as to avoid the recognition errors what caused by the same image names in two cameras, that is, exporting the images from the two cameras respectively and stored them in the two folders respectively and named them respectively. And we should pay attention to the corresponding photos in two folders shouldn't name unanimously, at the same time we should check the photos and the corresponding POS data, check whether the photos in two folders correspond to the POS information, and delete the POS points without the corresponding photos. Among them, the POS data is copied from the aircraft, then the text files were exported, and check to see whether the photos correspond one-to-one. The POS data could provide the accurate external elements for the oblique

images by the error correction of the aircraft aerial photography system, and get the three-dimensional information of the DEM grid points by the condition of three points collinear. It could improve the efficiency of the post-processing software. After the data preprocessing finished, we can carry out the production of Ann Nine railway oblique three dimensional model.

3.2 The production of 3D model

3.2.1 The aerial triangulation.

This research design adopts the Context Capture image post-processing software to perform the model production of the oblique photogrammetric data for the Ann Nine Railway in the research area. The main processes of the oblique model are as follows: ①Photo modeling the pre-processed images in the Context Capture Center Master. ②Creating a new block and importing the information of the POS files, the POS file has been made into a text file in the preprocessing process. In order to obtain the optimal performance, the image must be divided into one or more image groups. The image group is a collection of the similar images, all of these images are from the same physical camera what has totally same internal orientation (image size, sensor size, focal length, etc.). After the images are classified and renamed in the process of preprocessing, the software can automatically determine the different image groups in the relevant file directory when importing. ③Checking whether the image attributes added in the information column of the imported photos are complete, if not complete, the software needs to be did the Empty Three encryption solution. And checking the information on the right side attribute column is mainly to compare the coordinates and the elevation information of the images whether is corresponding to each other. ④Submitting the aerial triangulation, the Context Capture software carries out a large number of the feature points extraction and matching of the same name for the oblique images. And calculating the three-diensional coordinates of each image and the attitude angle of the photos so that determing the relationship between the images, the function of the aerial triangulation is to calculate the spatial three-dimensional coordinates of the images. ⑤Checking whether the processed image information is complete. If it is not complete, we need to match the image feature points and resubmit the Empty Three operations. ⑥After the end of the Empty Three, it could be view the results of the aerial triangulation by the 3D view view window. Clicking on the each waypoint at the top of the view to look over the relative position information of each image.

3.2.2 The reconstruction of 3D model.

After the aerial triangulation processing of the oblique photogrammetric data is completed, the construction of the three-dimensional model in the research area can be performed. There are mainly the following processes:

①The reconstruction of the oblique models is started after the success of the Empty Three solutions. The model reconstruction needs to reset the relevant parameters of the reconstruction models and define the output model spatial reference system. This research changed the coordinate system to the WGS84 coordinate system. In general, the data amount of the whole model is so large that the ordinary computers' performance could not reach the requirement of the model reconstruction operation. Therefore, the whole model is cut into blocks, this experiment defines the block mode as the regular stereoscopic block. extracting the tiles of the interest region to perform the model reconstruction, the setting of the tile size is referred to the computer's performance. The smaller the tile is, the more the number of tiles is, and the smaller the computer memory used in the reconstruction process is, and the higher the processing efficiency is.

②Setting the relevant parameters of the reconstruction model and defining the output model spatial reference system. This research sets the coordinate system to the WGS84 coordinate system. Taking the part of the section of Ann Nine Railway as the reference case, the spatial frame of the block area view was edited according to the interests and set as: the spatial reference system selection WGS84/UTM ZONE 50N, the mode is the regular stereoscopic cutting, the tile size is set as 100 meters, the expected maximum RAM usage of a task is 2GB.

③When the setting of the spatial frame is completed, submitting the new production project, in the guide of model reconstruction, it could perform the achievement output format and the selection of the achievement output quality .And it could define and output the 3MX,S3S,OSGB etc. and kinds of

format data. In this research, the corresponding WGS84/UTM ZONE 50N coordinate is selected in the option of the research experiment spatial reference system.

④The oblique model reconstruction is carried out by software automation. The operation efficiency of the image processing is related to the computer graphics processor, the high or low of the model reconstruction efficiency depends on the computer's performance. The higher the graphics card performance is, the higher the processing efficiency is. It could be viewed the production process of the three-dimensional models in the 3D view window, and it also could check the completion progress of each tile. After the reconstruction model is successful, the interface will display that all the tiles are processed, and the model effect is viewed in the 3D view window, as shown in Fig.2

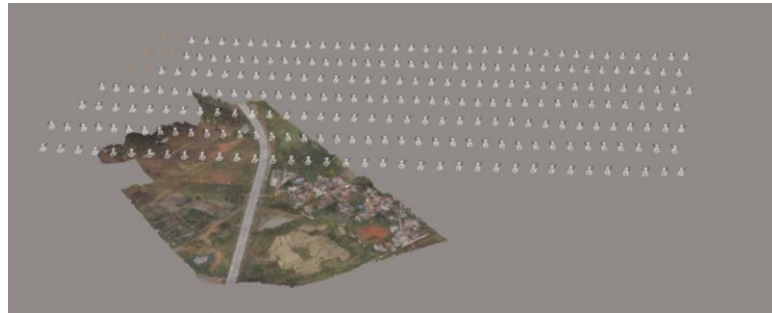


Figure 2. Viewing Model effects in 3D View.

4. Achievement application

Viewing the results of Ann Nine Railway oblique 3D model in Acute3D. Acute3D Viewer is a lightweight visual module of Context Capture, which has been optimized for 3MX and S3C formats of Context Capture, it could deal with detail levels, paging and streaming transmission, as well as allow for the fluent frame rate to visualize 3D data locally or online. The 3MX format files produced after the model reconstruction in Acute3D can view the effect of the oblique 3D mode, and after the measurement analysis data processing of the model could obtain the kinds of formats oblique photogrammetry 3D model productions of Ann Nine Railway Hubei province Huanggang section. As shown in Fig.3 is the view effect of Ann Nine Railway Hubei province Huanggang section oblique 3D model in Acute3D.



Figure 3. The view of the 3D model.

4.1. The auxiliary planning and design

4.1.1 Auxiliary view of the filed planing picture.

The planning map is an important basis for the work of government planing departments and the planning design departments [10]. There are many deficiencies in the traditional way of viewing. First of all, the planning map are often made up of color blocks and lines, such plane planning maps are too abstract to correspond the corresponding areas and drawings for those unfamiliar with this area. The oblique photogrammetry could effectively solve the shortcomings. On basis of the 3D model results and the remote sensing images we could make the planning maps to connect the real scene with the planning maps, which could help users to intuitively and vividly understand the planning areas. It is

easier to obtain the image information by superposing the different types of planning maps such as the oblique 3D model, the remote images and the general planning maps, which could bring a great convenience to the planners.

4.1.2 *Assisting the railway to choose lines.*

The towards design of the preset line of Ann Nine Railway in this research area should not only pay attention to the geological situation of the location, but also should pay attention to the land use and development of this area such as the agriculture land, the construction land and the unused land. On the one hand, the state strictly restricts the conversion of agricultural land to construction land, and strictly controls the total amount of the land used for construction, and strictly controls the conversion of cultivated land to non-cultivated land, the urban land use planning can not be easily changed, the lines should be less occupied by the cultivated land. On the other hand, the railway will attract a large number of passengers after the construction and the operation, which makes the population in the city center will spread around the city. So that causing the change of land use natures around the railway station, and the two should be coordinated and jointly plan for development [11]. It is difficult to discriminate the land use situation in the present location at the preset lines in the ordinary town planning, however the oblique photogrammetry measurement technology could solve this problem. As shown in Fig.4, making use of the oblique photogrammetry measurement technology could superimpose the oblique 3D model of the planning area to the remote images by the LocaSpace software. It is easier to obtain the effective information of the land use situation by linking the planning area and the real geographical location of the provinces and counties in the area scope to help the planners more intuitively and vividly understand.

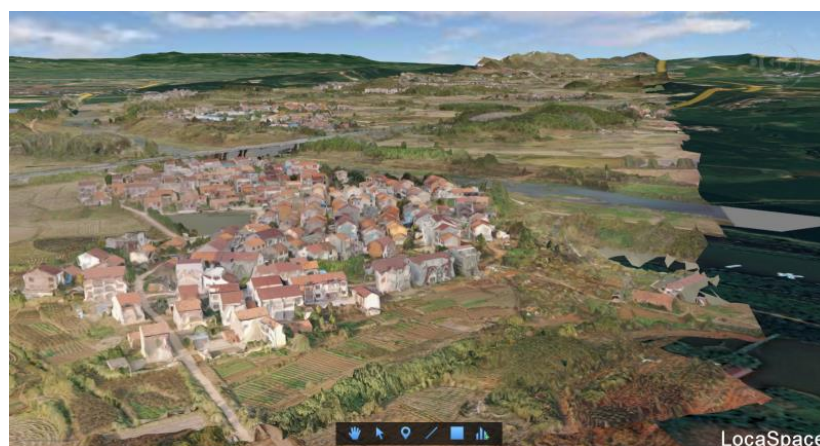


Figure 4. The view of land use status.

It is of great significance for the engineering decision-making to use the complete three-dimensional model of Ann Nine Railway which was acquired by the oblique photogrammetry measurement technology. For example, the preset lines should reduce the partition of the cultivated land and choose the scheme of the near the mountain. The interpretation of the key ground objects such as the electric towers what was near the mountain passed, and graves and so on, the scope area statistics of the villages the preset lines passed where needed to be demolished, the two periods quick construction of the planning before and after, the comparison of the non-conforming buildings, the compensation estimated for the auxiliary demolition. All of these brought the revolutionary change for the engineering planning and approval, management and decision-making. As shown in Fig.5, auxiliary line selection for the clear oblique photography 3D model of Railway, the key ground objects such as the electric towers and the graves can be interpreted.

The compensation estimation work of the single house demolition is carried out in Acute3D, Aute3D can not only view the three-dimensional effect of the house, but also the operation is simple. The area measurement of the single house is the surface measurement, the bottom area of the house is measured by 360 degrees surrounding finding the four corners of the house. And then performing the total areas estimate work of the house demolition by observing the number of house layer, the story height and so

on. The area measurement of the single house can also be carried out in Acute3D, so as to assist the compensation estimation of demolition.

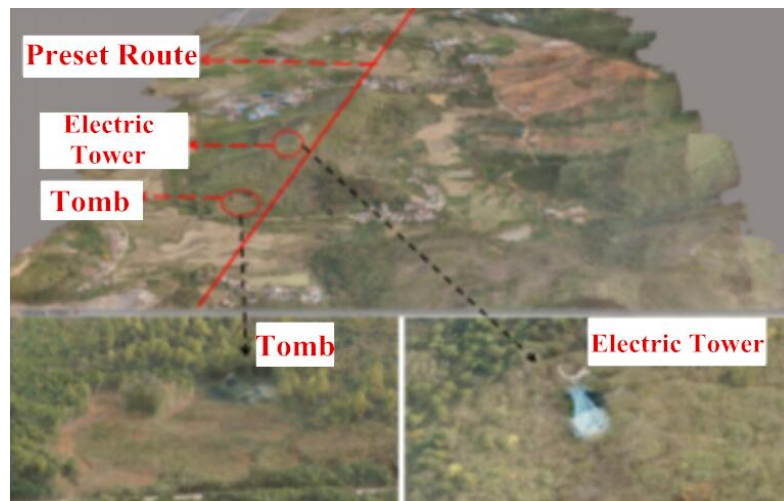


Figure 5. The oblique model to assist the key ground objects to interpret.

4.1.3 Making the classification diagram of the house building.

Due to the design of the Hubei province Huanggang section of Ann Nine Railway through the rural towns, it took many problems to the urban construction of Ann Nine Railway and Hubei province Huanggang Huangmei town, etc. Such as the planning adjustment, the design change, the investment increase and the delay of the construction period. Especially the problem of house demolition work through the Ann Nine Railway Hubei province Huanggang section, the rural demolition work involves many aspects interests, the improper adjustment of demolition work will lead to various contradictions and disputes. Ann Nine Railway construction must take into account the many-sided interests such as the rural urban policies, the interests of the masses, the economic development and the social benefit [12]. Therefore, this research put forward that take the oblique photogrammetry measurement technology as the guidance, based on the Ann Nine Railway oblique three-dimensional model to make the house building structure and quality classification diagram of the rural urban in the research area. As shown in Fig.6, as well as the classification summary chart of the house structure and quality, this data has important reference value for the demolition compensation of Ann Nine Railway construction.

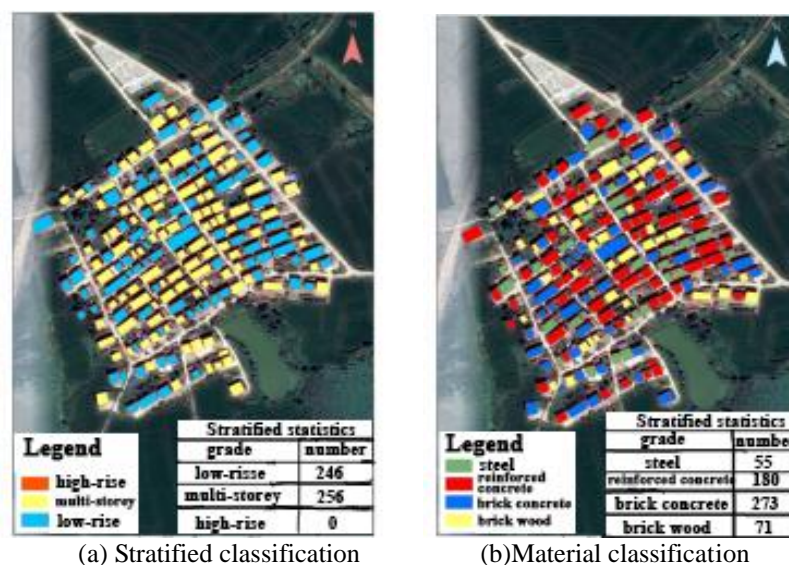


Figure 6. Classification of houses in Zhang Puxing village.

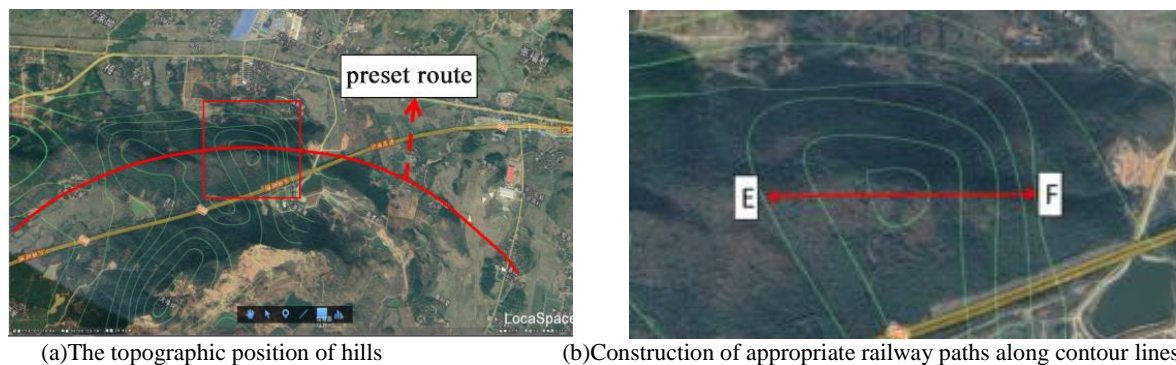
This research classifying and summarizing the building quality of Hubei province Huanggang section rural towns where was passed by Ann Nine Railway. This data will serve as an important reference basis for planning and design and assist the demolition compensation work. According to the principles of “suit one’s measurement to local conditions, take into consideration both needs of the state and the interests of the collectives, orderly propulsion, classification guidance and comprehensive improvement”, and it has the important value and significance to apply the oblique photogrammetry measurement technology into the road planning and design.

4.2. The auxiliary construction survey

In LocaSpace software, it is of great significance to carry out other measurement work and spatial analysis to the 3D model of Ann Nine Railway oblique photogrammetry for the engineering planning and examining and approving, management and decision-making, which could assist Ann Nine Railway construction work.

4.2.1 The generation and application of contour line.

Extracting the elevation points of a mountain section of the Ann Nine Railway, and extracting the elevation points of the sampling points in the range area according to the required draw rectangle and the selected area, which could extract the latitude and longitude and elevation information of the sampling points. At the same time, exporting these information in the format of grd data and importing them in LocaSpace to generate the contour terrain map. These contour data could provide the topographic reference such as judging the topographic slope is steep or smooth of the preset lines, recognition of the terrain types, drawing the river direction and the topographic profile and so on. The planning of Ann Nine Railway can be selected as far as possible on the smooth slopes to avoid the steep cliffs and the areas with poor geological conditions. At the same time, the contour terrain map is of great significance for the railway auxiliary lines selection. The railway lines are generally constructed along the contour lines, and in the construction of railway within the terrain of the hill should refer to the contour terrain map of this region. As shown in Fig.7, it is the topographic position of hills where is passed by Ann Nine Railway preset lines. On the right of the figure, it is the suitable route was built along the contour lines of hill terrain. Constructing the railway between E and F could effectively reduce the construction difficulty and reduce the amount of the road engineering, and it is not easy to cause the phenomenon such as the soil and water loss, which could facilitate the construction of railway tunnels and vehicles driving.



(a)The topographic position of hills

(b)Construction of appropriate railway paths along contour lines

Figure 7. Choosing the appropriate path for railway Construction.

4.2.2 The spatial analysis.

Taking advantage of the LocaSpace software to perform the spatial analysis of Ann Nine Railway Hubei province Huanggang section for assisting the construction decision-making, such as the visibility analysis, the visible range analysis, the fill and excavation analysis and the profile analysis and so on. The general analysis operation steps is click the left mouse button on the two points that need to perform the visibility analysis. LocaSpace will automatically draw the visual view situation from the start point to the end point. The visible regions are in green, and the invisible regions are in red. This function could judge whether are visible or shelters between the two points. As shown in Fig.9, taking a point as the observation starting point to research the terrain of a certain area’s visible

situation. And the spatial distance is 916.39 meters between the start point and the end point, the vertical distance is 57.35 meters, the horizontal distance is 914.60 meters and the altitude is 92.98 from the start point, the visual condition between two points is invisible.

The visual area analysis operation steps is clicking the start point on the left mouse button on the map, as the start visual point, moving the mouse to click the above corresponding end point again, and taking the distance between the two points as the radius of the visual area analysis. It could be automatically generate the 360 degree visual status from the point of view to the surrounding range. The visible regions are in green, the invisible regions are in red. The visible region analysis realizes the circumferential effect of simulating the human's eyes, it could look around the visual situations of the surrounding regions, and it could adjust the height of the viewpoint by setting the view height. As shown in Fig.10, the start point height is 3 meters, the radius of the visible region is 981.77 meters, the longitude is 115.997685 °, and the latitude is 30.088544 °.



Fig 8. Visibility analysis of partial section of Ann Nine Railway

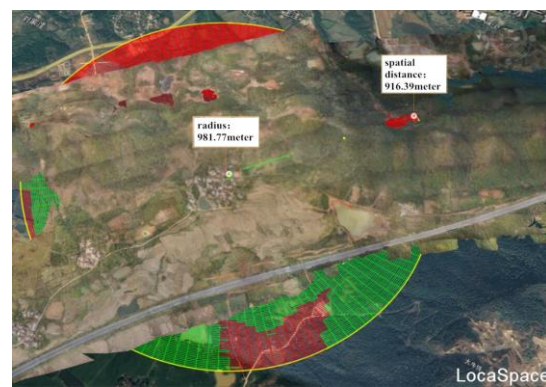
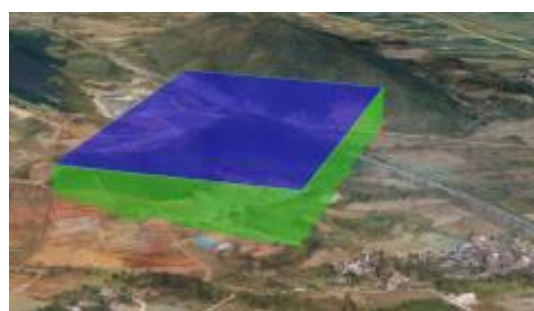


Fig 9. Visual analysis of the corresponding sections of Ann Nine Railway

The filling and excavating analysis can draw a polygon on the map to automatically entry the analysis results display interface and adjust the elevation values of the base level. Anew performing the filling and excavating analysis, it could be also directly select the surface by clicking the selection surface as the range of the filling and excavating analysis. When the preset route of Ann Nine Railway passes through the small hill terrain, it can analyze the various information of the filling and excavating according to the selected range and the defined elevation of the basis level. The information are include: the highest point, the lowest point, the filling amount, the excavation quality, the total amount of the excavation, the area of the filling region, the area of the excavation and filling region, as well as the total area of the region, etc. As shown in Fig.10 is the filling and excavation analysis of the Ann Nine Railway oblique images passed by a small hill. According to the calculation result, the elevation of the basis level in the research area is 158 meters, the highest point is 105.13 meters, the total amount of the filling and excavation is $3.44 \times 10^8 \text{ m}^3$, and the total area of the filling and excavation is 416452.49 m^2 . Combined with the project's reality, analyzing the calculation of the roadbed filling and excavation can effectively assist the construction decision-making of Ann Nine Railway.



(a)Excavation area required for Ann Nine Railway preset route



(b)Calculation of fill and excavation in small hills area

Figure 10. The area and calculation of filling region in small hills area.

The profile analysis could directly select points on the map, drawing a line on the place where needs to perform the profile analysis, it could automatically analyze the elevation change situation of this line and draw it in the format of graph. As shown in Fig.11 is the profile analysis between the two points, A and B of a section of Ann Nine Railway. The calculation results show that the start point A's longitude is 115.990623°, A's latitude is 30.086982°, and it's elevation is 163.34 meters, the end point B's longitude is 115.994316°, B's latitude is 30.086613°, and it's elevation is 76.40 meters. The projection distance is 402.85 meters, and the number of the sampling points is 100. These 100 sampling points give the longitude and latitude and the elevation information, and the textual data in the csv format can be exported, these data provide the important reference for the construction decision of Ann Nine Railway. In a word, it is of great significance for the Ann Nine Railway construction decision-making to use the oblique photogrammetry to generate the three-dimensional data with OSGB format so as to carry out all kinds of spatial analysis work by LocaSpace.

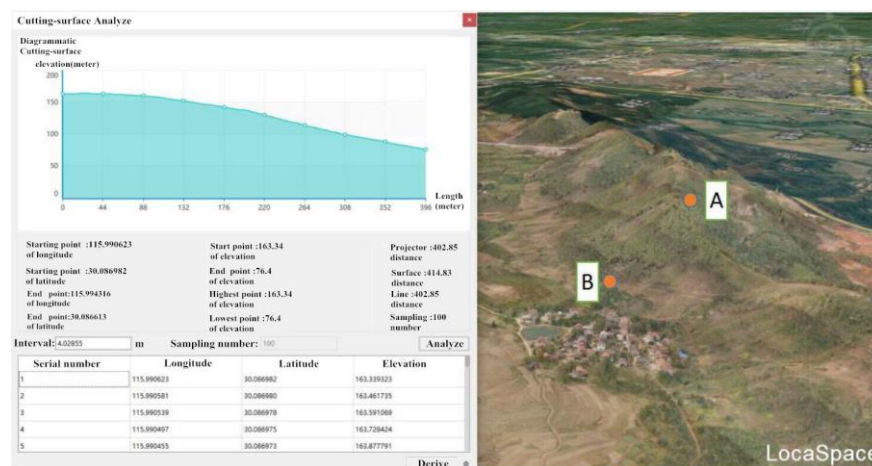


Figure 11. The profile analysis of a section of Ann Nine Railway

5. Conclusion

This research applied the oblique photogrammetry measurement technology to the planning and design of Ann Nine Railway, assisting the planning, design, management and decision-making of Ann Nine Railway, which reflects the application values of this technology in the engineering projects. Taking the planning of Ann Nine Railway as the research object, this research introduces the model reconstruction of oblique photogrammetry measurement data by using the Context Capture software, and introduces the model restoration based on the Geomagic repairing model software, as well as the measurement and the spatial analysis of Acute3D and LocaSpace. The application results show that the establishment of the real 3D model based on the oblique photogrammetry data could be applied in the planning and design of Ann Nine Railway. Such as assisting the line selection of Ann Nine Railway planning, assisting the estimate of the demolition compensation, making the thematic maps and assisting the decision-making of construction and so on. It provide the reference value of the important data support for the planning and design, management, examining and approving, construction decision-making of the Ann Nine Railway engineering projects.

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