Demarcation of River based on UAV LIDAR Point Cloud Data

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Abstract. Delimiting the scope and boundary of river and lake management is the primary work of strengthening river and lake management, and is the precondition of water conservancy administration according to law. The precise scope of management and protection areas is defined for the purpose of regulating all activities within the area and carrying out water conservation activities within the area. The conventional surveying and mapping technology of acquiring terrain data, i.e., Computer Aided Design (CAD) drawing of river construction projects, mapping of 1:2 000 scale image, are not only time-consuming but also inaccurate. The high-resolution 3D point cloud data obtained from Unmanned Aerial Vehicle (UAV) lidar can identify the baseline lines of river management demarcation, i.e., ank toe line, dike toe line, bank revetment top line, bank slope line, etc. Through spatial analysis and manual visual interpretation, the boundary of river management area can be accurately demarcated. The accuracy of the baseline lines of river management demarcation drawn by ARCGIS depends on the resolution of 3D point cloud data, the environment of the river and the deviation of manual visual interpretation.

Keywords: dike toe line; the designed water surface line; Delineation the scope of Management; UAV Lidar survey

1. Introduction

To demarcate the extent of river and lake administration according to law and define the boundary of river and lake administration is the primary work of strengthening river and lake administration and the prerequisite condition of the water conservancy department's administration according to law. The definition of the scope of river course management is conducive to the implementation of local principal responsibilities in accordance with laws and regulations, the coordination and integration of all forces, the clarification of the responsibilities of the river course management, to ensure the normal operation of river course projects and the safety of flood discharge. In the course
of delimiting the scope of river and lake management, the most time-consuming technical link is in the field of basic data collection. Conventional measurement methods mainly use GNSS-RTK combined with total station data acquisition mode. Although this mode has high precision and few omissions, it requires a lot of outdoor measurement work, heavy work, long cycle and high cost, and it has limitation in the area where villages are scattered.

Traditional surveying and mapping technology has the low efficiency of acquiring terrain data. Traditional field measurements are very time-consuming and labor-intensive. Optical remote sensing is fraught with "saturation effect". The CAD drawings of the river construction project and 1:2000 scale image maps and other conventional basic data used in the traditional methods cannot clearly and accurately identify the demarcation line of rivers management. Another shortcoming of traditional surveying and mapping technology is the low efficiency of acquiring terrain data.

However, UAV LiDAR technology is a new remote sensing technology, through integrated Inertial Measurement Unit (IMU) /DGPS differential positioning products, can efficiently and quickly obtain three-dimensional spatial information. Moreover, this technology has the characteristics of a high degree of automation, little weather influence, short data production cycle, and high precision.

In contrast, advances in airborne lidar measurements have made it possible to collect field data quickly and efficiently. Unmanned Aerial Vehicle (UAV) reduces about 90% of the fieldwork and ultimately saving labor and time cost to the maximum extent. The development of UAV airborne light detection and ranging (LiDAR) provides a new method for obtaining high-resolution geospatial and topographic information for the demarcation of the river. The UAV airborne LiDAR system is mainly composed of global positioning systems (GPSs), laser scanners (LSs), and inertial navigation systems (INSs). Currently, UAV LiDAR data have been used in many fields, such as digital elevation model (DEM) acquisition \(^1\), road extraction \(^2\) and extraction of urban power lines \(^3\).

We applied 3D point cloud data to draw the baseline of the river management boundary. The accuracy of the baseline lines of river management demarcation drawn by ArcGIS depends on the resolution of 3D point cloud data, the environment of the river and deviation of manual visual interpretation. It is necessary to develop and apply a new surveying and mapping technology on the basis of the existing data measurement technology. Therefore, this paper carries out systematic research and analysis on the application of UAV aerial survey technology in river and lake delimitation, in the hope of combining with the practice to study the measurement technology optimization measures with high efficiency and high quality.

2. Study area and Materials

The research area of this paper is located in Lianjiang and Xingzihe rivers in Lianzhou city, Guangdong Province.

Experimental Data includes of 0.02m resolution aerial photography orthoimage of the study area seen in figure1 and 20 points per square meter resolution the true color point cloud. The details of the true color point cloud can be seen in figure2. The Xingzihe River and Lianjiang River in Guangdong Province were the experimental areas, and the boundary of management based on point cloud was demarcated.
3. Methods

3.1 Technical route

The technical route of river and lake management area demarcation is shown in Figure 3. The specific workflow is as follows:

(1) Carry out research work in the study area, and collect relevant basic data and basis for the demarcation of rivers. The work outline and implementation plan shall be drawn up according to the investigation and investigation.

(2) Topographic survey. On the one hand, determine the final aerial survey range of the river. Carry out field survey and image control for the river. DEM, orthophoto data, point cloud model of the river channel is obtained by internal data processing and calculation. On the other hand, the section line measurement of the embankment reach is divided into two parts: internal and external work, and finally the channel section topographic map is obtained.

(3) River delimitation. Using the topographic map and high precision orthophoto map as base maps, river demarcation is carried out by internal data processing and field survey. For river constructed with embankment, we draw a toe the line, bank revetment top line and the slope.
toe the line based on point cloud model and the orthophoto map. As these datum lines, and according to the specification of levee project design, width of buffer analysis was carried out. For river constructed without embankment and no planning requirements, design flood water surface line was calculated and drawn. For unlevelled reaches river, 15 meters extension of the shoreline shall be used as the boundary line of the scope of management.

3.2 UAV lidar measurement technology method
3.2.1 UAV LIDAR aerial measurement process
CW-30Lidar airborne LIDAR system acquisition process is mainly divided into uav operation preparation and flight, laser point cloud data pretreatment, laser point cloud data accuracy verification, and laser point cloud data classification. According to the site survey of the operation area: check whether there are ground elevation fluctuations, high-rise buildings and high-voltage lines in the flight area, and choose reasonable base station erection position and takeoff and landing point. By importing the KML file of the operation area into the CW Commander Ground station software, the route can be generated manually or automatically according to the KML file, and the route can be modified according to the elevation difference of the terrain to achieve ground imitation flight. The flight is based on the mapping scale, point cloud bandwidth, point cloud density, UAV cruising speed, survey area terrain, and equipment parameters.

The site investigation and investigation of the locations and facilities of the photography area shall be carried out according to the provided range lines and other information, mainly including the following contents:
(1) To understand and investigate the topography, topography, geomorphology, social resources of the shooting area, whether there is a military no-fly zone, whether there is an airport, whether there is a large disturbance, etc.;
(2) Selection of aerial photography time;
(3) Field test experiments on facilities affecting aerial photography;
(4) Divide the survey area into aerial photography zones according to the designed topographic map and on-site investigation;
(5) Selection and verification of aerial camera and lens;
(6) Flight test and photo test.

The ground base station is installed to obtain static coordinate data for LIDAR data calculation. The base station shall be erected in an area free from high voltage lines and with an open field of vision, and shall be marked with paint or nails.

Figure 4. Schematic diagram of LIDAR onboard UAV

During the flight, the ground station software can monitor the flight status of the aircraft and the working status of the airborne radar system in real-time. Dapeng Vertical Take-off and Landing Fixed-wing LiDAR System (CW-30 LiDAR Mapping Version) was used in this experiment.

3.2.2 Point cloud data preprocessing technology method

In the processing of POS data, we use NovAtel Inertial Explorer 8.7 software to acquire high-precision flight tracks. Firstly, it needs to prepare the required data, including the base station data (Base.txt), mobile station data (GNSS.txt) and inertial navigation (INS) data (IMU.txt). Adding the converted base station data, mobile station data separately and INS data to the project and writing the base station coordination. Then, using TC tight coupling calculating methods, equipment, data file with inertial navigation value types, equipment lever arm, rotating Angle, can be directly are combined to solve. Lastly, exporting the pos result file according to the POS data format template provided by JoLiDAR software.

JoLiDAR pretreatment software was used to preprocess the original 3D laser point cloud data and POS data into the general point cloud data format, LAS, and convert it into the required coordinate system for subsequent data post-processing and data analysis.

TerraSolid 2013 is used for point cloud browsing, airstrip matching viewing and point cloud classification. Open the MicroStation V8i software, load out the TerraScan module, load in the
point cloud, and display it according to elevation. Use Routine in its Classify toolbar to set the classification parameters and isolate the ground points, seen in figure 5.

3.3 Digital elevation model production
Firstly, the Terrasolid software is used for irregular partitioning of point cloud data to obtain polygons of the river and its surrounding point cloud data for calculating operation range. Then, point cloud filtering (automatic filtering calculation) is carried out, and fine terrain point cloud data is obtained through category reset, isolated point detection, and triangular network progressive encryption and filtering. Finally, DEM interpolation was carried out in Terrasolid software, and the interpolation was carried out in accordance with the average elevation method of points within the grid, and the DEM data of terrain around the river with the accuracy of 1M*1M was obtained. DEM result is shown in figure 6.

Figure 5. ground point clouds
Figure 6. 1 m resolution DEM from LIDAR

3.4 Plotting the datum line of river constructed with the embankment
The characteristic lines of the embankments are plotted on the true-color point clouds as the reference lines of the river management area. This paper uses SouthLIDAR software to capture the points in the point cloud of the embankment to draw a dike toe line with high accuracy and efficiency like figure 7. The ground points after classification removed the influence of vegetation. Capturing points on the ground point cloud close to the levee terrain to depict the dike toe line.

Figure 7. plotting the dike toe line of river on the true color point cloud after classification
3.5 Plotting the datum line of river constructed without embankment

The HEC-RAS software was used to analyze and calculate design level of sections with certain flood control standards. After that, we transformed data interpolation points with design level calculation with Z value attribute to be river design level raster data. Then, COV grid overlay analysis method for DEM and the design level raster data of the grid in ArcGIS software was used to get the riverbank intersection line (submerged range line) of two kind data. The results can be seen in figure 8. For the unprotected river section of without flood control standards and without embankment, we plot the bank slope line on the true color ground point cloud after the classification, like figure 9.

![Diagram of river construction](image)

**Figure 8.** Extraction of the designed water surface line

4. Results and Comparison

The plotted lines and parallel epitaxial line are superimposed on the orthophoto in map of the demarcation, which displaying the resulting diagram of the starting line and management line of river course management range based on point cloud data. The submerged position and elevation of the water surface line measured by RTK and the elevation value Z of the corresponding point cloud data were compared, resulting in reasonable errors.

As for the comparison of methods, production of DEM from point cloud data was used to extract the designed water surface line automatically and plot dike toe line with human interaction. The original method was manual: the elevation points were punctuated by the water level elevation on the CAD chart and then connected. The method proposed in this paper is more efficiently and accurately.
Datum line of river constructed without embankment
Datum line of river constructed with embankment
River management scope line

Figure 9. Map of the demarcation of Lianjiang River (a) and Map of the demarcation of Xingzihe River (b)

5. Conclusions

In this paper, a method of demarcation of river based on UAV Lidar point cloud data was proposed. CW-30 unmanned aerial vehicle is equipped with a laser radar scanner for operation, and the point cloud acquired has high resolution, which can meet the measurement accuracy requirements of this mission. It can extract river feature lines and other terrain information to provide effective and accurate data support for river and lake demarcation in the later period. The airborne laser radar of UAV can efficiently acquire the data of the regional scale and obtain the complete Three-Dimension information of the research area. DEM data based on 3D point cloud interpolation can be superimposed and analyzed with raster data of designed flood level. And then we can plot the plane position of design water surface line of river without embankment. Based on the ground point cloud data separated from the scanning true-color point cloud data around the river channel, it can plot the dike toe line of river and the bank slope line of river without levee. The data point density basically conforms to the mapping requirement of the datum line of the management scope at the river level. Point clouds at ground locations are classified by point clouds to screen out most of the interference from trees and weeds.

The accuracy of terrain elevation information based on UAV airborne laser radar scanning technology is about 15 cm, which is better than traditional UAV photogrammetry technology. Although the precision is lower than the traditional total station surveying and mapping technology, but high efficiency, single measurement range is larger. The precision of the laser point cloud is higher, and the demarcation efficiency of the embankment foot line and bank slope line is improved.

Future projects will dynamically modify the scope line based on terrain changes. It is necessary to study the algorithm-based automatic extraction of the bank base line and bank slope line on the river bank point cloud. The cross-section line of the levee is generated and the points on the baseline are automatically extracted and connected into line data. To develop an algorithm to automatically extract the shoreline and embankment toe by extracting point cloud coordinates on the section line, the difficulty is to remove the noise points.

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