Research on the application of consumer UAV in river and lake demarcation

ZHUI Wei¹a, ZHANG Zhuanzhuan²b, WANG Ze³c
¹ Northwestern Polytechnical University Ming de College, Xian, Shangxi, China
² Northwestern Polytechnical University Ming de College, Xian, Shangxi, China
³ Northwestern Polytechnical University Ming de College, Xian, Shangxi, China
aemail: 326460095@qq.com, bemail: 275752414@qq.com, cemail: 460863178@qq.com

Abstract: The delimitation of rivers and lakes is the basis for clarifying the management scope and protection scope of river courses and lakes, and implementing the property right system of natural resources and effective management of natural ecological resources. The development of UAV low altitude photogrammetry technology provides a strong support for river and lake demarcation in terms of cost, efficiency and quality. In this paper, the reliability of the data in the test area is verified by selecting the project test area, and the feasibility of the application of consumer UAVs in the river and lake demarcation project is obtained, which provides some technical reference for the application of consumer UAVs in engineering projects.

1. Introduction
Currently, problems exist in some rivers and lakes in China, such as haze management boundaries, disorderly occupation, piles and construction, posing a great impact on the flood control and ecological security of the hydraulic engineering projects along the rivers and lakes. To define the scopes of management and protection along the rivers and lakes and form a property right system for natural resources with clear ownership, well-defined rights and responsibilities, and adequate supervision is an effective way to manage natural space and promote sustainable development. China is a country with a large number of rivers and lakes. So far, the government has invested a tremendous amount of money in the demarcation of rivers and lakes. The river-lake demarcation surveying and mapping system in China is still facing new challenges and opportunities at the same time. Therefore, we need to develop and apply the most cutting-edge surveying and mapping technologies based on the existing ones. [1]

Unmanned aerial vehicle (UAV) technologies have several advantages such as high-efficiency, high-resolution, low cost, low risk and repeatability, with wide applications in fields like geodesy, disaster monitoring, meteorological monitoring, military applications and resource investigation.[2] The digital cameras mounted on consumer drones belong to non-metric cameras, which means they have not been professionally calibrated. Thanks to the development of sensor technology, the pixels of non-metric cameras have already met or even exceeded photography’s technical requirements. Therefore, using consumer drones for low-altitude aerial photography has become a research hotspot.

Based on a river-lake demarcation project in a certain area, this paper aims to provide technical support for applying consumer-grade drones in this specific project by evaluating the accuracy of the
flight data in the test site.

2. Project Background and Technical Route

2.1. Main tasks of river-lake demarcation

The main tasks of this project are to delimit the waterfront control lines, management scope lines and the protection scope lines of the river and the reservoirs along the river. The waterfront control line refers to the management control line drawn on the riverside slope of the riverbank in the flow direction or the lake coast facing the water. To delimit the waterfront control line is a basic requirement for stabilizing the river regime, ensuring smooth flood drainage, and maintaining the healthy life cycle of the river.[3] Management scope line is the basic standard for effectively managing rivers and lakes. The protection scope line, with another name as outer edge control line, refers to the outer edge boundaries for shoreline resource protection and management. [3]

As per the technical requirements, the river-lake demarcation shall be based on a 1:2000 topographical map, accurately determine the boundary of the river and overlay DOM to form vector data.

2.2. Advantages of Phantom 4 Pro

Phantom 4 Pro is a kind of small size, lightweight and portable quadcopter drone with a mounted 20-million-pixel digital camera. A Phantom 4 Pro is cheaper to build. Its flight control software GisPro can help with route planning and realize one-button takeoff, so it is also easy to operate. Phantom 4 Pro has mature applications in topographic mapping and oblique photography. For instance, in the paper Using Non-metric Drone Images to Quickly Obtaining Digital Maps, Li et al. studied the method of acquiring digital maps through non-metric drones and analyzed the precision of this method, as followed by quantitative conclusions at the end[4].

2.3. Technical scheme

The project is located in the hinterland of Longdong loess plateau, with a length of 47.7 kilometers from north to south and a width of 34.8 kilometers from east to west. The region is filled with ravines of all directions and the overall topography is rather complicated, with large altitude difference and scarce surface features. An area of typicality was selected as the test site of about 1.7 km in length and 750 m in width. To verify the precision of surveying and mapping in the site, we set up a total of 7 photo control points, of which 5 were horizontal control points and 2 were vertical control points. We then set up 4 checkpoints and measured 10 outstanding points.

The overall technical scheme for the test site is as follows: First, set up photo control points and checkpoints to ensure the photo control points can cover the whole test site. Second, based on the camera’s parameters shown in Table 1, determine the flying height of the UAV and manipulate the drone to perform flying missions. Third, use Pix4Dmapper to automatically match the obtained junction points, photo control points and aerial triangulation encryption and generate the orthophotomaps. Fourth, observe the checkpoints and outstanding points with Mapmatrix. Finally, based on the point position errors, obtain the results for the whole test site and come to a decisive conclusion on how to apply consumer drones in this project. The overall technical route can be seen in Figure 1.
3. Scheme Execution

3.1. Photo control point layout

Generally speaking, to set up photo control points, the non-full field layout is adopted, which can be divided into airline network method and regional network method. The airline network method can be applied to traditional photogrammetry, in which the route can be planned through calculation on the parameters obtained by the aerial cameras, and elements like the air route, photographic baseline, and the terrain of the test site are taken into consideration during the photo control point layout. Regarding the regional network method, the emphasis is generally placed on the entirety of the test site, in which the horizontal control points would be set up around the site and the vertical control points set up in the site based on the elements such as the precision and terrain. The photo control point layout of the test site was designed based on the terrain of the test site and the adopted regional network in the site, as shown in Figure 2, in which horizontal control points would be set up at the boundary of the site, 500 meters away from each other along the river. Eventually, the photo control point layout would resemble the English letter “S.”
3.2. Aerial photography design and flight mission

3.2.1. Aerial photography design

Generally speaking, based on the requirements of the mission and the low-altitude digital aerial photography standards, parameters of the UAV aerial photography such as the flight height, image overlap, air route and the image number should be designed. As for the consumer-grade drone Phantom 4 Pro, the flight control software GisPro can automatically generate the air route and image number based on the flight height and image overlap. Therefore, the aerial photography design for Phantom 4 Pro mainly includes the design of flight height and image overlap.

**Flight height:** The flight height of the drone can be calculated from the relative flight height. The relative flight height refers to the distance from the photo center to the mean elevation plane. For a drone to perform a flight mission, the absolute flight height should be calculated based on the relative flight height and the height of the takeoff point. The relative flight height can be calculated through Formula 1.

\[
H = \frac{f \times GSD}{a}
\]

Wherein \(H\) refers to the relative flight height (m); \(f\) refers to the focal length (mm); \(a\) refers to the pixel size of the camera (mm); \(GSD\) refers to the ground sampling distance (m).

\(GSD\) can be determined through the relations between the mapping scale and the ground sampling distance, According to the regulations, choose better than 0.2 meters resolution.

**Image overlap:** As required by the standards of low-altitude digital aerial photography, the fore-and-aft overlap generally ranges from 60% to 80%, with a minimum of 53%; the side overlap generally ranges from 15% to 60%, with a minimum of 8%.\(^{(4)}\) For a consumer-grade drone, on the premise that the image overlap meets the requirements of the standards, the image overlap should be set at its maximum to make the planimetric and topographic points in the mapping area reach over 9%.

**Aerial photography design in the test site:** Based on the above conditions, the parameters of the aerial photography in the test site were set, as shown in Table 1;

![Figure 2 photo control point](image-url)
Table 1 aerial photography of the test site were

| model        | relatively high | Course overlap | Lateral overlap |
|--------------|-----------------|----------------|----------------|
| Phantom 4 Pro | 180m            | 80%            | 75%            |

**Flight mission:** The flight mission was performed based on the parameters. The results of the flight mission in the test site can be shown in Table 2;

Table 2 mission results

| model        | relatively high | time | sorties | Number of images |
|--------------|-----------------|------|---------|------------------|
| Phantom 4 Pro | 180m            | 1h   | 2       | 572              |

3.3. *Image preprocessing and adjustment calculation*

3.3.1. *Image preprocessing*

The central projection was adopted for the non-metric camera to obtain images. In such circumstances, no distortion can be seen at the principal point of an image, and the distortion existing at other image points is directly proportional to the distance between the image points and the principal point. Therefore, during image processing, the distortion of the image must be corrected.

3.3.2. *Adjustment calculation*

Pix4Dmapper is widely used in processing drone images with the advantages of high automation degree, fast processing speed and high precision. Therefore, the UAV image data obtained in the test site would be processed with this software.

(1) Generating point cloud by automatically matching junction points

Pix4Dmapper is equipped with an advanced image matching algorithm to match the junction points. Its matching precision can reach 0.5 pixels. At the same time, when generating point cloud data, the users can select the ratios of the point clouds to adjust the point density. Through processing.

(2) Aerial triangulation encryption

The relative orientation of the image can be completed by automatically matching the junction points and generating point cloud data. After introducing the absolute coordinates of the control points, we could obtain the absolute coordinates of each junction. The coordinates of the photo control points were obtained through RTK’s smooth measurement. The software can automatically generate DOM after aerial triangulation encryption.

4. *Precision Verification*

4.1. *Pix4Dmapper control point precision*

We performed adjustment calculation on the aerial triangulation encryption of the test site. The report can be seen in Figure 3. The report showed that in terms of the control point in the X direction, the error is 0.0141 mm and the maximum absolute value of the residual is 0.016 m; in the Y direction, the error is 0.0227 mm and the maximum absolute value of the residual is 0.01 m; in the Z direction, the error is 0.0383 mm and the maximum absolute value of the residual is 0.013 m. In terms of the checkpoint in the X direction, the error is 0.4616 mm and the maximum absolute value of the residual is 0.0777 m; in the Y direction, the error is 0.5165 mm and the maximum absolute value of the residual is 0.0938 m; in the Z direction, the error is 0.8398 mm and the maximum absolute value of the residual is 0.083 m. The precision meets the requirements of low-altitude digital aerial photography.
4.2. Positional precision of the outstanding points

Ten outstanding points were evenly distributed in the test site. They were mostly house corners, greenhouse corners, fence endpoints and the bottom of the transmission towers. The three-dimensional coordinates of the points were obtained through RTK smooth measurement. They were considered as the real coordinates used to evaluate the actual precision of the topographic map. The observation coordinates of the outstanding points were obtained through the data acquisition system Mapmatrix. Then the comparison differences between the two kinds of coordinates and their root mean square error were calculated as the criterion for the planimetric and height precision. By doing these, we could obtain the statistical table for outstanding points, as shown in Table 3.

| Ptid | measuredX/m | measuredY/m | measuredZ/m | observationX/m | observationY/m | observationZ/m | ΔX/m | ΔY/m | ΔXY/m | ΔZ/m |
|------|-------------|-------------|-------------|----------------|----------------|----------------|-------|-------|-------|-------|
| DWD1 | *6781.41    | *412.37     | 1015.46     | *6781.06       | *412.01        | 1014.78        | 0.34  | 0.3   | 0.5   | 0.68  |
| DWD2 | *6695.59    | *279.49     | 1001.96     | *6695.87       | *279.25        | 1001.47        | -0.28 | 0.24  | 0.37  | 0.49  |
| DWD3 | *6562.64    | *108.49     | 1020.37     | *6562.3        | *108.63        | 1020.97        | 0.35  | -0.14 | 0.38  | -0.6  |
| DWD4 | *6151.6     | *353.55     | 1142.18     | *6151.17       | *353.3         | 1141.85        | 0.43  | 0.25  | 0.33  | 0.33  |
| DWD5 | *6064.85    | *798.51     | 1008.82     | *6065.21       | *798.89        | 1008.26        | -0.36 | -0.38 | 0.52  | 0.56  |
| DWD6 | *6443.35    | *826.36     | 1009.71     | *6443.09       | *826.16        | 1009.12        | 0.26  | 0.2   | 0.33  | 0.59  |
| DWD7 | *5971.25    | *606.95     | 1019.08     | *5970.93       | *606.69        | 1018.23        | 0.33  | 0.26  | 0.42  | 0.84  |
| DWD8 | *5835.4     | *850.78     | 993.88      | *5835.86       | *850.42        | 993.11         | -0.47 | 0.36  | 0.59  | 0.77  |
| DWD9 | *5716.62    | *616.43     | 1093.5      | *5716.38       | *616.7         | 1093.93        | 0.23  | -0.27 | 0.35  | -0.44 |
| DWD10| *5630.26    | *021.32     | 994.41      | *5630.63       | *021.07        | 994.99         | -0.37 | 0.25  | 0.44  | -0.59 |

We can see from the table that for outstanding points, error in the X direction is 0.35 m, error in the Y direction is 0.28 m, error in the planimetric positions is 0.45 m < 0.6 m, and the maximum absolute value of the residual in the X direction is 0.47 m < 1.2 m, and in the Y direction is 0.38 m < 1.2m; the
mean square error of the outstanding point elevation is 0.61m < 0.8m and the maximum absolute value of the residual is 0.84m < 1.6m. Its precision meets the requirements of 1:2000 digital line graphics.

5. Conclusions and Suggestions
As mentioned in the precision evaluation, the consumer-grade drone Phantom 4 Pro operated at a flight height of 180 m. Its precision meets the requirements of 1:2000 digital line graphics. Therefore, Phantom 4 Pro can be applied in this river-lake demarcation project.

It can be seen that obvious drawbacks still existed in the application of consumer-grade drones in this project. First, aerial flight tests must be performed at the chosen test sites, and the drone can only be used for project product after verification. Second, as restricted by the parameters of the camera, the number of images acquired per flight is tremendous, which increases the difficulty of data processing. Third, due to the short endurance and narrow signal reach of the consumer-grade drone, when conducting aerial photography for a large-scale region, we need to divide the region into a large number aerial photography zones, which increases the workload of aerial photography. Last but not least, quantitative analysis is still lacking in the applications of consumer drones in engineering projects.

In this experiment, the author verified the feasibility of applying consumer-grade drones in engineering projects. Consumer-grade drones still have their drawbacks, but most of them are the results of their hardware. With science and technology keep advancing, the drawbacks of hardware will gradually be solved by technological innovations. It is foreseeable that in the future, consumer-grade drones will be widely used in engineering projects.

References
[1] Li,T,Gao,B,Zhang,Y,T,Gao,J,J.(2019)Research on illegal mining monitoring based on UAV aerial survey technology. Bulletin of Surveying and Mapping, 3:151-154.
[2] Lu,XP.(2014) Empirical Study on the Mapping Precision Based on UAV Low-altitude Photogrammetry. China University of Mining and Technology,Beijing.
[3] Zhao,RJ,Yu,HM.(2010) The division and application of river coast area. Water Resources & Hydropower of Northeast China,3:1-2,8,71.
[4] Li,FD.(2015)Research on the Precision of UAV Aerial Photography System. Guilin university of technology,Guilin.