Yellow River Icicle Hazard Dynamic Monitoring Using UAV Aerial Remote Sensing Technology

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Abstract. Monitoring the response of Yellow River icicle hazard change requires accurate and repeatable topographic surveys. A new method based on unmanned aerial vehicle (UAV) aerial remote sensing technology is proposed for real-time data processing in Yellow River icicle hazard dynamic monitoring. The monitoring area is located in the Yellow River ice intensive care area in southern BaoTou of Inner Mongolia autonomous region. Monitoring time is from the 20th February to 30th March in 2013. Using the proposed video data processing method, automatic extraction covering area of 7.8 km^2 of video key frame image 1832 frames took 34.786 seconds. The stitching and correcting time was 122.34 seconds and the accuracy was better than 0.5 m. Through the comparison of precise processing of sequence video stitching image, the method determines the change of the Yellow River ice and locates accurate positioning of ice bar, improving the traditional visual method by more than 100 times. The results provide accurate aid decision information for the Yellow River ice prevention headquarters. Finally, the effect of dam break is repeatedly monitored and ice break five meter accuracy is calculated through accurate monitoring and evaluation analysis.

1. Introduction

The Yellow River is the fifth largest river in the world, which spans 23 longitudes in East-west direction and 10 latitudes in North-south direction. Topography, landforms and runoff in different areas are divergent. The Yellow River in Inner Mongolia from Ningxia to Inner Mongolia, located in the northern tip of the Yellow River, is 840km. But the total drop is only 162.5m. The river slope is low and the watercourse is complicated.

The Yellow River in Inner Mongolia has its own features, such as high-intensity cooling, ice-run frozen early; large flow in freezing period, tank's large storage capacity; temperature rose late in thaw period and big rise, making it easy to form ice dams blocking ice and accumulating water, which causes lower reaches level soared. Cold and defensive difficulties can easily cause levee burst disaster

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in the winter. The country must invest a lot of human, financial and material resources to carry ice prevention, anti-flood work every year.

In order to resist ice flood hazard, at present, people on both sides of the Yellow River have taken various effective measures. There are four main ways including defence, accumulation, bypass and draining. It is difficult to obtain data about icicle in a timely manner, rapid and accurate access because the existing techniques are based mainly on human observation. This paper presents a dynamic monitoring technology and real-time data processing methods of the Yellow River ice using the UAV remote sensing technology. Experimental results show that the new method improves the accuracy of the transformation matrix effectively and the quality and efficiency of image stitching. The product can be directly used for real-time dynamic monitoring of the Yellow River ice and accurately locate the position of ice dams, which provides accurate information for the ice prevention and anti-flood.

2. Data acquisition and processing key technology

2.1 Low-altitude unmanned aerial vehicle wireless video remote sensing data acquisition system

To satisfy the needs of technical equipment for emergency mapping data acquisition and stereo sensor monitoring network in disaster area and break through the unmanned flying platform, high-definition light and small CCD sensor, 2-axis auto rotation tringle head, miniature image transmitting terminal, automatic flight control systems and other technical indicators and integration technology, many techniques are implemented. There are hand throw, catapult, parachuting and other landing technique for multiple geographical environment, real-time video data transmission technique from machine to ground station for high-speed flight conditions, miniature low-altitude unmanned aerial vehicle wireless video remote sensing data acquisition system, real-time remote sensing data acquisition technique for estitchency mapping and disaster monitoring.

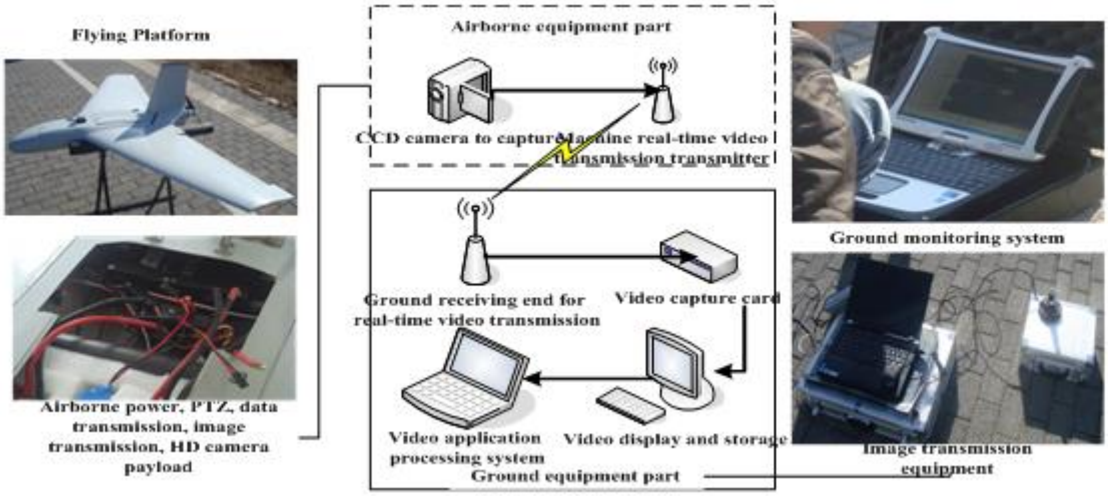


Figure.1 Integrated schematic of aerial remote sensing system

2.2 Real-time stitching of UAV video key frame image

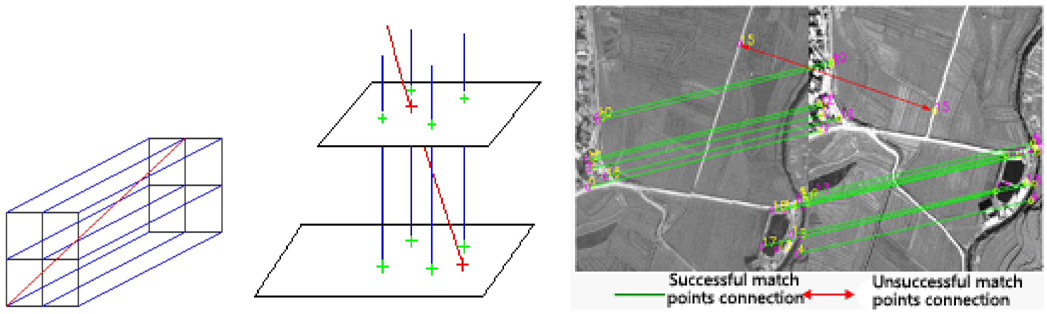
2.2.1. Adaptive extraction technique of video key frame image. Key frames of real-time source are grabbed when the camera is in the video preview mode. Aerial video streaming is processed based on

Microsoft Directshow COM programming interface. Sampling of Layer 2 frames is implemented using an adaptive to capture data in the WDM driver model capture card. Frames overlap and frame interval piecewise linear model are established on the first layer. Quasi key frames meeting certain overlap are extracted adaptively through constantly updated sampling frame interval by "prediction - inspection - revise". On the second layer, based on the first layer's sampling, final key frames meeting certain conditions is extracted using frame by frame detection method from the quasi key frames. And then corresponding post-process is implemented and the result is stored to realize key frame images quickly adaptive extracting .

2.2.2 Automatic matching of high spin side video key frame image

Define the geometric relationship of image matching points:

Video key images have the same resolution. According to analysis, matching points ($\{(x_1,y_1),(x_2,y_2),\cdots(x_n,y_n)\}$ and $\{(x_1^{'},y_1^{'}),(x_2^{'},y_2^{'}),\cdots(x_n^{'},y_n^{'})\}$) have the same distance (D) and slope (K). So, mismatching points can be eliminated through rough fuzzy C-means method.



(a) (b) (c)

Figure.2 (a) and (b) Geometric relationship schematic of the same resolution image matching points; (c)experimental results.

Rough fuzzy C-means eliminates mismatching points with geometric constraints:

- The feature vector information of real-time image and the reference image are extracted by SIFT.
- Based on the two images' SIFT feature vectors, euclidean distance of feature vectors in key points is considered as the similarity determination measure. The least ratio of distance between the nearest neighbor (NN) and the second neighbor (SCN) is the specific principle of the similarity determination measure.
- Calculating the geometric constraints between images based on matching points documents and image resolution information of step 2: If the resolution is the same, the slope and the distance of matching points are calculated.
- Using rough fuzzy C-means method (RFCM) to seek the membership of (k, S) or (X, Y), all the matching points are on the cluster analysis to remove different types points, leaving only points included in the affirmative gathered collection.
- Relatively precise points are doing precise matching with the least squares method.

2.2.3 Perspective projection transformation matrix estimation based on L-M algorithm

Perspective projection transformation is used in the process of image stitching. According to the mathematical model of matching points and L-M model parameter estimation, perspective projection transformation is calculated. Using the perspective transformation matrix parameters, we project the two images onto a unified coordinate system to achieve an initial image stitching.

In the formula (1), (x_i, y_i) and (x'_i, y'_i) are matching point coordinates of two images to be stitched .

$$\begin{pmatrix} x_i' \\ y_i' \\ 1 \end{pmatrix} = \begin{pmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{pmatrix} \begin{pmatrix} x_i \\ y_i \\ 1 \end{pmatrix} \quad (1)$$

By the formula (1), it can be rewritten as

$$x_i' = \frac{m_{11}x_i + m_{12}y_i + m_{13}}{m_{31}x_i + m_{32}y_i + 1}, y_i' = \frac{m_{21}x_i + m_{22}y_i + m_{23}}{m_{31}x_i + m_{32}y_i + 1} \quad (2)$$

To obtain the optimal solution of eight parameters of the transformation matrix, the applied principle is that the distance between all the image points and matching points of the feature points is the smallest, namely, F(m) is obtained the minimum.

$$F(m) = \sum_i \left[\left(\frac{m_{11}x_i + m_{12}y_i + m_{13}}{m_{31}x_i + m_{32}y_i + 1} - x_i' \right)^2 + \left(\frac{m_{21}x_i + m_{22}y_i + m_{23}}{m_{31}x_i + m_{32}y_i + 1} - y_i' \right)^2 \right]^{\frac{1}{2}} \quad (3)$$

Then formula (3) can be calculated with L-M algorithm similar to formula (1).

2.2.4 Stitching Image fusion

After image stitching is completed, suture boundary lines need to smooth so that suture is natural transition. Eliminating discontinuity of light intensity or color caused by sampling images at different times makes seam between images not obvious, so that the stitching seems more natural. Image fusion methods are commonly used by average method, weighted average method and multi-resolution method. Although average method has small amount of calculation, the stitching is ineffective. Weighted average method has high quality image fusion, but the calculation is large. The paper is mainly used for general image stitching, precision requirements for stitching is not very high. So image fusion is used by weighted average method. The main idea of the method is that pixel intensity of image overlapping area is added and synthesized to a new image on the basis of a certain weight.

Assuming adjacent images I_1 , I_2 are overlapping in the interval $[x_1, x_2]$, $W_1(x)$, $W_2(x)$ are the weighting function, which is generally expressed by formula 4.

$$W_2(x) = 1 - W_1(x) = 1 - i / W \quad (4)$$

Among them, $0 < i < W$, W is the width of the overlapping area. Then the pixel intensity value in this interval (x, y) of overlapping image I is:

$$I(x, y) = I_1(x, y) * W_1(x) + I_2(x, y) * W_2(x) \quad (5)$$

Using the weighted average method makes excessive part relatively smooth, with no obvious steps, which eliminates splicing gap better and achieves a smooth transition.

3. Experiment and Analysis

Monitoring area located at southern BaoTou Yellow River ice intensive care area in the Inner Mongolia autonomous region, monitoring during 20th February to 30th March in 2013. Experimental flying height is 120m and Flight speed is 90km/h. Facing Photography is used. Video image is sampled with 25 frame/sand resolution is 0.05m. Camera is calibrated used the two-dimensional plane calibration. Specific parameters is in Table.1.Using the proposed video data processing method, automatic extraction covering area of 7.8 km^2 of video key frame image 1832 frame, take 34.786 seconds, the stitching and correcting time was 122.34 seconds, and the accuracy was better than 0.5 m. Through the precise processing sequence video stitching image contrast analysis, to determine the change of the Yellow River ice, and accurate positioning ice bar location, than traditional visual sure ice bar position increased more than 100 times, as the Yellow River ice prevention headquarters provide accurate aid decision making information. Finally, the effect of dam break the repeated monitoring of ice dam break effect of accurate monitoring and evaluation analysis, arrived at the ice break 5 m accuracy.

Table.1 Panorama experimental results.

Interval(Millisecon)	Overlap(%)	Capture images(Frame)	Damaged image(Frame)	Stitching time(Millisecond)
500	63.2	1832	2	34786

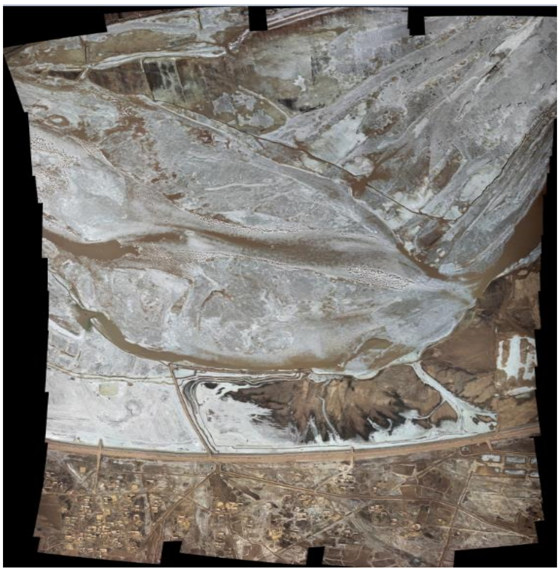


Figure.3 The results of video key images automatic stitching.

4. Conclusion

This paper presents UAV aerial remote sensing technology for the Yellow River icicle hazard dynamic monitoring and real-time data processing. Through the study of low-altitude UAV platforms, high-resolution mini-type CCD camera, high speed video data compression and transmission hardware and software systems under real-time data integration technology, the cyclical dynamic monitoring of the Yellow River Icicle is realized. The study solves adaptive algorithm to extract key frame images from video images, matching algorithm combined with the least squares and video key frame image scale-invariant feature based on high-spin state of partial, mismatching points quickly removed based on random sampling conformance testing and other algorithms. For global registration problems, the LM (Levenberg-Marquardt) method is improved. Iterative quality assessment is added in the iterative update. Iteration parameters are improved to avoid jacobian matrix singular situation that ensures using trust region methods of solving optimization problems, that ensures global convergence of the method, improves the accuracy of the transformation matrix and image quality and efficiency of stitching. Through the precise processing sequence video stitching image contrast analysis, to determine the change of the Yellow River ice, and accurate positioning ice dam location, than traditional visual sure ice dam position increased more than 100 times, as the Yellow River ice prevention headquarters provide accurate aid decision making information. Finally, repeated monitoring, precise monitoring and assessment analysis of ice dam breaking effect show that the accuracy of ice breaking reaches 5m.

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