Ice flood velocity calculating approach based on single view metrology

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Abstract: Yellow River is the river in which the ice flood occurs most frequently in China, hence, the Ice flood forecasting has great significance for the river flood prevention work. In various ice flood forecast models, the flow velocity is one of the most important parameters. In spite of the great significance of the flow velocity, its acquisition heavily relies on manual observation or deriving from empirical formula. In recent years, with the high development of video surveillance technology and wireless transmission network, the Yellow River Conservancy Commission set up the ice situation monitoring system, in which live videos can be transmitted to the monitoring center through 3G mobile networks. In this paper, an approach to get the ice velocity based on single view metrology and motion tracking technique using monitoring videos as input data is proposed. First of all, River way can be approximated as a plane. On this condition, we analyze the geometry relevance between the object side and the image side. Besides, we present the principle to measure length in object side from image. Secondly, we use LK optical flow which support pyramid data to track the ice in motion. Combining the result of camera calibration and single view metrology, we propose a flow to calculate the real velocity of ice flood. At last we realize a prototype system by programming and use it to test the reliability and rationality of the whole solution.

1 INTRODUCTION

Yellow River, which is the second longest river in China and the fourth longest in the world, is 3,395 km long. Originating in the Bayankala Mountains in Qinghai Province in eastern Tibet, it flows through nine provinces of China and empties into the Bohai Sea. The Yellow River basin has an east-west distance of 1900 km, and north-south distance of 1100 km. Total basin area is 752443 km².

Yellow River is also the river where the ice flood occurs most frequently in China, thus, the ice flood forecasting has great significance for the river flood prevention work. In various ice flood forecast models, the flow velocity is one of the most important parameters. But its acquisition heavily
relies on manual observation or deriving from empirical formula. In recent years, with the high
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In this paper, an approach to get the ice velocity based on single view metrology and motion
tracking technique using monitoring videos as input data is proposed. First of all, River way can be
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side and the image side and presented the principle to measure length in object side from image.
Secondly, we use LK optical flow which support pyramid data to track the ice in motion. Combining
the result of camera calibration and single view metrology, we propose a flow to calculate the real
velocity of ice flood. At last we realized a prototype system by programming and used it to test the
reliability and rationality of the whole solution.

2 METHODS

2.1 Principle of single view measurement and motion detection

According to the perspective projection model, one point \( M_i \left( X_i, Y_i, Z_i, 1 \right) \) in space can be projected
to a two-dimensional image plane through a projection matrix \( P \). We call the projected point
\( m_i \left( u_i, v_i, 1 \right) \). The geometric relationship between the two points is:

\[
\lambda M_i = PM_i = \left( p_1 \quad p_2 \quad p_3 \quad p_4 \right) M_i
\]

\( \lambda \) is a non-zero proportionality factor.

When \( M_i \left( X_i, Y_i, Z_i, 1 \right) \) becomes a point on the plane \( W \) and set the plane \( W \) to \( Z_w = 0 \), the
Formula 2-1 becomes:

\[
\lambda \begin{pmatrix} u_i \\ v_i \\ 1 \end{pmatrix} = P \begin{pmatrix} X_i \\ Y_i \\ 0 \end{pmatrix} = \left( p_1 \quad p_2 \quad p_3 \right) \begin{pmatrix} X_i \\ Y_i \\ 1 \end{pmatrix}
\]

\( H = \left( p_1 \quad p_2 \quad p_3 \right) \) is called homography matrix.

When the homography matrix \( H \) is known, any point on the image can be projected to the object
plane. Thus we can calculate the distance and the angle between two points in the object plane. This is
the basic principle of the single view measurement\(^1\).

In the context of this application, motion detection in the video is undoubtedly an important issue on
which target tracking, target classification, target behavior analysis and many other applications
depend. Consequently, an accurate, robust, fast and effective target detection method has been the goal
pursued by the computer vision researchers. Although, a variety of detecting algorithm for different
applications have been proposed, due to the complexity and variety of applications, it is difficult to
have a universal algorithm. At present, background subtraction method, inter frame difference method
and optical flow method\(^3\) are relatively mature methods that are commonly used.

The instantaneous motion projected by spatial moving object on the image plane is called the
optical flow. Visual psychology identify that human beings perceive the movement and structural
information of the moving object by observing the optical characteristics on the object surface.
Similarly, when a camera is used to photograph a target with relative motion, the motion of the
brightness characteristic is called optical flow. In other words, when the moving object is projected to
the image plane, the optical flow is formed.

Optical flow intuitive performance target motion states and processes, in turn, it can be determined
by the optical flow motion targets. In computer vision, optical flow has vital research value. Based on
it, segmentation, identification, tracking, and many other tasks can be done\(^3\).

Lucas-Kanade algorithm\(^4\) (also known as the LK algorithm) is used to calculate dense optical flow
at the beginning. However, since the algorithm can be easily applied to a set of points from input
image, it subsequently became a crucial method for seeking sparse optical flow. In contrast, LK
algorithm only requires partial information around the points of interest surrounding a small window,
thus it can be applied to sparse content.

There is a fatal flaw in basic LK optical flow method. That is the presence of incoherent motion. We need a large window to capture its movement, but this will be in conflict with the assumptions in the LK algorithm. We can use the image pyramid, however, to deal with this contradiction. The function of the approach is to track on a larger spatial scale initially. After that, it can be used at the next level as staring point and we will repeat the process until it reaches the bottom of the pyramid. With this strategy, we can reduce the possibility of movement which does not satisfy the motion assumptions and achieve faster and longer motion tracking as well.

2.2 Solution

In general, when choosing detection algorithm, the background of the moving object and the motion characteristics of the target should be taken into consideration. Depending on the operating mode of the camera, the moving object can be divided into background static background and dynamic background. Motion characteristics mainly refer to the color, size, shape, quantity, stiffness and other characteristics of the moving object itself.

The background subtraction method is expedient for the application of fixed or invariant background. Since the moving object background in this paper is the changeable river water, the method is not suitable. The main advantages of inter-frame difference method are: simple algorithm, program of low complexity and suitable for real-time monitoring. However, feature point set obtained by this method is not the most appropriate set of tracked feature points. As the optical flow method does not need to predict any motion information in advance, it is applicable for the application in this article.

Considering the motion tracking, the size, shape and quantity of the target to be tracked can be changed at any time. Under the impact of water, ice tends to be gathered and dispersed frequently. Tracking method based on active contour cannot be applied to this situation in which the shape of target changes frequently. Besides, method based on the regional and deformable template tracking requires the use of a template or model in advance. That is extremely difficult for real-time application.

Considering that what we concern is the overall speed of the target in the scene and we do not treat ice blocks as individuals, tracking method based on feature points is the most appropriate.

We propose an ice flood velocity calculation process shown in Figure 2-1:

![Figure 2-1 Velocity calculation flow](image)

The specific calculation steps are:

1. Get the video frame rate(FPS, unit: frames / sec);
2. Get the i-th frame image and the i+k-th frame images from video, k can be understood as a video object sampling interval;
3. Feature extraction from \( f_i(x, y) \), get the feature point set, recorded as \( P_i \). We used the feature points which are easy to be tracked by the strong corner point proposed by Shi\(^5\) as feature points;
4. Set \( P_i \) from \( f_i(x, y) \) as the input feature points to be tracked. Use LK optical flow supporting pyramid to predict the position of \( P_i \) in \( f_{i+k}(x, y) \), recorded as \( D_i \);
5. Calculate the actual distance between a pair of feature points from \( P_i \) and \( D_i \) by using the single view measurement principle. Record as \( S_{ij} \);
6. Calculate the average displacement of the points in the \( P_i \). Record the point set which have been successfully tracked in \( P_i \) as \( Q_i \). Assume \( Q_i \)'s size is n, then the average displacement of a frame can be calculate by Formula 2-3;
\[ S_i = \frac{\sum s_{ij}}{n} \]  

Formula 2-3

(7) Calculate the time difference between \( f_i(x, y) \) and \( f_{i+h}(x, y) \) by Formula 2-4;

\[ t_i = \frac{60 \times k}{FPS} \]  

Formula 2-4

(8) Calculate the ice flood velocity \( V_i \) by Formula 2-5;

\[ V_i = \frac{S_i}{t_j} \]  

Formula 2-5

(9) Calculate the average speed of the flow in a period of time by Formula 2-6;

\[ V = \frac{\sum_{m=1}^{n} V_i}{m} \]  

Formula 2-6

(10) Display the tracking results. Mark the racking results on the next frame by arrows with direction.

3 EXPERIMENT AND ANALYSIS

3.1 Experimental background

In order to verify the feasibility and reliability of our method, we conduct experiment at ten observation stations (Labawan, Toudaoguai, Fuan-bridge, Caojiawan, Dengkou, Fujiagedu, Huajiangyinzi, Sanhuhekou, Bayangaole, Sanchakou) in the Yellow River basin in February 2013. Laptop, sign board, Interphone, diving equipment, safety rope and other equipment are used in the experiment.

\[ \text{Figure 3-1 Experimental location map} \]

3.2 Design of sign board

In the process of ice velocity calculation, we need to obtain the longitudinal information on the river plane using the single view measurement method. The key to the realization of the single view measurement is to acquire the homography matrix between the reference plane and the image plane. The calculation of the matrix is based on point correspondence or line correspondence.

No known geometrical information can be utilized in the river channel, thus the camera calibration can be carried out by using the self-made sign board. In the designing process of the sign board, the following points must be taken into account:

(1) Data source is from the existing ice monitoring system. Due to the restriction of 3G transmission cost, the original video data resolution is very low (352*480), thus sign board should not be too small;
(2) To be placed on the river ice, the sign board must be waterproof. Taking into account the possible wind conditions in the field work environment, the sign plate should also be tough;
(3) Taking into account the site may be obscured, reflective, the feature points on the flag board
must be redundant.

In this paper, the sign board we design as shown in Figure 3-2. It is made by waterproof materials, light, tough and easy to take along. Sign board has four 1 meter wide and 0.5 meters long rectangle, a total of 12 easily identified critical corners, the shortest distance between them is 0.5 meters.

3.3 Estimation of accuracy

In order to estimate the accuracy of the measurement, the following experiments are designed. The image was captured from the Sanhuhekou observation station, as shown in Figure 3-3. Use the sign board to calculate the homography matrix and calculate the length of the L1-L8 which actual length are 50cm. Obtain the results as shown in Table 3-1.

As can be seen from table 3-1, the overall relative error is higher than that of indoor experiments, reaching 9%. From figure 3-4 we can find, deviation of measurement results of L5-L8 are even greater and the relative error is significantly higher than L1-L4. If the coplanar condition is kept better, the error should be close to the average relative error of L1-L4, which is about 6%.

3.4 Experiment and analysis

Using the break-up period of ice flow video as experimental data, we realize a prototype system by programming and use it to test the reliability and rationality of the whole solution. In some video data, the ice flow is not obvious, but our program has also calculated the results. The direction of motion of the feature points which have been tracked have been displayed on the second frame by arrows. Thus we can judge the tracking results are correct. The tracking results of Caojiawan, Labawan and Sanhuhekou as shown in Figure 3-4 to Figure 3-6.
In Figure 3-8, we recorded the speed of ice by setting the sampling interval to 2 seconds.

From the figure above we can find the calculated results from Caojiawan and Labawan are stable and reliable while the calculated results from Sanhuhekou has frequent volatility. Through the analysis of the video, we think the limited number of ice targets lead to this result.

4 CONCLUSION

In this paper, an approach to get the ice velocity based on single view metrology and motion tracking technique using monitoring videos as input data is proposed. Specifically, the following work has been done:

1 The characteristics of flowing ice block have been analyzed in this paper. Considering its features, we identify the LK optical flow method using strong corner feature points as tracking targets is the most suitable method.
2 This paper presents a field camera calibration method based on sign board. Relying on the calibration results, we can calculate the actual velocity of ice block’s displacement in the video.
3 We realize a prototype system by programming and use it to test the reliability and rationality of the whole solution.
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