Surveillance of muddy river flow by telemetry system

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Abstract. This paper shows the dynamic characteristic evaluation system to monitor muddy river flow by video image. The dynamic character is evaluated by the flow speed and direction in each small block distinguished evenly on a video frame. By evaluating dynamic character of river surface, water behavior and dangerous area will be distinguished. Aim of this study is to discover the dangerous area, to presume disasters and to inform local or national government and alarm people.

1. Introduction
Heavy rain and typhoon cause muddy river flow. When such flow becomes heavily, various kinds of water disaster are occurred to life and social infrastructures like houses, plants, bridges, roads and railways. And also human lives are lost.

Monitoring system for muddy river flow is necessary and useful to predict the water disasters. As nobody want to be at the river side. Then, that system should be constructed as a telemetry system.

Telemetry system proposed in this paper monitors state of the river surface at onsite system and estimates dangerous area in the river at host system far from the river. Observer can know the dynamic state of dangerousness of the river in parallel of distributions of river flow speed and direction. And also he can inform the dangerousness to people living near the river. In this telemetry system, onsite and host system are communicated through "Cloud" system.

2. Structure of telemetry system of river flow
Figure 1 shows the system construction of telemetry system to monitor the river. The system is constructed by two parts; Onsite and Host system. Onsite system placed near river is the measurement system of river flow. Host system is the monitoring system at remote place from river.

Onsite system has GPS Receiver, Camera, Computer and Mail Interface. GPS Receiver gets parameter of latitude, longitude, absolute time and Circular Error Probability. They are stored in Location Parameter (.csv) and saved to Parameter Folder. Camera takes a picture of river surface firstly. The first shot image is saved to Parameter Folder. Camera also shoots VGA (640pixel*480pixel) size video. Computer calculates vector of river flow by using captures of the video. The parameters of start point and end point of vector is stored in parameter file (.csv). The file is saved to Parameter Folder in each capture. Computer counts the file in Parameter Folder. If the number of parameter files is sufficient, Parameter Folder is compressed (.zip). After the compression, Computer deletes all contents of the folder. Computer attaches the zip file to mail. Mail Interface sends the mail to cloud system.
Host system has Computer, Mail Interface and Monitor Window. Mail Interface receives mail from “Cloud” system. This program gets the zip file and save to Contemporary Parameter Folder and Temporary Parameter Folder. Computer refers Temporary Parameter Folder. Computer extracts the zip file. First shot image and Location Parameters are displayed on Monitor Window. Computer also reads parameter of vector from parameter files. After that, this Computer estimates flow speed and flow direction by using the parameter. From the flow speed and direction, Computer analyzes dangerousness and characteristic on river surface. The analysis is fit together first shot image and displayed on Monitor Window. That is to say, it is possible to observe safely by using this telemetry system.

3. Vector calculation of river flow
To get the vector of river flow, each image are distinguished as small square areas (8pixel*8pixel). Figure 2 shows the original image and segmentation. An image segment block is defined as Region of Interest (ROI). The vector is calculated for each blocks.

Figure 3 shows how to find the movement of ROI blocks. To find the movement of an original ROI block in an image frame, correlation to blocks in next image frame is calculated. The searched range is 24pixel*24pixel centered at same position with the original ROI block in previous image frame. Original ROI block and searched range image are converted from RGB into gray scale. The intensity values the size is 8pixel*8pixel are obtained from upper left corner of searched range image. The correlation is calculated by using the intensity values from searched range image and original image. This calculation is repeated by sliding 1pixel on searched range image. After the calculation, the highest correlation value of the block is discovered. The block is the most resemble block with original ROI block. The vector is decided by connecting the two blocks.

Figure 2. Segmentation of image frame

Figure 3. Generation of a movement vector of a ROI block
4. Estimation of dangerousness on river surface

4.1. Estimation of flow speed and direction
The flow speed and direction of original ROI block are estimated by the vector.
To estimate the flow speed, the vertical and horizontal lengths of 1 pixel is needed. The length is calculated by actual measured value. Using the vector, lengths and frame rate, the flow speed is calculated (1).

\[
V = \sqrt{((x'-x) \cdot h)^2 + ((y'-y) \cdot v)^2 / (1/f)}
\]  \hspace{1cm} (1)

\(V\) means flow speed [meter/sec], \(x\) and \(y\) means coordinate of start point on image, while \(x'\) and \(y'\) means coordinate of end point on image, \(h\) means horizontal length [meter/pixel], \(v\) means vertical length [meter/pixel], \(f\) means frame rate and \((1/f)\) means interval of two images [sec].

Flow direction is classified by the angle of vector. The angle of vector is calculated by the inverse trigonometric function (2).

\[
\theta = \tan^{-1}\left(\frac{y'-y}{x'-x}\right)
\]  \hspace{1cm} (2)

Here, \(\theta\) means angle of vector, \(x\) and \(y\) means coordinate of start point on image, while \(x'\) and \(y'\) means coordinate of end point on image. From the calculation, the angle is classified into 8 directions. (Table1)

Figure 4 and 5 shows the results of flow speed and direction. They are expressed by color in each ROI blocks.

Table1. Direction to color conversion table

| Color | Direction |
|-------|-----------|
| blue  | 135° ≤ 0 < 180° |
| purple| 90° ≤ 0 < 135°  |
| pink  | 45° ≤ 0 < 90°   |
| red   | 0° ≤ 0 < 45°    |
| yellow| -45° ≤ 0 < 0°   |
| green | -90° ≤ 0 < -45° |
| cyan  | -135° ≤ 0 < -90°|
| blue  | -180° ≤ 0 < -135°|

(a) Flow speed image (b) Color chart of flow speed

Figure 4. Distribution of flow speed

(a) Flow direction image (b) Color chart and number of flow direction

Figure 5. Distribution of flow direction

4.2. Estimation of turbulent flow
To evaluate dangerousness of river surface, it is necessary to estimate the dynamic state of the turbulence of river flow. The turbulence is estimated by the relation of flow directions.

Figure 6 shows how to estimate the turbulent flow. Number in each block shows the direction assigned in Figure 5 (b). 0 means no vector in the block. Figure 6 (a) shows the distribution of flow directions of nine blocks in previous image frame. Figure 6 (b) shows the flow direction of target block which is the center block in same nine blocks in present image frame. Comparing two kinds of
distributions, flows of two blocks assigned 1, 8 are same and adjacent direction to the target block. On the other hand, flows of six blocks assigned 6, 7 are different directions to the target block. The number of different direction segments is counted. Turbulence is estimated by the number.

4.3. Estimation of characteristic of river surface

From the flow speed and directions, the characteristic of river surface is estimated. Table 2 shows the relation. The flow speed is distinguished to 3 levels. They are “Extremely high speed”, “High speed” and “Low speed”. The river flow is also distinguished to 3 levels by the number of different direction blocks compared one block with neighbor blocks. They are “Turbulent flow”, “Normal flow” and “Orderly flow”. By these level divisions, the characteristic is classified into 5 modes. Mode 4 expresses the most dangerous state. Mode 3 expresses the dangerous state. Mode 2 expresses the careful state. Mode 1 expresses the calm state. Mode 0 expresses safe state. These levels are estimated each ROI blocks. (above 4 images in Figure 7)

Then, by emphasizing high density area of ROI blocks, the characteristic area is specified into each mode. Figure 7 shows the specification of characteristic area each mode. The arrow shows main flow direction in characteristic area. These characterized images are displayed to observer.

| Flow Speed | Turbulent | Normal | Orderly |
|------------|-----------|--------|---------|
| Extremely High | Mode 4 | Mode 4 | Mode 3 |
| High | Mode 3 | Mode 2 | Mode 2 |
| Low | Mode 1 | Mode 1 | Mode 0 |

Figure 7. Specification of characteristic area each modes

4.4. Estimation of dangerousness of river surface

Dangerousness area is estimated by the fusion of characteristic modes on river surface. At first, river picture is divided into small segments. A segment is formed by square of 8 pixels. In each segments, weights defined in each modes are added for 1 minute. The weight of Mode 4, Mode 3, Mode 2 and Mode 1 is 4, 3, 2 and 1. Figure 8 shows the distribution of dangerous area colored by sum of weights. High scores are colored by red. These are estimated as dangerous areas. And Low scores are colored by green. These are estimated as safe areas relatively.
5. Evaluation of river flow

5.1. Results of muddy river flow

Figure 9-12 show original image and results of evaluation in case of muddy river flow. In Figure 9, human feels this river is clearly dangerous. In Figure 10, flow speed is fast and flow direction is turbulent. In Figure 11, Mode4 area is the largest. Mode2 is so few and Mode3 and Mode1 do not spread. In Figure 12, dangerous level is so high. From these results, this river is estimated so dangerous by image processing. This evaluation is identical with human sense. Then, it is confirmed that this system has found invisible dangerous area.

5.2. Results of swollen river flow

Figure 13-16 show original image and results of evaluation in case of swollen river flow. In Figure 13, human feels less danger. In Figure 14, flow direction is turbulent around rock. In Figure 15, Mode2 area is the largest. Mode1 area is less than Mode2. Mode3 area is so few, and Mode4 area do not spread. In Figure 16, dangerous level around rock is higher than other places. From these results, the area around rock is dangerous by the estimation of image processing. This evaluation is different with human sense. It is also confirmed that this system has found invisible dangerous area.
5.3 Results of curve river flow

Figure 17-20 show original image and results of evaluation in case of winding river flow. In Figure 17, human feels this river is calm. In Figure 18, flow speed is so slow. In Figure 19, only Mode1 area spread on river surface. In Figure 20, dangerousness is expressed but the level is low. From these results, this river is not dangerous by the estimation of image processing. This evaluation is identical with human sense.

6. Conclusion

This paper has shown the telemetry system to surveil river flow. This system estimates dangerous area of the river by data fusion of flow speeds and flow directions of small segments divided river surface. This information becomes so helpful for people living near the river.

References

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