EVALUATION FOR THE VELOCITY OF DEBRIS FLOW THROUGH IMAGE PROCESSING TECHNIQUES

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ABSTRACT

The landforms and geologic structure in Taiwan are peculiar, and terrains are easily broken and unstable. Washout and rainstorms occur very frequently during the typhoon season and result in debris flows and landslides in mountain areas. In recent years, the Soil and Water Conservation Bureau has devoted much effort on monitoring and investigation for the debris flows. Several monitoring stations and equipments are set up to observe, receive and transfer data to disaster management center. The real-time image data grasped by CCD camera is then transferred back to the SWCB via satellite communication network. It allows relevant personnel to grasp the real-time spot situation of every monitoring station during the typhoon season.

Event happened in Shen-Mu Station, Nantou County, on July, second, 2004 is analyzed in this paper. It demonstrated that human eyes can clearly observe the motion of debris flow, but the velocity must be calculated based on the flowing distance of water manually. In order to strengthen the value of CCD camera images and applications of digital image processing, this research built a set of the rules to evaluate the velocity of debris flow. Technologies include feature extraction, image enhancement; spatial filtering and cell analysis are employed to build up the mechanism responsible for velocity interpretation. The result of velocity analysis can be taken as the reference and the evaluation of follow-up researches.

1. Introduction

The landforms and geologic structure in Taiwan are peculiar, and terrains are easily broken and unstable. Washout and rainstorms occur very frequently during the typhoon season and result in debris flows and landslides in mountain areas.

In recent years, the Soil and Water Conservation Bureau (SWCB) has devoted much effort on monitoring and investigation for the debris flows. Several monitoring stations and equipments are set up to observe, receive and transfer data to disaster management center. The real-time image data grasped by CCD camera is then transferred back to the SWCB via satellite communication network. It allows relevant personnel to grasp the real-time spot situation of every monitoring station during the typhoon season. In order to strengthen the value of CCD camera images and applications of digital image processing, this research built a set of the rules to evaluate the velocity of debris flow.

2. Debris monitoring in Taiwan

SWCB had built 13 monitoring stations continually from 2002 to 2005. 13 monitoring stations position distribution as shown in figure 2-1:

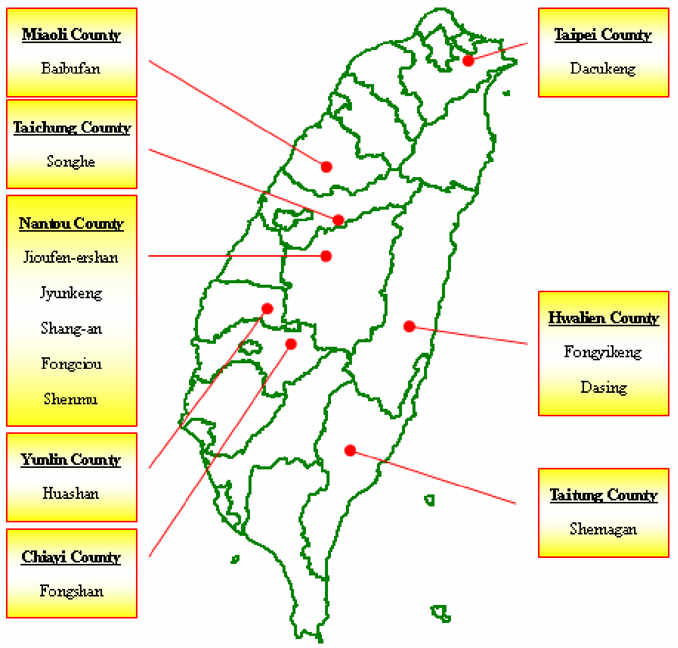


Figure 2-1 distribution of 13 monitoring stations

Because the debris flow occurrence time is short and cannot be forecasted, therefore SWCB uses many kinds of advanced instruments to monitor the location of observations. Equipments in each monitoring station include rain gauge, wire sensor, CCD camera, ultrasonic airborne lever meter, pore pressure transducer gauge and geophone. Those monitoring instruments will help enhance the monitoring efficiency. Figures 2-2 are images of equipments.

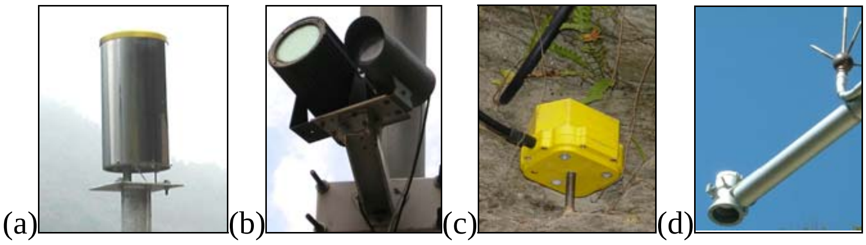


Figure 2-2 equipments in monitoring station:

(a) Rain gauge; (b) CCD camera; (c) geophone; (d) ultrasonic airborne level meter

3. System construction

In this paper, we use photos with digital image processing technologies to build a module that can analyze the velocity of debris flow. Those skills include image enhancement, feature extraction and spatial filtering. Figure 3-1 is a flow chart of the system which uses the theory of this research.

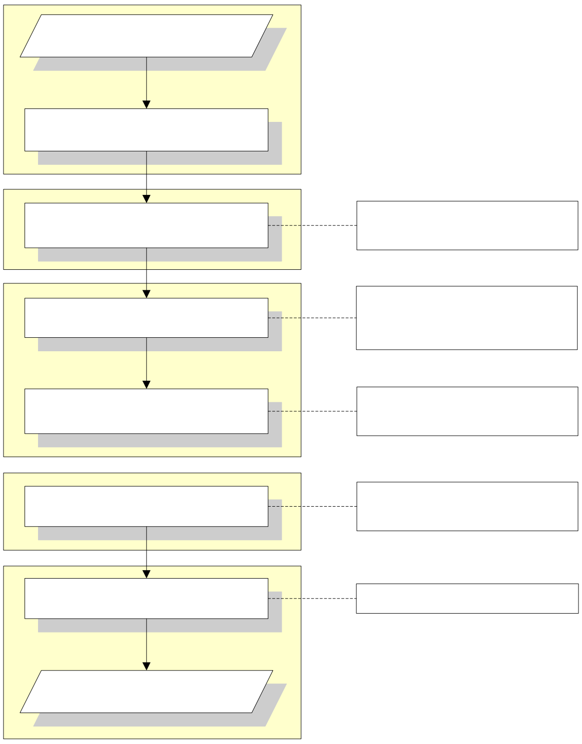


Figure 3-1 System flow chart

3.1 Image enhancement

Main features in the system are changed intensity of flowing water in riverbed. In order to decrease information capacity and speed up analysis, the first stage is changing RGB images into gray-scaled images. The second stage is transforming histogram of images into balance distribution through histogram equalization that enhance changed pixels of the image. Figures 3-2 are two images one is the original image and the other is the enhanced image.

Gathering images

Phase 1

Choosing and creating sample for analysis

Phase 2

Setting parameter

Figure 3-2 original image and enhanced image

3.2 Image subtraction

We get different pixels between two serial images by image subtraction, and furthermore we can filter out the needless objects such as trees, embankments and water drops. This shows, through image subtraction we could extract features from image and filter unnecessary objects that will improve the validity of analysis. Figures 3-3 are three images, first one and second one are serial images, third one is the result of image subtraction from first image and second image.

Figure 3-3 original images and the result of image subtraction

3.3 Binary image

A binary image splits pixel values into two categories by a special threshold. Here, we estimate a threshold with intensity of image. If the value of intensity fits in with the threshold, the pixel will be reserved; the other pixel will be ignored. In the system, the threshold of pixel values is 200, the result of binary processing as shown in figure 3-4.

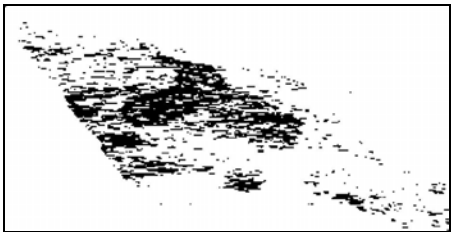


Figure 3-4 result of binary processing

3.4 Spatial filtering

After the process of binary image, it will retain the pixels really used in the system. The pixels in the image can be judged by person vision, but it would be hard to judge by computer vision. Because many pixels of flowing water in the riverbed are not continuous and will be determined to different objects. In the cause of solving this problem, we use the concept of smoothing spatial filter that contains 3*3 mask, 5*5 mask and 9*9 mask. By this way, it will strengthen the correlation of the valid parts and integrate the region of flowing water.

The formula of filter is $R = \frac{1}{n^2}\sum_{i=1}^{n^2} Z_i$, n is the matrix dimension of mask, ex.3*3 or 5*5 etc; Z is the value of each cell in masks. In this case, all values are 1.

3*3 filter-1: $R = \frac{1}{n^2}\sum_{i=1}^{n^2} Z_i$, $n=3$, $r=0.8$; if $R>=r$ then all values in the mask equal 1. Figure 3-5 (a) is the result of 3*3 filter in the first 3*3 stage.

3*3 filter-2: $R = \frac{1}{n^2}\sum_{i=1}^{n^2} Z_i$, $n=3$, $r=0.4$; if $R>=r$ then all values in the mask equal 1. Figure 3-5 (b) is the result of 3*3 filter in the second 3*3 stage.

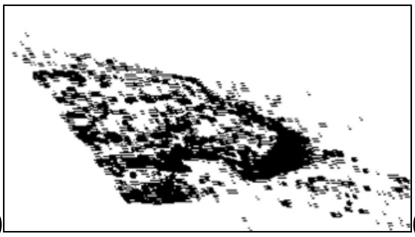
(a)  (b) 

Figure 3-5 results of 3*3 filter

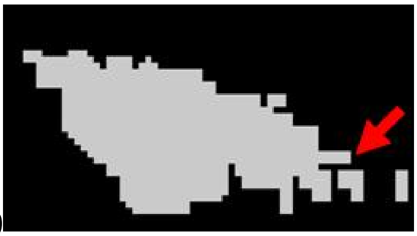
9*9 filter: $R = \frac{1}{n^2}\sum_{i=1}^{n^2} Z_i$, $n=9$, $r=0.3$. If $R \geq r$ then all values in the mask equal 1. Figure 3-6 (a) is the result of 9*9 filter.

5*5 filter: $R = \frac{1}{n^2}\sum_{i=1}^{n^2} Z_i$, $n=5$, $r=0.25$. If $R \geq r$ then all values in the mask equal 1. Figure 3-6 (b) is the result of 5*5 filter.

(a)  (b) 

Figure 3-6 the result of 9** filter and 5*5 filter

Following processes of image enhancement, binary image and spatial filtering, there will be a complete region left in the image. Employing this region, we can get a coordinate which represents the flowing distance of debris flow. Figure 3-7 (a) is the result that has been dealt with digital image processing, and the position which a red arrow pointed is the front coordinate of debris flow. Figure 3-7 (b) is a grid, and every cell shows a distance of each position. So we get the coordinate from the image, and overlay values to grid, then we can gain a moving distance. Using this moving distance and wasted time of debris flow, the velocity of debris flow will be gained.

(a)


(b)

row	1	2	3	4	5	6	7	8	9
1	20	20	30	30	30	36	36	53	53
2	20	30	30	30	36	36	53	53	70
3	30	30	30	36	36	53	53	70	70
4	30	30	36	36	53	53	70	70	70
5	30	36	36	53	53	70	70	70	70
6	36	36	53	53	70	70	70	70	87
7	36	53	53	70	70	70	70	87	87
8	53	53	70	70	70	70	87	87	87
9	53	70	70	70	70	87	87	87	87

column

Figure 3-7 (a) result after image processing; (b) definition of distance in the grid

3.5 result output and verify

In order to test and verify the accuracy of the rules in this paper, we use two results to compare that calculating by system and calculating by manual. In this paper, we take samples from 2004/05/20 to 2004/07/02. The results of each date are in the table 1.

Table 1 Result verification-2004/5/20

Date:2004/05/20	
Flowing distance	74m
Result by system	3.6667km/hr
Result by manual	3.027km/hr

Date:2004/05/29	
Flowing distance	104m
Result by system	4.303km/hr
Result by manual	3.566km/hr

Date:2004/06/11	
Flowing distance	104m
Result by system	5.539km/hr
Result by manual	5.673km/hr

Date:2004/07/02	
Flowing distance	130m
Result by system	37.4km/hr
Result by manual	46.8km/hr

4. Conclusion

Because the CCD cameras of each monitoring station set up in different environment, photographing angle and photographing objects of each station are different, too. The analysis method in this paper can’t imply to all of the monitoring stations. So photographing angle, photographing objects and flowing distance of water are important confusions of this method.

Images of Shen-Mu monitoring station are appropriate to analyze debris velocity. We use many technologies to process images and calculate debris velocity; those image processing technologies include image enhancement, feature extraction, spatial filtering, spatial correlation and raster data structure. We get the result of debris velocity by two ways. One is calculating by system that uses the analysis method in this paper, the other is calculating by manual computation. Through testing and verifying, the value of debris velocity is feasible and the tiny difference between systemic computation and manual computation is acceptable.

In the future, we may push this analysis module to other monitoring stations, and combine the precaution system, that will make a complete rule of debris monitoring and strengthen the value of monitoring stations.