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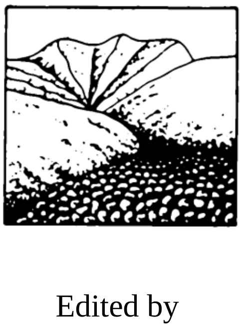

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СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита

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Conference logo is based on a figure from S.M. Fleishman’s book on Debris Flows (Moscow: Geografgiz, 1951, p. 51).

Intelligent debris flow monitoring and warning system

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Abstract. A debris flow monitoring and warning system is installed on midstream Yusui Stream, Taiwan. The monitoring station is a fully automatic warning station. The system is composed of 2 CCDs, 2 MEMS, and one rain gauge. The arrival of debris flow is detected and double-checked with CCD and MEMS signals. CCD image can also produce debris flow velocity and flow height. MEMS can produce the Phase speed and flow rate for debris flows. All data will be compared with a pre-simulation of all scenarios from debris flow. The ultimate influence area and degree of destruction can be obtained from the data. Warnings are issued through on-site control, voice messages, line messages, broadcasting, and web-warning.

Key words: *Automatic monitoring system, debris flow, image processing*

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Интеллектуальная система мониторинга и предупреждения селевых потоков

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Аннотация. Система мониторинга и предупреждения селевых потоков установлена в среднем течении руч. Юсуй (Тайвань). Она является полностью автоматической и состоит из двух ПЗС-матриц, двух МЭМС и одного осадкомера. Приход селевого потока обнаруживается и перепроверяется с помощью сигналов ПЗС и МЭМС. Изображение, полученное с помощью ПЗС-матрицы, может также отображать скорость и высоту потока. С помощью МЭМС можно получить данные о фазовой скорости и расходе селевых потоков. Все данные сравниваются с предварительным моделированием всех сценариев развития селевых потоков. На основе полученных данных можно определить конечную зону воздействия и степень разрушения. Предупреждения выдаются с помощью контроля на месте, голосовых сообщений, сообщений на линии, вещания и веб-предупреждений.

Ключевые слова: *Автоматическая система мониторинга, селевые потоки, обработка изображений*

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Introduction

Taiwan is characterized with its steep slope, fragile geological formation and concentrated heavy rainfalls, all these factors make debris flows a common phenomenon in the island. There are 1732 debris flow potential stream in a small island with area 36197Km^2, so there is one debris flow for every 21 km^2 area. Monitoring of these streams and providing hazard warning for the downstream area is essential.

There are 13 monitoring stations in Taiwan installed and monitor special locations. There is one mobile station that can move to specific location and start monitoring in a very short time. However, all monitoring stations only provides data, warning is not directly related to all monitored data. Actual warning is issued through rainfall data only. This is the same situation for many monitoring stations around the world [*Hurliman., Rickenmann and Graf, 2003; Berti, etc., 2000*]. To improve the usefulness of monitoring station, data analysis should be added and warning should be issued automatically from the monitored data.

This paper presents the new intelligent monitoring station where data collection, analysis is all done in one system.

System specification

The system is composed of 2 MEMS detector, 2 CCD, 1 rain gage and a processing unit. MEMS unit detect debris flows and calculate the energy of debris flows. CCD detects debris flows, capture the average free surface elevation and calculate the phase speed of debris flows. All data is collected through cable to local cabin where industrial standard computer is used to process and analyze all data. If debris flow is detected, warning is sent to downstream target area.

The method of analysis and detection is described below.

Ground vibration signal

The ground vibration signal is detected using a MEMS unit. The MEMS is Analog Devices ADXL 355, triaxial acceleration chip. The signal is analog and MEMS is cased in a water proof cylindrical box, with output cable connected. The cable can be extended to 450 m, so MEMS unit can be placed far away from the processing unit. This newly developed device can extend the range of monitoring to a much larger area. Furthermore, the price of the unit is very cheap, so we use it as an easily replaced unit and it is installed very close to the potential hazard area.

Detection principle

The maximum value of 2-s averaged data is used as the ambient noise level. If the detected signals have an amplitude of one order of magnitude larger than that of the long-period noise level, then these signals indicate the arrival of debris flows. To avoid

pulse noise, this system used a variation of accumulative signal power between 10 and 40 Hz [*Arattano, 1999; Abancó, Hürlimann and Moya, 2014*] from a time series that was 0.5 s or longer as the main index for debris flow detection. The detection threshold is not a constant threshold but a large increase (at least an order of magnitude larger) from the noise signal power. This method has proved to be effectively in WEI and LIU (2019).

The ground variation signal is also empirically related to the flow rate data, so flow rate data is also available for reference. The ground vibration data can be used to estimate the debris flow velocity as Arattano M, Marchi L (2005), but this is not used in this system.

CCD detection

Debris flow detection

The total grey-level method is used to identify debris-flow events. We calculate the total grey level in the region of interest (ROI) and if it changes, this indicates there are events occurring within the ROI. This can be used to identify debris flow. [*Liu, Kuo and Wei, 2022*]

ROI is first defined in the stream area. For each pixel in the ROI, color is transformed to grey level according to the standard from the International Telecommunication Union [*ITU-R, 1990*] code. where each pixel has a grey level from 0 to 255. Then the total grey level for the ROI is calculated This total grey level is then divided by the total number of pixels in the ROI to give the average grey level. If it is very dark, the average grey level will be close to 0. If it is very bright, the average grey level will be close to 255. Normal clear water flow will produce very bright and shining images, so the average grey level is around 150 or more. When debris flow or flood occurs, there is granular material and mud and the whole image becomes darker. As one of the characteristics of debris flows is a large amount of granular material concentrated at the front, the average grey level will become darker in a short period of time. The rate of change of the average grey level can be calculated.

With the temporal variation of average grey level obtained, a condition is required to determine the detection of debris flows. Since average grey level changes for different lighting conditions (sunlight, moonlight, rain), materials, and flow conditions, so the grey level average in “normal” condition is calculated once the system is running, then the noise average grey level will be updated every 5 min before any detection of event. for the stable state should be considered as the reference level.

To detect a change in average grey level, we use the slope. The rate of change of the grey level is calculated as: For every 10 s, we choose the maximum slope Smax within that 10 s as the representative parameter of flow condition. While Smax is small, the flow conditions remain the same. However, if at any moment the calculated slope is greater than twice the Smax value obtained 2s before, and this continues to be true for consecutive 5 points (1.5 s), this indicates event happened within the ROI. Then a debris flow warning will be issued after this detection process.

Velocity estimation

After detection of debris flow, two consecutive ROI average grey level variation will be adopted, the same. Assuming two very closed ROI should have the same variation of the grey level, the value of grey level slope is compared. Same grey level value occurred in two close ROI will have a time difference. The distance between two ROI divided by the difference of detection time provides the estimate of debris flow velocity.

Water level detection

When debris flow arrives, the flow depth will vary. As debris flow has different grey level than water, this can be identified through the difference of grey level for every pixel in the image. Therefore, once debris flow is detected, a simple search of pixels from top to bottom for fast grey level change can produce the debris flow area. The top boundary of the area is the flow depth. [*WEI etc., 2023*]

System and warning

All information is displayed in the web site as in Fig. 1.

After an event is identified by CCD and geophone detection is used as confirmation. Once the detection of debris flow is confirmed, warning on the potential affected area will be issued through line, message, radio triggered broadcasting and Web warning.

System location and monitoring record

The system is installed in Yu-Shui Stream, in Kaohsiung County. There was a serious debris flow event back in 2021 during Tropical Storm Lupit. The system is installed and fully functioned in June, 2023. After the system is installed, there are fog event, heavy rain event, and high concentration flow event, but none of the event induce downstream hazard. The system only reports the event but no false warning is issued.

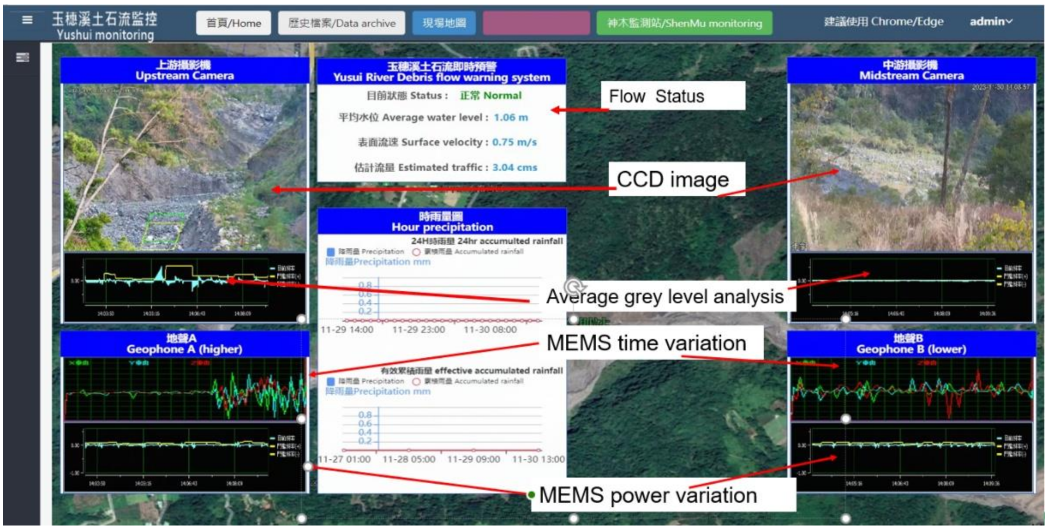

Fig. 1. Yu-Shui monitoring station instant information display

Conclusion

An automatic monitoring and warning system are developed in Taiwan. The system uses geophone to detect arrival of debris flow and estimates the flow rate. CCD is used for detection of debris flow, flow velocity and flow depth. All information is obtained and analyzed automatically. Once debris flow is detected, warning is sent out through different channel including broadcasting, machine control, messaging to people in charge and people in affected area.

Acknowledgement

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