Rock and Debris Fall Detection Using Total Gray Level Method

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Abstract: This study investigates the application of the total gray level method for identifying rock and debris falls through video analysis, offering a viable alternative to resource-heavy machine learning techniques. The method focuses on variations in total grayscale intensity within a specified Region of Interest (ROI) and establishes a detection threshold informed by environmental noise levels. Initial tests showed that this approach effectively detected ongoing rock and debris falls while requiring minimal computational resources. The findings indicated that while a threshold set at twice the noise level was too sensitive, increasing it to five times the noise level considerably enhanced accuracy.

Keywords: ***Debris fall detection, Early warning, Image analysis, Rockfall detection, Total gray level.***

Introduction

Rock and Debris fall are a common natural disaster that can cause significant damage to property, infrastructure, and human life. Monitoring of this event involves the continuous and systematic observation of landslide activity, including its movement, deformation, and other associated phenomena. Along with ground-based sensors and satellite monitoring, use of image analysis from video recordings is one of the important methods for monitoring landslides and slope land disasters (Liu, Kuo, & Wei, 2021) and (Noël et al., 2022). These monitoring data can help identify potential risks, assess the magnitude of rock and debris fall hazards, and inform decision-making processes for disaster management. With accurate and reliable monitoring, early warning systems can be established to notify communities and authorities in advance of potential landslide events, reducing the risk of loss of life and damage to infrastructure.

In today's world of machine learning which consumes high computational resources (Pham & Kim, 2022), simple image analysis methods which doesn't consume as much computational power can be a very important tool for detecting landslides (Liu et al., 2021). Using total gray level method, which calculates and compares the change in total gray level intensity of an image for detection, can be one of the effective methods.

Methodology

To analyze the movement of rock or debris particles in the video recording, a tracking block (Region of interest, ROI) is selected to limit the analyzing area. The total gray level $G_f(t_N)$ and the slope of gray level $S(t_N) = G_f{}'(t_N)$ in the ROI was calculated as an indicator.

For the detection of the event, noise is defined as the moving average of the gray level, while the slope of the noise represents the moving average of this gray level slope for a duration of an order larger than detection time threshold to smooth out the statistically insignificant peak events. The detection criteria hinge on two primary conditions:

First, the change in gray level must exceed a threshold

$$\mathit{Gray\ Level\ Change} > \alpha \times \mathit{Noise\ of\ Gray\ Level\ for\ } \Delta t_d$$

Second, the slope of the gray level change must also surpass a defined threshold

$$\mathit{Slope} > \beta \times \mathit{Slope\ of\ Noise, Positive\ for\ } \Delta t_d$$

Where, α and β are sensitivity factors which is greater than an order of magnitude larger than average noise and are based on the physical characteristics of the site and failure mechanisms including speed, size and type of potential failure. Δt_d is the time threshold for detection which is based on the smallest resolvable particle. To ensure accurate detection of landslide events, the parameters α, β and Δt_d should be determined in advance based on the specific conditions of the monitoring environment.

Results

This method was evaluated through both an experimental setup (Figure 1) and a real-world scenario (**Error! Reference source not found.**) using monitoring video footage of a landslide in Xindian, Taiwan. Preliminary tests of the Total Gray Level Method demonstrated success in detecting ongoing rock and debris falls with a stationary camera, even at low frame rates. The application of double threshold criteria allowed for the detection of fast-moving rock particles while effectively ignoring slower-moving particles that posed minimal risk to roads, resulting in a reduction of false positives compared to a single threshold approach. The detection time for this method was 0.03 seconds earlier in the experimental setup and 3.7 seconds earlier in the real-world scenario than visual detection.

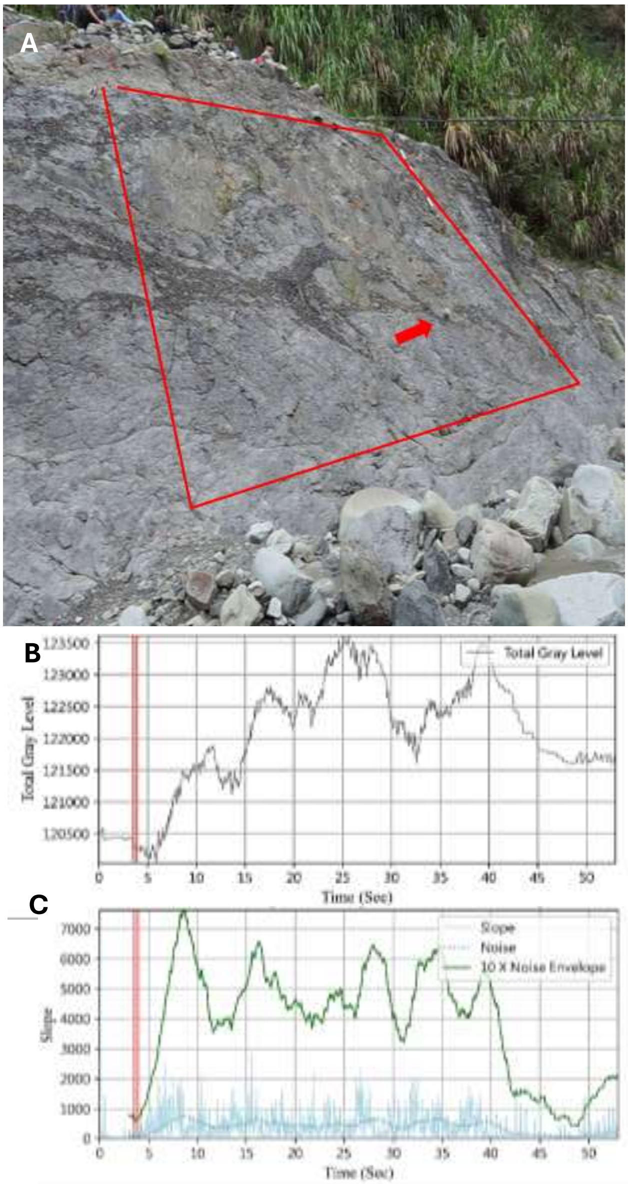

*Figure 1: Experimental setup for total gray scale method. **A**: experimental slope with ROI marked with red boundary and red arrow showing the detected rock from the program. **B**: the change of gray level for the selected ROI and **C**: is the change of slope for the selected ROI, blue markings show the change in slope, with blue line showing the noise level, the green line is the detection envelope. The red region in B and C shows the detection time.*

Conclusion

Use of traditional image analysis techniques such as total gray level method can be a low-cost and effective approach for detecting landslides. Using total gray level method can successfully detect ongoing landslides, even in low light conditions and low frame rate. Future work should focus on developing an algorithm to also determine the end of events, enabling the characterization of multiple events and their durations.

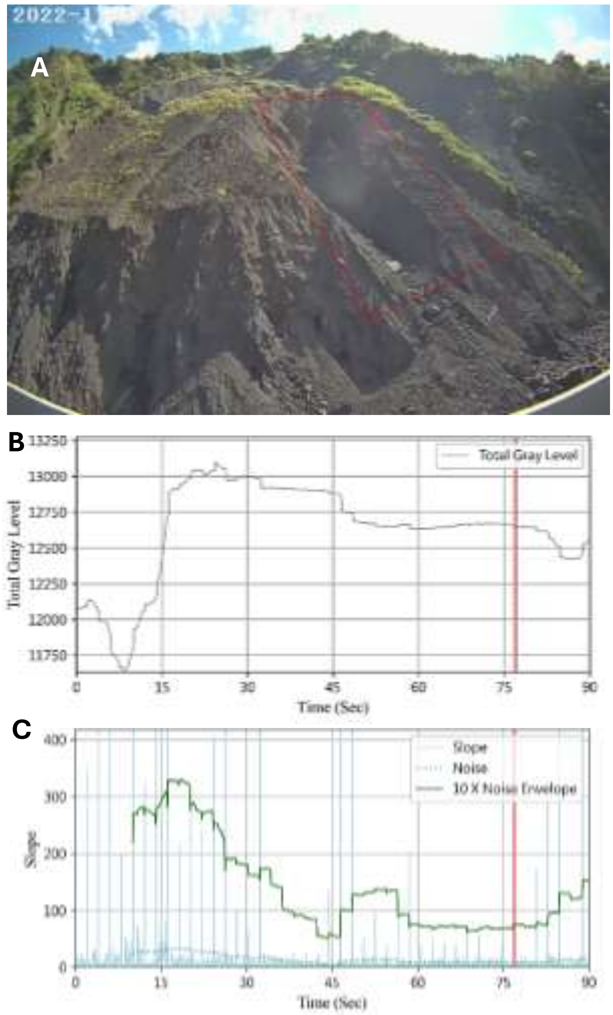

*Figure 2: Real-world monitoring at Xindian, Taiwan for total gray scale method. **A**: slope with ROI marked with red boundary. **B**: the change of gray level for the selected ROI and **C**: is the change of slope for the selected ROI, blue markings show the change in slope, with blue line showing the noise level, the green line is the detection envelope. The red region in B and C shows the detection time.*

References

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