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Computer vision monitoring and detection for landslides

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Abstract. There have been a few checking frameworks intended to ensure and improve the nature of their regular habitat. The greater part of these frameworks are constrained in their capacities. In this paper, the insightful checking framework intended for debacle help and administrations has been exhibited. The ideal administrations, necessities and coming about plan proposition have been indicated. This has prompted a framework that depends fundamentally on ecological examination so as to offer consideration and security administrations to give the self-governance of indigenous habitats. In this sense, ecological acknowledgment is considered, where, in light of past work, novel commitments have been made to help include based and PC vision situations. This epic PC vision procedure utilized as notice framework for avalanche identification depends on changes in the normal landscape. The multi-criteria basic leadership strategy is used to incorporate slope data and the level of variety of the highlights. The reproduction consequences of highlight point discovery are shown in highlight guide coordinating toward discover steady and coordinating component focuses and effectively identified utilizing these two systems, by examining the variety in the distinguished highlights and the element coordinating.

Keywords: landslide; natural disaster; feature based; computer vision; natural disasters detection; event warning system

1. Introduction

In the course of recent years, worldwide environmental change has been increasingly extraordinary. This has prompted an expansion in the rate of event and intensifying in the outcomes in an assortment of cataclysmic events, for example, seismic tremors, tidal waves, and avalanches achieved by extreme tempests. Catastrophic events cause sway society, making harm foundation annihilating structures and harvests, prompting immense financial misfortunes and even human losses. Van Aalst (2006) has depicted the variables that impact atmosphere changes and the connection between environmental change and outrageous climate marvels. Such information can be utilized to diminish the danger of cataclysmic events. It is especially essential for creating nations to create and apply procedures for the counteractive action and alleviation of the impacts of cataclysmic events (Alcántara-Ayala 2002). By and large, the requirement for the

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fiasco hazard evaluation, catastrophe location and contriving debacle cautioning frameworks has turned out to be progressively essential as of late. There have been a few ongoing works exploring the procedure of hazard evaluation, examining the sorts of harm that can be brought about by cataclysmic events and proposing diverse kinds of the models to survey the harm (see for example, Douglas (2007), Erdik *et al*. (2003), Lin *et al*. (2013a), Lin *et al*. (2013b), Jaffe and Gelfenbaum (2002), Lugeri *et al*. (2010), Huynh *et al*. (2017), Yu *et al*. (2018), and Markus *et al*. (2010). Other studies have focused on the natural disaster detection and the construction of warning systems (Wu and Teng 2002). Numerous strategies have been utilized to examine the conditions that lead to the event of avalanches, the degree of the harm they can cause and the parts that make up the avalanches. In contrast to the conventional strategies, in this investigation, we built up a flotsam and jetsam cautioning framework which utilizes the component based PC vision method. The component based technique with is qualities of repeatability, uniqueness and strength can conquer provokes, for example, changes in enlightenment to discover stable element focuses, for example, the corners and edges of items. The adequacy of this strategy is checked in reproductions dependent on data about genuine avalanches caught by various gadgets. An avalanche occasion cautioning framework is additionally proposed. The remainder of this paper is sorted out as pursues. To begin with, the related works in the writing are talked about, trailed by an exchange of the engineering of the proposed framework and its modules. Next, the avalanches identification strategy is utilized with genuine case models and the practicality of the avalanche occasion cautioning framework is illustrated. Last, we present our decisions and potential outcomes for future works.

2. Related works

Cataclysmic events can be arranged into four classifications dependent on sort: topographical, climatic, natural, and cosmic. In Taiwan, the most every now and again happening cataclysmic events are quakes, tidal waves, and avalanches which are delegated land and atmosphere calamities. Various investigations of seismic tremors have been completed in the course of the most recent couple of decades. Nakamura (1988) constructed the UrEDAS earthquake warning system which includes two steps: the fast cautioning and the precise cautioning. The brisk cautioning is given after landing of the P waves and the precise cautioning is given after entry of the S waves. Allen and Kanamori (2003) proposed a quake caution framework (ElarmS) which utilizes the recurrence of the arriving P-waves to decide the extent of the tremor, using this data to caution of harming ground movement. Wu and Zhao (2006) evaluated the extent of a tremor for early cautioning by utilizing the P-wave adequacy. Then again, Nakamura (1988), Allen and Kanamori (2003), Wu and Zhao (2006) utilized remotely detected satellite remote information to distinguish the harm brought about by tremors. They found that the procedure of harm order can be altogether improved by consolidating optical information and some SAR highlights. Others researched tidal waves, and discovered intriguing outcomes. For instance, Okal *et al*. (1999) used altimetry caught by satellites to pass judgment on the seriousness of a wave. They talked about seven cases, with just two being effective on account of the impact of Kuroshio Greidanus *et al.* (2005) utilized medium (25 meter) goals satellite radar symbolism to recognize harm from torrents. Their methodology is valuable to distinguish the beach front harm. In different examinations identified with avalanches, Arattano and Marchi (2008) assembled an avalanche observing and cautioning framework that incorporates a guidance ahead of time framework and occasion cautioning framework with a ultrasonic sensor arrange. Jin and Xu (2011) utilized high recurrence radar to recognize water content underneath the ground surface which can trigger an avalanche and Ellingwood (2001) performed ordinary checking and appraisal of avalanches by utilizing the FORMOSAT-2 and HJ-1-B (Environment and Disaster Monitoring Constellation 1) satellites, individually. Remote sensors are another sort of gadget which can be utilized to identify the catastrophic events. Lee *et al*. (2010) also used wireless sensors including the COORDINATOR sensor and the INSIDER sensor. The INSIDER sensor is used to collect data on landslides and the COORDINATOR sensor is the receiver which receives the information from the INSIDER sensor. Lin *et al.* (2013a) utilized a double camera to build a wide-edge, high-goals checking framework, which could watch itemized data. A few strategies have been proposed to address the issue of the cataclysmic events recognition and to develop a notice framework for the catastrophic events. Distinctive kinds of debacles can be recognized by utilizing a similar gadget. For instance, it is undisputed that high-goals satellite symbolism can be utilized to survey harm and furthermore can be utilized to identify tremors. Be that as it may, there has been an absence of mix. Consequently, we propose a novel PC vision method which is highlight based that can be utilized for the location of catastrophic events and accept an avalanche for instance.

3. System architecture

The proposed framework plans to distinguish avalanches and caution of the peril. So as to build an occasion cautioning framework, a few imperative assignments must be considered. The proposed framework incorporates three principle specialized segments: the foundation module, the observing module, and the occasion cautioning framework. To start with, we decide the steady element focuses for the foundation module by utilizing the element discovery technique. In this technique, a grouping of scenes from before the event of avalanche is utilized to locate the steady component focuses which are joined for the foundation module. Next, the observing module is created by utilizing the component point identification strategy and highlight point coordinating technique. The component point location technique is utilized to discover the element focuses om the present scene, and the element point coordinating strategy is utilized to coordinate element focuses between the foundation module and the present scene. The quantity of recognized and coordinated element focuses show extreme variances. At long last, we incorporate the data from the checking module to develop the occasion cautioning framework.

4. Background module

The background module aims to build stable feature points for the monitored scene before the occurrence of a landslide which can then be used to detect the variation in the environment. In this study, we used the SURF (Speeded up Robust Features) mechanism designed by Bay *et al.* (2006) to detect the feature points in the background and monitoring modules. This mechanism has the advantages characteristic of SURF which are repeatability, distinctiveness and robustness. In the SURF mechanism, the Hessian matrix is used for feature detection and is scaled to achieve the characteristic of scale invariance as shown in the following equation

$$H(I,\sigma) = \begin{bmatrix} L_{xx} & L_{xy} \\ L_{xy} & L_{yy} \end{bmatrix} \quad (1)$$

where I=(x,y) is the image, σ is the scale which is the standard Gaussian deviation, and $L_{xx}(x,\sigma)$ is the Gaussian second order derivative at point x. The expression of $L_{xx}(x,\sigma)$ is shown as follows

$$L_{xx}(I,\sigma) = G(\sigma) * I(x,y) \quad (2)$$

where $G(\sigma)$ is a Gaussian kernel function and $g(\sigma)$ is a Gaussian distribution function. The other symbols, $L_{xx}(I,\sigma)$ and $L_{yy}(I,\sigma)$, are similar to $L_{xx}(x,\sigma)$. The interesting features are selected from an image and are scaled according to the determinant of the Hessian matrix as shown in the following equation

$$\det(H) = L_{xx}L_{yy} - (L_{xy})^2 \quad (3)$$

Bay *et al.* (2006) used the difference of Gaussian (DoG) to approximate the Laplacian of the Gaussian (LoG) and this is used with the integral images to reduce the computational cost. Therefore, the determinant of the Hessian matrix can be rewritten by using the following equation

$$\det(H_{approx}) = D_{xx}D_{yy} - (\omega D_{xy})^2 \quad (4)$$

where ω is a parameter used to verify the errors cause by the DoG which is used to approximate LoG. Each feature is described as a vector of 64 dimensions including the orientation assignment and the descriptor components. Finally, the robust feature points are detected from the different scales of the image.

5. Monitoring module

When the foundation module is manufactured, we start to screen nature with the checking module. There are two phases to developing the checking module: highlight point discovery and highlight point coordinating. In highlight point identification, we utilize the SURF instrument portrayed above to recognize the highlights from the scene. In the component point coordinating stage, we locate the coordinating element focuses between the aftereffects of highlight point identification and the foundation module by utilizing the nearest neighbour search method. The coordinating procedure can be tedious, in this manner, the hint of the Hessian framework is used to diminish the computational time. For an increasingly itemized depiction of the approaches including "highlight point location" and "highlight point coordinating" if you don't mind allude to our past examination Lin *et al*. (2013b).

6. Landslide detection

The physical condition is developed of a wide range of sorts of highlights, both characteristic (trees, mountains, water) and artificial. The highlights in the characteristic landscape change in light of changes in the landforms brought about by the cataclysmic events. Lately, the events of avalanches have expanded as a result of the disregard of soil and water preservation and the event of increasingly extraordinary climatic changes and this has made outrageous harm the earth. The achievability of the proposed technique which joins highlight point discovery and highlight point coordinating for the recognition of avalanches is talked about. Two sorts of static pictures are breaking down, the satellite and observation pictures caught by satellites and reconnaissance cameras. In the pictures beneath, the identified highlights are prosecuted by hued circles, and the coordinated highlights are associated with straight hued lines. The satellite pictures show genuine instances of avalanches that happened in Taiwan. It tends to be seen that pieces of the mountainside, waterway, and the neighbouring territory have been devastated with extraordinary variety in the element focuses due to the avalanches. The coordinated element focuses between the when the avalanche can be figured utilizing the "include point coordinating" method. At the point when an avalanche happens, the territory is modified and includes in the view are changed. The element point coordinating strategy is utilized to discover stable highlights which exist both when the avalanches. The straight hued lines demonstrate stable component focuses which exist when the avalanche. There is a conspicuous decline in the quantity of coordinated element focuses on the grounds that the territory has been essentially adjusted and includes are obliterated.

As part of efforts to prevent terror attacks, different kinds of cameras, including fixed cameras and pan-tilt-zoom (PTZ) cameras, have been erected to monitor abnormal events. We utilize the existing camera devices to monitor landslides.

From the above examinations plainly variety in the quantity of identified and coordinated component focuses can be effectively used to pinpoint avalanches. At the point when an avalanche happens, the quantity of distinguished and coordinated component focuses will change. The two procedures are used to pass judgment on the extent and area of the avalanches.

7. Landslide warning system

We use the wonders of clear holes and changes in the quantity of distinguished and coordinated component focuses when the avalanche to build an occasion cautioning framework. Nonetheless, since it would be exceptionally hard to build a genuine full-scale trial condition in reality, 3D PC designs programming is used to develop a reenactment situation of the Hua-Shan region and the Fong-Ciou zone in Taiwan for examination of avalanches. An avalanche occasion cautioning framework is built utilizing the component based technique in the reproduction condition to demonstrate the practicality of the proposed strategy. There is an assortment of understood 3D PC illustrations programming, for example, 3DS MAX and MAYA which can be utilized to develop a reenacted domain for the displaying of catastrophic events. The easy to use interface given by the current 3D PC designs programming can assist software engineers with creating programs simpler and quicker. In the following segment, we talk about the aftereffects of highlight point discovery and highlight point coordinating for these two zones, including three cases, one for the Hua-Shan territory and two viewpoints for the Fong-Ciou region.

Simulation environments are constructed for simulation of landslides using 3D computer graphics software. The technique of feature-point detection is used to detect stable features in the observed views and detected feature points which are represented as colored circles.

The results of the feature-point matching are shown in Fig. 1. Figs. 1(a), 1(c) and 1(e) show the results of feature-point matching before the landslides, and Figs. 1(b), 1(d) and 1(f) show the results after the landslides. The stable features are matched between background module and current frame in this procedure, and the colored lines connect the stable features between the two images.

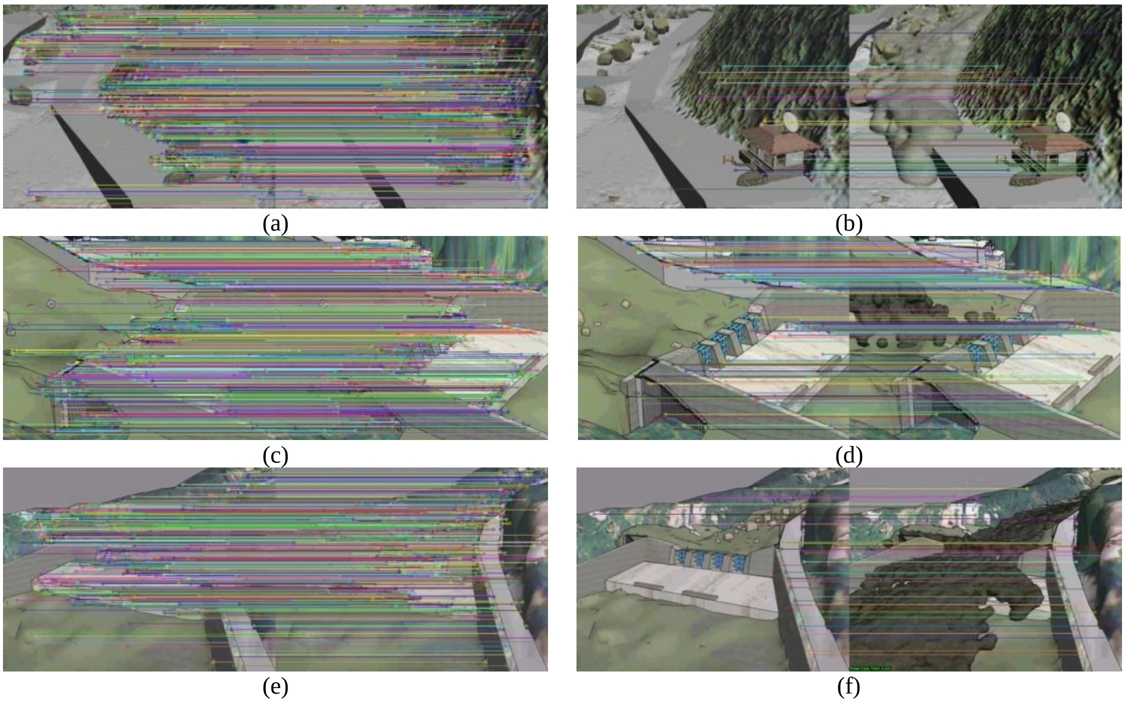

Fig. 1 The results of feature-point matching in the simulation environment.

When landslides happen, the original features disappear and new features are created, which causes the sudden decrease in the number of matched features. The statistical results for Fig. 1 are shown in Fig. 2(b). As seen in this figure, there is a clear gap between before and after the landslide. The results of feature-point detection and feature-point matching produced in the simulation environments conform to the results obtained in the real cases described in section 6.

We incorporate "highlight point recognition" and "highlight point coordinating" to build an avalanche occasion cautioning framework. So as to build the exactness of the avalanche cautioning framework, we propose utilizing a multi-criteria choice framework that incorporates slope data and the variety of the level of highlight focuses. For every rule, three reproduced cases are utilized, one for the Hua-Shan territory and two points of view for the Fong-Ciou territories, to demonstrate the attainability of the proposed framework.

In the case of the Hua-Shan area, the number of detected feature points and the number of matched feature points are recorded, as shown in Fig. 3. Figs. 3(a) and 3(b) show the original detected features and the original matched features, respectively.

Figs. 3(a) and 3(b) show rapid changes as indicated by the green lines that identify that a landslide is beginning to occur. However, using only the number of detected or matched features may cause a false alarm. Therefore, we integrate the results of “feature-point detection” and “feature-point matching” to create a landslide event warning system that also uses gradient information, as shown in Fig. 3(c).

In order to easily observe sudden changes of gradient in Figs. 3(a) and 3(b), the scale of these two figures is adjusted by using the log function and integrate to produce Fig. 3(d). The green line indicates a sudden change in the number of detected and matched feature points which can assist

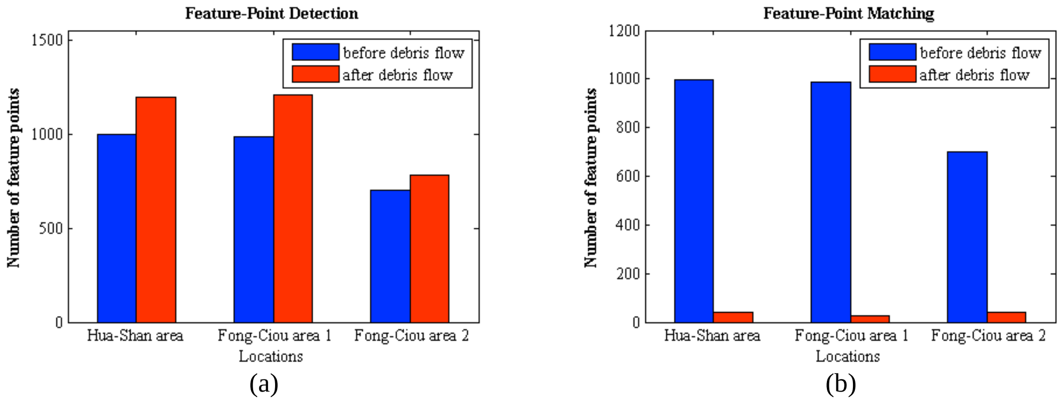

Fig. 2 The statistical chart for the simulation environment: (a) number of detected feature points; (b) number of matched features points

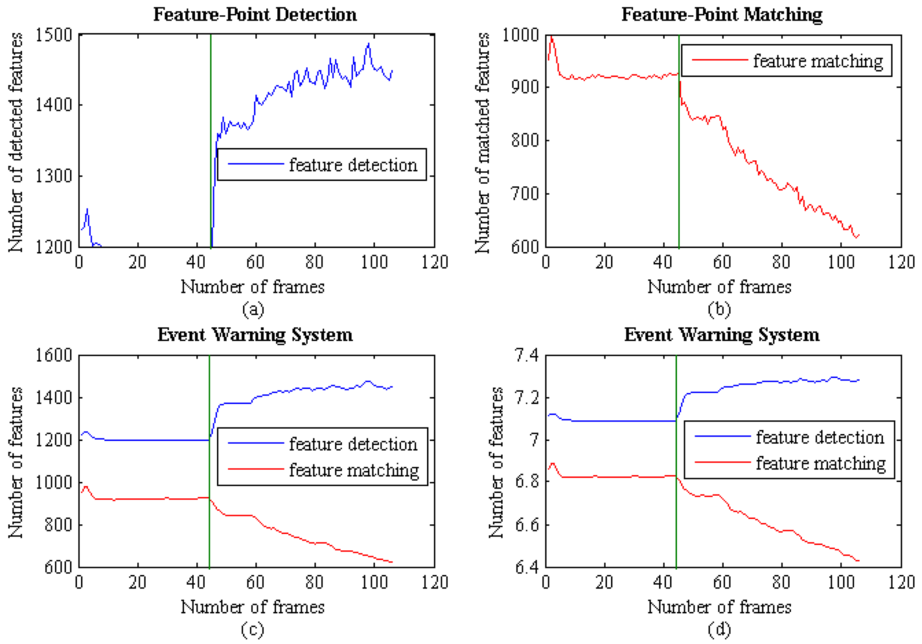

Fig. 3 The duration of the features in the debris flow sequence: (a) the number of detected features without smoothing, (b) the number of matched features without smoothing, (c) the combination of feature detection and feature matching with smoothing for the Hua-Shan area and (d) the combination of feature detection and feature matching with scaling using the log function for the Hua-Shan area

in detecting the occurrence of landslides. In this case, the fluctuation in the number of matched feature points is larger than the detected features. The results are combined to form one of the criteria for decisions in a landslide event warning system.

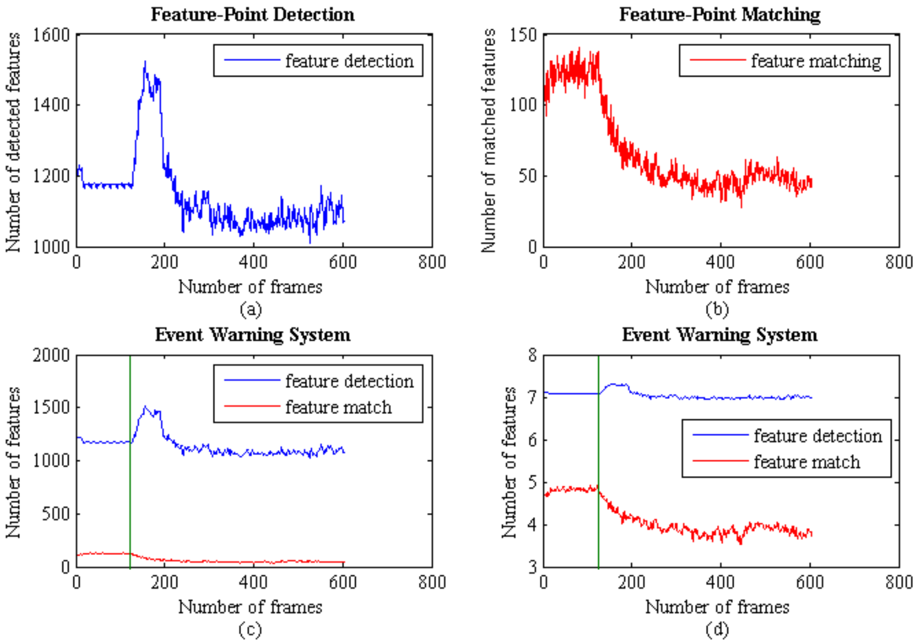

Fig. 4 The duration of features of debris flow sequence (a) the number of detected features without smooth, (b) the number of matched features without smooth, (c) the combination of feature detection and feature matching with smoothing in Fong-Ciou area with perspective 1 and (d) the combination of feature detection and feature matching with scaling using log function in Fong-Ciou area with perspective 1

In the last case, the simulation with the two perspectives of the Fong-Ciou area prove the feasibility of the landslide event warning system. Figs. 4(a) and 4(b) are the same of indicate the landslide event, while Fig 4(d) shows the results after log function scaling. The phenomena of the sudden changes of gradient in the number of detected and matched features reflect the occurrence of a landslide.

In the background module procedure, the average number of detected features and the average number of matched features is evaluated at the same time. The percentage of variation in the features for both feature detection and feature matching is calculated as follows

$$p_{fd_i} = \frac{N_{fd_i}}{Avg_{fd}} \quad \text{and} \quad p_{fm_i} = \frac{N_{fm_i}}{Avg_{fm}} \tag{5}$$

where p_{fd_i} and p_{fm_i} are the percentage of variation of features in feature detection and feature matching at time i, respectively; N_{fd_i} and N_{fm_i} are the number of detected feature points and matched feature points, respectively; and Avg_{fd} and Avg_{fm} are the average number of detected features and matched features, respectively, calculated in the background module procedure.

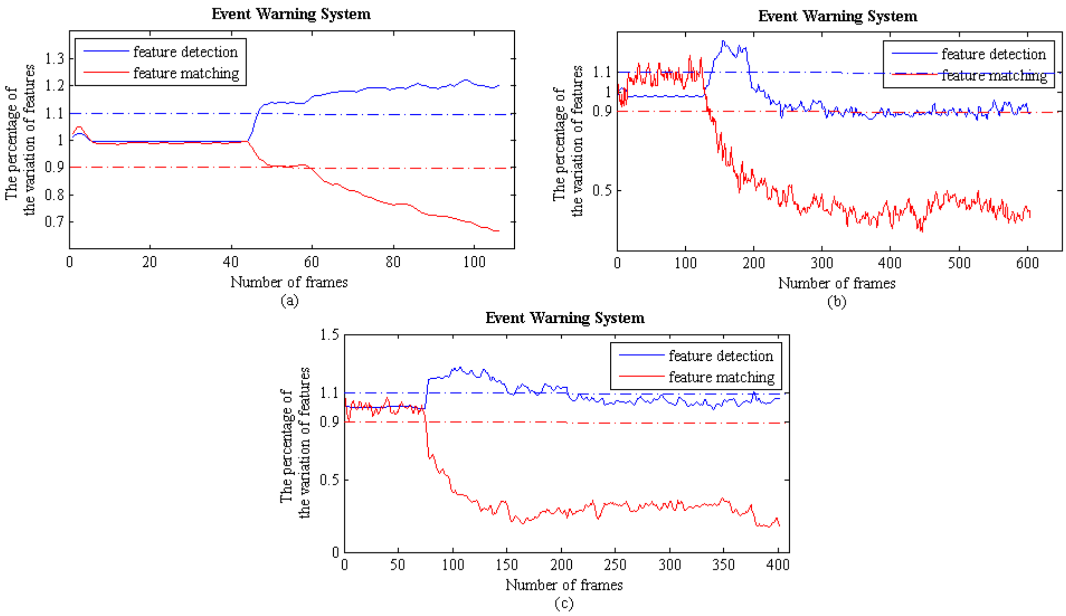

Fig. 5 The percentage of the variation of feature points for: (a) the Hua-Shan area, (b) the Fong-Ciou area, perspective 1 and (c) the Fong-Ciou area, perspective 2

The results of the percentage of variation of feature points are shown in Fig. 5. Figs. 5(a)-5(c) show the results for the Hua-Shan area, and Fong-Ciou area, perspective 1 and perspective 2. The red dashed line indicates the threshold of feature matching and the blue dashed line indicates the threshold of feature matching. In the experiments, the thresholds for feature matching and feature detection are set to be 0.9 and 1.1, respectively.

The landslide event warning system will be triggered if two conditions are satisfied at the same time: a rapid change of gradient and a rapid change in the percentage of variation of feature points within a short period of time.

8. Conclusions

In this examination, we used an element based PC vision method to identify the degree of avalanches and to develop an occasion cautioning framework. The proposed procedure is involved two modules: a foundation module and a checking module. Out of sight module, the steady element focuses are gained from a grouping of scenes utilizing highlight point identification and the normal number of highlight focuses for highlight recognition and highlight coordinating are recognized. The component point recognition process is utilized to distinguish the highlights from the watched view by utilizing an element based technique. In checking module, both component point discovery and highlight point coordinating are utilized. The consequences of highlight point identification are utilized in highlight direct coordinating toward discover steady and coordinating component focuses by examination between the foundation module and the present scene.

Avalanches are distinguished from the contrast between the highlights identified and coordinated when the event of a cataclysmic event. A structure for developing an avalanche occasion cautioning framework is recommended that incorporates slope data and the level of variety in the highlights. The foundation module and the checking module are consolidated, and the variety in the quantity of recognized and coordinated highlights watched. The viability of the recognition and cautioning framework is tried utilizing 3D PC designs programming to reproduce an avalanche for instance. The consequences of the avalanche recognition in the reenactment condition compare to the outcomes utilizing genuine cases, and the occasion cautioning framework is activated when an avalanche happens. The present framework uses pictures caught amid the day. Later on, we will think about the impacts of light and other climate conditions and apply the element based strategy to different sorts of basic harm investigation, for example, to structures and scaffolds.

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