Journal of Volcanology and Geothermal Research 190 (2010) 379–384

Contents lists available at ScienceDirect

Journal of Volcanology and Geothermal Research

journal homepage: www.elsevier.com/locate/jvolgeores

Short Communication

Automated block detection in lahars through 3-bands spectral analysis of video images

C. Gomez [a,b,*,1], F. Lavigne [b]

[a] Université Paris 7 Denis Diderot, Laboratoire PRODIG CNRS UMR 8586, Paris, France
[b] Université Paris 1 Panthéon Sorbonne, Laboratoire de Géographie Physique CNRS UMR 8591, Meudon, France

ARTICLE INFO

Article history:
Received 17 April 2009
Accepted 4 November 2009
Available online 17 November 2009

Keywords:
lahar
Semeru Volcano
block
automated detection
pattern recognition
warning system
machine vision

ABSTRACT

Lahars present a particular problem for automated block detection using machine vision, because their patterns and apparent sizes and shapes vary with the flow. To address this difficulty, we developed a simple algorithm to detect blocks in lahars at Semeru Volcano based on traditional RGB (Red Green Blue) 25 frame-per-second videos. The detection algorithm is based on the combination of two methods: (1) a determination of blocks by color segregation, and (2) objects movements' detection. After image processing, we converted the data into a signal that emphasizes the presence of large blocks. Results compare very well with video-images, since 100% of peaks of amplitude >300 corresponded to large blocks traveling down the channel.
This method ultimately aims at contributing to lahars automatic detection systems, where little funding is available, since it only requires a traditional camera and a computer.

1. Introduction

A lahar is a sediment-laden flow traveling from a volcano (Smith and Fritz, 1989). Such flows comprise a continuum from debris flows (sediment concentration >60 vol.%) to hyperconcentrated flows (sediment concentration between 20% and 60%) (Pierson and Costa, 1987). They are some of the most destructive phenomena associated with composite volcanoes: in 1985, a lahar from Nevado del Ruiz Volcano (Colombia) wiped the city of Armero from the map, killing 23,000 (Pierson, 1990; Voight, 1990a,b). Lahars are also common events, especially in humid climate zones like in Indonesia, occurring annually at Merapi Volcano (Lavigne and Thouret, 2003; Lavigne et al., 2000a; Thouret et al., 2000) or Semeru Volcano causing thousands of casualties during the 20th century alone (Thouret et al., 2007).

Volcanic risks are the product of interactions between natural hazards and human presence (Lavigne et al., 2008), thus mitigation can either act upon hazards or the human factor, with the development of warning systems being an example of the latter (e.g. Leonard et al., 2008). Traditional non-contact detection systems on volcanoes usually rely on seismic – RSAM and SSAM – (e.g. Okuda et al., 1979; Arattano, 1999) and/or acoustic technology – AFM – (e.g. Hadley and Lahussen, 1995; Itakura et al., 1997, 2000; Lahusen, 1996; Marcial et al., 1996; Zhang, 1993; Zobin et al., 2009).

Within lahars, blocks play a major destructive role on structures like bridges for example, due to dynamic impact forces (e.g. McArdell et al., 2007). Therefore, one of the aspects of a tunable lahar warning system could include block detection. In this paper, we discuss automated block detection inside lahars based on the analysis of RGB video images, in order to eventually complete present warning systems.

Objects detection and recognition from still and video images is a widely developed field of research that encompasses applications from intelligent vision for car-like vehicles (e.g. Chen and Feng, 2009) to biomedical and food engineering (e.g. Qin et al., 2009). Imaging techniques can be improved by the fusion of different sources, such as thermal and visible images (e.g. Bulanon et al., 2009) or hyperspectral analysis (Okamoto and Lee, 2009). The two main recognition techniques are concerned with patterns (e.g. Maldonado and Grana, 2009) and/or shapes (e.g. Yang and Sarkar, 2009).

2. Materials and methods

We conducted this study using a 10 minute long video recording (a total of 15,000 images at 25 fr s^{-1}) of the March 19th, 2007 lahar in Curah Lengkong valley at Semeru Volcano, Indonesia. The camera is located 9.5 km to the southeast of the summit, on a lahar terrace about 10 m above the bottom of the valley (Fig. 1: camera location and image).

Block detection and recognition in lahars are complex, because their shapes, sizes and patterns vary on each image, depending on their position in the flow. Therefore we combined two techniques, (1)

* Corresponding author.
E-mail address: christophergomez1101@yahoo.com (C. Gomez).
[1] Present address: Ecole Normale Superieure - Dept. LSH, CNRS UMR 5600 15, parvis René Descartes, BP 7000, 69342 Lyon Cedex 07, France.

0377-0273/$ – see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.jvolgeores.2009.11.005

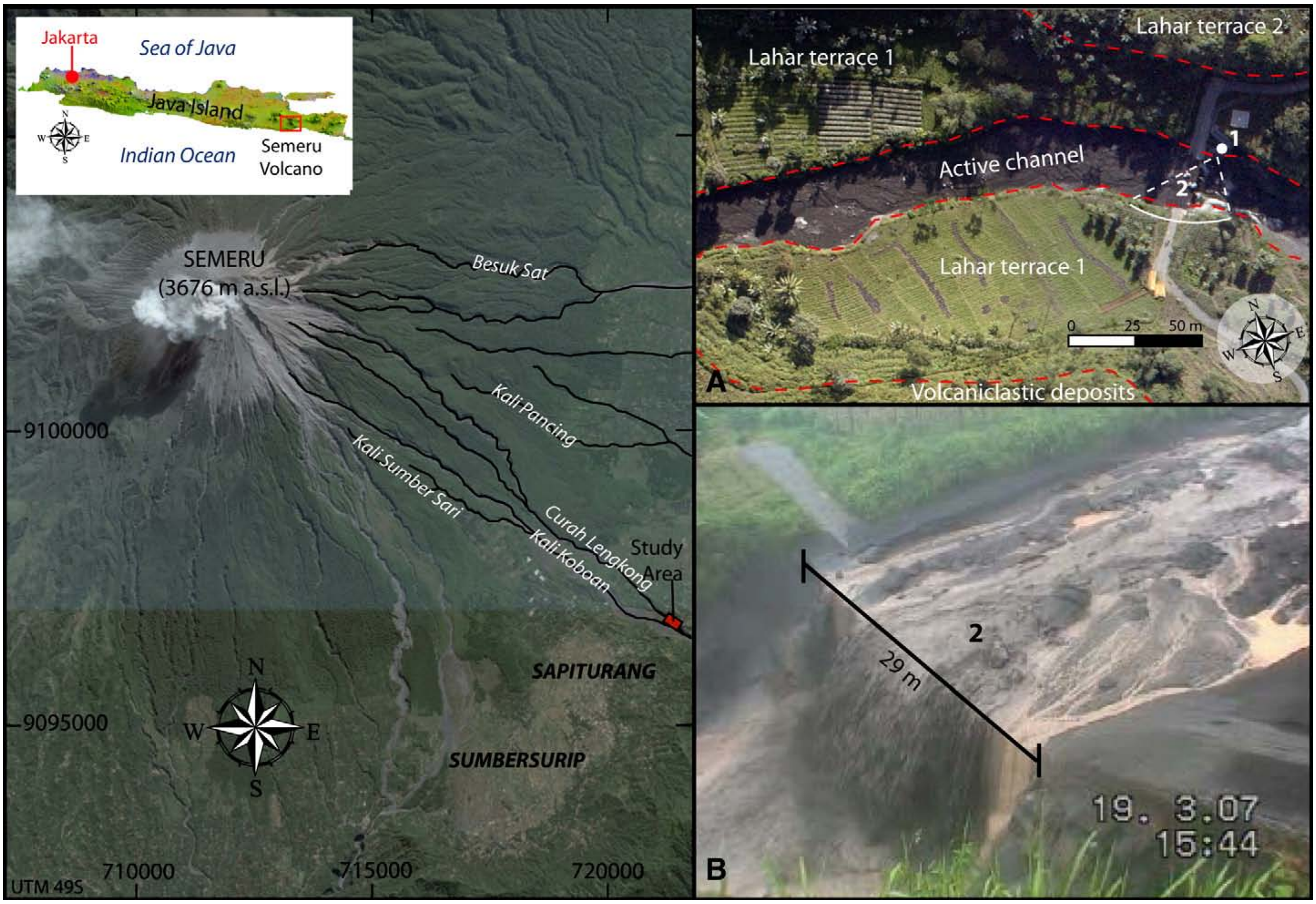

Fig. 1. Location of the study area, at Semeru Volcano. A: Aerial photograph (2008) of the study area in Lengkong Valley, showing locations (1) and (2) that were captured by a mobile camera for this research. B: Field of view captured by a mobile tripod-mounted camera. The "2" is given for correspondence between images A and B.

determining what was "not block", in order to eliminate it, and (2) comparing data from successive frames in order to identify moving objects.

2.1. Algorithm flow

Fig. 2 shows an outline of the algorithm flow that was devised in this study using Matlab®. The algorithm is separated into four parts, i.e. (1) pixel spectral preprocessing; (2) RGB segregation and block recognition by their reflectance; (3) movement recognition; and (4) transformation into a signal and basic processing.

2.2. Image preprocessing

To obtain a standard reflectance of objects, which naturally tend change with variations of luminosity, rainfall intensity, etc., we first performed flat-field corrections on the original images using the following Eq. (1):

$$C(\lambda) = Rs(\lambda) + (R1_{i,j}(\lambda) - Rs_{i,j}(\lambda)). \quad (1)$$

where C is the correction, Rs is the sample image (which is corrected), $R1_{i,j}$ is the first image with i,j as the horizontal and vertical address of pixels used for calibration, λ is the color in Red Green Blue (RGB). After calibrating the reflectance of all video images, we applied a mask to remove noisy background around the channel area, reducing the original image from 320 pixels × 240 pixels × 3 bands (RGB) to a 200 × 100 × 3 working area.

2.3. Filtering: reflectance recognition and movement recognition

Blocks in lahars can be floated by buoyancy, supported by turbulence, vertical segregation, etc. (Lavigne and Thouret, 2002; Vallance and Scott, 1997), so that they often appear irregularly at the surface of the lahar, or partially covered by a thin layer of mixed water with fine materials. Hence, we could not identify blocks on the basis of shape analysis, or pattern recognition:

(1) We therefore chose to recognize blocks using empirically selected reflectance threshold values, progressively corrected by experimentation. In addition to direct recognition we feed the algorithm with reflectance that possibly could not be blocks, removing most of the noise and background. This first filtering step allowed us to recognize blocks but it was not able to distinguish blocks carried by the flow from blocks immobile in the channel.
(2) We therefore introduced a second filter based on movement. This latter is based on changes from one up to 11 video-frames – n, $n+1$, $n+2$,…, $n+10$ – comparing pixels locations we previously recognized as pixels belonging to blocks — so that we can detect potential movement. For graphic purpose we used Matlab to draw moving blocks at n and $n+5$, respectively labeled in blue and red on Fig. 3. It is important to notice that