# Real-Time Thermo Graphic Analysis of Volcanic Eruptions

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***Abstract-*** Video surveillance systems are consolidated techniques for the monitoring of eruptive phenomena in volcanic areas. Along with this systems, which use standard video cameras, sometimes people working on this field make use of infrared cameras providing useful information about the thermal evolution of the eruptions. The surveillance of the Mount Etna volcano in Sicily, Italy, is in charge of the *Istituto Nazionale di Geofisica e di Vulcanologia - Catania site*, and a large amount of monitoring systems are installed along the mountain. Data transmission between these devices and the surveillance sites is a serious task, especially when a large transmission band is required. Moreover, in the case of image storing large memorization capabilities are mandatory. In this paper a new methodology is presented, which aims to improve the performances of surveillance systems in terms of transmission band and storing feature; the proposed methodology is based on the real-time thermo graphic analysis of the monitored area which can provide information on the on going activity and adapt the image transmission rate as well.

## I. Introduction

Video surveillance systems are now widely adopted to monitor the activity of volcanoes [1]. Video systems include standard cameras and infrared cameras [2-3]. Both of these devices furnish useful information on the volcanic activity which are usually processed by experts to manage emergencies. In particular, the use of infrared cameras is due to the influence of environmental conditions on the standard camera performances. The described approach requires the involvement of people monitoring in real-time mode the acquired images and alerting in case of emergency.
A typical video surveillance system is sketched in Figure 1 along with the required hardware for acquiring, processing and sending data to the surveillance site. As concerning the communication between the monitoring station and the surveillance site the image transmission rate represents the most critical parameter to be addressed during the design of the whole monitoring system. Moreover, images transferred to the surveillance site are usually stored to further elaboration and analysis, requiring large storing capability.
In this paper a new methodologies making use of infrared camera and suitable real-time image processing is proposed to overcome drawbacks (real-time people monitoring, high transmission rate and large storing capabilities) of conventional video surveillance systems. The methodologies is based on the thermo graphic analysis of the volcano monitored area. Actually, a deep analysis of the evolution of temperature histogram (hereinafter the color histogram, being temperature mapped into colors by the infrared camera) allows to classify between critical events during an eruptive activity as well as to notify the absence of any meaningful activity. In particular, events of main interest of people working in this field are: absence of eruptive activity, gaseous emission and lava effusion. A real-time classification of such events allows the optimization of the surveillance systems in terms of auto-alerting in case of emergency, event-dependent (adaptive) transmission rate, and as a consequence reduced storing requirements.

## II. An overview of the monitoring system developed

In the following sections an overview of the developed system is given along with experimental evidence of the obtained performances. In particular, the innovative surveillance system has been developed to monitor the activity of the mount Etna located in the southern part of Italy, which is an active volcano giving to people living there dangerous as well as terrific scenario [4].

### A. Description of the experimental set-up

As concerning the hardware tools required to implement the proposed monitoring methodology, the set-up sketched in Figure 1 can be adopted, without increasing the complexity and the effective cost

of the monitoring systems. In particular, the infrared adopted camera is the FLIR 160M device [5] with a focal plane array detector (uncooled microbolometer, 320x240 pixels).
The hardware supporting the communication with the surveillance site and the images transfer can vary on the basis of the operating conditions. Usually RF video transmitter-receiver are used to establish the communication between the monitoring station and the surveillance site PC, the latter performing the image processing (storing, classification, etc.). Sometimes image digitalization and processing is performed in the monitoring site by a PC connected with the cameras and then data are sent to the surveillance site. The acquired images are automatically processed by a dedicated software tool, providing the user with information on the on going status of the volcanic activity and giving alert message in case of emergency. Moreover, the frame rate of the storing process is automatically chosen on the basis of the revealed activity.
The improvement of the system performances as respect to the traditional approach is due to the features of the image processing tool which reduces the need of people monitoring the activity in real-time and optimizes the transmission rate and the storing process performances.

**B. The image processing tool and**

The main tasks performed by the processing tools are: images acquisition, images processing, frame rate setting and frames storages.
The proposed methodologies allowing for obtaining from the acquired frames information about the nature of the eruptive activity is based on the thermal analysis of the acquired images.
In particular, an analysis of the color histogram is performed frame by frame, allowing to classify between critical events during an eruptive activity as well as to notify the absence of any meaningful activity.
The classification algorithm uses threshold levels for a set of color being recognized as tracer of the above phenomenologies. In details, for the chosen color palette, an increase of the occurrences in the color bands 1 and 2 was considered meaningful in the case of a lava effusion event as well as an increase of color bands 3 and 4 is achieved in the case of a gaseous emission. The threshold levels for all the considered color bands was selected by analyzing a large set of reference images acquired in different condition of the eruptive activity. As an example, Figure 2 shows the color histogram in the absence of eruptive activity (on the left) as well as in the case of lava effusion (in the centre) and gaseous emission (on the right).

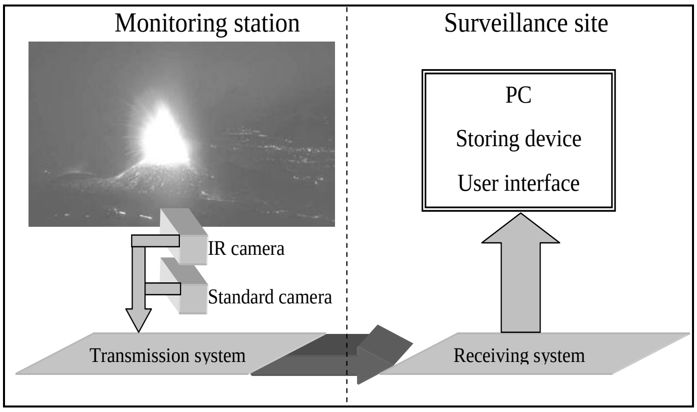

Figure 1. a typical surveillance system

As the event has been classified, the monitoring procedure will set the frame rate for the storing process (how many frames per second must be stored); in particular the choice to store 1 frame/s in case of a gaseous emission and 5 frame/s in the case of a lava emission was performed. At the same time the on going event is notified to the user. In the absence of any meaningful activity a 3 frame/s storing process is activated.

**C. the user interface**
The image processing tool has been developed in the LabVIEW™ environment due to its peculiarity in developing suitable user interface and performing real-time image processing.
Figure 3 is an example of the developed front panel, which shows, on the left-side, color histograms in the absence of activity and for the on going activity, respectively. Moreover, the last acquired frame is shown on the right side of the panel along with information on the classified event.

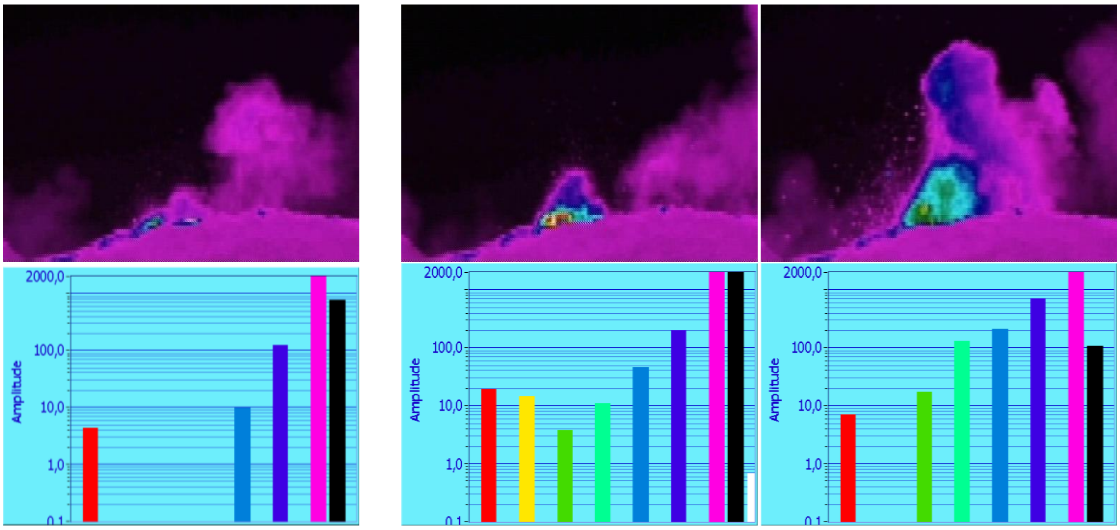


Figure 2. From left to right: a reference image and its color histogram, a typical lava explosion and its histogram where color bands 1 and 2 denotes the event, a typical gaseous emission and its histogram which evidences color bands 3 and 4.

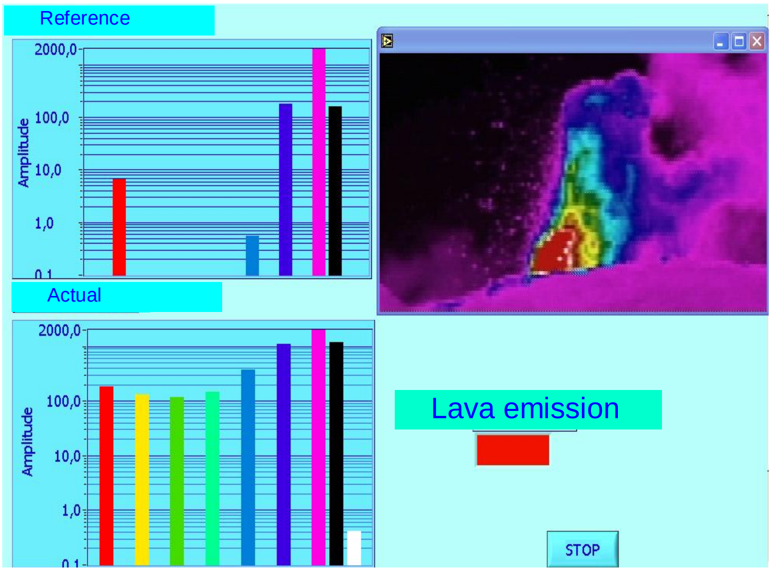


Figure 3. The front panel of the monitoring tool.

**III. Conclusions and results**

Figure 4 illustrate a real sequence recorded on the mount Etna during a lava emission. As it can be observed starting from the first image color histogram reveal the modification of bands 1 and 2 according to the previous considerations. In this case a frame rate of 3 frames/s is automatically set form the monitoring system until the phenomenon persists.

Several trials have been accomplished in order to test the behavior of the developed system and good performances were achieved.

Future developments of the monitoring and processing architecture will regard the implementation of a number of alarm systems aimed to inform experts about anomalous events which can be classified as suspected or alert occurrences.

Moreover, an smart tool aiming to obtain useful parameters characterizing the eruptive phenomena are under development. In particular, such kind of information is strictly necessary to experts for understanding the evolution of eruptive phenomena of a particular volcano and to study the way to assess and manage emergency in volcanic areas.

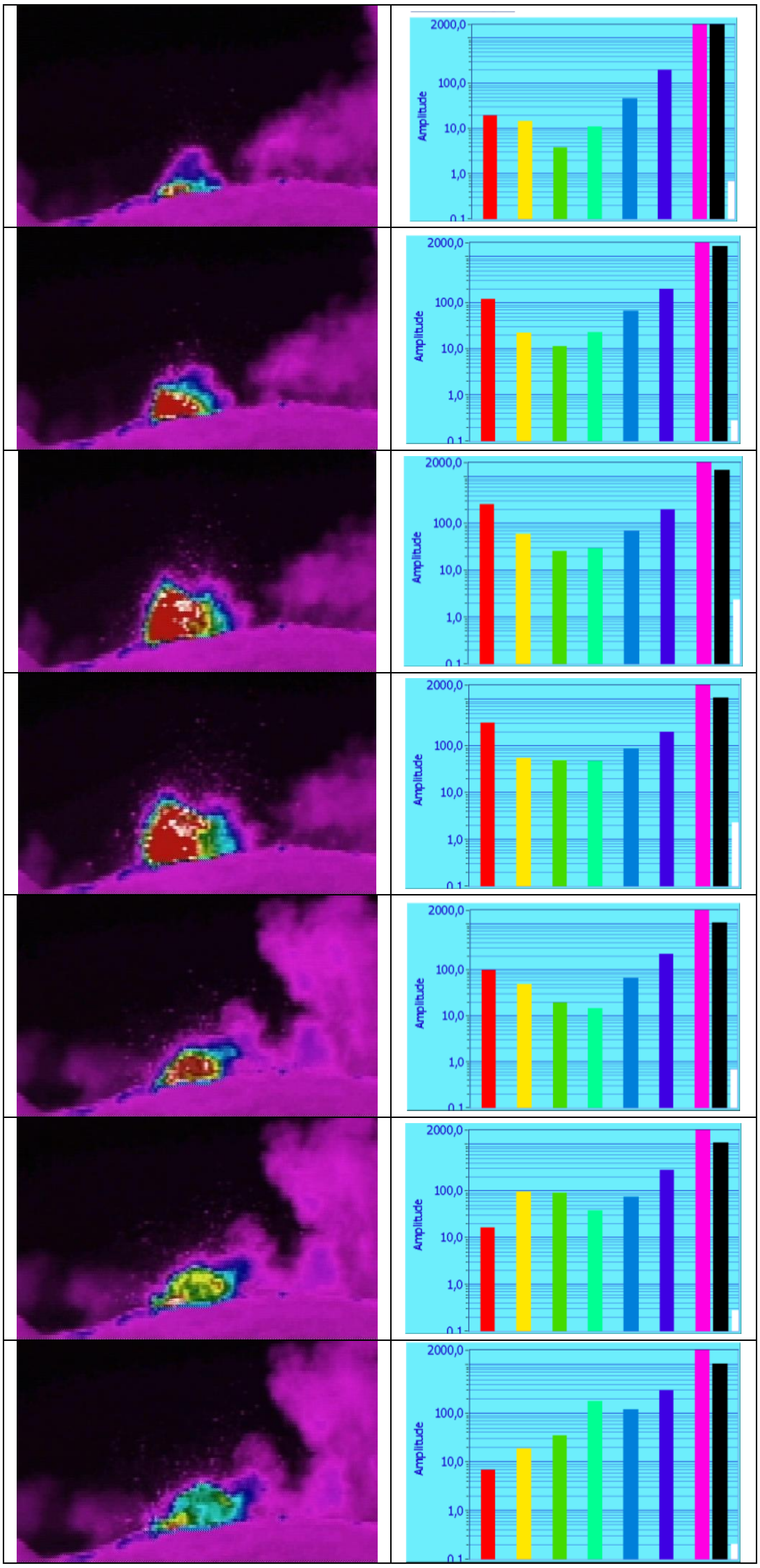


Figure 4. A frame sequence acquired during an eruptive phenomenon in the Mount Etna. As it can be observed the color histogram shows the evolution of color bands 1 and 2 according to the natural evolution of the lava explosion.

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