Technology Conference
Ottawa, Canada, 17-19 May 2005

A Measurement Tool for Investigating the Volcanic Activity

Bruno Andò[1], Emilio Pecora[2]
[1] Dipartimento di Ingegneria Elettrica, Elettronica e dei Sistemi, Università di Catania
Viale A. Doria, 6, 95125 – Catania, +39-095-7382309, bruno.ando@diees.unict.it
[2] Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania
Piazza Roma, 2, 95100 – Catania, +39-095-7165800, pecora@ct.ingv.it

Abstract – *Video surveillance systems are consolidated techniques for monitoring eruptive phenomena in volcanic areas. Along with these systems, which use standard video cameras, people working in this field sometimes make use of infrared cameras providing useful information about the thermal evolution of eruptions. Real-time analysis of the acquired frames is required along with image storing to analyze and classify the activity of volcanoes. Human efforts are hence required to perform monitoring tasks.*

In this paper a new strategy is presented, which aims to improve the performance of surveillance systems in terms of human-independent image processing. The proposed methodology is based on real time thermo graphic analysis of the area considered. The tool developed provides information about the activity being monitored.

Keywords – *Volcanoes monitoring, image processing, eruption analysis*

I. INTRODUCTION

Volcanic activity is one of the most attractive and impressive phenomena nature offers. Long red tongues of lava or Strombolian activity showering small pieces of burning stones everywhere are well known images in people's minds. This extraordinary scenario, which brings a large number of visitors to the most famous volcanic areas every year represents a problem for the inhabitants especially when the risk of either volcanic earthquakes or eruptions is consistent. Many decades ago people felt the need for serious monitoring of volcanic areas. Seismographic acquisitions, gravimetric and geomagnetic measurements and video acquisitions are the main techniques used.

The natural scenario where measurements have to be made is often a hostile environment and the external influencing parameters have a profound effect. In order to reduce these effects innovative techniques for both signal processing and process control can be used.

The optimization of video surveillance systems is another task to be accomplished.

Researchers at the DIEES of the Engineering Faculty at the University of Catania are deeply involved in developing tools for understanding and monitoring volcanic activity. This activity is conducted in collaboration with researchers from the National Institute of Geophysics and Volcanology (INGV) in Catania and other international research institutes [1-6].

Video surveillance systems, based on standard CCD cameras and infrared cameras, are consolidated techniques for the monitoring of eruptive phenomena in volcanic areas [7, 8, 9]. Both of these devices furnish useful information on the volcanic activity which is 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. This approach requires the involvement of people analyzing 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.

The hardware supporting the communication with the surveillance site (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 where a PC performs the image processing (storing, classification, etc.).

In [10] authors investigate a new strategy for monitoring and analyzing volcanic activity. The set-up developed makes use of an infrared camera and a software tool running at the surveillance site. The tool performs real-time image processing to optimize the frame storing rate and provide alerts in the event of emergencies. This task is important to overcome the drawbacks (real-time human monitoring and large storing capabilities) of conventional video surveillance systems. The methodology is based on the thermo-graphic analysis of the volcano area monitored. Careful analysis of evolution of the temperature histogram (temperature being mapped into colours by the infrared camera) allows critical events during an eruptive activity to be classified as well as notifying the absence of any meaningful activity. Events of main interest to people working in this field are: the absence of eruptive activity, gaseous emission and lava effusion. A real-time classification of such events allows for the optimization of surveillance systems in terms of systems automatically alerting in the event of emergencies, a reduction in human effort and adaptive setting of the storing rate, thus reducing storing requirements.

In this paper a new measurement tool is proposed, performing the analysis of the acquired frames and providing the experts with useful information on the volcanic activity.

The tool elaborates images acquired by a thermal camera to overcome drawbacks mentioned above. The developed environment operates in off-line mode on the images acquired, which is absolutely compatible with the specifications for this kind of analysis.

The tool is completely automatic and creates reports about the evolution of the eruptive activity of the selected crater as well as statistics on the meaningful occurrences. Advantages of the proposed strategy are intrinsic in the automatic analysis of the data acquired, thus providing experts with useful and objective information on the observed phenomena without involving human efforts.

In particular, activities of the Mount Etna and Stromboli volcanoes located in Sicily - Italy, are monitored.
The surveillance of these sites is in charge of the Istituto Nazionale di Geofisica e di Vulcanologia - Catania site, and a large amount of monitoring systems have been installed along the mountains, which are active volcanoes giving to people living there dangerous as well as terrific scenario [11].

II. THE TOOL ANALYZING THE ERUPTION ACTIVITY

The image processing tool was developed in the LabVIEW environment due to its peculiarity in developing suitable user interface and performing real-time image processing.

Automatic operating mode, low time consuming, report generation are the main features of the developed system, which offers the advantage of performing very fast analysis with reduced efforts of experts.

The tool operates in the surveillance site where images coming from the monitoring stations are stored.

Figure 2 shows a view of the user interface during the processing of a generic frame sequence. On the right hand side the analyzed frames are shown; on the left side hand information on the analyzed sequence are provided at the end of the images elaboration.

After a frame sequence is processed the following information are available:

Eruption typology: explosion or continuous effusion;
Aspect : directional or wide, tall or short;
Maximum width;
Maximum height;
Aspect ratio;
Duration in time of the analyzed sequence.

In the case of the Etna volcano two craters are inspected, indicated as Sx and Dx, while only one active crater is monitored at the Stromboli site.

In the following, some details on the image processing procedure are given.

As first, the hypothesis of a camera placed in a fixed position in respect to the mountain is required to define the crater areas.

Some views of the algorithm developed are sketched in figure 3. The tool performs in two main steps. The first step applies suitable filters to the original frames in order to highlight the eruptive events. In particular, the pre-filtering section applies a brightness, contrast, and gamma correction to the each frame.

The correction is performed by computing and applying a look-up table. Brightness, Contrast, and Gamma tools

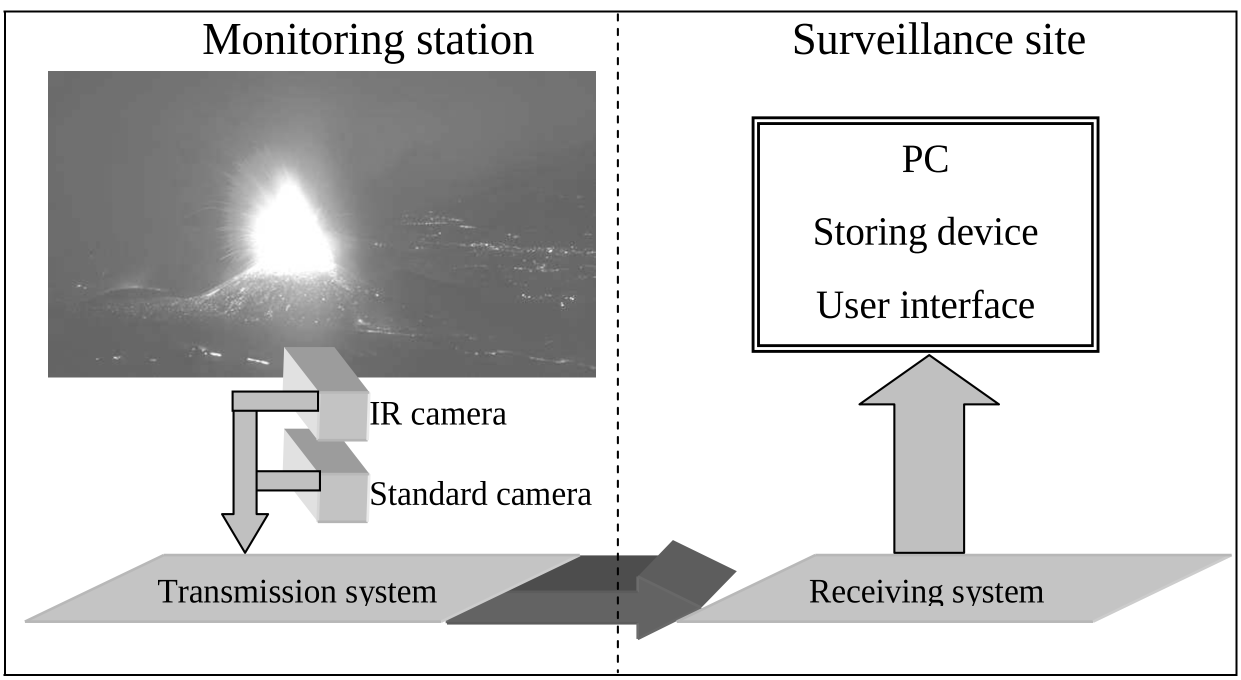

Fig.1. A schematization of a typical surveillance system.

Control the changes made to the transfer function represented by the look-up table.

The second step performs eruption area identification and size measurements. As it can be observed from the frame shown in figure 2, smart cursors, following the eruption edges, are used to define the eruptive events and hence to estimate the parameters above mentioned. As first, eruption edges are determined based on their contrast and slope, defined by the following parameters:

- Contrast specifying the threshold for the contrast of the edge. Only edges with a contrast greater than this value are used in the detection process. Contrast is defined as the difference between the average pixel intensity before the edge and the average pixel intensity after the edge;

- Filter width specifying the number of pixels that are averaged to find the contrast at either side of the edge;

- Steepness specifying the number of pixels that correspond to the transition area of the edge;

- Sub-sampling Ratio specifying the number of pixels that separates two consecutive search lines of the rake.

A first vertical hit-line to the eruption is calculated through the left-most edge detected. A second vertical line is calculated through the right-most edge. Up-most and bottom-most edges allow the calculation of the two horizontal lines clamping the vertical size of the eruption.

For each frame, distances between horizontal and vertical limits are then estimated along with the eruption area. At the end of the analysis of the selected sequence the Aspect Ratio, defined as the ratio between maximum height and maximum width, is estimated.

The estimated parameters (Aspect Ratio and Event Duration) allow the event to be classified. In particular, on the basis of the estimated duration the event will be classified as an explosion or a continuous emission; the effusion will then be classified as "wide" if the aspect ratio is less than 1, otherwise it will be classified as "directional". Moreover, comparing the estimated height with a user-defined threshold, which depends on the scenario considered, the explosion will be classified as "tall or short".

The results of the frame processing are given in the top section of the user interface, shown in figure 2. Moreover, parameters estimated for each frame are automatically included in a report and given on the bottom left hand side of the user interface.

Figure 2. The user interface of the developed analyzing too, during the elaboration of a sequence acquired in the Stromboli site. On the right hand side the analyzed frame is shown; on the left side hand information on the analyzed sequence is given at the end of the images elaboration.

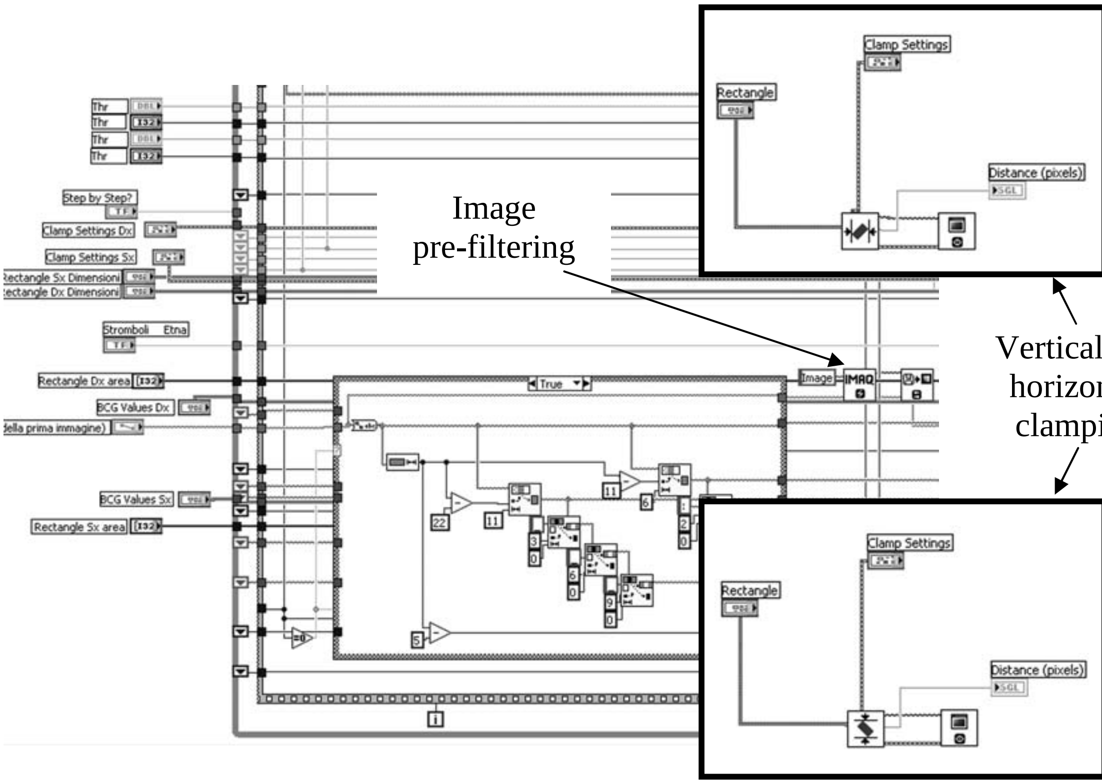

Figure 3. Some views of the algorithm developed.

Figure 4. A frame sequence processed by the analysis tool. As can be observed in Figure 2, the analyzed event has been classified as an explosion with an aspect ratio of 1.07.

III. PRELIMINARY RESULTS AND CONCLUSIONS

Figure 4 shows a frame sequence processed by the tool developed.

Vertical and horizontal cursors clamp the eruption event during the evolution observed. Data obtained from images processing, as described in section II, are recorded in files and information about each frame is provided to users through a report in the left-hand side of the user interface.

Moreover, real time statistics is performed which produce information about the Aspect Ratio, durations and dimensions provided in the upper-left side of the user interface.

As an example, Figure 2 shows that at the end of the processing the event analyzed has been classified as an explosion with an aspect ratio of 1.07.

Several trials were performed in order to test the behavior of the developed system and after expert supervised training good performance was achieved.

Experts dealing with the management and assessment of volcanic phenomena appreciated the tool due to its capacity to automatically classify volcanic activity and analyze classified events.

Future developments of the monitoring and processing architecture will regard the implementation of alarms aimed to inform experts about anomalous events.

REFERENCES

[1] Andò, B., Carbone, D., 2001, A Methodology for Reducing a Continuously Recording Gravity Meter for the Effect of Meteorological Parameters, IEEE Trans. on Instr. and Meas., 50, 5, 1248-1254.

[2] Andò, B., Coltelli, M., Sambataro, M., 2004, A Measurement Tool for Investigating Cooling Lava Properties, IEEE Trans. on Instr. and Meas., 53, 2, 507-513.

[3] Budetta, G., Carbone, D., Greco, F., 1999, Subsurface mass redistributions at Mount Etna (Italy) during the 1995-96 explosive activity detected by microgravity studies, Geoph. J. Int., 138, 77-88.

[4] Del Negro, C., Napoli, R., Sicali, A, 2002, Automated System for Magnetic Monitoring of Active Volcanoes. Bull. Volcanol., 64, 94-99.

[5] Fortuna, L., Graziani, S., Lo Presti, M., Nunnari, G., 1991, A neural Network for Seismic Events Classification, IEEE IGARSS'91, Helsinki, Finlandia, 1663-1665.

[6] Muscato, G., 2000, ROBOVOLC: A robot for volcano exploration, a new european project arising from the CLAWAR network, CLAWAR News: The Newsletter of the EC Brite Euram Thematic Network for Climbing and Walking Robots, 9, 5.

[7] Hunter, G., H. Pinkerton, R. Airey, S. Calvari, "The application of a long-range laser scanner for monitoring volcanic activity on Mount Etna", Journal of Volcanology and Geothermal Research, 123, 1/2, 203-210, 2003.

[8] Ernest O. Doebelin, Measuring Systems: Application and Design, Fourth ed., McGraw Hill Int., New York, 1990.

[9] M. Coltelli, M. Pompilio, "Direct measurement of heat transfer in cooling lava flow", International Workshop on European Laboratory Volcanoes, 18-20 June, 1994.

[10] Bruno Andò, Emilio Pecora, Nicola Pitrone, "Real-Time Thermo Graphic Analysis of Volcanic Eruptions", IMEKO-TC4, Athens, 2004.

[11] Behncke, B., M. Neri, The July-August 2001 eruption of Mt. Etna (Sicily). Bull Volcanol, 65, 461-476, DOI: 10.1007/s00445-003-0274-1, 2003.