engineering proceedings

MDPI

*Extended Abstract*

# A Novel Vision-Based Approach for the Analysis of Volcanic Ash Granulometry †

**Bruno Andò [1], Salvatore Baglio [1], Salvatore Castorina [1,*] and Vincenzo Marletta [1]**

[1] Dept. of Electric Electronic and Information Engineering (DIEEI), University of Catania, Italy; bruno.ando@unict.it, salvatore.baglio@unict.it, salvatore.castorina@unict.it, vincenzo.marletta@dieei.unict.it
* Correspondence: salvatore.castorina@unict.it
† Presented at the 8th International Symposium on Sensor Science, 17-28 May 2021, Online.

**Abstract:** Volcanic ash fall-out represents a serious hazard for air and road traffic. The forecasting models used to predict its time-space evolution require information about characteristic parameters such as the ash granulometry. Typically, such information is gained by spot direct observation of the ash at the ground or by using expensive instrumentation. In this paper, a vision-based methodology aimed at the estimation of the ash granulometry is presented. A dedicated image processing paradigm has been developed and implemented in LabVIEW™. The methodology has been validated experimentally using digital images and the accuracy of the image processing paradigm has been estimated.

**Keywords:** volcanic ash; ash fall-out; ash granulometry; granulometry classification; vision-based paradigm.

## 1. Introduction

The ash fall-out phenomenon following the explosive activity of volcanoes represents a considerable factor of risk for people's health and a serious hazard for air traffic, including potential damages on aircraft components [1-3], flight safety issues and operational disruption and physical damage at airports. In many cases the consequence of the ash fall-out is the flight cancellations or temporary closures of the airport for hours to weeks with inconvenience for passengers and loss of profit for airlines and airport operators.

Different techniques have been used worldwide to alert airports of volcanic activity. Real-time monitoring of explosive volcanoes by seismic and infrasonic instruments [4-6], forecasts of ash dispersion and deposition [6, 8] and detection of approaching ash clouds using high-cost instrumentation typically based on satellites [9], X-Band dual-polarization radars [10], ground Thermal InfraRed camera (TIR) [11] or ground-based Doppler radar [12] and vision systems [13, 14], laser diffraction and image processing techniques [15], are some examples of adopted solutions. Although these solutions provide accurate information about the volcanic activity and ash fall-out phenomenon, they are expensive, difficult to be installed and maintained and provide information with a low degree of spatial resolution (typically they are used to perform spot measurements). Moreover, to provide a reliable support for aeronautical authorities, the forecasting models used to predict the time-space evolution of the ash fall-out phenomenon, should be supplied by spatially distributed information about characteristic parameters of the ash fall-out such as ash granulometry and flowrate in addition to weather conditions. In this framework a distributed Wireless Sensor Network (WSN) of low-cost monitoring stations would represent a suitable solution in performing a continuous monitoring and gaining a high spatial resolution awareness of the ash fall-out phenomenon.

Within the framework of the SECESTA project [16], aimed at the development of an early-warning wireless network of low-cost multi-sensor nodes for the measurement of typical parameters of volcanic ash fall-out phenomenon (flowrate and granulometry) providing a spatially distributed information, authors have developed low-cost sensing methodologies to gain information about the selective presence of volcanic ash, its average granulometry and flowrate [17, 18].

In this paper, a novel vision-based methodology aimed at the investigation of the ash granulometry is presented. The image processing paradigm has been developed and implemented in LabVIEW™.

## 2. The proposed approach

The focus of this paper is mainly related to the image processing methodology adopted to perform particles detection and analysis. Aspects related to the image acquisition system will not be developed through this work.

The measurement approach proposed is based on the image processing of pictures of deposited ash grains, ideally on a white background, in order to maximize the contrast of the image.

The detailed operation of the image processing algorithm is described by the flow chart shown in Figure 1. The sequence of image processing steps is described below:

- Open image.
- Image inversion: inverts the pixel intensities of the image to compute the negative image.
- Threshold: computes the optimal threshold value for an image and applies the computed threshold.
- Reject border eliminates particles that touch the border of an image.
- Particle analysis: returns the number of particles detected in a binary image and a 2D array of requested measurements about the particle, with particular regards to the perimeter and area estimation. To such aim the paradigm estimates the number of pixels per each particle.
- Count objects: locates, counts, and measures objects in a rectangular search area. This block uses a threshold on the pixel intensities to segment the objects from their background.
- For each identified element in the picture the algorithm finds some particle features such as the smallest bounded rectangle (minor-major axes). aspect ratio and elongation factor, allowing to estimate the shape of the detected particle. Obtained results are stored for further processing.

The image processing paradigm sketched in Figure 1 has been implemented in LabVIEW™. The front panel of the Virtual Instrument (VI) developed, showing the processed image achieved with real volcanic ash particles is shown in Figure 2.

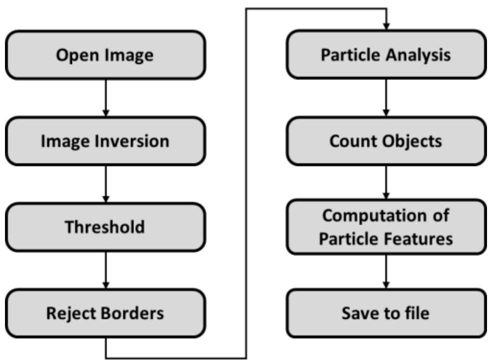


**Figure 1.** Flow chart of the image processing algorithm.

**Citation:** Lastname, F.; Lastname, F.; Lastname, F. Title. *Eng. Proc.* **2021**, *3*, x. https://doi.org/10.3390/xxxxx

Published: date

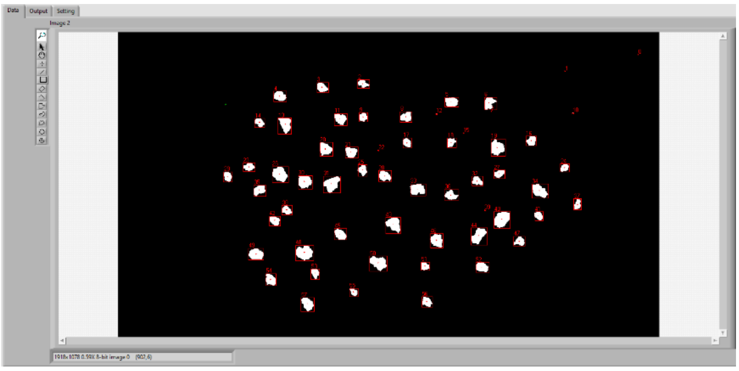

**Figure 2.** The front panel of the LabVIEW™ VI showing the processed image of a set of real volcanic ash particles.

## 3. Assessment of the image processing paradigm

The image processing paradigm has been assessed by providing the VI with reference digital images, made of objects of known dimensions (in pixels), and analyzing features estimated by the algorithm. Two examples of test images used during the assessment phase are shown in Figure 3a, b respectively.

The residuals between nominal and estimated values of area, perimeter, major and minor axis of samples in the test images have been used to assess the performance of the developed algorithm.

Results in terms of mean values and standard deviations of above defined performance indexes estimated for the particle factors (perimeter, area, major and minor axis) and for each object in test images are reported in Figure 4. Achieved data show that the most suitable index of the methodology reliability is the estimated area. The worst case computed as the maximum relative residual between the nominal and estimated area, through the whole set of considered samples results in an uncertainty of 1.8%.

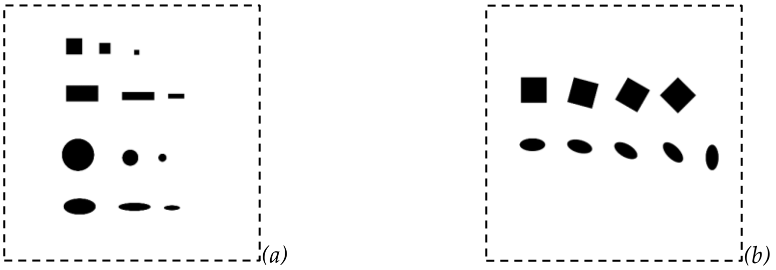

**Figure 3.** Two examples of test images used for the assessment of the image processing paradigm: *(a)* reference picture and *(b)* rotated picture.

## 4. Conclusions

In this paper a computer vision-based methodology for the automatic estimation of characteristic parameters of volcanic ash particles has been reported. The image processing paradigm developed takes pictures of deposited ash grains as input, and estimates geometric features, such as major and minor axes, perimeter, area and aspect ratio of all the particles contained in the image, which are stored in a file for further elaborations. The proposed methodology has been implemented as a LabView™ tool and assessed by means of reference digital images. The performance of the developed algorithm, estimated by taking into account the residuals between nominal and estimated values of samples' features in the test images, confirm the suitability of the adopted approach.

**Acknowledgments:** this project has been developed under the SECESTA-VIASAFE project, funded under Action 1.1.5 POR FESR 2014-2020, CUP G69J18001010007.

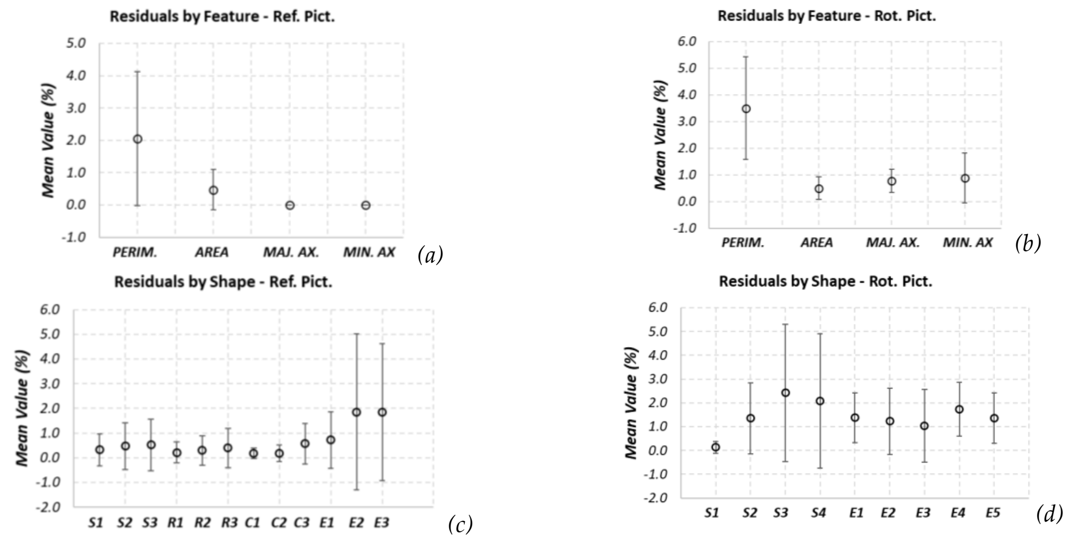


**Figure 4**. Results obtained for the test images, in terms of mean values and standard deviations of the performance indexes organized by each particle factor (*a=reference* and *b=rotated*) and by object type (*c=reference* and *d=rotated*). Results are given in pixel. Legend: S = square, R = Rectangle, C = Circle, E = Ellipse.

## References


1. A. Marti, A. Folch, O. Jorba, Z. Janjic, Volcanic ash modeling with the online NMMB-MONARCH-ASH v1.0 model: model description, case simulation, and evaluation, Atmos. Chem. Phys., 17, 4005–4030, 2017.
2. C. Horwell, P. Baxter, The health hazards of volcanic ash - A guide for the public, Available at http://www.ivhhn.org/images/pamphlets/Health_Guidelines_English_WEB.pdf (accessed on 08 January 2019).
3. ICAO, Flight Safety and Volcanic Ash, Doc9974 AN/487, 2012.
4. M. Guffanti, G. C. Mayberry, T. J. Casadevall, R. Wunderman, Volcanic hazards to airports, Natural Hazards, v. 51, p. 287-302, 2009, doi:10.1007/s11069-008-9254-2.
5. B. Andò, S. Baglio, G. L'Episcopo, V. Marletta, N. Savalli, C. Trigona, A BE-SOI MEMS for Inertial Measurement in Geophysical Applications, IEEE Transactions on Instrumentation and Measurement, vol. 60. N.5, pp. 1901-1908, 2011.
6. S. Scollo, M. Prestifilippo, G. Spata, M. D'Agostino, M. Coltelli, Monitoring and forecasting Etna volcanic plumes, Nat. Hazards Earth Syst. Sci. 9 (2009) 1573–1585, doi:10.5194/nhess-9-1573-2009.
7. G. Werner-Allen, J. Johnson, M. Ruiz, J. Lees, M. Welsh, "Monitoring Volcanic Eruptions with a Wireless Sensor Network", Proc. of the IEEE Second European Workshop on Wireless Sensor Networks, pp. 108-120, 2005.
8. P. W. Webley, K. Dean, J. E. Bailey, J. Dehn, R. Peterson, "Automated forecasting of volcanic ash dispersion utilizing Virtual Globes", Nat. Hazards (2009) 51:345-361, doi: 10.1007/s11069-008-9246-2.
9. F. Marchese, R. Corrado, N. Genzano, G. Mazzeo, R. Paciello, N. Pergola, V. Tramutoli, Assessment of the Robust Satellite Technique (RST) for volcanic ash plume identification and tracking, Use of Remote Sensing Techniques for Monitoring Volcanoes and Seismogenic Areas, USEReST 2008. Second Workshop on, pp. 1-5, 2008.
10. F. S. Marzano, E. Picciotti, G. Vulpiani, M. Montopoli, Synthetic Signatures of Volcanic Ash Cloud Particles From X-Band Dual-Polarization Radar, Geoscience and Remote Sensing, IEEE Trans. on, Vol. 50, N. 1, pp. 193 – 211, 2012.
11. S. Corradini, C. Tirelli, G. Gangale, S. Pugnaghi, E. Carboni, "Theoretical Study on Volcanic Plume $SO_2$ and Ash Retrievals Using Ground TIR Camera: Sensitivity Analysis and Retrieval Procedure Developments, Geoscience and Remote Sensing", IEEE Transactions on vol. 48, no. 3, part 2, pp. 1619-1628, 2010, doi: 10.1109/TGRS.2009.2032242
12. F. S. Marzano, S. Barbieri, G. Vulpiani, W. I. Rose, "Volcanic ash cloud retrieval by ground-based microwave weather radar", IEEE Trans Geosci. Remote Sens. 44:3235–3246, 2006.
13. B. Andò, E. Pecora, An advanced video-based system for monitoring active volcanoes, Computers & Geosciences, Vol. 32, Issue 1, pp. 85-91, 2006.
14. A.J. Prata, C. Bernardo, Retrieval of volcanic ash particle size, mass and optical depth from a ground-based thermal infrared camera, J. Volcanol. Geotherm. Res. 186 (2009) 91–107.
15. Horiba Partica LA-960V2. Available online: https://www.horiba.com/en_en/products/detail/action/show/Product/partica-la-960v2-1944/ (accessed on 22 March 2021).
16. SECESTA project, 4.1.1.1 - POR FESR Sicilia 2007-2013, (CUP. G53F11000040004), http://secesta.pmf-research.eu.
17. B. Andò, S. Baglio, V. Marletta, Selective Measurement of Volcanic Ash Flow-rate, IEEE Transactions on Instrumentation and Measurement, vol. 63, n. 5, pp. 1356-1363, 2014.
18. B. Andò, M. Coltelli, M. Prestifilippo, S. Scollo, A Lab-Scale Experiment to Measure Terminal Velocity of Volcanic Ash, IEEE Transactions on Instrumentation and Measurement, Vol. 60, N. 4, pp. 1340 – 1347, 2011.