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A Smart Multisensor System for the Ash Fall-Out Monitoring

Bruno Andò, Salvatore Baglio, Vincenzo Marletta *

Dipartimento di Ingegneria Elettrica Elettronica e Informatica (DIEEI) - University of Catania
v.le A. Doria 6, Catania, 95125, Italy

Abstract

The ash fall-out following explosion activity of volcanoes represents a relevant factor of risk for people and facilities in the area near the volcano and a serious hazard for air traffic civil and otherwise [1] mainly when airports are close to active volcanoes. This is the case of the international Fontanarossa Airport in Catania close to Mount Etna.
Researchers at DIEEI of the University of Catania are facing the challenge of developing a low-cost smart multisensor system for the monitoring of ash fall-out phenomena by measuring ash presence, average granulometry and ash flow rate. Moreover, the system must discriminate volcanic ash from others sediments such as dust, sand or soil. This paper is particularly focused on the methodology adopted for ash granulometry detection. The main idea is to use a piezoelectric transducer to convert ash impacts in electrical signals which should provide information about ash granulometry. Experimental investigations have been performed using volcanic ash with three different granulometries (big, medium and small) ranging from 2 mm to 0.2 mm.
Experimental results are presented together with the methodology developed to classify ash granulometry.

Keywords: volcanic ash; ash fall-out detection; granulometry classification; piezoelectric sensor; multisensor architecture.

1. Introduction

The atmospheric dispersion of ash produced by the explosive activity of the Etna volcano is a relevant factor of risk for eastern Sicily and in particular for the Catania area. Ash fall-out causes extensive damages to roads, sanitation systems [2], agriculture, health [3] and daily activities of people living in the countries on the slopes of the volcano, but also a substantial hazard factor to air traffic [1] with consequently inconvenience for passengers and loss of profit for airlines. This is the case of the

* Bruno Andò. Tel.: +39-095-738-2601; fax: +39-095-738-7965.
E-mail address: bruno.ando@dieei.unict.it

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international Fontanarossa airport, the sixth major (in terms of number of passengers) airport in Italy, which in last years has been repeatedly shut down because of ash plumes spewed by the volcano Etna.

Researchers at DIEEI are facing the challenge of developing a low-cost smart multisensor system for the measurements of typical parameters of volcanic ash fall-out phenomena. This activity is developed under the SECESTA project [4] of the POR FESR Sicilia 2007-2013.

The goal of the project is the development of a wireless sensor network for the monitoring of ash fall-out in the area spreading from Etna volcano to the Fontanarossa airport. Each node consists of a microcontroller based multi-sensor architecture aimed to provide information on the ash fall-out phenomena (presence, ash flow and ash granulometry) aimed to foresight the time-space evolution of the phenomena. This kind of information could be useful to implement an optimized planning of actions required to both restore the functionalities of the airport and to manage air traffic during the ongoing phenomenon.

2. The sensing strategy and the experimental results

The multisensor system for the monitoring of ash fall-out phenomena is in charge of measuring ash presence, average granulometry and ash flow rate. Moreover, the system must discriminate volcanic ash from others sediments such as dust, sand or soil. A schematization of the node prototype and the microcontroller multisensory architecture, developed at the DIEEI laboratories, are shown in Fig. 1 and Fig. 2, respectively.

In particular, this paper will addresses the methodology adopted for the estimation of the ash granulometry. The main idea is to use a piezoelectric transducer to convert ash particles impacts in electrical signals which should be converted in information about ash granulometry. To this purpose a piezoelectric disk is placed within a on purpose developed structure to convey the falling ash on the sensing area of the device. A charge amplifier followed by an inverting amplifier has been used as the conditioning circuit for the piezoelectric sensor. Signals coming from the conditioning circuits (of the piezoelectric and of the others sensors onboard) are then acquired and pre-processed by the microcontroller based architecture and successively transmitted to the system server.

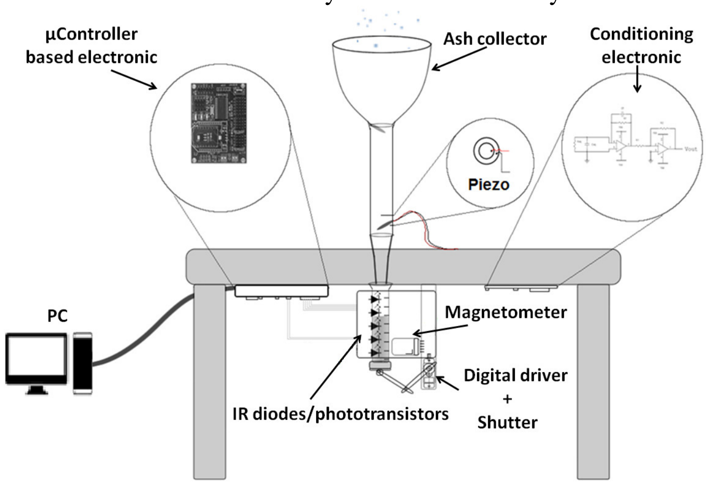


Fig. 1: Schematization of the multisensor node.

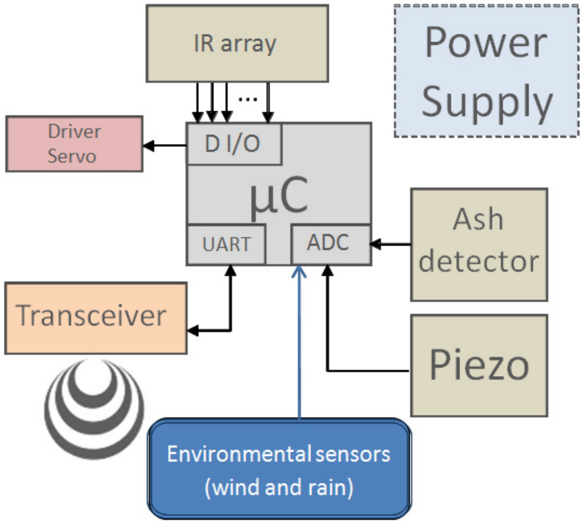


Fig. 2: Schematization of the multisensory architecture.

A preliminary characterization of the system developed has been performed by a set of repeated single particle impacts, in order to investigate the ability of the piezoelectric transducer to produce signals useful for the classification of ash particles granulometry.

Experimental investigations have been performed using volcanic ash with three different granulometries (big, medium and small) ranging from 2 mm to 0.2 mm, as shown in Fig. 3.

It is expected that impacts of ash particle with different sizes produce different output voltage signals (in terms of amplitude) from the piezoelectric transducer. A typical output voltage signal provided by the readout electronics of the piezoelectric sensor as a consequence of single particle impact is shown in Fig. 4a. A Matlab® algorithm has been developed to automatically windowing the raw signal and to extract signal characteristics related to the granulometry of the ash grain. An example of a processed signal is shown in Fig. 4b, while the distribution of voltage amplitudes detected for repeated impacts of three sizes granulometries investigated is shown in Fig. 5. A classification paradigm has been developed to correlate the output voltage amplitude to different ash granulometries. As a first approach, a threshold mechanism, e.g. implemented through the two values Th1 and Th2, was adopted for the sake of granulometry classification. Future efforts will be dedicated to the implementation of more sophisticated classification procedures.

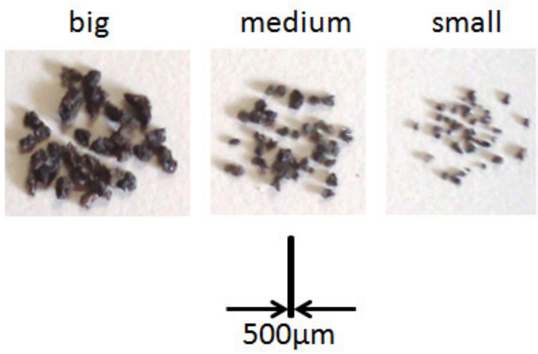
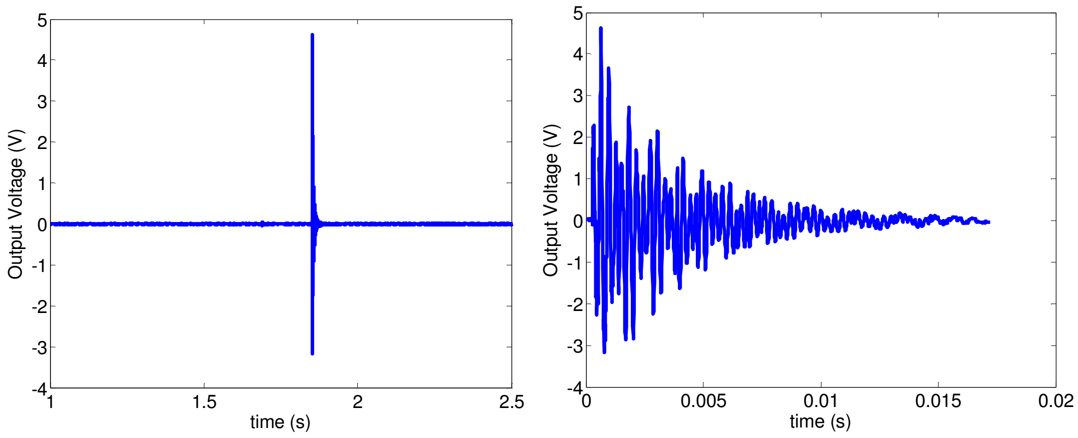


Fig. 3: Volcanic ash with three different granulometry used to perform experimental investigations.



(a) (b)

Fig. 4: (a) Raw output voltage signal from the conditioning electronic for the piezoelectric; (b) The output voltage signal after windowing.

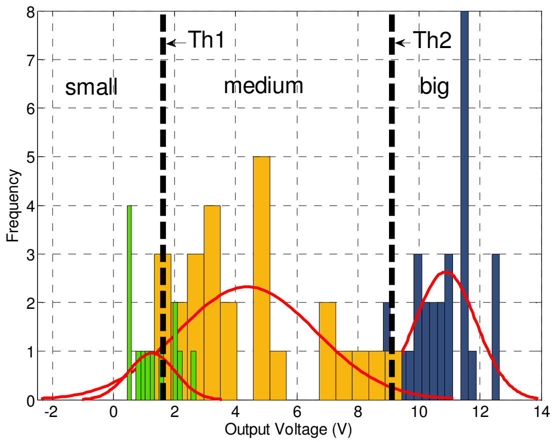


Fig. 5: Distribution of the peaks of the output voltage. Two threshold values (Th1 and Th2) can be identified for classification.

Acknowledgement

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