The smart noise monitoring system implemented in the frame of the Life MONZA project

Chiara Bartalucci, Francesco Borchi, Monica Carfagni, Rocco Furferi, Lapo Governi, Alessandro Lapini
Department of Industrial Engineering, via di S.Marta 3, 50139, Florence, Italy.

Raffaella Bellomini, Sergio Luzzi
Vie en.ro.se. Ingegneria Srl, via Stradivari 19, 50139 Florence, Italy

Luca Nencini
Blue Wave Srl, via del Fonditore 344, 58022 Follonica, Italy

Summary

One of the main goal of the LIFE MONZA Project, which started in September 2016, is to reduce the average noise levels present in the Libertà district by means of both top-down (creation of a limited traffic zone to forbid the access to trucks, limitation of vehicles speed, lanes-width reduction and pedestrian crossing introduction, substitution of the current asphalt with a silent one) and encouraged bottom up actions (pedibus service, etc). In order to monitor the noise levels trends before and after the interventions implementation, both smart and traditional noise monitoring systems have been de-signed and installed. The smart monitoring system consists in 10 low cost noise monitoring units in-stalled in strategic position in the Libertà district, acquiring the noise time history, every second, of the sound pressure in terms of broadband and 1/3 octave band levels. The transmission system on board of each control unit is designed to guarantee a minimum transmission time per hour to a central server unit from which data can be visualized in almost real time, elaborated and downloaded. The smart monitoring system was first tested for two months in correspondence of the Polo Scientifico of Sesto Fiorentino and then installed in the Libertà district of Monza where it started to collect data from June 2017. Furthermore, an on site verification procedure was developed and three verifications have been performed until now. In this paper the structure and the positioning of the smart noise monitoring system is presented, together with indications about how data can be visualized in the server. Moreover, first results obtained after the first monitoring period are illustrated.

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1. Introduction

Currently, noise is considered as one of the most dangerous pollutants affecting urban realities. Important contributes to manage this issue has been given by some concluded European projects such as LIFE+2010 QUADMAP, LIFE+2008 HUSH and LIFE+2009 NADIA [1,2]. As an additional contribution LIFE MONZA project (Methodologies fOr Noise low emission Zones introduction And management - LIFE15 ENV/ IT/000586) aims at developing an easy-replicable method and related guidelines, for the identification and the management of the Noise Low Emission Zone, an urban area subject to traffic restrictions, whose impacts and benefits regarding noise issues will be analysed and tested in the pilot area of the city of Monza, located in Northern Italy. LIFE MONZA project foresees to carry out some noise monitoring activities planned in a pilot area, refer-ring to standard methods, using sound level meters

of class I precision, and also by developing and using a smart low-cost monitoring system.
As a preliminary action, the state of the art about smart noise monitoring systems has been investigated [3,4], in order to understand the accuracy, the performance and the maintenance features characterizing this kind of devices. Then, a new smart noise monitoring system has been developed [4] in order to be used as a continuous monitoring network in the ex ante and ex post scenarios (one year + one year) into the pilot area of LIFE MONZA project. At the end of the LIFE MONZA project, the prototype will be given for free to the city of Monza that will take care of using it for monitoring activities in the three years after LIFE period.

2. Noise monitoring network: specifications and design

According to what already defined in [4] the pilot area to be monitored consists of a district of the city of Monza as shown in Figure 1.

Figure 1. Perimeter of the pilot area ("Libertà" district, city of Monza).

In the selected pilot area a main road (Libertà street) and roads affected by medium-low traffic are present. Significant average levels of noise pollution affect a large number of citizens so that Libertà district is identified as a hotspot in the Action Plan of the city of Monza. The noise strategic map of the city of Monza, dated 2012, highlights that in a range of 30 m from the Viale Libertà al-most the 100% of the receivers are exposed to levels higher than 65 dB(A) during the day and 55 dB(A) during the night.
The Smart Noise Monitoring System (SNMS) network is meant to adequately cover the pilot area and the different types of roads. Secondarily, the possibility to have a connection to the electric energy network (avoiding the use a solar panel) is considered as an added value for the selection of measuring positions.
From a practical point of view, 10 monitoring stations are expected to be installed in the pilot area of Libertà district, as illustrated in Figure 2. In particular, 2-3 microphones will be placed along the Viale Libertà, the main street where the traffic flow mix is expected to mainly change from ante to post operam scenario. The other microphones will be uniformly distributed along other streets be-longing to the pilot area.

Figure 2. Site plan with the identification of noise monitoring stations.

3. Noise monitoring unit: specifications and design

The SNMS technical specifications were defined keeping in mind the aim of a long-term monitoring of acoustic parameters. These are expected to be useful to understand the variability of acoustic climate in the pilot area with mainly reference to the overall A-weighted continuous equivalent sound pressure level.
According to the previous general requirements and to the outcome of the state of the art analysis described in [3;4], the following main specifications of monitoring units are defined:
- acoustic parameters: overall A-weighted continuous equivalent sound pressure level, “LAeq” and continuous equivalent sound pressure level, “Leq”, as 1/3 octave band spectrum data;
- timing for data recording: data will be acquired with a time basis of 1 second in order to permit the recognition of unusual events in the eventual analysis phase;
- timing for data transmission: data will be sent to the remote server every one hour;

- data transmission network: the data will be transmitted through the 3G cellular telephonic network;
- power supply: small solar panel (30cm x 20cm) and battery for energy storage or direct connection to electricity network;
- sensors location: on streetlight or on façade, height 4 m above the ground level;
- sensor type: ¼ or ½ inch low-cost microphone with removable rain protection;
- floor noise < 35 dB(A);
- frequency response at nominal frequencies of 1/3 octave within the class I specs ± 1dB.

Starting from the specs listed above, the monitoring system architecture has been mainly based on monitoring units designed in the Life DYNAMAP project (these units comply with all the specs), tailoring the data transmission, storage and post-analysis to the needs of the LIFE MONZA project.
Referring to the hardware components, each monitoring unit is designed to achieve a high energy efficiency and low computational burden. In particular, it has an average variable electric absorption among 200 mW and 400 mW, depending on uplink transmitting power in function of the distance to the nearest radio base station of cellular network and the kind of used transmission protocol (2G, 3G). They thus can be powered through solar panels (size 30cm x 35cm) and an integrated power battery with the possibility of being directly connected to the electricity network.
In order to obtain these high performances of energy efficiency, digital MEMS microphones were used that do not require the use of an external ADC. The MEMS microphones have been adapted onto a ½ inch cylindrical plastic support to allow the insertion of a standard acoustic calibrator.
These units are also equipped with a low-power microcontroller able to perform, by mean of IIR digital filtering, the calculation of the A-weighted continuous equivalent sound pressure level, "LAeq", and, by mean of FFT, of the 1/3 octave band continuous equivalent sound pressure level, "Leq".
In the usage scenario foreseen for the pilot area, the units will periodically (every hour) connect to the internet and transfer the gathered acoustic data, together with statistics on battery level and quality of the transmission signal. The data will populate a dedicated database, optimized for handling large amounts of data. It has been also planned to build up a web application that allows visualization of the location of the control units on a navigable map, data representation and download.

4. SNMS verification

As already mentioned, the low-cost sensors challenge consists in maintaining network performance during long term periods of outdoor operation.
A periodic check of the system will be performed to understand if the measurement accuracy is maintained in time or if sensors need to be repaired or replaced. Two system check procedures are proposed in [4] to verify the noise monitoring system performance:

- a preliminary check procedure;
- a long term on site verification procedure.

The preliminary check has been performed for a reduced time period (two months) before the monitoring period in the pilot area starts.
The long term on site verifications are planned to be performed every four months at least for two years during the noise monitoring period in the pilot area (1 year in the ante-operam scenario and 1 year in the post-operam scenario).
At the current time, three on site verifications were performed, the first one in July 2017, the second one in November 2017 and the third one in March 2018.

5. Current results

The smart noise monitoring system was installed in the Libertà district of Monza where it started to collect noise data from June 2017.
A web interface (Figure 3) has been developed aiming to make possible to view and download data referred to a user-defined time period.

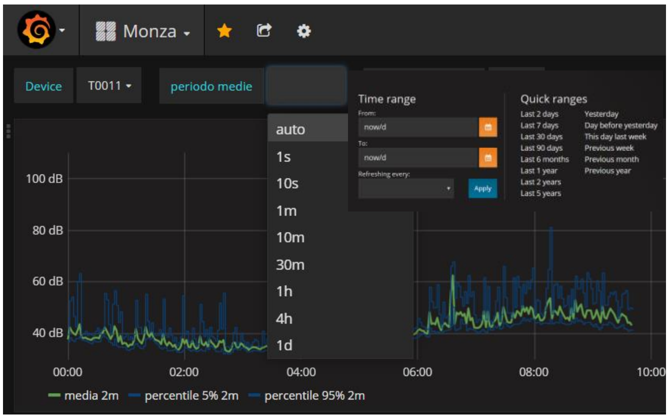

Figure 3. Web interface with possibility of selecting the time period to view and/or download.

The SNMS network has been working since June 2017, continuously recording data (LAeq,1s as broadband value, and Leq,1s in terms of 1/3 octave band values) at 10 measurement stations.
Until now the system has proven to be robust. There was only one breakage of a microphone downstream of a significant weather event. From the web inteface it was possible to verify the breakage of the microphone that led to an interruption of the signal (Figure 4) and to quickly proceed to the replacement of the sensor.

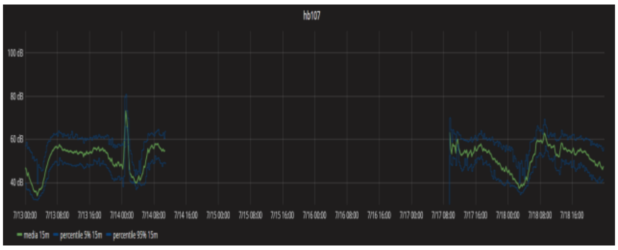

Figure 4. Breakage of microphone put in evidence by the signal interruption shown by the time history of sound pressure levels.

In addition, periodic long term on-site verifications have made it possible to check the system's operating status over time. After the first checks, it was found that all MEMS microphones, adapted to a ½ inch support, require an initial running-in phase, during which they are subject to a reduction in sensitivity over time. Instead, for electret microphones mounted on a ¼ inch support, the above phenomenon is not observable.
However, the sensitivity of MEMS microphones seems to stabilise over time after the first life period. In fact, for example, with reference to the checks carried out with an acoustic calibrator (which emits a pure tone at 1000 Hz, of 94 dB amplitude), the results are as follow: between the first control (carried out one week after installation) and the second one (carried out 4 months after installation) an appreciable reduction in sensitivity (1-2 dB) was found, while between the second and the third control (carried out 8 months after installation) the reduction in sensitivity is no longer appreciable.
According to the first results of on site verifications it is in evidence that, for the correct use of sound pressure data collected by using MEMS microphones, it is necessary to define the sensitivity of each sensor over time and use it to correct the raw collected data.
Therefore, with reference to the production and installation of new sensors, in order not to incur a phase of sensitivity reduction to be compensated by software, it is planned to carry out a preliminary phase of break-in of the MEMS microphones during the production phase.

6. Conclusions

Smart low-cost noise monitoring systems, allowing an extensive and long-term noise monitoring, in medium sized territorial scale as urban area, seem to be able to ensure a satisfactory quality output measurement data.
In particular, according to the objectives of the monitoring activities of LIFE MONZA project, a smart noise monitoring network has been designed and developed. Moreover, some procedures to periodically verify the performance maintenance have been proposed and firstly used to test the prototype system. Periodic long term on-site verifications have made it possible to check the system's operating status over time.
After the first checks, it was found that all MEMS microphones, adapted to a ½ inch support, were subject to a reduction in sensitivity over first life time. Instead, for electret microphones mounted on a ¼ inch support, the above phenomenon is not observable. As a consequence, according to the first results coming from on-site verifications, it is in evidence that, for the correct use of sound pressure data collected by using MEMS microphones, it is necessary to define the sensitivity over time of each sensor and use it to correct the raw collected data. Therefore, with reference to the production and installation of new MEMS microphones, in order not to incur a phase of sensitivity reduction to be compensated by software, it is planned to carry out a preliminary phase of break-in of the microphones before the monitoring period starts.

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