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The LIFE DYNAMAP project: Towards a procedure for dynamic noise mapping in urban areas

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ABSTRACT

Noise maps are considered a powerful tool for determining the population exposure to environmental noise. To make the process of updating noise maps easier, more cost effective and more frequent, there is a need for integrated systems that combine real-time measurement and processing to assess the acoustic impact of noise sources. To this end, a dedicated project, named Dynamic Acoustic Mapping (DYNAMAP), has been proposed and co-financed in the framework of the Financial Instrument for the Environment (LIFE) 2013 program with the aim of developing a dynamic noise mapping system capable of detecting and representing in real-time the acoustic impact of road infrastructures. Noise maps are updated by scaling the noise levels of pre-calculated noise maps as functions of the differences observed between measured and calculated original grid data. The total map is updated by energetic summation of single source levels from updated noise maps. Given the large number of roads present in Milan city, obtaining the dynamics acoustics map of this city requires application of a statistical approach where the roads having similar flow conditions—and thus similar noise trends—are grouped (clustered) together. In order to obtain these groups (clusters), an extensive measurement campaign was executed. The maps obtained using this method can be associated with an error that will depend on the chosen integration time of noise levels. Results show that two statistical clusters differentiated by rush hour traffic flow are sufficient and better for categorization than the road types provided by Italian road regulation.

1. Introduction

Urban traffic noise has been investigated in several studies aimed at various aspects of its impact [1–6]. Initially, environmental noise was studied by using systematic sampling, which selects measurements points using grids over a map [2]. However, this approach proved to be too expensive and time consuming for road administrations and local or central authorities, and it gave more weight to noisier streets [7], thus providing biased maps. In fact, the noise on a street generally depends on numerous factors, e.g. its activity, width, use in urban context, presence of reflecting surfaces, presence of obstacles, type of paving. Acoustic simulation algorithms, implemented in software, allow reproduction of noise emission and propagation over a wide area, starting from some static information about sound sources and environment.

Presently, noise maps are considered a powerful tool for determining the population exposure to environmental noise and identifying the most appropriate mitigation measures. Current maps of noise generated from roads are normally obtained by using the vehicle flows averaged over long periods (usually one year); consequently, the noise levels that are obtained refer to these periods of time as well. The possibility of having a representation of traffic noise with a shorter time intervals (less than one year, at least one hour) would allow for a more accurate view of the actual environmental noise, determining more quickly the causes of high levels and, consequently, any mitigation action required. Furthermore, the Environmental Noise Directive requires that noise maps must be regularly updated every five years to check for and report changes that occurred during the reference period. This updating process is usually achieved using a standardized approach, consisting of collating and processing information through acoustic models to produce the updated maps. This procedure is time consuming and costly.

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Presently, noise measurements are mainly used to validate results obtained from computational models, yet they are rarely involved directly in the noise mapping process. To this end, a dedicated project, named Dynamic Acoustic Mapping (DYNAMAP), has been proposed and co-financed in the framework of the Financial Instrument for the Environment (LIFE) 2013 program, with the aim of developing a dynamic approach for noise mapping that is capable of updating environmental noise levels through a direct link with a limited number of noise monitoring terminals. The original assumption of the project is that an experimental approach based on real-time noise measurements could be used to map road sources in urban areas. This approach seems quite promising in areas where noise sources are well identified such as those close to main roads. In complex scenarios, such as in agglomerations, further considerations and testing are needed to make the idea feasible. Noise maps are updated by scaling the noise levels of precalculated (basic) noise maps as functions of the difference observed between measured and calculated original grid data (at specific points). This operation should be performed for each road in the mapping area. The total map is updated by energetic summation of single source levels from updated basic noise maps.

The main goal of the project is to demonstrate that noise maps can be automatically updated in real time using a limited numbers of low-cost sensors and a general purpose GIS platform. The use of low-cost sensors allows for a large monitoring network with steady access to continuous noise data for long periods of time. This feature introduces a different role for the experimental measurements in the noise mapping process. To that end, customized sensors and communication devices will be developed in order to reduce the cost of monitoring the road network. An advanced management and reporting interface will be designed to update noise maps and inform the public. Such an interface will be implemented on a GIS platform, thereby eliminating the need for expensive dedicated acoustic software for data processing. The feasibility of this approach will be proved by testing the systems in two pilot areas with different territorial and environmental characteristics: an urban agglomeration and an extra-urban major road. The first pilot area will cover a significant portion of the city of Milan (identified by Municipality classification in Zone 9) including different types of roads and acoustical scenarios, whereas the second one will be located along motorway A90 that surrounds the city of Rome [23].

In order to reduce the cost of the automatic mapping system, a limited number of monitoring terminals should be installed. In agglomerations, where the road network is large and quite complex, this means that only selected roads—those representative of the acoustic trend of roads showing the same behaviour—should be monitored. Hence, the need to group road networks in homogeneous clusters represents a reliable method for sizing the network of monitoring terminals. Roads sharing the same characteristics for some parameters, such as vehicle flow capacity and number of lanes, are grouped together. Such parameters are usually included in the functional classification of roads and linked to their role played in urban mobility. However, this classification generally reflects neither the actual use of roads nor, therefore, the actual noise emission. For a better description of the real behaviour of noise in complex scenarios, such as the road network of the city of Milan, we approached the problem considering an aggregation method based upon similarities among the 24-h continuous acoustic monitoring of the hourly sound pressure L_{Aeqh} levels. For this purpose, we collected all the historical monitoring campaigns performed in Milan in the recent past and made new ones as well. Once normalized, such trend profiles provide a tool for grouping together roads according to their vehicular dynamics, thereby allowing for a more realistic description of such road networks. Within the DYNAMAP project, 24 roads representative of the clusters will be identified in the urban pilot area and continuously monitored to provide noise levels for noise map updating. The maps that will be obtained using this method will be associated with an error that will depend on the time of representation chosen.

In this paper, the two main activities performed to achieve the dynamic map of the city of Milan will be described. Firstly, we describe the monitoring activities (including data collection managing) performed to characterize the road noise of the city so that it can be represented with a small number of clusters. Secondly, we describe the procedure used to identify the best clustering method and errors connected.

2. Measurement campaign

The construction of a database containing noise emission data related to the Milan road network is necessary to characterize the ‘acoustic behaviour’ of homogeneous groups of roads. Therefore, one of the first actions of the project is the realization of a large-scale noise monitoring investigation specifically made to collect, improve, integrate and refine the acoustic data obtained from previous monitoring campaigns. To this end, a wide traffic noise monitoring campaign was planned for the entire area of the city of Milan considering the space–time variability of the noise emissions generated by traffic sources. For each measurement point, different series of equivalent sound pressure levels with different time resolutions were obtained for a period of 24 h. The monitoring activities comprise the following steps:

- collection and selection of previous noise data;
- selection of monitoring sites based on specific criteria;
- acquisition of the acoustic data;
- correlation of acoustic data with weather data;
- identification and deletion of abnormal events;
- acquisition of series of equivalent sound pressure levels;
- compilation of data into a geodatabase.

2.1. Collection of existing acoustic data

The first activity involved the collection and storage of previous noise measurements. From all the historical data available, only those specifically related to road sources with durations of at least 24 h were selected. Since 2009, the Department of Environment and Territory and Earth Sciences has carried out several acoustic measures in the city of Milan. The collected data have different origins. Some sound level measurements were performed for research purposes and others for collaborative activities for local authorities and agencies such as the Lombardy Region, the Municipality of Milan and the Milan Territory Environment Agency Mobility (AMAT). The dataset of previous continuous noise monitoring consists of 49 sites, related to eight different road categories. In Fig. 1, the positions of the monitoring points are shown.

2.2. Execution of acoustic monitoring campaign

The second phase of this study involved the planning and execution of a new acoustic monitoring campaign, closely related to the purposes of the DYNAMAP project. In order to create a representative statistical sample of the entire road network of the city, the following general criteria were adopted to identify the measuring sites:

- homogeneous distribution of the entire metropolitan area and the nine city districts of Milan;
- uniform distribution between the different Italian road categories (A, D, E, F) and road subclasses (E1, E2, F0, F1; F2, F3);

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