DYNAMAP: A SYSTEM WITH LOW-COST HARDWARE AND ARTIFICIAL INTELLIGENCE TO COMPUTE REAL TIME NOISE MAPS.

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ABSTRACT

The DYNAMAP project has been approved for co-financing by the European Commission through the Life+ 2013 program last May 2014. DYNAMAP aims at the installation of a prototype system in the municipalities of Rome and Milan. It is based on pervasive low-cost hardware network for noise measurement together with some artificial intelligence algorithm to perform the automatic creation of real time noise maps. This work explains the concept of the project and some technical specifications about the low-cost hardware and the smart detection algorithm that will be implemented to avoid biasing the noise maps with sound events that do not come from road traffic.

INTRODUCTION

The DYNAMAP project (Dynamic Acoustic Mapping - Development of low cost sensors networks for real time noise mapping) aims at developing a dynamic noise mapping system able to detect and represent in real time the acoustic impact due to road infrastructures. Scope of the project is the European Directive 2002/49/EC relating to the assessment and management of environmental noise (END) [1]. In particular, the project refers to the need of updating noise maps every five years, as stated in the END.

As a matter of fact, the update of noise maps using a standard approach is time and cost consuming and has a significant impact on the financial statements of the authorities responsible for providing noise maps, such as road administrations and local or central authorities.

To ease the update of noise maps and reduce their economic impact, the reiteration of noise mapping activities can be automated developing an integrated system for data acquisition and processing able to detect and report in real time the acoustic impact due to noise sources. The system will be composed by low cost sensors measuring the sound pressure levels emitted by the noise sources present in the area to be mapped and by a software tool based on a GIS platform performing real time noise maps updating. Noise sensors will be based on low power microcontroller systems like the ones used in Noisemote [2].Moreover, the system will be endowed with artificial intelligence capabilities that will allow to detect noise events caused by sources other than road traffic. The objective is that the rendered noise maps will faithfully represent the noise levels caused by road infrastructures solely. This anomalous noise event detection algorithm builds on previous works on environmental sound source recognition and classification [3,4].

THE DYNAMAP SYSTEM

The system to be developed will use acoustic maps automatically updated using measured data provided by low cost monitoring stations located close to sound sources, such as roads, rails and industrial plants. This application is nowadays extremely fast as no further recalculation of the sound propagation is required to adapt the noise map to the measured data. The monitoring stations are installed at relevant receiver locations where sound pressure levels are dominated by sources. For each of the monitored source and for the remaining sources a complete noise map is calculated and saved for the entire mapping area. In figure 1, a scheme of the system is presented.

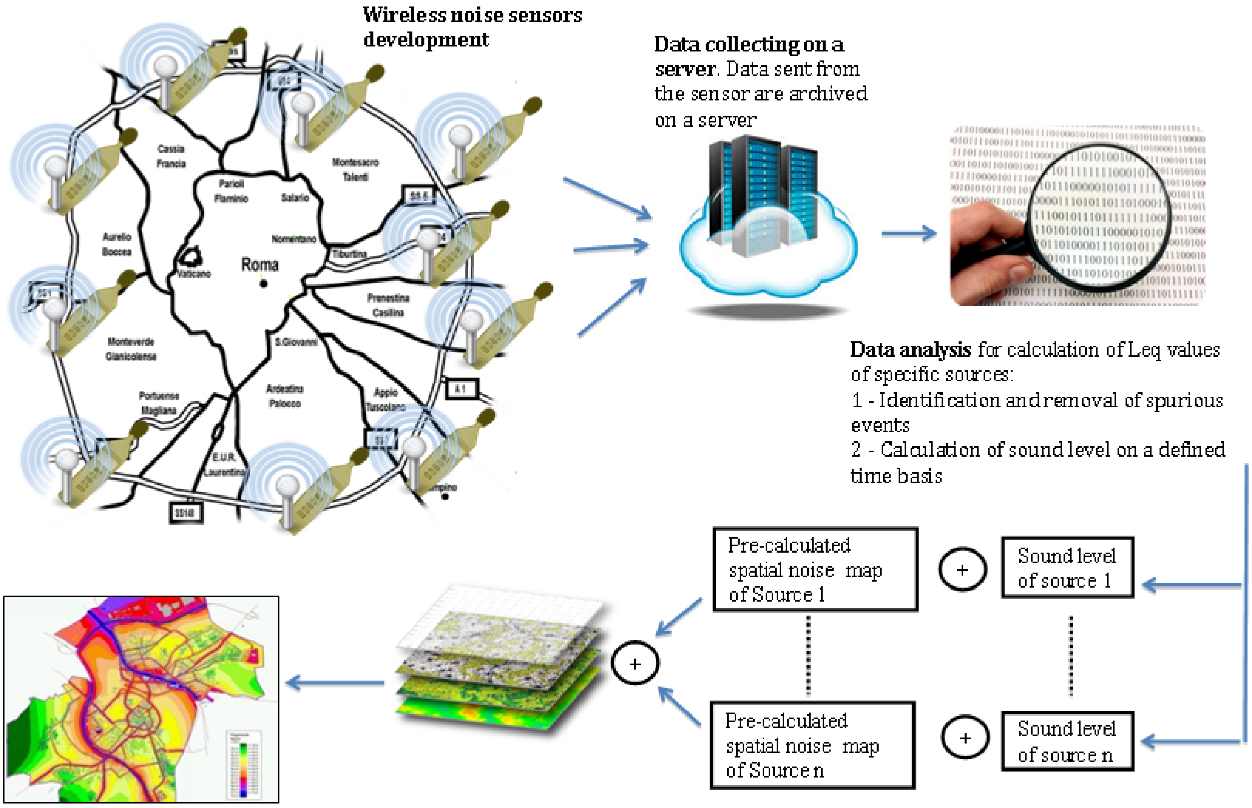

Figure 1 – DYNAMAP working principle

Two pilot areas will be selected in which to test the automatic mapping DYNAMAP system:

1 - The first pilot area will be located in the city of Milan and will cover a significant portion of the town including different types of roads and acoustical scenarios. Roads will be classified and assigned to three clusters, based on traffic characteristics. Twenty four roads representative of the clusters will be continuously monitored to provide noise levels for noise maps updating. Traffic data collected by on-site available vehicle counting devices will be integrated in the dynamic noise mapping system to improve and refine noise maps with real traffic information.

2 - The second pilot area will be located along a major suburban road: the ring road surrounding the city of Rome. Sensors devices will be installed in hot spots where vehicle counting devices are unavailable to feed the dynamic mapping system with real time information on noise levels. About 25 devices will be used to provide information on the noise levels caused by the ring road traffic and dynamically update noise maps.

THE SENSOR NETWORK

The sensor nodes will be based on low power microcontroller devices with basic Digital Signal Processing (DSP) capabilities in order to calculate noise levels. Electret microphones will be used as they provide very flat frequency response all over the acoustic frequency range. Each microphone will be protected against environmental agents and provided whit appropriate wind shield. The working range will be calibrated in order to guarantee at least a 60 dB(A) linearity range, starting from 30-40 dB(A) floor level.

The collected data will be transmitted by means of GPRS network or by WIFI urban network where available.

One of the most difficult tasks will be to identify the right location for sensor positioning in order to avoid field effects that are not taken into account in the approximate geometric model used to generate the pre-calculated noise maps.

THE ANOMALOUS NOISE EVENT DETECTION ALGORITHM

The goal of the anomalous noise event detection (ANED) algorithm is to identify the events that are not representative of road traffic noise, which could distort the noise levels measured by the sensors.

Because dynamic noise maps should display the noise levels generated by road traffic vehicles in real time, any noise event produced by another noise source could alter the levels detected by the sensors. For instance, an aircraft flying over may increase the noise level, causing a wrong picture of the noise impact on the map. The same problem may arise with multiple interfering noises, such as those produced by railways, ambulance sirens, church bells, crickets, etc. Bearing in mind that our purpose is to assess only the road traffic noise, such events should be detected and eliminated to provide a reliable picture of the road noise impact.

To that end, an algorithm able to automatically identify anomalous events and exclude them from the calculation of the noise level is necessary.

The algorithm takes as input data the information provided by the sensors installed on the road. Two kind of sensors are foreseen in the deployment of the DYNAMAP networks: low computation capacity sensors and high computation capacity sensors. Therefore, two kind of algorithms will be developed for each type of sensor, as detailed below.

1) Low computation capacity sensors: these sensors will be installed in locations where the electric grid is not available. In this case, sensors will only provide information about the equivalent noise level (Leq). Therefore, the anomalous event detection algorithm will only take the time evolution of the Leq as input information.

2) High computation capacity sensors: this type of sensor will be installed in locations where the electric grid is available and where the complexity of the environment requires more detailed information. In this case a spectral analysis of the signal will be carried out in addition to the overall equivalent noise level. Hence, the anomalous event detection algorithm will take both the equivalent sound pressure level (Leq) and the spectral data as input information.

In both cases, anomalous events will be eliminated using a supervised learning technique consisting of two main processes: i) signal feature extraction, and ii) noise event recognition. On one hand, the signal feature extraction process aims at obtaining a set of numeric coefficients (or features) representing the acoustic characteristics of the noise signal. On the other hand, the noise event recognition process should automatically decide whether the noise signal corresponds to road traffic noise or not. To that end, it will be necessary to train the classifier system with samples of labelled noise data recorded at each sensor location. To that end, on-site inspections will be carried out to collate location characteristics and record environmental noise samples.

CONCLUSIONS

Traffic noise is one of the most common and complex factors affecting citizens' lives, and as such it constitutes one of the pivotal axis of the transformation of urban environments into Smart Cities.

Despite there exists several pieces of environmental noise legislation (both at European and at national level) to regulate the limits of noise exposure, authorities lack affordable tools to certify those regulations are met with the required level of precision.

For these reasons, the DYNAMAP project aims at placing itself as one of the references at European level in the field of real time traffic noise mapping through the development of low cost sensor networks. The implementation of two prototype systems in the cities of Milan and Rome will validate the proposal in real scenarios, which will allow determining its technical capabilities and limitations. The analysis of the results of the DYNAMAP project will provide interested stakeholders with a guideline to adapt and implement real time noise mapping systems in urban locations.

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BIBLIOGRAPHY

[1] EU Directive (2002), Directive 2002/49/EC of the European parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise, Official Journal of the European Communities, L189/12, July 2002.

[2] Luca Nencini, Daniele Mastri; "Evaluation of accuracy of a low-cost noise monitoring system by direct comparison with class I instrumentation", AIA National Congress, June 2014

[3] Xavier Valero, Francesc Alías; "Gammatone Cepstral Coefficients: Biologically Inspired Features for Non-Speech Audio Classification", IEEE Transactions on Multimedia, vol. 14 (6), pp. 1684–1689, December 2012

[4] Xavier Valero, Francesc Alías; "Narrow-band Autocorrelation function features for the automatic recognition of acoustic environments", Journal of the Acoustical Society of America, 134 (1), Pt. 2, pp. 880-890, July 2013