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Crowdsourcing Data for the Elaboration of Noise Maps: a Methodological Proposal

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Abstract. In recent decades, the awareness that noise pollution caused by traffic, industry and recreational activities constitutes one of the main environmental problems is growing. In order to control the environmental noise, many regulations propose the creation of noise maps according to standard procedures that involves the data acquisition, analysis and elaboration. In this paper, crowdsourcing noise data collection is described. It involves volunteers that can record sound pressure levels thanks to specific applications on their mobile devices, such as the "NoiseCapture" app developed in France by CNRS and IFSTTAR, and upload the measurement, with their GPS location data, on a continuously updated map. This approach mainly contributes to citizens' greater awareness about noise pollution in an urban area. Beside this mode of data acquisition, the paper focuses on the analysis of the acquired data with the kernel density estimation technique, implemented in a GIS environment. The results allows the elaboration of sound density maps, defined from the spatial and temporal point of view, that can support the appropriate mitigation actions.

1. Introduction

Urbanization, population and economic growth are some causes of the environmental noise pollution. Specifically, its effects on human health can be assumed mostly deriving from an increase of mankind's industrial, commercial, transport-related and recreational activities [1].
Currently, the health impacts of environmental noise are a growing concern among both the general public and authorities in Europe. Already in 1999, World Health Organization (WHO), highlighting the negative effects of noise on health, published recommendations on guideline values to protect public health [2]. In 2018, these guidelines were updated to the transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise [3]. Moreover, the European Union (EU) enacted a directive on the environmental noise in 2002, inviting the EU Member States to produce strategic noise maps and action plans [4]. According to it, the maps can be produced in relation to sound emission calculations and mathematical models for the propagation law of sound, using standard or advanced methods (see for instance [5-8]), or with the aid of a measurement campaign.
Recently, another approach, that involves people in the data acquisition, is becoming increasingly popular in the research field [9]. Each citizen, with his smartphone and tablet, can easily contribute to environmental noise data collection [10]. These devices, indeed, combined with the GPS tracking, allow the display of the results in interactive maps and the generation of noise maps [11] in a GIS-based model. Despite the lower quality of acoustic measurements than the traditional methods, in [9] is discussed the relevance of the approach. Consequently, the participatory sensing can be considered a low-cost

alternative to large-scale and costly infrastructures sensing based on sensor networks [11]. Moreover, this approach allows the production of more realistic noise maps [12], integrating all the involved sound sources and their temporal dynamics.
Starting from these considerations, this paper aims to deepen the aspects related to environmental noise mapping. In particular, the goals are to highlight the potential of crowdsourcing data collection tool for the acquisition of voluntary data on sound pressure levels, and to generate sound density maps, in a GIS environment, in order to better understand the noise distribution, spatially and temporally.

2. Noise mapping tools

Among the several tools proposed for crowdsourced data collection, in this paper the focus is on the Noise-Planet project [13], that is led by two French research teams: the Environmental Acoustics Laboratory (Eiffel University, former IFSTTAR) for environmental noise research and the DECIDE Team (Lab-STICC - CNRS UMR) for GISciences. In this project, the data is collected from the free and open-source Android NoiseCapture application and shared from the OnoM@p Spatial Data Infrastructure (SDI) [14, 15]. The Noise-Planet project is integrated also with a free GIS-based model to compute noise maps and an interactive maps viewer, to display noise data collected by the community.
The NoiseCapture approach consists in computing each second the equivalent A-weighted sound levels along a path and then sharing data with the community. All data are aggregated in cells with the shape of a hexagon, in order to produce mean noise indicators in each one [12].
In order to overcome the problem of non-continuity between cells, the function of the kernel density estimation can be applied. Among Point Pattern Analysis, that is a family of the spatial analysis techniques, the function of density is estimated by counting the number of events in a region, said kernel, centered at the point where it is preferred to have the estimate. While the simple density function examines the number of events for each element of the regular grid that composes the study region, the kernel density considers a movable surface in three dimensions, which weighs the events according to their distance from the point of which the intensity is estimated [16].
The density or intensity $\lambda(L)$ of the distribution at the point L can be defined by the equation:

$$\lambda(L) = \sum_{i=1}^{n} \frac{1}{\tau^2} k\left(\frac{L - L_i}{\tau}\right) \tag{1}$$

where L_i is the i-th event, $k(L, L_i, \tau)$ is the kernel function, which weighs the events according to their distance from the point it is estimated, and τ is the bandwidth, i.e. the radius of the circle centered at L within which the events contribute to the estimate. The bandwidth must be evaluated according to the phenomenon and must be analyzed and determined for subsequent adjustments.
Thanks to the integration of Kernel Density Estimation in a GIS environment it is possible to produce raster maps in function of the attributes associated with geometric primitives, that are representative of the designed pattern [17].

3. Methodology for noise analysis and mapping

Starting from the participatory noise platform and the stakeholders involved, a methodology for noise data analysis and mapping is developed in this paragraph. The proposal regards the experts who, with the data collected in crowdsourcing, can make further analysis. The whole process can be developed in a GIS environment and is organized in two phases (Fig. 1).
First of all, the expert builds a database made of the crowdsourcing data, open data and all the official information shared by other infrastructures, like public bodies and technical offices.
The second phase performs a spatial analysis of the phenomenon. Since both acoustical and statistical indicators are computed for the whole duration of the measurement, it is possible to generate their density maps through the Kernel Density Estimation function. These maps can be understood as sound effective and perceived maps of the study region, that can support the policymakers' decision and, as a consequent, address the actions that affect citizens.

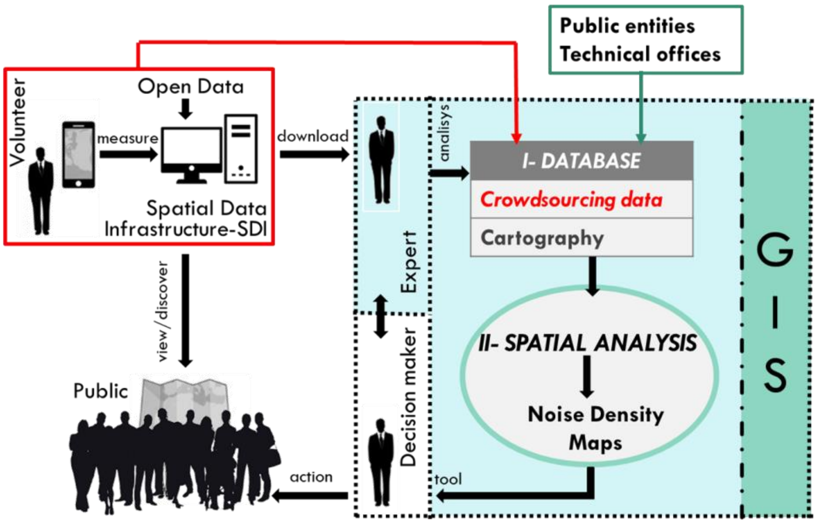

Figure 1. The methodology diagram.

4. The case study of Fisciano Campus

The case study is the Fisciano Campus of the University of Salerno, located in the Municipality of Fisciano, in South Italy (Fig. 2). The choice of this case study derives from the availability of the sound environmental noise measurements carried out mostly in two sound-walks (NoiseCapture Parties) organized by the Applied Physics Laboratory at the Department of Civil Engineering of the University. In these events, organized on May 17, 2018 and May 24, 2019 in the Campus, most of volunteers, who collected data with the NoiseCapture app, were students of the Physics course of the Bachelor Degree of the study programs offered by the above Department. The students were asked to calibrate their own smartphones in the lab and use them to record the environmental noise. Indeed, the aim was to bring together a large number of noise measures simultaneously along a path and, then, to share data with the community, in order to create a participatory noise map. These measurement campaigns were organized to cover the largest possible area in the Campus and some areas were preferred for their destination and use. The criteria for choosing the paths were the proximity to the squares, where a large number of people concentrate during the day, the roads and the car parks, for the vehicles' noise, and the green parks, within which it was supposed that there would be a pleasant noise condition.

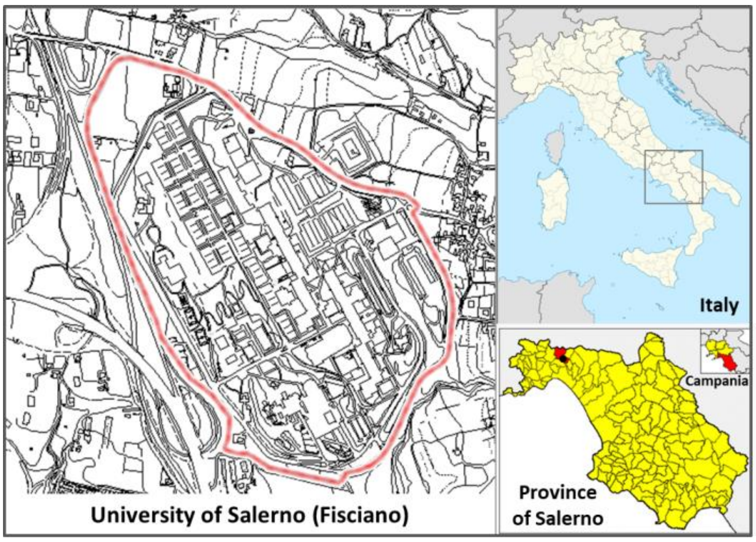

Figure 2. Fisciano Campus – University of Salerno (Italy).

From the noise-planet.org website, the noise measurements of the Fisciano Campus were acquired in *.geojson* format, divided into *points* and *areas* files, which have specific characteristics in terms of geometry and other information.

The first type, the *points* file, contains the value of sound pressure level measured at that point in a time of 1 second, expressed in dB. The *areas* file corresponds to a basic post-processing of all measurements produced by the community and all data are aggregated in hexagons, in order to produce mean noise indicators and information in each hexagon [12]. The file contains only the hexagons with at least one measurement point belonging at the *points* file. Its attributes table has several fields, but those relevant for this work are the $L_{A,eq}$ (Fig. 3).

The *points* and *areas* files were converted into *shapefile* format and processed in a GIS environment with the function of the kernel density. The output is a raster map for each measured parameter, generated in ArcMap© produced by ESRI. For the study case, the function has been evaluated considering 100 m for the radius is and a cell sized 20 m x 20 m, with a total area of 400 m^2, comparable to the area of the hexagons (Fig. 4).

The creation of different density maps, representing the spatial distribution of sound pressure level of the points and the areas, should define a protocol for future measurement campaigns necessary to implement the noise maps and monitor the acoustic status of the campus.

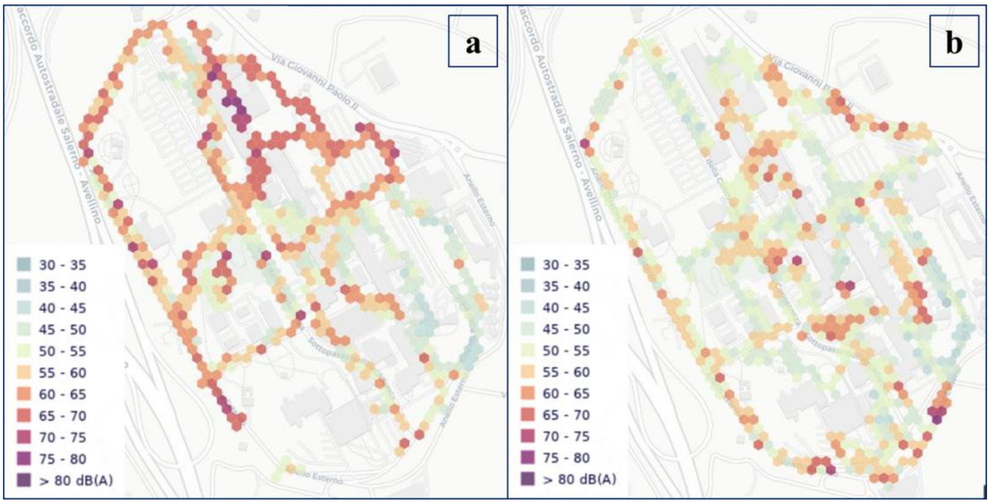

Figure 3. NoiseCapture Party Maps – a. 17/05/2018; b. 24/05/2019 (noise-planet.org, ODbL).

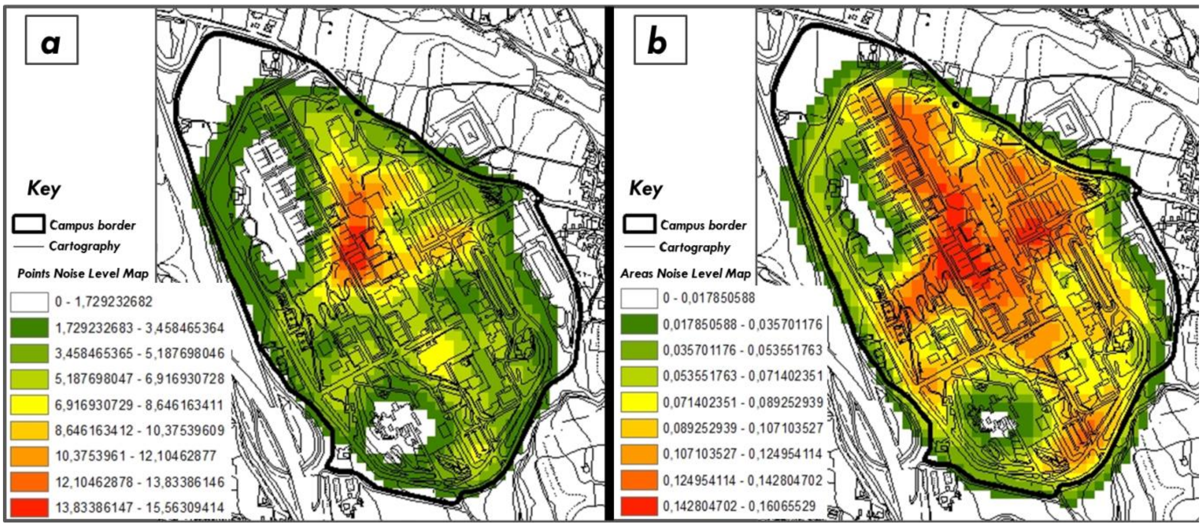

Figure 4. Noise Level Density Maps deriving from: a. *Points* measures; b. *Areas* measures.

5. Conclusions

In this paper, spatial and temporal density maps of sound pressure levels have been generated, starting from data measured by citizens. A methodology for spatial and temporal noise analysis and mapping has been defined. After the acquisition of the data and their analysis in the first phase, density maps of the acoustic parameters have been generated. The methodology has been tested in the Fisciano Campus of the University of Salerno, where crowdsourcing noise data collection was organized twice in the last years. Thanks to this data, recorded by volunteers and uploaded on the Noise-Planet platform, noise density maps were created in the GIS environment, with the use of the Kernel Density function. A future development of the research could be the interaction between the noise density maps and the different urban destinations, because most of functions can generate noise and suffer its effects. Consequently, the use of this methodology, on different territorial scales, can also be supportive both for the actions to be taken to reduce and contain noise, and for the location choices of the urban transformations.

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