DOI: 10.61782/fa.2023.0511

SOUNDSCAPE INDICATORS ASSESSMENT AND MAPPING IN A UNIVERSITY CAMPUS

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ABSTRACT

The acoustic environment of a University campus is very complex since it usually includes i) zones in which the quietness is very important, to foster concentration needed for working and studying, ii) parking lots and internal road networks, iii) vibrant areas, populated by students and personnel during free time. For this reason, the campuses can be a very interesting case study for testing soundscape analyses tools, as well as to perform research of innovative methodologies for soundscape assessment and mapping. In this paper, the Fisciano campus of the University of Salerno (Italy) is presented as a case study, in which several measurements have been performed. In particular, the results of a soundwalk performed according to the ISO TS 12913 will be presented, together with the data obtained in crowdsourcing mode, collected within the celebration of NoiseCapture parties, organized in the campus during the last years. The NoiseCapture app, in fact, allows to collect both the physical sound levels and the pleasantness rated by participants during the events. The available data of mean pleasantness recorded along the campus will give the chance to test new methodologies for mapping of the detected soundscape. In particular, an Inverse Distance Weighting (IDW) interpolation technique will be proposed and validated on the mean pleasantness measured during the soundwalk. The results will give interesting hints about the proposed methodology.

Keywords: *Soundwalk, GIS mapping, NoiseCapture app, sound perception, pleasantness.*

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1. INTRODUCTION

The soundscape research is becoming more and more relevant in the scientific literature, thanks to a large awareness of the damages and risks deriving from living in noisy and annoying environments. Beside the development of new techniques for noise assessment and modeling, in fact, there is a large part of the acoustic community that is now turning on soundscape analyses to involve the subjective perception in their studies.

In this framework, the study of particular locations such as schools, universities, workplaces, vibrant areas, sport facilities, etc., is very important to highlight possible peculiarities in the soundscape, according to the land use and to the activities pursued in the site under study. There are several studies, for example, devoted to the investigation of the natural soundscape in parks or green areas. Uebel et al. provided more evidence to the idea that natural sounds can improve the quality of the perceived acoustic environment and even mask urban noises. In particular, their studies proved that the increase of natural sounds levels does not reduce the positive perception of the environment, differently from anthropic kinds of sounds. [1]. Liu et al. proposed questionnaire surveys to assess the relationship between soundscape perception and public visiting experience in the city parks, focusing on the changing of sound source characteristics in the urbanization process. [2].

Furthermore, a study by Masullo et al. assessed the possibility that even being surrounded by historical-artistic art forms could be just as relevant as a natural component for people's restorative capacity. [3]

The perceptive side was combined with the physical one in the research of Can et al. that proposed a procedure to physically describe and to categorize urban sound environments making it possible to determine particular

areas and periods remarkably suitable for stress recovery [4].
Also, the ecoacoustic soundscape studies are more and more developed, using sound recordings to calculate ecoacoustic indexes and to infer details about health quality of the natural area under study [5-6].
As for University campuses, some studies can be found in literature.
Puspagarini et al. reported how the soundscape in the campus of Yogyakarta, in Indonesia, was influenced both by anthrophony and natural sound sources, as any urban park. With respect to different locations, different sources were analyzed and found to be dominant, including animals and in particular insects, water sounds, road traffic noise and even human voices [7].
In [8], Aletta et al. estimated the willingness of users to stay in an open public space at the University of Sheffield (UK), measuring people staying time under different music stimuli and in a controlled condition.
In [9], the soundscape of the campus of Fisciano of the University of Salerno, Italy, was assessed by means of a soundwalk organized by some of the authors, using the recommendation reported in the ISO 12913–2 [10]. The results confirmed the expectations that the vibrant areas, as well as the small park in the campus, were the locations with the best soundscape in terms of appropriateness and willingness to return.
In [11], the same data has been used for a deeper investigation, including also a circumplex model 2D plane plot, that relates all the soundscape attributes and shows the relations among them.
In this paper, the authors propose a soundscape mapping of the campus of Fisciano, University of Salerno, based on pleasantness data recorded with a trained crowdsourcing technique. The data, in fact, are provided by students of the Engineering Departments, trained by some of the authors to provide reliable sound level measurements and assessment of the soundscape quality. Results will be compared with the data collected during the soundwalk activity and presented in [9] and [11], to validate the mapping procedure and to highlight strength points and/or possible shortcoming of the proposed methodology.

2. MATERIALS AND METHODS

In this paper a methodology to draw a soundscape map of the campus under study is presented, starting from the sound perception rating provided by the participants to 4 events at the University of Salerno (Figure 1), named after "NoiseCapture parties".

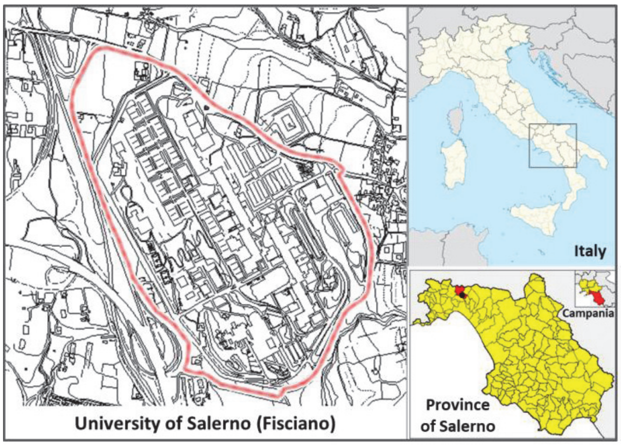


Figure 1. Location of the campus of Fisciano, University of Salerno [11]. Red line in the left plot is the Campus border.

These parties have been organized by some of the coauthors, under the patronage of the Noise-Planet project team [12], with the aim of spreading the noise awareness among future engineers (all the participants were students of engineering disciplines) and promoting the tools for environmental noise assessment developed within the project. Among these tools, in fact, the colleagues from Université Gustave Eiffel, CEREMA, UMRAE, France, developed the NoiseCapture app for Android, for measuring the sound levels with the mobile phone's microphone [13]. At the end of each measurement, the user can provide a rating of the pleasantness, on a five-points unipolar continuous-category scale, together with the identification of the predominant sources operating during the measurement (see Figure 2). The measurement is embedded with the device identifier and the GPS position and, once stopped, can be uploaded on a cloud that feeds the online and real time map available at the Noise-Planet project website [12]. The pleasantness rated by the user is assigned to the measurement and averaged with all the pleasantness recorded in the same hexagonal area.
The raw data packages are updated on a daily basis and can be downloaded from a repository, selecting the country, in a compressed folder including points, areas and trajectories files of the measurements uploaded by the users. Once downloaded, the data can be imported and handled in any GIS software.

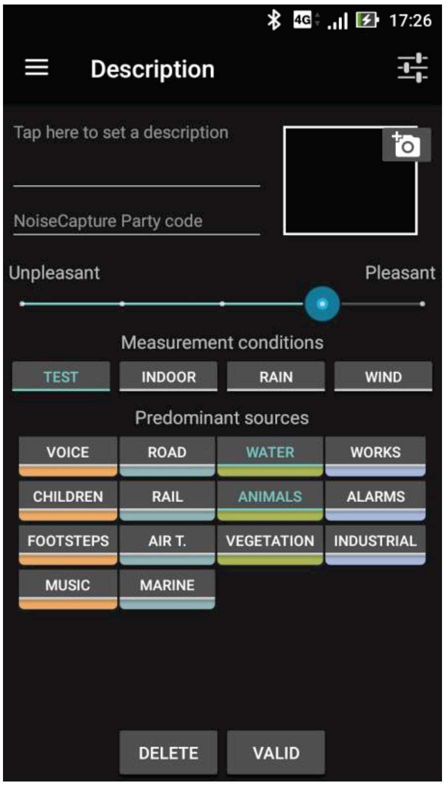


Figure 2. Screen of the app NoiseCapture at the end of measurement, with the five-points unipolar scale to provide pleasantness rating and predominant sources [12].

The idea presented in this paper is to use the mean pleasantness recorded by trained users during selected sessions of NoiseCapture measurements, that are the NoiseCapture parties, to draw soundscape maps of the area under study.

During a NoiseCapture party the participants are firstly asked to calibrate their mobile phone's microphone with one of the several possible techniques listed in the app itself. In the University of Salerno's events, calibration of the used devices has been achieved either by the comparison with a first-class sound level meter or by the spreading of the proper sound level correction factors from a calibrated mobile phone to another via wireless connection.

The students have been divided in 5 teams, each of them including at least 3 calibrated mobile phones, and they have been asked to walk along the route assigned to each group, as in Figure 3a, measuring the environmental sound level. The students have been asked to stop the measurement each time a relevant variation of the soundscape occurred, in order to provide homogeneous information about pleasantness and predominant sources. This rule leads to many short measurements that can be handled in a GIS environment and can be used for mapping purposes. In this case, the authors used QGIS©.

In addition to the NoiseCapture parties, the authors organized a soundwalk, performed following the ISO 12913-2 [10], using questionnaires proposed in method A and method B reported in Annex C3. The soundwalk was carried out on March 8, 2019, with the participation of 22 students, following the route and the points reported in Figure 3b. The selected students regularly frequent the campus and, thus, have been considered local experts of the area under study. This kind of contribution is crucial to collect and analyze ecologically valid acoustical and perceptual data [10]. More details about the soundwalk are reported in [11], in which a comprehensive description of the activity is reported, together with a detailed data analysis. Table 1 reports a summary of the main features of the selected points, as well as the sound continuous equivalent levels measured in each point, with a calibrated class 1 sound level meter (Fusion, 01dB).

Table 1. Description of the measurement points and L_{eq} results.

Location	Description	L_{eq} [dBA]
Point 1	Vehicles entrance and parking lots	55.2
Point 2	Main park, close to the scientific library	53.3
Point 3	Rectorate square, close to the main library	48.3
Point 4	Central square, close to a fountain and a bar	57.0
Point 5	External area, close to HVAC plants	68.2
Point 6	Pedestrian road to the bus station and canteen	55.4

This soundwalk provided robust subjective data about the soundscape of the campus that will be used for comparison with the pleasantness map produced in this paper, to validate the methodology proposed.

It is worthy to notice that the pleasantness provided by the NoiseCapture data is given in percentage, rating from 0% to 100%, respectively from unpleasant to pleasant, with steps of 25%. On the other hand, the data collected according to

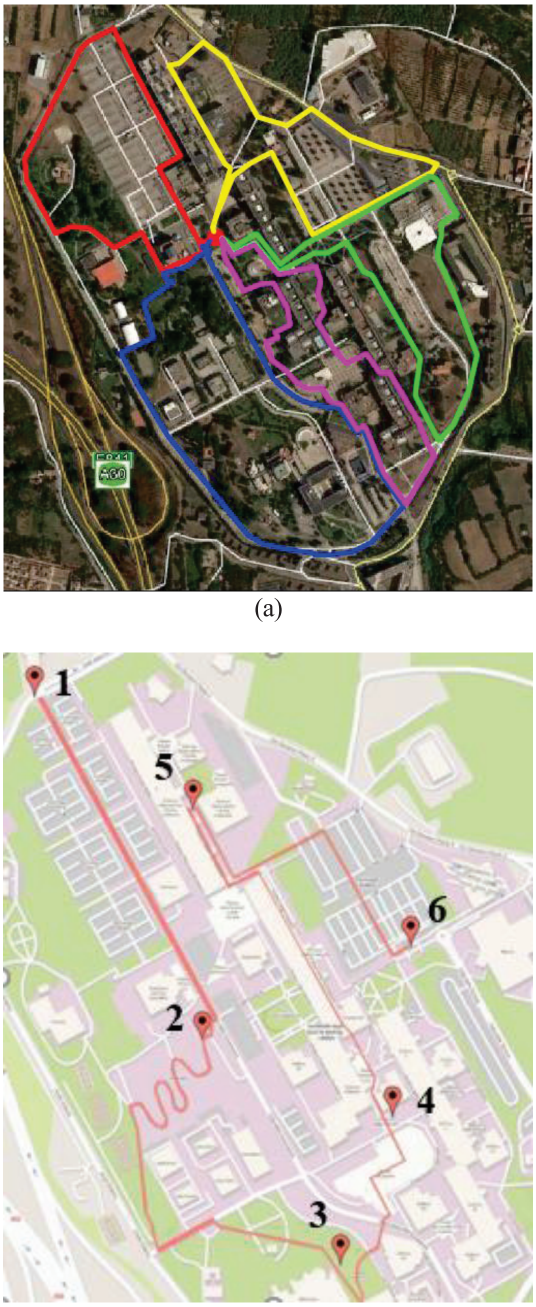
method A of the ISO standard are given in a scale from 5 to 1, from "strongly agree" to "strongly disagree" about how pleasant the soundscape of each point is. The two scales are not directly comparable, thus the authors converted the 5-1 scale of method A to 100%-0%. This was possible because of the availability of the single questionnaire results.
As for method B results, since they refer to the soundscape unpleasantness rating, they have been converted into the mean pleasantness by assuming that "non unpleasant" is "pleasant". This procedure, of course, can lead to a misestimation of the pleasantness, since the subjective rating of how much a location is unpleasant may be affected by the question structure. Asking about the unpleasantness, in fact, may influence the participant and let her/him focus on the negative factors more than on the positive ones, and vice versa. This peculiarity of method B will be confirmed by a general underestimation in the pleasantness results presented in the next section and will lead the authors to use method A results for validation of the mapping, adopting the scale in percentage, as proposed in the NoiseCapture application. The app, in fact, asks to rate the unpleasantness/pleasantness perception in a more neutral way, using a five-point unipolar scale (see Figure 2).

3. CASE STUDY AND RESULTS

The case study presented in this paper is the campus of Fisciano of the University of Salerno. The authors downloaded the data related to Italy and to Salerno province, in which the campus is located. A filter on the date and on the hour has been implemented, to select only the measurements performed during the NoiseCapture party events, celebrated in:

- NoiseCapture@Unisa 2018: 17th of May
- NoiseCapture@Unisa 2019: 24th of May
- NoiseCapture@Unisa 2022: 16th of May
- NoiseCapture@Unisa 2022 fall edit.: 9th of November

This allowed to work with controlled data, recorded by trained users, that are the students involved in the events, thus reducing the probability of corrupted data uploading. Firstly, the mean pleasantness attribute present in each hexagonal area of the campus has been plotted with a color gradient scale (Figure 4). At this stage, the map does not include any spatial interpolation of the data, but only serves as a "guide for the eye" and represents the database used for the following analysis.



(a)

(b)

Figure 3. (a) Paths of the NoiseCapture parties (modified from Google Maps©) and (b) route of the soundwalk [11].

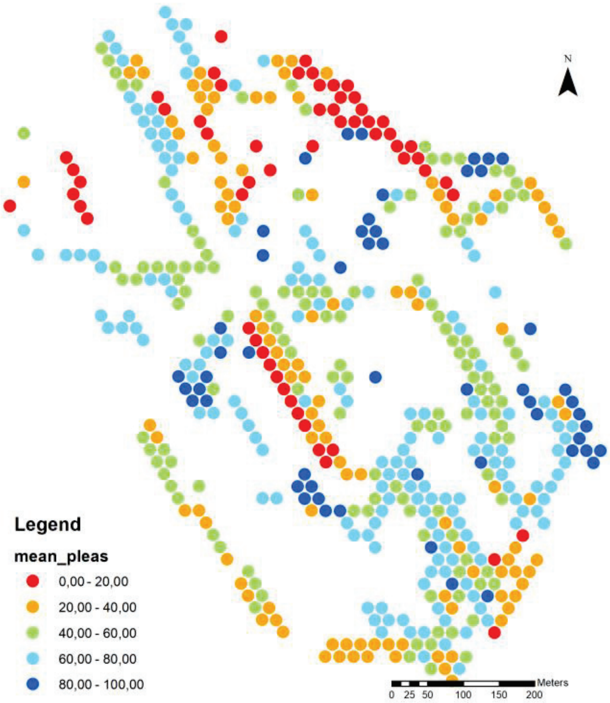


Figure 4. Mean pleasantness measured during the NoiseCapture parties, aggregated on the centroids of the hexagonal grid elements of the OnoMap used for Noise-Planet project.

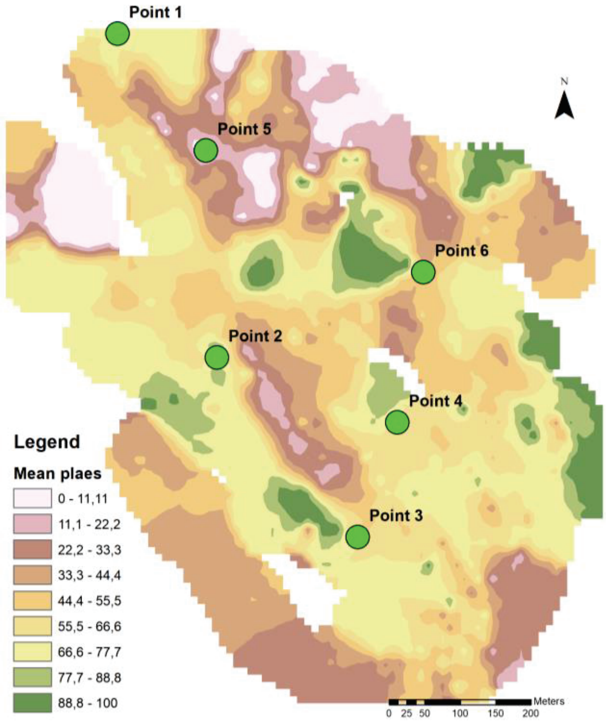


Figure 5. IDW interpolation map of the mean pleasantness in the Campus of Fisciano. The green points are the soundwalk stations.

Preliminary comments have been drawn, noting that the areas in which the mean pleasantness is low correspond to those locations in which there is a relevant noise coming from heating/cooling systems or from the nearby roads. On the contrary, the areas with higher pleasantness in the map correspond to locations generally with a better soundscape, for instance the parks and the vibrant areas.

Table 2. Mean pleasantness measured with the soundwalk methods and simulated with IDW mapping.

Point	Method A [%]	Method B [%]	IDW map [%]
Point 1	52.3	50.9	75.0
Point 2	72.7	58.6	77.5
Point 3	67.1	57.2	60.3
Point 4	61.4	52.8	61.0
Point 5	2.3	9.0	4.9
Point 6	54.4	46.0	46.6

Starting from the mean pleasantness recorded during the NoiseCapture parties in each hexagonal area, the authors decided to perform an Inverse Distance Weighting (IDW) interpolation to produce a map of the campus pleasantness. The fixed search radius for the IDW interpolation has been set to 50 m. The classification has been obtained with natural break method. The resulting map is reported in Figure 5.

The map built with the above-described procedure has been then compared with the pleasantness recorded during the soundwalk performed by a group of students, as described in section 2. In particular, the pleasantness measured during the soundwalk, according to method A and method B, has been compared with the results obtained by the IDW interpolation in the 6 points of the soundwalk (see Figure 3b and Figure 5). These data are resumed in Table 2 and plotted in Figure 5.

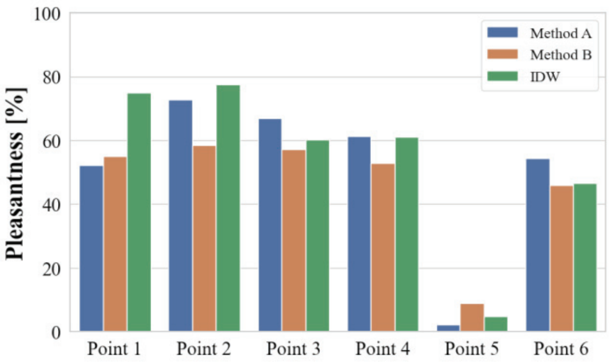


Figure 6. Comparison of mean pleasantness measured with the two methods during the soundwalk and simulated with the IDW interpolation of the NoiseCapture parties data.

The comparison highlights that the IDW interpolation is in a quite good agreement with method A in almost all the points, except for Point 1. It is important to note that this point is affected by lack of surrounding measured data (see Figure 4). To overcome this problem, a mean of the pleasantness recorded in the nearest points in a range of 100 m has been calculated, resulting in a value of 60.4%, that is much closer to the value measured during the soundwalk. This could be considered a good option to overcome the problem of missing data in the interpolation dataset. The choice of 100 m for the proximity analysis was supported by the homogeneity of the soundscape of the area, in which roads and parking lots are present as main sources. The influence of the radius selected to consider a measurement "close enough" to influence the pleasantness in a given point is of course a key point of this calculation. When applying the same procedure and calculating the mean pleasantness of nearby measurements for the other points, in fact, results are not always converging to the method A measured pleasantness, that can be considered as a benchmark. In point 5, in fact, the inclusion of measurements that are 100 meters away from the point led to a value of 35.3%, that is much higher than 2.3% of method A result and is not in line with the personal experience of the authors. Point 5, in fact, is very close to noisy cooling/heating plants [11]. In the authors' point of view, it's hard to give a fixed value for the "influence radius", that can be considered acceptable in all the applications, since the proximity should be estimated in terms of soundscape homogeneity. A more detailed analysis of sensitivity to distance radius could be performed in further studies, to obtain optimal thresholds ranges.

As already discussed in section 2, method B is affected by the formulation of the question during the survey, since it asks to rate from 1 to 5 how much unpleasant the location under study is, influencing the participant to focus on the negative factors of the site. Point 2 result is a good example of this comment. It is located in a green park of the campus, full of natural sounds and greenery. Anyway, the soundscape of this point is affected by the highway that runs very close to the campus border, a few hundreds of meters away from the park. For this reason, the same participants gave a high rating in method A questionnaires about how much pleasant this site is, including also the visual factors and the presence of the natural sounds. However, when they concentrated about the unpleasantness, they focused on the presence of the annoying noise coming from the highway and the overall results were worse than the one measured with method A. This effect is not included in the NoiseCapture parties data, in which the question about pleasant-unpleasant soundscape is given in a more neutral way.

Despite the comments reported above, the agreement between the IDW interpolated map and the results of the soundwalk is reasonable. The mean errors are about -2.5% and -8.5%, respectively for method A and method B. The general overestimation of the IDW map is influenced by the results in point 1. Excluding this point from the calculation of the error, because of the bad interpolation due to missing measured data, the mean errors are respectively +1.5% and -5.3%.

4. CONCLUSIONS

The need to map soundscape attributes and indices is becoming more and more important. In this paper, the authors proposed a methodology to map the pleasantness of a University campus, by using crowdsourced data, provided by the NoiseCapture app during the celebration of "NoiseCapture parties at Unisa", with a selected group of trained students. These data, averaged in a hexagonal grid, have been used for building a IDW interpolation map. The results of the mapping have been validated on 6 points included in a soundwalk carried out by some of the authors in the same campus, according to the ISO standards.

The validation showed that the mean pleasantness obtained by the IDW mapping in the 6 points was comparable with the values measured with method A of the ISO, assumed as benchmark, with a slight overestimation and a mean error of -2.5%. Considering the first point as an outlier, because there were no nearby points for the IDW interpolation, the mean error was +1.5%.

More in general, it can be concluded that the map of the pleasantness obtained with the IDW interpolation of the NoiseCapture parties data is a reliable tool to provide information about the spatial distribution of the phenomenon, even though the results can be affected by the homogeneity of the soundscape of the site. Anyway, a proper choice of the simulation parameters and the possibility to merge results from nearby points may be useful to finely tune the mapping procedure and to produce even more robust results.

5. ACKNOWLEDGMENTS

The authors are grateful to all the students that took part in the NoiseCapture parties along the years. The authors also acknowledge the contribution of the bachelor and master students that worked on this project during their thesis activity. A special thank goes to the students Antonio Marino, Valentina Pepe, David Vuto, Simone Toscano and Francesca Castella, that voluntarily realized the short videos of the events, published at [14].

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