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THE ROLE OF PLEASANTNESS MAPPING IN A UNIVERSITY CAMPUS FOR STUDYING SOUNDSCAPE SUBJECTIVE PERCEPTION IN EVOLVING ENVIRONMENTS

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ABSTRACT

The diversity of acoustic environments within a University campus makes it an ideal case study for exploring soundscape mapping and assessment methodologies. This study focuses on the Fisciano campus of the University of Salerno (Italy), where acoustic and soundscape data have been collected over recent years at different times of the day and across various seasons, offering insights into the temporal evolution of distinct acoustic environments. Soundscape maps were created using spatialization techniques based on perceptual metrics such as pleasantness, while physical sound levels were considered to better understand the acoustic characteristics of the areas. The data were obtained through soundwalks conducted in accordance with ISO 12913 guidelines, as well as crowdsourcing campaigns using the NoiseCapture app. In this work, the maps are used to facilitate an analysis of the campus soundscape's evolution, by comparing results obtained using data collected over the years and considering changes in daily and seasonal activities. This work highlights the potential of soundscape mapping to understand the interplay between acoustic environments and human perception in complex settings that evolve over time, contributing to the development of innovative tools for soundscape analysis and urban planning.

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1. INTRODUCTION

Globalization, economic growth, and international policies aimed at broadening access to higher education have led to a rise in student enrollment worldwide [1, 2], with projections indicating that the number of students could even exceed 600 million by 2040 [3]. As a consequence, university campuses have become increasingly dense and complex environments, where various factors influence both student well-being and their academic performance. Among these, the acoustic environment plays a crucial role as it directly impacts psychological health and learning outcomes. Numerous studies have shown that noise conditions within campuses can significantly affect students' listening abilities, cognitive performance, and overall mental well-being [4, 5], highlighting the need for careful planning of university spaces. Mealings et al. conducted a scoping review that highlighted a considerable negative relationship between road noise and students' acoustic comfort [6]. Therefore, recent research has shifted toward a more holistic approach, emphasizing not only noise reduction but also the quality of the overall acoustic environment. In this context, the concept of soundscapes within university campuses has gained attention. However, analyzing the soundscape of such areas can be challenging as they are not entirely uniform, presenting various ranges of areas and functions and exhibiting significant variability in their acoustic characteristics. Hence, studying the university's soundscape requires an

approach that accounts for the different acoustic contexts of the various zones across the campus, each influenced by unique configurations and interactions. This is the case of Zhuang and Shang's study, who observed that Linyi campus (China) is characterized by teaching areas and green spaces which generally meet national noise standards, while dormitories, restaurants, sports fields, and the main gate exceed them due to chatting and traffic noise [7]. Similarly, D'Alessandro et al. highlighted how in urban university settings, high traffic and noise pollution can compromise the quality of external spaces [8]. On the other hand, natural sounds can help to enhance soundscape perception. Nevertheless, during high-traffic periods, the masking effect produced by natural sounds and surrounding context may not be enough to minimize such negative sounds [9]. It's then clear that to study the soundscape of a university campus, it's essential to understand how the acoustic environment, its landscape, and all its features evolve and vary.
This variation occurs both spatially, as different sound sources shape the acoustic environment in distinct areas, as stated earlier, and temporally, as the soundscape transforms over time due to daily activity patterns, seasonal changes, and special events that can influence the overall acoustic dynamics. Within this framework, this paper aims to investigate the soundscape of the Fisciano campus of the University of Salerno (Italy) as a case study. The analysis relies on soundscape data collected at specific locations through soundwalks, along with pleasantness data gathered via a crowdsourcing method [10, 11]. Additionally, soundscape pleasantness maps, derived from the interpolation of this crowdsourced data [12–14], will be analyzed, with a particular focus on temporal dynamics. Specifically, the dataset used includes measurements collected over multiple years and across different seasons, enabling a more comprehensive examination of both the spatial distribution and temporal evolution of the campus soundscape. This approach may offer deeper insights into the interplay between physical parameters, perceptual evaluations, and the acoustic environment, shedding light on how these factors interact and transform over time.

2. METHODOLOGY

In this study, the methodology proposed by Mascolo et al. [12, 13, 15] for generating pleasantness maps of a given area is applied with different time references to analyze the evolution of the campus soundscape over time. The process relies on the collection of sound perception ratings for a specific soundscape attribute to be represented by the maps—in this case, pleasantness.
For this reason, a series of volunteer-based participatory events (i.e., "NoiseCapture parties" [16]) were organized to help with data collection. These events aim at raising awareness regarding noise pollution and promoting the use of tools for environmental noise assessment, particularly those developed within the framework of the NoisePlanet project [17]. Through the use of the "NoiseCapture app", indeed, participants can measure sound levels using their mobile phones' microphones and provide perceptual ratings of the pleasantness of the soundscape on a five-point scale. These measurements constitute the crowdsourced database that has been used to generate the soundscape maps. After completing each measurement, users can also specify the predominant noise sources [15]. The recorded measurements, along with the corresponding pleasantness ratings, can be retrieved from a public repository, allowing users to download point, track, and area datasets. Pleasantness values are available in both the point and area datasets. In the point dataset, these values are assigned to each point along the recorded trajectory, with all the points collectively representing the track followed during the measurement. As for the area dataset, pleasantness values are calculated as the average of all individual point-based ratings that fall within each predefined hexagonal grid cell. By averaging the ratings from all the points within the hexagon, this approach provides a spatially aggregated representation of how users perceive the acoustic environment in that area.
In the authors' previous studies [12, 13, 15], the analysis was pursued on area-based layers and thus with mean values of pleasantness collected throughout the years. Thus, it provided an overview of spatial variations but did not allow for a more detailed temporal analysis. In contrast, the present study aims to examine the soundscape evolution over time by processing point-based data. By doing so, a year-by-year comparison of how the perceived acoustic environment has changed across time could be achieved, generating pleasantness maps for each edition of the NoiseCapture parties. Pleasantness maps have been drawn in a GIS environment through an Inverse Distance Weighted Interpolation method (IDW). To validate the interpolated maps, the authors organized two soundwalk activities across the campus under study to rate the pleasantness in specific locations. The first soundwalk included 6 designated stopping points where participants paused to experience the soundscape and subsequently filled out the questionnaires. The second soundwalk comprised the

same 6 points, plus 3 additional stepovers used to improve the analysis. The pleasantness ratings were obtained following the ISO 12913-2 guidelines [18], using questionnaires from method A, Annex C3, of the Technical Specification.

3. CASE STUDY

The study focuses on the Fisciano campus of the University of Salerno, Italy. The campus hosts a variety of facilities, including lecture halls, laboratories, offices, libraries, the canteen, and sports facilities. The architectural layout integrates pedestrian pathways, vehicular roads, and multiple gathering spaces and green areas.
Figure 1 provides the exact location of the stepovers used during the soundwalk activities, with points from the first soundwalk marked in red and those added during the second one marked in blue.

3.1 Acoustics characteristic of the Campus

The campus' acoustic environment is shaped by the different characteristics and functions of each zone. All areas of the campus, with their predominant sound sources and, thus, the experience users have there, tend to follow a consistent pattern. However, their acoustic environments are not always static and can vary depending on factors such as the time of day, season, and weather conditions.
Certain zones, for example, are characterized by a lot of greenery, with natural sounds like birdsong and wind, offering a tranquil atmosphere. Parks and tree-lined walkways also serve as buffer zones that can mitigate the propagation of near-road traffic, contributing to a more balanced acoustic environment. However, seasonal changes may influence the presence of vegetation and wildlife, while weather conditions, such as wind or rain, may alter sound propagation and overall auditory perception.
The central part of the campus is occupied by buildings, including lecture halls, laboratories, faculty offices, libraries, and the canteen. The acoustic environment in these areas is primarily influenced by human activities, such as conversations, footsteps, and so on. They can be very dynamic environments, changing throughout the day, with peak noise levels during class transitions and breaks and quieter periods during lectures or outside standard working hours. Moreover, in winter, noise from heating systems may be present. Lastly, multiple roadways and parking areas introduce traffic-related noise inside the campus environment. Vehicular movements, particularly during peak hours, for example, right before class hours, affect the surrounding soundscapes. Variations in traffic levels can be observed within different seasons, particularly during course periods or exam sessions. Table 1 shows the main characteristics of the points investigated in the Fisciano Campus of the University of Salerno.

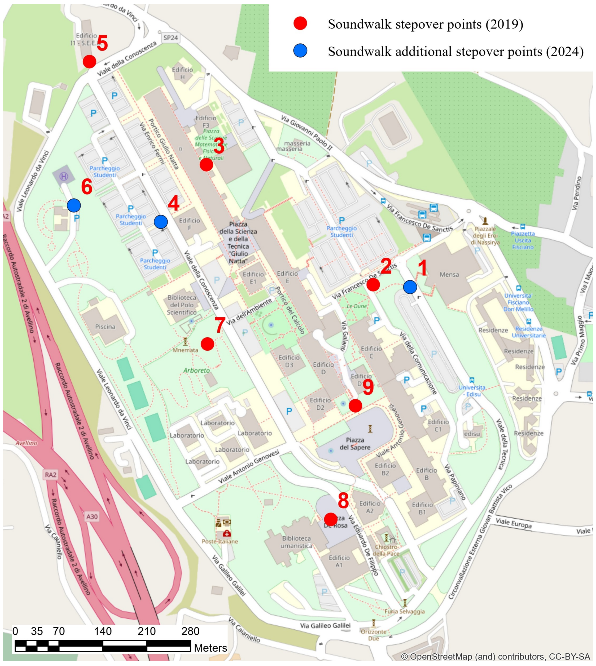

Figure 1. Map of the campus from OSM [19] with soundwalks stepover points: red points are from the first soundwalk, blue points are the additional points from the second soundwalk.

3.2 Data Collection and Analysis

The data analyzed in this study were collected through structured measurement campaigns, including both NoiseCapture parties and soundwalks. As for the NoiseCapture parties, to reduce the risk of erroneous data entries, participants received proper training before each activity. Since measurements are collected while walking, they were instructed to stop recording whenever they perceived a significant change in the soundscape, ensuring that the recorded pleasantness ratings accurately reflected distinct acoustic conditions. However, during the first NoiseCapture party in 2018, the authors were not yet focused on the soundscape approach, resulting in many measurement tracks missing the pleasantness values. Thus, these data were excluded from the present analysis.

Table 1. Soundwalks stepover points characteristics.

Point	Description	Main sound sources
1	Street, near the canteen building	Chatting, road traffic noise
2	Green area, near parking lots and academic buildings	Chatting, road traffic noise, nature
3	Academic building area	Chatting, HVAC implants in winter
4	Academic building area, near parking lots	Chatting, road traffic noise
5	Street, near parking lots and academic buildings	Chatting, road traffic noise, nature
6	Green area	Nature
7	Green area	Nature, road traffic noise
8	Square Area	Chatting
9	Square Area	Chatting

Moreover, to build a reliable dataset, the "*Accuracy*" of each measurement point has also been considered, where "Accuracy" refers to the GPS localization accuracy in meters, i.e., the radius within which there is a 68% probability that the actual location of the measurement point lies. Only points with an accuracy of less than 10 meters have been considered in this study. Moreover, points with missing pleasantness values have been discarded.
As mentioned earlier, soundwalks were also conducted to obtain detailed assessments of the soundscape in specific stepovers [18]. A first soundwalk activity was carried out on March 8, 2019, and a more recent one took place on November 5, 2024. In both soundwalks, a training session was conducted for the participants, and sound continuous equivalent levels were measured at each point with a calibrated class 1 sound level meter (Fusion, 01dB).
The main information for both the NoiseCapture parties (noted as "NC") and the soundwalk activities (noted as "SW") is provided in Table 2. The time of day during which the measurement campaigns took place, the number of participants, and the number of points that make up each year's dataset after the cleaning process are also provided, while for the soundwalks, the number of stepover points is also provided.

4. RESULTS AND DISCUSSION

Following the methodology presented in [12, 13], maps of the pleasantness across the Fisciano Campus of the University of Salerno have been generated for each edition of the NoiseCapture party. For the sake of brevity, the maps will not be reported in this contribution, but only values obtained through the interpolation will be discussed.
To enable a more detailed analysis of the temporal evolution of the campus soundscape features, the first step involved merging all data collected during the various NoiseCapture Party activities into a single dataset to create an overall pleasantness map, consistent with previous studies [12, 13, 15], under the assumption that the campus acoustics characteristics remain relatively stable over time. This served as a baseline for comparison with individual-year pleasantness maps, allowing for the identification of potential temporal variations. For the interpolation process, fixed search radii of 50 and 100 meters were adopted to assess variations at different spatial scales. Table 3 presents a comparative analysis of pleasantness values as measured through the soundwalk activity and estimated via IDW interpolation using both the 2024 dataset and the total cleaned dataset with different search radii. Alongside these, the equivalent continuous sound level $L_{\mathrm{A,eq}}$ measured during the 2024 soundwalk edition is also included, offering a direct correlation between the perceptual data and the acoustic measurements at the specified locations.
The pleasantness values obtained through the IDW maps demonstrate relative stability across the different influence radii with both datasets. Moreover, comparing values from the total dataset with those of 2024 shows that some points remained relatively stable over time while others changed significantly. For instance, Point 2 and Point 3 exhibit only minor variations between the IDW-interpolated values from the total dataset and those from the 2024 dataset, suggesting that the acoustic and environmental conditions at these locations have not changed a lot. Specifically, for Point 2, the IDW values for both datasets and search radii remain within a narrow range (approximately 53-58%), and the soundwalk measurement (56.80%) confirms this consistency. Similarly, at Point 3, the IDW values for the total dataset (30.71% for r = 50 m and 30.98% for r = 100 m) are very close to those from the 2024 dataset (24.71% and 26.86%, respectively), while the soundwalk result (21.00%) is just slightly lower, reinforcing the stability of this location.
Conversely, some points show considerable changes over

Table 2. NoiseCapture parties and soundwalk activities main information.

Event	Date	Season	Time of day	Number of participants	Number of points
SW	08/03/2019	Winter	Morning	22	6
NC	24/05/2019	Spring	Morning	39	11766
NC	16/05/2022	Spring	Afternoon	40	4902
NC	09/11/2022	Autumn	Morning	113	24056
NC	26/10/2023	Autumn	Afternoon	78	12560
NC	05/11/2024	Autumn	Afternoon	64	23984
SW	05/11/2024	Autumn	Afternoon	52	9

Table 3. Comparison of pleasantness as measured through soundwalk activity and computed through IDW interpolation with 2024 data and with the total cleaned dataset with different search radius *r*.

Point	$L_{\mathrm{A,eq}}$ [dBA]	Pleasantness value [%]				
		IDW map (total, *r=50m*)	IDW map (total, *r=100m*)	IDW map (2024, *r=50m*)	IDW map (2024, *r=100m*)	Soundwalk (2024)
1	61.1	86.30	84.95	33.43	41.14	44.81
2	51.1	53.80	54.00	58.09	56.80	61.00
3	57.8	30.71	30.98	24.71	26.86	21.00
4	51.0	60.69	59.59	35.29	28.80	52.55
5	50.8	47.49	47.67	47.00	-	60.20
6	47.1	-	48.39	-	38.08	77.27
7	44.6	79.60	73.49	70.30	63.34	86.58
8	49.3	62.31	62.92	-	61.37	71.25
9	47.2	53.09	53.88	52.63	53.25	71.15

time, likely due to modifications in their acoustic environment. In Point 1, for example, while the IDW interpolation for the total dataset shows relatively high pleasantness values (86.30% for r = 50 m and 84.95% for r = 100 m), the 2024 dataset reports much lower values (33.43% for r = 50 m and 41.14% for r = 100 m). The soundwalk measurement (44.81%) is closer to the latter, suggesting that recent conditions have negatively influenced perception. This decline may be because 2024 measurements were taken during peak traffic hours, when vehicular noise from the near parking lot was at its highest, as shown by the high $L_{\mathrm{A,eq}}$ value. Moreover, ongoing construction work in the canteen building likely masked more pleasant sounds, reducing the perceived pleasantness. Since such works in progress were not present in previous years, the change highlights the dynamic nature of the acoustic environment and the impact of temporary but significant alterations in the soundscape.

Point 4 has undergone a noticeable change. Previously, this location was primarily a parking lot, but a new building has been constructed in recent years, altering both the soundscape and the overall environmental perception. The IDW-interpolated pleasantness values have consequently changed, with a slight decrease compared to the total dataset (from approximately 60% to 35% in the 2024 dataset with r = 50 m). The soundwalk measurement (52.55%) indicates a more moderate perception of pleasantness, possibly influenced by the mixed presence of new infrastructure and residual green areas.

Point 5 is characterized by IDW interpolation values that have remained relatively stable between the total dataset and the 2024 dataset (around 47%). However, the soundwalk measurement (60.20%) is significantly higher than that, suggesting that direct human perception of pleasantness at this location is more favorable than predicted by the model. Given the noise level ($L_{\mathrm{A,eq}}$ = 50.8 dBA), this discrepancy might be explained by additional environmental factors, such as the presence of green spaces and, thus, natural sounds, which enhance the overall experience. The stability of the IDW values suggests that this location has not undergone major transformations, but the difference between the interpolated and measured values underscores the limitations of the IDW method.

Point 6, instead, exhibits a unique pattern due to data limitations. While an IDW-interpolated value was available for the total dataset for r = 100m (48.39%), the absence of a value for r = 50 m suggests a lack of sufficient nearby data points, likely due to fewer participants passing through that area or due to the cleaning process. Consequently, the interpolation may not accurately capture the complexity of local sound conditions, which is instead completely acknowledged during the soundwalk. With influence radii of 100 m, the inclusion of data from more distant points allowed for the generation of estimates. However, these data are predominantly from points near the external road, where perceived pleasantness is likely much lower than in the greener surroundings of the green area in point 6 itself. This aspect underscores the crucial role of the search radius in IDW interpolation, as it defines the spatial extent within which surrounding data affect the estimated values [13].

Another interesting case is Point 7, where pleasantness values have remained high but still show variations between datasets. However, the 2024 dataset shows a slight decrease in interpolated values (70.30% for r = 50 m compared to 79.60% in the total dataset). The soundwalk measurement (86.58%) confirms that the area remains one of the most pleasant locations, but the interpolation discrepancy suggests that the location possesses specific attributes, likely visual or environmental factors, such as greenery, that enhance positive perception when stationary but may not be fully captured by a moving listener.

Points 8 and 9 have a similar trend. While IDW determines relatively stable pleasantness values between the total dataset, the soundwalk measurement tends to be considerably higher, indicating that participants perceived the area as more pleasant than estimated through spatial interpolation. This discrepancy, however, may be influenced by the different times at which participants engaged in the two activities. While both activities started simultaneously, participants in the NoiseCapture Party completed their route more quickly, passing through certain points earlier in the day, when background noise levels were still elevated due to ongoing academic and social activities. In contrast, the soundwalk included scheduled stops and required participants to answer questionnaires, resulting in a longer duration and a later passage through some locations. By that time, the acoustic environment may have been quieter, enhancing the perception of pleasantness. For example, participants in the soundwalk activity passed by Point 8 and 9 around by 6 P.M. when academic activities were almost over and a quite environment was experienced, while the NoiseCapture party participants, passing by during peak hour around 4 P.M., had the full experience of a crowded and chaotic acoustic environment, which may not be perceived as fully pleasant.

4.1 Evolution of the Campus Over the Years

Table 4 provides a comparison of pleasantness values computed through IDW interpolation for each year's dataset with search radius r=100m and measured during the two soundwalks. A clear distinction emerges between areas where the acoustic environment has remained relatively stable and those where it has undergone significant changes. For instance, locations such as Points 2 and 7 exhibit only minor fluctuations, indicating that the environmental and acoustic conditions at these sites have remained mostly unchanged over the years. This stability may be attributed to the consistency of the surrounding areas and the lack of significant alterations to the land use. In contrast, other points of the campus have seen considerable shifts. Several ongoing construction activities have been present lately on the campus, in particular near Points 1, 4, and 5. These modifications in the campus infrastructure have led to an increased auditory presence of disruptive elements, overshadowing the more pleasant sounds that once contributed to the area's positive acoustic perception. For instance, the introduction of a new building near Point 4 appears to have altered the local soundscape, with the IDW interpolation suggesting a drop in pleasantness values in 2024.

4.2 Evolution of the Campus Throughout the Day

While the temporal evolution of the campus over the years reveals broader trends, a closer examination of the daily changes in the soundscape at specific points offers additional insight into the fluctuating nature of the soundscape. Analyzing the data from Table 4 gives a more nuanced understanding of how the soundscape at partic-

Table 4. Comparison of pleasantness computed through IDW interpolation with different datasets and search radius *r=100m*, and measured during soundwalks.

Point	Pleasantness value [%]							
	IDW 2019	IDW 2022i	IDW 2022ii	IDW 2023	IDW 2024	IDW Total	SW 2019	SW 2024
	Morning	*Afternoon*	*Morning*	*Afternoon*	*Afternoon*	-	*Morning*	*Afternoon*
1	74.26	38.34	77.56	65.51	41.14	84.95	-	44.81
2	57.02	30.57	59.74	46.51	56.80	54.00	54.40	61.00
3	48.36	25.31	25.43	26.61	26.86	30.98	2.30	21.00
4	73.31	100.00	69.53	41.77	39.13	59.59	-	52.55
5	-	-	-	-	46.77	47.67	52.30	60.20
6	61.00	-	60.85	75.00	38.08	48.39	-	77.27
7	77.42	-	75.94	75.43	63.34	73.49	72.70	86.58
8	66.82	100.00	56.03	76.35	61.37	62.92	67.10	71.25
9	55.65	100.00	49.75	63.68	53.25	53.88	61.40	71.15

ular locations evolves. For instance, Point 1 demonstrates a marked decrease in perceived pleasantness in the first edition of the 2022 and 2024 datasets compared to previous years, likely due to increased vehicular noise from nearby parking facilities during peak hours when such activities took place. Thereafter, Point 7, which is characterized mainly by green spaces and relatively low noise levels, maintains a high perception of pleasantness. However, a slight decrease in pleasantness between the 2024 dataset and the total dataset suggests that time-of-day factors shape the acoustic experience. The timing of the NoiseCapture party activities, which occurred during peak traffic hours, may have contributed to a more intrusive soundscape at this location, probably due to a nearby external road. Similarly, the discrepancies notable in Points 8 and 9 can be attributed to the fact that, while both activities started simultaneously, participants in the NoiseCapture Party completed their route more quickly and passed through these points earlier, when background noise was higher due to ongoing activities, whereas the soundwalk took place later, in quieter conditions, as explained earlier.

5. CONCLUSIONS

This study presented an updated analysis of the soundscape and perceived pleasantness across the Fisciano Campus of the University of Salerno. Using crowd-sourced data, a comparison between pleasantness ratings collected over multiple years was performed. Areas with stable pleasantness values and others showing significant shifts over time were identified. Notably, some locations exhibited a marked decrease in pleasantness, potentially related to temporary or permanent changes such as increased traffic during peak hours or construction work. The evolving nature of the campus underscores the utility of continuous monitoring to capture these transformations and maintain an accurate understanding of how soundscapes change over time.

The obtained results highlighted the relevance of a multi-methodological approach but also the limitations of the interpolation method in fully reflecting subjective perception, confirming the need for complementary approaches to better capture the complexity of the soundscape.

Nevertheless, the findings support the potential of participatory soundscape mapping as a valuable tool for environmental monitoring. By integrating quantitative acoustic indicators with perceptual data, it is possible to develop a richer understanding of sound environments and their evolution. This integrated perspective can also influence the design and planning of future modifications to campus areas, guiding interventions aimed at enhancing environmental quality and users' well-being.

Future steps may involve combining spatial and temporal analysis to support the identification of emerging trends and critical transitions in campus soundscapes.

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