Combining mobile measurements on noise and soundscape evaluation in a University Campus after a renovation plan

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ABSTRACT

This paper contributes on the popular topic of smartphone-based noise mapping and in general participatory sensing. It has a dual aim as on one hand it provides a methodological framework on the spatio-temporal variability of noise and soundscape and in parallel it investigates the role of green space and water features on soundscape preference with respect to certain activities. The study was organised in Zernike University Campus in Groningen, Netherlands around 13 predefined locations, equipped with seating facilities. A big part of the study area was recently redesigned as part of the Zernike promenade. Students, enrolled in the course of Environment and Engineering, used the ArcGIS 123 Survey and the NoiseCapture mobile applications for soundscape and noise data collection respectively. Statistical analysis and GIS tools were used to investigate the noise and soundscape variability in different time periods from morning to evening. Additionally, the effect of green space and water features on soundscape quality and users' preference is identified exploring the links with activities related to socializing and relaxing. The contribution of the above-mentioned technologies in participatory planning and urban design interventions is discussed parallel to the educational benefit of these tools in the achievement of the course learning objectives.

1. INTRODUCTION

Over the years the topic of soundscape has gained more and more attention in multidisciplinary fields expanding from the traditional area of acoustic ecology [1]. Despite the technological progress with new approaches integrating VR, deep learning or image analysis techniques, it still remains a challenge to integrate the theoretical and analytical tools presented through the soundscape ISO series (12913-a,b,c) in the planning process. This should not undermine the fact that certain progress has been made in the field of participatory planning using mobile apps to assess the acoustic and visual environment (e.g Hush City [2], Noisetube [3]).

It is also true that previous studies assessing the soundscape in a University campus did not always consider the landscape composition (e.g presence of green and blue elements), mainly emphasising on the socio-acoustic perspective [4] or a perceptual investigation restricted on the correlation

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between physical and psychoacoustic parameters [5]. It is very promising however that recent studies have indeed confirmed that a proper built environemnt in a University Campus can trigger creative encounters in public spaces [6].

Having this in mind, the current research also focuses on the public space of a University Campus. It contributes in the field of participatory sensing and VGI [7] with an aim to describe a robust methodology for noise and soundscape analysis using a smartphone-based data collection protocol [8] and innovative visualization techniques. The applied practices build on the ongoing discussion in three interlinked directions as presented below:

a) Diversification of participatory tools and methods that are applicable in soundscape analysis and design.
b) Soundscape and new technologies as a pedagogical tool in Higher Education combined with the corresponding learning objectives.
c) Soundscape assessment as a dynamic diagnostic tool able to be incorporated in sustainable urban design.

2. METHODS

2.1. Study area and measurement point selection

Zernike Campus is located at the north-west part of the city of Groningen and is the country's fastest growing campus with 198 companies and start-ups in 2018 and the majority of 34,000 students studying in the University of Groningen. The closest highway (N370) runs 150m away from the southern border of the case study area with a dense vegetation in between. The Campus has undergone a big regeneration project (Upgrade Zernikelaan) - finalized in October 2021 - with an aim to make it more accessible and attractive for its users. For this research, the most significant locations are part of the new Zernike Promenade, a wide park along the Duisenberg pond with more than 200 trees, a bike and a footpath forming a connection of almost 1600 meters along the Campus. Coupled with the adjustment communal areas it provides an ideal recreational space with varied functions that is worthwhile to be investigated from an acoustic perspective concerning its efficiency and public acceptance. An overview of the Duisenberg pond is shown in Figure 1.

Figure x1: Perspective of the area around Duisenberg pond before and after the renovation project (Zernike promenade).

The entire acoustic project run as part of the 3rd year course of Environment and Engineering, where students are called to familiarize themselves with the physics of sound propagation and aspects related to soundscape theory and assessment.

The sample locations for analysis were selected taking into account the Zernike promenade and contextual factors of dominant use and visibility as presented by [9] in the SSID Protocol. The criterion of dominant use corresponds to the available so called "*passive zones*" in the Campus, which aim at promoting activities such as sitting, resting and socializing. Meanwhile, visibility in this study refers both to blue and green spaces in an attempt to account for the visual stimuli. In total 13 measurement locations as shown in Figure 2 (right) were selected with one of them acting more as a reference point valuable mainly in the stage of spatial analysis.

Figure 2: Study area (left) and identification of the 13 sampling locations in Zernike campus (right), including the arrows specifying the perceived gaze direction of the participants during the data collection process.

Except for the reference point, all the other locations were characterized by the presence of benches or some kind of sitting facilities, serving as destination spaces. Table 1 below presents the main characteristics of the sampling points and their proximity to water, green and road entities. There was an intentional attempt to balance the direct visibility from the sampling location towards green and blue features in an attempt to test relevant results from previous studies (e.g [10],[11]) linking visibility with soundscape descriptors.

Table 1: Details of the measurement locations with respect to their visibility and proximity to green and blue spaces.

Points		Visibility		Proximity (Planar distance in meters)		
Point_ID	Location	Green	Water	Green	Water	Closest road
1	Aletta Jacobs entrance	yes	yes	0	35	63
2	Aletta Jacobs bridge*	yes	yes	30	0	40
3	Waterfront 1	yes	yes	0	15	16
4	Waterfront 2	yes	yes	0	15	16
5	Foodcourt	yes	yes	35	48	5
12	Pont(Nettelbosje)	yes	yes	0	3	14
6	Bernouliborg front	yes	No	7	68	35
7	Bernouliborg back	yes	No	0	60	113
8	Marie KamphuisBorg	yes	No	0	156	10
9	Zernikeplein (Sportcentrum)	yes	No	0	115	15
10	Zernikeplein (Fountain)	yes	No	3	174	13
11	Duisenberg (back)	yes	No	0	95	18
13	Mercator (entrance)	yes	No	8	114	15

2.2. Data collection

In total 82 third-year students formed 19 groups of four members and three groups of two members, making sure that at least one group member has an Android mobile device. This was necessary for the noise level mobile application. Every group represented an acoustic consultancy firm as part of the course with three main aims:

a) To provide a spatio-temporal analysis of the noise environment
b) To provide a spatio-temporal soundscape analysis
c) To provide engineering and soundscape solutions based on their acoustic objectives

There were different data collection strategies followed both in the soundscape and the noise measurement session, which are explained below. What both assessments have in common is that the big number of groups combined with the relatively small sample area size paved the way for the design of a data collection process of high temporal resolution.

2.3. Structure of the soundwalk and the noise measurement campaign

The data collection period was set from the 8th up to the 21st of March 2022 with one more week serving as a back-up, accounting for all uncontrolled circumstances such as the weather conditions. Within this official three-week period each weekday was split into three equal time intervals {a:(09:00 - 12:00), b:(12:00 - 15:00), c:(15:00 - 18:00)} comprising of multiple continuous 45-minute time slots as shown in Table 2. The latter corresponds to the approximate duration of the soundwalk with a normal walking pace.

It was also decided to conduct the soundscape evaluation twice, once using the point sequence from 1-13 and then in reverse from 13-1, with a view to minimize any possible bias related to the order of visiting the locations. These two circular routes were named “clockwise” and “anticlockwise”. The noise measurement session used the same time intervals as specified above, where each group had to pick an A,B,C **or** D timeslot both anticlockwise and clockwise as shown in Table 2. In this case the two sessions facilitated the data comparability under different temporal circumstances.

This versatile methodology ensured primarily that students could self-enrol in time slots that would not overlap with their courses, while making sure that each time slot would be selected at least once during the entire measurement period. In total each group member had to perform the assessment not necessarily during the same day, nevertheless with an obligation to fill in the time slots in a shared Google document in advance following a first come, first served order. Not more than two group members from different groups were allowed to start a soundwalk simultaneously from the same starting point. This accounted for a total two soundwalks per person or eight soundwalks per group (4 clockwise & 4 anticlockwise). In absolute numbers this equals to a total of 104 entries per group, reaching finally a total of 2,282 unique entries.

Table 2: Example of the soundwalk spreadsheet with the allocated group numbers in different time slots for the two sessions (clockwise-anticlockwise).

Days	**Soundwalk**	1-13 (Anticlockwise)				13-1 (Clockwise)			
Tue, 08 Mar	11	A	B	C	D	A	B	C	D
Wed, 09 Mar	12	A	B	17 (N)	D	A	B	C	17 (N)
Thu, 10 Mar	13	A	B	6	17 (M)	A	B	17 (M)	D
Fri, 11 Mar	14	A	B	C	D	A	B	C	D
Mon, 14 Mar	15	A	B	C	D	17(M)	B	C	D
Tue, 15 Mar	16	8 (O)	18 (L)	C	D	8(W)	17(M)	18 (L)	D
Wed, 16 Mar	17	17(M)	17(M)	19 (MR)	D	23	23	23	23; 19(MR)
Thu, 17 Mar	18	14	**4**; 14	4; 14	14	14	14	14,4	4; 14
Fri, 18 Mar	19	A	B	19		A	B		19
Mon, 21 Mar	20	7,18	7 & 20	7 & 2	7 & 2	7 & 2	7 & 2	7	7 & 20
Session	**Afternoon**	12:00 - 12:45	12:45 - 13:30	13:30 - 14:15	14:15 - 15:00	12:00 - 12:45	12:45 - 13:30	13:30 - 14:15	14:15 - 15:00

Familiarity with the case study area and the digital data collection instrument was achieved to a great extent through the arrangement of three group soundwalks prior to the agreed data collection period. However, out of the three, only one was finally performed to a satisfactory extent, due to extreme weather conditions. During the group soundwalk, all students were instructed on the correct gaze direction, as part of their “*listening in search”* experiment based on the proximity to the adjacent green or water features. In each point it was necessary to spend 30 seconds of listening before filling in the questionnaire in silence. Figure 3 below presents the collected points both for the soundscape and noise evaluation.

All data were collected with a default anonymity, where each entry is characterized by a unique 23-digit string code. For the environmental noise investigation, the same self-enrolment process was used among the groups. Nevertheless, the only difference was that the soundscape evaluation was based on multiple point-based measurements per session, while the noise evaluation was conducted based on individual continuous recordings as each participant was walking in silence from one point to the other.

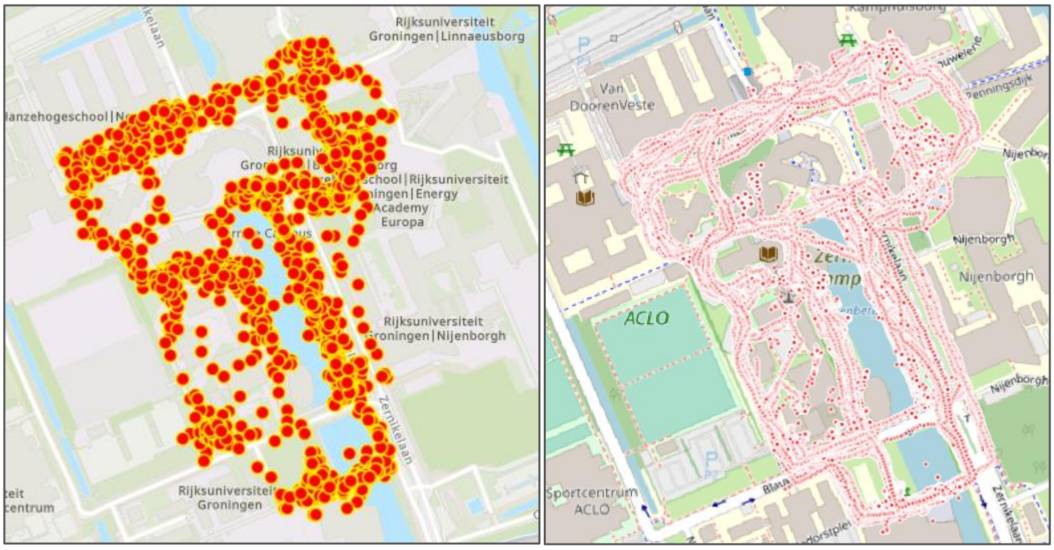

Figure 3: Final dataset for perceptual (left) and objective noise levels (right) based on ArcGIS Survey 123 and the NoiseCapture mobile applications.

2.4. Questionnaire survey and equipment

For the soundscape evaluation, in situ questionnaires were conducted using a slightly altered version of Method A from Annex C of the ISO/TS 12913-2:2018 technical specifications. A more detailed version with an emphasis on activities was also added. The survey was designed on the ArcGIS Survey 123 application and was easily accessible via Android and IOS mobiles.

Default questions covered the following topics: Point ID, date and time and Creator. There were additional questions covering the audible sound sources (anthropogenic & natural), the eight ISO-based perceptual attributes and two groups of questions inspired by [12] with the first one referring to: the surrounding sound environment, the visual environment, the perceptual loudness and the matching expectations with the acoustic environment. The latter covered aspects related to the actual activities in the predefined locations, such as: socializing, experiencing peace and quietness, escaping stress and nature appreciation. All questions were built based on a *5-point* Likert scale with “1” corresponding always to the worst condition and “5” to the optimal.

All Android mobiles (v.10-12) used in the data collection were calibrated in advance of the data collection perido using the “*auto-calibration with a calibrated smartphone”* option in the NoiseCapture app. Before this, the tutor’s mobile was calibrated using a certified Sound Level Meter using the option “*Manual Calibration with a reference”* (95 dB). The NoiseCapture app. is provided in an open-source format only for Android phones and currently it is the only noise application connected with a publicly accessible spatial database [13]. Since the app is programmed to regulate on an event-based log per second, binning techniques are suitable to overcome the overlapping data issue. The only value that was collected by the app was the average L_{eq} per point.

2.5 Noise and soundscape mapping techniques

The noise mapping followed a sophisticated approach by generating a tessellated hexagon grid of 40m diameter or else 1,000m^2. The hexagon size was calculated in accordance with the size of the case study area and the sound source variability. When intersected with the noise data, 68/180 or 37% of the hexagons had at least one point to investigate. This number slightly varies per student group depending on the route that each participant followed and the GPS accuracy of their mobiles.

Soundscape mapping was conducted using a prediction surface created via the Ordinary Kriging interpolation technique. Similar studies in the past have also highlighted the value of interpolation methods in soundscape representation [14,15].

3. RESULTS

3.1 Noise and soundscape mapping analysis

The tesselation analysis revealed that results are overall time-dependent in terms of the sound source dominance as reflected in the L_{eq} levels. However the differences between the clockwise and anti-clockwise sessions as shown in Figure 4 can still provide an approximation of the quiet and noisy areas around the Campus. It is important to consider that the current differences represent the divergence in L_{eq} due to the interference of different sound sources (e.g birds, wind, cars) and do not reflect seldom the noise levels from the mechanical sound sources.

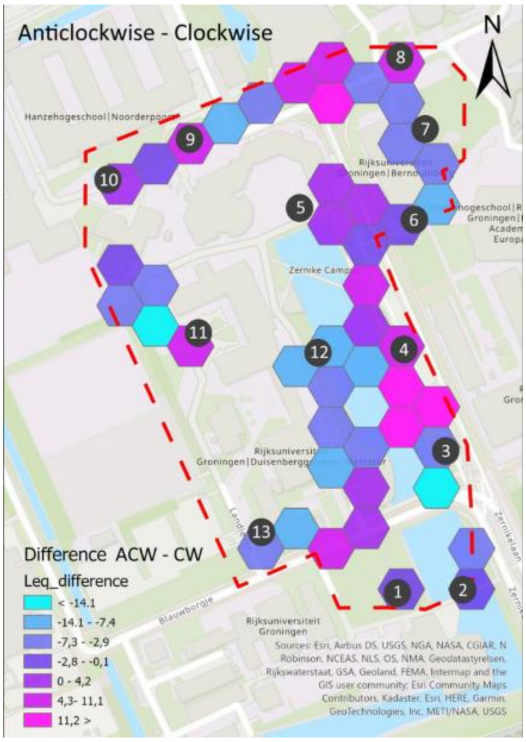

Figure 4: Instance of the L_{eq} difference (dB) using the tessellation tool and data from the measurement session conducted during an afternoon time slot (15:00 – 15:45) by Group 20.

The ISO-based scatter plots presented in Figure 5 show that there is a clear distinction between the points facing towards water and green features. The water points are considerably more pleasant than the green points, with a few exceptions. This can be mainly because areas for socialising, calmness and escaping stress are found along the water points in the Campus. The green points on the east side of the study area (points 10, 11 and 13) scored low on both the “Eventfulness” and “Pleasantness” axes. A more clustered approach of all the sample points is presented on the anticlockwise session with small variations to be explained by temporal traffic conditions or the presence of students in the public paths as the data collection period coincides with their lunch break.

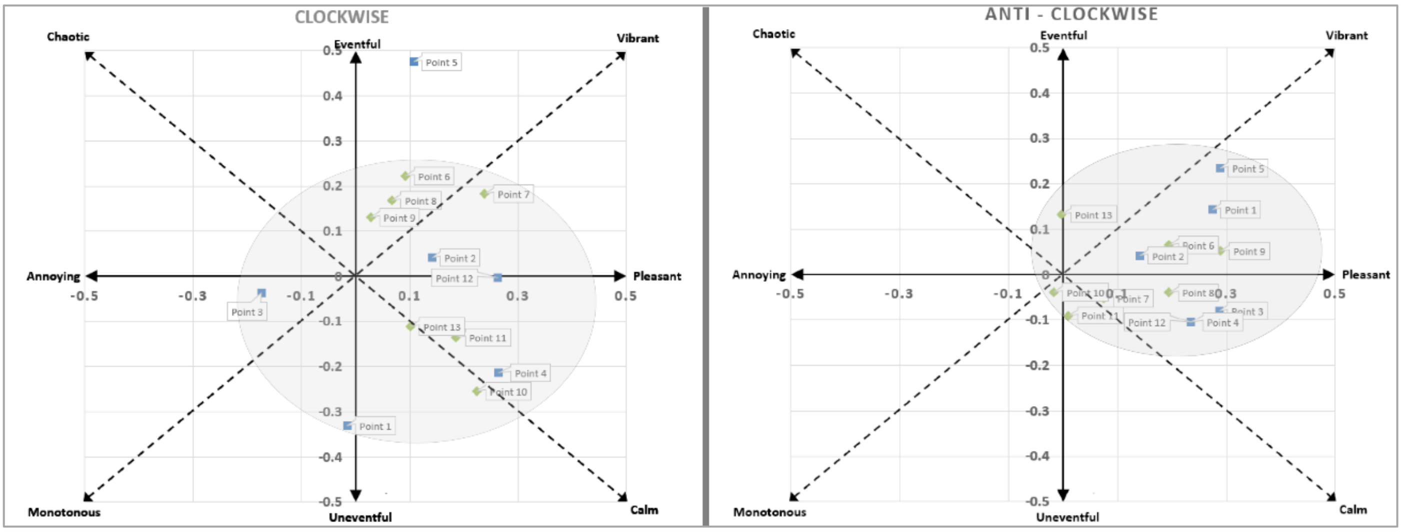

Figure 5: A point-based evaluation of the perceptual attributes per sample location based on ISO 12913-3 from data collected by Group 15 between 09:00-12:00. Green and blue points link to the corresponding visibility on vegetation and water respectively during the soundwalks.

There are two aspects to be discussed with respect to Figure 6 below. The first one relates to the overlapping areas in experiencig a stress relief atmosphere and quietness, which seems to cover the Zernikelaan and the Zernike Promenade. Apparently such resutls can also act as a confirmation that the current project serves its purspose in creating an inclusive environment for various types of users. Having said this, the aspect of socializing although not directly visually represented is expected to present big similarities with the aforementioend pattenrs.

The second aspect relates more with the broader discussion in the use of geostatistical interpolation technicques and their accuracy in soundscape studies. It is vital to highlight that these techniques do not take into account the physiscs of sound propagation and by no means can they represent the official noise mapping process. Nevertheless the pattern shown in all the three pictures below calls for action in order to mitigate the mechanical sound sources surrounding the case study area. The solutions presented by the group experts to achieve specific acoustic objetives will constitute part of a future research paper.

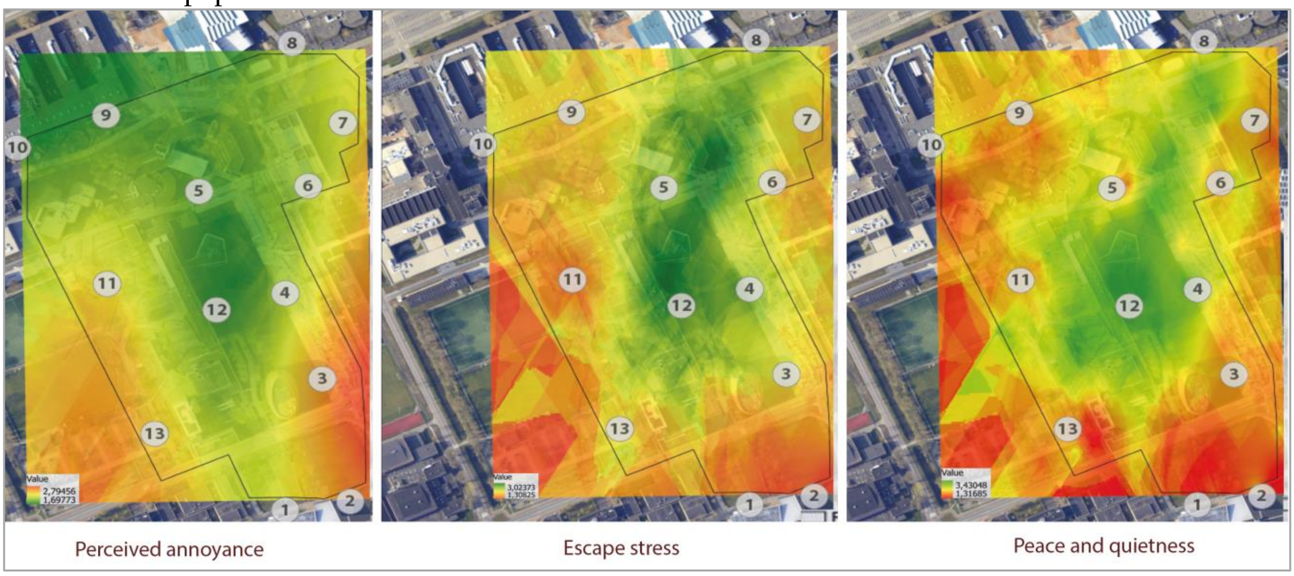

Figure 6: identifying areas of annoyance, stress escape and quietness in the case study area. The values in all three cases range between 1.31 and 3.43 out of 5 (max).

4. CONCLUSIONS

Over a period of three weeks, 82 University students split in 22 groups, took part in a field survey as part of a research-led teaching assignment in the course of Environment and Engineering. The assignment touched upon the aspects of participatory sensing, smartphone sound measurement and noise/soundscape mapping aiming at providing a smartphone-based noise and soundscape assessment within the renovated area of Zernike University Campus. Two mobile applications (123 Survey & NoiseCapture) were used for data collection installed in calibrated phones. A detailed methodological protocol was applied in order to collect multiple data on a daily basis only during the working days from 09:00 to 18:00. Specific spatial tools (e.g tesselation, interpolation) were used in order to visualise the noise and soundscape variabiltiy around Zernikelaan in combination with the current guidelines from ISO 12913-3.

Further research on the applied smartphone-based soundscape and noise protocol and its applicability both in education and in planning is required. On one hand, it can facilitate students' engagement with multisensory aspects in a dynamic way and on the other it can promote the dialogue on how soundscape criteria, big data and acoustic objectives can gradually become integral part of a human-centric urban design.

5. ACKNOWLEDGEMENTS

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