

Soundscapes across two historical cities: Piazza del Popolo in Faenza and Leicester Square in London

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Abstract—Research in outdoor acoustics is not widely studied in room acoustics from an immersive-experience point of view. However, the combination of 3D audio with a panoramic view makes the urban environment more engaging when played back. For this campaign of measurements, a 64-channel spherical array microphone has been used, corresponding to a resolution equal to high-order ambisonics (HOA), but for simplicity, it has been analyzed up to the 3rd order (O3A). This paper deals with the analysis of a soundscape comparison between Piazza del Popolo in Faenza and Leicester Square in London, two historical places located in Italy and the UK, respectively. These two public squares are not very busy in terms of vehicular road traffic noise, hence they are excellent places for community gatherings and to interact with other people. The audio recordings have been analyzed by using environmental parameters such as loudness, sharpness, prominence, and roughness.

Keywords—*soundscape, signal processing, Faenza, London.*

I. INTRODUCTION

Soundscape capture is important for understanding specific outdoor environments that characterise public spaces. When the audio is even 3D that fully embrace the solid angle with a high order Ambisonics, the experience is furthermore engaging. Additionally, a 3D audio experience results with a more detailed sound spatialization in terms of sound perception, as the sound arrive to the listener from multiple direction featured with a narrower beaming directionality [1].

This paper analyses two different environments located in Faenza and London in order to understand the reasons for individuals' preferences for some places over others. The microphone was installed at the centre of these two squares, in Faenza and London, while the 360° camera recorded a videoclip used during the post-processing phase to coordinate audio and video rendering in a single file [2].

II. HISTORICAL VALUE OF PIAZZA DEL POPOLO IN FAENZA

Piazza del Popolo lies at the intersection of the two main Roman roads: *cardo* and *decumanus*. *Faventia*, as it was the original name when it was founded in the 2nd century BC, had its Roman forum in this place, representing the civic and administrative center of the town. Characteristics of this square are *Palazzo del Podestà*, built during the Middle Ages, and *Palazzo Comunale*, erected in the same period, featuring a double arcade and elegant Istrian stone mullioned windows during this period, shaping the square's harmonious layout [3].

In 1760, the Podestà's palace featured a two-story arcade to match the opposite side of the square. However, at the end of the 19th century, both porticoes were redesigned in Neoclassical style by two local engineers, adding symmetry and elegance. It has to be mentioned that the Clock Tower, originally built in the 17th century, was destroyed by German forces in 1944 and faithfully rebuilt after WWII. Another important building facing the square is the Masini theatre, commissioned by the *Accademia dei Remoti*. Nowadays, this square is the center of civic life with its markets running for three weekly days, surrounded by cafes along the porched walkway [4]. Figure 1 shows the characteristics of Piazza del Popolo in Faenza.



Fig. 1. Aerial view of Piazza del Popolo in Faenza, Italy (from Google Earth).

III. HISTORICAL VALUE OF LEICESTER SQUARE IN LONDON

Leicester Square is located in the heart of London's West End and has long held cultural and social significance as a central gathering place for entertainment and public life. Its history dates back to the 17th century, when the area was developed around Leicester House, built in 1635 for the Earl of Leicester. The square gradually evolved from an aristocratic residential area into a vibrant public space [5].

By the 19th century, Leicester Square had become a hub for nightlife and popular entertainment, with music halls, theatres, and exhibitions drawing large crowds. In the early 20th century, the square solidified its role as the epicenter of British cinema. Major film premieres have been held there, and it remains home to several flagship cinemas, including the Odeon Luxe, known for hosting royal film premieres [6]. In the 2010s, the square was redesigned to improve its pedestrian environment and restore its historic character. Statues and plaques throughout the square commemorate figures from the arts and sciences, including William Shakespeare at its center. Figure 2 shows an aerial view of the square [7].



Fig. 2. Aerial view of Leicester Square in London, UK (from Google Earth).

IV. AUDIO RECORDING

The equipment related to audio capture is a multichannel microphone, which is composed of 64 transducers, known as em64 Eigenmike®, utilised in both Faenza and London. This microphone can enrich a high level of ambisonics resolution, up to 7th order, making the subdivision of the solid angle very accurate to detect the sound arrival [8]. In addition to the microphone, the recorded files were stored on a personal computer connected to the microphone [9].

The microphone was placed at a height of 1.7 m from the ground, with a windshield. The wind speed was < 1.3 m/s as average along all the measurement duration (i.e., 2 min) [10].

The audio reproduction can then be realised in two different ways: by using an audio system inside a specialised listening room, where the disposition of the speakers is distributed over the surface of a sphere with a seat at the centre of it [11]. Alternatively, a head-mounted display (HMD) can be another optimal solution with limited costs and similar audio quality, in combination with a pair of headphones [12]. Both solutions can have an audio resolution equivalent to O3A.

V. VIDEO OVERLAY

The video was captured with a 360° camera (Insta360) that was installed above the microphone, and oriented on the x-axis along the channel No. 1. This setting allows the audio captured by the microphone with the video captured by the camera [13].

The video can be saved in MP4 format to be readable with VLC software or similar commercial software, where the user is able to navigate the virtual space on the screen, or alternatively by using a visor like Oculus Quest2 for a more immersive experience [14].

An additional option is represented by overlapping the colour map over the raw video, created by processing the multichannel audio track.

VI. SOUNDSCAPE MEASUREMENTS

The audio recording has been carried out during weekdays, between 1200 and 1600, as the busiest time of day. The overall duration is 5 minutes, as a representative of a standard day [15].

Figures 3 and 4 show the elaboration of the acoustic video mapping and the visualization of sound intensity highlighted with orange colours while an individual was talking [16]. The colour scale indicates the sound energy arriving at the microphone probe, with orange-red illustrating a higher level of sound.



Fig. 3. Acoustic measurement in Piazza del Popolo in Faenza.

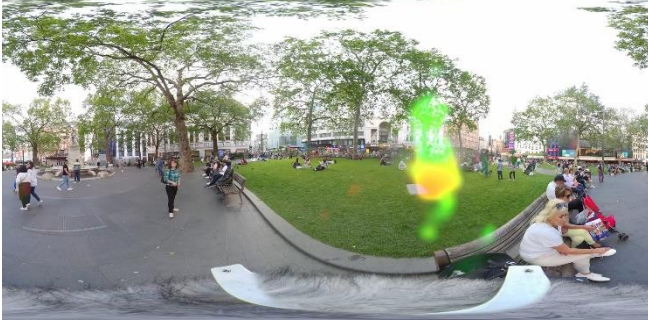


Fig. 4. Acoustic measurement in Leicester Square, London.

In Piazza del Popolo in Faenza, the main source of noise was represented by transient bicycle pass-by, as shown in Figure 3 highlighted in green, and random individuals' conversations [17]. In Leicester Square, the soundscape was dominated by kids playing on the grass, as a green-orange cloud highlights in Figure 4, in the middle of the photo [18].

VII. ACOUSTIC ANALYSIS OF MEASURED RESULTS

The acoustic parameters analysed for outdoor soundscapes are different from those related to building acoustics. These environmental parameters are Loudness [19], Sharpness [20], Roughness [20], and Prominence [21]. Table I summarizes the values of each parameter based on the measured audio recordings.

These parameters have been calculated with Matlab 2024b software, consisting of uploading the audio recordings and setting the analysis for a fixed time period, in order to have the same duration.

TABLE I. ENVIRONMENTAL ACOUSTIC PARAMETERS.

Location	Mean Loudness (sones)	Mean Sharpness (acum)	Mean Roughness (asper)	Mean Prominence (dB)
P.za del Popolo	1.0	1.1	5	0.5
Leicester Square	4.6	0.2	51	5.4

Among the two case studies, the loudness in Piazza del Popolo was found to be around 1.0 sonas, on average, across the period, while some peaks also reach 5.1 sonas. As it is known that 1 sone corresponds to a loudness of a 1 kHz tone at 40 dB SPL [19], Figure 5 shows that in Piazza del Popolo, the noise levels were around 0.9 sonas for the majority of the time. This means that Piazza del Popolo corresponds to a quieter background level, equivalent to a SPL 40 dBA. In Leicester Square, the average value of loudness was found around 4-5 sonas, with wider amplitude in the recording signal due to amplified music from street artists [22]. The equivalent sound pressure level is SPL 63-65 dBA.

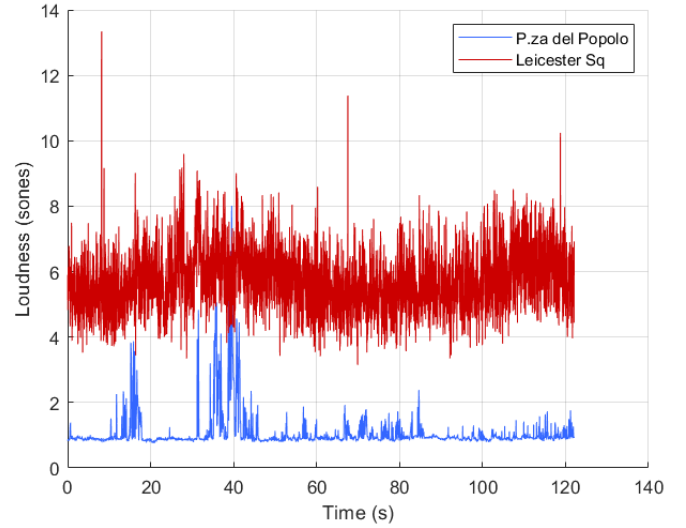


Fig. 5. Loudness outcomes.

Sharpness is another environmental parameter that refers to high-frequency content in a sound signal: the greater the proportion of high octaves, the sharper the sound [23]. In our case, the values of sharpness are around 1.1 acum in Piazza del Popolo and 0.5 acum in Leicester Square. Effectively, the sound recorded in both squares were related mainly to conversations, without any particular sound characterised by high-frequency content, as could have been a siren or heavy breaks [24]. Figure 6 illustrates the sharpness related to the two places.

The roughness is a perceptual measurement of modulations in amplitude or frequency that are too narrow to be discerned separately. Usually, the modulations for roughness are between 20 and 300 times per second [25]. Specifically, roughness is used to quantify high frequency modulations, like buzzing that we can hear in any enclosed space due to lighting fixtures or similar [26].

In our case, the roughness between the two sites is dissimilar, around 50 aspers when averaged across the time period in Leicester Square and close to zero in Piazza del Popolo. However, Piazza del Popolo shows peaks around 30 aspers, which is considered very noticeable, as shown in Figure 7, which are not comparable with extraordinary events like outdoor crowd noise [27].

The prominence ratio (PR) is an environmental acoustic parameter used to quantify the presence of distinctly audible tones in a sound signal [28], like broken glasses against a surface [29]. The level of the prominent tone must be at least 8 dB above the level of the adjacent octaves representing the masking/background noise level, otherwise it is not perceived by listener [30]. The prominence around 0.5-1.0 dB, as registered in both sites, is not considered prominent, such that they are inaudible to the listener.

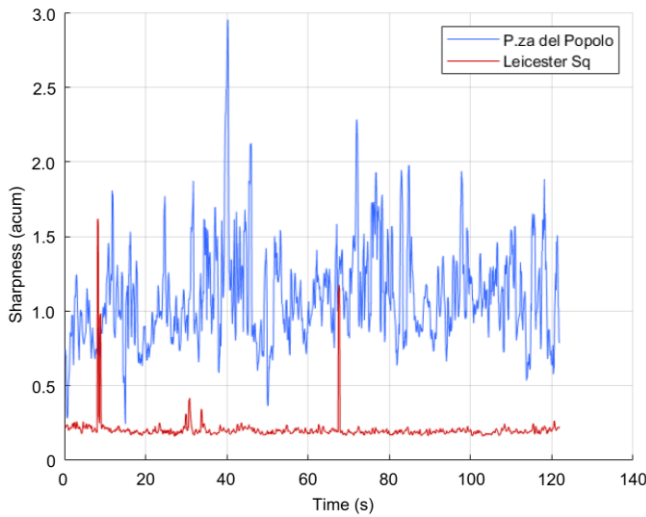


Fig. 6. Sharpness outcomes.

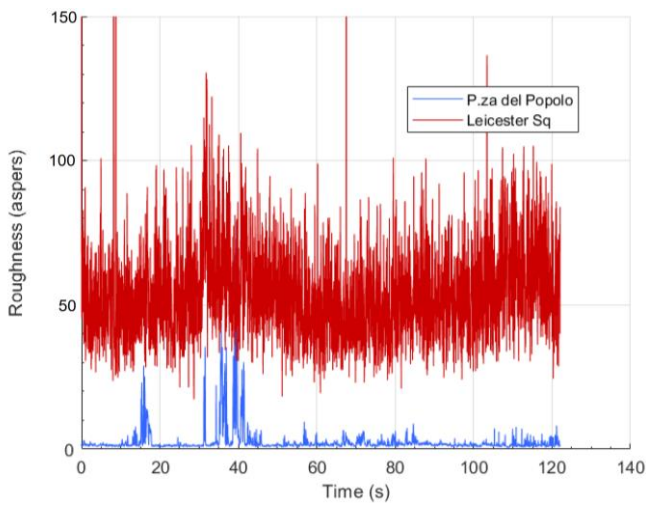


Fig. 7. Roughness outcomes.

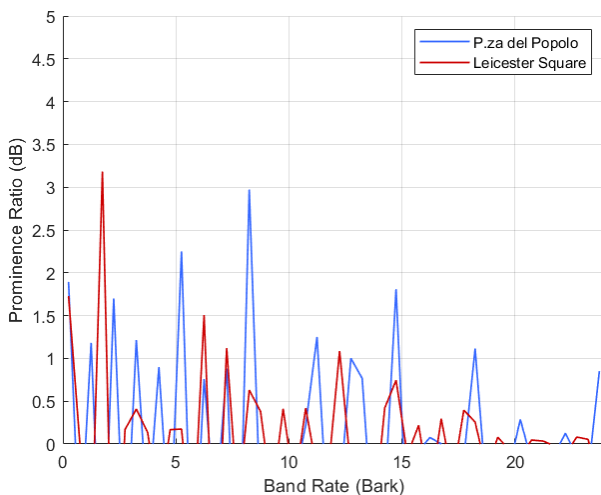


Fig. 8. Prominence Ratio outcomes.

VIII. CONCLUSIONS

This research study is focused on the analysis of the external soundscape through an immersive experience given by the recordings captured by a multi-channel spherical array microphone. The technical challenge consists of creating a

3D audio for detecting the arrival of sound from all directions when the microphone is recording. The high level of capsules over a microphone probe allows for achieving a high-order Ambisonics (HOA). Specifically, the outdoor measurements have been performed by using a 64-channel microphones, which is a very advanced technology compared to standard monoaural or binaural equipment for audio acquisition [31]. The analysis of the environmental acoustic parameters highlights that the soundscapes recorded in these two sites are not particularly affected by specific sound sources that can be considered annoying. In fact, the main source of noise were merely conversations of transient individuals.

These type of soundscape have been compared to other similar ones captured in other squares of Emilia Romagna region in Italy, as they have been historically represented similar importance for the local community.

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