

Measured soundscapes in Piazzale San Francesco in Parma and Trafalgar Square in London

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Abstract— Inclusivity is a topic that different scientific fields are trying to add besides the scientific goals to be achieved. As such, the Agora project is focused on acoustic inclusivity by virtually connecting impaired individuals with an immersive soundscape experienced outdoors. Acoustic measurements have been carried out to understand the urban environment related to different squares, Piazzale San Francesco in Parma, Italy, and Trafalgar Square in London, UK. Audio immersivity is rendered by a multichannel microphone composed of a 19-channel probe (Zylia ZM-1), which allows for obtaining an output signal up to 3rd order ambisonics (O3A) resolution. This equipment is capable of detecting the dynamic sources typical of an urban environment. These two public spaces represent different characteristics: the first is in front of a music academy and is not trafficked generally, except for the timing corresponding to the entrance shifts; the second is one of the main squares in London where live concerts and events are generally organized. If one side of Piazzale San Francesco is crossed by road vehicles, in Trafalgar Square, the vehicles are on three sides (except for the side where the National Gallery is placed). However, both of them are in the core of the city. The environmental parameters are analyzed to scientifically assess the differences between the two squares.

Keywords—soundscape, signal processing, Parma, London, Agora.

I. INTRODUCTION

Many studies on urban sounds are deeply detailed in relation to sleep disturbance and other health concerns that have led standards and guidelines to establish some top limits with respect to the activity of the local community [1]. However, the majority of the recordings are carried out with monoaural microphones since the directivity component was not taken into account for the scopes just described. This paper deals with immersive 3D soundscapes that are conducted in order to be more realistic when played back by users, having the intention of addressing the lack of knowledge in terms of 360° audio rendering [2]. The audio recordings have been carried out at third-order Ambisonics,

which is significantly good to have the spatialization of sounds [3].

The scope of this paper is to audio photograph the soundscapes in two squares characterised by different features: Piazzale San Francesco in Parma, Italy, and Trafalgar Square in London, UK. The multichannel spherical array microphone was paired with a 360° camera that were combined in the phase of post processing [4].

Regarding soundscapes, scholars have developed predictive models for the vibrancy descriptor based on objective parameters, calibrated using questionnaires administered to individuals. This soundscape model gains robustness by combining environmental parameters, such as roughness and sharpness, with subjective ratings of pleasantness, eventfulness, and vibrancy [5].

The limitations of this study lie in the correlation between objective parameters and the personal feedback of individuals experiencing the space, as well as in the limited time allocated for recording. Long-term measurements correlated with participants' feedback would have provided a more robust basis for determining soundscapes [6]. However, the present analysis focuses on detailing the directivity of sound, which shapes perception not only through the direct sound emitted by typical outdoor sources but also through the reflections from surrounding buildings [7].

II. IMPORTANCE OF PIAZZALE SAN FRANCESCO IN PARMA

The name given to this square is due to the presence of the church dedicated to San Francesco del Prato, as the Franciscan influence in Parma was florant in medieval and Renaissance periods. Originally a Gothic church from the 13th century, over time it was used as a prison (from the 19th century until the late 20th century), which altered its interior significantly [8].

Another historical building surrounding this square is Palazzo Cusani, a Renaissance palace built around 1450 by the Cusani family. Nowadays, it functions as Casa della

Musica with music and theater performances that are usually exhibited in the outdoor courtyard or inside the auditorium [9].

Casa del Suono (House of Sound) instead stands on the opposite side of the road serving this square, just in front of San Francesco's church [10]. As a deconsecrated building, Casa del Suono is a museum dedicated to the history and technology of sound reproduction, as founded by Prof. Angelo Farina. It offers interactive exhibitions on the evolution of audio equipment and the science of acoustics, making it a unique cultural attraction in Parma. A view of the square is shown in Figure 1.



Fig. 1. Aerial view of Piazzale San Francesco in Parma, Italy (from Google Earth).

III. IMPORTANCE OF TRAFALGAR SQUARE IN LONDON

Trafalgar Square is one of London's most iconic public spaces in the UK, named to commemorate the Battle of Trafalgar (1805) after Ad. Nelson's victory against Napoleon. This historical memory is represented by Nelson's column, guarded by four large bronze lions.

Trafalgar Square is the spot for political demonstrations and celebrations. On top of the basement level, the National Gallery stands as the house of one of the world's greatest collections of European paintings [11].

On the opposite side of the National Gallery, there are two other government buildings: Canada House, hosting the Canadian High Commission, and South Africa House, which hosts the South African High Commission. Figure 2 shows the aerial view of Trafalgar Square.



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

IV. AUDIO RECORDING

The equipment related to audio capture is a multichannel microphone, that is composed of 19 channels for Zylia ZM-1, as employed in London, and 64 channel for em64 Eigenmike® [12], as utilised in Parma. The difference between the two microphone probes consists of the ambisonics resolution in terms of directivity, but the dynamic range is equivalent as well as the frequency bandwidth [13].

The acoustic survey was carried out with the following equipment:

a) 64-channel spherical array (MH Acoustic em64 Eigenmike®) for Parma [12].

b) 19-channel spherical array (Zylia ZM-1) for London.

c) Personal Computer connected to one of the two microphones.

The microphone was placed at a height of 1.6 m from the ground, with a windshield. The wind speed was < 2.1 m/s as average along all the measurement duration (i.e., 5 min) [14].

The audio reproduction can be realised by using a common head-mounted display (HMD) paired with headphones, which is a very cheap solution. If there is the possibility to join a specialised listening room, the audio rendering would be given by sitting at the centre of a hypothetical sphere, at the surface of which there are multiple speakers mounted to generate different Ambisonics orders [15]. However, both solutions can have an audio resolution equal to O3A, with the possibility of being connected to another remote individual equipped with a multi-channel microphone that executes the outdoor audio recording.

V. VIDEO OVERLAY

The video is captured with a 360° camera (Kandao QooCam3) [16] that is installed above the centre of the microphone, and oriented on the x-axis along the capsule No. 1. This setting allows for aligning the audio captured by the microphone and the video captured by the camera.

The video can be saved in MKV and/or MP4 formats to be readable with VLC software or similar on a computer, where the user is able to navigate the virtual space on screen, or by using a visor like Oculus Quest2 for a more immersive experience.

An additional option is represented by overlapping the colour map over the video [17]. This can be created with the plugin Flare from Blue Ripple, which processes the multichannel audio track, representing the easiest way to detect the noise source in the recorded scene.

VI. OUTDOOR ACOUSTIC MEASUREMENTS

The first audio measurements have been carried out in Piazzale San Francesco, Parma. The measurements have been carried out during weekdays, between 1600 and 1700, for 2 minutes.

Figure 3 shows a shot while a car was crossing the square. The central orange cloud highlights the sound level during this specific event. For the rest of the time, the background noise level was dominated by conversations among individuals. The elaboration shown in Figure 3 relates to the visualization of sound intensity highlighted with

colours in combination with the panoramic view recorded by a camera [18]. The colour scale indicates the sound energy arriving at the microphone probe with a high level of intensity, while the blue colours refer to low energy content.



Fig. 3. Acoustic survey in Piazzale San Francesco, Parma, by using an Eigenmike em64 microphone.

In Trafalgar Square, the main source of noise was represented by a guitarist performing with a reinforcement system at 30 m distance from the microphone, as the colour map in Figure 4 is detecting after the post-processing with the Frare plugin suitable for Plogue Bidule software [19]. General conversations of transient individuals were masked by the music in the background.



Fig. 4. Acoustic measurement in Trafalgar Square, London, using ZM-1 microphone.

VII. ACOUSTIC ANALYSIS OF MEASURED RESULTS

The acoustic parameters analysed for these two different environments are typical of outdoor sound sources. These environmental parameters are Loudness [20], Sharpness [21], Roughness [21], and Prominence [22]. Table I summarizes the values of each parameter based on the measured audio recordings lasting for two minutes, as representative of a brief slot of time compared to a daily activity running in these public spaces.

TABLE I. ENVIRONMENTAL ACOUSTIC PARAMETERS.

Location	Mean Loudness (sones)	Mean Sharpness (acum)	Mean Roughness (asper)	Mean Prominence (dB)
P.le San Francesco	1.7	3.0	4	0.28
Trafalgar Square	6.8	2.1	22	0.3

Figure 5 shows a comparison of loudness values between Piazzale San Francesco and Trafalgar Square in the time domain. In particular, the difference is very evident, highlighting that the values related to Piazzale San Francesco are quieter, around 1.7 sonas, corresponding to an overall

SPL around 36-40 dBA. In contrast, the average in Trafalgar Square is found to be higher, around 5 sonas for the first minute and rising to 6.8 sonas in the second half of the period [20]. It has to be mentioned that the main source of sound in Trafalgar Square was due to amplified music from a street artist, located approximately 30 m away from the microphone, while in Piazzale San Francesco, the background was dominated only by individual conversations.

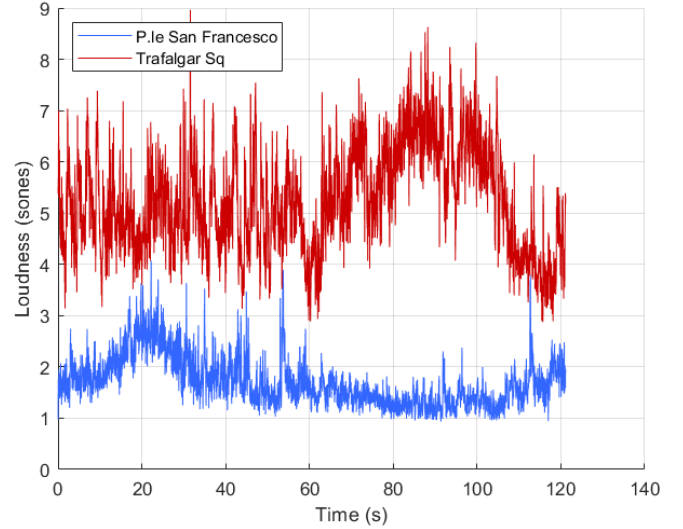


Fig. 5. Measured Loudness.

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 [21]. This parameter can be compared to the sound of a glass shattering on the floor of a quiet room [22], or to a gunshot echoing in a forest.

In our case, Figure 6 illustrates the measured values of sharpness in comparison between the two squares subject of analysis. In Piazzale San Francesco, the sharpness values are around 2 acum, with some peaks reaching 8 acum, corresponding to an individual's laugh that resonated across all the outdoor space [21]. In Trafalgar Square, the sharpness was generally found between 2 and 3 acum, with the maximum peak at 6.3 A-weighted units, based on the music played by the reinforcement system as the main source of sound in the square.

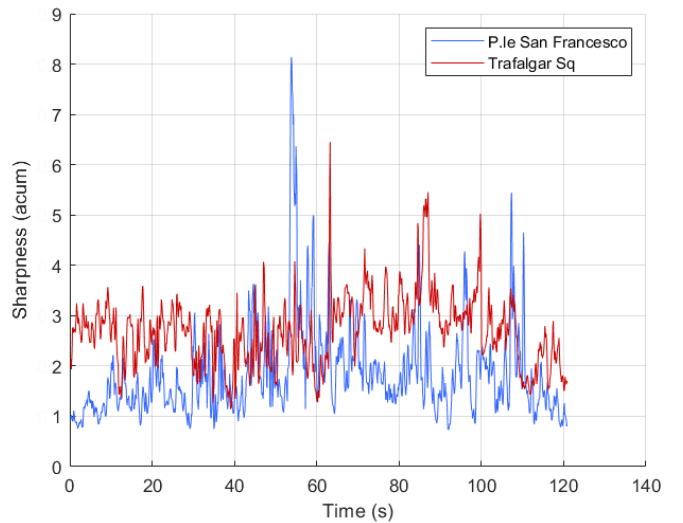


Fig. 6. Measured Sharpness.

The roughness is a perceptual measurement of modulations in amplitude or frequency. Usually, the modulations for roughness are between 20 and 300 times per second, higher than those related to fluctuation strength [23]. The difference between these two parameters is that roughness is used to quantify high-frequency modulations, while fluctuation strength is used to quantify the low-frequency ones [24]. For the selected sites, the highest roughness has been found in Trafalgar Square, to be around 20-22 aspers, very noticeable compared to Piazzale San Francesco, which is found around 5 aspers, while in Piazzale San Francesco, the peak levels are at the order of 10-13 aspers.

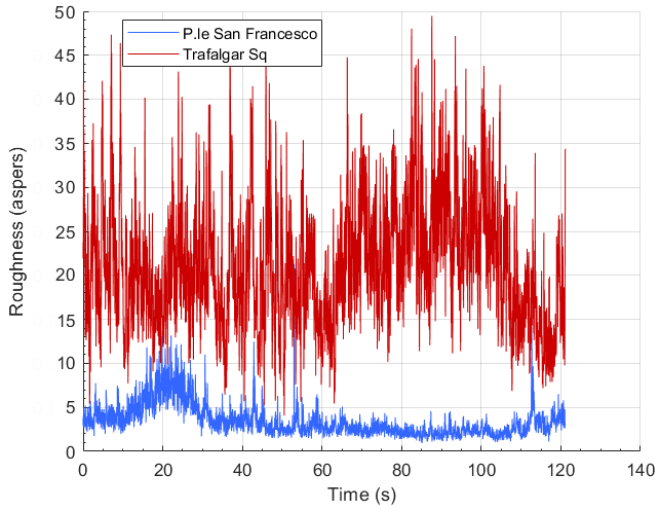


Fig. 7. Measured Roughness.

The prominence ratio (PR) is an environmental acoustic parameter used to quantify the presence of distinctly audible tones in a sound signal. 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 the listener [25]. This type of noise can be assimilated to a train pass-by in a quiet environment [26].

Particularly, the prominence in Piazzale San Francesco is generally between 0 and 1 dB, with some peaks reaching 3-4 dB. These outcomes are not perceived by the listener according to the regulation. The prominence ratio values in Trafalgar Square were found to be higher, with some peaks reaching also 8 dB, corresponding to around 8 Barks, which can be perceived by the listener very clearly.

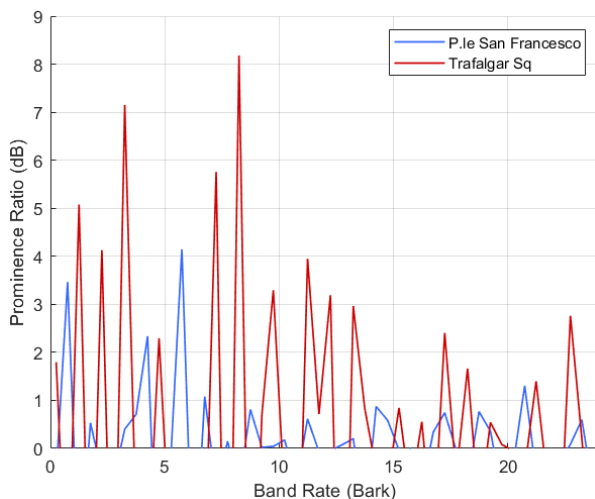


Fig. 8. Measured Prominence Ratio.

VIII. CONCLUSIONS

The Agora research project is in charge of applying the acoustic technology to offer people with limited motion to listen to the external world through an immersive experience given by the 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 streaming the recording in real-time [27]. These challenges consist of achieving a high-order Ambisonics (HOA) through telecommunication.

The outdoor measurements have been performed by using a 19-channel and a 64-channel microphone, which allow an immersive audio experience. The results in terms of loudness were found to be higher in Trafalgar Square than Piazzale San Francesco in Parma, since the main background in the English square was dominated by amplified music played by a street artist with a reinforcement system of a loudspeaker [28]. In a similar way, all the other acoustic environmental parameters were found higher in Trafalgar Square, like the roughness around 22-24 aspers and the prominence ratio with peaks reaching 7-8 dB. Only the sharpness values in Piazzale San Francesco were found higher at the peak level, around 8 acum, while the average values in Trafalgar Square were found slightly higher.

However, these conclusions are valid only for the period during which the recordings were made and cannot be considered absolute, as the dynamics of squares and other outdoor public spaces are influenced by events and social gatherings, which are inherently unpredictable [29].

Future research development will focus on the possibility of building seating areas with a breathing enclosure made of metamaterials, providing both privacy and shielding the public from traffic noise, which is inevitable in urban contexts [30]. According to the literature, approaches using 2D scatterers have already been studied and show promise in increasing absorption at mid-to-high frequencies [31].

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