

Two soundscapes in comparison: Piazza Cavour in Rimini and Buckingham Palace Square in London

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Abstract— With the Agora project, research in acoustics aims to virtually reconstruct an immersive soundscape experience through the combination of 3D audio and panoramic view. The audio station, itinerant across different parts of any urban environment, uses a multichannel microphone composed of 19 channels evenly distributed over the surface of the spherical array. The output signal is an audio with a resolution equal to 3rd order ambisonics (O3A), which renders a very accurate sound directivity to localize the different sound sources movable around the microphone. This paper presents a comparative analysis of the soundscapes of Piazza Cavour in Rimini, Italy, and Buckingham Palace Square in London, UK. These two public spaces are highly frequented by tourists for their architectural and landscape attractions. Their common factors consist of limited traffic zones, accessible only to authorized vehicles, while visitors are free to explore the architecture that dominates the squares. Environmental parameters were analyzed in terms of loudness, sharpness, prominence, and roughness, highlighting the differences between the two environments.

Keywords—*soundscape, signal processing, Rimini, Agora.*

I. INTRODUCTION

The exploration of urban sounds in acoustics is more deeply into the development of immersive 3D soundscapes that contain a high level of realistic audio rendering for any type of reproduction. One of the concerns in 3D audio remains the accessibility via telecommunications, since many platforms for video calls do not support the high definition of audio directivity, so-called high-order ambisonics (HOA) [1, 2]. Nevertheless, it is important to achieve a 3D audio experience even with less detailed sound spatialization, which is actually possible for O1A and, in some cases, also for O3A [3]. This function is primarily important when musical ensembles encounter the necessity of rehearsing in different places, capable of rendering the spatialization and the sound quality with a wide dynamic range.

Given the rapid climate change that challenges the existence of many animals, it became important to have

natural sounds preserved with particular attention to the impact of anthropogenic invasion and their vehicles, such as planes and road vehicles [4].

This paper aims to analyse two different environments in order to investigate the factors influencing individuals' preferences for certain urban places. The microphone was installed at the centre of these two squares while the 360° camera recorded a videoclip, useful in post processing to coordinate audio and video rendering in a single file [5, 6].

According to the literature, 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 [7].

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 [8]. 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 [9].

II. HISTORICAL VALUE OF PIAZZA CAVOUR IN RIMINI

Piazza Cavour in Rimini holds significant historical value due to its importance from a political and cultural perspective. Piazza Cavour has been a central civic space since the Middle Ages, hosting key administrative and judicial buildings that reflected the city's governance. Political importance was enhanced by the Malatesta family, who ruled Rimini from the 1290s until 1528. Malatesta developed the city from an architectural perspective as well, as testified by the Tempio Malatestiano, which is a stunning Renaissance church in Rimini, designed by Leon Battista Alberti [10].

Piazza Cavour in Rimini is surrounded by different significant buildings: Palazzo dell'Arengo, built in 1204 in Romanesque style, was considered the center of justice during medieval times; Palazzo del Podestà built in 1334 as the residence of the city's chief magistrate in Gothic style; Teatro Galli, designed in 1843 by Luigi Poletti and restored after WWII [10]. A view of the square is shown in Figure 1.



Fig. 1. Aerial view of Piazza Cavour in Rimini, Italy (from Google Earth).

III. HISTORICAL VALUE OF BUCKINGHAM PALACE SQUARE IN LONDON

Buckingham Palace Square is historically and symbolically significant for British culture, dominated at its focal point by a grand monument, the Victoria Memorial, honouring Queen Victoria, who reigned from 1837 to 1901. At the top stands a gilded statue of Victory, flanked by figures representing Constancy and Courage, beside Truth, Justice, and Charity [11].

The square is the ceremonial front yard of Buckingham Palace, the official London residence of the monarchs. It also serves for national celebrations, royal events, and state ceremonies, including the famous Changing of the Guard. The square is often filled with crowds during key events like royal weddings and jubilees. Figure 2 shows a top view of Buckingham Palace Square.

This square is also bordered by two green areas: Green Park and St James Park, and represents the point where these two parks converge, separated only by the road network.

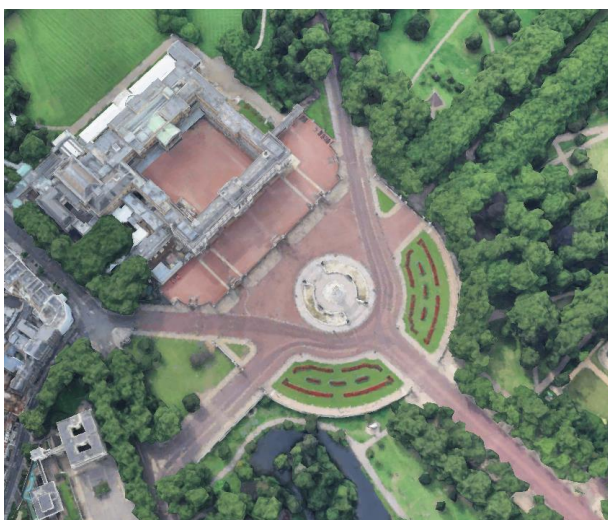


Fig. 2. Aerial view of Buckingham Palace Square, UK (from Google Earth).

IV. AUDIO RECORDING

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

The acoustic survey was carried out with the following equipment:

- a) 64-channel spherical array (MH Acoustic em64 Eigenmike®) for Rimini [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 < 2.5 m/s as average along all the measurement duration (i.e., 5 min) [13].

The audio reproduction can then be realised in two different ways: by using the audio equipment inside a specialised listening room, where the disposition of the speakers is distributed over the spherical surface of a sphere with a seat at the centre of it. Alternatively, a head-mounted display (HMD) [14] can be another optimal solution when combined with headphones in a binaural rendering. Both solutions can have an audio resolution equal to O3A. For completeness, another remote individual can be connected to the audio station, rendering a 3D audio in real time.

V. VIDEO OVERLAY

The video is usually captured with a 360° camera (Kandao QooCam3) [15] that is installed above the centre of the microphone, along the same vertical axis, and oriented along the transducer No. 1. This setting allows to align the invisible directivity of sound captured by the microphone with the correspondent visualization of the environment captured with the panoramic camera [16].

The video can be saved in MKV and/or MP4 formats to be readable by VLC software or similar, where the user is able to pan the view if the focal setting is on, while a visor like Oculus Quest2 can be an alternative 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 in a window. This represents the easiest way to detect the noise source in the recorded scene.

VI. SOUNDSCAPE MEASUREMENTS

The first audio measurements have been carried out in Piazza Cavour of Rimini.

The measurements have been carried out during weekdays, between 1200 and 1400, as the busiest time of day. The overall duration is 5 minutes.

Piazza Cavour in Rimini was dominated by occasional conversations of visitors. Figure 3 shows the elaboration of the

acoustic video mapping and the visualization of sound intensity highlighted with colours. The colour scale indicates the sound energy arriving at the microphone probe, from blue-violet when the sound has less energy to orange-red illustrating high sound levels [18]. This methodology is widely used for enclosed spaces, especially complex geometry and room shapes characterised with a reverberation more than 1.0 s, where it is easier to detect early and late reflections [19].



Fig. 3. Acoustic survey in Piazza Cavour, Rimini, by using an Eigenmike em64 microphone.

In Buckingham Palace Square, the main source of noise was represented by individuals chatting while some road vehicles passed by around the Queen Victoria memorial. Figure 4 shows one of the moments when people are chatting on the right-hand side of the 360° view, detectable with the colours created with the Flare plugin [20].



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

VII. ACOUSTIC ANALYSIS OF MEASURED RESULTS

The acoustic parameters analysed for these soundscapes differ from those typically used in building acoustics due to their characteristics to be suitable for environmental sound sources. These environmental parameters are Loudness [21], Sharpness [21], Roughness [22], and Prominence [23]. Table I summarizes the values of each parameter based on the measured audio recordings.

TABLE I. ENVIRONMENTAL ACOUSTIC PARAMETERS.

Location	Mean Loudness (sones)	Mean Sharpness (acum)	Mean Roughness (asper)	Mean Prominence (dB)
P.za Cavour Rimini	1.6	1.1	10.6	1.9
Buck'am Palace Sq	1.3	1.3	5.6	3.2

Among the two case studies, the difference in terms of noisy parameters is not very evident. Specifically, the loudness was found slightly higher in Piazza Cavour in Rimini, to be equal to 1.6 sones, while in Buckingham Palace Square it was found equal to 1.3 sones. As it is known that 1 sone corresponds to a loudness of a 1 kHz tone at 40 dB SPL [24], Figures 5 and 6 illustrate the graphs of loudness in the time domain, related to the two places. In these graphs, it is evident that the majority of values are around 1 and 2 sones, corresponding to an overall SPL around 36 dBA in Rimini and 34 dBA in London [25].

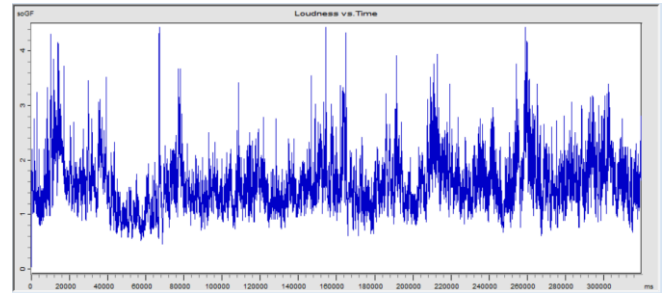


Fig. 5. Loudness outcomes in Piazza Cavour, in Rimini.

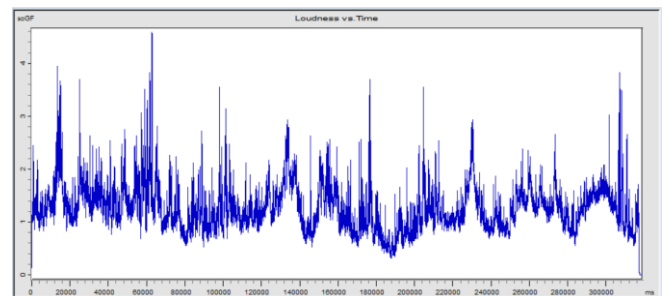


Fig. 6. Loudness outcomes in Buckingham Palace, London.

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 [26]. This parameter can be compared to the sound of a glass shattering on the floor of a quiet room [27], or to a gunshot echoing in a forest.

In our case, the values of sharpness are very comparable, around 1.1-1.3 acum. Effectively, the sounds recorded in both squares were related mainly to conversations, without any particular sound characterised by high-frequency content, as could have been a siren. Figures 7 and 8 illustrate the sharpness related to the two places.

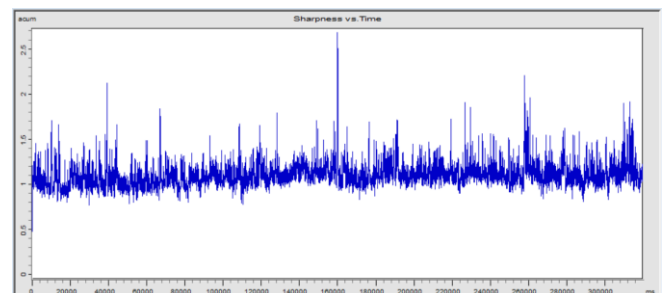


Fig. 7. Sharpness outcomes in Piazza Cavour, in Rimini.

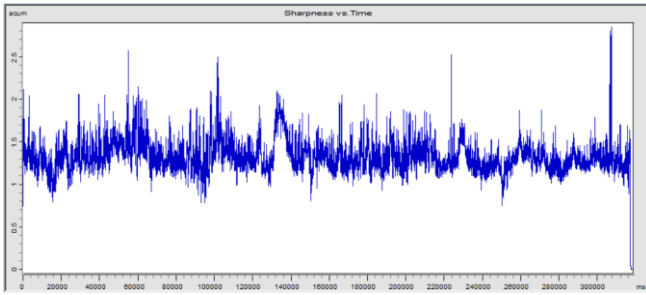


Fig. 8. Sharpness outcomes in Buckingham Palace, London.

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, compared to the fluctuation strength that has 20 modulations per second, or even less [21]. The difference between these two parameters is that roughness is used to quantify high-frequency modulations, like buzzing, while fluctuation strength is used to quantify low-frequency modulations [28].

For the selected sites, the highest roughness has been found in Piazza Cavour, to be around 11 asper, slightly more noticeable compared to Buckingham Palace, where the mean roughness value is around 6 asper. Figure 9 illustrates the roughness in Piazza Cavour, which is generally around 10 aspers, with a few exceptions found between 30 and 50 aspers.

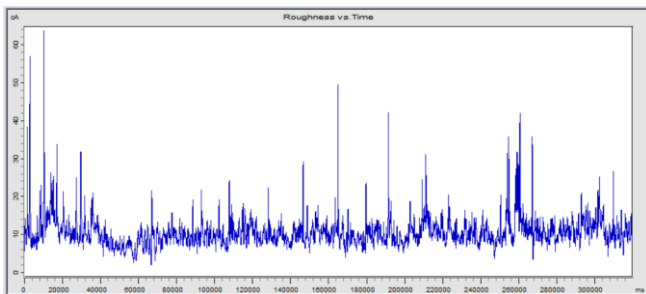


Fig. 9. Roughness outcomes in Piazza Cavour, in Rimini.

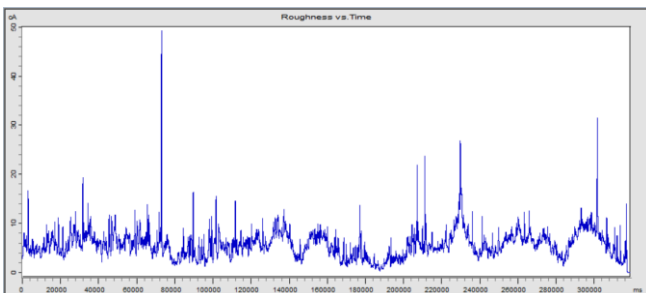


Fig. 10. Roughness outcomes in Buckingham Palace, London.

In Buckingham Palace, roughness was generally below 10 aspers, and only a spike reaching 49 aspers was detected, along with a few peaks around 20-30 aspers [22], as shown in Figure 10. This means that the soundscapes in both places were predominantly characterised by mid-to-low frequencies.

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 [29]. Particularly, the

prominence at the order of 2-3 dB, as registered in Piazza Cavour and Buckingham Palace, is not considered prominent, such that they are inaudible to the listener.

VIII. CONCLUSIONS

The Agora research project aims to apply 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 [30]. These challenges consist of achieving a high-order Ambisonics (HOA) through telecommunication [31]. Outdoor measurements were performed using a 19-channel and a 64-channel microphone, which allow an immersive audio experience.

Despite the limited duration of the audio recording, which, if extended, could have contributed to more comprehensive conclusions, the analysis of the environmental acoustic parameters indicates that the soundscapes recorded at the two sites were not significantly influenced by specific sound sources typically perceived as disturbing [1]. 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. In Buckingham Palace Square, for example, events featuring army musical bands and large crowds are common during royal celebrations [32]; however, these do not reflect the typical soundscape of a standard working day.

The analysis of the environmental acoustic parameters highlights that the soundscapes recorded in these two sites are not particularly affected by sources that can be considered annoying. In fact, the main source of noise was merely the conversations of transient tourists.

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