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Towards a soundscape surround index

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ABSTRACT

Sound sources are being spread in public spaces during urban design and planning processes, yet little is known about the effect their spatial pattern can have on soundscape. The aim is to investigate if associations can be made between the dynamic relation between static sound sources and listener in public space and the perceived soundscape dimensions. An index for measuring spatial variability of sound sources in an urban acoustic environment is proposed to describe physical features of the investigated phenomena and help to predict its influence on the perceptual outcomes.

Keywords: Apparent source width, Sound source distance, Sound envelopment, Gyroscopic interaction

1. INTRODUCTION

Soundscape is a perceptual construct used for characterisation of urban acoustic environment (1). It is influenced by a variety of auditory and non-auditory factors (2). While auditory factors analyses are looking at signal characteristics, sound source preference, perceptual dimensions and acoustical properties, the site-specific, 'micro spatial' and three-dimensional distribution of sound sources has been somewhat overlooked in soundscape research. This study argues that it is an important perceptual factor in urban open space settings.

The spatial distribution of sound sources is an inherent part of urban and landscape design tasks but there is a lack of knowledge on how to optimise position of sound sources, more specifically which pattern to use and how to design it in relation to locations of other sound (noise) sources and proposed activities. For example, we might be annoyed more by a busy road in front of us than by the one behind us, but it is not clear if that is influenced by the visibility of noise sources or perhaps by the head orientation. Further, we might find a soundscape more vibrant if we experience sounds all around us rather than just in front of us, but it has not been explored how strong this effect of spatial distribution could be.

The recent research conducted by (3) and (4) showed that the spatiality of the auditory stimulus doesn't have a significant influence on soundscape dimensions defined by the pleasantness vs arousal model, which was proposed and validated by (5) and integrated in the ISO/TS 12913 (6). However, the before mentioned recent studies were focused on assessment of certain reproduction techniques and didn't report on the spatiality of the recordings used for the experiments in detail. Therefore, it is considered that the spatial distribution might be contributing to the overall setting, or very specific dimensions, i.e. perceived eventfulness.

There are still no adequate tools to accurately describe the spatial complexity of an acoustic environment (7). (8) indicated that the interaural difference caused by location of a sound source might influence the efficiency of a cognitive task performed. Further, following the research focused on concert hall acoustics and the intent to control factors such as the apparent source width by design (9, 10), this research aims to investigate the effect of similar concepts with focus on the application in design of public spaces. As the current work on the standardization of acoustic measures possibly moves from monaural to binaural measurements to better characterise all of the site-specific complexity (11, 6), this study raises a question of possible value spatial audio data can have in characterisation of an acoustic environment. Moreover, it aims to provide a conceptual framework needed to characterise the perceptual value of spatial variability of sound sources in public space.

2. SOUNDSCAPE SURROUND INDEX FRAMEWORK

The soundscape surround index is proposed to describe the spatial quality of the acoustic environment in public space while keeping the complexity imbedded in soundscape approach. In a typical public space various factors influencing the acoustic environment are present, such as: active and passive use, temporal and spatial variability of sound sources, different openness resulting in different reflections and scattering.

The following framework is suggested to encompass both dynamic and stationary receivers and sources, and both physical properties of an acoustic environment and perceptual attributes, as pictured in Figure 1.

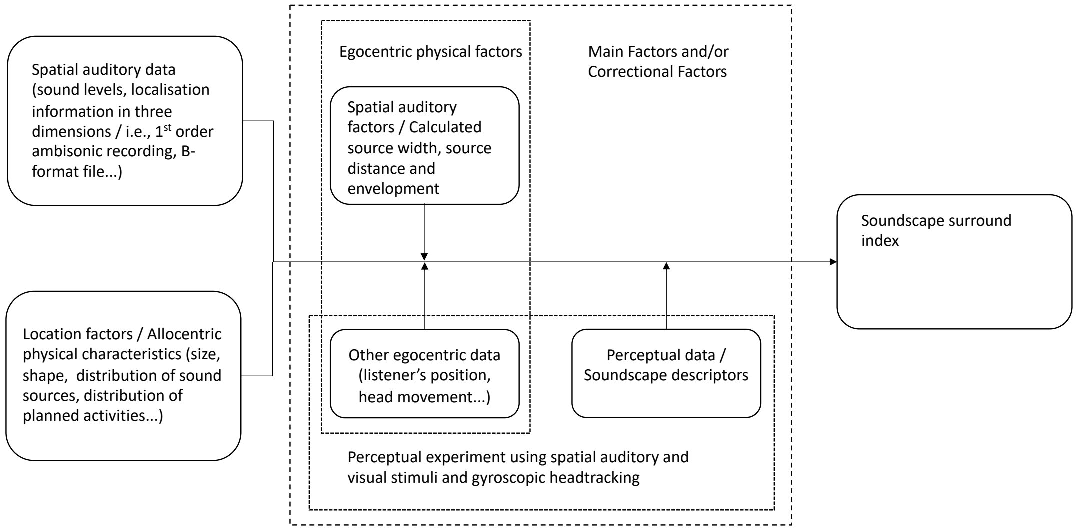

Figure 1 –Framework for developing the soundscape surround index

One of the trademarks of soundscape research is finding a balance between quantitative and qualitative data. The proposed index is calculated from location data (stationary and allocentric, i.e., planar shape of the stationary sound sources considered, size and shape of the public space itself) and spatial audio data (recorded or simulated) collected from a number of measurement points (egocentric level, i.e., receiver's position changes in relation to the sound source analysed). To characterise a whole place with clear physical boundaries, such as square, or even a loosely defined area, the index would be then calculated following the method similar to a method such as ISO 3382 for measuring reverberation time of a room (12, 11), where different sound – receiver positions would be used to calculate the mean value for the space analysed and compensate for relative sound pressure levels, lateral energy fractions and other site-specific characteristics.

2.1 Location factors

Location factors represent the contextual characteristics of a public space. They include the shape of the analysed sound sources in relation to the layout of the space analysed, so they inform the potential number of measurement points needed.

Stationary sound sources in public space are designed in different 'planar patterns' or 'shapes'. For the purpose of the index, the simplification to a point, line and an area pattern is suggested for two-dimensional layouts, as in Figure 2, applicable to both horizontal and vertical planes. The term 'spatial pattern' was preferred to 'spatial distribution' since it implies a designed form rather than a random distribution. Conversely, the term pattern might imply the temporal aspect of the phenomena or even the directivity pattern of a microphone, which however was not conceived in that sense within this research.

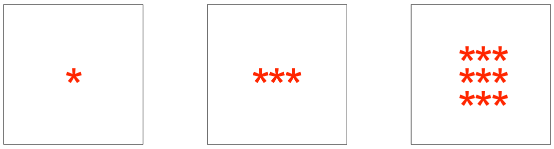

Figure 2 – Three basic spatial patterns according to which the stationary sound sources can be designed in a public space: point, line and area pattern (from left to right)

Most typical use of the classification proposed might be the layout of water fountains in a square, as pictured in Figure 3. They allow a listener to experience it from outside (point and linear patterns) or from within (areal pattern). In the three sites shown in the Figure 3, the fountains interpreted as point and line might also be experienced from all sides, which doesn't always necessarily need to be the case. The pattern may be applied to planar stationary sound sources, vertical or more spatially complex ones accordingly. Therefore, receiver points could be besides, within, above or below the sound source pattern.

Figure 3 – Examples of water fountains following the three basic spatial patterns featured in three squares in Sheffield (from top to bottom): Barker's Pool (point), Leopold Square (line) and Sheaf Square (area)

Further location factors include the size and the reverberation time which contribute to the listener's envelopment but also the functional aspect of the design, i.e. accessibility, shape of areas for staying or passing by.

2.2 Spatial audio factors

Spatial audio factors, derived from spatial audio refer to the data obtained from a measurement point which contains information on sound energy on the X, Y and Z axes. Following the use of figure-of-eight microphone (13) and complex microphone arrays (14, 15) for predicting listener's envelopment in concert halls, it is expected that decomposing spatial audio signal may be used for the development of the surround index.

The objective factors considered to be calculated using the spatial audio information are:

- source width which describes the angle between a listener and analysed sound source pattern as illustrated in Figure 4;
- source distance in free field which describes the distance between a listener and the analysed sound source pattern;
- listener envelopment which describes the influence of lateral reflections;
- temporal structure / loudness variability (i.e., N5 and N95) calculated for X, Y and Z axes, which describes how dynamic is an acoustic environment in time and space in terms of the perceived loudness.

Each of the before mentioned measures (source distance, width and envelopment) were initially based on subjective measures (such as Apparent Source Width, Listener Envelopment, Specific Distance Tendency)(16, 10) but they also allow for calculating objective indicators which were found to be highly correlated with subjective results, i.e. the late lateral sound level (13).

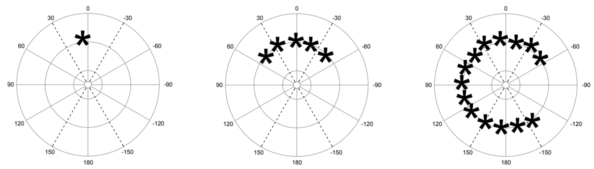

Figure 4 – Source width in three basic settings - the point, linear and areal source

2.3 Allocentric and egocentric factors

Human brain can locate objects in space on the allocentric and on the egocentric level, where the former is relative to the head and the later relative to the world (17). This is crucial having in mind that movement of people is a key feature of a public space. It is suggested that the soundscape surround quality in an urban environment should be regarded in a similar manner:

- Allocentric level – following the way the sound sources are organised in space,
- Egocentric level – following the (dynamic) position between a listener and sound sources.

Both depend on the physical position of fixed sound sources, their physical accessibility (i.e., the pedestrian path can lead between the sound sources or just tangle them from one side) and contextual factors influencing the listener's attention and experience. For instance, egocentric auditory distance largely depends on the perceived reverberation (16), which is a location factor.

Allocentric factors look at the position of source in relation to the public space. Similar to the location factors, the allocentric ones tackle the number and position of measurement points needed. They take into account whether a stationary source is near the edge of the public space so it can be experienced only from one side, or is it in the centre so it can be experienced from all sides; or does it cover a large portion of the public space so it can be experience from within.

Egocentric factors on the other hand describe the position of sound sources in relation to the receiver, such as front, back or side position. While the narrow front/back localization is often confusing (18), this might also be true for the third dimension (19). Egocentric factors change as the receiver moves through public space and as she/he moves her/his head. This is important as by doing so, he/she will experience the same stationary sound source from different angles and distances. Therefore, the framework pictured in Figure 5 is suggested to test how nine basic scenarios perform in terms of objective and perceptual attributes. A1, A3 and B3 might perform very similar as the receiver sees only a point source. B1 and C1 might be perceived similar as well as the receiver sees only a line source. On the other hand, B2 and C2 might be similarly perceived as well.

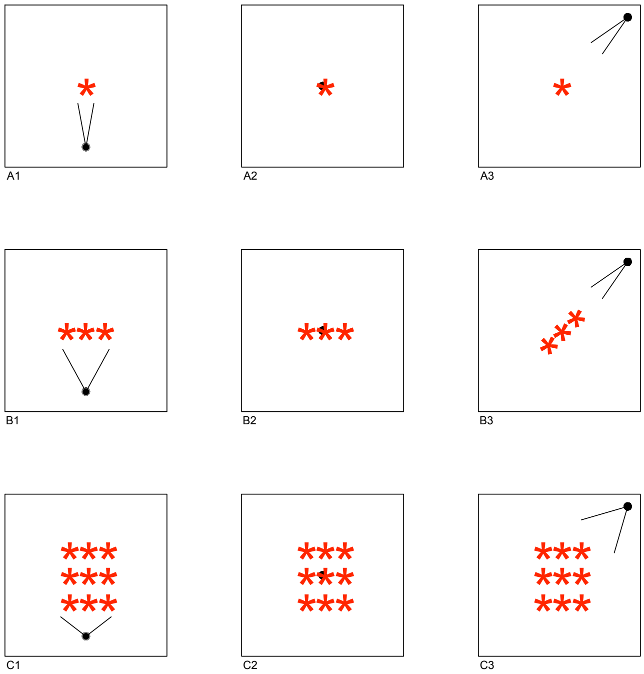

Figure 5 The framework showing nine basic scenarios of source – receiver relations. The three basic source patterns (point, line and area) are pictured in red, while the receiver and the source width in relation to the receiver are pictured in black.

To characterise a space that features a stationary sound source, a sufficient number of receiver points needs to be considered. Further research would need to be carried out to optimise the necessary pattern of receiver points.

2.4 Perceptual factors

It is well known that a lot of physical acoustic metrics do not necessarily translate to perceptual dimension in a linear way (20, 21, 16). Perceptual data within this framework refer to usual soundscape descriptors (5, 6) and the perceptual values of spatial audio factors – source width, source distance and listener envelopment. For the purpose of the index, they are intended to be used as correction factors.

3. SOUNDSCAPE SURROUND INDEX DEVELOPMENT AND APPLICABILITY

The soundscape surround index is conceived within the larger framework of soundscape indices and its primary role is to adequately address auditory spatiality. Therefore, it doesn't consider quantifying non-auditory factors such as the visibility of sound sources and/or other contextual factors, since those are imbedded within the larger framework (22).

The effect of spatial relations between the sources and the listener has been mainly limited to applications in concert venues and audio production (23). The idea behind the soundscape surround index is to provide a metric derived from recorded or simulated spatial audio data and from location it describes. It would comprise of physical measures and correctional factors.

The index could be used to predict the effect of a sound source to be introduced but would also be useful for an assessment of the overall auditory spatiality in existing acoustic environments which don't necessarily feature designed stationary sound sources.

The soundscape surround index would enhance urban and design practice in tasks considering designed stationary sound sources such as water features, noise sources moving along the constant route, different activities such as sitting or passing by along the designed route. It might also contribute to spatially informed noise masking.

To develop and validate the index a perceptual experiment will follow, featuring the relevant sound-receiver scenarios. Egocentric factors need to be tracked and controlled during the listening experiments, for example by using gyroscopic tracking of head movements (24).

It is expected that the higher surround value and the higher spatial variability of sound sources increase perceptual values along the arousal dimension (eventful/uneventful).

4. CONCLUDING REMARKS

In this paper, the framework and key factors for developing soundscape surround index have been discussed.

The proposed soundscape surround index is aimed to describe perceptual quality of acoustic environment's spatiality by combining indicators used in concert hall acoustics (listener envelopment, sound source width, sound source distance), environmental acoustics (psychoacoustical loudness), neuroscience (allocentric and egocentric aspects) and soundscape research (perceptual dimensions). It is conceived to enhance the practice of introducing sound sources in public spaces and contribute to spatially informed masking of noise sources, restoration and overall enjoyment in public space.

Within the framework of the research project Soundscape Indices, the soundscape surround index would figure as one of the fuzzy-logic-indices or as a correction factor for a single soundscape index.

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