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Soundscape quality analysis by fuzzy logic: A field study in Cordoba, Argentina

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ABSTRACT

This research studies urban soundscapes through the comparative analysis of twelve public open spaces in the city of Córdoba (Argentina), taken as case studies. The work aims to examine selection of indicators and assessment tools intended to characterize soundscape quality. The field study was carried out through surveys and acoustic and psychoacoustic indicators, that are used together to objectively describe the sound quality of urban spaces.

The study shows that, while there is a relationship of these indicators with the sound quality of the spaces, this is not linear. Their relative importance or influence depends on the interrelations occurring between the parameters studied. A model analyzing and correlating the parameters with the sound quality, based on the postulates of fuzzy logic, was applied as a tool of analysis, and it was seen to achieve a very close approximation to the subjective or perceptual response of the inhabitants. This close match between the model results and the perceptual response of the users confirms the fuzzy model as an effective tool for the study, not only of soundscapes, but also for those situations in which objective parameters must be related to the perceptual response of users.

1. Introduction

The evaluation of sound is a complex system that relates various disciplines: acoustics, physiology, sociology, psychology, anthropology and statistics [1,2]. Research concerning the problem of urban noise has focused on two main areas considered priority for their impact on city populations: quantitative analysis of acoustic conditions [3,4] and subjective evaluation of the response of the inhabitants [5–9].

In recent times, there is a tendency to pay attention not only to the negative aspects of sound, mainly discomfort, but also to the sound quality of the space [10–12]. This approach involves the concept of "sound environment design" as a stage beyond the control or reduction of noise to acceptable limits. It involves a comprehensive methodological development that takes the interaction between people, sound and context into account [13–17].

The urban soundscape normally consists of a mixture of various sounds with varying intensities, directions and durations, which makes its assessment more difficult [18]. Sound sources are analyzed not only from the physical point of view, by means of acoustic indicators, but semantically, looking for the meanings that sound has for the population and the specific users [19–23]. This analysis is usually conducted through a study based on the application of opinion polls on site simultaneously with measurements [24–27].

Ambient sound can cause subjective reactions, and may be appropriate, pleasant, familiar, useful for orientation, irritating, among others. Such attributes, and their meanings, respectively have a great impact on the assessment of the soundscape [28–31]. The soundscape cannot be studied independently. The condition of comfort of an environment is the result of the integration of several factors, one of which is the acoustic. It is evident that the response of tolerance or discomfort to a sound stimulus is conditioned by other visual, thermal and/or multisensory factors [32–39].

Different authors have begun recently to apply the psychoacoustic descriptors, originally developed to define the sound quality of products [40–44], to the assessment of environmental situations such as soundscapes [45–47]. Psychoacoustics studies sound from the point of view of its subjective perception, looking for relationships between the physical stimulus and the psychological response that it causes in people. Applying this type of descriptors can help in the evaluation of soundscape quality, relating ambient sound with the level of anticipated discomfort.

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This study analyzes a set of urban public spaces located in the central area of the city of Córdoba, in Argentina. The study of the sound quality of public spaces in the city center enables the analysis of the different reactions and degree of acceptance of the users of urban open spaces in which the objective sound conditions are similar. A methodological approach is proposed for the analysis of the soundscape, based on a mechanical practice for objective evaluation, integrating and interrelating the acoustic descriptors selected through a system of fuzzy logic. The importance of fuzzy logic [48] is based on its similarity with human reasoning, tending to obtain results that are not necessarily exact but are rather perfectible. Fuzzy logic has been used successfully in several studies related to the problem of noise in relation to aspects such as the modelling of working efficiency in noisy environments [49]; definition of discomfort from noise [50,51]; prediction of train noise [52]; and interference in communication [53].

2. Methodology

2.1. Field of study

Fig. 1 shows the location of the twelve public spaces, squares and promenades analyzed, which make up the main network of public spaces in the city center. All of the spaces have common characteristics that were taken as a starting point for their selection: they are in areas of high population and building density, are bordered with avenues and streets with high traffic levels, and together make up the main network of urban spaces corresponding to the central area of the city. The differences between the mentioned cases can be seen in their shape, the ratio of green areas to paved areas and especially in their function. Urban spaces can be arranged according to their main purpose, as squares, suitable for relaxation (Pa Sb, Pl Es), meeting or strolling (Pl VS, Pl SM, Pl Co, Pl It); pedestrian areas intended for circulation with a significant presence of bars (Plz F) and shops (Pt CJ, Pt SC); markets (Pa BP, Pa Ar), and recreation spaces used for informal sports activities (Pl In).

2.2. Acoustic measurements

Objective acoustic assessment of the urban spaces in this study was performed by means of noise measurements followed by statistical noise analysis in the inner areas of the spaces and at their perimeters, coinciding with vehicle traffic routes. The parameters measured were L_{Aeq}, L_{Ceq}, percentiles L_N ($N = 1, 5, 10, 50, 90, 95, 99$) and L_{Zeq} in third octave bands from 12.5 Hz to 20 kHz. The measurements were performed with a Brüel & Kjær type 2250 sound level meter equipped with software for analysis in frequency BZ 7223.

Fig. 1. Location of the spaces analyzed.