

Soundscape quality indicators for city parks, the Antwerp case study

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Summary

Urban parks are areas of nature and leisure which should have a favorable acoustic environment. The quality of this soundscape is not only determined by the equivalent noise level but also by the sounds that visitors walking through the park are likely to notice. To investigate which indicators, derived from physical measurements, could be used as an indicator for the soundscape quality, a study in 8 urban parks within Antwerp, one of the largest urban areas in Belgium, was conducted. The study combined a sound measurement campaign and a survey administered to visitors. Continuous, mobile sound recordings were performed with two to three sound recording devices, carried by researchers performing random walks through the parks. Next to the audio, instantaneous 1/3-octave band levels were logged, as well as instantaneous GPS data, such that the walks could be fully reconstructed afterwards. During the time periods that the measurements were performed, a face-to-face questionnaire survey was conducted among the park visitors, in order to find out their opinion on various acoustical aspects of the parks. In this paper, firstly, results of the measurement campaign are presented in the form of noise maps. Secondly, a range of acoustical indicators is compared to the individual interview responses using regression analysis. One of these indicators is the noticeability of different sounds within the soundscape of each park, calculated using a biologically inspired automated sound recognition model. This validates the methodology for assessing park soundscape quality that is applied in this study.

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1. INTRODUCTION

Parks, especially the ones in large urban areas, are considered one of the most important spaces for people's outdoor relaxation. Whether it is for going out for a walk or to do various sports activities, people expect these areas to have a situationally appropriate environment. This does not only extend to a pleasant visual scene (without disturbing and unpleasant distractions), but also to an appropriate soundscape.

Previous research of urban park soundscapes encompassed studies conducted in Stockholm [1], where 16 different parks were investigated using a survey as well as stationary measurements. More recently, a study of Italian parks, conducted in Milan and Rome [2, 3], showed that, although the soundscape approach can provide information useful for planning strategies, the limitations are on the environments investigated in the case studies. Additionally, research that considers quiet places in general [4] provides a set



Figure 1. Map of Antwerp city area with marked location borders of parks investigated in this case study. (source: Google maps)

of indicators that could also be used in assessment of the quality of the sonic environment in urban parks.

In this paper, the results of the Antwerp city parks soundscape case study are presented. The similar-

ties with previously studies extend to the methodology of data gathering (conducted surveys and measurements), as well as the statistical procedures used. However, in this study, measurements were conducted with mobile devices that are able to capture the whole area of interest more thoroughly and dynamically. Moreover, the present study differs from previous research in that the data is further analyzed with a computational auditory attention model that is based on a recurrent neural network.

2. METHODS

The data gathering campaign was conducted during August and September 2013 and in total covered eight different parks in Antwerp (locations of which are given in Figure 1) during 23 days of measurements. The campaign consisted of perceptual and personal data gathering by questionnaire surveys, and at the same time physical environment capturing by measurements. The measurement systems used were both stationary and mobile. The former included an Ambisonics recording and a Svantek measurement system; the latter included custom produced equipment, which is briefly explained in the next section.

2.1. Mobile measurements

Park areas were covered by people walking with a mobile measurement device placed inside a backpack. Each device (i.e. sensor node) consists of a microphone, a single-board computer with audio card, and a GPS sensor [5]. Alongside with the GPS signal, the 1/3-octave band levels as well as the audio signal is continuously recorded. After each day of measurements, data was uploaded to a central database, which provides convenient access for later analyses (the total amount of data gathered exceeded 370 gigabytes). While measuring, participating researchers who were carrying the backpacks were asked not to disturb the acoustic environment, therefore great care was taken not to record footsteps and other undesirable sounds.

2.2. Questionnaire survey

The campaign also included questionnaire surveys of parks visitors during the time of the measurements. The surveys were organized by the Antwerp city administration that deals with noise issues, and included up to three enquêteurs that interviewed randomly selected park visitors. In order to be able to draw statistically significant conclusions, at least 80 people were interviewed per park, resulting in a total of 660 participants.

The questions were based on surveys that were used in previously conducted studies. For instance, the questions on quality of the park soundscape included a set of semantic differentials (11-point scale) as well as a checklist of noticed sound categories, that

was also used in the Stockholm parks study [1]. Additionally, personal factors were investigated not only by questioning personal data but also the attitude and beliefs of people with regard to tranquility. Lastly, the perception of the overall environment was investigated by asking about the quality of the surroundings. One interesting result that this question provided was that the visitors ranked noise and traffic as the third nuisance factor in the investigated parks, which encourages research in this field.

3. RESULTS AND DISCUSSION

Data obtained during the campaign was compared through statistical analysis; in particular, principal components analysis, correlation analysis and linear regression. Moreover, a computational human auditory attention model based on a recurrent neural network was used to determine the sounds that an average person would most likely pay attention to.

3.1. Statistical analysis

For connection with the interview survey data, sound level data recorded with the mobile devices was selected 15 minutes before the start of each interview (comparable to the 10 minutes used in e.g. [1]). This is assumed to be the state of the sonic environment that people most likely were referring to when responding to the questionnaires.

One of the regression models is presented in Figure 2 and shows the relation between the A-weighted 50-percentile sound level (L_{A50}) and reported quietness, one of the four semantic differential questions related to soundscape quality. Regression is shown on park level, and the error bars indicate the covered spread of survey responses and 15 minute levels respectively. Even though the figure displays a reasonable trend on park level, on an individual level this trend is much less pronounced. As it was proven in previous research, e.g. [4], L_{A50} correlated reasonably well with the quality in tranquil areas and therefore this indicator is shown as an example here.

The perceived soundscape quality that was used in this research was derived from a principal component analysis of the four soundscape perceptual dimension scales. The first principal component was chosen as the quality parameter that emphasizes heavily on pleasant, tranquil, and quiet.

Several linear models for quality on individual response were extracted during analysis and two of them are shown in Table I. Both models produce similar coefficients of determination, although the first model has a higher F-value. In comparison to those results, models that contained L_{A50} as the only acoustical property of the environment, but also the frequency of hearing different categories of sounds, were found to be better. Their coefficient of determination increased

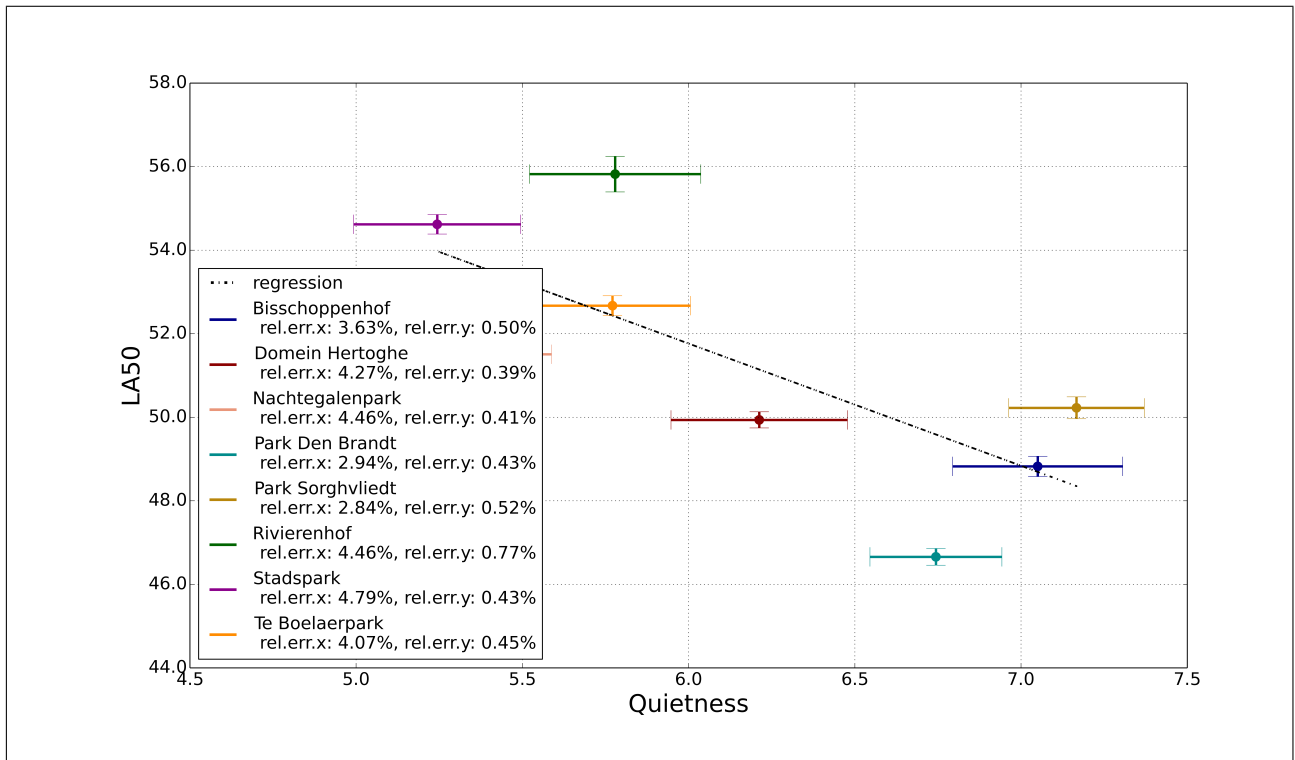


Figure 2. Linear regression between $L_{A50,15min}$ and reported perceived quietness. Each point shows the average value for a park together with standard error bars.

Table I. Stepwise regression models with soundscape quality as dependent and spectral and statistical acoustical indicators as independent input variables.

	Model 1	Model 2
Intercept	13.46***	15.52***
$L_{Ceq} - L_{Aeq}$	-0.093***	-0.104***
L_{A50}	-0.118***	/
L_{A90}	/	-0.111***
L_{A10}	/	-0.045*
R^2	0.074	0.083
$F - stat.$	26.3	19.6

to 0.309 (after adding all three groups of reported noticed sounds – human, natural and mechanical) with an F-value of 72.9. This could be seen as proof that sounds perceived by people in the parks play a role in determining the quality of the park soundscape.

3.2. Automated attention model analysis

A computational human auditory attention model was used for identifying from purely acoustic information which sounds people are likely to pay attention to. The model implementation consisted of a recurrent neural network [6] of which the third layer output is presented in Figures 3 and 4. The evaluation of 1/3-octave band levels converted to sound

features was done with the model trained unsupervised on data from seven different days of measurements. Although results show some promising development in separation of attended sounds, further analysis should include also supervised training what will be accomplished by using an extended database of labeled sounds.¹

3.3. Mapping of parks soundscape

For clear representation and identification of different soundscape zones, maps of various indicators can be produced on the basis of the data that was gathered by the continuous mobile measurements. As it was reported above, L_{A50} correlates reasonably well with the perceived quietness (and quality correspondingly). As an illustration, maps of this indicator are shown in Figures 3 and 4. Areas of relatively high as well as low median sound level can be identified in both parks. For instance, Stadspark (city park, located in Antwerp city center) has a favorable environment towards quietness only in the middle of the park. This corresponds to the park location since the park is surrounded by busy streets where traffic is a dominant noise source. On the other hand, the map of L_{A50} for park Sorghvliedt, which is located on the outskirts of

¹ Recorded park sounds were extracted by taking the most prominent output from the attention model, and were uploaded to the *Noiseplay* game database (www.noiseplay.org). That growing database of sounds serves as a training collection for the auditory attention model.



Figure 3. Map of Stadspark. The park border is shown in blue. The yellow-to-red colored dots represent the 1-minute moving average of the A-weighted sound level, sampled every 10 seconds. The purple dots indicate the activation of **vocalization** concept neurons in the auditory attention model.

Antwerp, shows a different pattern. Even though the park is surrounded by streets, the quiet area can be seen as a more spread over the whole park. However, in the middle of the park there is a quite different area.

An analysis of data with the auditory attention model was used to distinguish the various dominant sounds in each area. In Figure 4, the spatial distribution of concepts that represent various types of water sounds is shown. This corresponds to the real situation found in the park, where three water fountains were situated on the lake next to the path where recordings were made. Similarly, in Figure 3, the spatial distribution of the concept that is mostly activated next to the busy playground area is representative for vocalizations of children playing.

4. CONCLUSIONS

This paper presented the results from a measurement and survey campaign conducted in eight Antwerp urban parks, as part of a soundscape case study on city parks. A brief overview of data gathering procedures as well as the initial results using statistical analysis and a computational attention model have been shown. The obtained results show that the perception on various soundscape dimensions combined into a quality indicator is better explained by models including the sound categories that the visitors reported to have heard. This encourages the research on com-



Figure 4. Map of park Sorghvliedt. The park border is shown in blue. The yellow-to-red colored dots represent the 1-minute moving average of the A-weighted sound level, sampled every 10 seconds. The purple dots indicate the activation of **water sound** concept neurons in the auditory attention model.

putational auditory scene analysis and models for attention to sounds. Eventually, these may prove very valuable for categorization, understanding and designing soundscapes.

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