Soundscape characterization of an urban park area and its surroundings using sound perception maps: a case study in Aachen

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Introduction

Since 2002, the European Parliament and Council established that European medium size cities should provide noise maps each five years to help urban planning through environmental noise assessments [1]. Those noise maps are based on sound equivalent pressure level, which is not suitable predictor for human sound perception. This predictor indicates well the acoustic physical phenomenon in an area and if it is polluted or not, but characteristics of the sound quality of the area are not shown through a traditional noise map.

In 2014 the European Environmental Agency published a report called "Good practice guide on quiet areas". It was established some methods to identify quiet areas, such as: noise mapping, measurements of sound pressure level, evaluation of user /visitor experiences and expert assessments [2]. Perception maps are one of the ways to show the sound quality of an area and experts started to use this tool on their assessments.

Several studies [3, 4, 5] showed the use of Geographic Information System (GIS) on sound perception mapping, but until now, there is no official framework with best practices to develop a sound perception mapping.

The aim of this study is to investigate different interpolation methods and methodologies in sound perception mapping.

Previous work in perception mapping

Studies about perception mapping adopted three interpolation methods, until now, to provide perception maps with comprehensible results, as follows:

a) Regulised spline with tension: interpolation method that controls stiffness of a raster. This method was used in a research conducted in Rostock, Germany, and twelve sites were evaluated in a leisure area through 23 participants, and used questionnaires with 5-point linear scale answers [3].

b) Ordinary Kriging: this method uses semivariograms or covariances to express autocorrelations. It was used on researches in Brighton and Shefield, United Kingdom, and eight sites were evaluated in an urban park though 21 participants, and used questionnaires with 10-point continuous scale answers [4].

c) Kernel Density: It creates a density surface from point and line features. This option was used on a research in Paris, France, using 89 evaluation sites of an urban area, evaluated by 20 participants [5].

This study will compare the three above cited methods, to interpolate perceptual data related to the sonic environment of an urban park. An adaptation was made related to the Kernel Density method. In our study the Kernel Smoothing method was used, which is a first-order local polynomial method that prevents instability in a similar way as ridge regression.

Study Area

The study was conducted at Stadtgarten/Farwickpark in Aachen, Germany. It is a park in the border of the city center and includes a leisure area called Carolus Thermen, a Casino, a Conference Hall, several courts, fountains and playgrounds. Figure 1 is showing the study area, where the presented green dots are soundwalks evaluation sites, yellow dots are places where interviews with residents were conducted, orange dashed line are soundwalks routes. The study area is divided in seven areas to help the soundscape characterization. Inside each area, there are one soundwalk evaluation site and the correspondents' interviews places with residents for those areas.

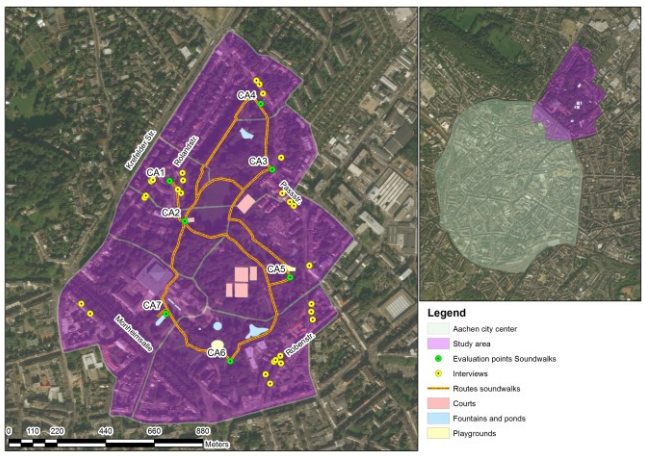

Figure 1: Study Area – Aachen: Stadtgarten / Farwickpark

Methodology

In this study 30 subjects took part in soundwalks. They had to evaluate the acoustic environment of three evaluation sites (green dots) inside the park. The data collection happened during March 2016. Additionally 34 residents participated in interviews at their homes (yellow dots) and answered similar questions from soundwalks. The interviews with residents were performed during October 2016.

This study will analyze the reported sound sources (nominal data), intensity and comfort (ordinary data) related to the

sound sources. For the ordinary variable it was used a 5-point Likert scale.

To reduce the variability of the nominal data, it was used a categorization of sound sources according to the taxonomy work indicated by Brown et al. (2009) [6]. Basically the mentioned categorization divides the reported sound sources into: motorized transport, human movement, electro-mechanical, voice and instrument, other human, social/communal, domesticated animals and nature.

After the categorization of sound sources, it was possible to verify which are the most reported categories in each evaluation site and perform the interpolation methods reported in the previous section for intensity and acoustical comfort. The interpolation was performed with the help of ArcGIS.

Results

Using soundwalks, the most reported sources are related to motorised transport and nature, as shown on Figure 2 and Table 1.

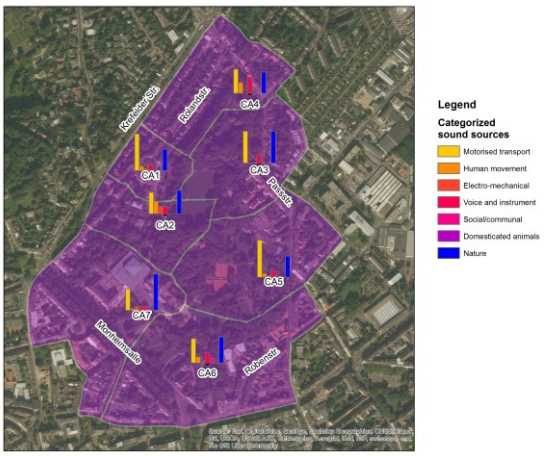

Figure 2: Categories from perceived sound sources through soundwalks with participants

Table 1: Absolute quantities for perceived sound categories in each evaluation site - soundwalks

Point	MT	HM	EM	VI	SC	DA	N
CA1	17	2	1	3	0	0	10
CA2	12	7	4	4	0	0	13
CA3	4	0	0	1	0	0	4
CA4	9	4	0	6	0	0	8
CA5	28	3	1	5	1	0	16
CA6	16	4	0	7	3	0	17
CA7	23	2	4	4	4	1	39

Legend: MT- motorised transport, HM – human movement, EM – electro-mechanical, VI – voice and instrument, SC – social/communal, DA – domesticated animals, N – nature.

In the interviews with residents, the most reported sound source category was motorized transport as shown in Figure 3 and Table 2.

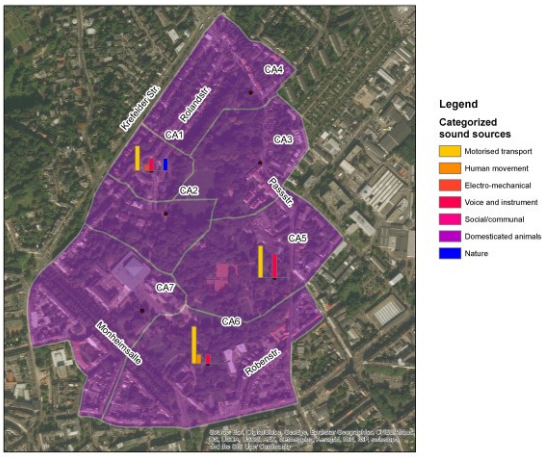

Figure 3: Categories perceived sound sources through interviews with residents

Table 2: Absolute quantities for perceived sound categories in each evaluation site - interviews

Point	MT	HM	EM	VI	SC	DA	N
CA1	4	0	1	2	0	0	2
CA2	1	0	1	0	0	0	0
CA3	2	0	0	1	0	0	0
CA4	2	0	0	0	0	0	0
CA5	4	0	0	3	0	0	0
CA6	4	1	0	1	0	0	0
CA7	1	0	0	0	0	0	0

Legend: MT- motorised transport, HM – human movement, EM – electro-mechanical, VI – voice and instrument, SC – social/communal, DA – domesticated animals, N – nature.

Due the quantity of perception answers, in this study the further analysis based on soundwalks answers of motorised transport category. First, different interpolation method are investigated. Figures 4-6 are showing the tested interpolation methods.

To help the interpretation of the following results, the color pattern shown in the perception maps from Figures 4-7, related to intensity of motorised transport is: red – noisy, orange – slightly noisy, yellow – neutral, light green – slightly quiet – dark green – quiet.

The results showed that the most reliable method for this quantity of data and spatial distribution is the Regulised spline with tension. The noisy attribute is matching with some main streets of the area, like Krefelder Str. and Monheimnsalle, as well as the quiet attribute is indicated in the direction of the middle of the park, distant from places where you can find traffic.

The other methods are not fitting well because of the spatial distribution for the example of Ordinary Kriging, and little quantity of data for the example of Kernel Smoothing. Ordinary Kriging works well when there is a well-defined grid of evaluation sites.

Figure 4: Intensity of Motorised transport sources using Ordinary Kriging interpolation

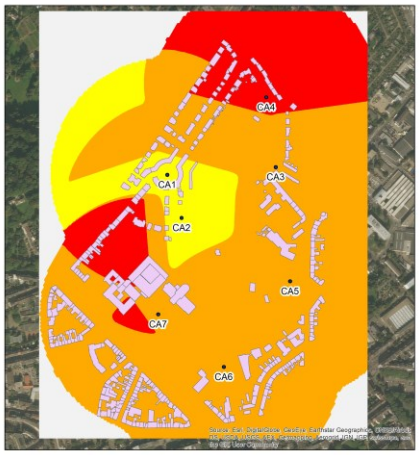

Figure 5: Intensity of Motorised transport sources using Kernel Smoothing interpolation

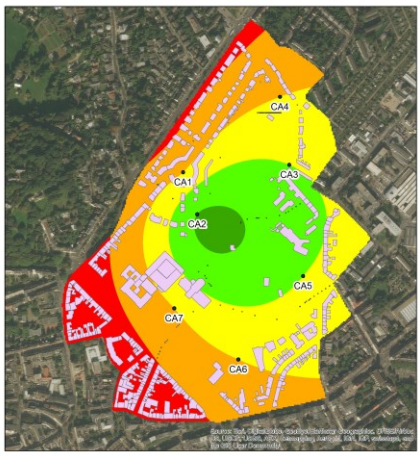

Figure 6: Intensity of Motorised transport sources using Regulised spline with tension interpolation

If we compare the interpolation results from Figure 6 with the relative frequencies results from Figure 7, it is possible to see that the interpolation is reliable on the left side of the map. It can be improved on the right side of the perception map (Fig.6), due some missing categories answers, like: slightly noisy, in the evaluation sites CA5 and CA3. An improvement possibility of the interpolation is the selection of evaluation sites that are not so distant from each other, in order to reduce interpolation errors.

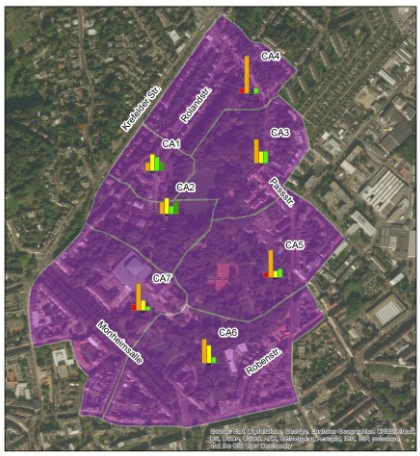

Figure 7: Relative frequencies from intensity of Motorised transport

To help the interpretation of Figure 8 and Figure 9, the colors presented on the perception map of comfort indicate: uncomfortable - red, slightly uncomfortable - orange, neutral - yellow, slightly comfortable - light green and comfortable - dark green.

The comparison of the results from Figure 8 and Figure 9 shows that the main answers categories are shown in each evaluation site areas, but not all answers categories are indicated on those areas.

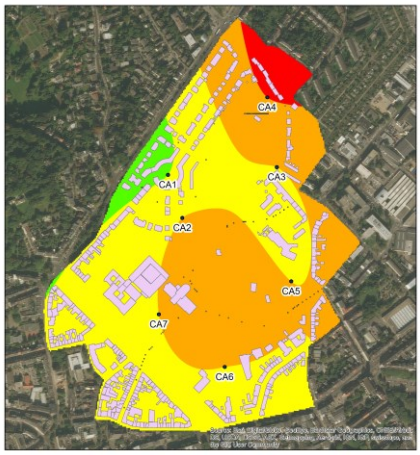

Figure 8: Comfort of Motorised transport sources using Regulised spline with tension interpolation

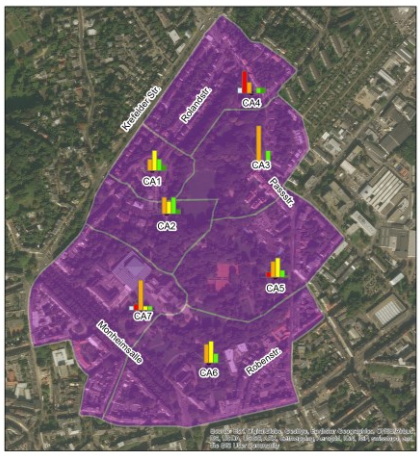

Figure 9: Relative frequencies from comfort of Motorised transport

In CA1 the category slightly comfortable is indicated in the reverse direction. The results show, that more evaluation sites inside the study area need to be taken into account in order to get a larger dataset for each evaluation site and improve the quality of the interpolation.

To show a better transition between categories answers, the adoption of, at least, 7-point Likert scale is expected to improve the results.

Conclusion

One of the aims of this study was to compare the three interpolation methods, to interpolate perceptual data related to the sonic environment of an urban park.

According the spatial distribution and quantity of dataset of the study case, Regulised spline with tension method showed the best spatial resolution regarding to the perceived intensity of sound sources (motorised transport).

It turned out that a well-defined grid with greater amount of evaluation sites is needed to conduct Ordinary Kriging and Kernel Smoothing as interpolation options.

An alternative for the representation of perception mapping with few data is the use of charts with relative frequencies.

The other aim of this study was verify which type of questions can be used in sound perception maps in order to help urban planning.

Categorical variables can be used on sound perception mapping, but we expect that a 7-point scale improves the results to represent spatially the attributes related to perceived sound sources.

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