Analysis of Urban Noise Frequency Characteristics Using a Smartphone

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Abstract. This paper describes an attempt to analyze frequencies of noise occurring in urban areas using an Android-based smartphone. The proposed solution enables audio writing to the device's memory, analysis on the device and transmission of results to the server. The article presents results of tests carried out in the city of Krakow.

1 Introduction

Urban development, contributing to development of local transport and industry, increases the intensity of sounds in a limited area to a level that can be described as harmful [1]. One of methods to reduce the noise level in areas particularly affected by this problem, thus ensuring the proper acoustic climate for urban residents is installation of noise barriers. It should be noted, however, that noise barriers are not an effective means of dampening of low frequency noise. Monitoring noise levels in urban areas is a necessity resulting from the requirements of the European Union [2].

The purpose of this publication is to demonstrate that it is possible to carry out rough, extensive measurements of spectrum characteristics of noise in urban areas, using low-cost, commonly available mobile devices.

This article is divided into 5 parts. Chapter 2 presents some issues related to the impact of specific frequency components of noise on human health, regardless of their intensity. Chapter 3 describes test methods used in this paper and the techniques used to validate the measurement system. In chapter 4, the obtained results are presented. Chapter 5 presents plans for further work in this area.

2 Impact of Frequency Noise Components on Human Health

Prolonged exposure to high noise level can lead to disorders that cause diseases such as hypertension, neurosis etc. [3]. A vexing noise also hampers any mental work and all forms of recreation. Due to the increasing number of anthropogenic sources of infrasound, especially in the urban environment, the impact of this frequency range for human health attracts an increasing interest [4]. In 2005, in the Institute of Occupational Medicine in Łódź, a group of volunteers were subjected to the influence of low frequency noise (10–250 Hz) at a level not exceeding 50 dB. Participants, which remained under

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the influence of noise, committed multiple errors and worked less effectively than those not subjected to low frequency. Furthermore, participants under influence of noise had impaired cognitive function [5]. The results of these studies also show that exposure to infrasound can cause dysfunction of the human balance system, such as loss of balance or nystagmus.

Ultrasonic noise can also have adverse effects on the human body [6]. Ultrasonic noise is characterized by a spectrum in which the high frequency audible components are present, and low audible ultrasound of 10 kHz to 40 kHz. Research into effects of ultrasound noise on hearing organ is difficult, because ultrasound noise is usually accompanied by the audible noise. It is difficult to determine, whether changes in hearing are due to audible or ultrasonic noise only, or as a result of the simultaneous operation of both these components. Currently, common views are that as a result of nonlinear influence of ultrasound, subharmonic components of the sound cause pressure levels of the same order of magnitude as the basic component of the ultrasound. Therefore, this phenomenon may cause hearing impairment. A next negative effect of ultrasound is related to the vestibular organ in the inner ear, manifested by headaches, dizziness, imbalance, nausea, sleepiness during the day or excessive fatigue [6].

3 Method of Analysis

An important problem during the implementation of the work described in this paper was the choice of method for computation of the Fourier transform, which, as the basis one for the spectral analysis, has been selected from other transforms, e.g. piecewise-linear ones [7, 8]. Several different algorithms for calculating the DFT were also tested. Due to its high efficiency, *fftpack* library was used [9], which allows for calculation of the DFT for the 2048 elements sized vector for the audio signal sampled at 44 kHz, in the real time, on Android-based Samsung Galaxy S3 smartphone.

In order to simplify the analysis, it was assumed that as the dominant frequency band, the amplitude filter of 3 dB bandwidth was used. The procedure for detecting dominant band was based on finding the maximum values in coefficients obtained from the DFT. Next, number of samples that met the 3 dB criterion was determined. To calculate the energy associated with the selected band, the Parseval's theorem was used.

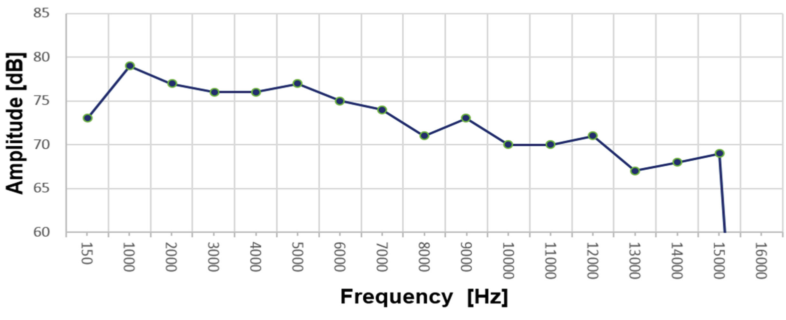

Fig. 1. Typical frequency responses of microphone

The frequency response of microphones in all devices used during the test were analyzed [10] with the use of the methodology described in [11]. An example of the frequency response of the Samsung Galaxy S3 smartphone in presented in Fig. 1. A similar procedure was also performed for tests based on recording and analyzing of sounds of selected frequencies.

4 Results

The presented results were obtained in separate research processes, at different times of the working day and on weekends, in the same places throughout the city. The measuring points were chosen based on maximum diversity in intensity and spectrum of noise, depending on the time of day. In the morning, usually the main factor generating the roadway noise were the combustion engines, with the clear low-frequency dominant High frequency component, caused as an effect of rotating wheels of vehicles (tire noise) had a low level due to traffic jams [12]. Noise registered in the afternoon usually was determined by both factors mentioned above. In the evening, smaller traffic, and a lower concentration of people resulted in a lower sound levels, and changes in the spectral characteristics of recorded sounds.

Analysis of the results show that the vast majority of the measured noise is dominated by the low-frequency range from 200 to 500 Hz, and the medium-frequency approx. 500 to 4 kHz [13]. The noise with the high-frequency dominant above 4 kHz, was observed only in the vicinity of construction sites.

Table 1. List of noise measurement points.

No.	Measurement point name	Location
1.	Opolska St., street side	50°09’13.4”N 19°92’51.3”E
2.	Opolska St., behind noise barriers	50°09’19.2”N 19°92’54.8”E
3.	Krowoderski Park	50°08’82.9”N 19°92’42.6”E
4.	Rydla St.	50°08’10.6”N 19°90’58.3”E
5.	Stańczyka and Armii Krajowej Crossroads	50°07’76.5”N 19°88’96.2”E
6.	Lea St.	50°07’36.2”N 19°89’58.0”E
7.	AGH Campus	50°06’80.7”N 19°90’72.4”E
8.	Czarnowiejska and Mickiewicza Crossroads	50°06’51.9”N 19°92’37.3”E
9.	Main Station in Kraków	50°06’82.8”N 19°94’68.6”E
10.	Floriańska and Św. Marka Crossroads	50°06’37.4”N 19°06’37.4”E
11.	Rynek Główny/Main Square	50°06’04.9”N 19°93’60.6”E
12.	Bulwar Czerwieński St.	50°05’37.8”N 19°93’12.0”E

The results of the measurements carried out at the points listed in Table 1 are indicated on the maps in Figs. 2, 3 and 4, for different times of day. Each measuring point is represented by a circle. Both the radius of the circle and the color depends on the dominant frequency recorded in a given measurement point. The meaning of color measurement points are shown in Table 2.

Table 2. Meaning of colors of measurement points from Fig. 1.

Dominant frequencies [Hz]	Color of the Measurement Point
0 - 150	
151 - 300	
301 - 550	
550 - 2kHz	
> 2 kHz	

Measurements carried out up to 600 m from the measurement point 1 and 2, i.e. at Opolska St., show that in the morning the dominant frequency is about 100 Hz lower than average dominant frequency of the urban noise. This is a result of frequent traffic jams in the morning, on the streets of Krakow. The main generators of noise in the traffic jams are vehicle engines, which generate sounds with the low frequency components, lower than 500 Hz. Diesel engines generate noise at frequencies lower than 200 Hz.

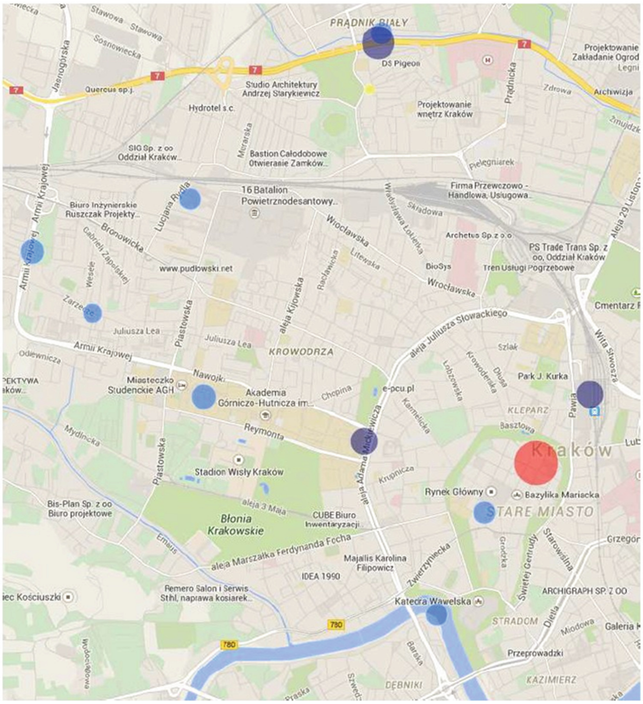

Fig. 2. The frequency characteristics of urban noise in the morning

Harmonics related to the tire noise, have less impact on the noise spectrum in the morning. The results of measurements obtained close to the footbridge over the Opolska St., became the basis for finding, that noise barriers have a significant effect on the spectral characteristics of the noise. Better suppression was observed for the medium and high frequencies. Measurements taken immediately before and behind the noise barriers on Opolska St. show the impact on the frequency spectrum of the urban noise. Sound recorded on the side of the street has the dominant frequency in the range 500 to 800 Hz, while signal registered behind the barriers is characterized by the dominant frequency in the range from 400 to 550 Hz. It should be noted that the power of the dominant band is decreased by about 10 dB, when compared to the power of the sound recorded from the Opolska St.. These results correspond to the efficiency of noise barriers with a height of 6 m [12].

For the measuring points 8 and 9, the frequency characteristics were similar to the measuring points 1 and 2, with the dominant low-frequency and mid-frequency noise. The high-frequency noise was observed in the location 10. It was associated with operation of construction machines with dominant frequency range of 8 kHz to 11 kHz.

Sounds recorded in location 3, had a fairly uniform frequency with the dominant components of 150 Hz. Spectra recorded in sections 4, 5, 6, 7, and 12 had the largest energy associated with the frequency band from about 300 to 550 Hz. Frequency characteristics of short recordings often show frequencies of large amplitude, outside the specified range. These amplitudes are related to specific incidents, for example with a screech associated with slipping tires.

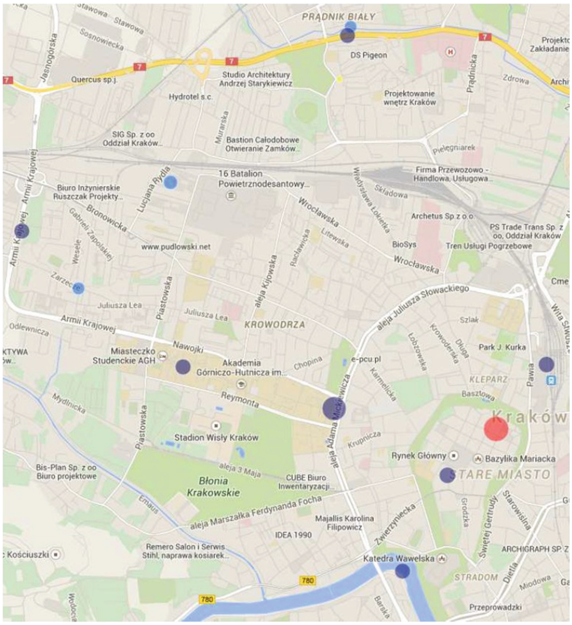

Fig. 3. The frequency characteristics of urban noise around noon

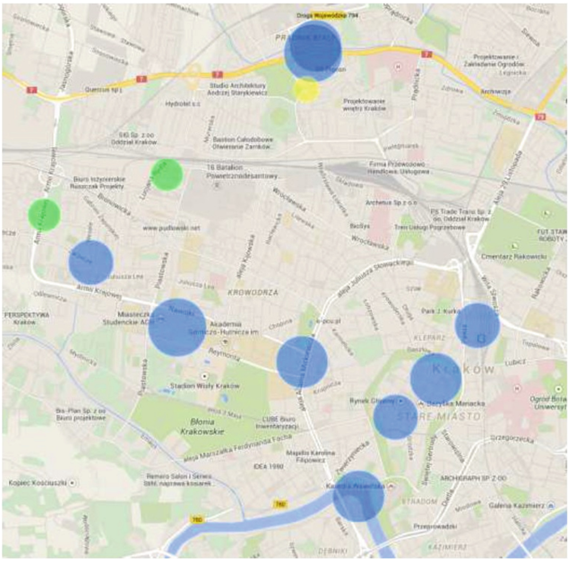

Fig. 4. The frequency characteristics of urban noise in the evening

Dominant components of noise in the measurement point 10 were of medium-frequency and high-frequency, when the equipment in the construction site was working.

In addition to measurements performed in the points specified in Table 1, sounds recorded at other, random places in the city of Krakow were analyzed. Based on over 200 measurements carried out in areas not included in Table 1, it was possible to observe, that noise that occurs e.g. in city buses has dominant frequencies in the range from 250 to 450 Hz. A siren of an ambulance was registered, too with the dominant frequency of approximately 1200 Hz. The observed amplitude of sound of the siren has local maximums at around 3500 Hz and 6500 Hz. Figure 5 illustrates the spectrum of an ambulance siren sound recorded with the smartphone. In the spectrogram shown in Fig. 6 the Doppler effect arising from movement of the vehicle is also visible.

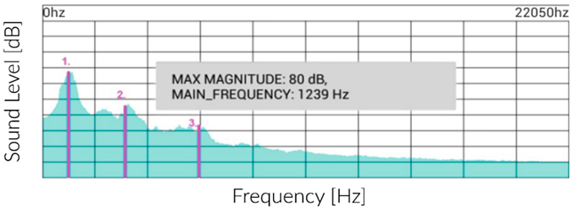

Fig. 5. The spectrum of sounds emitted by a siren of an ambulance

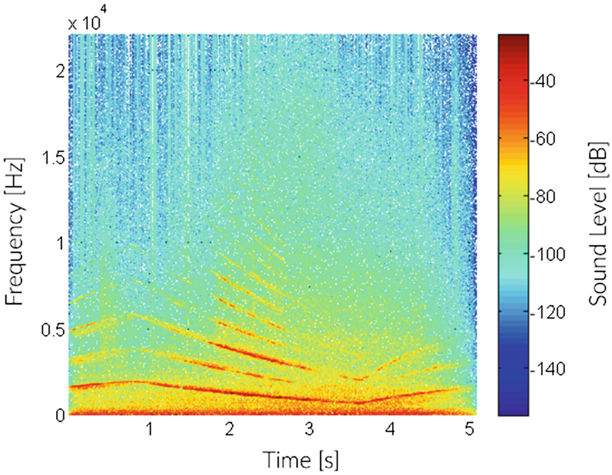

Fig. 6. Spectrogram of sounds emitted by a siren of an ambulance

5 Conclusions

The presented study demonstrated the possibility of using a mobile smartphone to perform qualitative noise tests in an urban environment, in a limited frequency range where the accuracy of the measurement is not critical. Performed tests confirmed the suitability of the proposed measuring system. It was observed that noise level in Krakow has the dominant components with the low and medium frequencies, and furthermore, as would be expected, the frequency spectrum depends on the time of day. The noise is virtually unchanged in the same time of working day, which results from the typical circadian rhythm of city life. The noise registered near congested roads and streets is dominated by the lower frequencies than in the case of roads without traffic jams. Moreover, as expected, noise barriers significantly affect the noise spectrum, mainly suppressing the high and medium frequencies.

The further work on the proposed solution is planned. These plants are related to rebuilding the application and its networking interface to enable parallel measurements on multiple devices simultaneously. This solution will enable a dynamic creation of rough, qualitative, acoustic maps of cities. Therefore, observing the changes in noise characteristics without the need for expensive, dedicated research will be possible. Qualitative acoustic maps could allow public to draw attention to the problem of exposure to noise.

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