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INVESTIGATION OF THE ROAD NOISE SOURCE EMPLOYING AN AUTOMATIC NOISE MONITORING STATION

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The paper presents a pilot investigation of noise source models in two selected localizations in the context of future dynamic noise map creation. The experiments were carried out using the automatic noise monitoring station engineered at the Multimedia Systems Department of the Gdańsk University of Technology. The results of the noise measurements employing monitoring stations and its comparison to the reference values are depicted. Short- and long-term studies of noise level are also presented. The experiments described include a comparison between environmental measurement results and the noise level prediction results. Data obtained from the NMPB-96 (Nouvelle Méthode de Prévision du Bruit) and the Harmonoise model data provide the subject of the analysis. The proposed solution of permanent noise monitoring system is also shortly described.

Keywords: noise, noise prediction, road noise model, dynamic noise map.

1. Introduction

High noise level prevails in many communities where people live or work. The European Directive 2002/49/EC, published on 18/02/2002 obliges large European cities to determine environmental noise level, according to the assessment methods used by the Member States. In recent years numerous technical means have been used in order to assess an acoustic climate in European cities. Such solutions are based on two main approaches: noise measuring and prediction. The first attempt utilizes a grid of noise measuring stations, registering sound pressure level values and other associated indices. Alternatively, the acoustic disturbance distribution may be predicted and estimated. Such systems are based on the noise source and propagation modelling, and have been implemented in most of large European cities. Both of the mentioned noise monitoring approaches have some significant advantages and disadvantages. Continuous noise measurement provides most accurate and descriptive results, however in its basic form it is suitable only for the mapping of noise in monitoring stations localizations. Implementing a network of monitoring stations expanded to cover all key locations in a given city would not be economical. Alternatively, predicted noise maps are based on statistical information characterizing modeled noise sources, i.e.: traffic volume, type of road pavement, etc. In such a case the implementation and running costs of such a system are reduced to the license costs of the noise prediction software. However, due to the characteristics of discussed data, generated noise maps are heavily generalized, infrequently updated and they do not include short-term events and noise fluctuations in the acoustic level.

A system which unifies the two discussed approaches has been designed and developed at the Multimedia Systems Department, Gdańsk University of Technology for the comprehensive assessment of the environmental noise [6, 11]. Through the grid of monitoring stations, the solution proposed produces noise map contours, based on the data gathered from mobile terminals. The utilized noise prediction model, implemented in a cluster-type computer, allows for fast and accurate updates of the maps generated [12, 15]. A feature-rich and easily accessible Internet visualization module of the system allows for an efficient dissemination of environmental noise threat information and makes it available to general public.

The aim of the presented work is to examine the engineered noise monitoring stations and the implemented numerical models of noise source and propagation in comparison to the reference methods.

2. The simulation methods

Various models embedded in software packages can be used to estimate noise level. The practice has proven that different software applications based on the same prediction standard may produce different results even in simple cases [16]. The new quality brought in by the dynamic noise map requires short-term modeled noise level accuracy compared to the real circumstances. The dynamic noise mapping provide one of the subjects related to noise monitoring systems research conducted at the Multimedia Systems Department [4–7, 11, 12, 15].

Conducted measurements are directed towards the comparison of the noise level distribution model output to the measured values. The following models for the calculation of the noise level estimation were used: NMPB-96 [3] embedded in the CadnaA software and the Harmonoise [10, 14], which have been implemented by the authors of this paper as a software application.

In addition, the road source and the propagation models employing the acoustic ray tracing method [13] were implemented at the Multimedia Systems Department [12], since they were not included entirely in any available software. The resulting program, called the Noise Propagation Model, is designed to operate on the computer cluster in order to increase its performance and has been tested on the Supercomputer of the Academic Computer Centre in Gdańsk [15].

3. Measurements

The measurements were conducted in two different locations. In the first location both short- and long-term sound level measurements were carried out, and in the second one only long-term measurements were performed.

The first selected location is positioned in the city part where practically no other sources of noise than the car traffic occur. Vehicles do not reach high speed in the street section being analyzed, with the average speed of around 40 km/h. The short-term measurements in this location were designed for verification of the propagation model. The arrangement of the microphones is shown in Fig. 1.

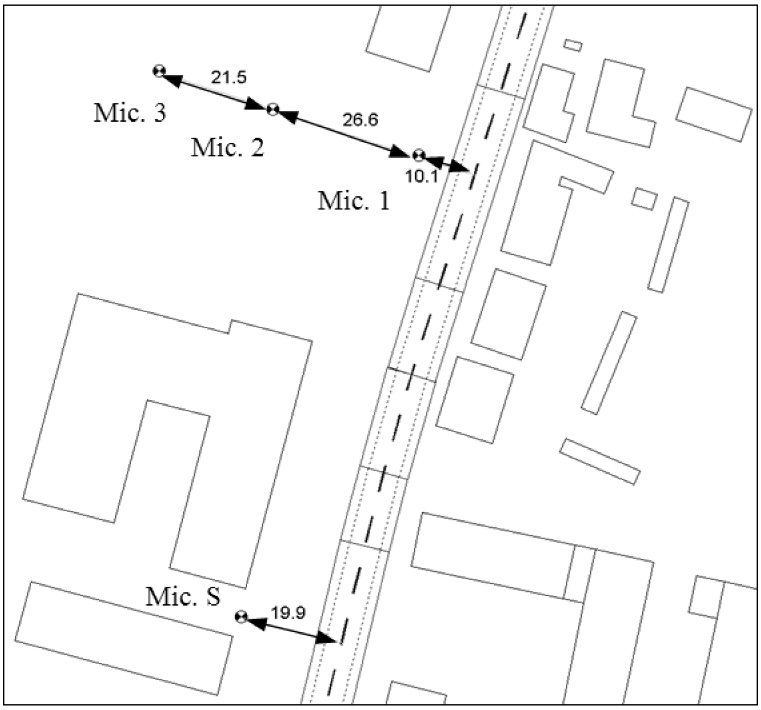

Fig. 1. Microphone placement details.

The measurement microphones (in positions 1 to 3) were mounted 4 meters above the ground surface. Two different systems were used at the same time: the engineered monitoring stations and the PULSE measuring system produced by Brüel&Kjær. Traffic volume and meteorological data were also acquired. The monitoring stations used all-weather microphones of the Sonopan WK21WP type. The PULSE system cassette type 3560C and microphones type 4189A21 were employed as the second measuring system. Noise samples were recorded by the Time Data Recorder software (v. 12) and analyzed offline using the Pulse LabShop (v. 12) software. All microphones diameters were 1/2″. Systems were time-synchronized and calibrated with B&K 4231 acoustic calibrator. Both systems were powered by batteries. The duration of measurements was 1 hour. The PULSE system was used as the reference system to which all measurements and simulations were compared to. The microphone applied for the long- term measurements (Mic. S in Fig. 1) was mounted 6.5 m above the ground.

Second series of measurements was carried out in a village outside of Gdańsk near a straight section of a national road. Most vehicles typically were moving with high speed (approx. 80 km/h) on this road. The microphone was placed 5 m above ground, 50 m from the road axis.

The pilot long-term series of measurements were conducted with usage of the automatic noise monitoring stations permanently installed in both mentioned locations. Each station was additionally equipped with a digital camera for the analysis of the traffic flow, one of the monitoring station functionalities is also a possibility to record the noise events [4]. These stations had been gathering data continuously for 7 days. The traffic characteristics of both analyzed roads were very similar and contained 1200 vehicles per hour in peak time. Instantaneous noise level and traffic statistics were recorded in one minute intervals. All noise measurements results are the equivalent level corrected by the A curve, averaged for 1 hour, referenced to $2 \cdot 10^{-5}$ Pa [1]. The 1 hour averaging was done in order to match the input and the output of the numerical road noise source model [3, 14]. The monitoring stations were calibrated with the B&K 4231 device.

4. Comparative study results

The real noise source parameters provided the input data for the noise calculation software. The averaged 1-hour traffic density and speed data gathered from long-term measurements were introduced to the model. 168 data sets from both localizations were used. The results of long-term testing of the French (NMPB-96) model are presented in Fig. 2. Figure 3 presents long-term test results for the Harmonoise model.

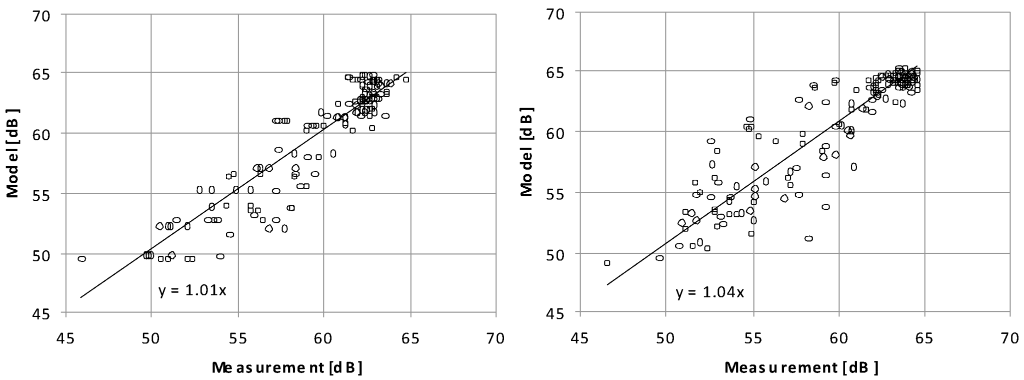

Fig. 2. Accuracy of the NMPB model, in first (left) and second localizations (right).

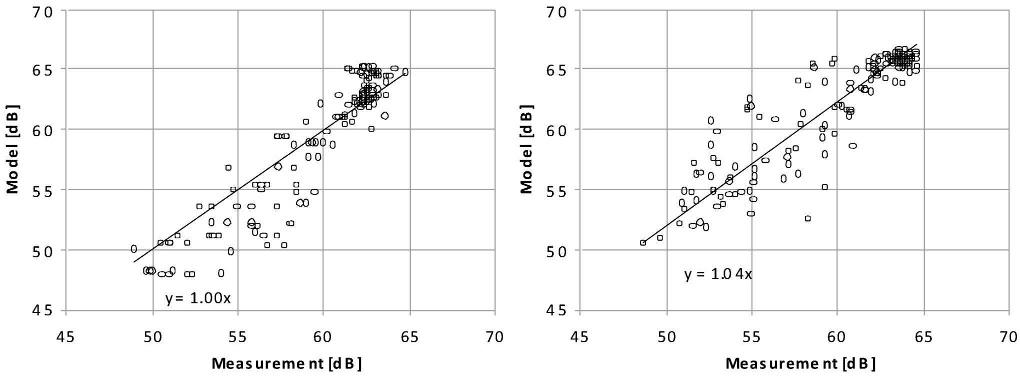

Fig. 3. Accuracy of the Harmonoise model, in first (left) and second localizations (right).

Convergence of modeled and measured noise levels can be observed for two models. The regression line in each case is nearly ideal $y = x$ (there is a lack of differences between measurement and simulation), with correlation coefficients of 0.83 for the NPM, 0.86 for the CadnaA, and 0.81 for both models in the second localization.

In the city location noise measurements indicate low noise level despite large traffic density. This may be however influenced by the specific street layout. This street has a slight slope, there is a crossroad nearby. These factors cause that vehicles are practically rolling idle down and are moving slowly in the opposite direction.

Various loud ambient sounds (eg. dogs barking in the second localization) causes that instantaneous noise levels differ from these which should occur for a given value of traffic volume.

The results of the short-term measurement employing the Brüel&Kjær system (PULSE) and monitoring stations (KSM) along with the comparisons to the CadnaA (CNA) and the Noise Propagation Model (NPM) are included in Table 1. Outcomes from the monitoring stations are similar to those gathered by the PULSE system (rows 1 and 3). A larger difference is observed for point No. 2. Differences may be caused by different sensitivities and weather coverings of the microphones.

Table 1. Measurement results and differences (abbreviations in text).

Mic. no.	L_{AEq} [dB]				Difference [dB]				
	PULSE	KSM	CNA	NPM	KSM – PULSE	CNA – PULSE	NPM – PULSE	CNA – KSM	NPM – KSM
1	63.7	64.5	67.6	63.9	0.8	2.2	0.2	1.3	−0.6
2	56.6	58.7	59.6	55.8	2.1	1.3	−0.8	−0.8	−2.9
3	51.8	52.8	55.5	52.4	1.0	1.9	0.6	0.8	−0.4

Output noise levels computed by CadnaA are higher than measured by the PULSE system. The ones computed by the Noise Propagation Model had less error in comparison to the PULSE measurements. The results show that CadnaA is characterized by a smaller attenuation on the sound propagation path from source to receiver than the Noise Prediction Model. The ground absorption coefficient was set to 0.8, but there is no available information what type of ground it corresponds to (0 – reflecting, 1 – absorbing). Setting to 1 decreases level in each point by 0.2 dB, so the source model returns overestimated results. In the NPM ground type was set to 'grass' which is related to real circumstances.

5. Conclusions

The conducted long-term pilot measurements and comparative analyzes allow for stating that the high compatibility between measurement and model outcome has been achieved. Moreover, the monitoring stations and the PULSE system returned compatible results. It is also important to stress that the implemented source model is working properly.

The achievement of the proper results of the model is conditioned by providing exact data of the traffic parameters, even though it cannot be guaranteed that the computed level is always equal to the real one. Experiments have shown that local sound events have an important influence on the total instantaneous noise level. The verification based on real measurements increases credibility of the simulation results. The possibility of sound sample recording by the monitoring station was found very useful, because it helps to exclude sound events not related to the noise traffic.

Future work will focus on expanding the number of monitoring stations to form a system able to indicate noise threat in a city area and help to produce credible noise maps of larger urban areas.

Acknowledgments

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