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# Dynamic noise mapping in the city of Gdansk

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## ABSTRACT

Investigation results of the system for creating dynamic noise maps are presented. Brief description of the system engineered at the Multimedia Department of Gdansk University of Technology is introduced. The method for acquiring input data to the numerical model for computing the distribution of the acoustic field over urban area is described. Distribution in the city area of stations for road traffic volume and noise level monitoring is illustrated. Pilot series of experiments aiming at investigation of operating efficiency of dynamic noise maps is presented. The noise maps obtained as an output of algorithms implemented on the supercomputer are shown. The time needed for updating a map for a particular fragment of city is investigated. Moreover, the outcomes obtained by modeling and by measurements done in the places of station deployment are compared.

## 1. INTRODUCTION

Noise mapping for illustration of threat of excessive sound influence is now common in many countries. For evaluation of the noise level many legal acts have been elaborated, such as the European Parliament and Council directive[1] which introduces urban noise monitoring in all Member States. It obliges large European cities to determine environmental noise level. The result is presented as a noise map and published in the Internet to ensure that the public is informed about environmental noise and its effects. Noise maps required by regulations are heavily generalized, infrequently updated and do not include temporal changes in the acoustic level. In order to react to these disadvantages, a concept of dynamic noise maps has appeared. Such a map could be more accurate in a sense of present more up-to-date noise level. To fulfill this task, the system of multimedia noise monitoring has been developed at the Multimedia Department of Gdansk University of Technology.[2,3] The system, presented widely in earlier papers, is designed for the continuous monitoring of an acoustic climate of urban areas. The assessment is performed basing on online data, acquired through a grid of monitoring stations. The gathered information consists of current noise level values and associated data including noise source description. The utilized software for calculation of noise level distribution, implemented on a cluster-type computer, allows for fast updates of generated maps. This paper presents the results of long-term noise measurements provided by the multimedia noise monitoring system. Moreover experiments carried out in order to compare dynamically calculated noise level with real measurement are presented and discussed.

## 2. THE SIMULATION METHODS

The concept of dynamic noise map can be accomplished by using real measurements of sound level or numerically computed based on the source parameters. Engineered monitoring

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stations allow connecting these two methods. Experiments carried out were aimed to compare real noise level with one obtained by numerical model. The stations were also utilized to obtain measured long-term noise level.

Method of computing sound level is based on source description and propagation modeling. The method requires data on the noise source non acoustical parameters and propagation environment properties. The source taken into account in case of this study is a road traffic. The main reason of the latter is that the traffic is the only source of noise in the investigated areas.

Measurements were carried out with use of the noise monitoring system developed at the Multimedia Systems Department of Gdansk University of Technology. The system architecture was presented in our earlier papers,[4-7] nevertheless main issues will be reminded. The system consists of dispersed autonomous monitoring stations. Two types of station are designed, namely the first equipped with sensible microphone and the second with the microphone and the video camera. The role of the camera is to provide video stream to the road traffic analysis algorithms.[8,9] The output of the latter is number of vehicles passed and their speed classified into desired categories. Stations measure continuously of environmental parameters in places of deployment. The outcomes are send to the central database in regular intervals. The application designed for the noise map calculation resides in the central computer and starts when the request for update of the map contents arises.

For the purpose of calculation of the sound level produced by road, the Harmonoise model[10,11] was exploited. This model was designed to replace all different European models for European Union state members. The model uses detailed input data and all calculations are made in 1/3 octave bands. Moreover, sound emission and propagation are completely separated. It assumes that for estimation of noise emission from a linear source representing a road, two separate models for vehicle and traffic have to be distinguished. The vehicle model, describing the sound power of a single moving vehicle, uses the velocity as input data and returns the sound power output for a specific vehicle type. Each vehicle is represented by 2 noise sources located at different heights. The traffic model, combining the noise emission of numerous vehicles to calculate the sound power per one meter length of the linear source, provides a statistical description of sound power output of the total traffic flow. The Harmonoise model assumes division of road vehicles into categories according to their weight and number of axles. The input data concerning traffic has to be provided in 3 categories (for light, medium and heavy vehicles). The total sound power of a unit length road section is obtained by summation over the different vehicle categories.

The main engine of discussed noise mapping software is the propagation model which employs the acoustic ray tracing method.[12,13] The propagation model computes the total sound level in a grid of points which are called receivers. The propagation method[14-16] describes the attenuation between each source point and a receiver point. The algorithm uses a concept of the sound propagation paths representing the schematic, straight-line tracks of the sound waves between source and receiver. Point to point (from a point source to a point receiver) sound propagation paths are obtained by segmentation linear source, resulting in mutually incoherent point sources. The short-term, 1 hour equivalent sound pressure level for i-th 1/3 octave band (Leq,1h,i) at a certain receiver position is calculated by summation over a number of point-to-point contributions from N propagation paths, according to Eq. 1,

$$L_{eq1h,i} = 10\log\sum_{n=1}^{N} 10^{L_{eq1h,i,n}/10} \qquad (1)$$

where: $L_{eq1h,i,n}$ – the short-term, equivalent sound pressure level caused by a source segment n (represented by a point source).

The algorithms were implemented on the supercomputer Galera located in Gdansk University of Technology. This advance allows shortening of computation time, significantly.

## 3. RESULTS OF SIMULATIONS AND MEASUREMENTS

### A. Long-term measurements

The series of measurements have been conducted in selected localizations in Gdansk and its surroundings. Measurement outcomes originate from 3 selected stations: two located in the city part, one in the village. The monitoring station in Sobieskiego St. ('A') is distant 22m from the road axis, in Jaskowa Dolina St. ('B') 27m, and station in Chwaszczyno ('C') 44m. The microphones are situated 4m above the ground. Correct determination of the number of vehicles requires calibration of the scene observed by camera. At present monitoring station 'A' has the calibration procedure completed. Measured sound level is A-weighted and averaged for 1 hour. Figures 1-3 present long-term measurement outcome. For all stations 60 days of continuous measurements were used to create charts.

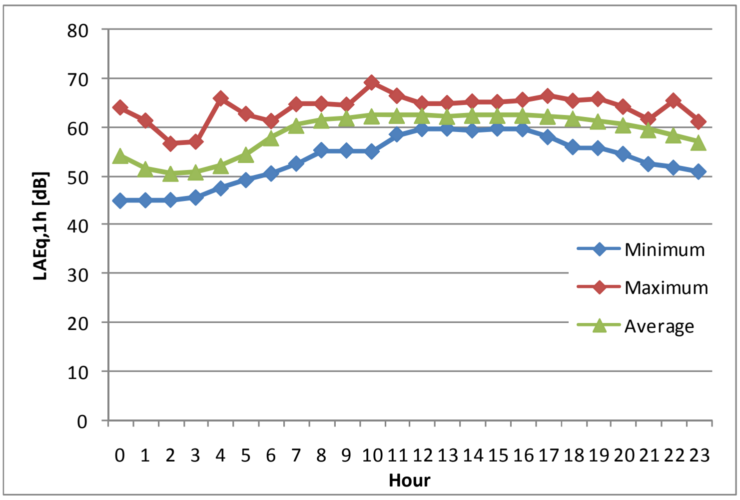


**Figure 1**: Noise measurements for localization 'C'

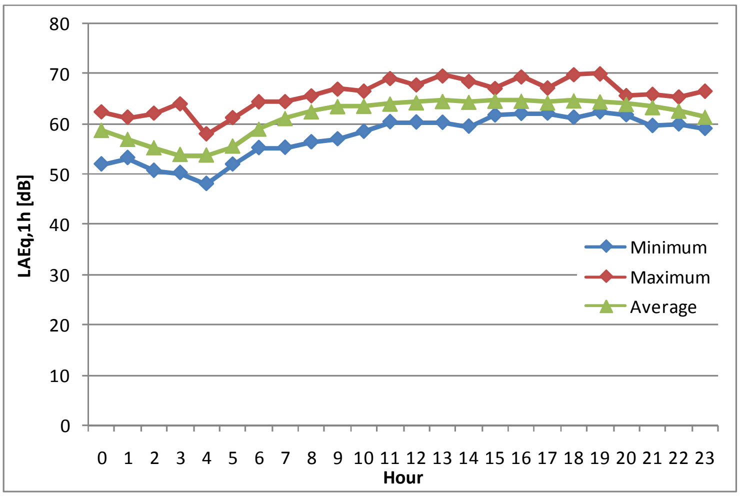


**Figure 2**: Noise measurements for localization 'B'

Fig. 3 presents both noise level measured and estimated by using computational methods. The comparison is done for the monitoring station 'A' where the scene captured by camera is calibrated and the number of counted vehicles is pre-validated.

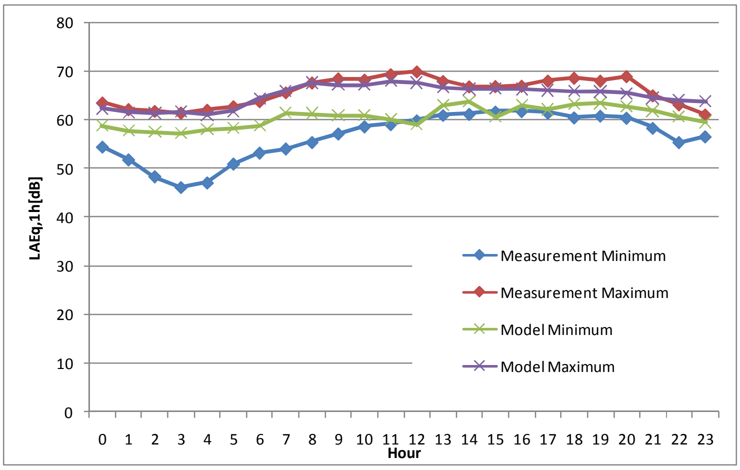


**Figure 3**: Comparison of model and measurements for localization 'A'

Measured sound level varies in a range of 5 to 19 dB between minimum and maximum values. For measurements from station 'B' standard deviation changes from 0.9 at 20 hour to 2.9 at 3 and for station 'C' from 0.9 at 15 to 2.9 at 4. The computed noise level is too large during night hours when traffic is low, nevertheless fits boundaries of measurement minimum and maximum. Values obtained with numerical model are more clustered. Sound level averaged for 1 hour and corresponding traffic volume measured by monitoring station 'A' is shown in Fig. 4. A periodicity of noise level generated by road can be observed. An average noise level for particular days is almost the same.

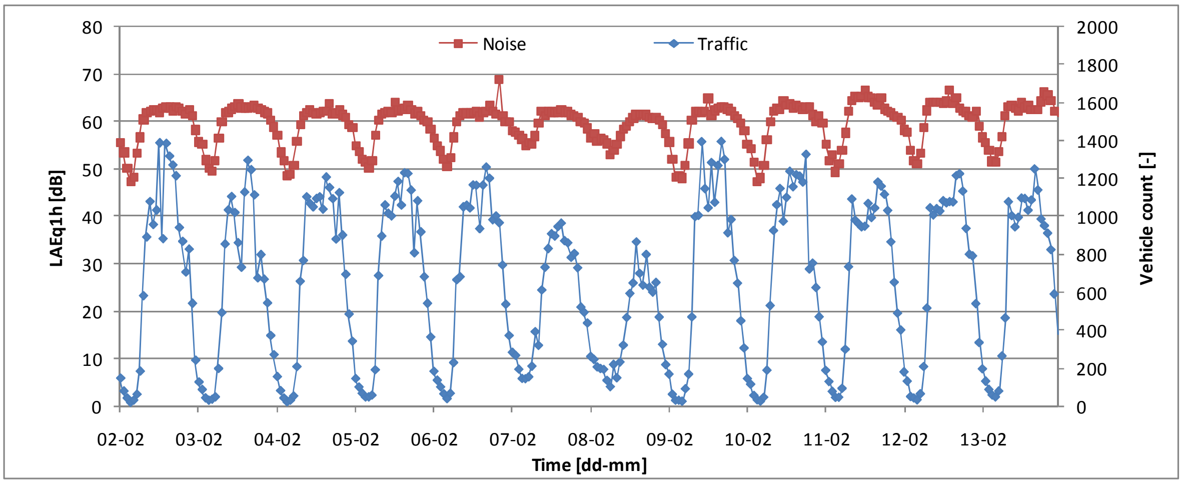


**Figure 4**: Example of long-term measurements of noise and vehicle number (station 'A')

## B. Dynamic noise map

An attempt to create noise map based on dynamically measured traffic parameters was made. The calculations were carried out for the fragment of the city map of Gdansk in the neighborhood of two monitoring stations. The map of region of monitoring stations 'A' and 'B' deployment and the roads observed by the stations is presented in Fig. 5

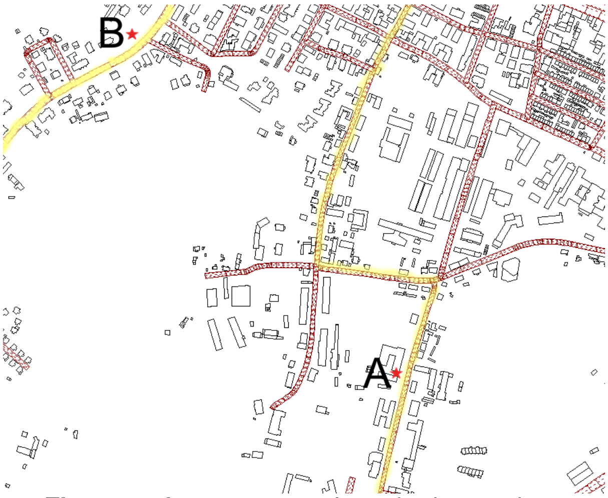


**Figure 5**: Arrangement of monitoring stations

Parameters of the noise source were gathered lively and utilized for the calculation of the dynamic noise map. The measurements had been collected for 1 hour and include sum of vehicles passing by during this period. Dimensions of area for computations were 1300×1000m with spacing of receiver points 8×8m. The main parameters of propagation model were set as follow: reflections of the 1st order, search ray 2000 meters, reflected ray 100 m, distance between following rays 2 degrees, and building sound reflection coefficient 0.8. The input data for the software consisted of geometrical description of roads (5116 road segments) and buildings (91200 buildings), number of vehicles and its speed. All other parameters in program were set to default values, i.e. pavement DAC/SMA, uninterrupted traffic flow, flat roads. Ground attenuation for the whole area was described by flow resistivity 20000 kN·s·m$^{-4}$, which corresponds to asphalt or concrete.

Arbitrary traffic data for all roads not embraced by monitoring stations was assumed. For daytime 300 light vehicles/h, 10 medium heavy vehicles/h, 5 heavy vehicles/h and speed 50km/h and for night time 30 light, 3 medium heavy, 1 heavy vehicles/h and speed 50km/h. Traffic data measured by station ‘A’ was substituted to the road near station ‘B’. Attained example dynamic noise maps are presented in Fig. 6 and Fig. 7, illustrating sound level distribution for day and night period, consequently. Maps present equivalent sound level, averaged for 1 hour.

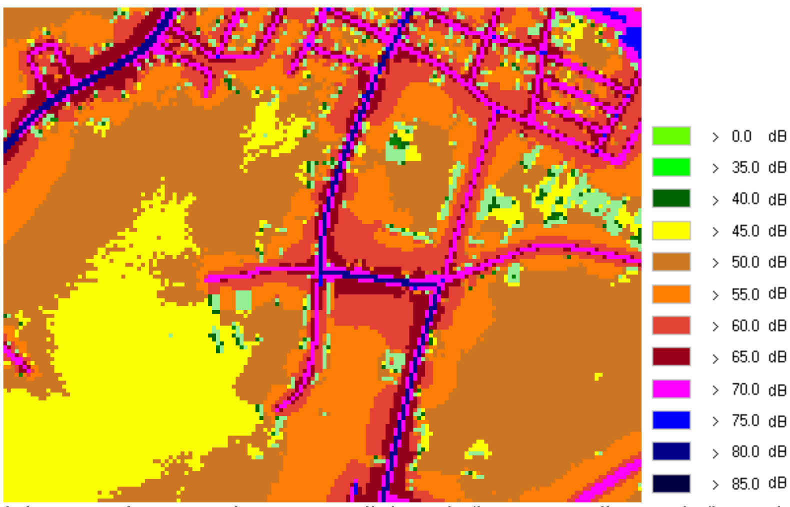


**Figure 6**: Noise map for 15:00 hour, 1104 light veh./h, 100 medium veh./h, 10 heavy veh./h

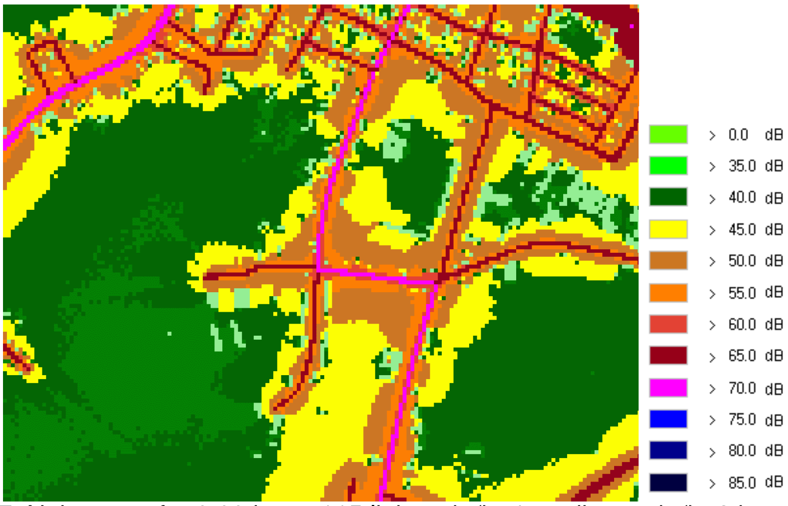


**Figure 7**: Noise map for 0:00 hour, 115 light veh./h, 4 medium veh./h, 2 heavy veh./h

The computation time on 1016 cores equalled 1126 s for the map as in Fig. 6 and 1153 s for the map as in Fig. 7. The difference between measured sound level and calculated value for the monitoring station ‘A’ was 0.9 dB at 15 hour and 2.7 dB at midnight.

## 4. CONCLUSIONS

A practical realization of the concept of the dynamically updated noise maps was presented in this paper. Conducted experiments show that in some situations it is difficult to achieve noise level estimated by model being close to the real noise values. Outputs of models are sometimes burdened with errors with reference to measurements. For example: singular vehicles passing within large time distances cause in real circumstances a lower noise than it results from model-based estimations. Opposite situations when real noise is higher than calculated one can be also noticed, but no application for noise mapping meets the non-typical acoustical events like for example noise caused by construction works. Our previous investigations show that realistic period of noise map update for the whole city of Gdansk is less than 48 hours.

The system after its planned further development will be able to indicate real noise threat in a city area in order to produce credible noise maps of larger urban areas. It is worth mentioning that a coordination of the developed noise mapping software with the urban traffic model would be very useful and would help to precisely estimate the number of vehicles in the streets not embraced by monitoring stations range. The dynamic noise map can be also updated based on the data from the other sources such as the municipal traffic management system. Moreover, the functionality of the whole system can be further extended by including parameters of the railway noise sources.

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