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Data mining with various optimization methods

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ABSTRACT

Road traffic represents the main source of noise in urban environments that is proven to significantly affect human mental and physical health and labour productivity. Thus, in order to control noise sound level in urban areas, it is very important to develop methods for modelling the road traffic noise. As observed in the literature, the models that deal with this issue are mainly based on regression analysis, while other approaches are very rare. In this paper a novel approach for modelling traffic noise that is based on optimization is presented. Four optimization techniques were used in simulation in this work: genetic algorithms, Hooke and Jeeves algorithm, simulated annealing and particle swarm optimization. Two different scenarios are presented in this paper. In the first scenario the optimization methods use the whole measurement dataset to find the most suitable parameters, whereas in the second scenario optimized parameters were found using only some of the measurement data, while the rest of the data was used to evaluate the predictive capabilities of the model. The goodness of the model is evaluated by the coefficient of determination and other statistical parameters, and results show agreement of high extent between measured data and calculated values in both scenarios. In addition, the model was compared with classical statistical model, and superior capabilities of proposed model were demonstrated. The simulations were done using the originally developed user friendly software package.

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1. Introduction

Road traffic noise along with the noise coming from railways and industries represents very important factor regarding environmental pollution in urban areas. The influence of traffic noise on human health has been studied on numerous occasions in recent years (Brink, 2011; Fyhri & Klboe, 2009; Pirrera, De Valck, & Cluydts, 2010) resulting that this kind of annoyance significantly affects both mental and physical health in many ways: causing anxiety, stress, hearing impediments, sleep disturbance, cardiovascular problems, etc. Thus, in order to control noise sound level in urban areas, it is very important to develop methods for prediction of the traffic noise. Due to the rapid development of means of transportation and road traffic, the influence of the traffic flow structure on the level of traffic noise is an important area of research. Through the monitoring of basic flow parameters and their trends it is possible to predict and monitor noise that appears in the certain part of the transport network. In this way, the effect of noise reduction can be achieved through different modes of traffic management, which is particularly important for human health and environmental improvement.

The first traffic noise prediction (TNP) models date back to early 1950s. Since then large number of methods and models for traffic noise prediction has been developed. The critical reviews of the most used ones are given in Steele (2001) and Quartieri et al. (2009). Most of the TNP models that are presented in literature are based on linear regression analysis. The main limit of those models, as concluded in Quartieri et al. (2009) and Guarnaccia, Lenza, Mastorakis, and Quartieri (2011), is "that they do not take into account the intrinsic random nature of traffic flow, in the sense that they do not take care of how vehicles really run, considering only how many they are". More advanced models involve artificial neural networks (ANN) (Cammarata, Cavalieri, & Fichera, 1995; Givargis & Karimi, 2010) and genetic algorithms (Gndogdu, Gkdad, & Yksel, 2005; Rahmani, Mousavi, & Kamali, 2011). ANN model that was used in Cammarata et al. (1995) has 3 inputs: equivalent number of vehicles, which was obtained by adding to the number of cars number of motorcycles multiplied by 3 and number of trucks multiplied by 6, the average height of the buildings on the sides of the road, and the width of the road. In order to increase the number of inputs authors decomposed equivalent number of vehicles into the number of cars, the number of

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motorcycles, and the number of trucks, and got the ANN model with 5 inputs. In terms of the parameters involved in the CoRTN (Calculation of Road Traffic Noise) model (Quartieri et al., 2009), which was initially developed in 1975 by the Transport and Road Research Laboratory and the Department of Transport of the United Kingdom, the ANN model that was used in Givargis and Karimi (2010) has 5 input variables: the total hourly traffic flow, the percentage of heavy vehicles, the hourly mean traffic speed, the gradient of the road, and the angle of view. Authors tested the developed model on the data collected on Tehran's roads, and found no significant differences between the outputs of the developed ANN and the calibrated CoRTN model. In Gndogdu et al. (2005) genetic algorithm was used to model the traffic noise in relation to traffic composition (vehicle per hour), the road gradient and the ratio of building height to the road width. In Rahmani et al. (2011) the proposed model is a function of total equivalent traffic flow and equivalent traffic speed. In both papers the authors used MATLAB to find the optimized values of model parameters.

In this paper an application of four optimization techniques for the prediction of traffic noise is presented. These techniques are: genetic algorithms, Hooke and Jeeves algorithm, simulated annealing, and particle swarm optimization. The model that is proposed consists of five variables: the number of light motor vehicles, the number of medium trucks, the number of heavy trucks, the number of buses and the average traffic flow speed. All optimized models are tested on data measured on Serbian road using the originally developed user friendly software package.

2. Problem formulation

The most suitable measure for depicting traffic noise emission is equivalent sound pressure level (L_{eq}), which is expressed in units of dbA and corresponds to fictitious noise source emitting steady noise, which in specific period of time contains the same acoustic energy as the observed source with fluctuating noise. For a number of discrete measurements (N), L_{eq} for time period T is expressed by following equation:

$$L_{eq} = 10 log_{10}\left(1/T\sum_{i=1}^{N}10^{\frac{L_i}{10}}\right) \tag{1}$$

where L_i is sound pressure level, which corresponds to i^{th} measurement.

In order to reduce the noise it is necessary to know functional relationship between the equivalent sound pressure level and influential parameters. L_{eq} is correlated to numerous parameters, such as numbers and types of vehicles, their velocities, type of road surface, width and slope of the road, height of buildings facing the road, etc. As mentioned in the introduction, in this paper the following variables were considered: the number of light motor vehicles (LMV), the number of medium trucks (STV), the number of heavy trucks (TTV), the number of buses (BUS) and the average traffic flow speed (Vavg). A brief description of how these variables were measured is given in the following chapter.

3. Data sampling

For traffic data measurement and for noise measurement on the road M5, automatic traffic counters QLTC-10C and sound level meter Bruel&Kajer type 2230 class 1 respectively were used. The equivalent sound pressure levels were measured for time period of 15 min. In order to include greater number of scenarios that might occur in urban environments, a total of 124 measurements of equivalent noise levels for time periods of 15 min were carried out. Measurements of L_{eq} for time period of 15 min were performed at various times to include diversity of the traffic flow as much as possible. Simultaneously, variations in traffic flow, traffic speed and composition of traffic flow were measured. For that reasons the surveys at the same time also consist of the following parameters: the number of light motor vehicles, the number of medium trucks, the number of heavy trucks, the number of buses, and the average traffic speed in the given time periods.

Measurements were taken in accordance with recommendations for road traffic noise measurement; microphone was mounted away from reflecting facades, at a height of 1.2 m above the ground level and 7.5 m away from central line of the road. During the measurements it has been taken care that climate conditions are as similar as possible (no wind, no rain) in order to eliminate their influence.

4. Mathematical model and methods

The equivalent sound pressure level is supposed to be modeled by the following equation:

$$L_{eq} = N_1 * log_{10}(LMV) + N_2 * log_{10}(STV) + N_3 * log_{10}(TTV) + N_4 * log_{10}(BUS) + N_5 * Vavg^{N_6} + N_7 * log_{10}(Vavg) \tag{2}$$

where $N_i(i = 1 - 7)$ are coefficients. The problem transforms to find coefficients N_i, such that supposed model best fits experimental data. For that purpose genetic algorithms, Hooke and Jeeves algorithm, simulated annealing, and particle swarm optimization are used. These techniques are briefly described in following subchapters.

4.1. Genetic algorithms

Genetic algorithms (Rao, 1996) are class of evolutionary algorithms that could be used for a large number of different application areas. The principle of genetic algorithms is based on Darwin's theory of evolution, by which the fittest individuals have the best chances to survive. Genetic algorithms operate with a set of individuals (chromosomes) called population. The information

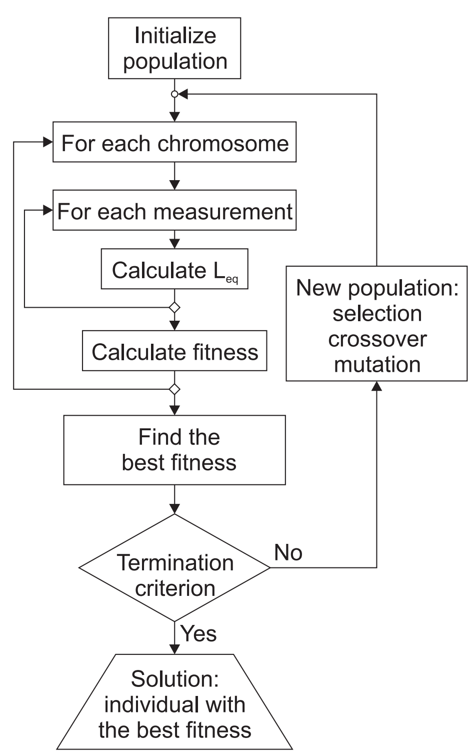

Fig. 1. Flowchart of the Genetic algorithm workflow.

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