Method for Evaluating the Statistical Relationship between Sound Pressure Level and Noise Annoyance Based on a Nonlinear Time Series Regression Model and an Experiment

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Identifying the quantitative relationship between the sound pressure level and noise annoyance for environmental noises is important from the viewpoint of noise assessment. In this study, a method for predicting the probabilistic evaluation quantities like L_x ($(100-x)$ percentile level) and L_{Aeq} (equivalent A-weighted sound pressure level) of the noise environment is proposed by introducing a nonlinear time series regression model between the sound pressure level and noise annoyance. More specifically, the joint probability distribution is expanded in an orthonormal expansion series in which linear and nonlinear correlation information is reflected hierarchically in each expansion coefficient. Next, statistical methods for predicting the sound pressure level and the noise annoyance are proposed by introducing a nonlinear time series regression model based on the above probability distribution. The validity of the proposed method is confirmed by applying it to a set of instantaneous data on sound pressure level and noise annoyance observed in a real sound environment.

1. INTRODUCTION

Identifying the quantitative relationship between the sound pressure level and noise annoyance for environmental noise is important from the viewpoint of noise assessment.[1–3] Usually, an investigation based on the questionnaires is performed, as the experimental measurement at all points in the entire area of the regional sound environment is difficult. Furthermore, statistical sound evaluation quantities, such as L_x based on the probability distribution of sound pressure level and L_{Aeq} based on averaged energy of sound pressure level, are widely used in the evaluation of the sound environment. Therefore, it is very important to determine the relationship between the noise annoyance and the sound pressure level from a statistical point of view.

In a previous study, a state estimation method was proposed for the fluctuation waveform of the sound pressure level by time-dependent sound pressure level based on the observation data of noise annoyance from the viewpoint of systems theory.[4] The relationship of the sound pressure level and noise annoyance was regarded as the input and output of a fuzzy probability system with uncertainty and vagueness. A method was theoretically derived for estimating the fluctuation waveform of the sound pressure level or the system input by use of the observation data of the noise annoyance or the system output. In analyses of environmental noise, two approaches can be considered. One is analysis from the bottom-up viewpoint, structurally based on the fundamental mechanism on the relationship between noise annoyance and sound pressure level. The other is the top-down method, which is connected with evaluation of environmental noise in the case of unknown structural mechanism. Since the analysis method considering the physical mechanism from the bottom-up viewpoint was adopted in the previous study, the derivation process of the estimation algorithm was rather complicated.

On the other hand, a method based on the top-down viewpoint can be proposed by regarding time-dependent sound pressure level and noise annoyance as the resultant time series data and by considering their mutual correlation information. In this paper, a practical evaluation method is proposed, which is simple in form as compared with the previous study. The joint probability distribution for the sound pressure level and noise annoyance is first considered for the purpose of using the usual liner correlation as well as the higher order nonlinear correlation information between both variables. Next, two probabilistic methods are proposed based on the joint probability distribution in an orthonormal expansion series[5], where linear and nonlinear correlation information is reflected hierarchically in each expansion coefficient. One method predicts the noise annoyance based on the observation of sound pressure level, and the other is a prediction for the sound pressure level from the noise annoyance. Finally, the effectiveness of the proposed methods are confirmed by applying them to a psychological experiment with the road traffic noise, where the linear regression model and neural network are compared.