Prediction of Probability Distribution for the Psychological Evaluation of Noise in the Environment Based on Fuzzy Theory

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It is necessary for the statistical evaluation of noise in the environment to find the relationship between the sound level fluctuation of environmental noise and its human response. In this paper, the psychological methods for evaluating noise in the environment are discussed theoretically by introducing fuzzy theory. More specifically, two types of methods for predicting the probability distributions of the sound level and noise annoyance are proposed. Furthermore, by applying the proposed theory to actual road traffic noise data, the effectiveness of the theory is confirmed experimentally.

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1. INTRODUCTION

The determination of the quantitative relationship between human noise annoyance and the physical sound level for environmental noises is important from the viewpoint of noise assessment. (The "sound level" and "sound pressure level" mean "A-weighted sound pressure level" throughout the paper.) In the evaluation of noise in a regional environment, an investigation based on questionnaires to the regional inhabitants is often made when the experimental measurement at every point in the entire area of the region is difficult. Therefore, it is very important to determine the relationship between noise annoyance and the sound pressure level from a statistical viewpoint. The relationship found will be connected closely to the investigation through questionnaires and the noise evaluation quantities: used such as L_{eq} (averaged energy on a decibel scale), L_x ($(100-x)$ percentile level, $x = 5, 10, 50, 90, 95$), and $L_{\max}$ (maximum level), etc.

In previous studies by S. Yamaguchi et al.,[1-4] the probability of the psychological impression about random noise was predicted on the basis of the observed data for the sound pressure level, by introducing a fuzzy set theory. However, they predicted the probability descriptively and did not consider quantitatively and structurally the relationship between the statistical information concerning the sound pressure level with several orders and the probability of the psychological impression. In particular, it appears that the so-called inverse problem of predicting the sound pressure level distribution based on the information about the psychological impression was not discussed at all by many researchers.

The sound level in an actual environment shows various forms of fluctuation, and is not necessarily characterised by a standard Gaussian distribution.[5,6] This is because of the diverse nature of the factors affecting the properties of the physical phenomena. Therefore, it is necessary to consider the lower and higher order statistics of the sound level for the statistical evaluation of the relationship between the noise annoyance and the sound pressure level.

In this study, methods for predicting the probability distribution for the psychological evaluation of the noise environment are proposed by introducing fuzzy theory. More specifically, a method of predicting the probability distribution for the annoyance scores based on the observed data of the sound pressure level is first proposed by applying the fuzzy theory. For seven annoyance scores showing seven groups in the scattering diagram of the observed data, a method of evaluating quantitatively how the statistics with several orders of sound pressure level affect the probability distribution for the noise annoyance scores is theoretically proposed. This proposal is made by introducing an expression for the probability distribution which reflects hierarchically the lower and higher order statistics of the sound pressure level. Next, the human noise annoyance scores were regarded as observation data with fuzziness, by using fuzzy probability. Then a prediction method for the probability density function for the sound level with non-Gaussian properties was proposed on the basis of information for noise annoyance scores as an inverse problem. By applying the proposed theory to the questionnaires for regional inhabitants, the noise environmental assessment should be possible. Finally, the fundamental validity and effectiveness of the proposed method are confirmed by undertaking a psychological evaluation experiment in a laboratory room using recorded road traffic noise.