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Psycho-acoustic evaluation of the indoor noise in cabins of a naval vessel using a back-propagation neural network algorithm

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ABSTRACT: *The indoor noise of a ship is usually determined using the A-weighted sound pressure level. However, in order to better understand this phenomenon, evaluation parameters that more accurately reflect the human sense of hearing are required. To find the level of the satisfaction index of the noise inside a naval vessel such as "Loudness" and "Annoyance", psycho-acoustic evaluation of various sound recordings from the naval vessel was performed in a laboratory. The objective of this paper is to develop a single index of "Loudness" and "Annoyance" for noise inside a naval vessel according to a psycho-acoustic evaluation by using psychological responses such as Noise Rating (NR), Noise Criterion (NC), Room Criterion (RC), Preferred Speech Interference Level (PSIL) and loudness level. Additionally, in order to determine a single index of satisfaction for noise such as "Loudness" and "Annoyance", with respect to a human's sense of hearing, a back-propagation neural network is applied.*

KEY WORDS: Noise in a naval vessel; Indoor noise; Psycho-acoustic evaluation; Linear regression; Back-propagation neural network.

INTRODUCTION

Even though the concept of noise and vibration in the industry is primarily focused on the reliability of machinery, there has been a shift in research focus to examining the ways in which convenience and pleasantness of noise and vibration relates to a human's level of comfort. Low noise inside a ship or offshore structure is necessary to create a comfortable internal environment. In the past, ships were regarded as very loud spaces. However, environmental noise is one of the important properties of a ship because employees in the cabin and office areas of a ship require a low noise environment. Additionally, when considering a naval vessel, where crews live for a longer period of time compared to crews on a merchant ship, the reduction of indoor noise is particularly important.

Crews that live for an extended period of time in offshore structures require a quiet space for rest. The appropriate level of noise inside the cabin of an offshore structure, such as a floating production, storage and offloading (FPSO) structure, is 45 *dBA* (Joo and Lee, 2009). When compared to the IMO's standard for noise levels in the cabin of a merchant ship (60 *dBA* max.), this is very low (IMO, 1982). The standard for a naval vessel is similar to an FPSO and requires a more conservative level of noise. Since the noise limit suggested by IMO is not proper to apply to the naval vessel, the new specification of the noise level in the naval vessel which can respect crew's satisfaction for the noise is necessary.

Even though specifications of indoor noise have been suggested by various research institutes, much of the research related to the noise limit is still being performed because the specifications cannot perfectly replicate a human's sense of hearing. Ju et al. (2010) researched noise produced by heavy construction machines using psycho-acoustic evaluation. He suggested

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the limit of the noise for these machines by completing a correlation analysis that examined the measured noise level and a human's perception of that noise. Chun et al. (2008) performed psycho-acoustic evaluation on the annoyance of noise resulting from express trains and local trains and suggested that the noise limit should be different according to the type of train. He suggested the method to make a limit of the noise from the train by the psycho-acoustic evaluation in a laboratory. Lee et al. (2008) suggested the relationship between subjective response by human and the noise from water supply and drain installation in the apartment bathroom. In this paper, the noise quality could be evaluated with psycho-acoustic evaluation and the relationship between the noise and human's response with sound parameters such as *dBA*, NR and N.

Tamura et al. (1997) researched experimentally about the effect on sleep from the noise in a ship based on the IMO standard. The psycho-acoustic evaluation was performed in a laboratory with the audio tracks recorded in various ships. He found that the noise over 65 *dBA* can cause sleeping problem for a human. Lee et al. (2010) researched about the relationship between environmental noise and sleeping problem of a human. He performed the psycho-acoustic evaluation for 2 weeks with 20 people. Through the statistical analysis, it can be found that the loudness of the noise affect the sleeping problem rather than quality or pattern of the sound.

Recently, researchers have attempted to replicate human behavior using artificial intelligence. A neural network is one of the popular artificial intelligence techniques because it can be used to represent a non-linear response, such as satisfaction regarding indoor noise. Nannariello et al. (2001) used the neural network algorithm to predict appropriate speech levels in university classrooms. His research examined the relationship between sound propagation levels and design factors of the classrooms that affect sound propagation, such as size, listener location, source location, and reverberation time. For the booming sound of a vehicle, Lee et al. (2006) suggested an evaluation algorithm that embodied a back-propagation neural network that used general sound quality parameters, such as loudness, sharpness, roughness, and fluctuation strength.

In this research, a psycho-acoustic evaluation is performed to determine the satisfaction index of the noise inside a naval vessel such as "Loudness" and "Annoyance" using recorded audio tracks. Audio tracks were recorded in various naval vessels and created by modulation with recorded audio tracks. Through psycho-acoustic evaluation, the limit of the satisfaction index of the noise inside a naval vessel was determined using various parameters that evaluated noise, such as A-weighted sound pressure level, NR, NC, RC, PSIL, and Zwicker's Loudness level. Additionally, the linear regression and back-propagation neural network algorithm were applied to determine the satisfaction index of the noise using various evaluation parameters.

METHODOLOGY

In previous research, a crew living in a naval vessel completed a survey to determine their satisfaction with the level of noise (Han et al., 2010). The result of this survey showed that the satisfaction index of the noise could be determined using a multiple linear regression model. However, the maximum allowable noise level included some errors because the survey was completed by numerous crews living in different cabins on different ships. Since the conditions of the ship were not uniform, the sounds that were measured could not be precisely matched with the surveyed results.

Therefore, in order to reduce errors in the survey results, the psycho-acoustic evaluation was performed at the same place and the recorded sound sources were assessed by a finite number of evaluators. In our previous research (Hong et al., 2010), the psycho-acoustic evaluation was performed with recorded and modulated audio tracks. Using a B&K type 4189 microphone and a Type 3560B data acquisition system, these audio tracks were recorded in various cabins on the naval vessel. Psycho-acoustic evaluation was performed in a small auditorium as shown in Fig. 1 (Hong et al., 2010). Ten jurors evaluated the 50 different audio tracks. The background noise was 30 *dBA*, sufficiently low compared to the replaying audio tracks (45 *dBA*~75 *dBA*). The jury consisted of 8 men and 2 women, aged 30 to 50, who worked for the DTaQ (Defense agency for Technology and Quality).

Replayed audio tracks were evaluated using an index level ("Loudness" and "Annoyance"), which was derived from the survey shown in Table 1. The average "Loudness" and "Annoyance" levels for each audio track were calculated based on the 10 jurors' response to the survey shown in Table 1 (Hong et al., 2010).