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BASIC STUDY OF SOUND QUALITY CONTROL BASED ON INDIVIDUAL PREFERENCE

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Abstract. *In recent years, sound quality control using active noise control has been used as a noise reduction method, targeting low frequency noise. Our previous study revealed that individual differences affect the impression of individual sounds. Therefore, this method is difficult to apply to products that have unified preference. In this study, we proposed the engine sound control system according to the preference of each subject. Targeted motorcycle engine sound which is thought to be preference tendency easily when connected to their driving pattern. From the result of this categorization, we performed auditory tests to conform to each subject's preference and determined the sound characterized by each individual's preference. As a result, we produced the active sound quality control system, which allows automatic generation of the preferred sound quality of each individual.*
Keywords: ANC, Engine sound, ASQC

1. **Introduction.** In recent years, ANC (Active Noise Control) technology [1] has been paid attention to. However, rather than the noise measures, it has been considered as the elements that give the impression even running sound for motorcycles or car. So there is desire across industries not only reducing sound levels but also creating a preferred, pleasant sound. That is, the control countermeasure for the engine sound [2,3] is shifted from noise reduction to sound design. It is necessary to evaluate not only the sound pressure reduction but also psychological experiments and neuroanatomical methods, the reason being to provide a pleasurable driving experience for an individual that enjoys engine sounds. For such a driver, reducing the engine sound by ANC will decrease their pleasure. According to our previous study, the differences in each subject's preference affect their impression of individual sounds [4]. In the previous study, Active Sound Quality Control system (ASQC) was proposed. ASQC technology based on ANC technology has been proposed for the design of engine sound. Specifically, we proposed an algorithm that amplified and reduced the engine specific order components [5]. Thus, in this study, in order to apply the preferred tendency of each subject, we created Self-Organization Maps (SOM) [6] from the speed data of each subject and considered the relationship with the preferred sound quality of each subject. As a feature of SOM, 1) the feature value of each participant can be plotted on the map, and 2) it can be categorized from color depth and distance between nodes. Lastly, we propose an algorithm that adjusts the degree component according to the sound quality of participant's preference and we consider the

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possibility of automatically generating the optimal sound quality for each subject in this system.

2. **Proposed Algorithm.** Figure 1 shows the ASQC algorithm adopting to individual preferences. This is based on Harmonic Command Filtered-x LMS algorithm. $x(n)$ is the input signal, $e(n)$ is the error signal, $c(n)$ is the control signal, and W is an adaptive filter. To adapt to individual preference from individual feature such as driving patterns, acceleration, and speed, a control signal $c(n)$ could be created by the output of the Deep Neural Network (DNN).

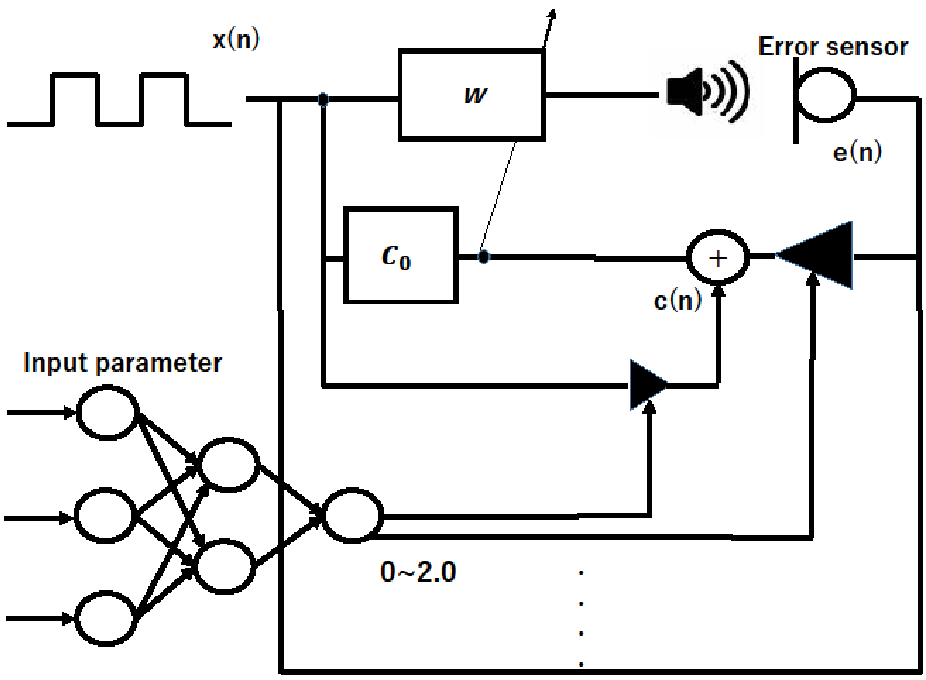


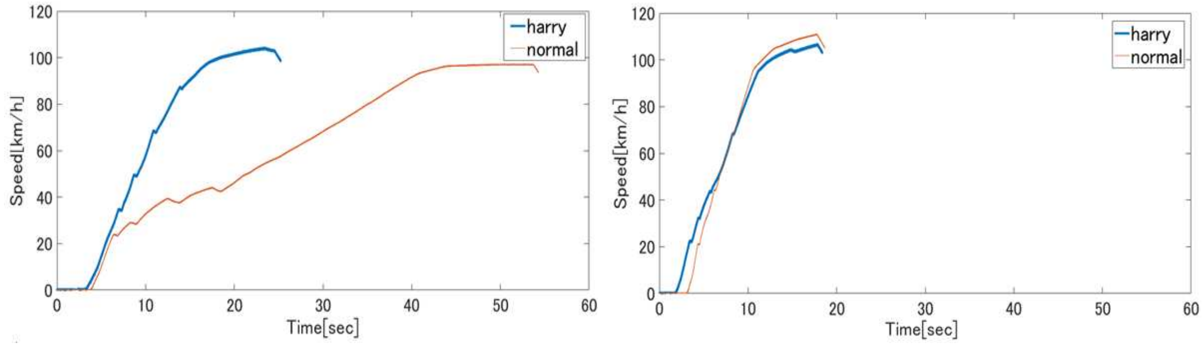
FIGURE 1. Control algorithm

In this case, as shown in Figure 1, the inputs of the DNN are a subject's acceleration patterns and the outputs are a command signal for controlling the sound quality to adjust to an individual preference.

In this study, based on the result of SOM, there are two primary control signal outputs: reducing the sound quality in the case of sound pressure amplification and amplifying the sound quality. Changing the input value to the control signal allows control of the sound quality adjustment as per the preference of each subject.

3. **Experiment Contents.** First, we conducted a questionnaire to clarify each participant's sound and driving preference. From the questionnaire results, we determined five evaluation points as characteristics that showed significant differences in each subject. These differences are seat vibration, speed, accelerator opening, engine sound, and ignition pulse. Twelve male drivers were chosen. They were all 20 to 40 years old men with 3 to 28 years of driving history. They performed driving patterns in both normal and hurried situations. For the experimental conditions, they accelerated up to approximately 100km/h and maintained this speed for 5. Gear changes after the acceleration were allowed. Figures 2(a) and 2(b) show speed data of subjects A and B, which represent the clear differences in each subject. This differing speed data was used as input parameter. In addition, Figure 3 shows the hurried driving data of all subjects.

Since the driving pattern differences of each subject were remarkably confirmed, the harried driving pattern was taken as the input parameter for the SOM of the DNN. From



(a) Subject A (b) Subject B

Figure 2. Example of speed data

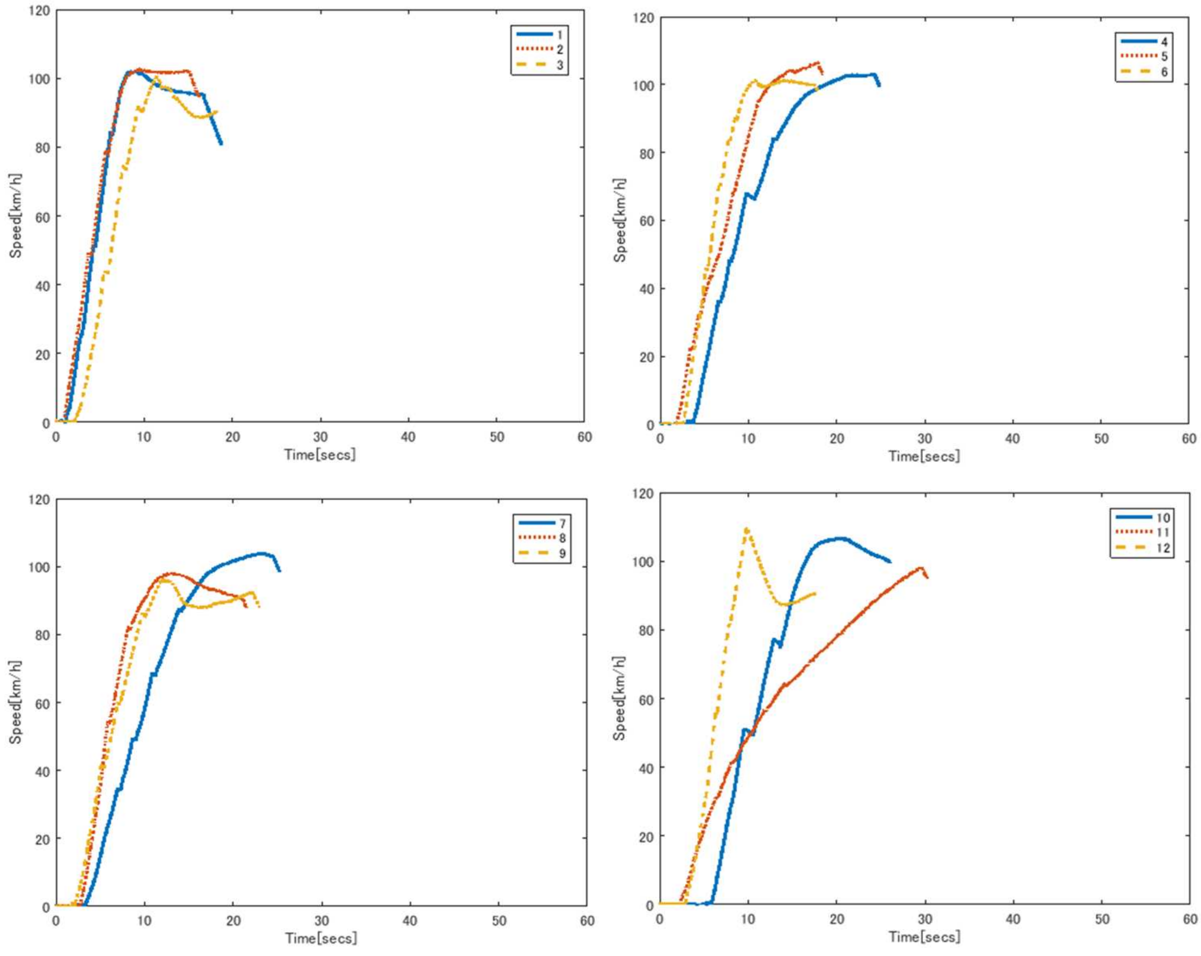


Figure 3. All subjects of the speed data

result categorization, to find the sound quality preference for 12 subjects, an auditory impression experiment was also conducted. Moreover, a four cylinder four stroke engine sound was used as the stimulus sound. Three types of sound source prepared for the sound source were: (1) 20-dB amplification for first and second order components, (2) 20-dB reduction for first and second order components, and (3) no control. Subsequently, the sound preference of each subject was approximately divided to three classes. This result corresponded to the SOM driving pattern, where the command signal in the Command Least Mean Square (CLMS) algorithm could be estimated by the individual driving pattern in each case.

4. **Experimental Result.** Figure 4 shows the clustered result of using the SOM. The feature value of each subject can be plotted on the SOM map. Therefore, the feature indexes of each participant were plotted on the map as four groups. By comparing the speed data of subjects in each group, we confirmed that the driving pattern are similar. Accordingly, it was suggested that the automatic identification could be performed from the driving pattern. From this result, an auditory experiment was also conducted to find the preferred tendency for each participant.

Figure 5 shows the experimental results of the auditory impression and the SOM correspondence. As shown in Figure 5, the sound preference of each participant was plotted on the map as three groups. From this result, it was confirmed that Figure 4 and Figure 5 are similar. In addition, it became possible to assign a preferred sound quality for each subject from Figure 5. This result corresponded to the driving pattern on the SOM, where

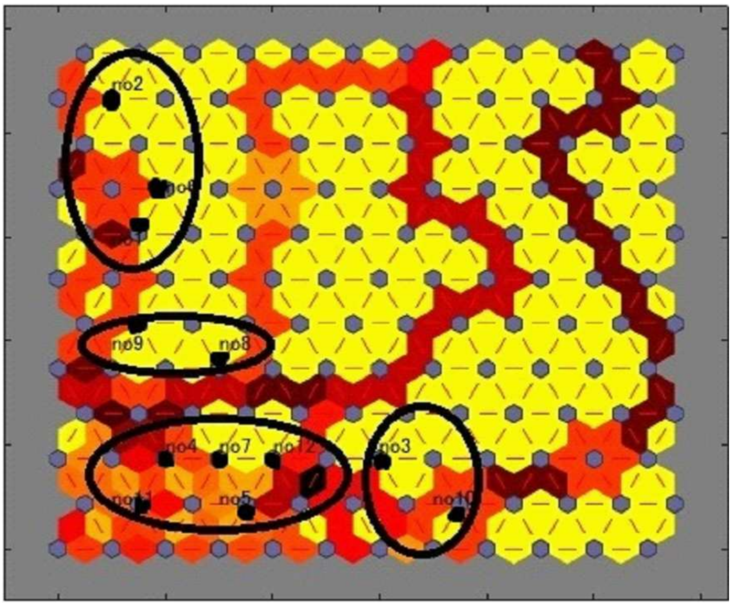


FIGURE 4. Identification result of SOM

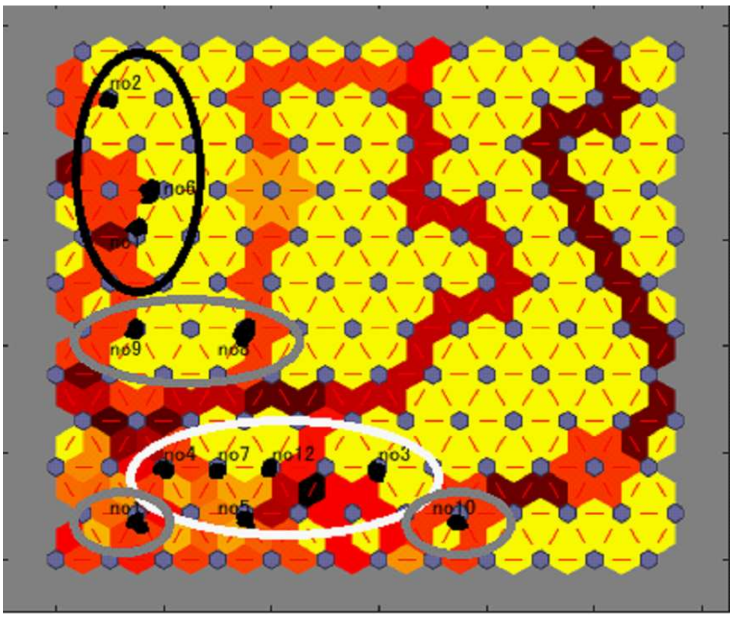


FIGURE 5. Auditory impression experiments result and correspondence of SOM

the command signal in the proposed algorithm could be estimated using an individual's driving pattern.

5. **Conclusions.** In this study, we used the driving pattern of each subject to identify the SOM. As a result, we were able to categorize the subjects into four groups. In addition, we identified the sound quality of each participant's preference from auditory impression experiment. From this result, we associated the relationship between the driving pattern and the tone quality of each preference. Therefore, it is possible to automatically generate the sound quality as per each preference. However, in this study, we identified the input parameters by a signal type of speed data. By increasing the input parameters, the subdivided subjects can be individually identified.

In future studies, we will estimate the command signal in the proposed algorithm and apply it to an actual automotive case.

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