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Analysis of Psychoacoustic Index Using Psysound3

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1 Introduction

It is believed that sound is an important factor that raises and adds value to products consumed by humans. In other words, the sound radiated from a product creates an impression, which affects its value as perceived by humans. Consequently, the impression can be considered as a meaningfulness. However, there is a possibility that the actual objective physical evaluation of a product differs from the impression it creates. In such situations, the psychoacoustic index is used to analyze the sound perceived by humans. In this study, we analyze a sound using the psychoacoustic index, and investigate the applicability of the PsySound3 software to sound quality estimation.

2 Psychoacoustic index

By analyzing and evaluating the sound radiated from a given product, its physical parameters could be defined. However, in this method, the human impression cannot be considered, and is therefore not practical. To address this problem, an effective method was devised to quantify human impression, which is called the psychoacoustic index. Its principle is based on the functioning mechanism of the ears, auditory nerve, and the statistical results of auditory experiments. The psychoacoustic index includes parameters such as loudness, sharpness, roughness and fluctuation intensity that may correspond to human impression. In this study, we focused on a loudness that represents perceived sound pressure level so that the sound applied to this experiment could be perceived by humans as a noise and make them annoying due to the sound pressure level. The following section introduces the details of an index loudness applied in this study.

3 Loudness

Loudness has been defined by JIS Z 8106 International electrotechnical vocabulary Chapter 801: Acoustics and electroacoustics [2] as one of the characteristics of sound in terms of auditory sensation, and it is arrayed from small to large on the scale. The pressure level of sound mainly depends on the sound pressure, in addition to frequency, wave form, and duration, and is called loudness. “Sone” is a unit of loudness and 1 sone equals to the level of a pure tone at a power pressure level and frequency of 40 dB and 1000 Hz, respectively. Thus, loudness is a phycological quantity that can be used to order the sound perceived by human ears on a scale ranging from quiet to loud. The psychological scale corresponds to a physical scale known as the A-weighted sound pressure level.

3.1 Calculation of loudness

The following algorithms are generally applied to calculate the loudness: Zwicker algorithm [3], Moore–Glasberg algorithm [4-7], Moore–Glasberg–Schlittenlacher algorithm [8]. According to the calculation methods standardized in ISO 532:2017 [9,10], the Zwicker algorithm is capable of analyzing the stable sound patterns and non-stable sound patterns while the Moore–Glasberg algorithm is limited to stable sound patterns and is applicable to complex sound with a pure tone, bandwidth noise and specific spectrum. It also includes the situation wherein the difference occurs between the left and right ears. Moore–Glasberg–Schlittenlacher algorithm is applicable to non-stable sound pattern with a discrete spectrum such as speech or music. In addition, the method is available to calculate two types of loudness. In this study, we adapted the Moore–Glasberg–Schlittenlacher algorithm to investigate an usefulness of those and also a possibility to adapt to an industrial product sound.

3.2 Moore–Glasberg–Schlittenlacher algorithm

In this algorithm, short-term loudness and long-term loudness are defined to be able to operate speech or music. Short-term loudness represents a temporary impression, that is, the real-time impression when humans perceive the sound. On the other hand, long-term loudness represents an impression held after the period when humans perceive the sound; for instance, the impression of loudness remains for a long time when humans perceive a loud sound. An impression is quantified as follows.

(1) An input sound is filtered by a finite impulse response filter that plays a role of the transmission through an external ear and a middle ear.
(2) Short-term loudness is calculated using fast Fourier transform.
(3) The excitation pattern is calculated using a physical spectrum.
(4) The excitation pattern is converted into loudness pattern.
(5) It results in instantaneous loudness.
(6) Short-term loudness is calculated using instantaneous loudness.
(7) Long-term loudness is calculated using the short-term loudness.

4 PsySound3

PsySound3 is a software used to analyze audio files. It mainly adapts psychoacoustic models to the sound characteristics [11]. This section describes the operation procedure of PsySound3. This software has been programmed in MATLAB so that it can be performed on MATLAB. The following steps are involved:

1. Select an audio file and click on “Add File”.
2. By clicking on “Calibration” at the bottom of the right side and go to the next page. Furthermore, select a calibration tone, then click on “Associate File”.
3. By clicking “Analysers” on the bottom of the left side, go to the next page, and select the desired psychoacoustic index.
4. Finally, click on “Run Analysis” to conduct the analysis.
5. On completing the analysis, the page automatically moves to the next page which shows the results.

5 Application to an industrial copy machine

We used PsySound3 to analyze the sound radiated from an industrial copy machine, which is capable of copying 13,000 papers per hour. A calibration tone, which is a pure tone at 94 dB, was used for the analysis. Of Moore–Glasberg–Schlittenlacher algorithm was used as the psychological scale to quantify the loudness of the sound produced. Furthermore, for comparison, the sound was also analyzed using A-weighted sound pressure level.

Figures 1,2 and 3 represent the results of the measured short-term loudness, long-term loudness and A-weighted sound pressure level, respectively. The differences in the shape of curves in the three figures are clearly observed: Figure 1 shows a rough uneven curve with four peaks while figure 3 shows a relatively smooth and plane curve. As stated previously, short-term loudness reflects the temporary impression regarding the pressure level of perceived sound whereas the A-weighted sound pressure level represents the pressure level of the sound itself. The agreement between the results and the facts confirms: the actual radiated sound differs from perceived sound. It is also assumed from Figure 1 that in human perception, a characteristic sound (the peak in the curve) is repeated four times. Moreover, Figure 2 shows the long-term loudness peaks at 1 s after which it gradually falls to 0 [sone] from 2 to 6 s although the sound is radiated for approximately 1 s. As stated above, long-term loudness represents the impression after humans perceived. Thus, the impression of loudness continues to exist for a while in the human mind beyond the moment when the sound was perceived.

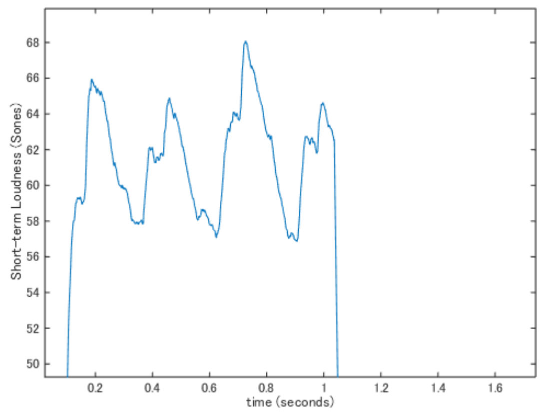

Figure 1: the analysing result using short-term loudness

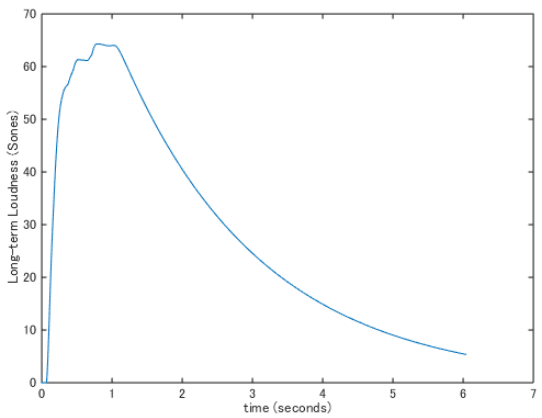

Figure 2: the analysing result using long-term loudness

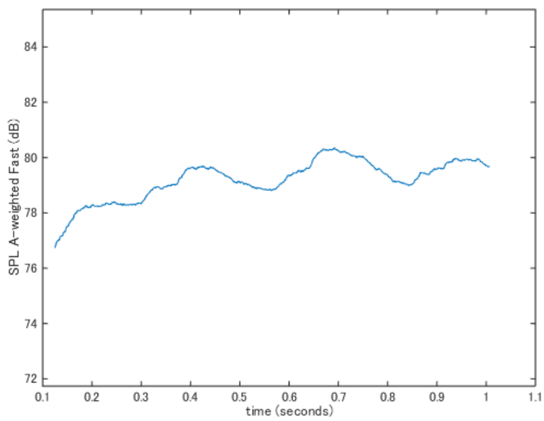

Figure 3: the analysing result using A-weighted sound pressure level

6 Conclusion

In this study, we described the operating procedure for the PsySound3 software and analyzed sound using the psychoacoustic index. The results confirmed that the difference between the actual sound characteristics and the human impression of the perceived sound. Although it is possible to perform the evaluation without using such index, its use speeds up the process of psychoacoustic quantification. Thus, using PsySound3 allows an easier and prompter sound analysis. Furthermore, we also demonstrated the usefulness of the psychoacoustic index in improving the worth of the products by raising the human impression. We will be able to utilize the software and the index to the noise of several industrial fields.

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