Frequency and Intensity Decision of Laser Microphone using Deep Leaning

Ryota Mori, Norio Tsuda, Jun Yamada
Dept. of Electrical and Electronics Engineering
Aichi Institute of Technology, AIT
Toyota, Japan
E-mail: v18723vv@aitech.ac.jp

***Abstract*—Laser Microphones do not use a diaphragm, and are hence able to detect sound waves over a wide frequency band, from low frequency waves to ultrasonic waves. They can also measure sound waves in fluids, such as under water, without contact. However, the output signal of the Laser Microphone has many superimposed noise components, digital filter processing may be necessary and there was a disadvantage that the amount of processing increased. Therefore, we verified whether the desired frequency and sound pressure intensity can be determined even in the presence of superimposed noise by learning the output signal in the non-processed state via Deep Learning. As a result, when the number of epochs corresponding to the learning amount is 500, frequency judgment was generally possible.**

Keywords-: Laser Microphone; self-coupling effect; deep learning;

I. INTRODUCTION

These days, many researches are actively and extensively engaged on the development of optical microphones that do not use a diaphragm, yet could detect sound waves over a wide band range, in fluid, and the like. Laser Microphone, which applies a self-coupling effect of a semiconductor Laser Diode (LD), has broadband and flat frequency characteristics, and is capable of 360° omnidirectional audio detection on a plane perpendicular to the laser optical axis [1]. However, many noise components are superimposed on the output signal of the Laser Microphone. Thus, after performing fast Fourier transform (FFT), it is necessary to judge its frequency and sound pressure intensity by carrying out digital processing.

However, there was a disadvantage that the amount of processing increased. Therefore, we verified by learning the output signal in the non-processed state via Deep Learning, whether the desired frequency and intensity can be determined even in the presence of superimposed noise. Moreover, it could be assumed that a state where it is impossible to judge the threshold by superimposing many noises could be avoided. This paper is organized as follows. Section II describes the principle and system of measurement using Deep Learning, Section III describes the measurement results, and Section IV summarizes what were found from the measurement results.

II. MEASUREMENT PRINCIPLE AND SYSTEM

The Sound wave detection in laser optical employs the self-coupling effect of LD. The self-coupling effect is a phenomenon in which the optical output of the LD slightly increases and decreases by returning a part of the laser optical emitted from the LD into the active layer by the reflecting material. Figure 1 shows the operating principle of the Laser Microphone.

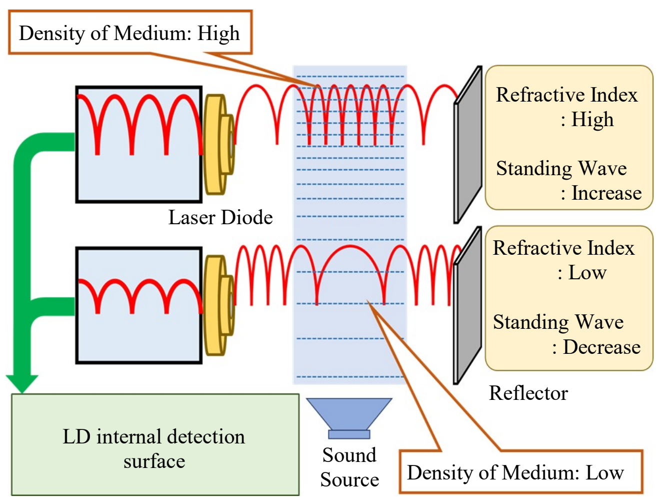

Figure 1. Operating Principle of Laser Microphone

Because sound waves are longitudinal waves, the density of the medium changes. High medium density increases slightly the refractive index of optical. On the contrary, low medium density also decreases the refractive index of optical. By repeating their states, the phase of the standing wave of the optical interference generated by the self-coupling effect periodically changes. The phase change of the optical interference coincides with the incident sound wave, and the change amount is proportional to the intensity. Thus, the frequency and intensity can be measured in the same way as a typical microphone.

The measurement system of frequency and intensity decision using Deep Learning is shown in Figure 2. LD uses a Distributed Feedback Laser diode (DFB-Laser), and the optical output was continuously oscillated at 25 mW. The prism sheet was used as the reflection plate was set to 10 cm.

A sound source was installed in a place 20 cm away so as to go straight to the laser beam. These measurement systems were fixed inside the anechoic box by a magnet. The output signal is processed by the personal computer. The Operating System (OS) of the personal computer uses Ubuntu16.04, while the framework for Deep Learning uses Chainer.

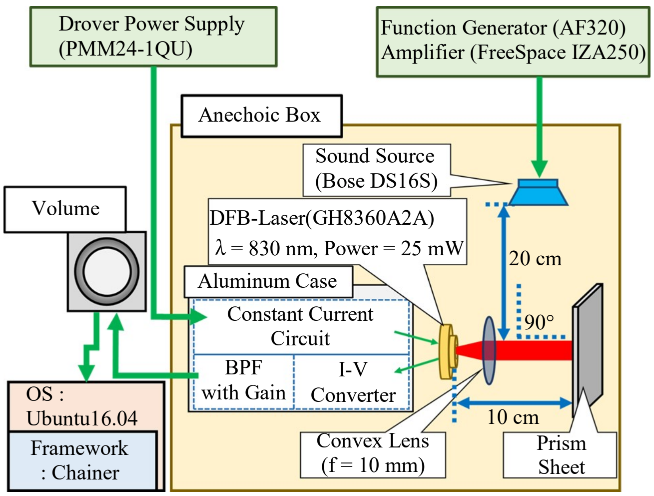

Figure 2. Measurement system

An overview of the Deep Learning program is shown in Figure 3. Neural network uses Recurrent Neural Network (RNN) with return value in the Hidden layer.

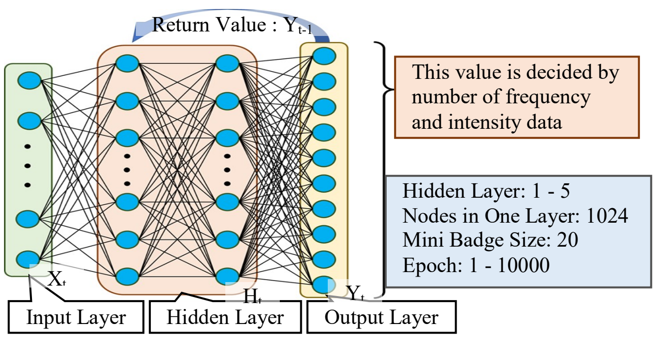

Figure 3. Overview of the Deep Learning Program

The number of nodes for one layer was 1024 and the mini batch size was fixed to 20, the number of epochs corresponding to the learning amount, and hidden layers are varied, and the frequency and intensity decision were carried out to measure the loss.

III. Measurement Results

In this abstract, the result is shown in Figure 4 when 100 Hz to 1 kHz sound waves are indent every 100 Hz and number of epoch is changed. The result of a typical microphone for comparison with the Laser Microphone is also shown in Figure 4.

In the same figure, the loss of decision using the Laser Microphone decreased until the number of epoch reached 500. This was because the output signal of the Laser Microphone contained a lot of noise components, error propagation within the program did not work well, and over-learning may have occurred.

On the other hand, when measuring with typical microphone, the losses decrease just like in the Laser Microphone. However, over-learning did not occur and the losses were approaching zero at an epoch of 500 or greater.

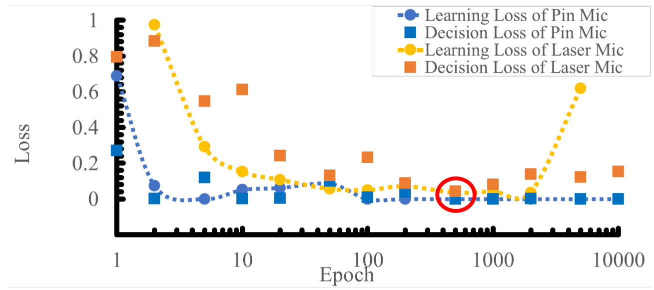

Figure 4. Result of decision using Laser Microphone

Moreover, the loss in both cases is smallest at an epoch of 500. Therefore, Epoch = 500 was assumed as the optimum place and the reference point where the Deep Learning program was created.

Figure 5 shows the answer rate for each frequency due to the change in epoch.

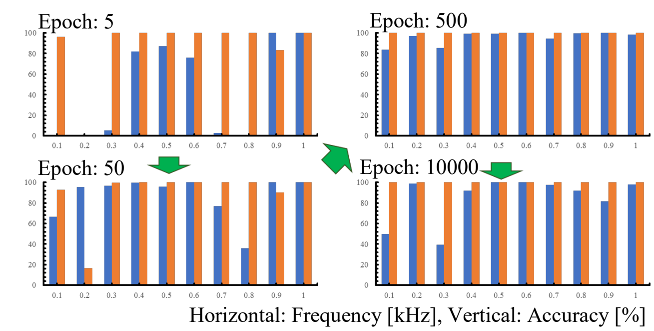

Figure 5. Result of decision using typical microphone

From Figure 5, in case of misjudgment, the desired frequency was judged as "Frequency of Adjacent".

IV. Conclusion

We found that it is possible to judge the frequency of the Laser Microphone using Deep Learning. Moreover, the Deep Learning program experiences the smallest loss when the number of epoch is 500. Future research will deal with the increase in the number of learning data and whether Laser Microphone can be used as a sound level meter for digital display. Furthermore, the results of change in loss due to change in hidden layers and intensity decision will be announced on the day of the conference.

References

[1] D. Mizushima, T. Yoshimatsu, K. Goshima, N. Tsuda, and J. Yamada: "SoundDetection by Laser Microphone Using Self-coupling of Semiconductor Laser" IEEJ Trans. EIS, Vol. 136-C, No. 7, pp. 1021-1026, 2016.