1Pa5-4

Highly accurate estimation of ultrasonic propagation time using deep learning

Yushi Hayasaka[1‡], Yuki Mimura[1], and Hirotaka Yanagida[1] ([1]Grad. School. Of Sci. & Eng., Yamagata Univ.)

1. Introduction

Wooden structures are susceptible to age-related damage from pests and the elements, and the cultural heritage buildings that are subject to protection have suffered considerable damage. Therefore, there is a need for an exploration technique to correctly determine the location and size of defect area without damaging the columnar structure.

A Computed Tomography (CT) technique using ultrasonic Time-Of-Flight (TOF) data has been proposed as a technique for this purpose [1]. However, this method has problems such as time-consuming data collection, discrepancies between the reconstructed image and the actual shape of the interior of the wooden pole, and lack of quantitative association between the pixel values obtained and the degree of decay of the wooden pole.

To improve the estimation accuracy, which is one of the problems, this study proposes a method to estimate TOF data using a neural network trained by simulating ultrasonic propagation assuming a wooden pole and using the obtained waveform data.

2. Methods

Training a neural network requires a large amount of data. Therefore, we employed simulations with the k-Wave Toolbox [2], a library that can rapidly calculate acoustic propagation inside elastic bodies. **Figure 1** shows a conceptual diagram of the simulations conducted in this study. In the simulation, a wooden pole with a radius of 0.11 m was assumed, and a defect area of 0.01 m~0.03 m was set inside the wooden pole. The speed of sound of the wooden pole is 2200 m/s and the speed of sound of the air is 340 m/s. Ultrasonic waves are transmitted from the ultrasonic transmitter to the wood column. Waves that pass through the defect area have a longer arrival time to the receiver. Sixty-four receivers are placed at equal intervals around the circumference of the wooden pole.

Convolutional Neural Network (CNN) [3] was used for the neural network structure. In this paper, we aimed to improve the accuracy of estimation with a one-dimensional CNN. TOF was estimated from noiseless and noisy ultrasound data. Reconstructed images were created with those TOFs and compared. In this paper, we constructed a 10-layer convolutional neural network as shown in **Figure 2**. It is trained so that the mean squared error between the output image and the input image is small.

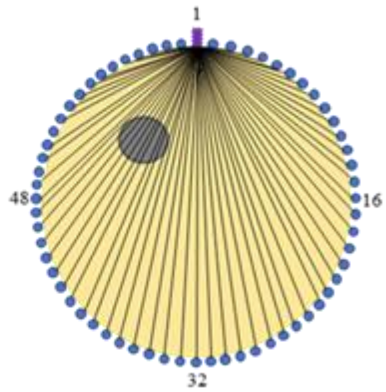

Fig. 1 Conceptual diagram of the simulation

In this paper, the FBP method was used to reconstruct images. The Filtered Back Projection (FBP) method is a method of analytically reconstructing the image by performing operations on the projected data using a matrix with a filter applied to each projection angle.

‡t222800m@st.yamagata-u.ac.jp

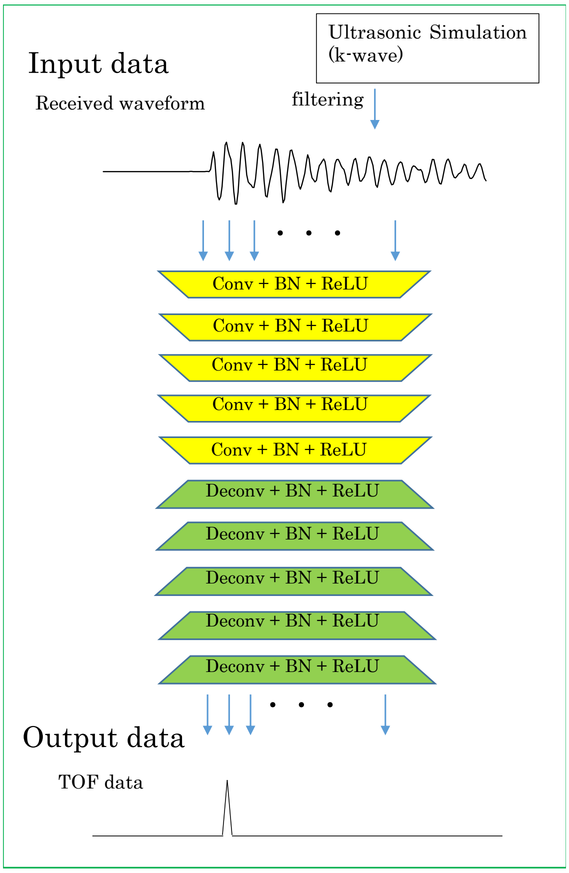

Fig. 2 CNN structure in this experiment

3. Results and Discussion

The images trained, estimated, and reconstructed with noiseless data are shown in **Figure 3**. The images trained, estimated, and reconstructed with noisy data are shown in **Figure 4**. The correct image is shown in **Figure 5**. For noiseless data, the image could be estimated close to the correct data. However, in the case of data with noise, contours and areas near defect area were largely missing.

4. Conclusion

We proposed a method for accurately estimating TOF from received waveforms using a 1D CNN. In this paper, ultrasound data was generated by ultrasound propagation simulation. The data was input into a 1D CNN to estimate TOF. While almost accurate estimation and reconstruction were achieved with noiseless data, accurate estimation was not possible with noisy data.

References

1. Y. Tomikawa, Y. Iwase, K. Arita, H. Yamada, Jpn. J. of Appl. Phys. **24** (1984) 187.
2. B. E. Treeby, J. Jaros, A. P. Rendell, and B. T. Cox, J. Acoust. Soc. Am., vol. **131**, No. 6, (2012) 4324-4336.
3. A. Krizhevsky, I. Suskever, G. E. Hinton, NIPS'12：Proc of the International Conference on Neural Information Processing Systems. Vol **1**. (2012) 1097-1105.

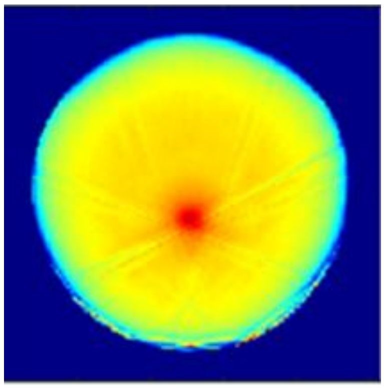
Fig. 3 Image reconstructed using noiseless data

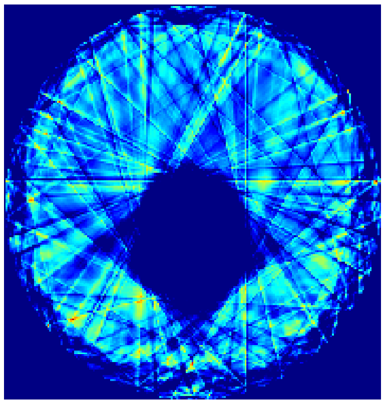
Fig. 4 Image reconstructed using noisy data

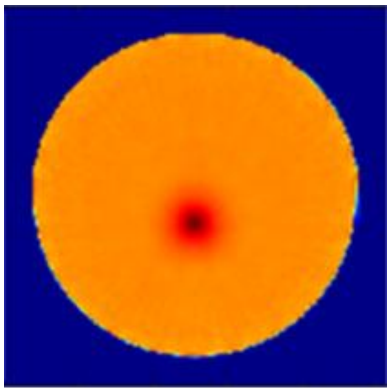
Fig. 5 Correct image