Estimation of 28 GHz Band Wave Propagation using Machine Learning

Yuta Watanabe and Keichi UEDA

Information Systems Technology Division, Tokyo Metropolitan Industrial Technology Research Institute,
2-4-10, Aomi, Koto-ku, 135-0064, Tokyo, Japan

Abstract

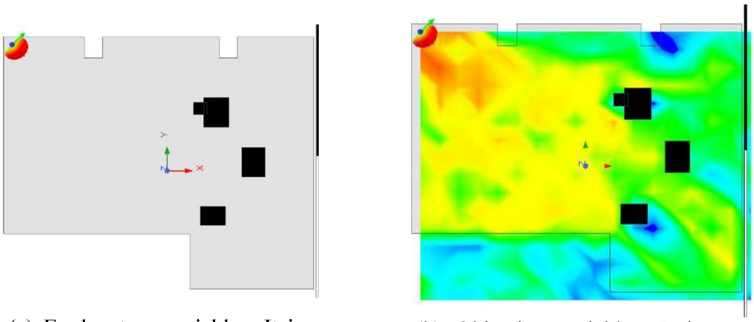
Millimeter wave band electromagnetic waves are used in 5G communication systems. They have a wide frequency range for wireless communication, however their short wavelength makes them susceptible to relatively small obstacles such as robots and people. In this study, we use machine learning to estimate the wave propagation of electromagnetic waves in the 28 GHz band in order to estimate the effect of obstacles. The ray tracing method was used as the teacher data for the machine learning. Comparison of the machine learning estimation results with the experimental results shows good agreement.

1 Introduction

Communication using millimeter wave (mmWave) is considered for use in 5G and beyond 5G[1]. In the mmWave band, wide frequency band electromagnetic waves are used for enhanced mobile broadband communication. Electromagnetic waves in the mmWave band are sensitive to obstacles, it is necessary to estimate changes in propagation caused by moving obstacles such as robots and people[2]. In this research, wave propagation in the 28 GHz band is obtained by machine learning to estimate the effect of moving obstacles. The analytical model and results of the ray tracing method[3] are used as explanatory and objective variables for machine learning.

2 Machine Learning of Wave Propagation

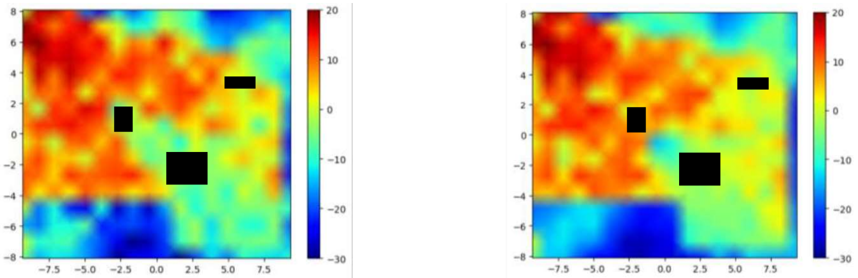
Machine learning requires a lot of training data consisting of explanatory and objective variables. Since it is difficult to use the measured results of wave propagation as training data, the analysis results of wave propagation obtained by the ray trace method are employed as training data in this study. Fig. 1 shows one of the explanatory and objective variables used machine learning. Fig. 1 (a) shows explanatory variable that is 75 x 67 pixels gray scale image represented by values from 0 to 255. Fig. 2 (b) shows objective variables image. Objective variable is an



(a) Explanatory variables. It is gray scale image that has 75 x 67 pixels.

(b) Objective variables. It is an amplitude of electric field in a space separated by 17 x 16 at 1 m intervals.

Figure 1: Explanatory and objective variables of machine learning.



(a) Simulation results obtained by ray trace method.

(b) Estimation results obtained by random forest.

Figure 2: Comparison with simulation results obtained by ray trace method and estimation result obtained by random forest.

amplitude of electric field in a space separated by 17 x 16 at 1 m intervals. The black rectangles in Fig. 1 indicate metal scatterers. Decision trees, random forests, and neural networks are employed for machine learning. The number, position, and size of the scatterers are randomly changed to create 1600 models. The wave propagation of the models is analyzed by the ray trace method. The 1500 data are used as teacher data and the 100 data are used as test data.

3 Results

The results of machine learning estimation are evaluated by the coefficient of determination

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y_i})^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \tag{1}$$

where y_i is electric field obtained by ray trace method, $\bar{y}$ is average of y_i, $\hat{y_i}$ is electric field estimated by machine learning. The coefficient of determination R^2_{dt}, R^2_{rf}, and R^2_{nn}, are 0.19, 0.51, and 0.15 when the 28 GHz band wave propagation is estimated by decision tree, random forest, and neural networks. Fig. 2 shows the analysis results of wave propagation in the 28 GHz band obtained by the ray trace method and the estimation results obtained by random forest. It can be seen in Fig. 2(a) and (b) that the trend of attenuation due to metal scatterers is consistent.

4 Conclusions

Decision trees, random forests, and neural networks are used to estimate wave propagation in the mmWave band. The analytical model and results of the ray trace method were used as explanatory variables and objective variables of machine learning. Estimation results with random forests were found to have the best coefficients of determination. The optimization of the hyperparameters of the neural network and their application to experimental results will be reported in a full paper.

References

[1] T. S. Rappaport, et al, Millimeter Wave Mobile Communications for 5G Cellular: It Will Work, IEEE Access, Vol. 1, pp. 335-349, 2013

[2] T. S. Rappaport, et al, Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design, IEEE Transactions on Communications, Vol. 63, No. 9, pp. 3029-3056, 2015.

[3] B. Neekzad, et al, Comparison of Ray Tracing Simulations and Millimeter Wave Channel Sounding Measurements, 2007 IEEE 18th International Symposium on Personal, Indoor and Mobile Radio Communications, 2007.