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Convolutional Neural Network for Prediction Method of Path Loss Characteristics considering Diffraction and Reflection in an Open-Square Environment

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Abstract

This paper proposes new path loss prediction model using CNN that is one of the famous method in fields such as image-recognition in recent years. The proposed model can solve problems with consideration for effect of diffraction and reflection which is not considered in previous model. To verify the model, ray-tracing simulation in Open-Square environment was conducted by multiple scenarios. One simulation result were used for verification of the proposed model, and other results were used for learning of CNN. As a result, estimation accuracy was improved RMS error about 1.5 dB compared with the previous model in Non-Line-of sight area.

1. Introduction

In recent years, researches using deep-learning is popular in fields such as image-recognition. In particular, the technique using convolutional neural network (CNN) is most popular, because its estimation accuracy was the highest by considering space using the matrix convolution. We have been studying estimation method using CNN in Open-Square environment. The environment is one of the high traffic environments under 5G consideration, e.g., the public squares in front of large stations [reference 1]. In reference 2, the estimation method using CNN is proposed, and the result of the study that it can consider spatial information such as buildings and obstacles around transmitting and receiving antenna were stated. In reference 3, although highly accurate estimation results were shown, consideration of influence of reflection and diffraction by obstacles in the Non-Line-of-Sight (NLoS) against the Line-of-Sight (Los) environment was a problem. In addition, in reference 3, they have been studying using the same model as the authors in macro-cell environment, and the estimation accuracy obtained is similar to the authors, but the effect of reflection and diffraction on estimation accuracy has not been taken into consideration. In order to improve the estimation accuracy of the proposed model, we try to consider the influence of reflection in the NLoS environment. In this paper, we report results for the recognition result of improved prediction model using new parameter for considering the influence.

2. Prediction Method and Model

Figure 1 shows the proposed path loss prediction model using a CNN based on reference 2. The CNN composition based on a model called AlexNet that has five convolutional layers and three fully connected layers [reference 4]. And, the input matrix data of reference is the square of 48 points with 0.1 m on one side, a matrix of 24 m square around the receiver (Rx) antenna. In reference 2, the matrix consisted of three layers: the height of the structure and building, the oblique distance from the transmitter (Tx), and the oblique distance from Rx. In addition, we add a flag (0 or 1) indicating that Line-of-Sight (LoS) or Non-Line-of-Sight (NLoS) in a fully-connected layer.

In this paper, we add new input matrix and some system parameters. System parameter of our previous model was only the LoS or NLoS flag. First, we add three new system parameter: the height of Rx, the height of Tx, and the distance to the reception in the nearest LoS point when it is NLoS point. The height of the antenna was add to consider the relationship between the height matrix of the building and the height of the antenna. It shows the depth of diffraction and was selected as a parameter that can be easily calculated. Furthermore, we add the angle formed by the straight line connecting Tx and Rx to the input matrix. It shows the depth of reflection too. We then verified whether the new parameters and input image could be used to consider diffraction and reflection for prediction path loss characteristics by using the ray-tracing simulation data similar to the environment of previous model.

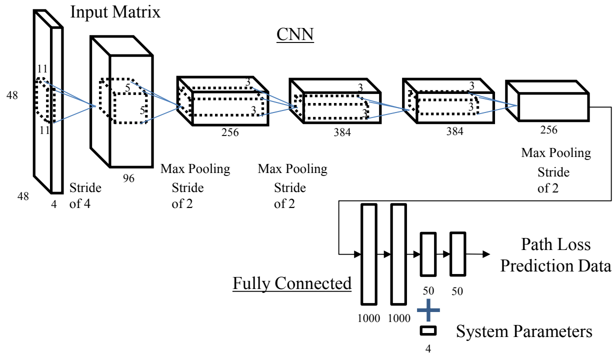

Figure 1. Proposed Path Loss Prediction Model with CNN.

3. Simulation Environment

Simulation was performed in the evaluation environment Figure 2, and propagation loss data was acquired by ray-tracing. The environment, which simulates a public square in front of a station in Shibuya, consists of three high-rise building, a structure simulating the under railway viaduct, and three to four obstacle. The buildings have a 30 m length, 30 m width, and 10 m height. The obstacles which simulate the size of existing objects such as trees, large buses, and the entrance to the subway, range from 3-10 m in length and width and from about 3-5 m in height. Concrete (relative dielectric constant 6.7) was used as the material. Figure 2 shows the positions of Tx and Rx antennas. The height of the Rx antennas was 1.5 m and the Tx antennas had two patterns of 3 m and 10 m. Using 600 Rx antennas and 40 Tx antennas, we conducted simulations at each of the transmitter heights. For the calculation process, the number of reflections was set to 3 times and the diffraction was set to 1 time.

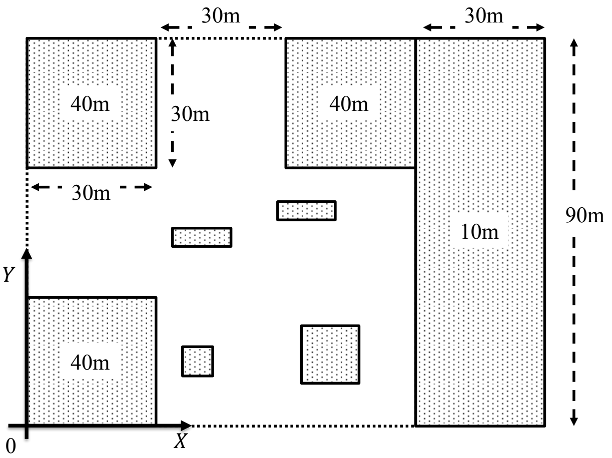

Figure 2. Evaluation Environment.

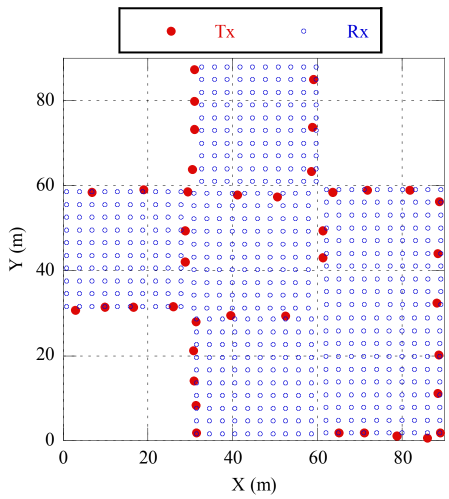

Figure 3. Antenna Position in Evaluation Environment.

4. Result

Figure 4 shows example of verification data by obtained ray-tracing. For visualization purposes it shows the excess loss, which is the path loss obtained by ray-tracing minus the free space loss. From this data, it can be confirmed the pass loss value is high in the NLoS area by high-rise buildings and obstacles. In addition, Figure 5 shows example of the estimation result by previous model. From the results, it can be confirmed that the difference of the pass loss value in the LoS area NLoS area can be generally learned, but it is considered that the gradation can't estimate the depth of reflection and diffraction in places such as X = 20 m and Y = 40 m. Figure 6 shows example of the estimation result of by proposed model. Against the result of Figure 5, it is confirmed that the gradation can estimate the depth of reflection and diffraction in places such as X = 20 m and Y = 40 m.

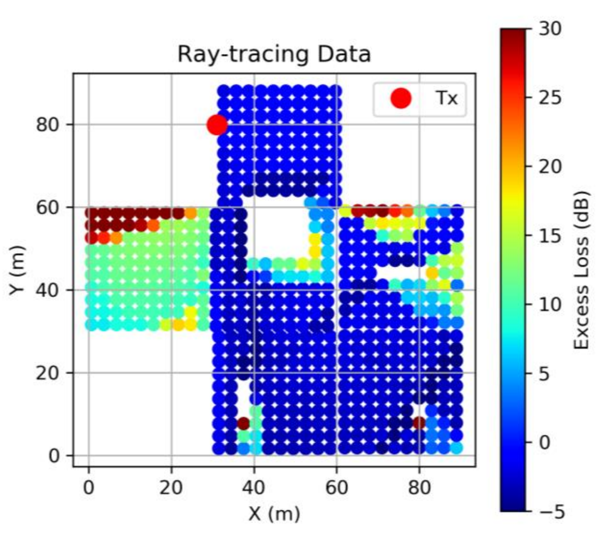

Figure 4. Example of Verification Data by Ray-Tracing.

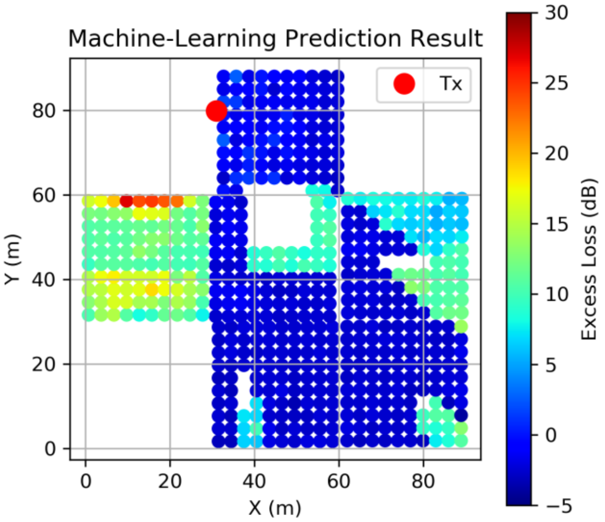

Figure 5. Example of Prediction Result by Previous Model.

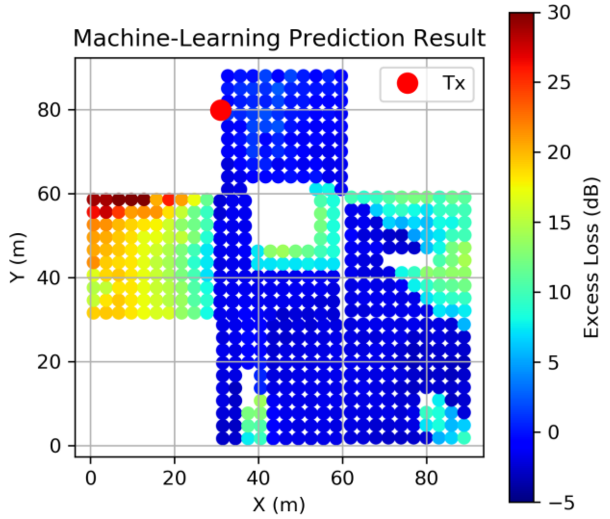

Figure 6. Example of Prediction Result by Previous Model.

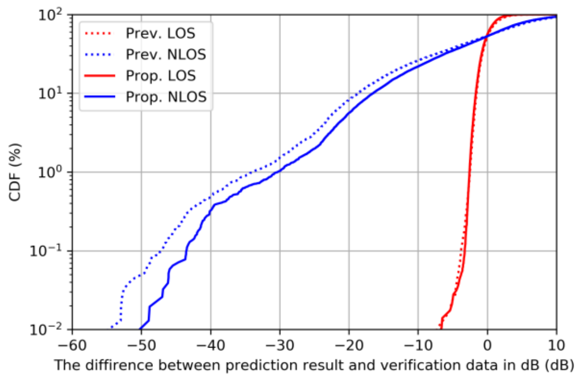

Figure 7. CDF of Prediction Error.

Table 1. Comparison of Estimation Reuslt.

	Φ	h_{Tx}&h_{Rx}	d_{LoS}	RMSE (dB)		
				LoS	NLoS	All
Prev.	-	-	-	1.50	11.37	3.03
No.1	✔	-	-	1.51	11.25	3.00
No.2	✔	✔	-	1.38	10.98	2.92
No.3	✔	-	✔	1.53	10.26	2.74
No.4	✔	✔	✔	1.38	10.20	2.72

Figure 7 shows the difference between prediction result and verification data in dB. The median is 0 dB, which indicates that the estimated value has no positive / negative bias with respect to the ray-tracing value. The difference in estimation result by adding each parameter is shown in Table 1, Φ is new angle input matrix, h_{Tx} / h_{Rx} is the height of Tx or Rx, and d_{LoS} is the distance to the nearest receiving point. From the table, it is found that the estimation accuracy is improved by adding the parameters, and finally the estimation error of NLoS is improved by about 1.5 dB when comparing the previous model with the proposed model of No. 4.

5. Conclusion

In this paper, we investigated the improvement effect by the new parameters considering the influence of diffraction and reflection for the path loss prediction model using CNN. The overall RMS error of the proposed model was about 2.72 dB, and RMS error in the NLoS area was improved about 1.5 dB.

6. References

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