IEEE PIMRC 2022
WS06 – Recent Progress on Scenario-based Radio Channel Modeling Techniques and Novel Antenna Designs & Manufacturing

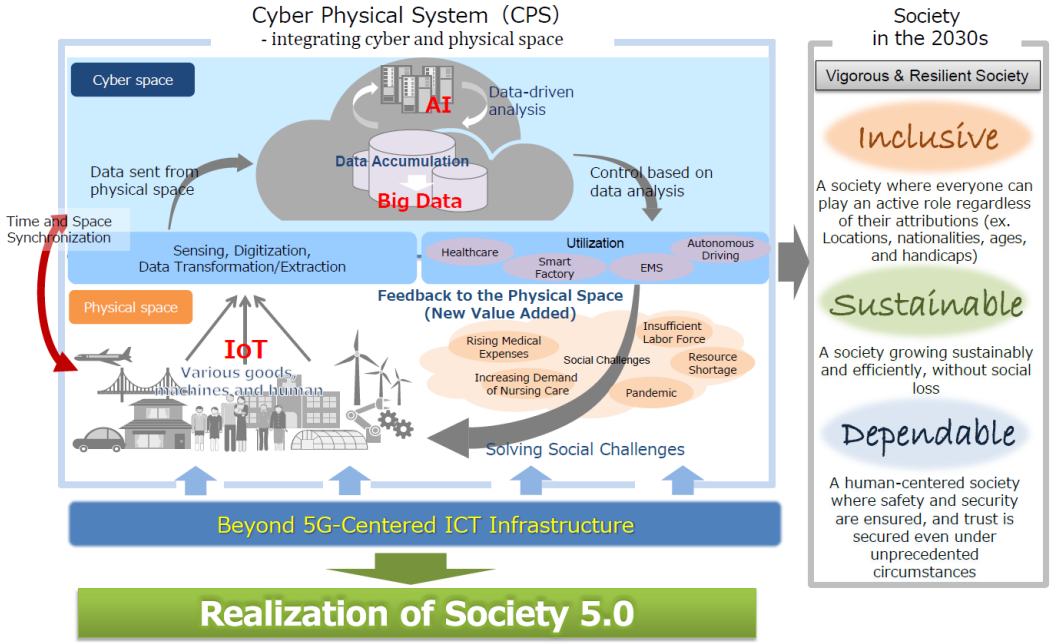
KDDI Research

A Study on Path Loss Modeling using ResNet and Pre-Training with Free Space Path Loss

Tatsuya Nagao and Takahiro Hayashi
KDDI Research, Inc.

Introduction

- In Beyond 5G era, Cyber Physical System (CPS) will be implemented in society.
  - Creating new value by using IoT, Big Data, and AI.
- Wireless communication will become diverse and more important technology as a social infrastructure.

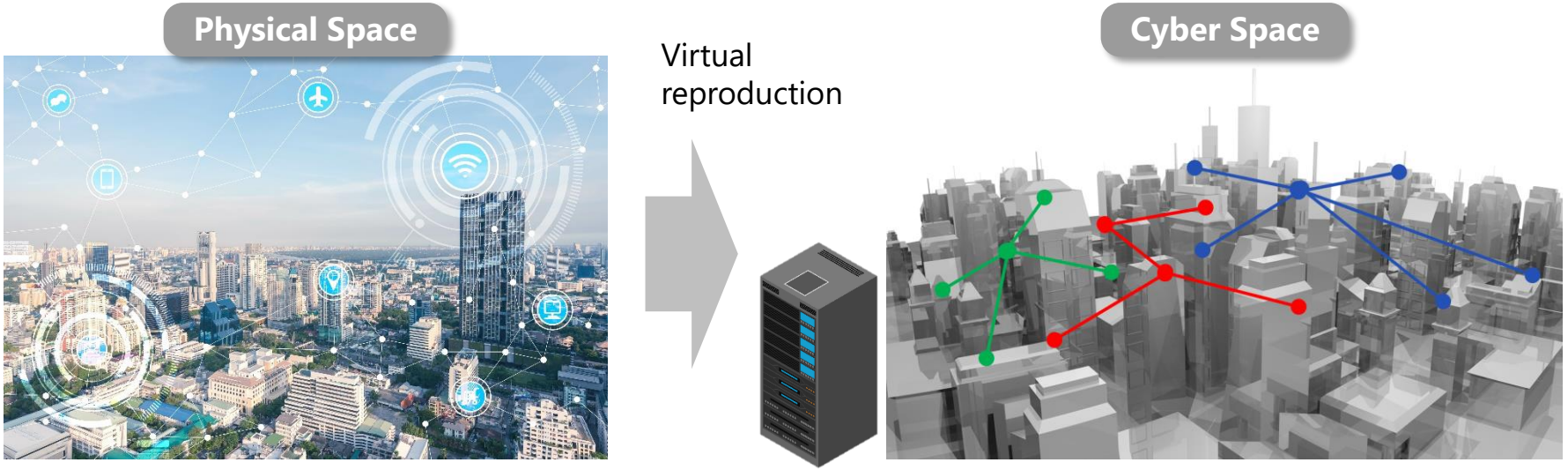


"Beyond 5G Promotion Strategy-Roadmap towards 6G-"(2020)
https://www.soumu.go.jp/main_sosiki/joho_tsusin/eng/presentation/pdf/Beyond_5G_Promotion_Strategy-Roadmap_towards_6G-.pdf

Introduction

- Evaluation and verification of wireless systems in real environments and with actual devices take a great deal of time and cost.

- **Wireless emulator in cyber space improves efficiency of system verification.**

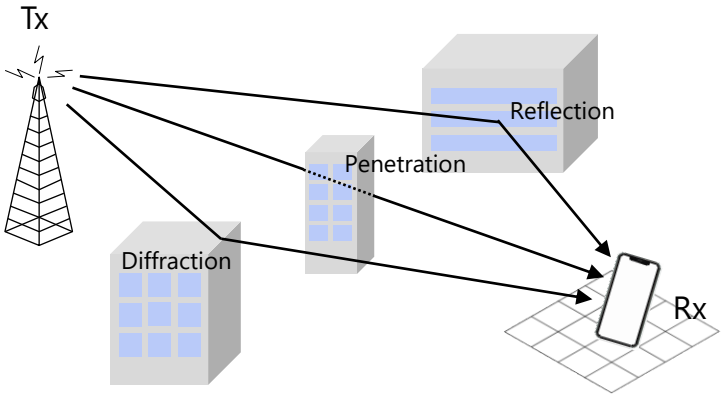


Introduction

- For highly accurate wireless emulation, a site-specific radio propagation model is required.
- Conventional methods have two approaches.

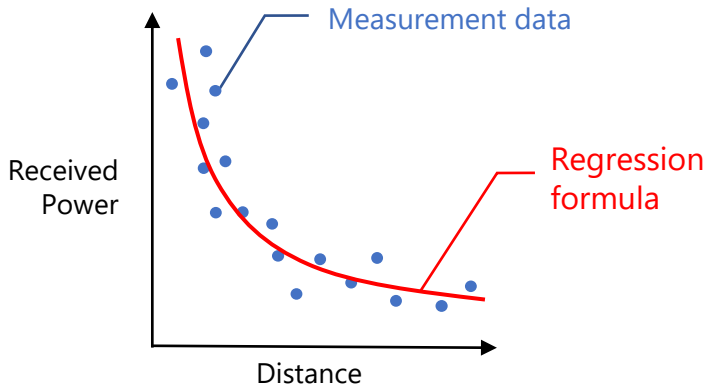
A theoretical approach (deductive)

- Reproduce objects in cyber space and sequentially calculate phenomena such as reflection and diffraction.
- Large-area calculations require enormous computational resources.



An experimental approach (inductive)

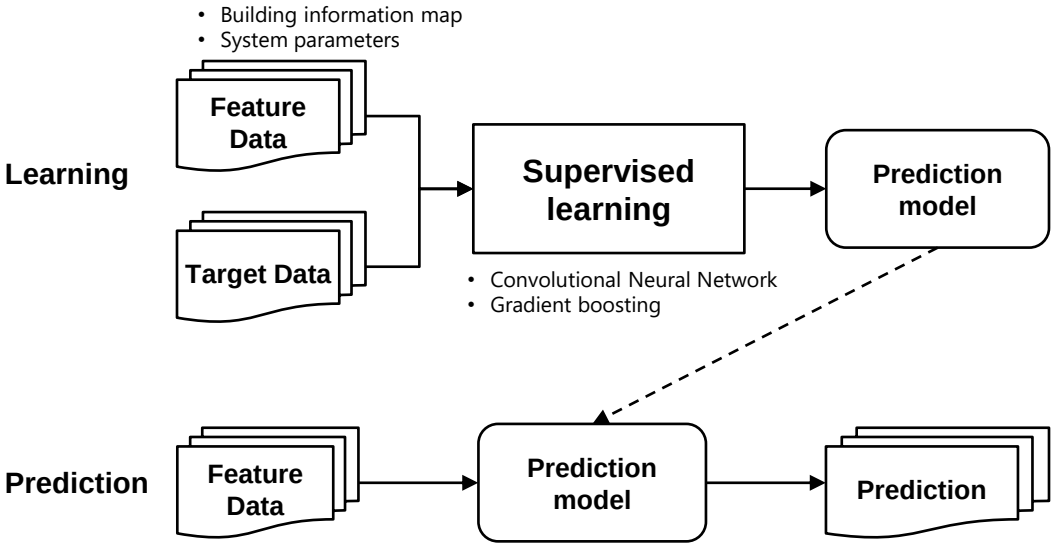
- Statistical analysis / regression from measured data
- Increasing the number of parameters complicates regression and makes modeling difficult.



Introduction

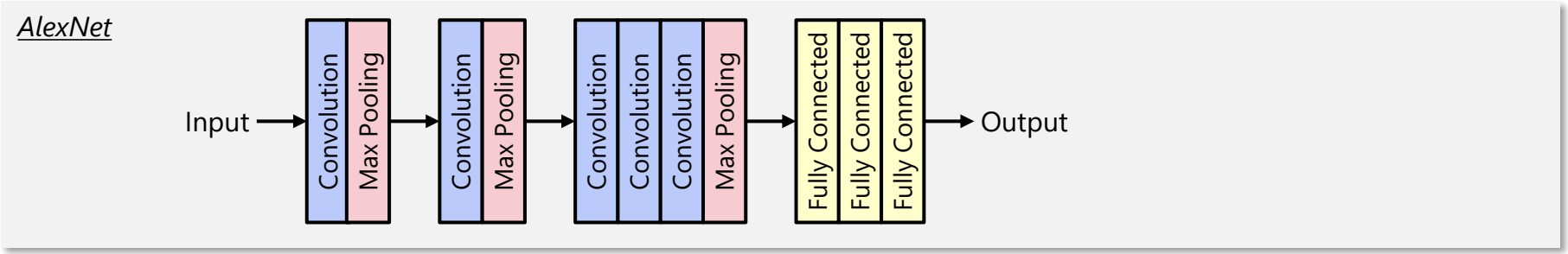
■ Machine learning-based methods for radio propagation prediction have been proposed.

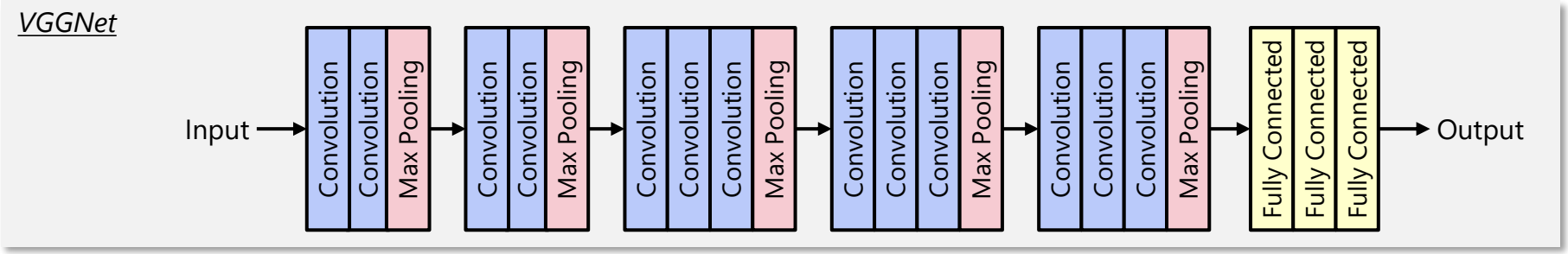
- An evolution of the experimental approach.
- Using building information map as the features. ⇒Site-specific information



Conventional methods based on CNN architecture

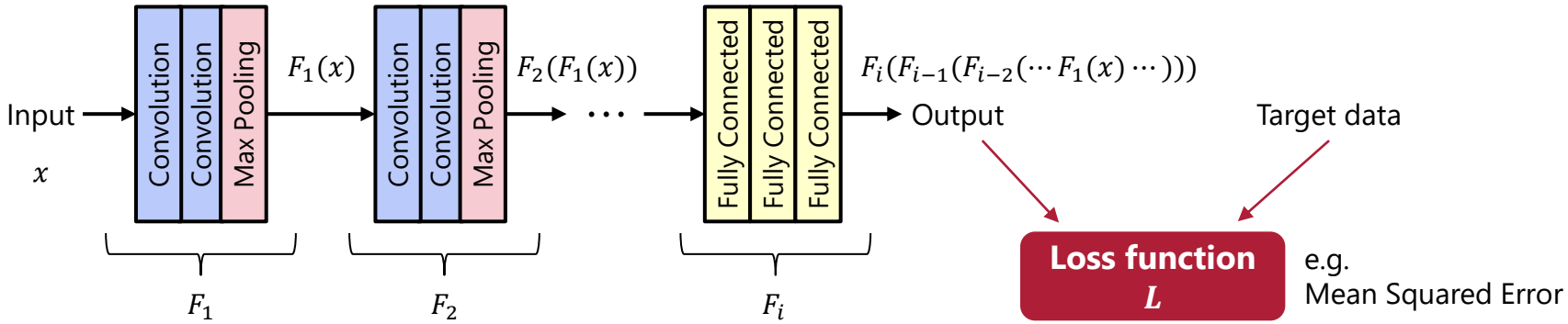
- The convolutional neural network (CNN) architecture is generally used.
- Conventional methods use simple architectures with convolution and pooling layers, such as *AlexNet* and *VGGNet*.





How Deep Learning learns

- In deep learning, deeper layers are intended to increase the representativeness of the model.
  - Represents complex function forms with composite functions.



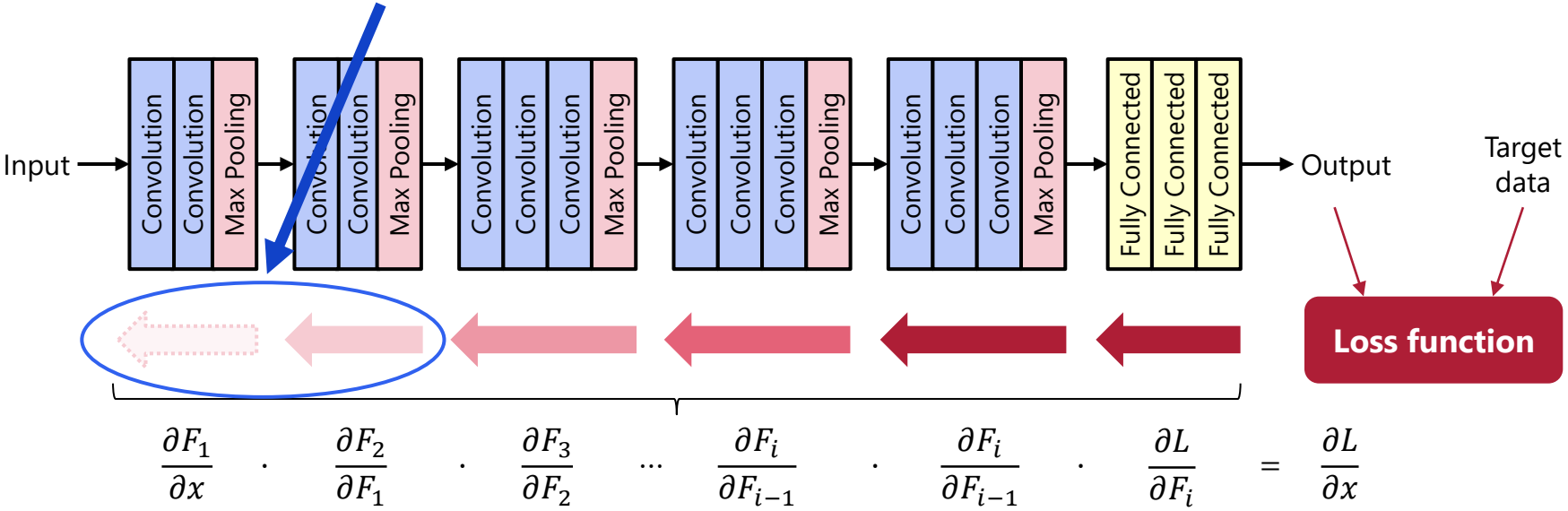
Calculate the gradient of the loss function
(Back propagation)

$$\frac{\partial L}{\partial x} = \frac{\partial L}{\partial F_i}\frac{\partial F_i}{\partial F_{i-1}}\cdots\frac{\partial F_2}{\partial F_1}\frac{\partial F_1}{\partial x}$$

The gradient of the loss function is calculated as the multiplication of the gradients at each layer based on the chain rule.

The vanishing gradient problem

- In deep architecture,
  - huge amount of parameters make the optimization difficult.
  - since the gradients at each layer are multiplied, the gradients become smaller at the upper layers (**vanishing gradient problem)**.



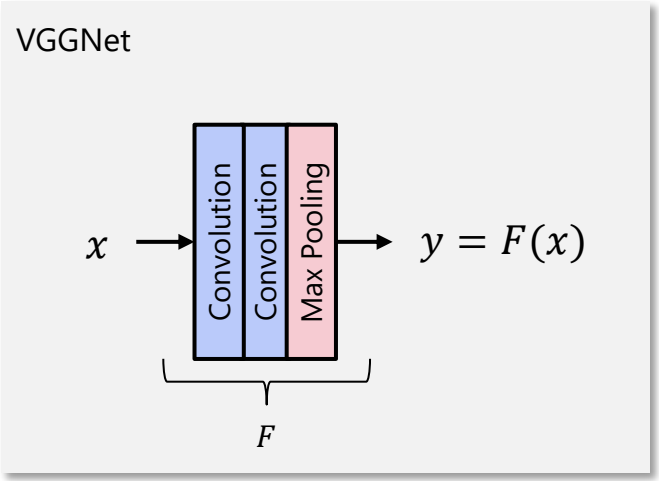
[15] He and Sun, "Convolutional neural networks at constrained time cost"

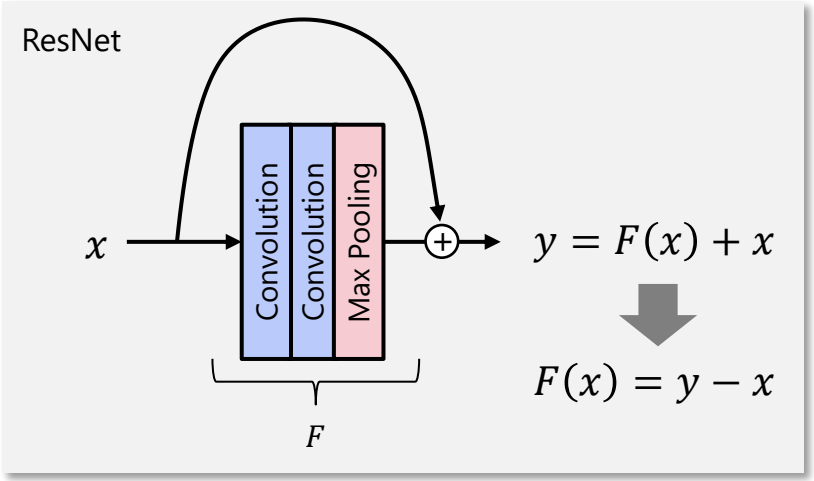
Proposed Method #1 : Application of ResNet

KDDI Research

■ Residual Network (ResNet)

- introduce “Shortcut connection” to propagate gradients to upper layers.



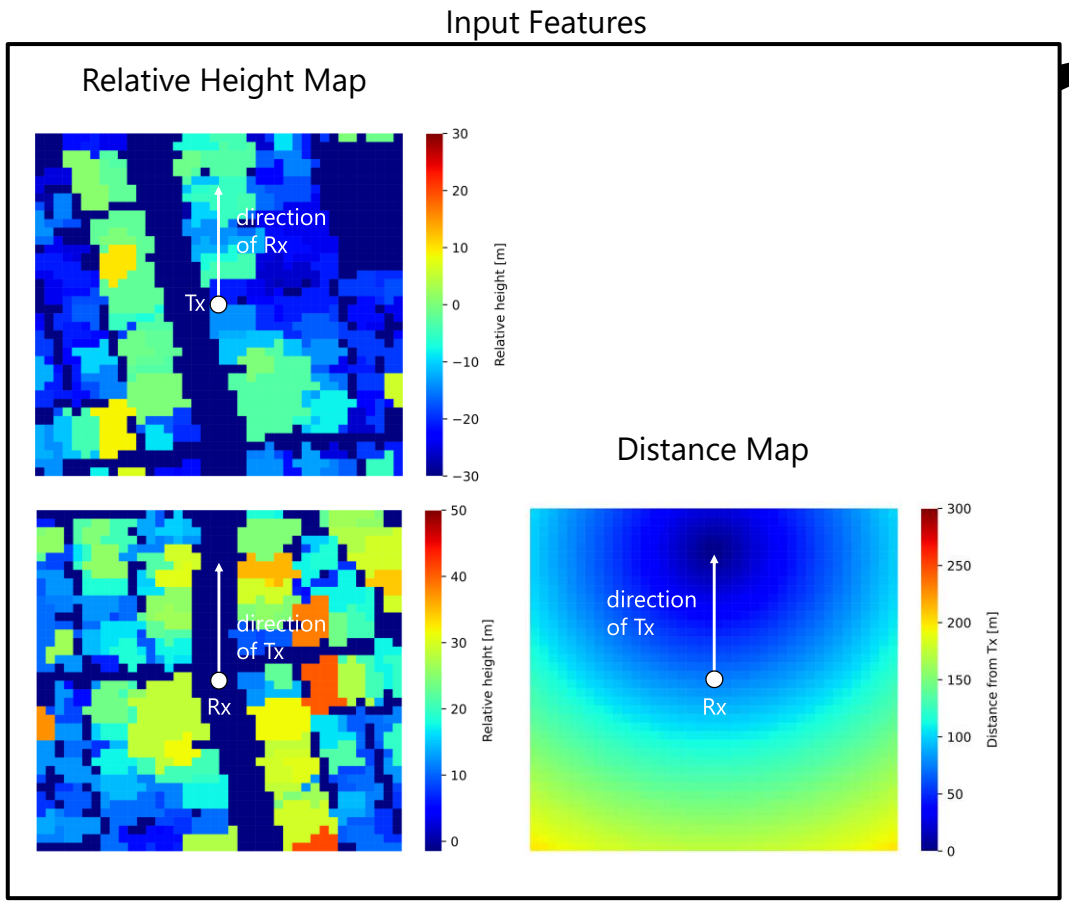


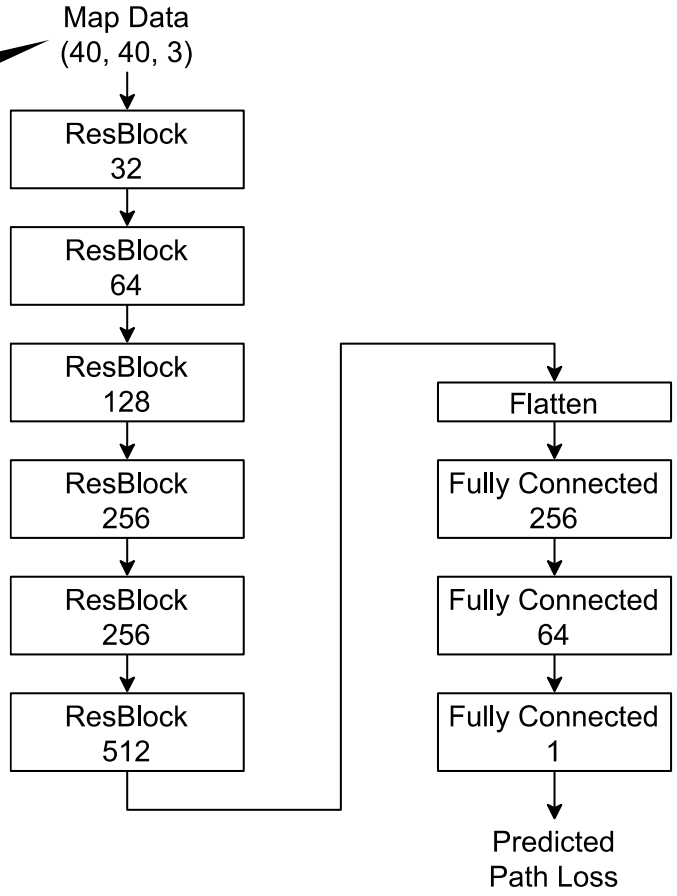
The learning targets are the weight parameters of the function F.

Shortcut connection enables learning the difference between input and output.

[16] K. He, X. Zhang, S. Ren, and J. Sun, “Deep residual learning for image recognition”

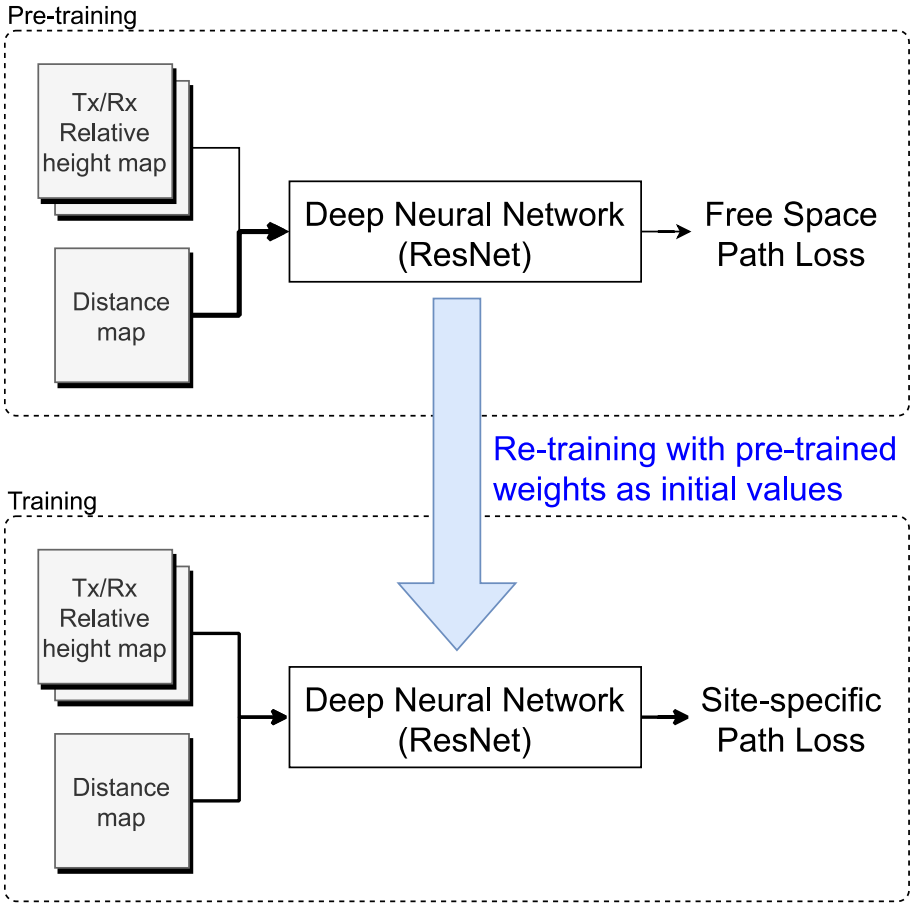
Input Features and Model Architecture of this study





Proposed Method #2 : Pre-training with Free Space Path Loss

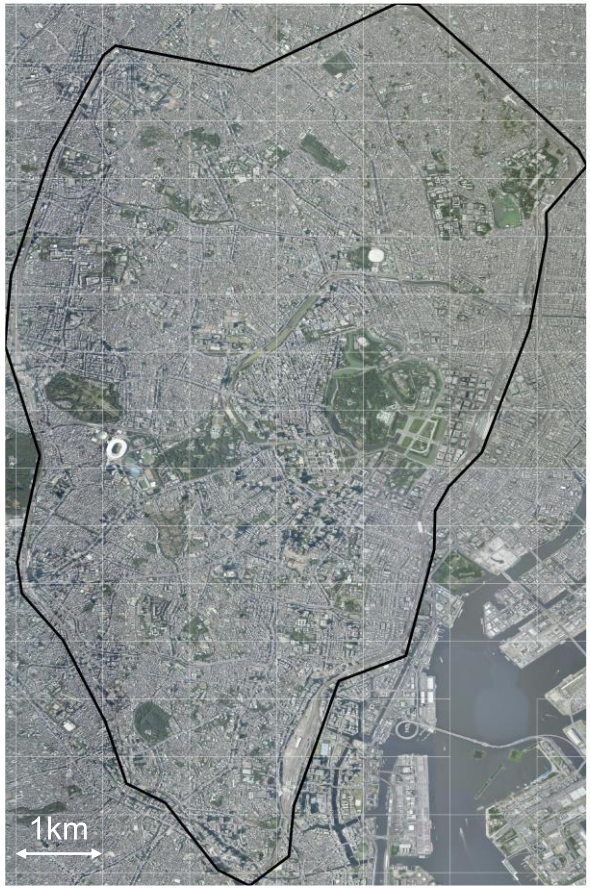
- The distance between Tx and Rx is the most basic parameter for path loss.
- **By pre-training with FSPL as the objective variable, emphasize the weight of distance characteristics and improve accuracy.**
- **With measurement data, the training focuses on shadowing terms due to buildings.**



Evaluation Data

- Measurement data acquired in the center of Tokyo by drive test.
- LTE of 2.1 GHz Band
- The median value for each 5m grid
- Approximately 89,000 points of path loss data

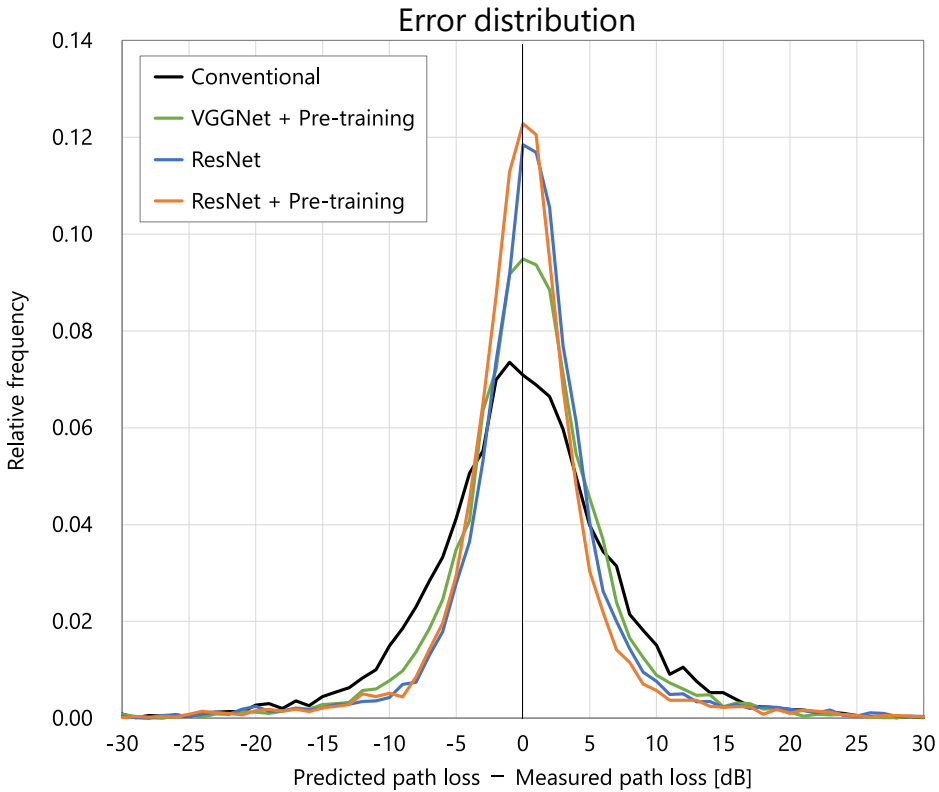
- We evaluated by cross-validation:
  90% for learning, 10% for validation.



Source: Geospatial Information Authority of Japan

Results : accuracy evaluation

■ Both “ResNet” and “Pre-training with FSPL” are effective in improving accuracy.

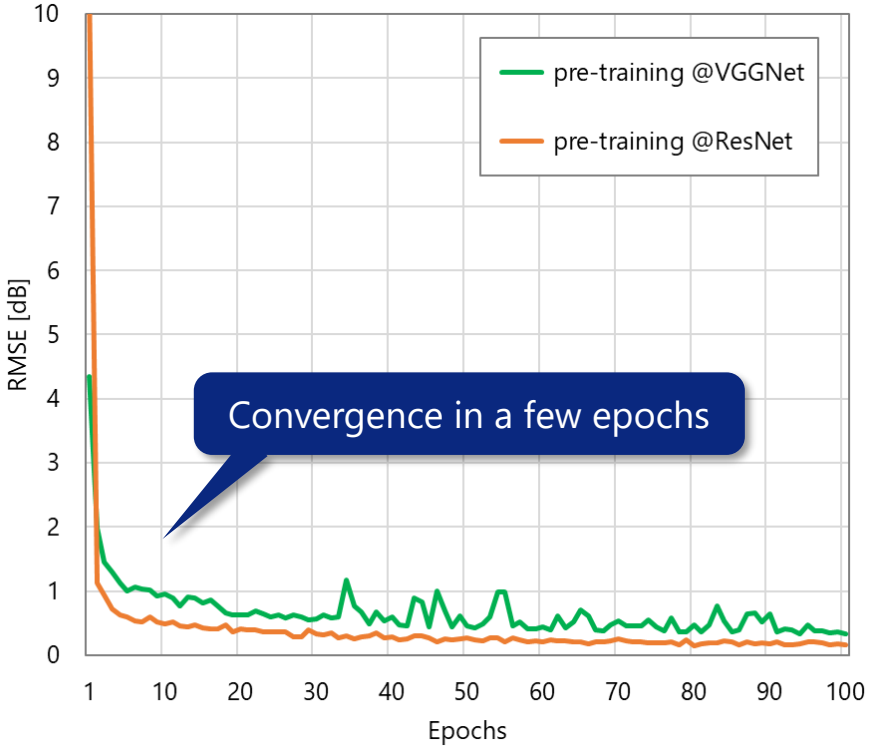


Method	RMSE [dB]	R^2
Conventional (VGGNet)	6.76	0.66
VGGNet +pre-training	5.92	0.76
ResNet	5.70	0.76
ResNet +pre-training	5.29	0.80

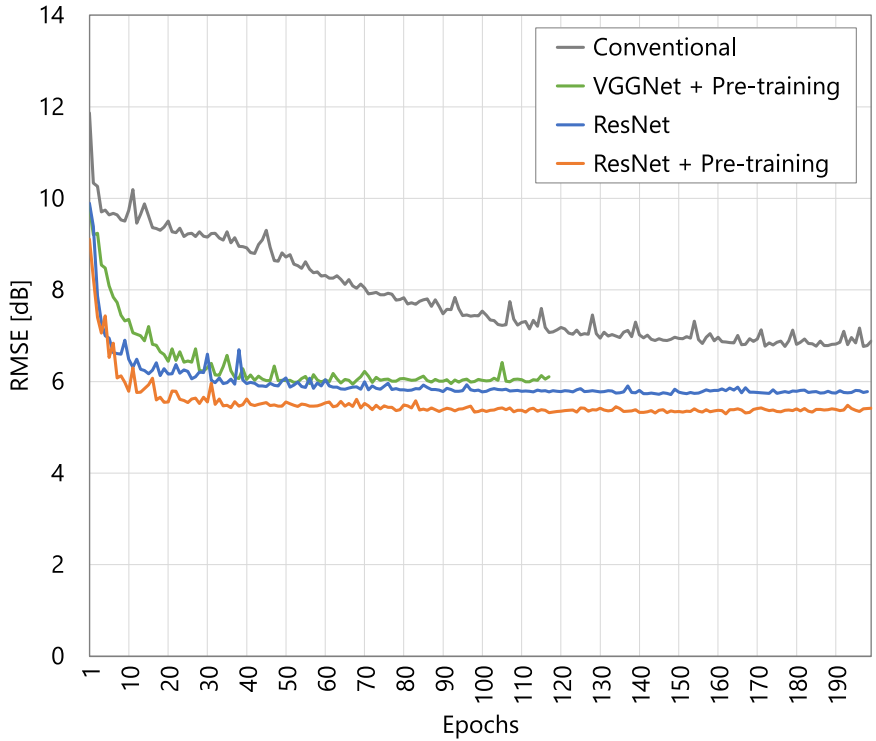
Results : learning curve

- The additional computational cost of pre-training is very small.

Pre-training with FSPL



Training with measurement data



Conclusion

- We proposed methods of
  - applying ResNet architecture for effective learning.
  - pre-training with Free Space Path Loss for improving accuracy.

- Evaluation using measurement data in urban area showed the effectiveness.

This research has been conducted under the contract "R&D for the realization of high-precision radio wave emulator in cyberspace" (JPJ000254) made with the Ministry of Internal Affairs and Communications of Japan.