Complex-valued convolutional neural network for terahertz image classification

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1.INTRODUCTION

The CNN network was first proposed for handwritten digit recognition. For several years, convolutional networks have been widely used in the fields of image recognition, voice recognition, and time series prediction . With the proposal of deep learning theory and the improvement of computer equipment, CNN have been developed toward large-scale direction. The field of complex-valued deep learning has only emerged in recent year. Using complex parameters has numerous advantages from computational, biological, and signal processing perspectives. A complex-valued feedforward neural network model for image recognition in [3]. [4] proposed a single-layer CVCNN for target detection and recognition of polarized synthetic aperture radar images. A wavelet scattering network using complex values was proposed in [5]. [6] is one of the most important papers in the field of CVCNN, which gives a CVCNN model that can be seen as nonlinear multiwavelet packets.

Based on the previous discussion, a complex-valued neural network algorithm for terahertz image classification is proposed. Like the LeNET real-valued classification network, the complex-valued neural network includes an input layer, a convolutional layer, a pooling layer, a fully connected layer, and a classifier layer. The terahertz MINIST handwriting dataset is constructed using the measured terahertz PSF spot. The coherence matrix of neighboring resolution units is used as input to examine. The rest of the paper is organized as follows. The second part reviews the theory of complex-valued neural networks and describes in detail the proposed scheme for terahertz image classification. The third part gives the experimental results and the final conclusions.

2.THEORY

The architecture of CV-CNN can be considered as a variant of real number neural networks. It is designed to take advantage of the two-dimensional structure of the input image. In the image classification task, the input to the network is a set of two-dimensional or two-channel data, and both the convolutional and pooling layers activation function layers process a set of two-dimensional matrices. For the terahertz images acquired by the imaging system of the vector network analyzer, they can be directly used as the input to the complex-valued neural network, thus making full use of the phase information of the images.

Convolutional Layer

The CVCNN is an extension of the traditional convolution in the real domain into a convolution in the complex domain.

$$Z^{l+1} = W^{l+1} * K^{l} + B^{l+1}$$

$$= \sum_{i=1}^{M} \begin{pmatrix} \sum_{p=1}^{N} \left(\Re(W_{ip}^{l+1}) * \Re(K_p^l) - \Im(W_{ip}^{l+1}) * \Im(K_p^l) \right) \\ +j \sum_{p=1}^{N} \left(\Re(W_{ip}^{l+1}) * \Im(K_p^l) - \Im(W_{ip}^{l+1}) * \Re(K_p^l) \right) + B^{l+1} \end{pmatrix} \quad (1)$$

where j is the imaginary unit, * is the convolution symbol, and and denote the real and imaginary parts of the complex numbers, respectively.

3.EXPERIMENTS AND RESULTS

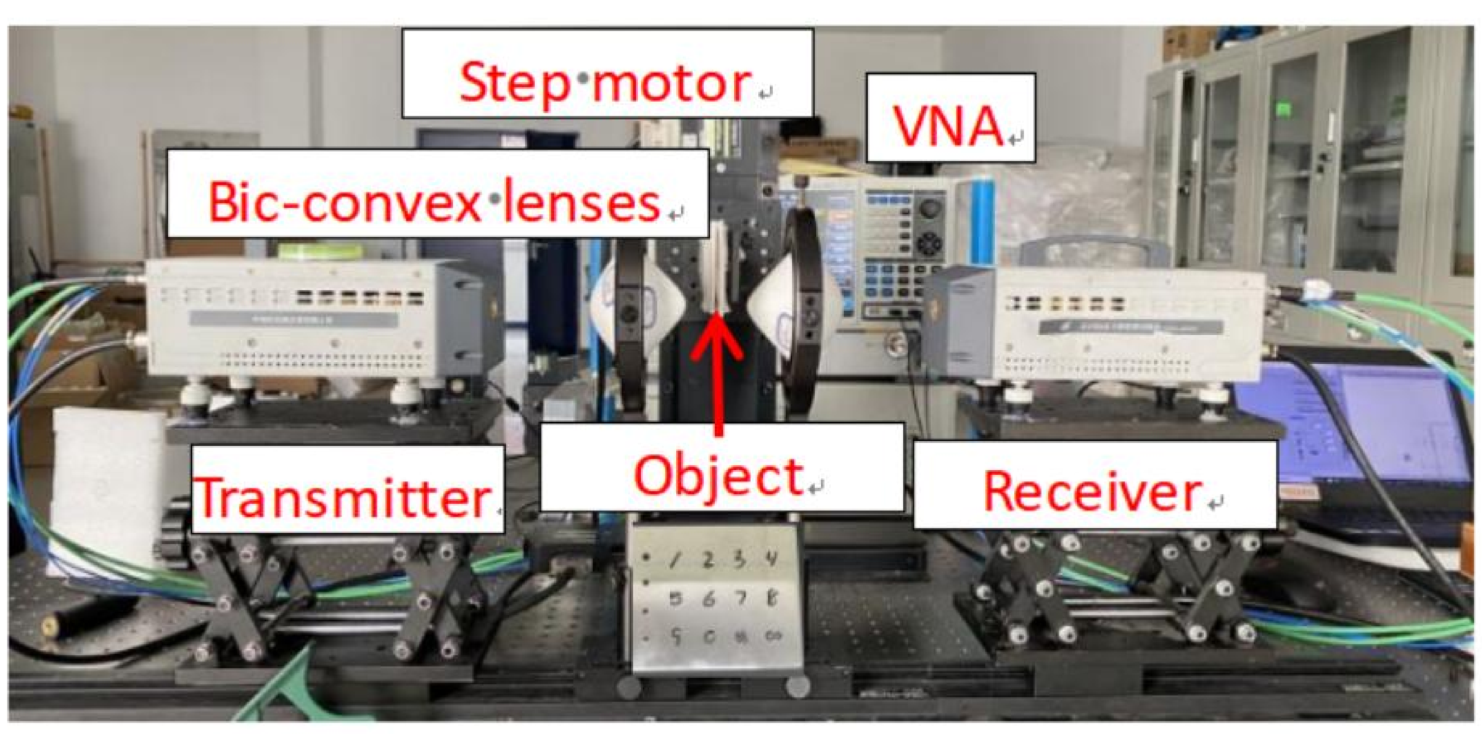

Fig. 1 Experimental setup of the THz imaging system

The MINIST handwriting is used as a high-resolution image, and the PSF spot is convolved to obtain the degraded and low-resolution image. In this paper, the terahertz transmission imaging system at 0.2 THz frequency is used to measure the PSF of 0.8 mm holes.The experimental setup of the imaging system is shown in Fig. 1.

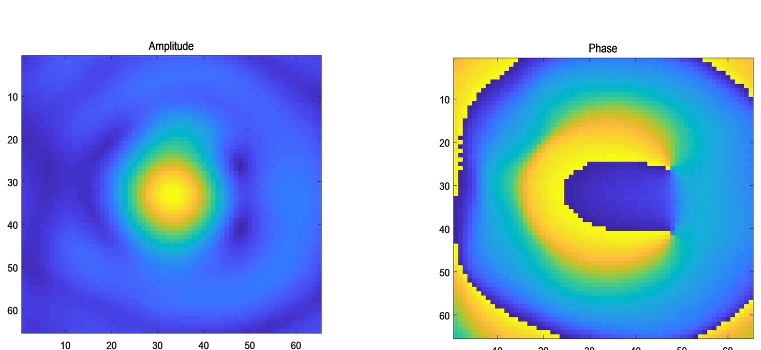

Fig. 2 THz amplitude and phase information of the 0.8 mm pinhole, of which the scanning step of the motor was set to be 0.1 mm

Assuming a linear observation system, the acquired degraded LR image is the convolution of PSF by the ideal image which is MINIST data. A set of ideal MINIST handwriting 0-9 image, and simulated terahertz image see Fig. 3.

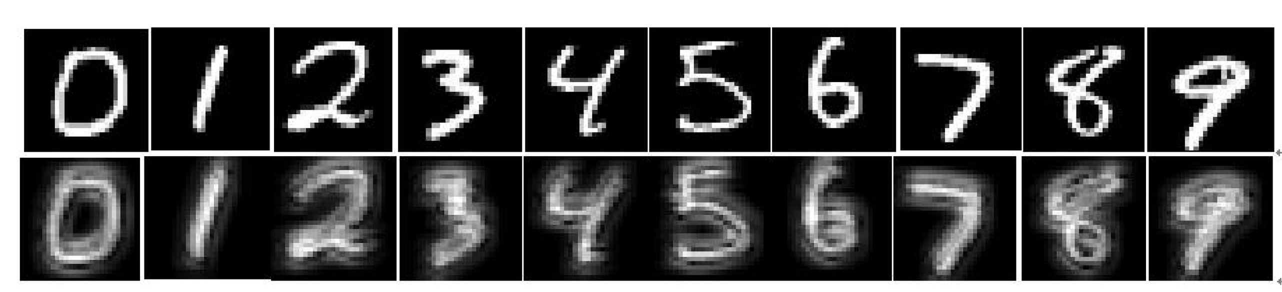

Fig. 3.A set of MINIST data and simulated terahertz image

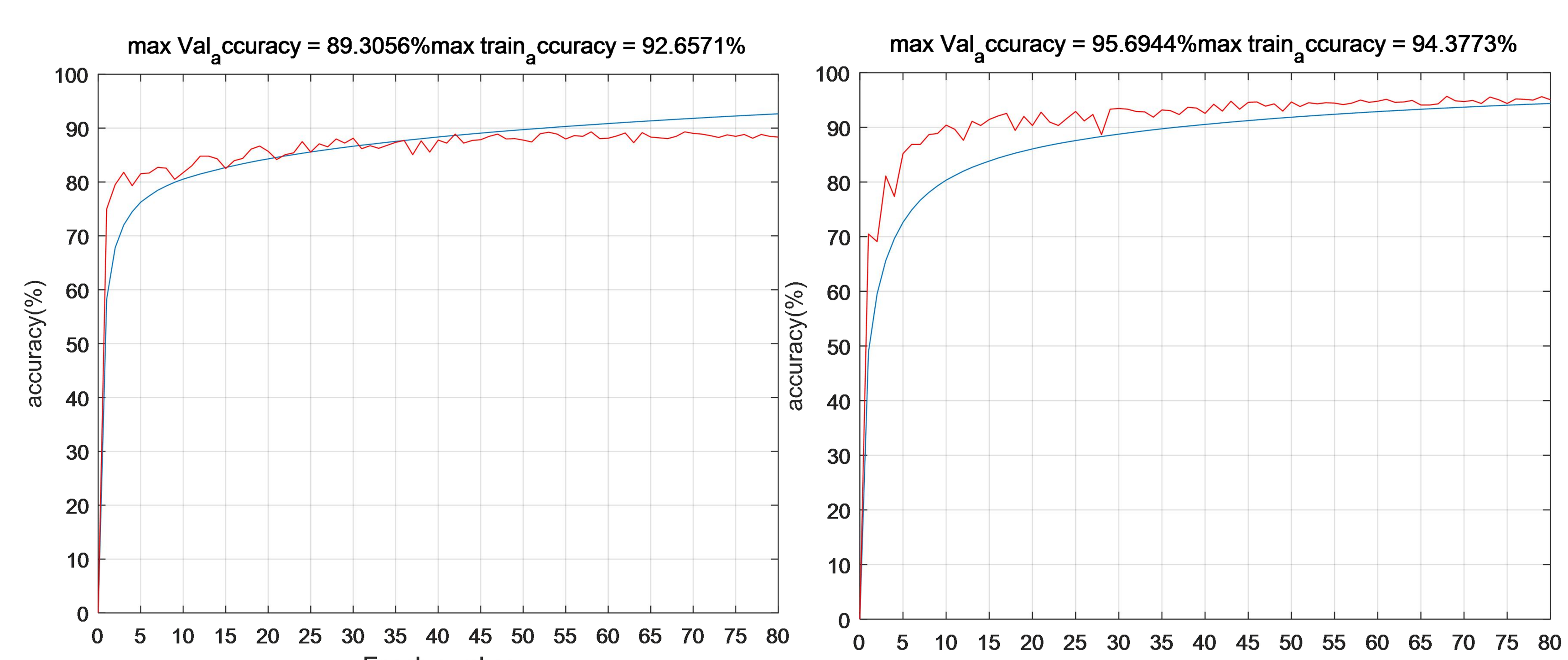

Fig. 4.Training and validation Accuracy of RVCNN(left) and CVCNN(right).

Figure 4 reveals the training and validation max accuracy of CVCNN is better than RVCNN, The validation accuracy of RVCNN model is lower than that of training after 30 iterations, which indicates the lack of complexity of the model. The DOF of CVCNN model is lower than that RV model, so CVCNN model has better classify performance and it is significantly less vulnerable to over- fitting.

4.CONCLUSION

In this letter, The CVCNN processing framework for terahertz image classification is proposed. Terahertz image datasets are constructed using MINIST handwritten datasets and PSF which was measured from our transmission system. Compared to RVCNN, CVCNN has a better accuracy rate, and it is significantly less vulnerable to over-fitting in terahertz image classification task.

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