Plasma parameter inversion method based on deep learning approach

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Abstract

As a dispersive medium, plasma has broad application prospects in stealth antenna and new attenuator design. Plasma parameters, such as electron density and collision frequency, are the basis for studying plasma property. At present, conventional plasma parameter inversion algorithms encounter some difficulties, such as large amount of calculation, long inversion time, low inversion accuracy. A deep learning model for plasma parameter inversion is proposed in this paper. The model takes full advantage of the characteristics of deep neural network, with simple structure, fast operation speed. And the plasma parameters can be reconstructed with high precision. The simulation results indicate that the inversion results are better than traditional methods even in the presence of noise.

Problem Statement

Before dicussing the relationship between deep learning and plasma parameters, the relationship of the scattering field and the electromagnetic parameters of the object. The EMIS problem can be described as

$$y = Ax$$

The above formula represents a nonlinear relationship between the electromagnetic field $E^S$and the electromadnetic parameters, generally referring to the relative permittivity ε_r. When the measured target is plasma, the relative permittivity can be written as

$$\varepsilon_r = 1 - \frac{\omega_p^2}{\omega^2 + \upsilon^2}\left(1 + i\frac{\upsilon}{\omega}\right)$$

The nonlinear relationship of the EMIS problem is transformed into the relationship between the scattered field and the plasma parameters, where refers to electron density and collision frequency.

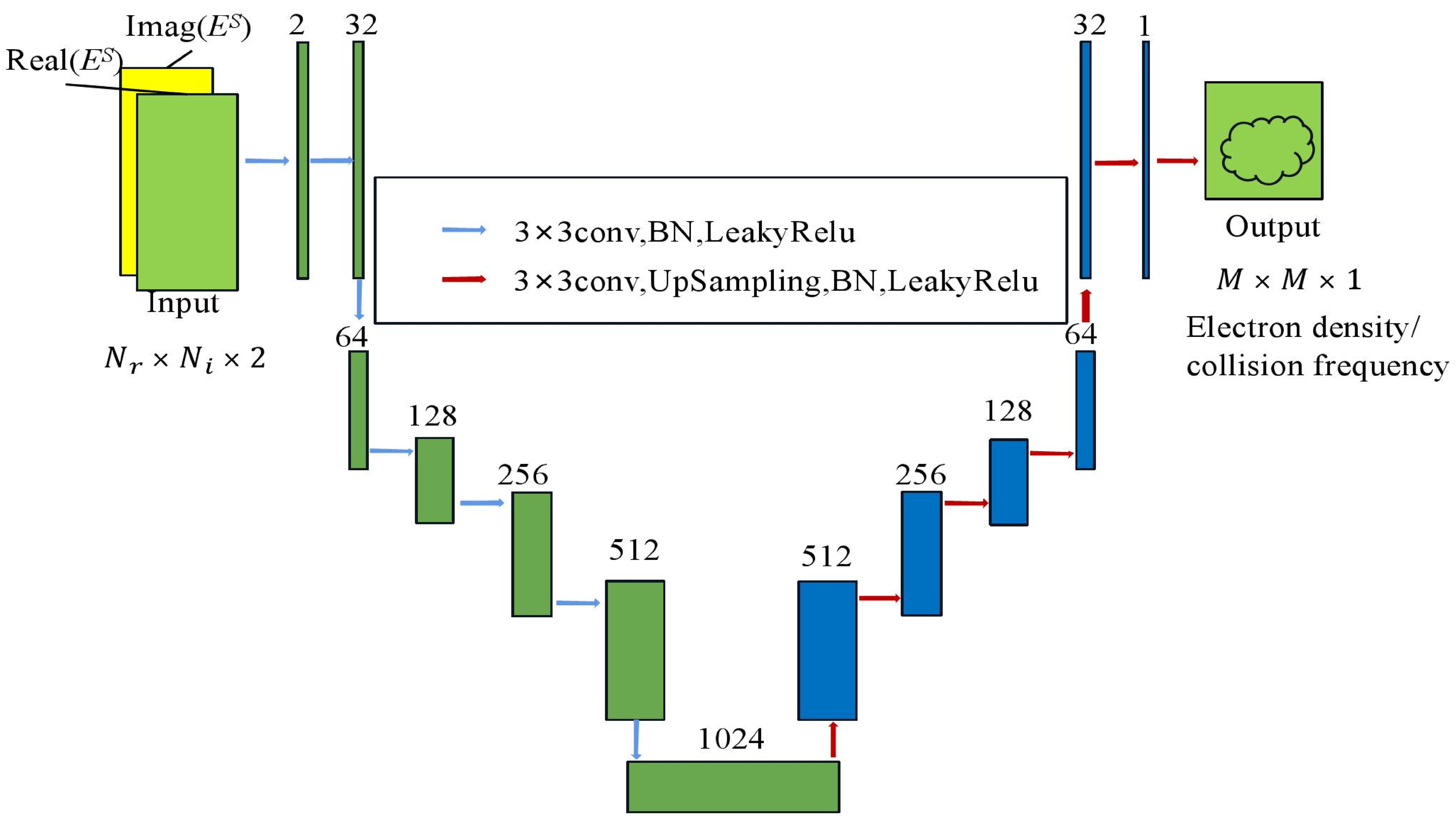

Fig. 1 . The architecture of DNN.

The scheme proposed in this paper is an improved network architecture based on the classic U-net. The architecture of scheme is shown in the Fig. 1, where the input data refer to the received scattered field E^S. The output data corresponding to the two plasma parameters to be measured, electron density and collision frequency.

Simulation Results

A：To investigate the effect of the provided model, corresponding inversion results for training real parts alone (ROs), training imaginary parts alone (IOs), and training real and imaginary parts (CVs) are provided. A single frequency is used, f = 400MHz, the following simulations all contain 15dB of Gaussian noise in this paper. The inversion results are shown in the Fig. 2 and Fig. 3.

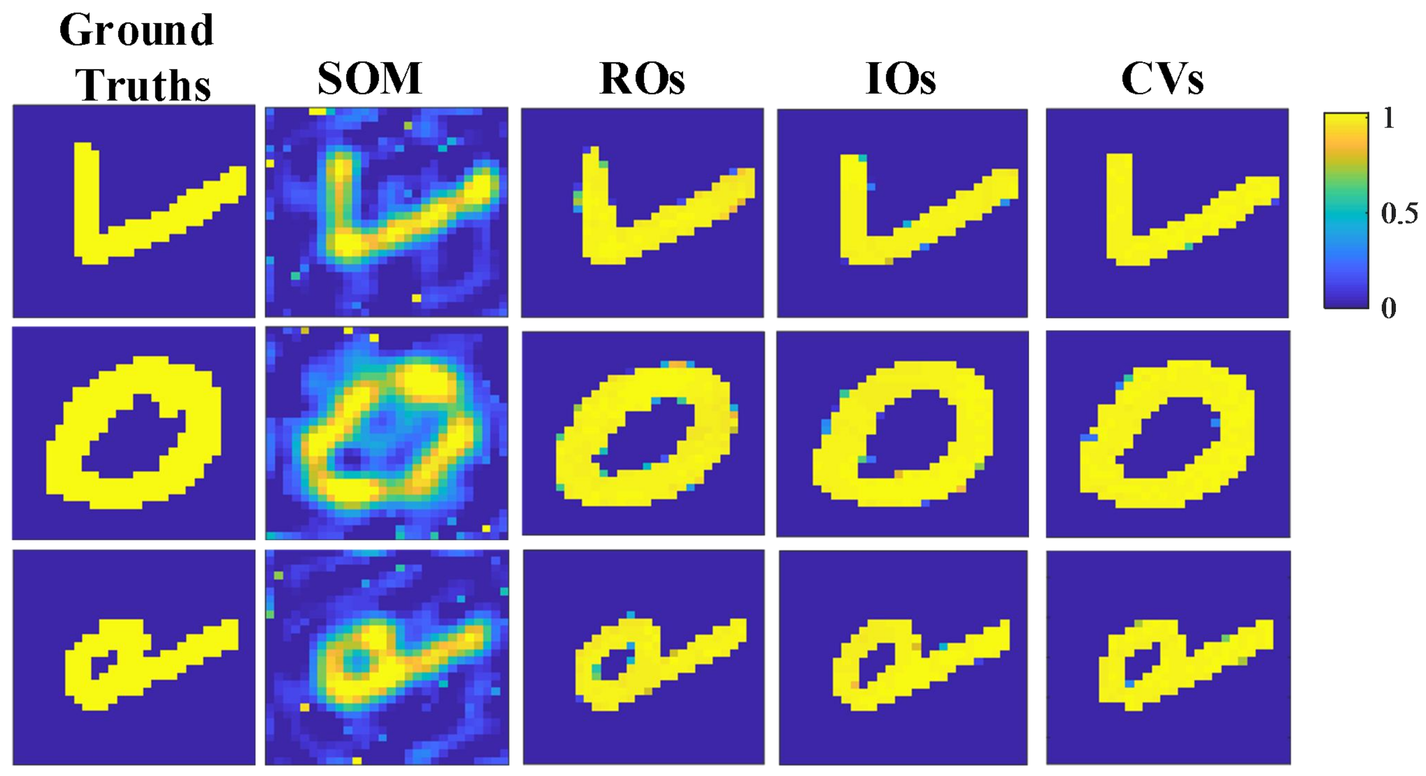

Fig. 2 . Reconstruction results of electron density by the diffenent algorithm.

B：From the discussions, we find that the reconstruction results based on DNN are better than those of traditional iterative methods, and the CVs scheme proposed in this paper has lower inversion errors.

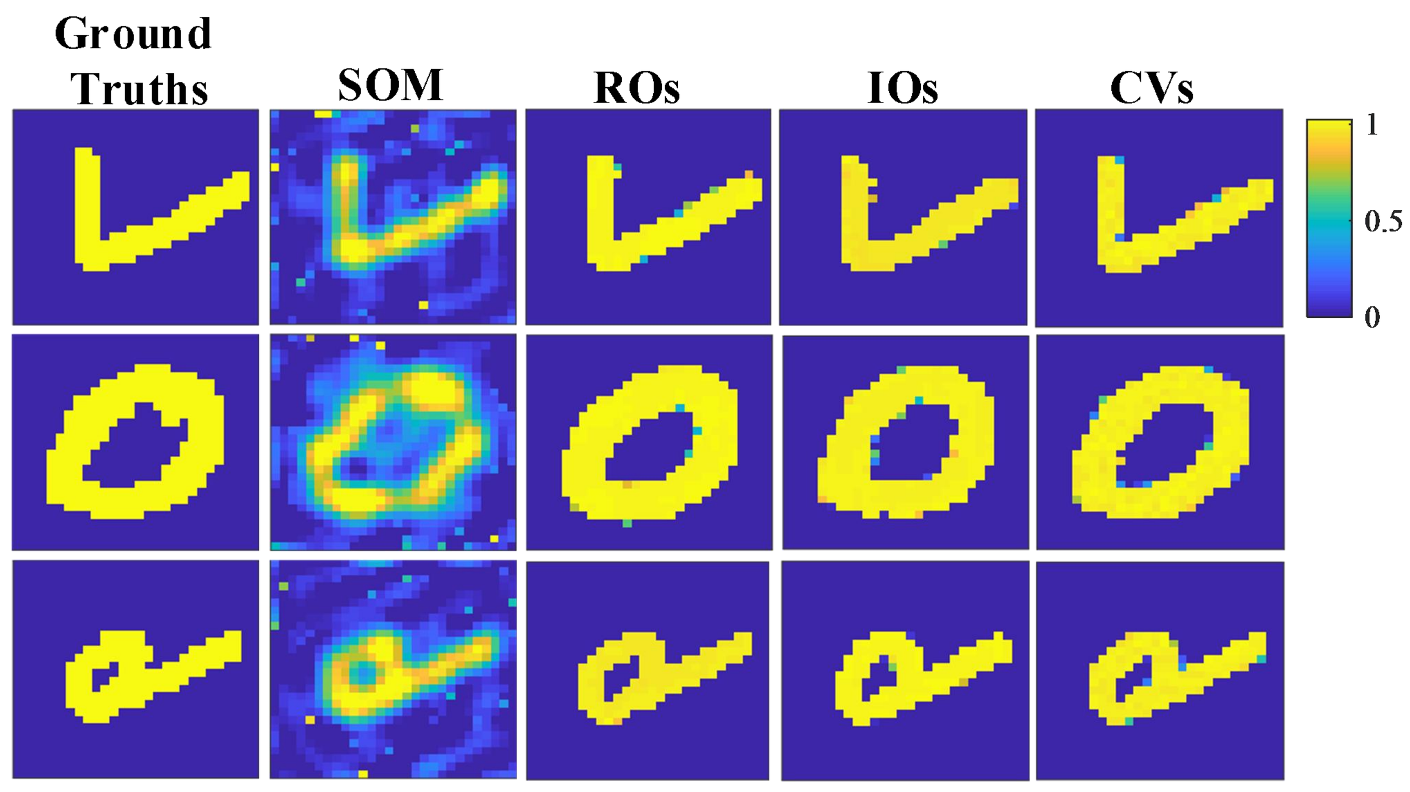

Fig. 3 . Reconstruction results of electron density by the diffenent algorithm.

Conclusion

In this paper, the plasma parameter inversion is realized based on the DNN, and a deep learning scheme that simultaneously trains the real and imaginary parts (CVs) is proposed. By comparing the proposed scheme with the results of previous traditional methods and other network models, the proposed scheme has the smallest inversion error. The method of this paper not only exploits the advantages of simple structure and fast calculation speed of traditional neural network, but also greatly increases the inversion accuracy and reduces the inversion time. The simulation results prove that deep learning has obvious advantages in plasma parameter inversion, and satisfactory results are obtained. The new scheme proposed in this paper is expected to provide new ideas for further improving the real-time performance and detection accuracy of plasma parameter measurement.