

Plasma Tomography at GOLEM Tokamak using Neural Network model

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The paper presents an artificial neural network-based model for tomography reconstruction of visible plasma radiation distribution at the GOLEM tokamak. The training dataset is constructed by samples consisting of emissivity phantoms and associated synthetic measurements from a poloidal cross-section of the GOLEM tokamak. To evaluate the performance of the trained model, a phantom test is performed, and the result shows the considerable prediction potential of the proposed model. In addition, the neural network-based model offers a significantly shorter prediction time compared to traditional tomography methods.

Introduction

The spectral and spatial distributions of radiation emitted by plasma is interpreted as a diagnostic tool to characterize plasma properties. In tokamak plasma, the tomographic inversion methods are implemented to reconstruct the spatial distribution of radiation using line integrated plasma projection data [1]. The importance of the computation time of the tomography reconstruction process leads to attempts in the implementation of Artificial Neural Network (ANN)-based models [2]. Besides the optimal neural network structure and the proper training method, the performance of the model critically depends on the coverage and completeness of the training data [3]. In this work, we apply a representative synthetic dataset to train an ANN-based tomography model. The synthetic dataset is constructed by samples consisting of emissivity phantoms and associated synthetic measurements corresponding to one poloidal cross-section of the GOLEM tokamak.

ANN-based Tomography Reconstruction at GOLEM Tokamak

The tokamak GOLEM is located at the faculty of Nuclear Physics and Physical Engineering (Czech Technical University in Prague). The diagnostic system to detect the visible plasma radiation is composed of two crossed view colour cameras (Radial (R) and Vertical (V)) installed on the same poloidal cross-section [4]. The cameras are reaching a speed up to 204,800 fps (1280×8 pixels) in 12-bit ADC dynamic range [5] with pixel size $10\mu\text{m}\times 10\mu\text{m}$ operating in the visible spectral range. The left side of Fig. 1 shows the schematic figure of one cross section

of the GOLEM with Line of Sight (LoS) layout of R and V cameras represented in pink and blue, respectively. On the middle side of the Fig. 1, it is showed that the line integrated data is used as the input of the ANN and the. A synthetic training dataset is constructed by using 3500 emissivity phantoms of one GOLEM poloidal cross-section with associated line integrated data. The database was diversified to include various shapes (such as Gaussian, Hollow, and Banana shapes) in a wide range of intensity and position, considering the most probably plasma distribution at GOLEM.

To train the model, a neural network architecture was designed based on the input and output features. The neural network was modelled with an input layer of 2560 neurons (number of input features), one hidden layer with 1024 neurons each, and an output layer with 1600 neurons (number of output features). The right side of Fig.1 shows the schematic of the ANN architecture.

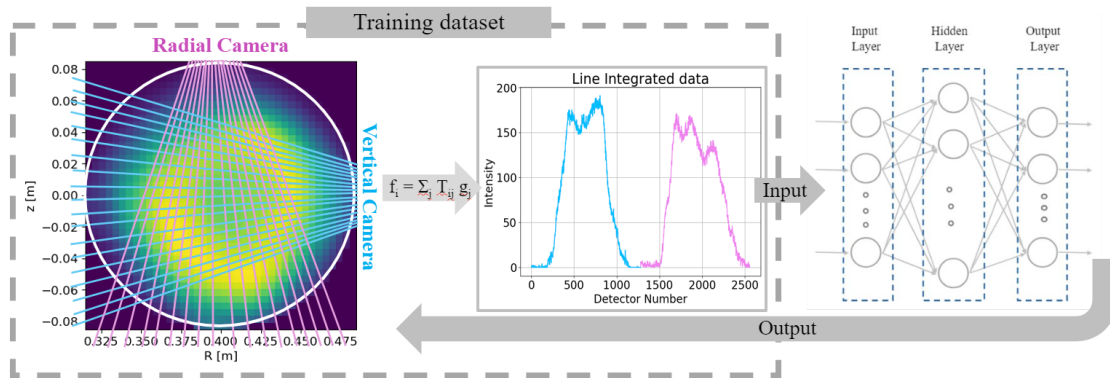


Fig 1. Schematic diagram of the ANN model performed on the GOLEM tokamak. Left side: Schematic figure of one poloidal cross-section of the GOLEM tokamak. Middle side: The line integrated data associated to the phantom data. Right side: The ANN architecture.

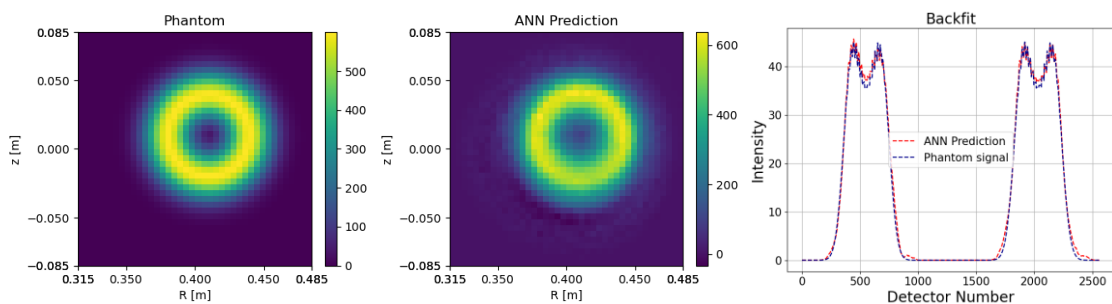


Fig 2. From left to right: the phantom, the ANN prediction of radiation function of one cross section and the corresponding backfit for the test data sample.

The trained ANN model was applied on the test dataset to predict the radiation function of one line integrated samples. Subsequently, the backfit was evaluated to compare the ANN's

predictions with the phantom corresponding to the sample. Fig. 2 shows (from left to right) the phantom sample, the ANN prediction of radiation function of one cross-section and the backfit for the test data sample. The result shows that the trained ANN model predicts the radiation function of line integrated samples very near to the corresponding phantom. The backfit analysis confirms the reliability of the proposed ANN model in reconstructing the radiation function. The ANN model requires time in order of 10 ms for prediction, which contrasts significantly with the traditional tomography reconstruction time of approximately 3 s, demonstrating a notable advantage in terms of speed.

Conclusion

In this work an artificial neural network model was applied to predict the visible plasma radiation distribution at the GOLEM tokamak. The training dataset was constructed using samples consisting of emissivity phantoms and associated synthetic measurements corresponding to one poloidal cross-section of GOLEM tokamak. The dataset was defined with different parameterization in distribution shape (Gaussian, Hollow, and Banana shapes) and intensity value depending on the spatial coordinate of the grid pixel. The backfit analysis confirms the reliability of the trained ANN model in reconstructing the radiation function. One of the key advantages of the ANN prediction model is its significantly shorter prediction time (approximately 10 ms) compared to traditional tomography reconstruction methods (approximately 3 s).

References

- [1] J. Mlynar et al 2010, *Fusion Science and Technology* 58.3, 733–741.
- [2] D.R. Ferreira et al 2018, *Fusion Science and Technology*, 74(1-2), 47-56.
- [3] X. Liang et al 2020, *IEEE 18th International Conference on Industrial Informatics (INDIN)* 1, 502–507.
- [4] S. Abbasi et al 2023, *Fusion Engineering and Design* 193, 113647.
- [5] Photron Europe Limited, Product datasheet mini UX fastcam series by photron, 2021, <http://photron.com/wp-content/uploads/2015/11/Mini-UX-REV16.9.29.pdf>