§29. Image Reconstruction Methods for Bolometer Tomography and a New Study of Neural Network

Iwama, N. (School of Informatics, Daido Univ.),
Teranishi, M. (Dept. of ISM, Hiroshima Inst. of Tech.),
Hosoda, Y. (Dept. of Inf. Sci., Fukui Univ.),
Peterson, B.J., Tamura, N.,
Liu, Y. (South-Western Inst. of Physics),
Kostryukov, A.Yu. (St. Petersburg Tech. Univ.)

The bolometer system for LHD plasma diagnostics, which is been developed from one-dimensional detecting arrays to 2-dimensional video cameras, gives a growing capability to observe the dynamic plasma behaviors. Study was made for refining the numerical methods of image reconstruction that have been developed for the 2-dimensional tomography in the semi-tangential cross section[1)], and also for exploring the possibility of 3-dim. one of the helical plasma.

With respect to the two fan-beam camera system of bolometer installed in a semi-tangential plane with the 3.5U/4-O ports, the direct approach of treating each pixel value as an unknown without any parametric model is promising because of the triangular shape of magnetic surface region. To meet a large missing of projection data, strong regularization is required for solving the under-determined linear equation $H\boldsymbol{f}=\boldsymbol{g}$ in the sense of least squares. The projection matrix H, in which the effect of beam spread relating to the pinhole geometry should be taken into account, is sparse and ill-conditioned; the condition number is 607.4 when evaluated for HC^{-1}, where C is the Laplacian operator, and the image and data vectors $\boldsymbol{f}$ and $\boldsymbol{g}$ have sizes of 32^2 and 40, respectively.

In changing the type of regularization term in the Lagrange objective function, and with and without a nonlinear constraint of nonnegative pixel values, a software series of image reconstruction has been built up and examined on experimental data of LHD[2)]: 1) the Tikhonov-Phillips method, 2) the maximum entropy method using the SMW formula, and 3) the Hopfield neural network. Efforts have been given to develop fast algorithms and also to get statistical tools of optimizing the plasma image with respect to the regularization parameter. Core software for movie production is ready to meet the long-time operation of LHD.

Recent progress was obtained on the behaviors of the optimization criteria including the approximate GCV (generalized cross-validation) and the L-curve for the nonlinear methods of maximum entropy and Hopfield, and also on extending to the weighted least squares analysis. Additionally, a new study of neural network was started.

The neural network collocation method (NNCM) proposed by Ma *et al.*[3)] is expected as another method that can be useful for sparse-data tomography. The method is based on a special usage of the perceptron; that is, the position coordinates of each pixel are fed to the inputs subsequently in order to give the corresponding pixel value as a single output. Training (learning) of the neural system is carried out so as to get a good least-square fitting for projection data. This usage of perceptron can be considered equivalently to be a series expansion of plasma profile with basis functions that are dependent on both the multi-layer arrangement of neurons and the projection data. This principle of nonlinear image reconstruction by NNCM can be explained well by revealing the acquired basis functions. With a 3-layered perceptron, which was equipped with the sigmoid and skimmer function in the hidden and output layer, respectively, a result of simulation is shown in Figs. 1 and 2. The NNCM may have an advantage of avoiding a large increase of unknown parameters even in the 3-dim. tomography, which is being planned for the purpose of studying the impurity behavior in LHD.

Feasibility was studied on applying the reconstruction methods to the large-sized inversion of 3-dim. tomography.

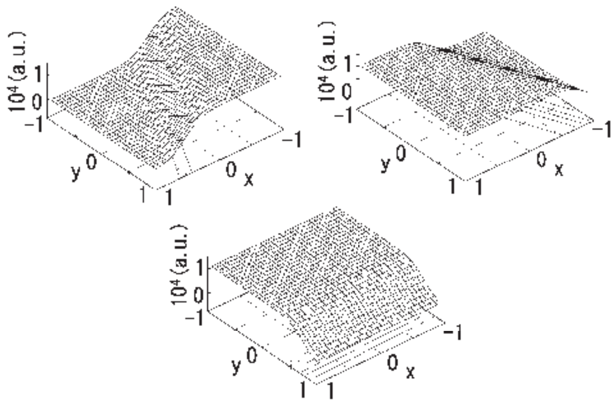

Fig. 1 Three basis functions which contribute to forming the edge of the semi-tangential cross section of LHD: the image region to [−1, 1] in both the x and y directions.

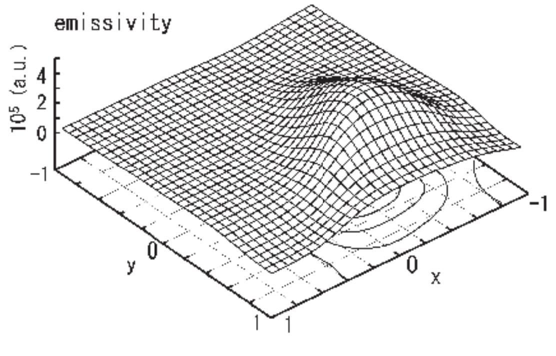

Fig. 2 Plasma image which was reconstructed by combining 12 basis functions as a result of training for numerically-simulated projection data of a phantom.

1) Peterson, B.J., Kostriukov, A.Yu., Ashikawa, N. *et al.*: Plasma Phys. Contr. Fusion, **45** (2003) 1167.
2) Iwama, N., Ichikawa, N., Hosoda, Y., Liu, Y. *et al.*: J. Plasma and Fusion Res. Series, **8** (2009) 975.
3) Ma, X.F., Fukuhara, M. and Takeda, T.: Nucl. Instrum. Meth. Phys. Res., **A 449** (2000) 366.