§27. Fast and Stable Image Reconstruction Test with Hopfield Neural Network in Bolometer Tomography of LHD Plasma

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With respect to the two fan-beam camera system of bolometer set up in a semi-tangential plane using the 3.5U/4-O ports of LHD[1, 2], numerical analysis study has been made to optimize the plasma imaging especially with the purpose of movie fabrication in view.

The Hopfield neural network is capable of reconstructing plasma images with smooth and positive-valued profiles, combining the good features of the Phillips regularization method and the maximum entropy method (MEM)[3]. The Hopfield neural net is a dynamical system. While the neural net is composed of neurons as many as pixels of plasma image, the neurons are provided with the forward operator of Tikhonov-Phillips least-squares regulation in terms of interconnecting weights, and also provided with a simple inversion (backprojection) of the detector output vector in terms of biases. The use of a nonlinear activation function of neuron keeps the neuron outputs (pixel values) always positive. A plasma image is obtained when the system dynamics is numerically simulated with an initial state in order to get convergence.

To use this Hopfield method for pursuing the time variation of LHD plasma, it is necessary to change the neuron biases according to the time change of detector outputs. Then, computing time and stability in image reconstruction are key-points. Firstly, in order to decrease the computing time, we have examined (i) the computer coding using the data structure of CCS/CRS in regard to the sparseness of the interconnecting weight matrix, (ii) the use of the reconstructed image for the initial state of neural net in obtaining the image of one sampling period later, and (iii) the increase of the learning coefficient in updating the neural state. Secondarily, in order to get a good stability, we have examined (i) the use of the skimmer function for the activation function, and (ii) the validity of a regularization parameter chosen with the L-curve in one plasma shot. As a result, with a small updating number of neural system decreased to 50, we have got a series of plasma images that are stable enough for movie fabrication: 400 images in one plasma shot of 4 [s], from the starting phase to the diminishing phase of plasma, with a sampling time of 10 [ms]. The total computing time was about 20 minutes with a 500-MHz workstation. The animation software of IDL was used.

Our numerical study on the bolometer tomographic imaging of LHD plasma was summarized in focusing on the Hopfield neural network and published in ICPP 2008 (Fukuoka)[4]. Complementary results of numerical simulation are exhibited in Figs. 1 and 2. A phantom f_0 composed with Gaussian peaks was assumed on the LHD plane, and the corresponding detector outputs Hf_0 were corrupted with Gaussian white noises. Concerning the plasma images $\hat{f}$ that were reconstructed by applying the Phillips method and MEM to the numerically generated data, the mean square errors and the GCV were plotted as functions of the regularization parameter. In comparison with thepoint determined by the Morozov (χ^2) condition, the GCV and its approximations GCV_1 and GCV_2 in MEM took minima, as marked with a square circles, in a way similar to the other experimental data analyses of tokamaks and of the satellite Yohkoh HXT.

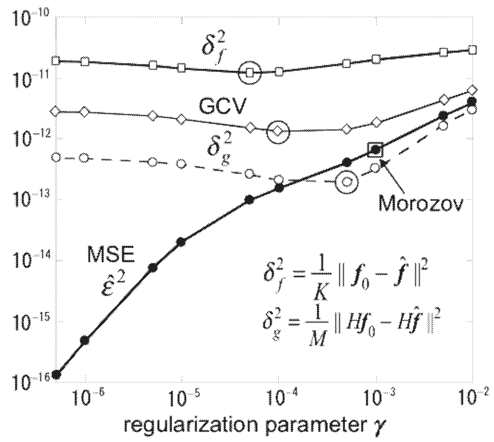

Fig. 1. Simulation result of the Phillips method.

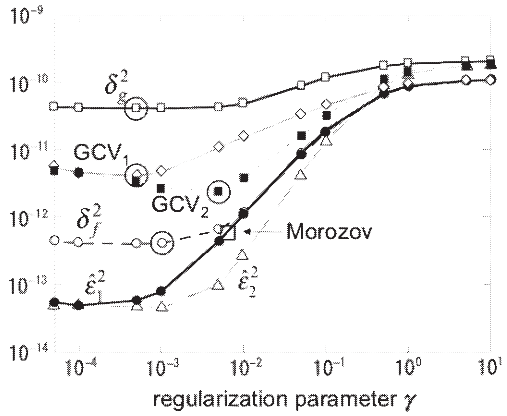

Fig. 2. Simulation result of MEM with GCV_1 and GCV_2, which are defined for the usual mean square error (MSE) $\hat{\varepsilon}_1^2 (= \hat{\varepsilon}^2)$ and a modified MSE $\hat{\varepsilon}_2^2$, respectively.

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2) Liu, Y., Tamura, N., Peterson, B.J., Iwama, N. et al.: Plasma and Fusion Research, **2** (2007) S1124.
3) Iwama, N., Ichikawa, N., Hosoda, Y., Liu, Y., Tamura, N. et al.: Ann. Rep. NIFS (2007-2008) 163.
4) Iwama, N., Ichikawa, N., Hosoda, Y., Liu, Y., Tamura, N. et al.: J. Plasma and Fusion Res. Series (to be published).