§20. Numerical Analysis for Image Reconstruction of Large Size

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Image reconstruction like the computerized tomography holds an important position in scientific imaging; one intends to reveal the interior of an object by observing from the outside. The size of the objective image to be reconstructed becomes large especially for three-dimensional (3D) imaging, which is in progress also in nuclear fusion research. For example, the 3D bolometer tomography of LHD needs to solve an underdetermined linear equation, with good regularization, for unknowns more than 10^4.

The progress of this fiscal year has been to develop the standard algebraic methods of plasma image reconstruction to the form that is applicable to problems of large size. That is, both the Tikhonov-Phillips (TP) regularization method and the maximum entropy method (MEM) were changed in algorithm to iterative solvers that do not use any matrix decomposition such as the singular value decomposition. The CGLS, which is the original form of the conjugate gradient method and known to be effective for the least squares problem [1], was adopted into minimizing the Lagrange function in TP method and into the Newton algorithm using the SMW formula. In adoption, the sparseness of the coefficient matrix (projection matrix) in linear equation was taken into account for fast computing.

The new algorithms were examined on electron tomography using the Zernicke phase contrast cryo-electron microscopy, which was developed in the National Institute of Physiological Sciences. The research subject is equivalent to a tomography using a rotational parallel beam camera with the angle that is limited to ±70°; the observation missing lies in the horizontal direction [2, 3]. Fig.1 shows a result of 2D image reconstruction in the scheme of multi-slice imaging. As the preprocessing of projection data, the normalization in both mean and variance was employed according to the standard electron-tomography software IMOD. The Tikhonov method using the square-integral penalty and also MEM worked reasonably. In each method, the iteration converged well; the reconstructed image and the related sum of the squared residuals changed reasonably with the regularization parameter. With good resolutions, both methods at convergence could give images as smooth as one that was obtained by early stopping the iteration of SIRT, which is the best method installed in IMOD. As long as the background of specimen was kept positive-valued as it was, both methods were similar in image reconstruction even if the use of entropy stabilized the image under the non-negativity constraint. The triangular artifacts in the left and right edge regions of specimen are caused by omission of some projection data before analysis. For the purpose of decreasing the effect of missing wedge (limited angle) on virus particle images, study is in progress particularly to improve the convergence of Laplacian operator regularization.

MEM has also been developed to a solver of deconvolution. At each step of Newton iteration, the nonlinear equation is rapidly solved with a conjugate gradient algorithm adopting the block-circulant matrix diagonalization. A result of application to a dirty map of the radio telescope Heliograph is shown in Fig. 2.

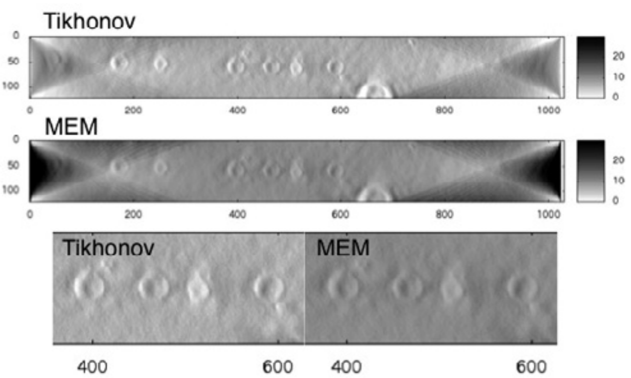

Fig. 1. Results on electron tomography. 2D images reconstructed by Tikhonov method and MEM with regularization parameters of 400 (Tikhonov method) and 5 (MEM) are displayed in whole and partial regions. Particles of ε15 phage embedded in vitreous ice are seen.

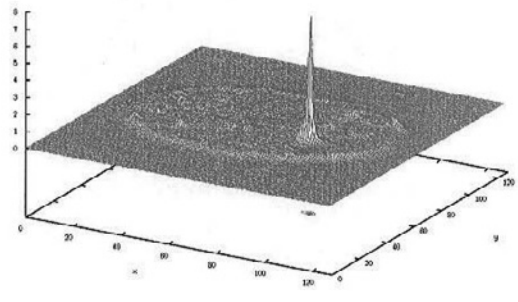

Fig. 2. Result of a method of maximum entropy on Nobeyama Heliograph. The photosphere and one flare of the sun are seen.

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2) Iwama, N. et al.: Ann. Rep. NIFS (2010-2011) 437.
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