§18. Extension of Plasma Imaging Technique to Other Fields: Biology and Astronomy

Iwama, N. (Daido Univ.),
Teranishi, M. (Hiroshima Inst. of Tech.),
Abe, K. (Gifu Shotoku Gakuen Univ.),
Nagayama, Y.

A small but significant project of imaging science has started. The numerical techniques of analyzing signals and images that have been developed for nuclear fusion research are applied and extended to other fields: biology and astronomy, particularly, with respect to the electron microscope and the adaptive-optics and radio telescopes. Results of this academic year are as follows.

(1) Extension to Electron Tomography

The phase contrast electron microscope that has been developed by the National Institute of Physiological Sciences (NIPS) [1] is remarkable for its striking feature on biological objects and winning a lot of successes, combined with 3D tomographic techniques of microscopy. Our research of image processing is firstly focused on the basic problem of "missing wedge" in single-axis specimen rotation; that is, the projection data are missed in the range of tilt angle as large as about ±20° owing to the increase in the effective thickness of the specimen. We also face the problem of SN ratio for unstained objects that is lowered by weakening the electron beam in order to avoid the specimen damage by repeating the irradiation many times (70 times with an equal tilt angle space of 2°).

With these regards the Hopfield neural network, whose property has been well investigated on the bolometer tomography of plasma [3], was employed as the first test tool for image reconstruction. A result is shown in Fig. 1. To test with a decreased size of computation, a 2D section of one virus was targeted with the number of pixels decreased by taking the moving average of noise reduction. For the resulting number of projection of 3,500 (50 x 70 angles) and that of pixels of 54,634 (W463 x D118), the neural system with the skimmer type of neuron activation function was found favorably to reach the state of minimal energy with 100 iterations. The computing time was greatly decreased to 7.5 min. (with the desktop PC: Dell-Precision 690) by using an improved algorithm of system state updating, which is efficient for the sparse neuron connection. This technical achievement will be fed back to the 3D tomography being prepared for LHD plasma. The next challenge in biology is addressed to the 3D image reconstruction over the whole field of view of microscope, that is, an inverse problem of extremely large size.

(2) Extension to Telescope Imaging

Study has just started with an intention of contributing to the adaptive optics related with the 3D tomography of atmospheric turbulence for the Subaru Telescope and also to the image synthesis in the radio telescope ALMA. The latter subject is an inverse problem of the type that is common to the wavenumber spectrum estimation of plasma fluctuations using the laser phase contrast method and the ECE imaging technique.

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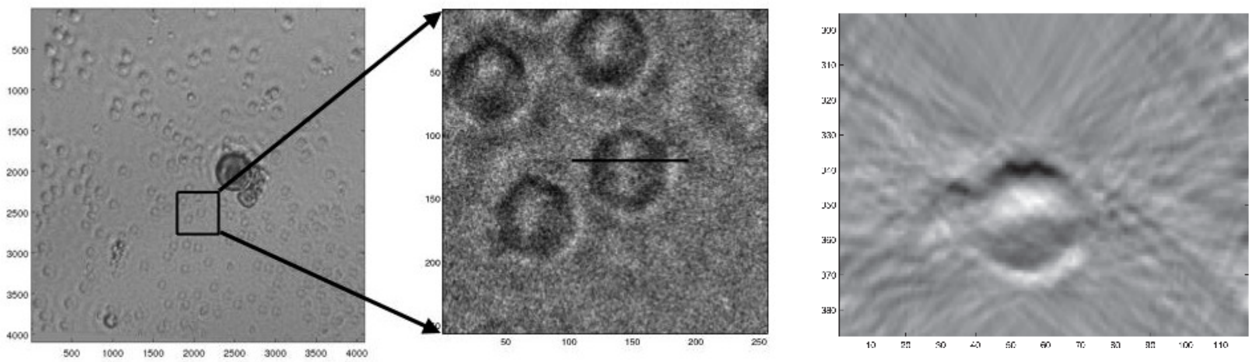

Fig. 1 Left and middle: a projection image of ε15 bacteriophages obtained by the Zernike phase contrast cryo-electron microscopy [2] (nearly zero tilt angle of −0.53°, data no. 090308e15, 200kV). Image reconstruction was made in the 2D particle section perpendicular to the page surface (indicated in the middle figure by a line segment 22.9 nm long).

Right: 2D image reconstructed by applying the Hopfield neural network to 1D projections as many as 70 (with reversion in black-and-white color). Streaking artifacts seen in the whole picture are related to the electron beams that passed from the right to the left with various tilt angles. With this view of the artifacts, one notes the missing of projection data in the vertical direction. The tailspike of virus is recognized on the left side of the particle.