

ON RECONSTRUCTION OF IMAGES FROM THEIR SPATIAL SPECTRA. Yu. V. Kornienko¹, S. I. Skuratovskiy¹. ¹Institute of Radio Physics and Electronics of Nat.Ac.Sci. of Ukraine, Ac. Proskura St. 12, 61085 Kharkov, Ukraine, milv@ire.kharkov.ua

The long-exposure astronomical images taken through the terrestrial atmosphere are known to be highly blurred. The loss of information becomes noticeably less if the long exposure is divided into many exposures which are short as compared to the life time of the wavefront disturbances. This is the fact the method of speckle interferometry is based upon [1,2]. However, the method provides only a partial solution, since the problem of optimal processing of the obtained image series is not even posed. Such a problem must be posed in the context of the Bayesian statistical approach [3,4,5]. Little is made in this direction so far.

One of the tasks appearing in investigations in this field consists in reconstruction of images from the modulus of their Fourier transform. A possibility to successfully solve this problem was noted in [6], where an iterative algorithm was proposed, which has been successfully realized in [7]. The result presented in [6] was confirmed in the more notorious work later [8]. However, the proposed algorithm provides convergence to the correct result only when the initial approximation is sufficiently close to the sought-for image (even in the absence of a registration noise); in the general case, the process may fall into the "traps", i.e., may converge to a false result. The way how the result depends on the initial approximation has not been analyzed in details so far; some new results obtained in computer simulations are presented in this work.

The image of a letter F 16 x 16 pixels in dimension, with brightness levels 0 and 1, placed in the frame of 32 x 32 elements was chosen as an object's model. The modulus of its Fourier transform was calculated, which was used as the initial data. The iteration cycle consisted of two steps: the Fourier transform was calculated at the first step, and the absolute values of its components were set to be equal to the specified ones; the inverse Fourier transform was fulfilled at the second step, and the brightness of the obtained image was set to equal zero outside the 16 x 16 square, as well as in the points where it turned out to be negative. The process was continuing until the facility accuracy is achieved.

The examples illustrating the character of the process convergence are shown in Fig. 1. The initial approximations are presented in each row first, and then the images obtained at various steps of the iteration process are presented (the iteration numbers are shown). The examples of convergence to the correct result and to the false one are presented.

In another experiment, the initial approximation was selected in a regular manner in some flat two-dimensional cross-section of a 256-dimensional image space S. The points of this space, which was selected as the initial approximation, formed a square grid in this plane, 250 x 250 nodes in dimension. For each node, a function F was being calculated, which was determined as the Euclidian distance between the obtained result

and the actual image (F=0 when the convergence is correct). The resulting function F was imaged as a map (Fig.2). A behavior of function F was a subject of the investigation.

Function F was found to take the values from a discrete set. This is an indication that a set of traps is discrete, and they may be separated from the correct result. At the same time, it is difficult to rely on finding of some regular algorithm for searching a region of correct convergence, since function F has a complicated fractal-like structure [9].

In Fig. 2a, a map representing function F within a 0.05 x 0.05 square is shown. Lighter tones correspond to smaller values. The regions originating convergence of the process to the correct solutions are shown in white. The region marked with a small square of 0.04 in size is shown in Fig. 2b expanded. A small square in Fig.2b of 0.00768 in dimension is shown in more details in Fig. 2c.

References: [1] Labeyrie A. (1970) *Astron. & Astrophys.* 6, No 1, 85-87. [2] Dudinov V.N., et al. (1982) *Proc. IAU colloq. No.67*, 191-198 [3] De Groot M. (1974) *Optimal statistical decisions Moscow: Mir*, 491 [4] Turchin V.F., Kozlov V.P., Malkevich M.S. (1970) *Uspekhi Fizicheskikh Nauk* 202, No. 3, 345-386. [5] Kornienko Yu.V. (2005) *Radiofizika i elektronika. IRE NANU proceedings 10, special number*, 652-676 [6] Kornienko Yu. V. (1977) *Doklad AN USSR, seriya A 10*, 931-933 [7] Babichev A.A., Kornienko Yu.V. Parusimov V.G., Stankevich D.G., Usikov A.Ya. (1980) *Preceding 14-th International congress on highspeed photography and photonics, Moscow, 19-24 oct.*, 436-439. [8] Fienup J.R. (1978) *Opt. Lett.* 3, 27-29. [9] Kornienko Yu.V., Skuratovskiy S.I. (2008) *Radiofizika i elektronika. IRE NANU proceedings 13, No. 1.*

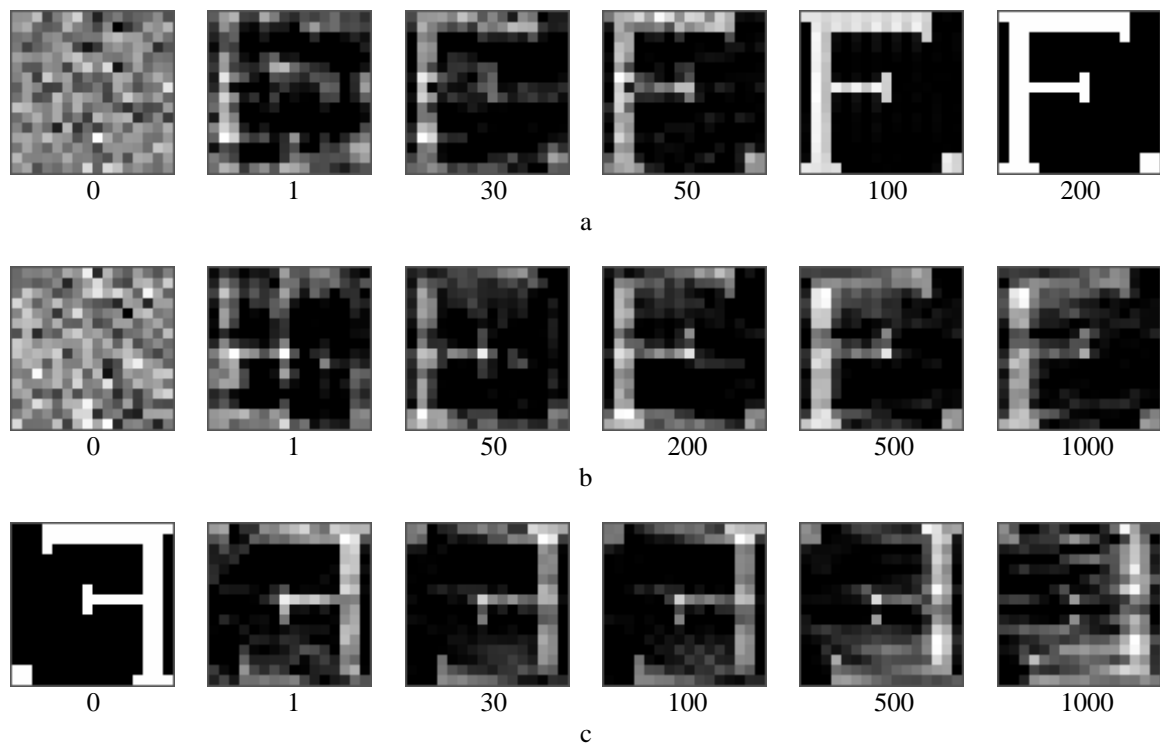


Fig. 1 – Restoration of object F images for a random initial approximation (a – successful result, b – a trap), and with the inverted object image used as the initial approximation (c).

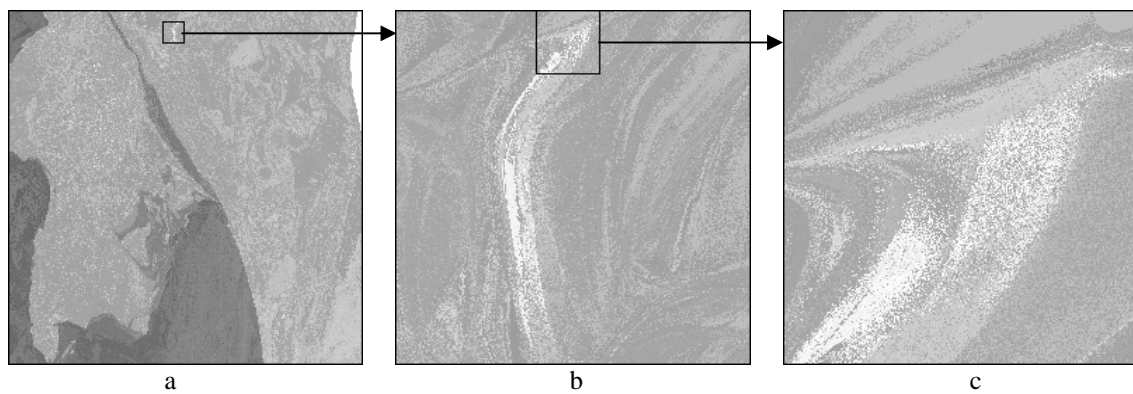


Fig. 2 – The maps of restoration of the object images within a region of 0.5 (a), 0.04 (b) and 0.00768 (c)