SOME GENERAL PRINCIPLES OF THREE-DIMENSIONAL DISPLAY OF TEM-IMAGES

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Scientific problem stating and its significance

Translucent type of electron microscopy allows investigating on micron and submicron levels.

But because of strong and substantially stable spherical aberrations the aperture's value of electron microscope is extremely slight, hereby the depth of focus is large and frequently exceeds the thickness of an object. Therefore TEM-images effect is always a projection of three-dimensional structure on the plane. It is one of the main difficulties in researching the dimensional microstructures' organization using electron microscope [1,2]. Correspondingly, the scientific interest to the elaboration of proper quantitative three-dimensional structure reduction methods by its microscopic images is understandable [3]. Third dimension reproduction is conducted by projection's set obtained at different angles.

The problem of three-dimensional reconstructions in TEM-images corresponds to the mathematical aspect of the lost third dimension reproduction taking into consideration projection's set. Projections may be received at different angles to the projection's axis. By availability of particular types of symmetry one structure image contains the information about different perspectives; the only TEM-image is equivalent to the projection's set, which is one additional trouble-making factor of 3D- reconstructions [1, 4].

The latest scientific investigations' analysis

One of the possible methods for reconstructing of three-dimensional organization of submicron structures is the method of double transformation of Fourier which was suggested by Klug and de Rosier [5,6]. The idea of this method is that Fourier transformation of electronic-microscope image submits three dimension structure on protuberant sets [2,8]. For the efficient application of Fourier's electron-microscopic translucent images synthesis different methods of improving image quality on the stage of preliminary processing should be used. In this respect the application of homomorphic functions of the Hirschberg's is long-term [9].

Summary

1. Protuberant sets principles in electron microscopy

Regardless of the concrete solution the general scheme of electron microscopic measuring can be represented in the following form:

$$\varepsilon = A \cdot f + \nu \qquad (1)$$

where $\varepsilon \in R^N$ - recorded signal; $A \in R^M \to R^N$ - linear operator, $f \in R^M$ - simulated signal parameters of the objects; $\nu \in R^M$ - friction modeling error process [3].

For the solution of (1) the theory of protuberant sets is used, which simulates the ideal projection process [7].

It is considered that there are the following [9,10] determinations of closed protuberant set and its projection operator.

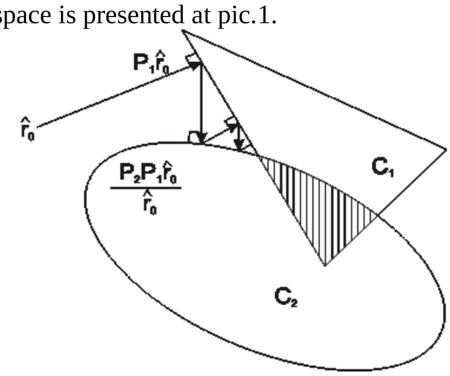
1. Any set S in Hilbert space H is called protuberant only when $\vec{x}_1, \vec{x}_2 \in S$ is converted in $\beta\vec{x}_1 + (1-\beta)\vec{x}_2 \in S \forall \beta \in [0,1]$.

2. It is known if X is closed protuberant set in H has singular element with minimal norm and for anyone $y \in H$ there is the only element $x \in X$ that is called projection Y on X that $\min\|x-y\| = \|x - Px\|$, where $P: H \to C$ –projection operator x and orthogonal projection Y on X .

Let us suppose that projection operator P is situated iteratively and we have m iterations of protuberant type, consequently closed protuberant sets are defined $C_i, i = 1, 2, ..., m$. Then $f \in C_0 = \Omega_{i=1} C_i$. Regarding manifolds of restricted sets $C_i, i = 1, 2, ..., m$ and projection operator P_i .the following sequence is appropriate:

$$\left\{\hat{f}_n\right\} : \hat{f}_n = P_m P_{m-1} \dots P_i \hat{f}_{n-1} \qquad (2)$$

Geometrical interpretation of iteration mechanism for two restricted sets C1 i C2in case of two dimensional Euclidean space is presented at pic.1.



Pic.1. Geometrical interpretation of iteration redection in two protuberant sets C1 and C2.

Here operators P_1 i P_2 are responded to projection operators, and value $\hat{f}_0$ reflects arbitrary "source"of algorithm $\hat{f}_n = P_2 P_1 \hat{f}_{n-1}$. It is formal statement of projection methods on protuberant set, when the decision is situated as an element of restricted protuberant sets intersection. Hereby a priori was expected that projection operators received on the basis of the main determination equation (1). Practically in electron microscopy operators P are determined in different ways. In some cases this is a particular variation remains restriction when the difference is associated with an assessment $\hat{f}$, which is distinguished as $r\left(\hat{f}\right) = g - D\hat{f}$. It is equivalent that $\left\|r\left(\hat{f}\right)\right\| = \|\nu\|$. The last may be reached by restricted assessment of set's element

$$C_b=\left\{y\in R^N:\|g-Dy\|^2\le a^2\right\}. \quad (3)$$

Boundary a^2 is presented as $a^2=cE\left\{\|r(f)\|^2\right\}=cE\left\{\|r(f)\|\right\}=cE\left\{\|v\|^2\right\}$, where $E\{\cdot\}$ - mathematical expectationand $c>0$ is determined with the assurance that common element image is an element of a particular set. Supposing Gauss distribution $v(i)\sim n\left(0,\sigma_v^2\right)$, it is received that $a^2=N\sigma_v^2+2\sqrt{2N}\sigma_v^2$. With these assumptions projection $P_b\vec{X}$ of arbitrary vector $\vec{X}$ on (0) is determined as following:

$$P_b\vec{X}=Z=X+\left(D^fD+\alpha I\right)^{-i}D^f\left(g-D\vec{X}\right) \quad (4)$$

whereLagrangian coefficient α is taken for the achievement of the boundary condition $\|r(Z)\|^2=a^2$. This scheme doesn't depend on the physical conditions of images forming and it is summarizing and those which is applied to the analysis of any electron microscopic images.

2. Previous correction of TEM – images.

Let us take a view from common position separate phases of digital electron-microscopic images processing. Electron-microscopic images of translucent type in particular taken in real conditions are of low contrast and with large additive friction.Therefore the problem of preliminary improvement of electron-microscopic images is significant.

For the answer to that problem the using of homomorphic processing is suggested [6,9,11]. The idea of homomorphic processing is in consolidation of non-linear problem to linear one with the help of any transformations. In such a case, the task of distribution, multiplication of signals is put to the procedure of taking the logarithm of compound signal. From that result the background logarithm is subtracted and logarithm of contrasting signal is distinguished.

For the set of electron-microscopic images, taken at different angles the following algorithm of homomorphic processing is suggested [13].

1. Firstly the contrast of an image is increasing. Contrast scaled in the range from 10 to 245 by the following formula:

$$I'_{ij}=\frac{\left(I_{ij}-I_{\min}\right)\cdot\left(I'_{\max}-I'_{\min}\right)}{I_{\max}-I_{\min}}+I'_{\min} \quad (5)$$

where I'_{ij} - element of new matrix image, I_{ij} - element of outgoing image matrix, $I_{\min}$ - minimum among elements of outgoing image matrix , $I_{\max}$ - maximum among outgoing image matrix, $I'_{\min}$ – lower boundary of elements of new matrix image, $I'_{\max}$ - upper boundary of elements of new matrix image.

2. Analogical method of half-tone image contrast is scaled in the range from 15 to 240by the following formula (5).

3. Taking the logarithm of received half-tone image [12]:

$$I'_j(x,y)=\lg\Big(b(x,y)\cos\big(2\pi f_0\left(x\cos\alpha_j+y\sin\alpha_j\right)+\varphi(x,y)\big)\Big)=$$
$$=\lg\big(b(x,y)\big)+\lg\Big(\cos\big(2\pi f_0\left(x\cos\alpha_j\right)+\varphi(x,y)\big)\Big);$$
$$I'_0(x,y)=\lg\big(b_0(x,y)\big). \quad (6)$$

4. Consequently half-tone image is multiplied by the coefficient i, which is experimentally selected from

$$\lg\big(b(x,y)\big)=i\cdot\lg\big(b_0(x,y)\big). \quad (7)$$

5. From that image the half-tone image is subtracted.

$$I''_j=(x,y)=I'_j(x,y)-i\cdot I'_o(x,y)=\lg\big(b(x,y)\big)+$$
$$+\lg\Big(\cos\big(2\pi f_0\left(x\cos\alpha_j+y\sin\alpha_j\right)+\varphi(x,y)\big)\Big)-$$
$$-i\cdot\lg\big(b_0(x,y)\big)= \quad (8)$$
$$=\lg\Big(\cos\big(2\pi f_0\left(x\cos\alpha_j+y\sin\alpha_j\right)+\varphi(x,y)\big)\Big)$$

6. The following image $I''_j(x,y)$ is multiplied by the coefficient i.

7. Then potentiating is conducted:

$$I'''_j(x,y)=\exp\left(I''_j(x,y)\right)=$$
$$=\cos\left(2\pi f_0\left(x\cos\alpha_j+y\sin\alpha_j\right)+\varphi(x,y)\right) \quad (9)$$

8. Image contrast $I''_j(x,y)$ is scaled in the range from 0to 255by the following formula (5).

That image taken as a result of the proceeding operations is improved by the image for j angle (slope).

3. The characteristics of Fourier synthesis used for the three-dimensional display of electron-microscopic images

Let us suppose, that micro relief is occurred in spacious-frequency field as a discrete Fourier transformation (DFT) [3,15], when z is known as a harmonic sets' sum of κ ,e.g. , for one dimensional case in the following way:

$$Z_k=\frac{1}{N}\sum_{n=0}^{N-1}G_nW^{n,k}, \quad (10)$$

where $W^{n,k}=e^{\frac{2\min}{N}k}$, G_n – amplitude of*n*harmonic.

In such formulation the iterative decision is optimal, Hirschberg algorithm application in particular[4,12].

This method is significant by its peculiarities:

1) by the probation of iterative equation characteristics of unknown quantity is appliedthat is prior information at each stage of iteration procedure;

2) there is no need to distinguish inverse operator deformation, that is in resumption procedure the same operator that distorted image is used;

3) by the realization of this method the work in interactive regulations may be used, this allows to solve the problem of acceptable grade of κ iteration decisionapproximation to the unknown quantity.

Iteration method is indispensable to the problems of 3D-display resumption of low contrast images. By the help of prior information about image for the most detailed spectral plane filling with frequency spectral components the iteration

Hirschberg's scheme, is appropriate for the X-ray photograph, should be used. Hirschberg iteration algorithm is recommended in those cases, when the amount of projection data is insufficient for the application of classic methods. More information about Hirschberg's algorithm is stated in the following works[12,13,14].

Summary

In this articlethe main problems of three dimensional display of TEM-images are outlined. The previous correction of TEM with the application of homomorphic functions and their combination in Fourier-synthesis procedure,discrete Fourier transformation (DFT) and computing Hirschberg's algorithm scheme – it is perspective tendency, that allows raising efficiency and accuracy of three-dimensional display of TEM-images, low contrast in particular.

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Some general principles of three-dimensional display of TEM–images

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The paper explores the issues of application in translucent electron-microscopy (TEM) the theory of protuberant sets. It is proposed to use mathematical set of homomorphic functions to improve the quality of TEM images at preliminary processingphase. The problems of integration of the discrete Fourier transformation and computational scheme of Hirschberg'salgorithm in 3-D reconstruction of TEM images are considered.