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Speeding Up the Tikhonov Regularization Iterative Procedure in Solving the Inverse Problem of Electrical Impedance Tomography

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Abstract—Algorithms of enhancing the speed of Tikhonov regularization algorithm for the conductivity zones method have been proposed; these algorithms make it possible to organize an iterative procedure with logarithmic step and evaluate the result of such iterative procedure through a single inversion of the matrix generated from the matrices of derivatives of phantom contour-edge voltages with respect to the surface conductivities of zones.

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Solving the problems of electrical impedance tomography [1–3] becomes increasingly important as a means of visualization of resistance (conductivity) distribution inside the object under investigation. Unlike such kinds of tomography as X-ray, emission, nuclear magnetic resonance, and ultrasonic, the complexity of this task involves the need of handling high orders of the system of equilibrium equations for the electric equivalent circuit of model (phantom) [4, 5] and a large quantity of desired conductivities for each finite element of such model [6, 7]. In particular, the use of the Newton–Raphson method leads to high orders of the matrix of derivatives of phantom contour-edge voltages with respect to conductivities of finite elements [1].

In solving the direct problem of both the whole phantom consisting of thousands and more finite elements and a zone phantom in iterative procedure the specified difficulties can be avoided by using the modification method [5, 8]. The order of the system of equations in the voltage derivatives with respect to finite elements conductivities and in correction increments of these conductivities can be reduced by using the conductivity zones method [9, 10].

Hence, for 14 conductivity zones in the presence of 16 electrodes over the contour-edge, the order of equation

$$-[\partial U_m / \partial \sigma_r] \cdot [\Delta \sigma_r] = [\Delta U_m] \tag{1}$$

for one iteration in the iterative procedure for the search of conductivity zones is equal to 14 that largely simplifies the task, because for 16 positions of independent current source it is easier to solve the iterative problem 16 times for equation (1) of the 14th order than to solve it one time if the order of this equation is 1000.

Here $[\partial U_m / \partial \sigma_r]$ is the square matrix of derivatives of phantom contour-edge voltages of the order $N = 14$; $[\Delta U_m]$ is the column-vector of the difference between the measured and calculated voltages at electrodes over the contour-edge of phantom for the given approximation of the surface conductivities distribution inside the phantom; $[\Delta \sigma_r]$ is the column of correction values of conductivities zones reducing residual $[\Delta U_m]$.

For finding correction increments $[\Delta \sigma_r]$ it is sufficient to solve (1), i.e.

$$[\Delta \sigma_r] = -[\partial U_m / \partial \sigma_r]^{-1} \cdot [\Delta U_m]. \tag{2}$$