

Ill-Posed Inverse Problems in Molecular Imaging

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Abstract : Inverse problems arise in medical (molecular) imaging. These problems are characterized by large in three dimensions, and by the diffusion equation which models the physical phenomena within the media. The inverse problems are posed as a nonlinear optimization where the unknown parameters are found by minimizing the difference between the predicted data and the measured data. To obtain a unique and stable solution to an ill-posed inverse problem, a priori information must be used. Mathematical conditions to obtain stable solutions are established in Tikhonov's regularization method, where the a priori information is introduced via a stabilizing functional, which may be designed to incorporate some relevant information of an inverse problem. Effective determination of the Tikhonov regularization parameter requires knowledge of the true solution, or in the case of optical imaging, the true image. Yet, in, clinically-based imaging, true image is not known. To alleviate these difficulties we have applied the penalty/modified barrier function (PMBF) method instead of Tikhonov regularization technique to make the inverse problems well-posed. Unlike the Tikhonov regularization method, the constrained optimization technique, which is based on simple bounds of the optical parameter properties of the tissue, can easily be implemented in the PMBF method. Imposing the constraints on the optical properties of the tissue explicitly restricts solution sets and can restore uniqueness. Like the Tikhonov regularization method, the PMBF method limits the size of the condition number of the Hessian matrix of the given objective function. The accuracy and the rapid convergence of the PMBF method require a good initial guess of the Lagrange multipliers. To obtain the initial guess of the multipliers, we use a least square unconstrained minimization problem. Three-dimensional images of fluorescence absorption coefficients and lifetimes were reconstructed from contact and noncontact experimentally measured data.

Keywords : constrained minimization, ill-conditioned inverse problems, Tikhonov regularization method, penalty modified barrier function method

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