Truncated SVD methods in the inverse source problems for the advection-diffusion-reaction models with image-type measurement data

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Abstract

The inverse source problems for nonlinear advection-diffusion-reaction models with image-type measurement data are considered. These inverse problems arise in the air quality studies when the measurement data is obtained in the form of time series, vertical concentration profiles or satellite images of concentration fields. The data is of large amount and of different value with respect to the considered inverse problem. The sensitivity operators constructed from the set of the adjoint problem solutions allow us to transform the inverse problem stated as the system of nonlinear ODE or PDE to the family of nonlinear operator equations depending on the given set of orthogonal functions in the space of the measurement results [1]. By the choice of the orthogonal functions the dimensionality of the problem can be reduced thus allowing for the efficient solution of the resulting operator equation with the relevant methods for nonlinear ill-posed operator equations. We consider Newton-Kantorovich type methods based on the truncated SVD. The operator form of the inverse problem can be exploited for the analysis and comparison of the different inverse problem statements, e.g. with the help of the spectral methods. For numerical solution, the discrete-analytical schemes for transport and transformation processes are applied. The schemes are constructed with the use of the locally-adjoint problems [2]. Multidimensional problems are treated according to the splitting technique with respect to spatial dimensions and physical processes. The accuracy of the sensitivity operator calculation is assured by the consistency of the numerical schemes for the direct and adjoint problems in the sense of Lagrange-type identities [3]. The numerical methods are tested on the atmospheric chemistry models.

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References

[1] Penenko A. V., Nikolaev S. V., Golushko, S. K., Romashenko, A. V., Kirilova I. A. Numerical Algorithms for Diffusion Coefficient Identification in Problems of Tissue Engineering // Math. Biol. Bioinf. 2016. Vol. 11. P. 426-444.

[2] Penenko V., Tsvetova E., Penenko A. Variational approach and Euler's integrating factors for environmental studies // Computers & Mathematics with Applications. 2014. Vol. 67. P. 2240-2256.

[3] Penenko A., Penenko V., Tsvetova E., Grishina A., Antokhin P. Sequential Variational Data Assimilation Algorithms at the Splitting Stages of a Numerical Atmospheric Chemistry Model // Large-Scale Scientific Computing, Springer International Publishing. 2018. P. 536-543.