Shahrood University of Technology

JOURNAL OF RESEARCH ON APPLIED GEOPHYSICS

(JRAG)
2023, VOL 8, NO 2
(DOI): 10.22044/JRAG.2021.10209.1305

Optimal selection of regularization parameter in inversion of magnetotelluric data

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Received: 1 November 2020; Accepted: 21 March 2021

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Keywords

Bushli,
Geothermal
Magnetotelluric
2D inversion algorithm
Regularization parameter
Lanczos bidiagonalization.

Extended Abstract

Summary

The essential issue in the interpretation of magnetotelluric (MT) field data is the solutions for inverse problems that should be in agreement with realistic subsurface geological structures. The MT data inverse modeling is known as an ill posed and nonlinear inverse problem, therefore, in order to prevent the problem of nonunique solution and to obtain meaningful results, it is normally solved using Tikhonov regularization method as the most popular regularization method. Another crucial problem in geophysical data inversion particularly MT field data is to reduce computation time and memory requirements. For achieving more precise inversion solutions, selection of the optimal regularization parameter value is an important factor in the inversion process. The novelty of the present study is to propose a new two-dimensional (2D) algorithm that has been developed for smooth inversion of MT data in which the optimal regularization parameter has been considered. In order to achieve this objective, the forward solution and Lanczos bidiagonalization (LB) algorithm have been implemented in a MATLAB code. For finding an appropriate value for the regularization parameter, adaptive regularization has been used and compared with modified generalized cross-validation (MGCV) and active constraint balancing (ACB) methods. The generated MT data by a 2D synthetic model and Bushli (Nir) geothermal MT field data in Ardabil Province, Iran, have been used in the inversion by the proposed algorithm. The results indicate that the proposed method is more effective and faster than the compared methods especially in less memory usage, decreasing elapsed time, and more accurate solution in the inversion process.

Introduction

Magnetotellurics is widely used for exploration of geothermal resources because of its potential in the conductivity contrast of deep geological structures in geothermal regions. Hence, 2D inversion of the MT data is a major step in determination of physical properties of exploration targets and their geometric quantitative dimensions. In recent years, many attempts have been made on the development of 2D MT inversion algorithms and interpretation of the results. The solutions for inverse problems of MT data are nonunique and unstable since the measured data are accompanied by noise. The Tikhonov regularization theory is a common method for resolving unstable and ill posed inverse problems. In solving this regularized inverse problem, selection of an optimal regulation parameter value is important for achieving an ideal inverse modeling result. This parameter controls the balancing between the minimization process of the stabilizing and the misfit function. Therefore, it must be chosen carefully. In this paper, a novel method has been presented in which the optimal value of the regularization parameter for 2D inversion of the MT data is selected based on the LB method to increase the speed and accuracy of the results of the inversion.

Methodology and Approaches

Numerical modeling of geophysical response for a given geophysical model is known as forward problem. The directly inverting of the forward sensitivity matrix is very difficult especially in large scale problems, instead, one needs to use iterative methods to calculate it quickly. To achieve this, a fast iterative solver like LB algorithm is used for smooth inversion of MT field data. In this method, the large forward sensitivity matrix is substituted by a smaller dimension bidiagonal matrix, which avoids large matrix multiplication and basis vectors storing. Therefore, the inversion process

speed in solving the large inversion problems and obtaining accurate results will increase, and the required memory and inversion calculation time will also be decreased. In order to find an appropriate value for the regularization parameter, a novel method has been presented in which adaptive regularization, has been used and compared with two conventional methods, namely MGCV and ACB. All these methods have been used in MATLAB codes and combined with the LB method, and then has been has been added to software package MT2DInvMatlab developed by Lee (2009). To demonstrate the efficiency of the proposed technique comprising of the above-mentioned methods, it has been applied on synthetic MT data having 3 percent Gaussian noise, and also, real MT data of the Bushli (Nir) geothermal field in Ardabil Province, Iran.

Results and Conclusions

The models produced from the inversion of the synthetic MT data and the Bushli MT field data set using the adaptive regularization, MGCV, and ACB methods are almost similar. The constructed model from using adaptive regularization is slightly better than the model obtained from MGCV and ACB methods. therefore, with respect to the results obtained from 2D inversion of the synthetic MT data and the Bushli (Nir) MT field data, the adaptive regularization method provides a more accurate solution especially in estimating the conductive layer and reservoir boundaries. In addition, this method, compared to the MGCV and ACB methods, is faster and requires less memory in the inversion process. Hence, this method can be considered as the most reliable method for selection of the optimal regularization parameter in the inversion of large 2D and 3D magnetotelluric data sets.