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A Gauss-Newton Based Inversion Tool for 1D/pseudo-2D Modeling of MaxMin EM Data

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Introduction

This work aims to develop a Python-based inversion algorithm for processing electromagnetic geophysical data acquired with the MaxMin system. This equipment employs the electromagnetic method to investigate subsurface structures by measuring the secondary components of the vertical magnetic field (in-phase and quadrature) at multiple acquisition stations. The lack of an accessible and specialized computational tool for inverting this data has hindered proper interpretation and limited more in-depth studies in the field. The proposed algorithm, based on the Gauss-Newton method, will enable the reconstruction of 1D and pseudo-2D conductivity/resistivity models, supporting research in hydrogeology, mineral exploration, and environmental studies. In addition to addressing an academic demand at the Federal University of Pará (UFPA), the use of Python ensures flexibility, open-source accessibility, and integration with other geophysical processing tools.

Method

The data inversion is performed using the Gauss-Newton method, where the sensitivity matrix is numerically approximated through finite differences. To ensure the accuracy of the numerical computation, the results will be compared with analytical solutions for specific models. The initial focus is on one-dimensional (1D) inversion, enabling the construction of pseudo-2D profiles from multiple measurement stations. The electromagnetic method relies on inducing secondary currents in conductive subsurface materials, which are detected by a receiver coil that records the in-phase and quadrature signal components at different frequencies. The proposed methodology will yield resistivity profiles as a function of depth, with direct applications in hydrogeology (e.g., aquifer studies and groundwater contamination) and mineral prospecting. Additionally, the method is suitable for geotechnical investigations, including fracture mapping in bedrock, buried structure detection, and saline intrusion mapping in coastal regions. The implementation of this inversion software will contribute to the training of students and researchers while expanding possibilities for applied geophysics research.

Conclusions

The development of this inversion software represents a major advancement in processing electromagnetic data obtained with the MaxMin system, providing an essential tool for both academic and professional communities. Cross-validation between numerical and analytical methods ensures result reliability, while multidisciplinary applications reinforce the method's relevance in environmental studies, water resource management, and mineral exploration. Future work will include extending the algorithm to 2D/3D inversion and integrating it with other geophysical techniques.