Deep learning based real-time 3d inversion of electromagnetic data

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Abstract

Accurate 3D inversion of geophysical electromagnetic (EM) data is critical for resolving the spatial variations in the electrical conductivity of subsurface structures. Traditional inversion methods, such as nonlinear conjugate gradient and Gauss-Newton methods, often face challenges due to their tendency to get trapped in local minima and high computational demands. These limitations are further exacerbated in complex 3D environments or when accounting for uncertainties, making real-time applications nearly infeasible due to the substantial computational costs involved. To overcome these challenges, we have developed a novel deep learning (DL) framework for real-time 3D inversion of frequency-domain EM data, offering a transformative alternative to conventional methods. Our approach leverages advanced DL architectures, including convolutional neural networks (CNNs), trained on synthetic datasets generated using pGEMINI—a massively parallelized software designed for Geophysical Electromagnetic Modeling and Inversion of Natural and Induced sources—combined with tens of thousands of realistic 3D subsurface conductivity models. These architectures effectively capture the complex spatial relationships inherent in 3D geophysical data, enabling accurate, efficient, and rapid inversion. Initial results demonstrate that the DL-based inversion achieves high fidelity in reconstructing 3D conductivity distributions, even in geologically complex scenarios. Notably, the trained DL models can deliver inversion results within seconds, representing a significant improvement compared to the hours or days required by traditional inversion methods. This presentation will provide an overview of the data generation, training process, performance evaluation, and real-time application of the DL-based inversion framework. The results highlight the potential of deep learning to revolutionize geophysical EM data analysis, providing an efficient, scalable, and real-time solution for 3D subsurface characterization. These advancements unlock new opportunities in fields such as utility undergrounding, environmental monitoring, resource exploration, and infrastructure planning.