JOURNAL OF RESEARCH ON APPLIED GEOPHYSICS

(JRAG)

Shahrood University of Technology

2025, VOL 11, NO 1

(DOI): 10.22044/JRAG.2024.14938.1360

Inversion of gravity data by total variation constraint using alternative direction method of multipliers

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Received: 13 August 2024; Accepted: 21 December 2024

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Keywords

Inversion
Gravity
Constraint
Norm-1
Total variation
Alternative direction of multipliers

Extended Abstract

Summary

This paper addresses the challenge of accurately detecting subsurface structures through gravity inversion, a crucial task in geophysical exploration. Traditional methods, particularly those based on Tikhonov regularization, often yield blurred models due to the inherent smoothness introduced by quadratic penalties. This research aims to develop a sparse inversion method that utilizes L1 norm regularization combined with total variation (TV) penalties to achieve a focused representation of subsurface boundaries. The methodology employs an alternative direction method of multipliers (ADMM) algorithm for optimization, enhanced by an adaptive method for selection of a regularization parameter and conjugate gradient methods to improve computational efficiency. The proposed method is validated through synthetic tests and real data analyses, demonstrating its effectiveness in accurately reproducing subsurface structures and sharp boundaries. The implications of this study extend to improved interpretation of geophysical data, facilitating more precise subsurface modeling.

Introduction

The motivation for this study arises from the challenges associated with gravity inversion techniques, specifically in accurately detecting subsurface structures and delineating clear boundaries for geological interpretation. Traditional inversion methods, such as Tikhonov regularization, often produce blurred models due to their inherent smoothing properties, which complicate the accurate representation of complex geological features. This research aims to enhance the resolution of gravity inversion results by introducing a novel approach that combines L1 norm regularization and total variation (TV) penalties to create a focused model that accurately captures sharp boundaries.

Methodology and Approaches

The methodology of this study involved a three-dimensional gravity inversion framework utilizing synthetic and real data, in which an alternative direction method of multipliers (ADMM) algorithm was employed to effectively solve the proposed L1-TV1 penalty-based inversion problem. The ADMM is a versatile and powerful optimization technique that excels in solving convex optimization problems with separable objectives and linear constraints. Its iterative approach, combined with the ability to decompose complex problems, makes it a valuable tool in many areas of research and application. To improve the efficiency of the algorithm, we use an adaptive regularization parameter selection method as well as conjugate gradient solver method. Participants in this study included datasets from both synthetic scenarios and actual geological surveys to validate the effectiveness of the new approach.

Results and Conclusions

Results demonstrated that the L1-TV1 penalty effectively mitigated the issues of excessive concentration and blurring found in previous models, allowing for a clearer representation of subsurface structures. The incorporation of the TV1 penalty specifically facilitated the recovery of sharp boundaries in the geological model, addressing a significant limitation of conventional approaches. The findings demonstrate that our proposed L1-TV1 inversion scheme not only accurately reconstructs the location, extent, and intensity of block models but also effectively captures fine details of causative bodies by imposing physical bounds. Furthermore, the method shows improved computational efficiency

through adaptive methods for optimal regularization parameter selection. The implications of this study suggest that the L1-TV1 regularization will enhance subsurface modeling practices, allowing for more accurate geological interpretations. The implications of this research extend to improved geological interpretation and resource exploration, as the enhanced resolution of gravity inversion models can lead to better decision-making in subsurface investigations. This research work contributes to the growing body of knowledge in geophysical inversion techniques and opens avenues for future research in the optimization of inversion methodologies.