Geoelectric data modeling using Mimetic Finite Difference Method (MFDM)

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Sharing is encouraged

1. Introduction

- DC resistivity is a geophysical method to obtain the resistivity image of subsurface.
- In this method, electrical current injection takes place via current electrodes.
- This results in potential or voltage distribution.
- Finally, surface potentials are measured to give subsurface image.

Applications :

- Detection of hydrocarbon.
- Mapping underground metallic structures.
- Detection of geological features.
- Aquifer mapping for groundwater management.

DC Resistivity equation :

$$-\mathbf{div}\, K\, \mathbf{grad}\, u = f, \qquad (1)$$

where, **div** : continuous divergence operator , **K :** conductivity tensor, **grad :** continuous gradient operator, **u :** scalar potential (electric potential), **f :** source/sink function.

2. Methodology

Mimetic Finite Difference Methods (MFDM)

1) MFDMs are a special class of methods, that tries to mimic the properties of the underlying physical process.

2) They take into account the basic theorems of integral and differential calculus, and also preserve the intrinsic properties like the conservation laws, symmetry, adjointness property.

3. Aim

Aim : To construct a numerical scheme based on the underlying principles of Mimetic Finite Difference Methods and implement to solve the DC Resistivity equation.

4. Discretisation

1) Cell (i,j) : Unknown scalar quantities discretised at cell centers and vector quantities discretised at cell nodes.

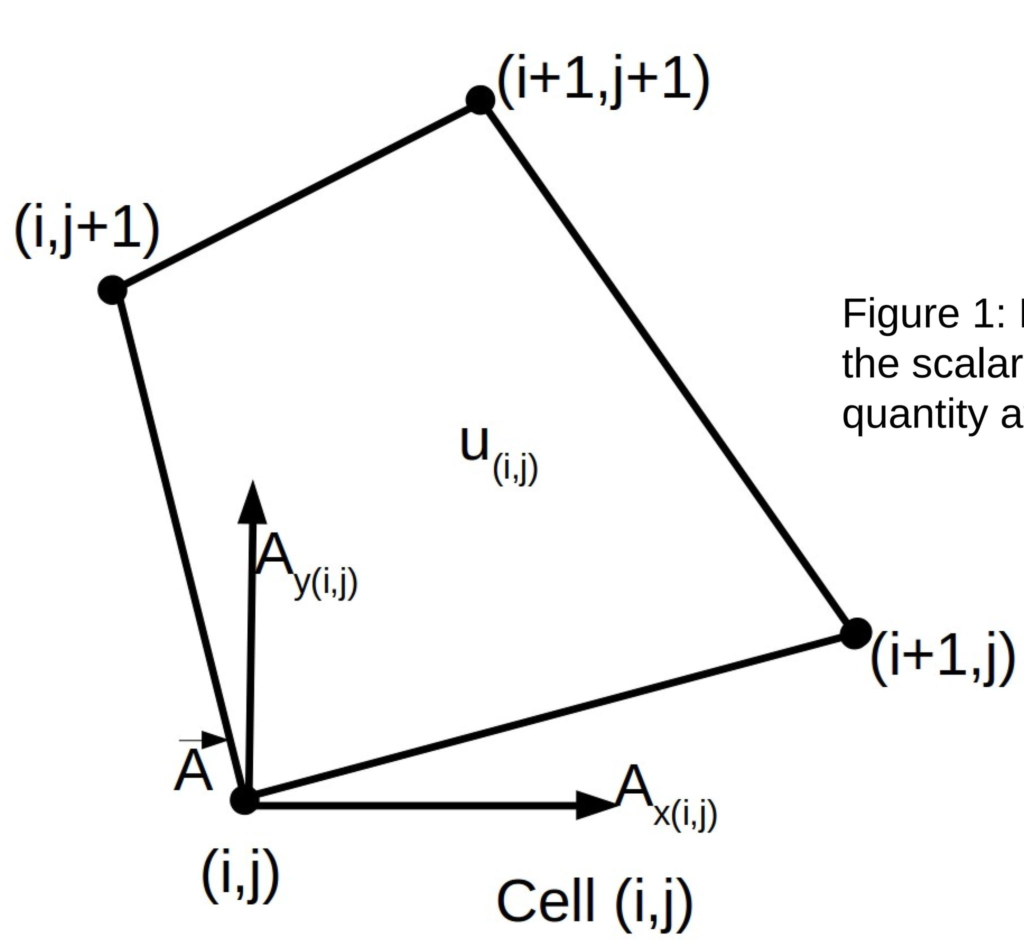

Figure 1: Representation of the cell (i,j), showing the scalar potential at the cell center and the vector quantity at the cell nodes for a quadrilateral cell.

2) Nine point stencil : MFDM scheme is implemented by constructing the difference equations on a nine point stencil for the operators in the continuum equation.

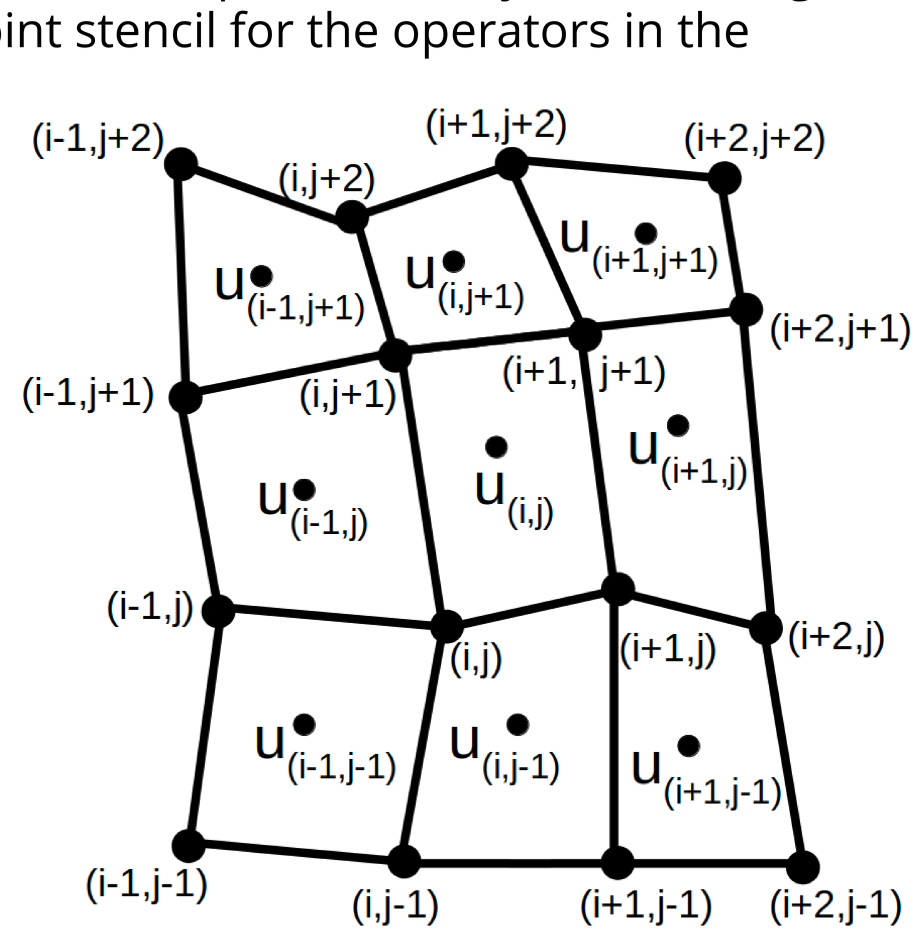

Figure 2: Nine-point stencil scheme used in the MFDM.

5. Model Testing and Results

5.1 Dyke Model

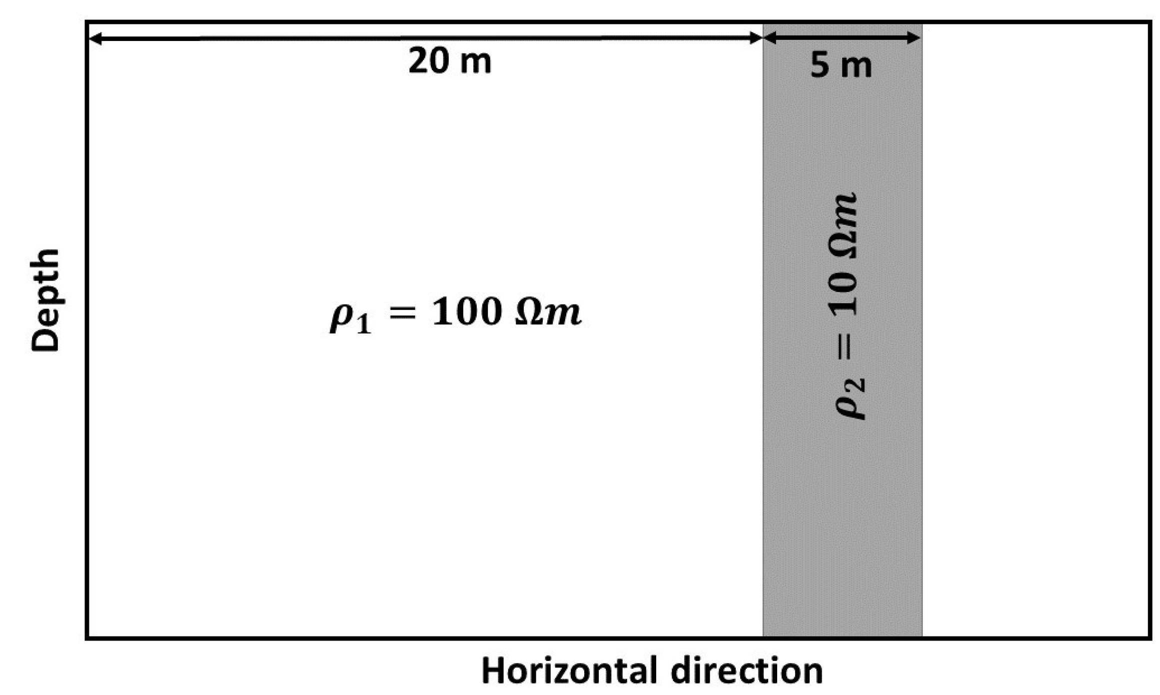

Figure 3: Schematic diagram of a vertical dyke model. The resistivity of the dyke is 10 Ωm and the Resistivity of the half space is 100 Ωm. The dyke has a width of 5 m and is placed at a distance of 20 m from the origin.

The developed scheme's accuracy is tested by solving the dc problem on different dyke models by varying the model contrast. Results are shown for a low contrast dyke model and a high contrast dyke model.

5.2 Low contrast dyke Model

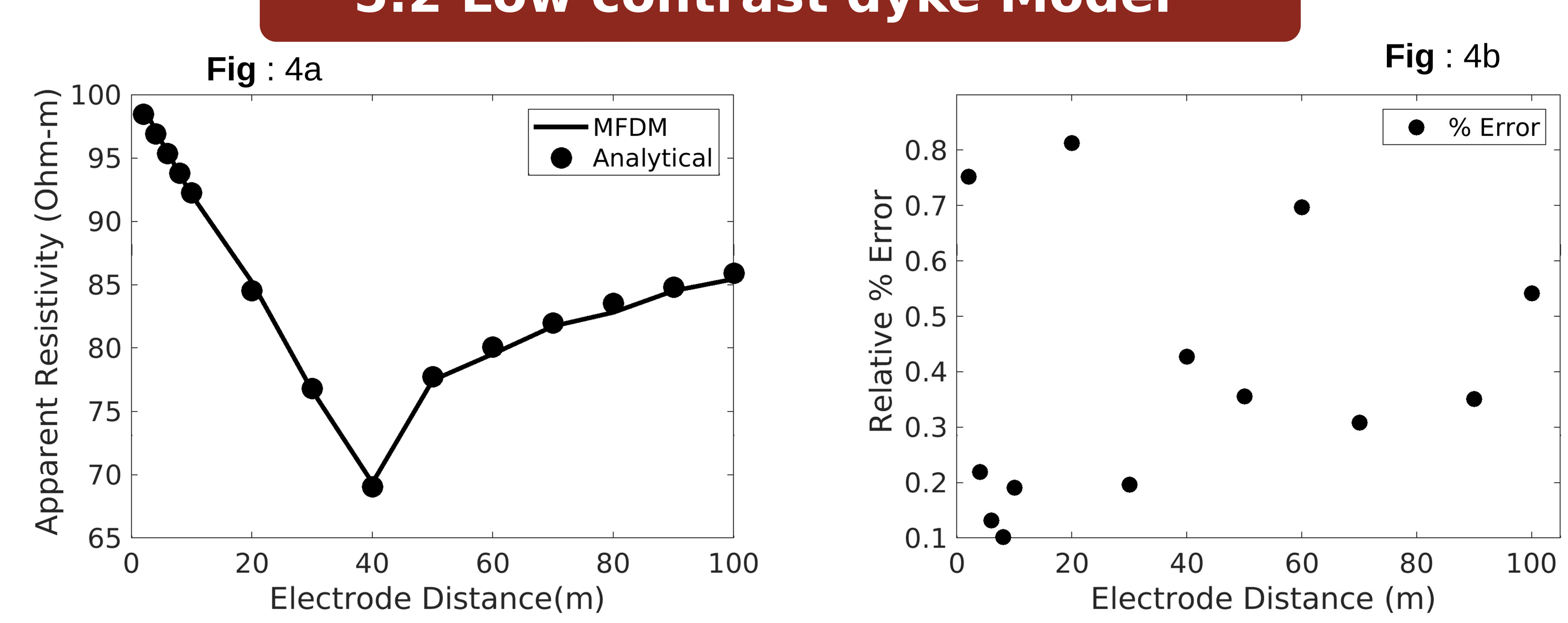

Figure 4:Low contrast dyke model experiment results, background conductivity 100 Ωm and dyke conductivity 10 Ωm (a) apparent resistivity obtained from the MFDM and the analytical solution and (b) plot shows the relative % error between the simulated response and the analytical solution.

5.3 High contrast dyke Model

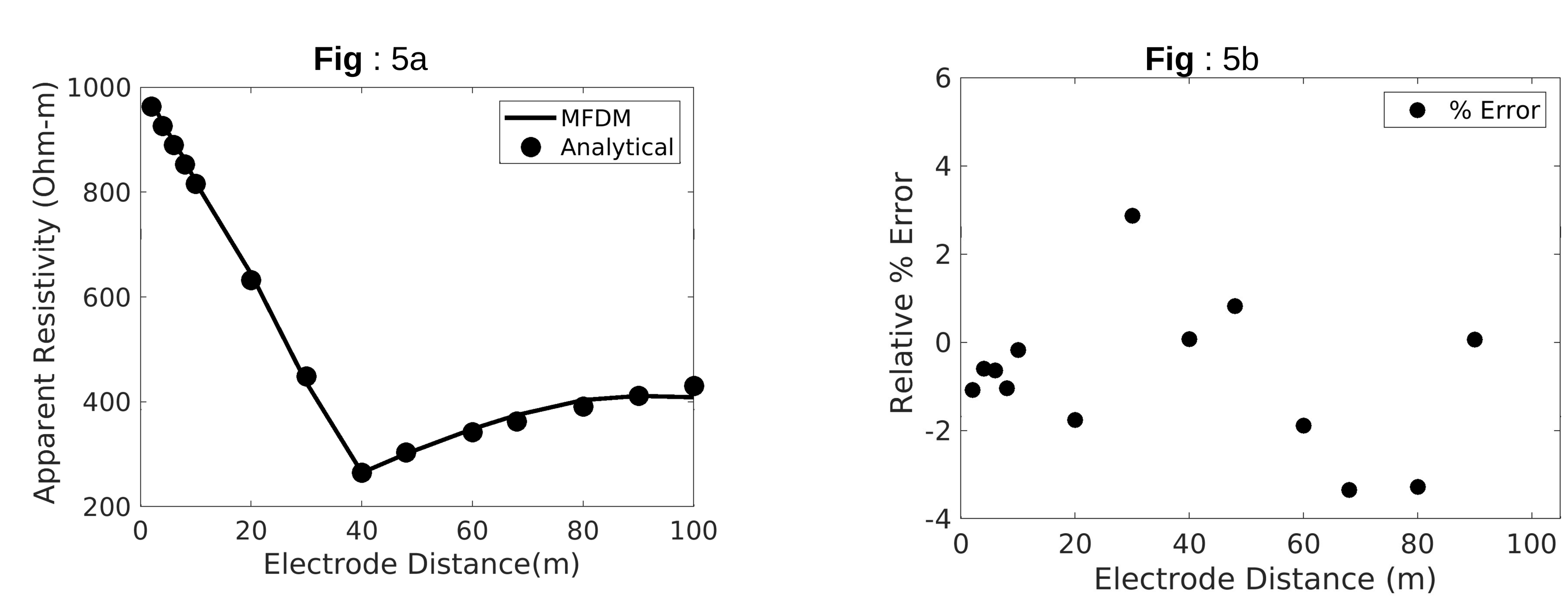

Figure 5: High contrast dyke model experiment results, background conductivity 1000 Ωm and dyke conductivity 10 Ωm (a) apparent resistivity obtained from the MFDM and the analytical solution and (b) plot show the relative % error between the simulated response and the analytical solution.

6. Further tests and Summary

1) Further experiments are carried out to test the applicability of the developed algorithm on anisotropic models, topographic models and highly distorted non-orthogonal grids.

2) It is verified that the model stands accurate and highly robust for the complex models incorporating highly distorted non-orthogonal grids.

3) Mimetic finite difference methods (MFDMs) allows multiresoltuion modelling, while preserving the conservation laws and continuum properties of the physical model.

4) The problem of singularity in DC is addressed using primary, secondary decomposition approach.