2D Numerical modeling to evaluate the detection sensitivity of the resistive method

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Abstract

We present a two-dimensional numerical modeling of the geophysical method of electrical resistivity aimed at evaluating the detection sensitivity of targets with different types of electrode arrays. For the numerical solution of the problem, we use the finite element method, a mathematical and computational technique capable of approximating the solution of the differential equation of the problem in a given domain by dividing it into a series of subdomains, called finite elements, in which the solution can be estimated individually. Direct modeling of the electrical resistivity method begins with the calculation of the secondary electrical potential due to the injection of galvanic current into a predefined geoelectric distribution. Due to the 2D nature of the problem, it is possible to transform its differential equation into the Fourier transform domain in one of the spatial dimensions, which facilitates the problem solution and significantly reduces the computational cost. For more complex geoelectric models, it is common to use unstructured computational meshes, which can better represent the structures and geometries in the models and are well suited in conjunction with the finite element method. After completion and validation of the numerical code, a sensitivity analysis of the method is performed for different types of electrode arrays, taking into account simple geometric heterogeneities whose physical parameters are slightly varied. The result of this analysis is then compared with the results calculated by the sensitivity function for a homogeneous medium, whose mathematical expression is given by Frechet derivatives. The sensitivity function essentially indicates how much a change in the resistivity of the model affects the measured electrical potential at the surface. The higher the value of the sensitivity function, the greater the effect of the subsurface on the measurement. The modeling work for this problem is performed in the Python programming language, which is quite efficient at performing complex calculations and incorporating large sparse systems due to the wide availability of numerical processing libraries. The finite element mesh representing a section of the study area is constructed using the free software Gmsh, which allows the creation of complex 2D and 3D geometries through a graphical interface. Gmsh is integrated into the Python code via an application programming interface (API). Modeling geophysical data is of great importance in evaluating the feasibility of survey methods. The study presented in this work is particularly useful in geophysical surveys where the best type of electrode array is sought for detecting a particular target. By using advanced mathematical and computational techniques such as the finite element method and the Fourier transform, it was possible to obtain accurate and reliable results on the detection sensitivity of targets in different types of electrode arrays. This type of study is essential to ensure the quality of the data obtained in the field, the accuracy of the information, and the correct interpretation of the results. Moreover, the methodology developed in this work can be used in future geophysical studies in different fields, contributing to the improvement of these studies and consequently to the increase of knowledge in areas such as mineral exploration, geotechnical engineering and environmental monitoring.