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Development of Numerical Code for Simultaneous Estimation of Subsurface Structure with Gravity and Magnetic Data

Yusuke Imaeda[1*], Hitoshi Morikawa[1]

[1]Tokyo TECH Dept. of Built Environment

We present the test calculation of simultaneous estimation of subsurface structure with gravity and magnetic data. The simultaneous estimation is performed by the construction of sensitivity matrix and its inversion. For this purpose, we developed a new numerical code for solving the singular value decomposition based on I-SVD scheme. Usually, the sensitivity matrix is ill-conditioned when the number of the observation data and the model points is large. We need some regularization to solve this ill-conditioned inversion. Some technical discussion is also presented.

Method

Trial model of subsurface structure is represented by M model points, which has k layers. While each layer has fixed given value, the depth of each model point z_i is variable. We change these depth z_i to account for the gravity and magnetic anomaly at N observation data on the surface.

Forward Calculation

We starts the calculation from the plane parallel model as an initial trial model. The prism gravity and magnetic field in arc tangent form is adopted for the gravity and the force calculation. When the depth is changed at each model point, a material in a prism shape volume is replaced from the lower side to the upper side, and vice versa.
The increment of gravity and magnetic field, generated by this replacement, is added to the previous value.

Inversion Calculation

Inversion calculation is performed by the construction of sensitivity matrix and its pseudo inverse matrix. The sensitivity matrix is defined by the differentiation of gravity and the magnetic field by each model depth. As the observation data, both the gravity and the magnetic data are used simultaneously. The size of this matrix becomes NxM. We calculate the depth change of each model point to account for the data difference between the model and the observation with the pseudo inverse matrix. However, the depth change sometimes becomes quite different from the adjacent ones, which is physically inappropriate for the successive conversion. Therefore, additional constraint condition is added to the sensitivity matrix, so that $\{\mathrm{Nabla}\}^2$ $\{\mathrm{delta}\}$z = 0. Then, the matrix size becomes (N+M)xM. This additional condition smooths out the adjacent fluctuation.

For this purpose, we developed a new numerical code for solving the singular value decomposition based on I-SVD scheme. Our numerical code is written by Fortran 95 in double precision, except for the lowermost DO loop for singular values calculation. This part is need to be written in quadruple precision.

With this code, we can reproduce the model subsurface structure from the model gravity and the magnetic data set.

We will also present the miscellaneous techniques for matrix regularization in the poster.The inclusion and the unification of microtremor data in this code may also be presented.

Keywords: numerical calcuration, subsurface structure, singular value decomposition