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3-D modelling and joint inversion of potential field data

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Potential field measurements (gravity and magnetic fields) provide a promising complement to seismic imaging – especially in regions where the seismic methods suffer from signal loss. In particular the measurement and interpretation of gravity gradients in addition to the vertical gravity component and their joint inversion improves the signal-to-noise ratio and therefore allows a better structural resolution of the near surface layers.

The algorithm introduced here allows the separate inversion of all fields as well as the joint inversion of the vertical gravity component and all independent entries of the full gravity tensor to gain 3-D density and susceptibility models, respectively. The algorithm uses a model built of rectangular volume elements of arbitrary sizes. These volumes are grouped into regions which simulate geological structures and represent the 3-D model bodies. Due to constant density and susceptibility distributions within the model bodies and a fixed model geometry the property inversion of potential field data as it is done here can be regarded as a linear inverse problem. To solve this problem the MMSE estimation (minimum mean-square error) is used. This method is a statistical approach and assumes that all involved parameters (measurements, initial properties, measurement noise) are Gaussian distributed.
The start parameters of the inversion process enable the user to give restrictions to the changes the initial model is allowed to undergo. For example, in places where bore-hole data or outcrops exist the initial model is well constrained. Therefore only very small model changes should be allowed in such places. Whereas in less constrained areas of the model bigger changes should be permitted. Furthermore, to smoothen the property distribution within the model specifically chosen and neighbouring model bodies can be correlated via distance. Although the model geometry is fixed structural changes in the model may be indicated by the estimated densities and susceptibilities, respectively.

For the calculation of the gravimetric and magnetic effect of a 3-D body the formula developed by Götze & Lahmeyer (1988) is used. This formula allows very efficient calculations of 3-D bodies represented as polyhedra. The main idea is to substitute the usual volume integral by a sum of line integrals.

The algorithm has been applied to synthetic data and real world data, representing different geological aspects. Reliability tests with noise were also carried out. Examples of each aspect will be shown and discussed. Furthermore, the first ideas of a geometry inversion will be introduced briefly. This kind of inversion is a non-linear problem and therefore requires a different mathematical approach.