AN ALGORITHM FOR GRAVITY ANOMALY INVERSION IN HPC

Work in Progress

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Extended Abstract

In the paper we analyze results of the inversion of geophysical anomalies in high performance computing platforms. We experiment the solution of this ill-posed problem [Hadamard, 1902], trying to bypass the complexity of the calculations [Wellmann et al, 2010] using simple algorithms [Högbom, 1974] that require huge calculation capacities offered by parallel systems. As the first step, the gravity anomalies are considered because of the simplicity of the gravity problem in geophysics [Lowrie, 2007].

The used algorithm is CLEAN proposed in [Högbom 1974], in our case it is based in a 3D grid of nodes covering the geosection and using an iterative process as follows:

a) starting with a 3D geosection array representing the rocks density and initialized by zeros, and a 2D gravity anomaly array measured in the field

b) searching the node in the geosection array, which effect offers the best least square approximation of the gravity anomaly array

c) incrementing the density of the selected node by a fixed amount (density step)

d) subtracting the effect of the modification of the geosection from the surface gravity anomaly

e) repeating the steps (b):(c):(d) until residual anomaly changes less than a fixed predefined value.

The focus of the study is the convergence rate of the algorithm and how the solution is approximated during the iterations. First results of the convergence in serial and parallel mode using OpenMP are presented in [Frasheri and Cico, 2011]. Tests were done with synthetic models, which permitted to compare the approximation error in both the anomalous body and the anomaly itself.

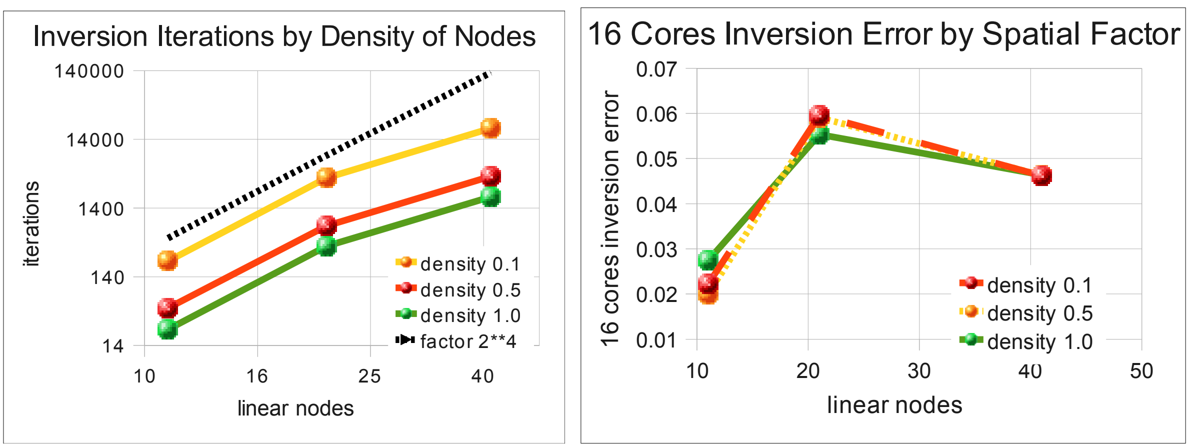

Fig.1 – Convergence rate and error: left – number of iterations per density of nodes, right inversion error per density of nodes. Curves are for different mass density steps.

Results show a decrease of the number of iterations when the spatial density of geosection nodes is increased. At the same time the mass density step used to increase the mass density of each node has the predicted effect in the number of iterations, but little effect in the error.

Further tests showed that the algorithm has the tendency to give bodies with higher mass density. From theoretical point of view, a variation by a factor of k of the mass density of the body would be compensated by the reversed variation of the linear size of the body by a factor of k**(1/3). In our model we used a body with density 5 g/cm3 and tested the algorithm for maximal accepted densities that varied from 1 g/cm3 to 9 g/cm3. The variation of the size of the body, in its central vertical 2D section, is presented in Fig. 2.

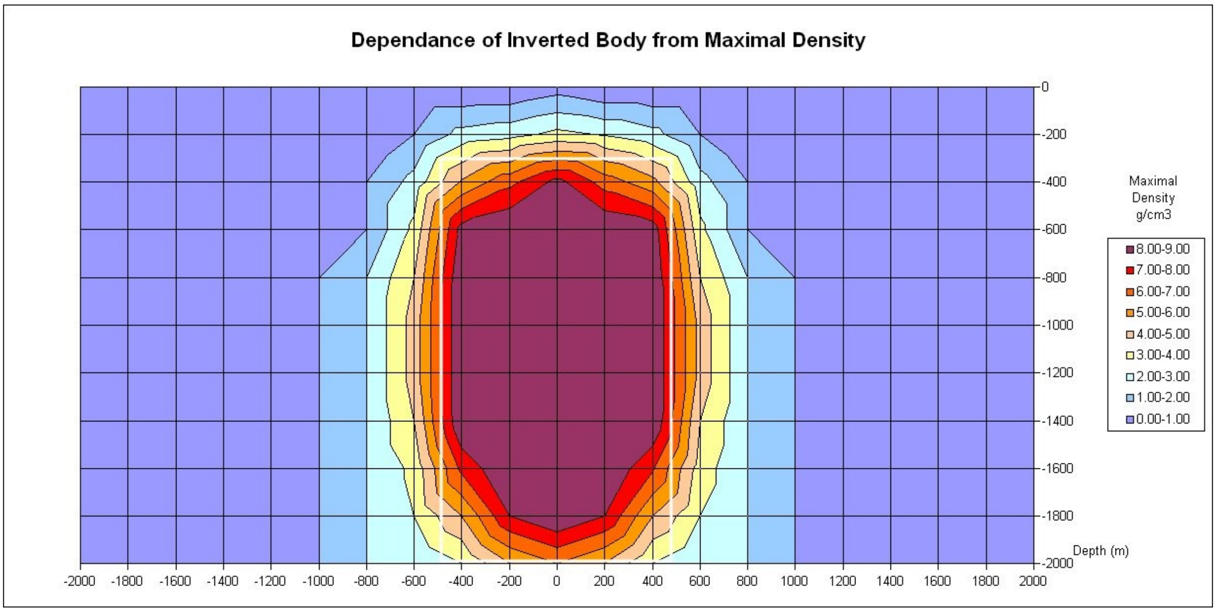

Fig. 2 – Variation of anomalous body obtained by inversion for different maximal accepted mass density

The theory and results supported the idea that keeping a maximal accepted mass density in the range of 2 – 3 g/cm3 would be optimal, higher values would simply lead to a reduction of the size of the body at most 20%. At the same time the tendency to give higher mass densities is an indication how the algorithm optimizes locally the solution.

To understand better how the optimization process during the iterations, we combined the central vertical 2D geosection for each iteration in a single 3D image (Fig. 3).

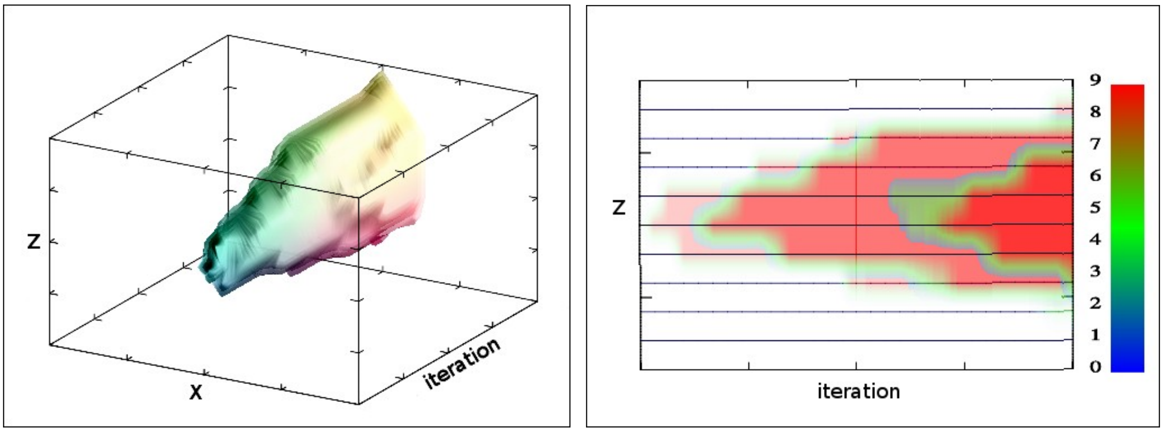

Fig. 3 – Development of the anomalous body section during inversion iterations (in 3D and 2D)

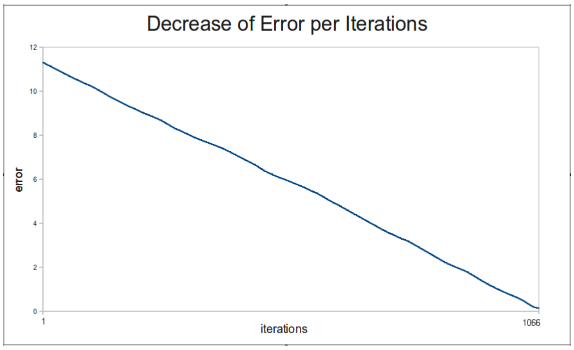

Fig. 4 – Decrease of the anomaly error per iteration

Results show that the local optimization is achieved through increasing of the mass of the geosection element instead of its spatial extension.

The decrease per iteration of the error of approximation of the anomaly is linear, curving to constant in last iterations (with a total of 1066 iterations, Fig. 4), while as seen the Fig. 3 the main section of the body is approximated with the half of iterations.

The algorithm tends to give point-like bodies, which requires careful interpretation in case of anomalies from extended spatial structures as in the case of Fig. 5, where the anomaly is created by extended magmatic structures.

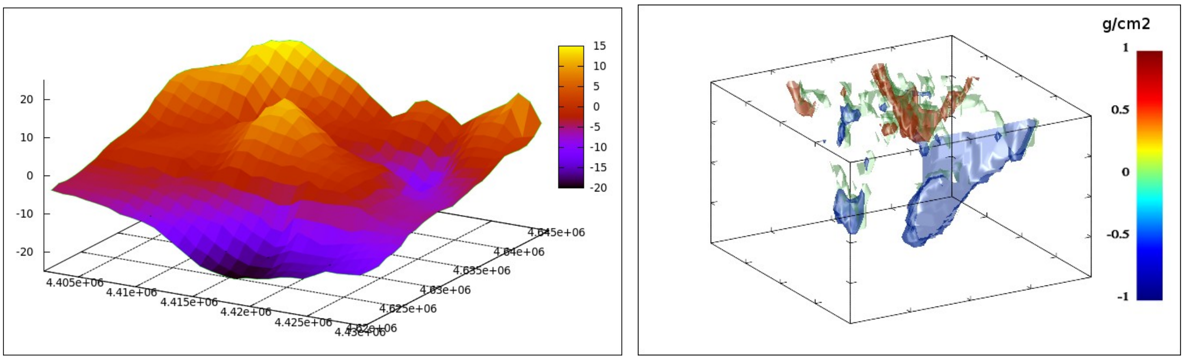

Fig. 5 – Field gravity anomaly from magmatic structures and their delineation from the inversion

The anomaly is created by combined effect of two mases – one (sedimentary, in cyan) with density less than the average and the other one (magmatic, in red) with density greater than the average.

This work makes use of results of the High-Performance Computing Infrastructure for South East Europe's Research Communities (HP-SEE), a project co-funded by the European Commission (under contract number 261499) through the Seventh Framework Programme. HP-SEE deals with multi-disciplinary international scientific communities (computational physics, computational chemistry, life sciences, etc.) stimulating the use regional HPC infrastructure and its services. Full information is available at http://www.hp-see.eu

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