AIDA – From airborne data inversion to in-depth analysis

Evolutionary algorithms for the 3D-inversion of geophysical fields: a contribution to the AIDA Project

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General Overview

The application of evolutionary algorithms in the context of 3D-inversion of geophysical field data - here of potential fields and their derivatives (FTG) - is the principal purpose of sub project SP4 in the research project AIDA. Closely related is the optimization of target functions for three-dimensional modelling of susceptibility, density and conductivity distributions by evolution strategy (ES) facilitating co-variance matrix adoption (CMA).

A special challenge is knowledge-based optimization, which goes beyond known methods. For the first time it will be possible to include (1) semantic constraints coming from the literature and (2) model topology preservation. A further aim is the examination of the applicability of the algorithms to inversion of electrical field data.

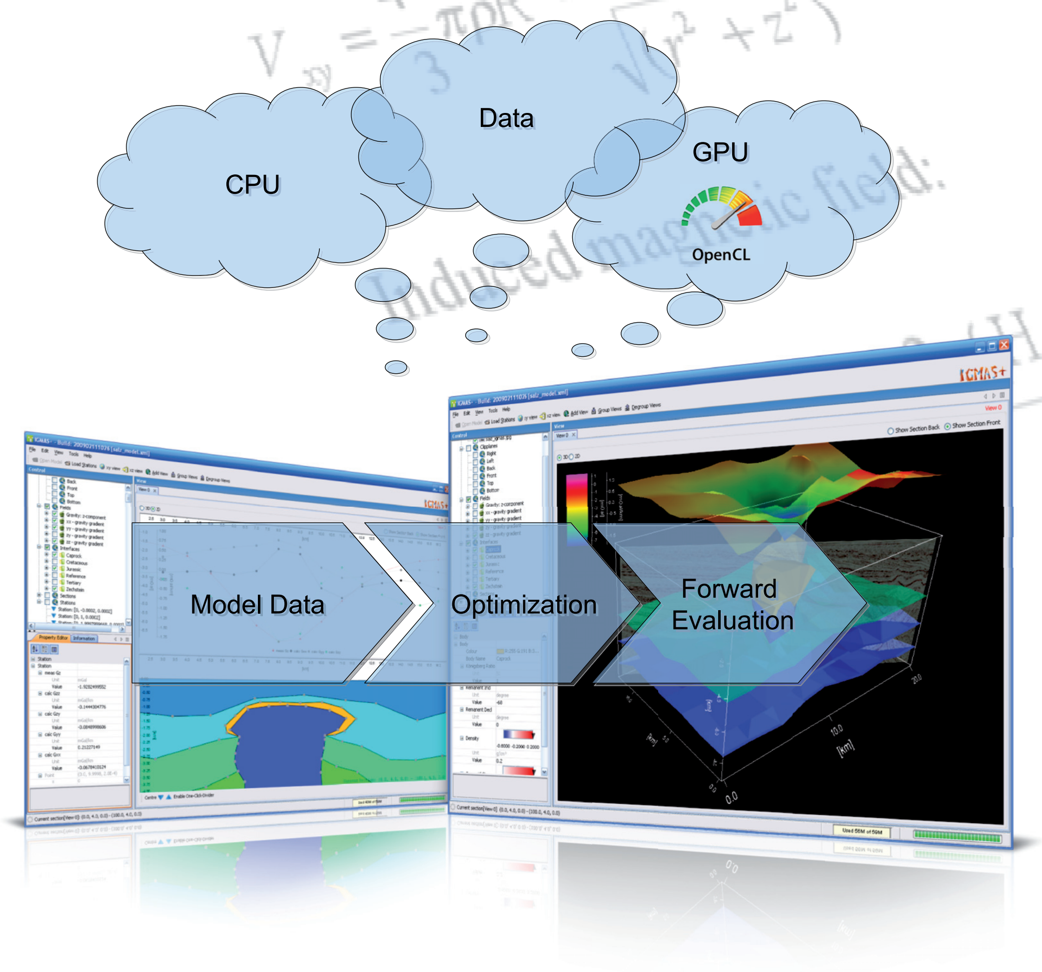
Parallel GPU Computing & FFT

For 3D-optimization of geophysical target functions, it is necessary to evaluate the fitness for each offspring of every individual of every generation. This leads to a massive increase of calculation tasks.

Through the intelligent use of existing hardware, tailored algorithms and distribute computing it becomes possible to manage these tasks.

The use of heterogeneous systems like GPUs with a open and royalty-free standard for cross-platform parallel programming gives an speedup per Computer node of a factor 200 (depending on used hardware).

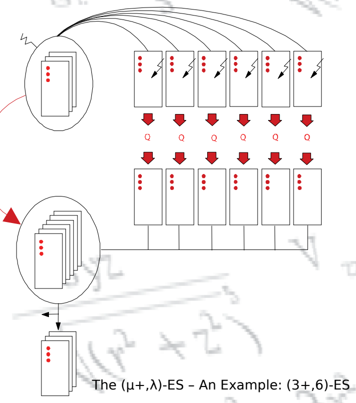
Although on the algorithm side we develop a method for calculation the effect in the wave number domain (FFT) instead of the spatial domain, wich give us also an speedup of factor 50.



Optimization Algorithm

Evolution Strategies (ES) are suitable for automatic high-dimensional parameter inversions adopting concepts from natural evolution: mutation, selection, recombination and isolation. Bioinformatics improves these concepts in trems of adoptation speed. They are implemented for the 3D-optimization of objective functions by means of both a (μ + λ) - and/or (μ, λ) - evolution strategy with covariance matrix adoption (CMA-ES).

The strategy parameters μ and λ describe the number of "parent" (-models) and/or number of "offspring" (-models). The „+ " symbolizes the inclusion of the parent populations into the selection process and „ , " a possible refusal of gained positions and thus the possibility to leave sub-optima in the solution space.



The (μ+,λ)-ES – An Example: (3+,6)-ES

CMA – Covariance Matrix Adaptation

$$x^{Nk} = x^E + \delta^E B^E z_k$$

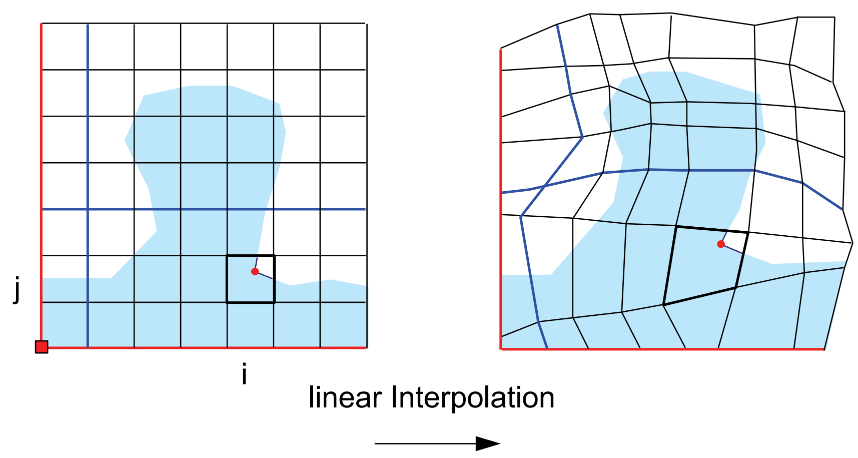
where

x	$=$	$(x_{1,\dots,} x_n)^t \in R^n$	Object variable vector to be optimized. *n* is the dimension of the problem.
E			Index for the parent (Elder).
N_k		$k = 1,\dots,\lambda$	Index for the descendant (Newer) *k*.
δ	$>$	0	Global step size.
B	$\in$	R^{nxn}	Matrix, wich linearly transforms *z*. *B* can be seen as the basis on wich the normal distribution works.

Preserving Model Topology

A particular challenge in geophysical 3D modeling is the implementation of an appropriate approach for geometry changes in the model space. In conventional approaches model coordinates have constraints or in other methods topologically false models, which are generated during an automatic optimization, will be discarded. This often leads to problems such as the "extinction" of good individuals and/or populations because of "small errors". Therefore there is a strong need for a topology preserving method, which overcomes these disadvantages.

One solution would be to keep the topology by changing the space rather than the model (coordinates) itself. In 3D a tetrahedron-grid should "wrap" the model and the edges of the tetrahedron are subject to optimized (in length > 0). A tetrahedron might (almost) disappear but the topology (of the starting model) is preserved. This promising approach will be evaluated in respect to of coarse-fine meshing and in adoption of finer sub-division of tetrahedrons where needed.



Publicationes:

B. Lahmeyer, H.J. Götze, S. Schmidt, M.R. Alvers, C. Plonka, C. Fichler, Interactive 3D Gravity and Magnetic Modelling in IGMAS+ and the Integration in the Depth Imaging Workflow: EAGE 2010, Barcelona, Spain

Alvers, M.R., Schmidt, S., Götze, H.-J., and Fichler, C., IGMAS+ Software for 3D Gravity, FTG and Magnetic Modeling – towards semantic constraints: EGM 2010 International Workshop - Extended Abstracts, Capri, Italy

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