

Open Source Interactive Electromagnetic Modelling

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SUMMARY

The marine controlled source electromagnetic method has developed during the last decade for direct hydrocarbon indication. Marine controlled source electromagnetic software is still in its infancy with only a small number of open source algorithms and even fewer integrated software environments. We have developed an open source software package to encourage the development and use of the marine controlled source electromagnetic method in both industry and educational institutions. The software was written in Java and was made to perform interactive real-time synthetic modeling for varying earth models or survey parameters.

Key words: MCSEM, interactive, forward modelling, electromagnetic

INTRODUCTION

The marine controlled source electromagnetic method (MCSEM) has been developed during the last decade to detect the presence of hydrocarbon. Development of marine controlled source electromagnetic software is still at its infancy in comparison to seismic. As a result, software is mainly available through commercial or research consortiums. This includes organisations such as EMGS, Interaction AS, Blueback Reservoir, Scripps institute of Oceanography, CEMI and UBC. Buying software from these institutions may not be viable or inviting for many organisations, particularly if they are reluctant to venture into MCSEM. An open source paradigm removes financial constraints and encourages experimenting with this field. Seismic products ranging from Seismic Unix (Cohen and Stockwell, 1997), OpendTect (OpendTect, 2011), CPSeisTM (CPSeis, 2011) and numerous Fortran and C++ geophysical libraries have been successful in the open source market. For MCSEM modeling there are several algorithms that utilize open source licensing. These include Dipole1D written by Kerry Key (2009) and Marco, as part of the AMIRA software package (AMIRA, 2010).

Our open source CSEMoMatic (Pethick, 2011) software package was developed for the benefit of prospective and in contribution to existing MCSEM communities including both commercial and educational institutions. CSEMoMatic facilitates rapid forward modeling and visualization of marine controlled source electromagnetic data through the integration of open source algorithms Dipole1D and Marco.

METHOD AND RESULTS

CSEMoMatic is licensed under the GNU v3.0 agreement (GNU General Public License, 2011). The GNU GPL license allows the free modification and distribution of source code.

We developed the software as an interactive 3D forward modeling package using Java 1.6 SDK with Eclipse Ganymede IDE. Java was used because of its portability and object oriented design. Our software was designed to work under Debian Linux, Mac OSX and Windows operating systems. One of the objectives was to develop the software to be algorithm independent, but a number of algorithms had to be integrated. This was achieved by using a generic data structure, by writing methods to import and export data and by providing command line execution tags. As of now, the Dipole1D (Key, 2009) algorithm and AMIRA's 3D Integral Equation Marco (AMIRA, 2010) algorithm have been integrated into CSEMoMatic. An in program screenshot is seen in Figure 4.

We have employed every effort to make our software interactive, efficient and intuitive. The 14 Principles of Polite Applications (Cooper, 1999), 8 Golden Rules of Human Computer Interaction (Shneiderman, 1992) and 10 Usability Heuristics (Nielsen, 1994) were applied to make the software as interactive and user friendly as possible. CSEMoMatic was designed primarily to be used without a keyboard and can be easily transferred onto a modern touch screen tablet on either Windows or Linux operating systems.

The primary goal of our software is to perform interactive real time forward modeling. All user interactions can be performed by using a mouse. The effect of parameters can be investigated by a mouse drag. The software encapsulates input file creation, importing and sorting export files and visualising data. This reduces user input and improves modeling speed. Rapid forward modeling improves the ability of users to understand how selected parameters influence data. One of the primary uses of our software is to perform feasibility studies. Target detectability can be established for various survey parameters by comparing the electromagnetic responses generated by target and background geoelectric models. Using Dipole 1D and Marco algorithms each synthetic electromagnetic response must be independently computed for each geoelectric model. Using this concept, the execution of target and background models can be multithreaded. Since each model is independent, there is a 50 percent improvement in execution time over batch execution.

Importing, sorting and displaying of a single transmitter and transmission frequency for 100 receivers over a 1D layered earth requires 0.16 seconds using Dipole1D on an Intel Core 2

Quad 2.4GHz for each execution. The execution of the algorithm is the time limiting factor. It constitutes 99.8% of the total time between the interaction and visualization. Figure 1 shows an interactive geoelectric model and the corresponding 1D target and background responses. In addition to this, a 20x20 2D grid is updated every 0.5s.

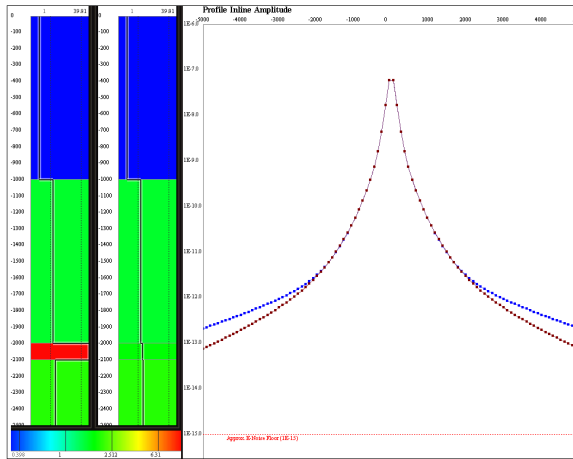


Figure 1: CSEMoMatic profile modeling. A single electric bipole transmitter and 100 multi-component electromagnetic receivers are positioned over two 1D geoelectric models (left) in turn, and these are forward modeled and visualized (right) within 0.16s on a Intel Core 2 Quad 2.4GHz (approximately six updates per second).

Real time 3D modeling is restrictive due to limited modeling speeds of Marco3D and CPU speeds. For example, a survey with a 200 cell (8x5x5) 3D prism requires 3.3 seconds and 7.9 seconds for the same survey profile and grid respectively.

Interactive Data Investigation

The interaction of an electromagnetic field with a 3D resistive body is complex. Attempting to understand the behavior of the field by using profiles is both unproductive and exhausting. The interaction of field paths with their geoelectric environments can be clearly explained by using other representations. A number of features have been created to assist in the understanding of the electromagnetic fields generated from an MCSEM survey.

The ability to visualize any component independently is required (i.e. inline, broadside and vertical components of the electric, magnetic and Poynting vector fields) to perform a thorough investigation. The electromagnetic field is typically analyzed by comparing amplitude, normalized amplitude, phase and phase difference and real and imaginary components. Our software allows the visualization and interpretation of these common properties. Interpreting these representations may be complex. A number of atypical representations are used to demystify complexities in the electromagnetic field. These include amplitude time series, polarization ellipses, time varying vectors and 2D streamlines.

For example, polarization ellipses represent the full range of time domain vector orientations as a single static structure. They illustrate the polarization of the electric, magnetic or Poynting vector fields on any 2D plane (i.e. Inline, broadside or plan). Figure 2 shows a typical total electric field amplitude

inline grid from a horizontal electric dipole for a 1D layered earth with a resistive three-dimensional body. The Figure also overlays the inline (x-z) electric field polarization ellipses with the initial field vectors at zero time. Perturbations in fields due to the presence of the resistive body can be seen; wrapping around the resistive prism resulting in a varied field on the ocean floor.

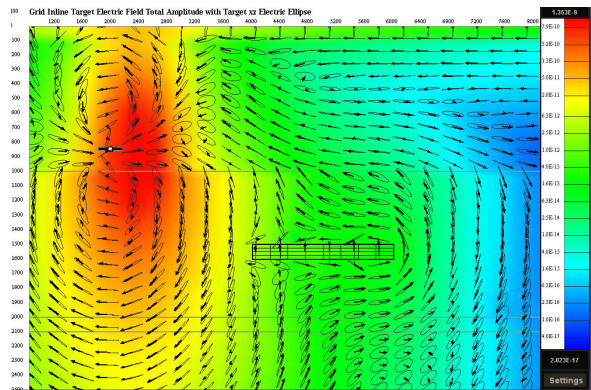


Figure 2: Inline total electric field electric field amplitude grid and inline electric field polarization ellipses resulting from 1Hz horizontal electric dipole transmitter.

It may be necessary to investigate the influence of a single geoelectric feature. This is performed by calculating the difference in the electromagnetic fields between two geoelectric models. The background response (layered response) in this example is subtracted from the total field response (layered and 3D prism response). Streamlines can be used to show the flux lines from electromagnetic sources. We have used second order Euler integration to quickly approximate the streamline path in our implementation. Figure 3 shows scattered streamlines at the maximum transmitted amplitude. The physical mechanism behind the variation in profiled data can be explained by using this representation. The streamlines can be interactively placed in any area of interest. Streamlines are added by painting seed positions in the synthetic data.

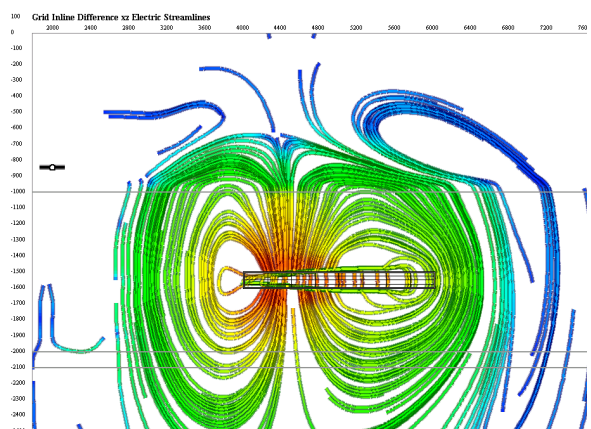


Figure 3: Scattered (target minus background response) streamlines resulting from a 3D prism in a 1D Layered earth. The colors represent amplitude. Using this

representation, complex variations in profiled data can be easily explained.

CONCLUSIONS

Marine controlled source electromagnetic software is still in its infancy. An open source marine controlled source electromagnetic modeling package has been created. This software will facilitate research and further development to introduce its use for organizations reluctant to enter the MCSEM market. Our software CSEMoMatic allows the free modification and distribution of its source code. It was written in Java for use in multiple operating systems. The software has a generic data structure tailored towards MCSEM, allowing the integration of any suitable algorithm; proprietary or open source. CSEMoMatic was created to be interactive. 1D modeling can be performed interactively in real time, allowing users to rapidly investigate the effect of varying the survey and geoelectric parameters. 3D modeling and 2D visualization can also be performed. Static profile representations of data were found to be inadequate due to the complex nature of electromagnetic fields. The software visualizes fields in the form of polarization ellipses, vectors and streamlines to overcome this. Overall our open source software was successful in the application of real time forward model and gives the users to represent and understand electromagnetic data with greater ease.

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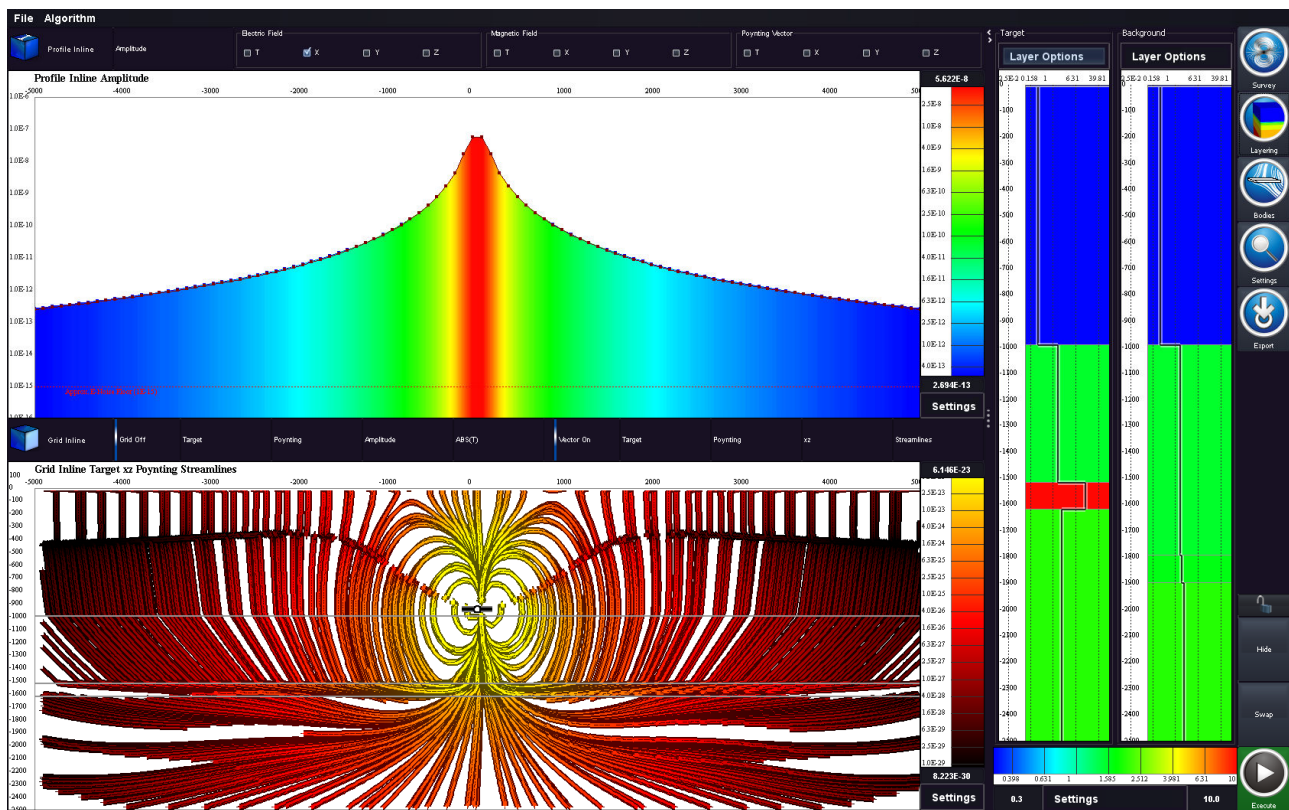


Figure 4: A in program screenshot of CSEMoMatic. The top panel shows the target inline E_x field profile. The bottom shows the target pointing vector streamlines. The right panel contains the settings for the software including survey, geoelectric, visualization and export parameters. The earth layers, transmitter, colour scales and grids are multi-touch interactive.