A Moment of War

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Magnetic dipole moments are a useful object property in potential UXO detection. In this article League Geophysics presents its inversion approach and compares it to packages on the market. We will show that our software favorably compares to those commercially available. Having insight in how the modeling is achieved gives us, and our clients, a tailored analysis and thus potential target reduction.

1 The defining moment

-introduction-

UnExploded Ordnance (UXO) either as remnants of war or in dumping grounds (at sea), form a significant risk to both the environment and public safety. The most well-established technique for ordnance detection at sea is magnetics. However, the potentially large number of possible targets in UXO surveys demand that ferromagnetic target characteristics are identified.

When selecting magnetic anomalies, the aim is to identify targets with the desired characteristics that could be caused by UXO. Besides taking direct measurement of anomaly size, shape and magnitude, the objects' magnetic (dipole-)moment can be modeled. The magnetic moment (expressed in units of $A \cdot m^2$) represents the objects' magnetic field, that is, its orientation and strength. It is a property of the object itself that, ideally, doesn't depend on characteristics of recorded survey data (i.e.. size, shape and magnitude of the anomaly). It is therefor the preferred property to differentiate and identify potential UXO.

League Geophysics has developed its own software to identify and discriminate potential UXO; in this package magnetic moments are obtained by inversion of (residual field) magnetic data. This software is part of a new GIS database plug-in which allows for a complete and comprehensive data analysis. The GIS implementation eases multi-data analysis by incorporation of different geophysical data sets (e.g., sidescan-sonar and high-resolution bathymetry). Additionally, League Geophysics' approach avoids the need for multiple external software packages. This makes 'blackbox' results, incompatible manufacturer-specific file formats and loss, reduction or corruption of data during program transfer a thing of the past!

2 This magic moment

-the technical details-

To estimate the position, orientation and magnitude of the source, the observed magnetic field needs to be modeled; and subsequently the difference between model and observation minimized.

To obtain an initial magnetic moment the anomaly's position is picked in the residual field grid. This location is used as input to a linear least squares solver.

$$(A^\top A)\vec{m} = A^\top \vec{B} \tag{1}$$

$\vec{B}$ = residual field data, $\vec{m}$ = magnetic moment and A is a matrix of regressors. The initial magnetic moment and target position are used in a Gauss-Newton non-linear solver to obtain the best model fit to the data. This two step iteration process is repeated till a stable solution is achieved (see example in figure 1 & 2).

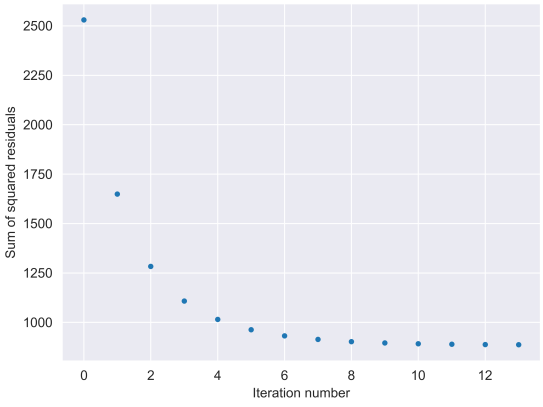

Figure 1: *Sum of squared residuals after each iteration step*

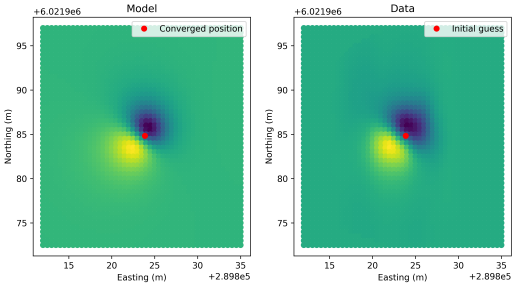

Figure 2: *Map of model result versus recorded data*

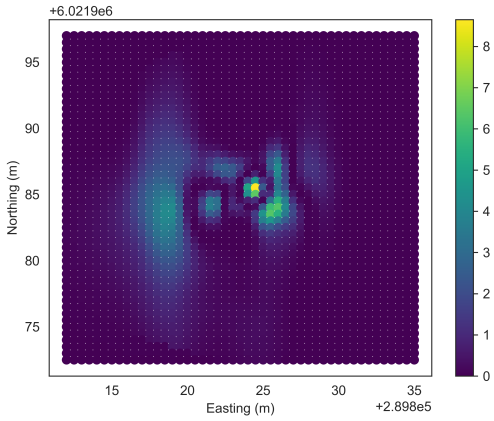

Figure 3: *Map of residuals after inversion*

3 At a moment's notice

-comaring the results-

A 150 targets have been marked on a residual field grid and had their magnetic moments inverted. Using the same data and pick locations, 3 different (commercially available) software packages were used to model magnetic moments:

- Geosoft OASIS Montaj v9.1
- SENSYS MAGNETO
- GEOMETRICS MagPick

Data from a 2018 project in the North Sea was used for the comparison. Where necessary IGRF values for correct location and date where implemented. The number of inverted SENSYS MAGNETO targets is lower due to licensing issues during the comparison; 9 targets did not invert in the 'grid inversion' of GEOMETRICS MagPick. The correlation between League Geophysics' inversion and the commercial packages is good (see table 1).

The model used by SENSYS MAGNETO (GmbH, 2008) compares well to the one used by League Geophysics (Blakely, 1995). The model used by Geosoft OASIS Montaj is unknown; however the high degree of correlation suggests a near similar model. The inversion approach used by GEOMETRICS MagPick (Tchernychev, 1998 is comparable; however the model deviates somewhat.

Though there is good correlation between the packages there are differences in absolute magnetic moment values. Both OASIS Montaj & MAGNETO return lower values (20.5% and 13.2% respectively). MagPick returns higher values (69.5%).

Table 1: *summed correlation*

Software	nr. targets	correlation
Geosoft OASIS Montaj v9.1	150	98%
SENSYS MAGNETO	17	99%
GEOMETRICS MagPick	141	84%

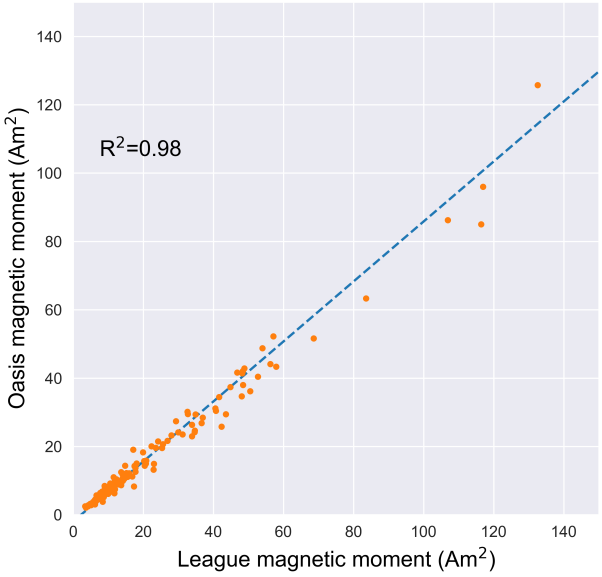

Figure 4: *League vs OASIS*

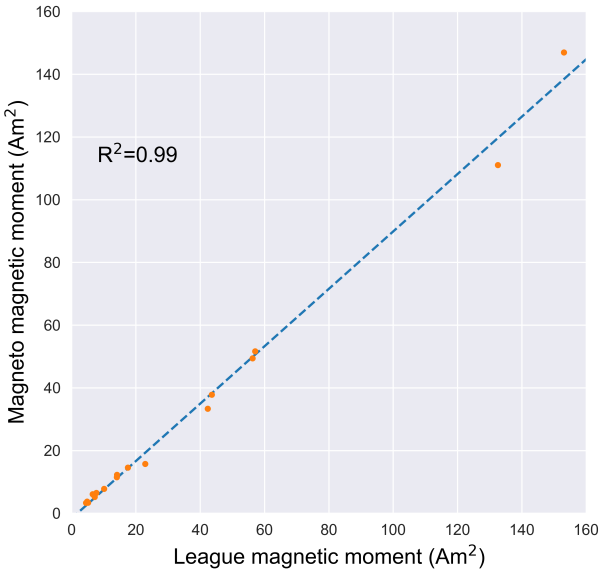

Figure 5: *League vs MAGNETO*

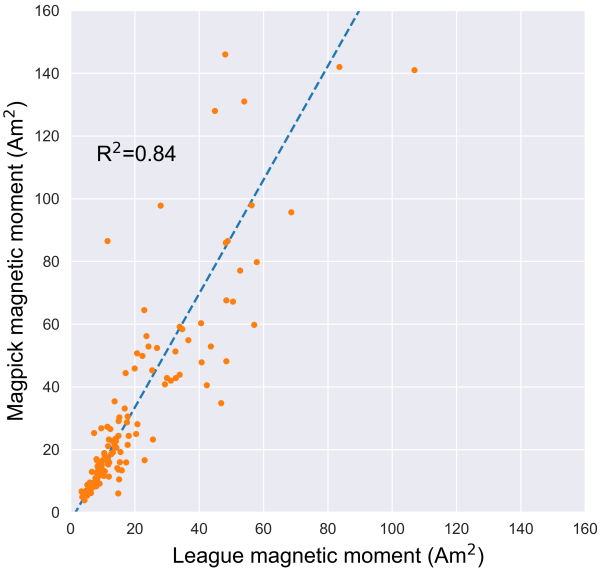

Figure 6: *League vs MagPick*

4 Conclusion

The summed correlation as presented in table 1 shows that magnetic moments, as modeled by League Geophysics software, have a reliability that is comparable to commercially available software packages.

Having developed this software in-house means that League Geophysics has a control at the base level of the inversion steps. This allows comprehensive insight into the quality of the inverted results - a thing not possible with off-the-shelf packages. Higher quality results can thus be obtained and presented to clients.

Reference

Blakely, Richard J. (1995). *Potential Theory in Gravity and Magnetic Applications*. United States Geological Survey, California: Cambridge University Press.

GmbH, SENSYS Sensorik & Systemtechnologie (July 2008). *Das Berechnungssmodell des induzierten magnetischen Momentes einer Stahlkugel*.

Lee, Laurie (1991). *A Moment of War*. City of Westminster, London: Penguin Books.

Reed, Lou (Mar. 1995). *This Magic Moment*. Doc Pomus tribute album.

Tchernychev, Mikhail (Feb. 1998). *MAGPICK - magnetic map & profile processing*.

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