Lifeguard for large-scale geophysical surveys

Automated anomaly-analysis of geomagnetic data using open-source GIS-tools

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Keywords: Geomagnetic Survey, Automated Processing, Classification, GIS, Open-Source

Drowning in data

Geophysical surveys rank among the most important and effective technologies for archaeological investigation and cultural heritage management. The performance of measuring systems has drastically increased in recent years: While earlier surveys using rather slow single-sensor systems produced a relatively manageable amount of data of about 0.5 ha per day under favorable conditions (Cf. Aitken 1974, 234f.), today a single person using one of the increasingly popular multisensor systems can cover 15 or more hectares per day, generating approx. one million readings per hectare plus geodetic datum. While this growing capacity allows for applying this type of survey for landscape-scale research objectives effectively, the tremendous amount of data exceeds the capacities of manual interpretation by far, especially since time and resources are often devoted more willingly to data collection than to office work (Cf. Aitken 1974, 234f.). The German Archaeological Institute (DAI) operates two 16-sensor fluxgate-magnetometer rigs, to date resulting in overall coverages of up to 10 km² at sites like, e.g., Avebury or the princely site of Vix at Mont Lassois. Beside the unaffordable time requirement, manual interpretative vectorization is always subjective and rather inaccurate. To analyze and interpret this amount of data in a reproducible and more efficient way, new tools and workflows had to be developed.

Fig. 1. Sensys MX V2 and V3 multisensor magnetometers in front of Mont Lassois. (© DAI/E. Runge)

Finding the edges

Interpreting vast amounts of data does not represent an entirely new problem in remote sensing applications. Satellites cover far more ground than any other survey technique and it comes as no surprise that a number of tools have been designed to classify satellite images and support their interpretation (Cf. ‘Image classification’, 2018). In the case of traditional geomagnetic data the interpretation is somewhat hampered by the fact that only the magnetic flux density is recorded. This, apart from being affected by past anthropogenic and geological activities, can also be distorted by a number of other factors, including the location on the

globe, the direction of measurement as well as disturbances caused by the vehicle or person moving the instrument. Archaeological features cannot easily be distinguished from these other anomalies; simply vectorizing the resulting noisy data automatically based on differences between cell-values would create a muddled polygon-cluster, each polygon representing a single value. Hence, the original measurement readings have to be reclassified, e.g., into a binary raster containing only the number 1 coding values above a certain threshold and 0 coding values below. The vectorization tool of choice can then be used to trace the edge between 1 and 0 resulting in polygon-features. Since the threshold value can be set down to 1/10 nT this method is far more precise than any manual vectorization. Further steps in this workflow include different buffers and smoothing resulting in an accurate and detailed image.

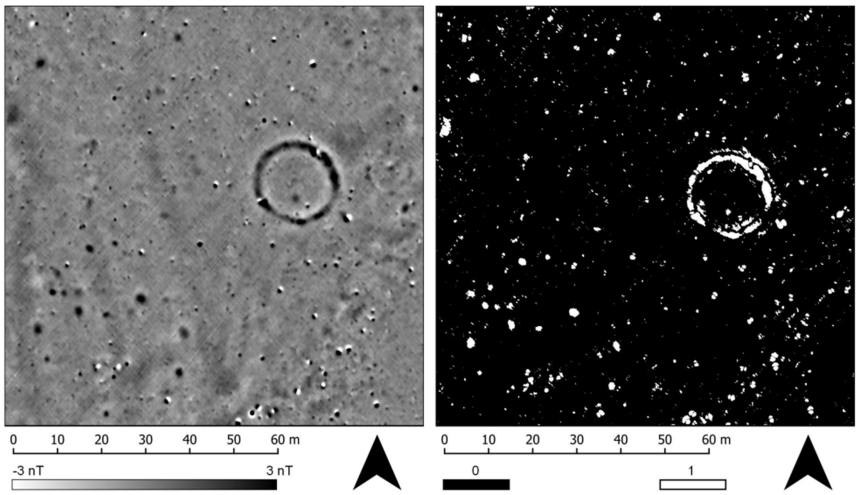

Fig. 2. From left to right: a) Original magnetogram. b) Binary raster created using a threshold of 2 nT. (© DAI/L. Goldmann)

Going open-source

The general approach to do this for geomagnetic data has been around quite a long time (Neubauer 2001, 125-129), but the actual methods were, if used at all, only implemented individually by a few computer enthusiasts. Instead of creating yet completely new and/or proprietary software, the DAI decided to make use of the tools already available in open-source GIS libraries, such as GRASS or SAGA. All necessary steps (binarization, vectorization, cleaning and smoothing) are implemented in QGIS – ready to use. In a first attempt these algorithms were applied in a sequence manually, which proved to be helpful, but also very time consuming (Goldmann 2017). Using the QGIS graphical modeler, the DAI recently developed a Python-based script to automatize this process. The script is intended to be published in the Official python plugin repository for QGIS. Using the free, open-source software QGIS and the widespread scripting language Python are meant to facilitate the dissemination and ease of use of this tool.

Applying terrain analyses for geomagnetic data

As mentioned above, raw geomagnetic data do not provide much potential for classification. However, there are certain characteristics, allowing for distinguishing anomalies, which can be statistically analyzed and used for automatic classification. Frequently, automatic recognition of dipole-features, mainly representing modern iron debris, would be a great help for analysts. Dipole-features are marked by a negative minimum paired with a positive maximum, which are, however, often not directly adjacent. Directly vectorizing such dipoles results in two separate polygons, which do not lend themselves to statistical analysis. Therefore, single features are created through buffering and merging these parts. The rapid change from high to low values is reflected in different terrain parameters, such as slope or terrain ruggedness index (TRI), all of which can be calculated in any GIS. Especially the TRI proved to be useful when screening dipoles from other features. An analysis of certain terrain parameters, therefore, was included in the plugin. The respective values are added to the attribute table of the vectorized features and can be used for a query-based classification (see Fig. 3b)

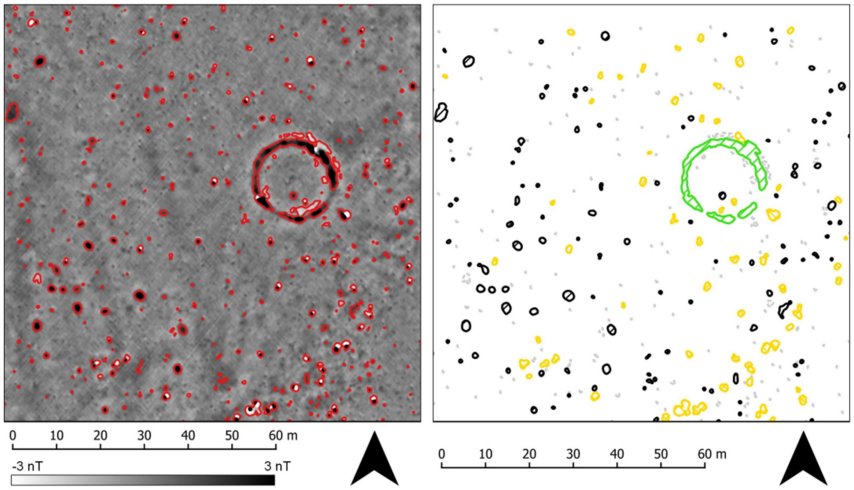

Fig. 3. From left to right: a) Magnetogram with vectorized anomalies. b) Anomalies semi-automatically classified as dipoles, pits, noise and a ditch feature. (© DAI/L. Goldmann)

The next step

The tool developed by the DAI facilitates the vectorization and interpretation of large survey areas considerably. Fields covering several hectares could be analyzed and visualized with an easily readable, classified vector map within minutes instead of hours. Tests so far show that it is very well suited for features like pits or well defined dipoles while it does not catch linear features like long ditches or walls with the same success. Of course, these tools do not replace the human analyst, who has to set the parameters and make the decisions in the end, but it provides an effective assistance as well as enabling transparency and reproducibility of the results. Further terrain parameters or other statistics are to be tested and eventually integrated into the workflow, which in principle would also be suitable for other types of survey data, such as ER, GPR or aerial photography. In the future, the plugin will benefit from the use, testing, critique and input of the GIS-Community.

References

Aitken, M. J. (1974). *Physics and Archaeology*. 2nd ed. Oxford: Oxford University Press.

Neubauer, W. (2001). *Magnetische Prospektion in der Archäologie*. Wien: Verlag der Österreichischen Akademie der Wissenschaften.

Goldmann, L. (2017). *'New glimpses of a hidden landscape in the surroundings of Mont Lassois. Analyses of survey data in the proximity of the Iron Age sites at Vix with special consideration of the geomagnetic surveys of the German Archaeological Institute 2013-2016*.' Institut für Prähistorische Archäologie. Freie Universität Berlin. Unpublished master thesis.

Image classification, (2018). grasswiki. Available at: https://grasswiki.osgeo.org/wiki/Image_classification (Accessed 26.06.2019).