

Automatic detection, outlining and classification of magnetic anomalies in large-scale archaeological magnetic prospection data

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IDENTIFYING ANOMALIES

A process consisting of several steps has been developed for the purpose of identifying anomalies. The first step is the identification of magnetic anomalies (Fig. 1). Therefore, we detect local magnetic maxima on a spatial magnetic map. The magnetic maximum under consideration has to be greater than an interactively set threshold value (usually 1 nT) and has to be the largest value with a certain distance (usually within a circle of 1 m radius). Then the corresponding minimum of the anomaly is detected. If both a local maximum and a local minimum are found, we assign these two points to a magnetic anomaly. Then we calculate some physical and geometrical properties of the anomaly for classification purposes. These properties are the maximum and minimum magnetic values, the difference between the maximum and minimum magnetic values (magnetic strength) and the spatial distance between the position of the maximum and minimum magnetic values.

ROUGH CLASSIFICATION

Using these properties the detected magnetic anomalies are assigned to two classes. The first class comprises anomalies that presumably originate from individual objects in the very shallow subsurface. These are called “iron litter” anomalies (Fig. 2). The second class of anomalies is assumed to originate from objects located in deeper soil layers and these are classified as “pits” (Fig. 3). These two classes are not exclusive. Some of the anomalies are assigned to both classes, when the selection criterion is close to the threshold value of the classes. The

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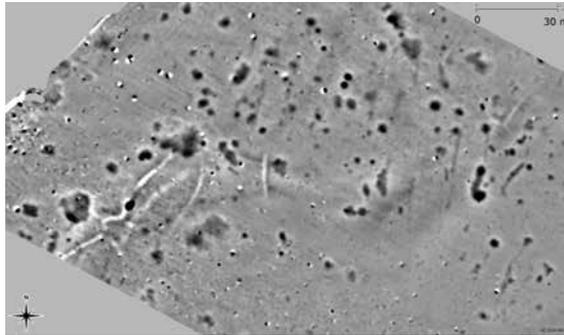


Fig. 1. Detail of a magnetic anomaly map with probably Neolithic structures from the LBI-ArchPro case studies area Kreutal. Gray scale range, white/black: $-4/6$ nT

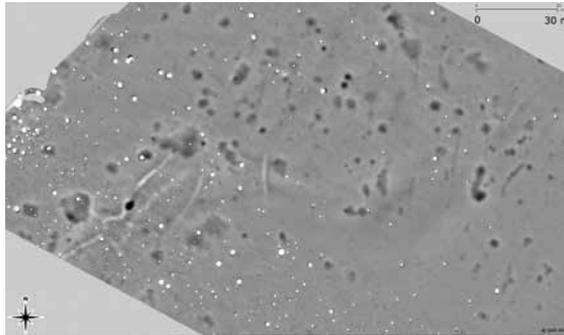


Fig. 2. Detected iron litter in white superposing the magnetic anomalies. Gray scale range magnetic map, white/black: $-16/24$ nT

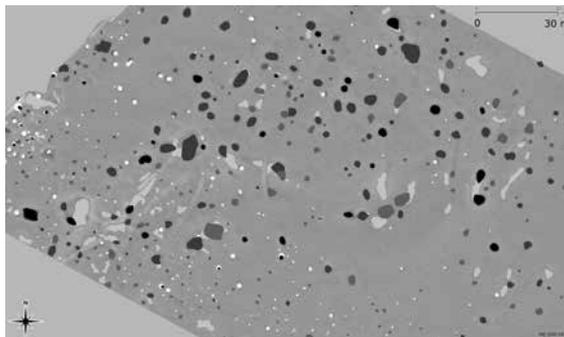


Fig. 3. Detected iron litter in white and detected pits in gray superposing the magnetic anomalies. Four classes of pits according to maximum magnetic anomaly are visualized. Gray scale range magnetic map, white/black: $-16/24$ nT

final classification is done in GIS using a combination of more properties than used in this first, rough classification step. The later criterion used for classification is the quotient of the strength of the magnetic anomaly and the spatial distance between the location of the maximum and minimum. If this relationship is high, the probability that the anomaly originates from iron litter is high as well. Likewise, if this quotient is small, the probability that the anomaly originates from a pit is high.

OUTLINING OF THE ANOMALIES

The detected and roughly classified anomalies are then visualized by drawing the outline of the anomaly. Therefore, a polygon consisting of 32 points is calculated, representing a virtual line of a certain magnetic value (a magnetic contour), usually drawn at 30% of the magnetic maximum. This polygon describes the location, size and shape of the detected magnetic anomaly. For each polygon further physical and geometrical properties are calculated and the polygon and its properties are written into a GIS shape-file, to be included into GIS for further classification in support of the archaeological interpretation.

The physical and geometrical properties calculated for each polygon are the maximum and minimum magnetic values, their difference, the orientation of the magnetic anomaly with respect to geomagnetic north (declination), the spatial distance between the position of the maximum and minimum magnetic values, the probability to be classified as “iron litter”, the size of the area defined by the polygon, the perimeter of the polygon, the maximum length and width of the polygon, the relation between length and width, the orientation of the length axes and a value that describes the circularity of the polygon. Additionally some statistical properties of the magnetic values within the polygon are calculated. These properties are the difference between the highest and lowest magnetic value within the polygon, the mean value and the standard deviation of all magnetic values within the polygon, the relative number of values higher than the half-value of the maximum value and the number of local maxima within the polygon.

INTERPRETATION WITHIN A GEOGRAPHICAL INFORMATION SYSTEM

The generated shapes and computed properties of the automatically detected magnetic anomalies are subsequently analysed, classified and interpreted in the GIS framework. The intelligent combination of selected properties can be used for a comfortable and efficient detailed classification of the anomalies in GIS. For instance, a refilled posthole on the one hand usually has a small corresponding magnetic anomaly, a circular polygon with a small diameter, a magnetic orientation to the north and a homogeneous magnetic anomaly (a small standard deviation of the anomalies within the polygon). A *Grubenhaus* on the other hand generally displays stronger, inhomogeneous magnetic values, a larger, rectangular shaped polygon of a certain (often known) size, (often) a known ratio of length to width, often a certain orientation and a low degree of circularity. All these properties can be parameterized in GIS and therefore used an automatic anomaly classification.

The described approach considerably speeds up the archaeological interpretation process when dealing with large quantities of high-resolution prospection data. The drawing of the outline of

the anomalies and the calculation of all the corresponding properties is a fully automated, very fast process. By using an intelligent selection and combination of ranges of appropriate properties, it is possible to generate a detailed data classification. The number of anomalies to be interpreted is not important anymore; it is almost as much work applying this classification approach to 100 as to 1 million anomalies. Furthermore, this automated classification approach is objective and comprehensible.

The interpreting archaeologist is not only unburdened from very time-consuming drawing tasks, but he or she is also automatically provided with a large amount of additional, objectively derived information and classified anomalies with meaningful properties, aside from mere data images and visualizations of magnetic anomalies. By relieving the interpreter through the here described approach, more valuable time and effort can be spent on the actual understanding and archaeological interpretation of the underlying structures that express themselves through the prospected magnetic anomalies.