Gradiometer Image Processing for Archaeology

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Abstract

In archaeological geophysics, image processing and filtration has remained a step in data interpretation that has been either ignored or conducted without much thought to the underlying data transformations by many interpreters. Image modification and filtration, however, can greatly enhance subtle patterns and weak signals that are characteristic of archaeological data including magnetic data. Most interpreters strive for an image where linear anomalies are enhanced and background values are smoothed. To this end, the most applicable filters for magnetic data are ones that can detect the presence of edges while suppressing all other values. Edge detection filters such as a derivitave-applying directional filter, and adaptive filters such as the Weiner and Frost filter produce images that, to varying degrees of success, achieve the goal of edge preservation and enhancement. Furthermore, these three types of filters preserve or can be modified to preserve the original integrity of the magnetic values inherent in the data. The resulting images improve the contrast between the linear anomalies and the background while still preserving the unique positive and negative values that is characteristic to background normalized magnetic data.

Magnetometery has been and continues to be one of the most popular applications of geophysical measurements to the field of archaeology. Magnetic surveys can be conducted relatively quickly, requires little expert knowledge to collect the data, and can cover a large area, especially in open terrain, making it an economical tool for a quick assessment of a site. While the attainment of large quantities of magnetic data can be quick and easy, the interpretation of the data may be anything but quick or simple. When magnetic data is first converted from a matrix of readings to an image, the result is rarely used as is for a final interpretation. Rouge high or low pixel values and the tendency for archaeological anomalies to possess weak valued magnitudes both lead to the display of an image where little of the depth of information that it contains can be discerned. Most archaeologists only go as far as applying a median filter and using a standard deviation clipping routine for the display of the data. Whereas the field of data presentation in archaeological geophysics has been limited in the past, the fields of remote sensing and computer image processing have been exploring various ways to improve rasters for data presentation for decades. For instance, there has been a wide range of literature produced on the enhancement and speckle suppression of Synthetic Aperture Radar (SAR) images (see Dong et al., 2001; Gibson, 1998). The speckle seen in SAR data can be thought of as analogous to iron spikes and soil noise that is common to archaeological magnetic data. To test the application of more sophisticated image filtering algorithms and remote sensing oriented filters, gradiometry data obtained over a site containing archaeologicaly significant remains was used. The data was collected using a Geoscan FM32 gradiometer zeroed to the background field with readings at 1m x 1m intervals in parallel mode creating 20 m x 20 m grids that were then mosaiced (figure 1). Images in this paper were produced using Matlab's Image Processing Toolbox, although the filters used can be applied from a wide variety of image processing software.

Unfortunately, image processing still remains somewhat a trial and error process by applying successively more dramatic filters until one is found that enhances the features of interest the best. In almost all cases, archaeological data processing strives to enhance edges and linear features while suppressing background noise and geology. Of the various filters that were tried on the gradiometry data, the ones that best achieved the aim of enhancing edge contrast while suppressing background speckle were the directional and the adaptive filters. In theory, the Frost filter, an adaptive filter, should be one of the best at filtering data containing anthropogenic features. The filter employs a damping coefficient to limit the amount of averaging done to edges, and utilizes a window, or neighborhood, around each pixel under consideration for the calculation of local statistics (Dong et al., 2001). However, when the Frost filter was applied to the data, the resulting image was not dramatically enhanced over the original (figure 2). One of the reasons for the similarities in the image could be the relatively good quality of the original image.

A second adaptive filter that was applied with considerable success to the gradiometer data set was the Weiner filter. This filter assumes that image has additive Gaussian noise. As with the Frost filter, the Weiner filter uses a small neighborhood around each pixel to calculate local statistics. The local statistics give the mean and variance of the pixel in relation to its surrounding neighborhood, and these values are used in conjunction with a noise variance parameter to filter the pixel (Matlab, 2004). As seen in figure 3, the resulting image has background values that are more uniform than the in the original image. The filter has removed the speckle from random debris and soil variation and allowed the weaker signals to occupy a greater range of the gray scale.

When the magetic image contains edges of interest that lie at an angle to semi-linear noise or unwanted anthropogenic signals, a directional edge detection filter can be used to take out the unwanted features. As seen in figure 1, the archaeological target is oriented at almost 45 degrees to the direction of the survey. Distortions created by the survey lines and by meshing the 20 m x 20 m grids together can be easily removed with a directional filter that preserves only edges perpendicular to the direction the filter is applied. In this case, two separate passes with a directional filter were then added together to enhance edges that were 45 degrees to the edges of the survey grids (figure 4a). The resulting image can be further enhanced with the application of a Wiener filter to an image with strongly highlighted linear features is created (figure 4b).

With the application of each additional filter to the original magnetic data, the user faces the problem of the further loss of the information stored in the pixel's value. For all data, but perhaps especially for noisy bipolar magnetic data, there is a trade off in the image between original data integrity and image clarity that filtering can produce. To this end and because the procedures and filters that are applied to data are highly dependant on the individual values of the pixels in the image, filtering should proceed from the highest frequency filtering to the lowest all the while minimizing the number of operations performed on the data. Filtered images should only be used in analysis when there is a clear benefit in highlighting features that were previously suppressed. Through the exploration of more advanced and sophisticated filters, geophysicists and archaeologists can enhance images to boost weak features that would otherwise be lost amongst dominating noise sources such as pipes, power lines, and metallic debris.

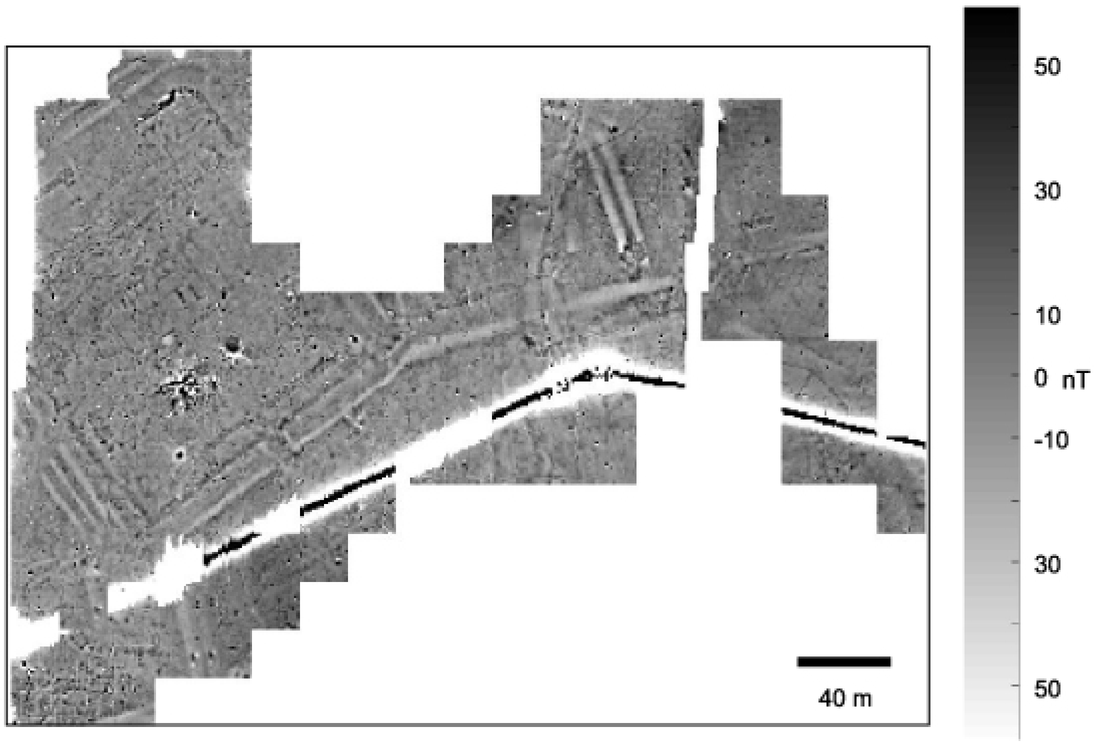

Figure 1: Original image with edge matching for mosaiced grids,

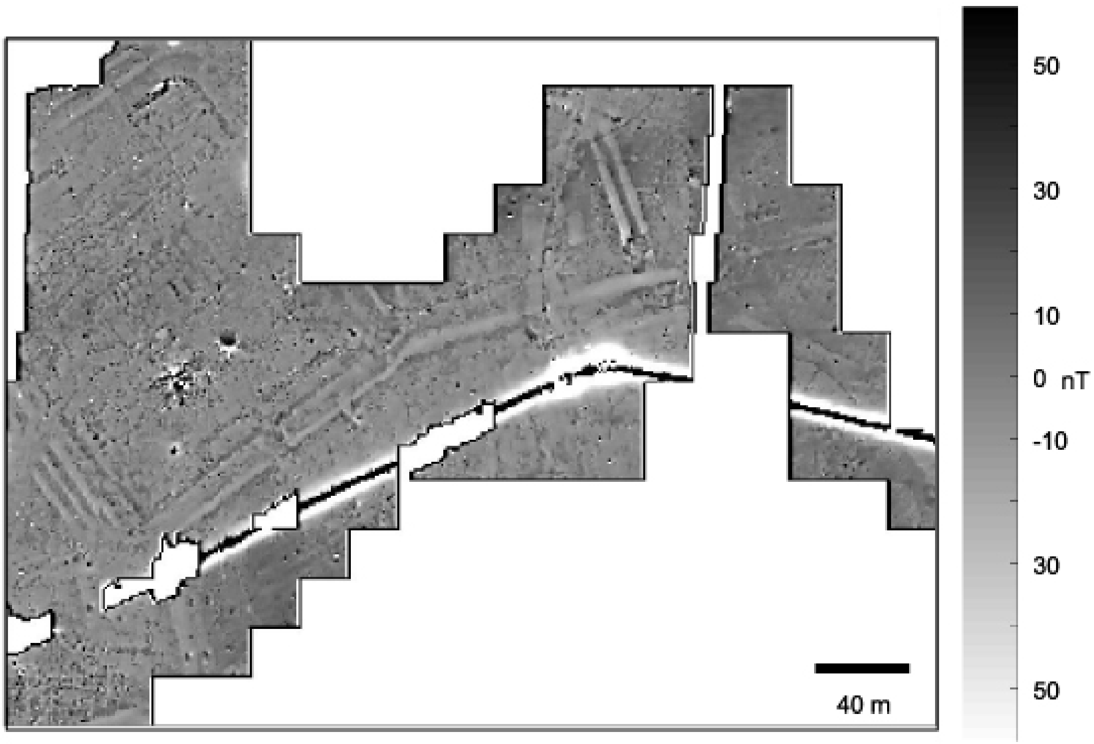

Figure 2: Frost filter applied to figure 1

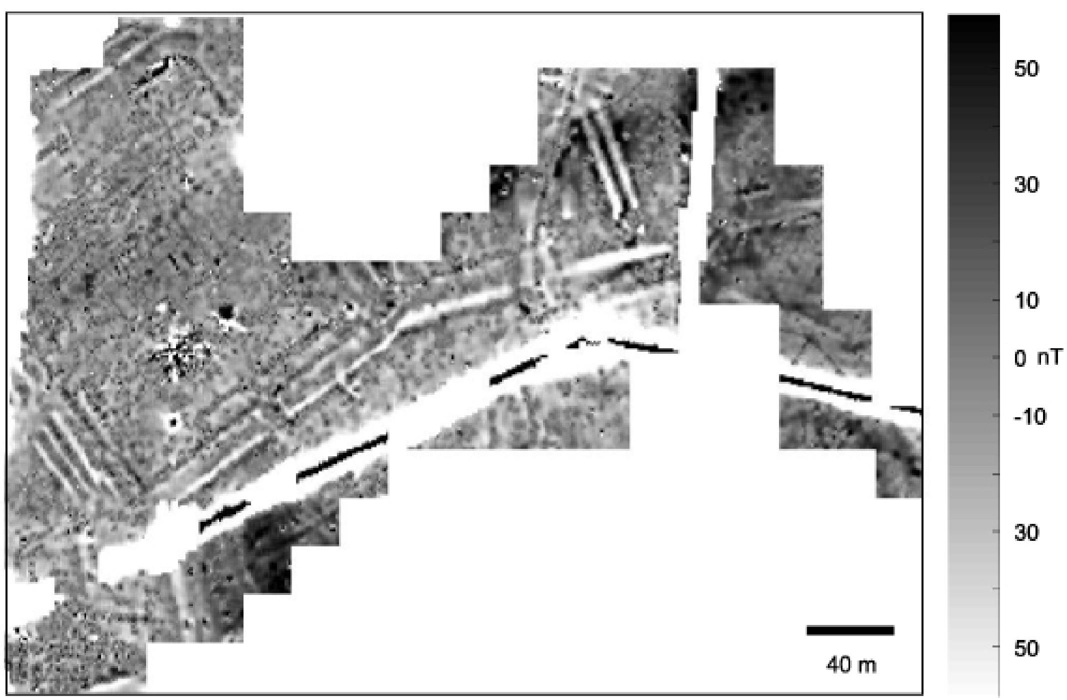

Figure 3: Wiener filter applied to figure 1

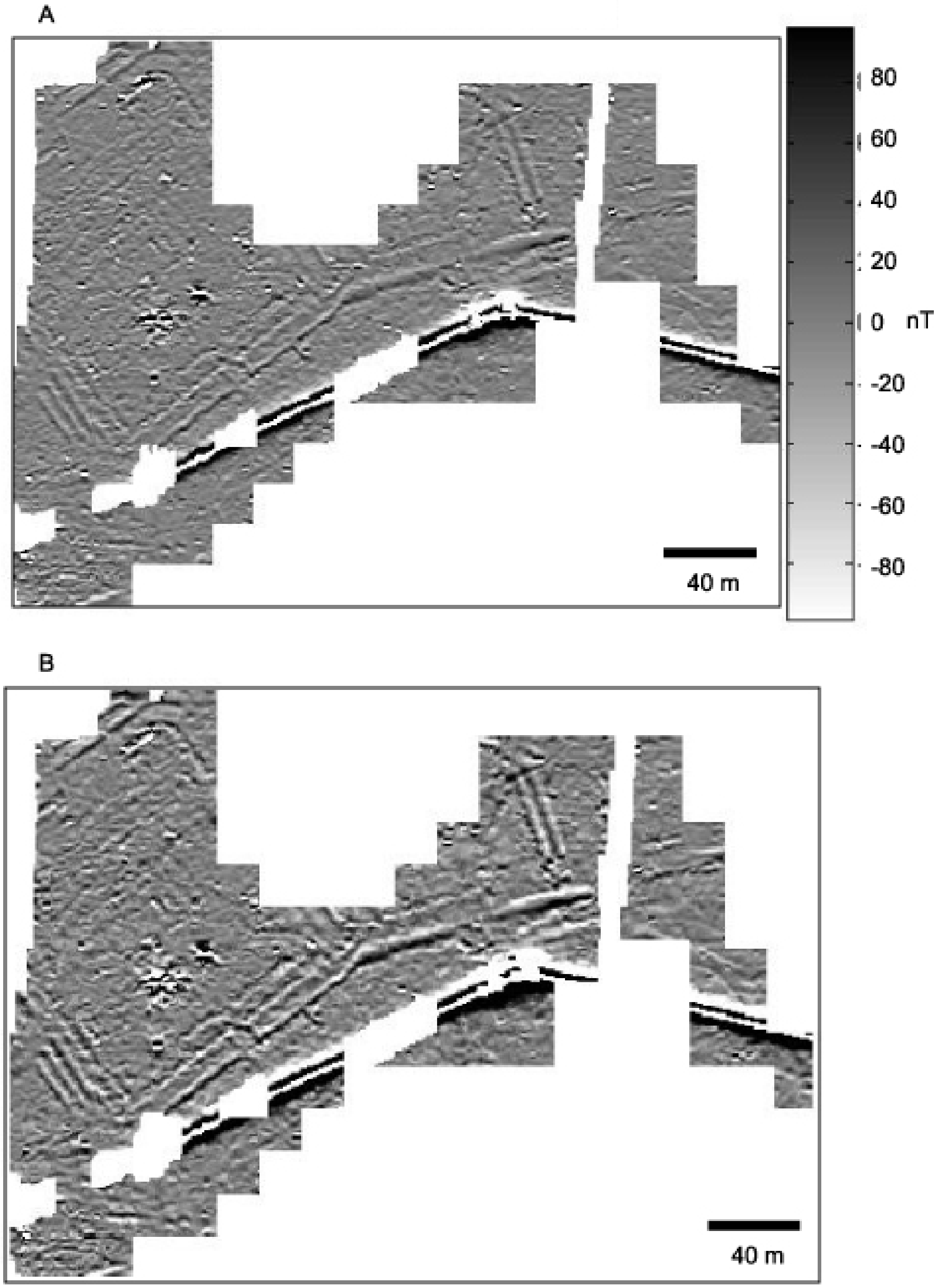

Figure 4: A) Directional filters at 45 and 135 degrees added together, B) Image from C with Wiener filter

References

Dong, Y., Milne, A.K., and Forster, B.C. Toward edge sharpening: a SAR speckle filtering algorithm. IEEE transactions on geoscience and remote sensing, vol. 39, 851-863, 2001.

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Matlab Image Processing Toolbox Documentation, http://www.mathworks.com/access/helpdesk_r13/help/toolbox/images/wiener2.html, 2004, accessed October 2005.