Analecta Praehistorica Leidensia 28 / Interfacing the past : computer applications and quantitative methods in archaeology CAA95 Vol. I
Kamermans, Hans; Fennema, Kelly; et al., ; Kamermans, Hans; Fennema, Kelly

ANALECTA PRAEHISTORICA LEIDENSIA 28

PUBLICATIONS OF THE INSTITUTE OF PREHISTORY
UNIVERSITY OF LEIDEN

INTERFACING THE PAST

COMPUTER APPLICATIONS AND QUANTITATIVE METHODS IN ARCHAEOLOGY CAA95 VOL. I

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UNIVERSITY OF LEIDEN 1996

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Phil Perkins

An image processing technique for the suppression of traces of modern agricultural activity in aerial photographs

1 The problem

Agricultural activity can make buried archaeological sites visible from the air. Ploughing creates soil marks and sowing creates crop marks. However, mechanised agriculture also creates other patterns in the soil or in crops. Ploughing leaves regular furrows and mechanised sowing leaves fine alignments of plants in the field and fertilisation or pesticide treatments can leave regular tractor tracks across fields. Traces of this agricultural activity are also visible from the air and may mask or confuse archaeological crop marks or soil marks. Archaeologists have employed image processing to aerial photographs for many reasons (Booth *et al*. 1991) and it offers some hope of enhancing this particular form of 'noise'.

A first approach in such cases where there is unwanted fine detail, such as furrows, is to convolve the image using an averaging filter. This removes fine detail in the image leaving coarse detail visible. However, the filter is indiscriminate and has the effect of blurring everything in the image equally. Certainly it removes traces of sowing and tractor tracks but it also corrupts the crop marks which are clearly visible in the data which have been removed from the image in the filtering process (fig. 1).

What is required is a filter which can discriminate between the regular traces of agriculture and the less regular traces of archaeological structures. Edge suppression filters offer some hope but in practice the edges of the archaeological features are also suppressed, reducing their legibility.

2 A solution

A solution to this problem is possible if we consider the image in the frequency domain as a sum of phase shifted sine waves. Determining which sine waves to use is the major concern of Fourier Analysis. Information about the amplitude and phase shift of the sine waves can be encoded as a Fourier transform, and since it is discrete sampled data we can use the Fast Fourier Transform. The image may now be filtered in the frequency domain as we might in the

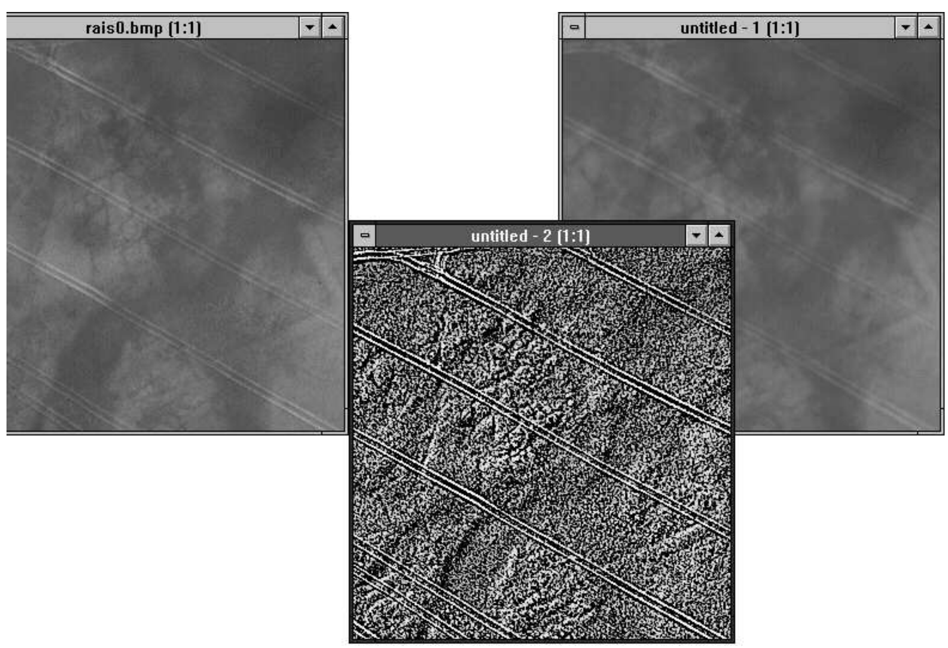

Figure 1. Left: the original photo. Right: blurred image after applying a 3×3 averaging filter. Centre: an equalised image of the difference between the before and after images. Many of the traces of the tractor tracks and alignments of plants have been removed and so are visible in the difference between the two images, however the crop mark itself is also visible and so has been corrupted.

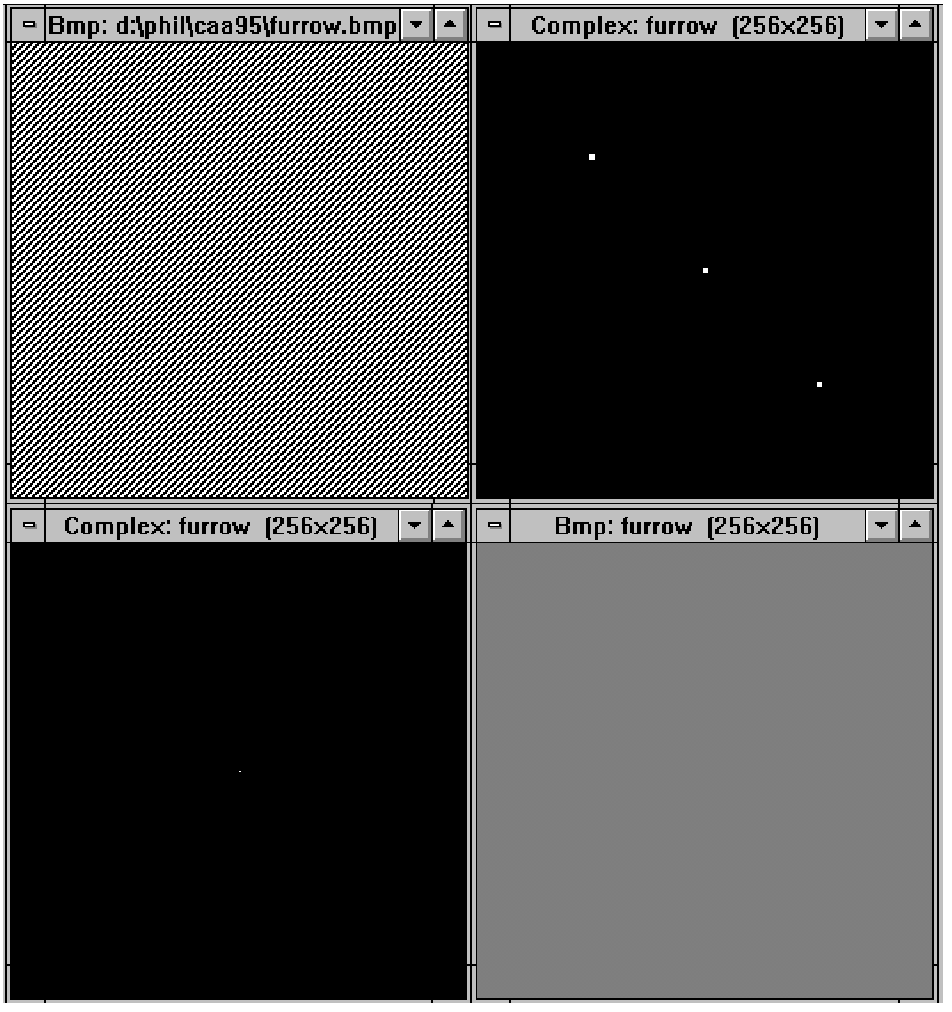

Figure 2. Frequency filtering applied to a data set simulating a ploughed field. Top left: simulated data. Top right: Fast Fourier Transform of simulated data. Bottom left: Fast Fourier Transform filtered by hand. Bottom right: Inverse Fast Fourier Transform of filtered simulated data.

spatial domain. Truncation of the high frequencies is equivalent to blurring the image in the spatial domain, that is the high frequencies are filtered out (the technique is fully described in theory in the context of antialiasing in Foley *et al*. 1990: 623-46). Filtering in the frequency domain allows the possibility to selectively filter the transforms of the coarseness or fineness of regular patterning along with the orientation of features in the spatial (unfiltered) domain.

2.1 Simulated data

In order to test the effects of frequency filtering and explore its impact on defined signals, a simulated data set consisting of a 256 × 256 pixel field of black and white diagonal lines representing furrows at 45° was created (fig. 2 top left). When transformed to the frequency domain with a Fast Fourier Transform the image appears as three bright dots aligned at 45° (fig. 2 top right). Filtering this image by hand these outlying peaks of high frequency are removed (fig. 2 bottom left). The Inverse Fast Fourier Transform applied to transform this filtered image back to the spatial domain results is a uniformly mid-grey field — the furrows have been effectively removed by filtering out their frequencies (fig. 2 bottom right). The filtering is extremely effective on such a simple image. However, add a simulated round barrow to the simulated field (fig. 3 top left) and the Fast Fourier Transform of the image appears much more complex (fig. 3 top right). Filtering out the frequencies known from the previous experiment to remove the traces of the furrows only (fig. 3 bottom left) and applying the Inverse Fast Fourier Transform (fig. 3 bottom right) effectively removes the traces of the furrows. The simulated round barrow, which was originally uniformly grey, rather than furrowed, has taken on zebra stripes due to the fact

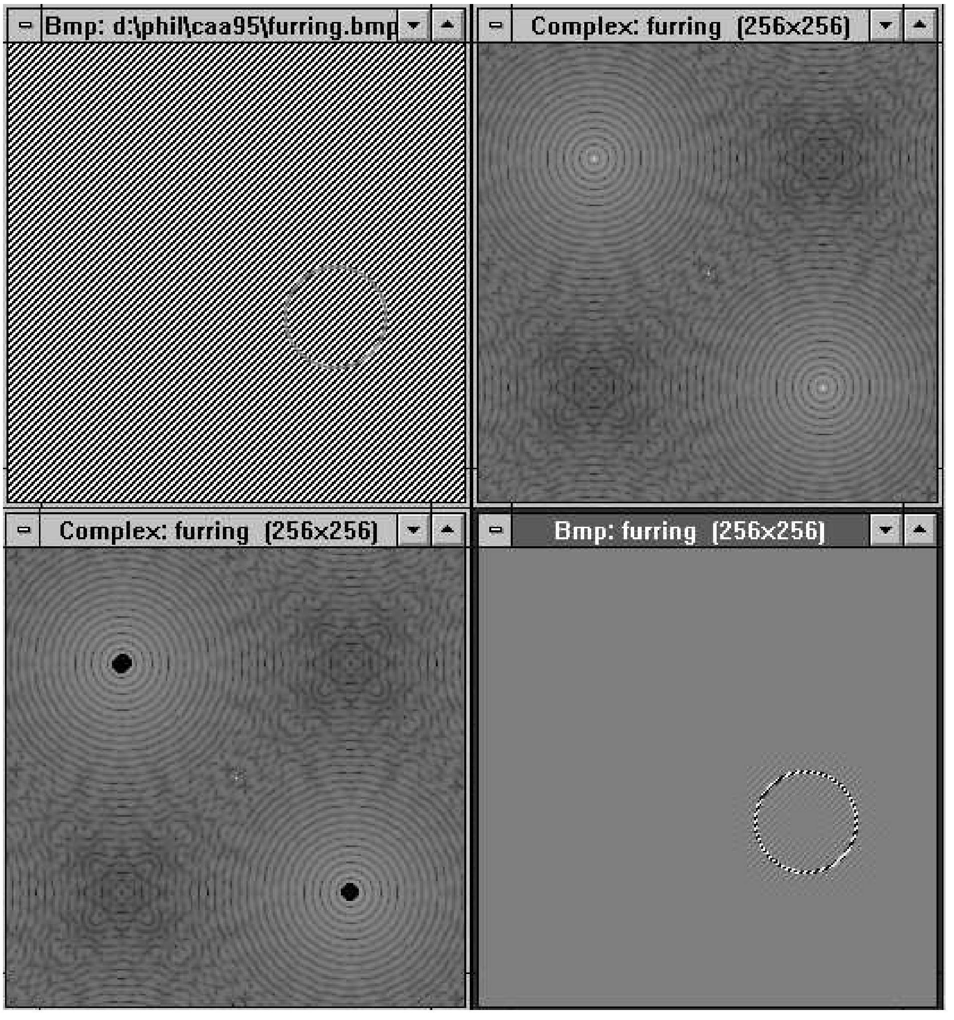

Figure 3. Frequency filtering applied to a data set simulating a ploughed field with a circular soil mark. Top left: simulated data. Top right: Fast Fourier Transform of simulated data. Bottom left: Fast Fourier Transform filtered by hand. Bottom right: Inverse Fast Fourier Transform of filtered simulated data.

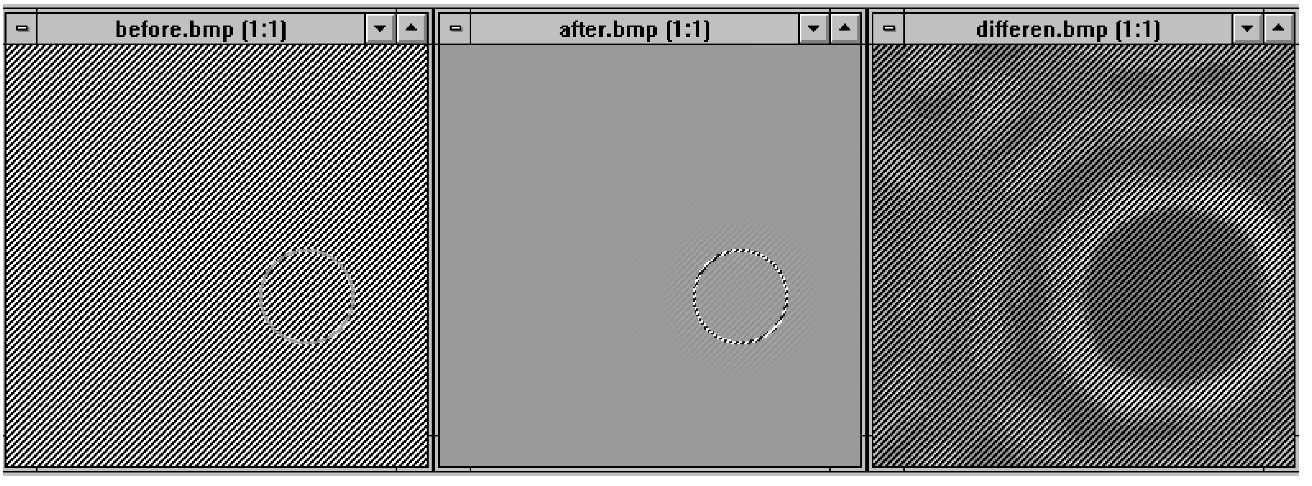

Figure 4. The simulated data of a ploughed field with a circular soil mark is shown before filtering (left) and after filtering (centre). The equalised difference between the two (right) shows, in an exaggerated way, the nature of the part of the signal that has been filtered out.

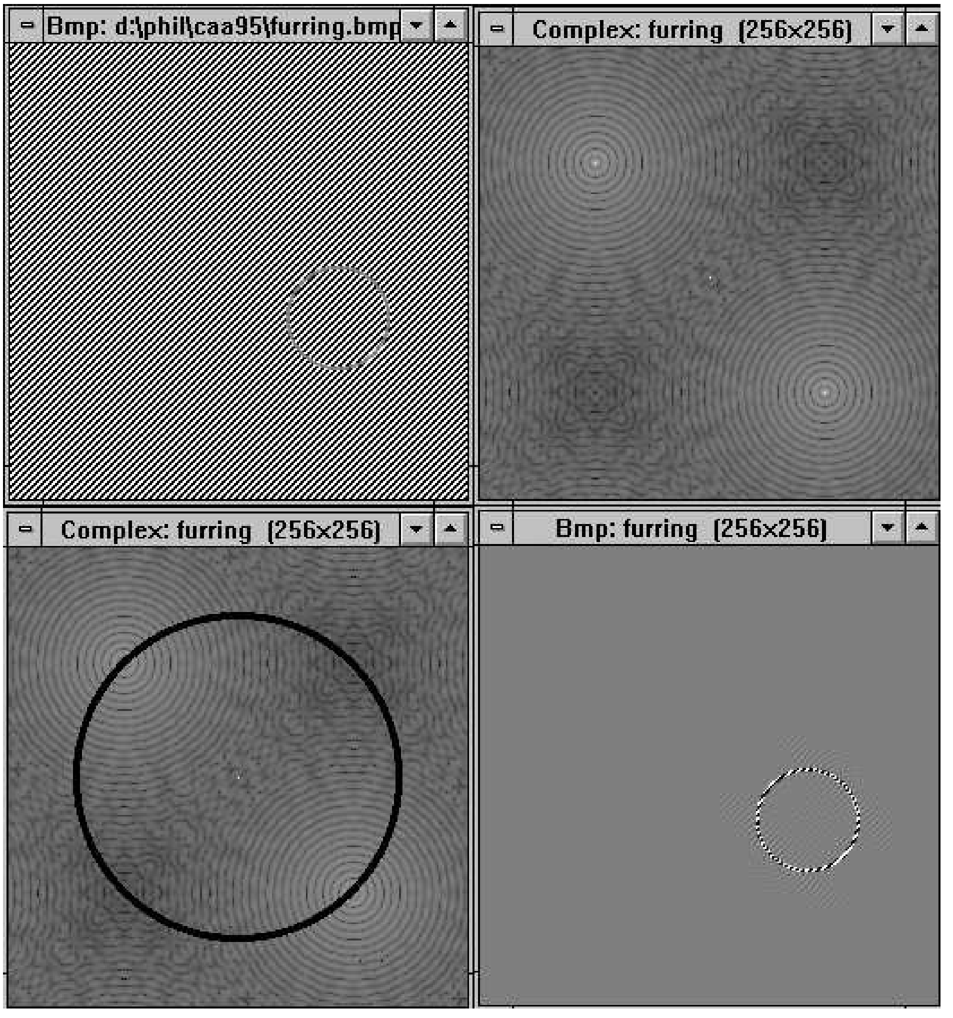

Figure 5. Frequency filtering applied to a data set simulating a ploughed field with a circular soil mark. Top left: simulated data. Top right: Fast Fourier Transform of simulated data. Bottom left: Fast Fourier Transform filtered with a band stop filter. Bottom right: Inverse Fast Fourier Transform of filtered simulated data.

that the values representing the furrows have been subtracted from it too. Around the ring there is some ‘rippling’ in the uniform grey of the field indicating that the technique is not perfect when more complex images are filtered. This is visualised in figure 4 where the simulated data is shown before (left) and after (centre) filtering and the equalised difference between the two (right) shows, in an exaggerated way, the nature of the part of the signal that has been filtered out.

Other filters instead of a heuristic hand filtering may also be applied to transformed images. For example a band stop filter, i.e. stopping the frequency which coincides with the peaks in frequency representing the furrows is applied in figure 5. The results are similar but the ‘rippling’ around the ring has a different form. The Fast Fourier Transform of a simulated complex crop mark (fig. 6 top left and right) can be seen to be more complex and less structured than the simple simulation. The filtering is still effective but the ‘rippling’ effects become more apparent closer to the simulated soil mark (fig. 6 bottom left and right).

Using real world data, figure 7 illustrates a variety of filtering strategies applied to the same photograph. The first column on the left shows at the top the image before filtering and below the Fast Fourier Transform of the image. The second column shows at the top a heuristic filter removing only low frequencies, in the centre is the

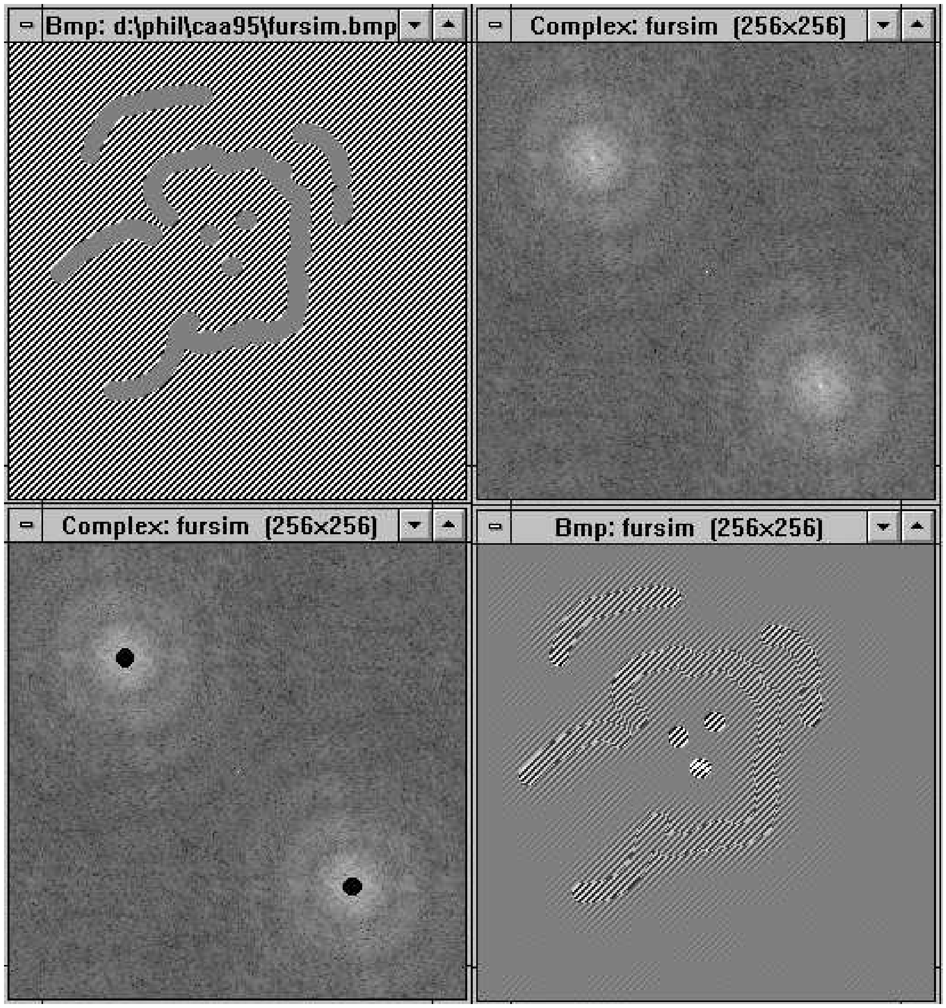

Figure 6. Frequency filtering applied to a data set simulating a ploughed field with a complex soil mark. Top left: simulated data. Top right: Fast Fourier Transform of simulated data. Bottom left: Fast Fourier Transform filtered by hand. Bottom right: Inverse Fast Fourier Transform of filtered simulated data.

filtered image and at the bottom an equalised image of the difference between the image before and after the filtering. Similarly the third column removes middle frequencies and the fourth only high frequencies. The fifth column on the right removes all frequencies with a particular frequency. Different filtering strategies may be adopted according to the nature of the noise to be removed from the image.

The Fourier Transform can only be applied to single band data, e.g., greyscale images only. To filter 'true' colour images it is first necessary to split the image into individual channels, in this case at Gussage All Saints red, green, blue. Each channel is then filtered separately and then the three filtered images may be recombined from the channels to produce a 'true' colour filtered image (fig. 8). Although differing parts of each band are filtered out when used carefully the technique does not impair the colour balance of the image.

3 Conclusions

This technique of filtering images of aerial photographs in the frequency domain has been found to be effective in the removal of systematic 'noise' in the images. It has been used in experiments to remove traces of ploughing thereby enhancing soil marks, traces seeding in young and mature crops, and tractor or machine tracks. It has been tested on images of regular olive groves but with limited success.

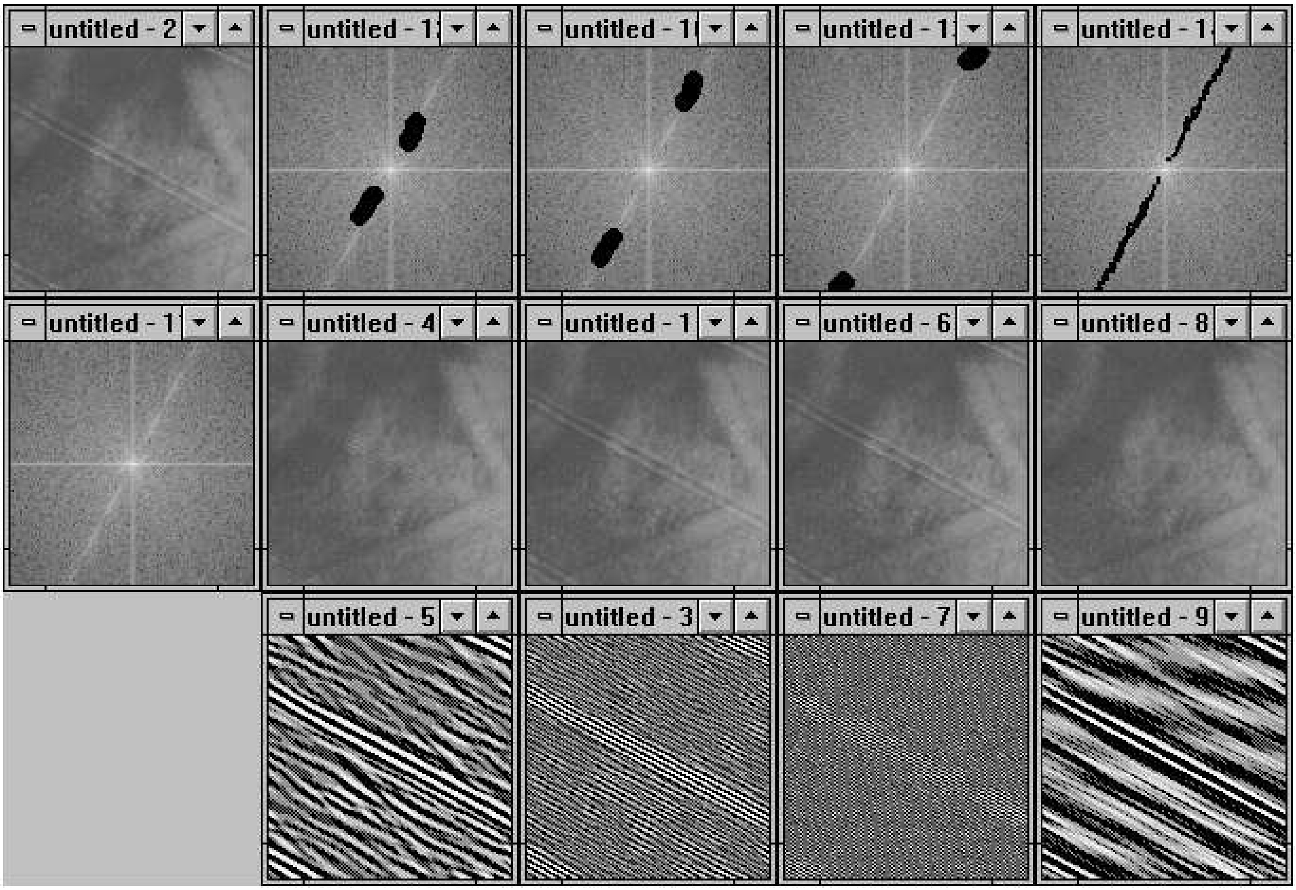

Figure 7. A variety of filtering strategies applied to the same photograph. The first column on the left shows at the top the image before filtering and below the Fast Fourier Transform of the image. The second column shows at the top a heuristic filter removing only low frequencies, in the centre is the filtered image and at the bottom an equalised image of the difference between the image before and after the filtering. Similarly the third column removes middle frequencies and the fourth only high frequencies. The fifth column on the right removes all frequencies with a particular frequency.

Such filtering has its limitations: the mathematics requires the image to be a perfect square, and large squares are computationally intensive. Most significant is that the filtering will only be effective on certain images. The ‘noise’ in the image, e.g. ploughing, needs to be reasonably regular in its linearity, spacing and orientation for good results to be obtained. The filtering will work on any square image, but if there is no regular ‘interference’ in the image, the Fourier Transform of the image becomes relatively even and offending frequencies become difficult to identify and filter out.

The technique has only been tested on aerial photographs to date but other forms of remote sensing, particularly those prone to banding due to systematic instrumentational mis-alignment or those that also detect agricultural phenomena might also benefit from filtering in the frequency domain.

Technical note
Large images were processed on a Sun Sparc IPX running IP an image processing suite which uses VIPS an image processing library written in C and developed as part of the VASARI Project at Birkbeck College. Smaller images were processed using a combination of Aldus PhotoStyler and ProFFT V. 1 a project developed by Marius Kjeldahl and four other students learning C++ at the Norwegian Institute of Technology, Trondheim, running on a variety of Viglen PC’s.

Acknowledgments
Thanks are due to Blaise Vyner who provided many of the aerial photographs used to experiment with the technique and to Kirk Martinez who introduced me to the frequency domain.

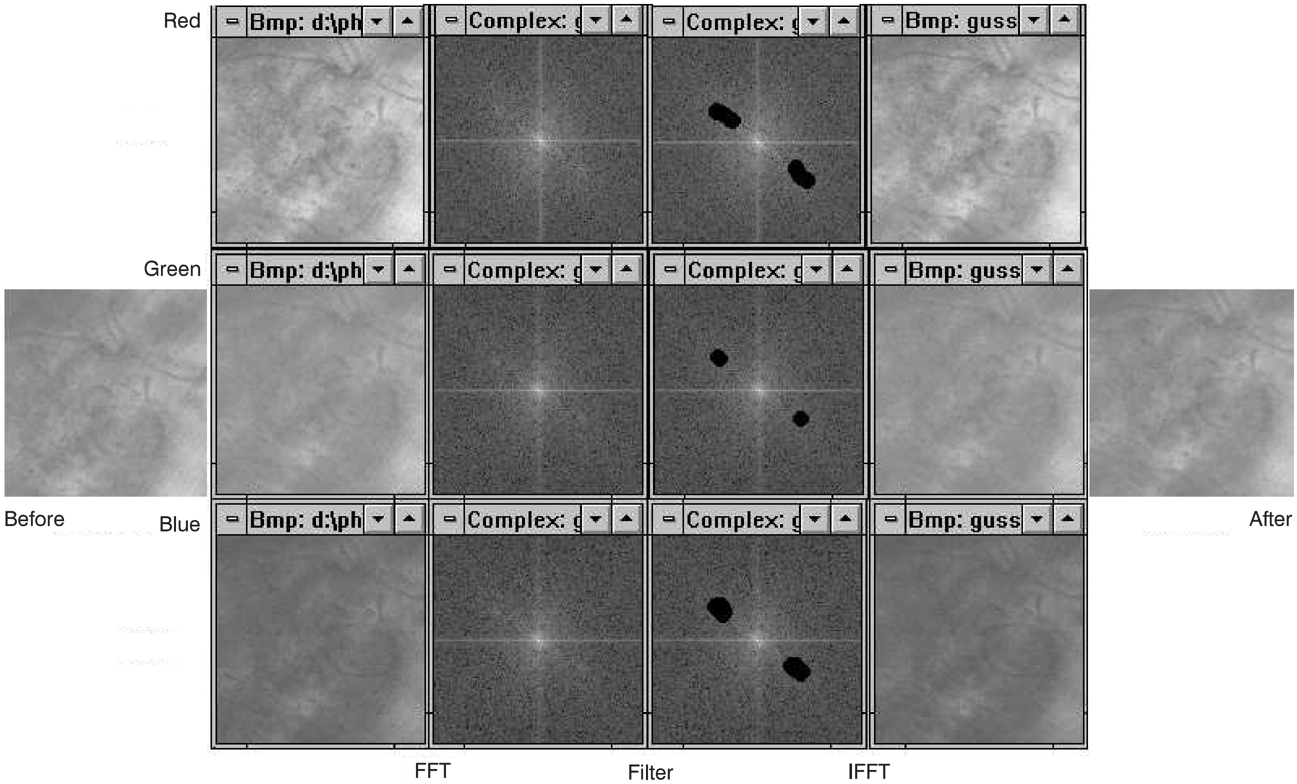

Figure 8. To filter 'true' colour images split the image into individual channels. Each channel is then filtered separately and then the three filtered images may be recombined from the channels to produce a 'true' colour filtered image. This image is of the Iron Age enclosure at Gussage All Saints (Original © Crown Copyright).

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