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Spatial filtering with a photographic replica of the Fourier transform of a half-tone picture

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Abstract Spatial filtering of the Fourier transform of a half-tone object (a newspaper picture) has been achieved using a photographic negative of the Fourier transform generated by illumination of a small portion of the object. The results show a real improvement over those of simple pinhole spatial filtering. Also reported is the use of a photographically reduced array of dots as a spatial filter, giving slightly inferior results but greater flexibility of use.

1 Introduction

A half-tone picture, as used in printed matter, consists of a square lattice of dots (figure 1). Its Fourier transform (FT) (figure 2) can be considered to have two components: one a square lattice of maxima (diffraction orders generated by the grid of dots) and the other the complex transform of the picture itself (full theory given by Brown 1965, Goodman 1968, Hecht and Zajac 1973).

With the dot component suppressed in the FT plane, an image formed by inverse Fourier transformation is free from dots. The simplest method of performing this filtering in the FT plane is by use of a pinhole aligned to pass only the zero-order maximum and immediately surrounding picture information (Cagnet 1962, Phillips 1969, Hecht and Zajac 1973). However, the higher spatial frequency components present are then lost and the resulting image lacks detail. The second method which was proposed (Marquet 1959, Marquet and Tsujiuchi 1961) is to produce a spatial filter consisting of a lattice of dots superimposed on the FT lattice produced by the half-tone picture. Investigators have produced spatial filters of this type but with a specially prepared object (Dammann and Kock 1971, Phillips 1969), i.e. by the use of a square object grid of the same spacing as the half-tone. It has been suggested (Phillips 1969, Nussbaum and Phillips 1976) that such a filter is difficult to construct and align. Two alternative photographic methods are reported here.

Figure 1 The original half-tone picture.

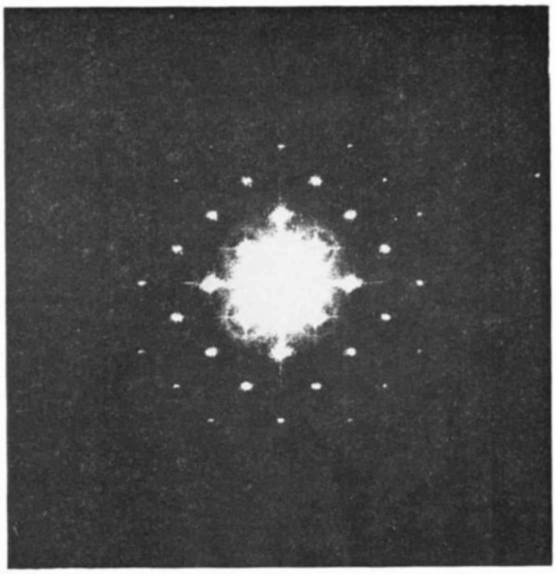

Figure 2 The Fourier transform of the original picture.

2 Developments

2.1 *Apparatus*

The optical system used is shown in figure 3. The source used was a 2 mW He–Ne laser ($\lambda = 632{\cdot}8$ nm). The design

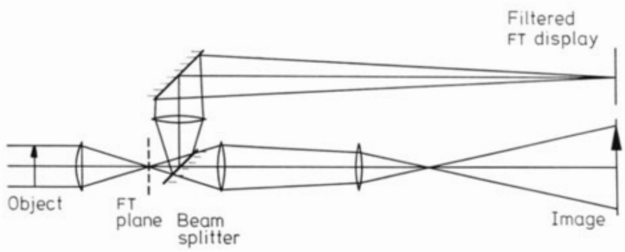

Figure 3 The apparatus.

enables the system to be employed in: (i) the production of a filter, (ii) its subsequent alignment for filtering, and (iii) the photographic recording of the filtered image.

2.2 *Filter A*

The object used was a photographic transparency of a half-tone newspaper illustration (figure 1). The filter was produced by reducing the illuminating beam to 1·5 mm diameter and taking a photograph in the FT plane. Very little of the object is illuminated by such a small beam and

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thus very little picture information is present in the FT, whilst there are still a sufficient number of half-tone dots illuminated to give an FT essentially indistinguishable from that of the whole grid of dots. The FT dot pattern can be optimised by selection of a part of the object giving the greatest contrast between the dot pattern and the FT of the picture. Figure 4 was obtained in this fashion. A high-contrast, red-sensitive lithographic film was employed for the filter (Kodak type 5669 (no longer available)).

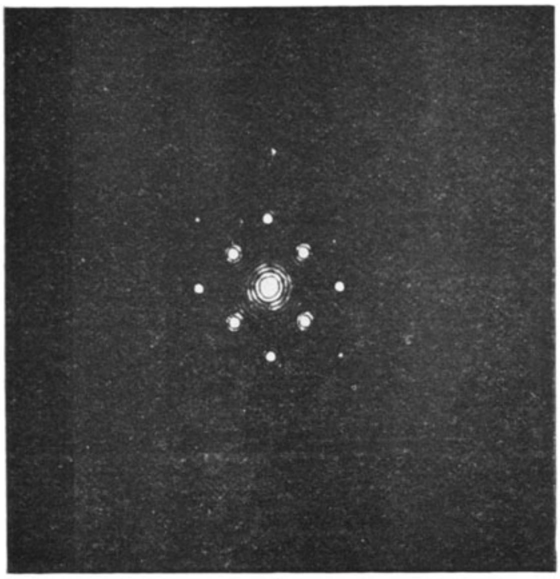

Figure 4 The Fourier transform using 1·5 mm beam illumination.

The exposure used in producing the filter is critical, as the recording must be dense enough to reduce the transmission of the dot component to an acceptable level, while the background must remain clear to pass the picture information. The zero-order maximum must not be recorded because removal of this component by the filter would result in contrast reversal in the image (Hecht and Zajac 1973). To prevent this, a black dot was marked in ink on a cover slip and aligned with the zero order immediately before the film plane. It was found necessary to extend the dot into a cross to keep the central region of the filter clear during the long exposure required for a dense recording. The resulting filter is shown in figure 5 and the filtered image in figure 6.

Figure 6 Result for filter A.

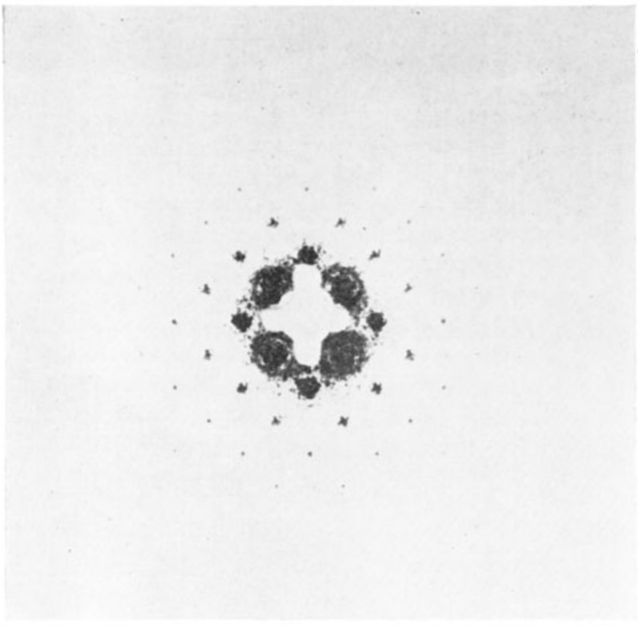

Figure 5 Filter A (1·5 mm beam illumination).

2.3 *Filter B*

A second, less precise filter was produced by photographic reduction of an array of equally sized black dots (figure 7), the required ratio of dot size to separation having been measured from a type A filter. The dot size was made 50% larger than required, in order to simplify alignment. The result of using this filter is shown in figure 8 and for comparison the best that could be achieved with pinhole spatial filtering is shown in figure 9.

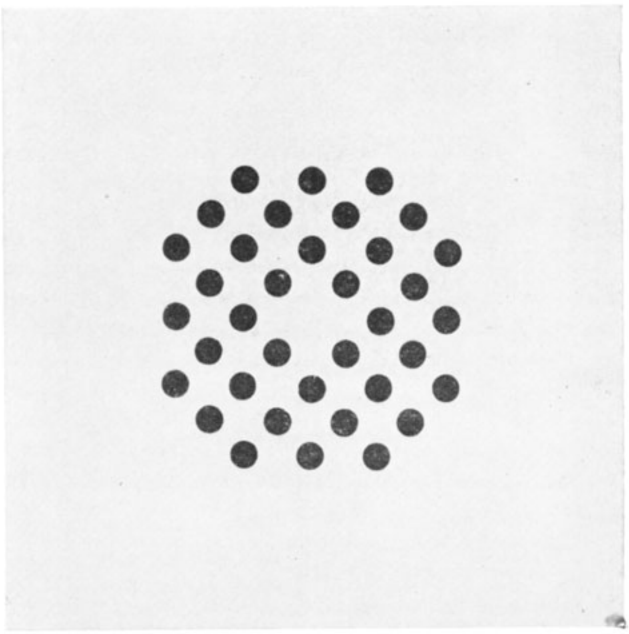

Figure 7 Filter B (photographically reduced).

Figure 8 Result for filter B.

Figure 9 Result for pinhole filter.

2.4 *Filter alignment*

The beam splitter displays a magnified image of the FT plane on a screen adjacent to the image plane (as demonstrated by F Lanzl at the European Optics Summer School, Reading 1975) so that what is actually transmitted by the filter can be seen. The filter is aligned for vertical, transverse and longitudinal position while viewing the magnified FT. Rotational alignment is achieved by rotating the object rather than the filter so as not to upset the former alignments.

3 Discussion

Both filters give results superior to those of pinhole spatial filtering, but judgment of the quality of the results is to a certain extent subjective. The results for filter A (narrow-beam object illumination) are highly dependent on the exposure used in producing the filter, better suppression of half-tone dots being accompanied by diminished picture clarity. With a grossly overexposed filter the resulting picture is similar to that of pinhole spatial filtering. This technique of narrow-beam object illumination obviates the need to go to a separate, specially prepared, object with the same half-tone dot spacing for producing the filter.

The result for filter B (photographically reduced) is grainy in comparison although sharper. The overall appearance of figure 6 (obtained with filter A) is thought to be more acceptable, although B would be more suitable for fast processing of a large number of different objects. In this case the objects' sizes would be photographically reduced to give the same dot spacing and in this respect a 4% tolerance could be accommodated by the 50% oversize filter. This method has been used many times (e.g. Watkins 1969) but for completeness it has been included.

The filtered images reveal detail not easily discernible in the original half-tone picture, in particular the lines on the forehead and joints of the fingers. The shades of grey have been produced in accordance with making the dark parts of the picture (the jacket) black and the light parts (shirt) white. Some detail has been lost on the darker parts of the picture (e.g. the hair line on the shadowed portion of the face) but the result is more acceptable when enlargements are to be made. This effect of losing detail in dark grey areas has been noticed in previous papers and so is not a peculiarity of our method.

The techniques developed here (Buckman 1977, Woolley 1977) are more suited to processing half-tones which are to be enlarged, but other uses are given in Dammann and Kock (1971) and Watkins (1969).

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