Optical Correlation for Terrain Type Discrimination

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ABSTRACT: *A useful operation for automatic terrain type discrimination is cross-correlation with a mask representing a basic shape element. This operation can be regarded as converting the distribution of elements of the given shape in the original terrain image into a brightness distribution in the correlogram. A two-channel noncoherent optical correlator suitable for performing such correlations is described. Correlograms showing the results of correlating sample terrain images with a bar-shaped mask are presented.*

AUTOMATIC TERRAIN TYPE DISCRIMINATION

THE discriminability of basic terrain types as seen on black-and-white, medium-scale aerial photographs seems to depend on at least two major factors:

(a) A given terrain type will generally have a characteristic spatial frequency spectrum; in particular, the spatial distribution of detail (or of contrasts) in samples of its image will tend to be similar. This factor can be used to discriminate among some easily distinguishable terrain types, for example to differentiate land from water, uncultivated from cultivated land, and urban from nonurban areas; in each case the first-mentioned type has the higher level of detail.

(b) In addition, a terrain type may be characterized by a high rate of occurrence of "elements" of a particular *shape* in its image. For example, areas of very rough terrain tend to contain jagged contour "boundaries"; wooded areas contain many small circular tree-shapes; cultivated land contains straight-line field boundaries; urban areas contain both straight lines (streets) and small rectangles (buildings).

Automatic terrain type discrimination is a key step in the direction of automatic aerial photo-interpretation. A general discussion of approaches to automatic photo-interpretation has been presented elsewhere (1). Experimental results of a simplified approach to terrain type identification, based on spatial frequency of detail distribution alone, have also been described elsewhere (2). These experiments showed that, while many terrain types (hydrographic features, cultivated land, urban residential areas) seemed to have characteristic spatial frequency signatures, other types (in particular wooded and industrial areas) could not be distinguished from one another on the basis of spatial frequency measurement.

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A more general approach to automatic terrain type identification involves the analysis of both the spatial frequency of detail and the rate of occurrence of "elements" of various shapes in the given image.

INSTRUMENTATION

In order to obtain rapid, simple measurements of the "degree" to which an image contains elements of a given shape, a simple two-channel noncoherent optical correlator was employed. This correlator uses flying spot scanner techniques to superimpose the projection of a shaped mask onto an aerial terrain photograph in a wide range of possible positions. It incorporates two optical chan-

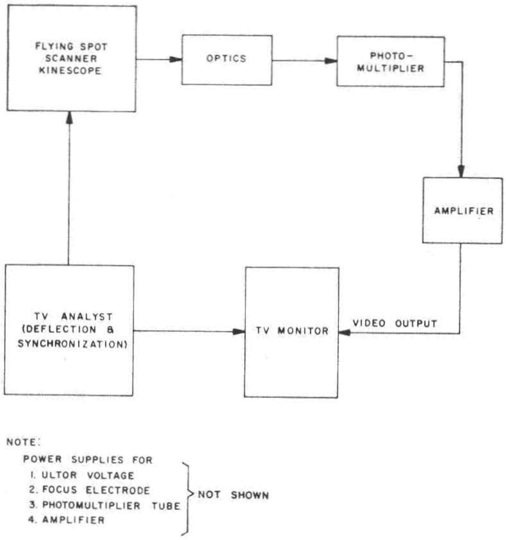

FIG. 1. Flying spot scanner unit—Block diagram.

nels, in one of which the mask is a "positive" of the given shape (transparent-on-opaque) and in the other a "negative" (opaque-on-transparent). By subtracting the signal obtained in the negative channel from that obtained in the positive channel, which effectively makes possible treating the transmitted light as a signed quantity (positive or negative), an enhanced degree of correlation is obtained. The use of color separation techniques makes possible physically combining the two channels up to (but not including) the photomultipliers. The cross-correlation of the mask and the photograph is displayed on a TV monitor.

With reference to the block diagram of Figure 1, the basic flying spot scanner unit consists of (1) a flying-spot kinescope; (2) deflection and synchronization circuitry; (3) optics and photomultipliers; (4) a video amplifier; (5) a TV monitor display; and (6–8) power supplies for the kinescope, photomultipliers and amplifiers.

The kinescope tube is a 5WP15 (5 inch, flat faced, P15 phosphor) with magnetic deflection and electrostatic focus. The phosphor has an extremely fast decay time, which permits scan of the tube at TV-compatible rates without degrading scanning resolution. In addition, it has a two-color peak light output (at 3,900 and 5,000 Angstroms); this makes possible using the scanner for two-color, dual-channel optical correlation studies.

The deflection signals are provided by a B & K Instruments TV Analyst, which also controls deflection amplitudes and linearities, filament power, and beam current. The Analyst feeds synchronizing signals to the kinescope and the TV monitor.

The scanning light spot is imaged on the transparency being scanned; the transmitted light is then collected and focused on the sensitive area of an RCA type 5819 multiplier phototube having S-11 spectral response (high between 3,500 and 5,500 Angstroms).

The video signal from the photomultiplier is fed to the transitorized video amplifier, the output of which intensity-modulates the TV monitor. This is a Miratel 17″ monitor which has been modified to accept external synchronization signals. The monitor has its own brightness, contrast and deflection controls. In addition, a DC restoring circuit in the monitor CRT grid insures that the DC component of the picture is faithfully reproduced.

The power supply for the kinescope is a Spellman high-voltage supply which provides the 27 kv. ultor voltage and the 3.3 kv. focus electrode voltage. The power supply for the multiplier phototube is a Northeast Scientific 300–1,500 volt supply. The video amplifier power supply provides ±12 volts. Oscilloscope monitoring of the video amplifier output is also provided for test purposes.

The dual-channel optical correlation configuration is shown in Figure 2. In this optical

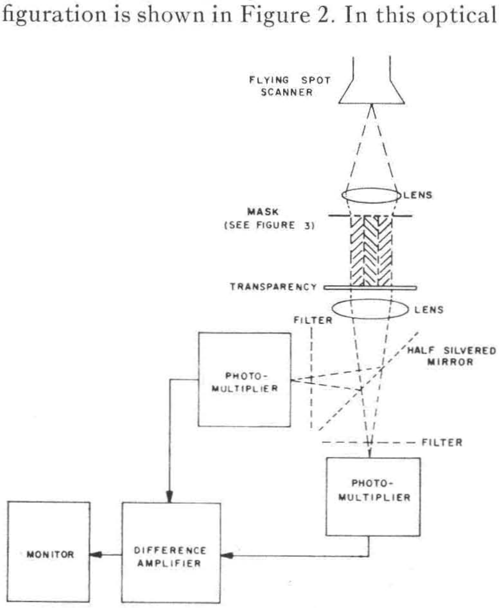

FIG. 2. Optical schematic of correlation.

correlator system, the light from the flying spot is approximately collimated and passed through a mask made from gelatin filters of two complementary spectral transparencies (Wratten filters Nos. 3 (Yellow) and 35 (Purple)). A typical mask is shown in Figure 3. This mask "shapes" the light beam into a core having the shape of the central portion of the mask, surrounded by a shell of complementarily colored light shaped like the annular portion of the mask. This two-color light beam passes through the picture transparency being analyzed and is then collected by a condensing lens. A half-silvered mirror is used to divide the light beam so that half of the light is focused on each of two identical photomultipliers. Filters are placed in front of these photomultipliers, so that each sees only one of the two colors in the beam. The video signals from the photomultipliers are fed into a transistorized difference amplifier, the video difference output of which is displayed on the TV monitor.

As the spot is scanned over the face of the kinescope tube, the shaped light beam systematically scans over the picture transparency. If the beam falls on a region of the picture which has the same shape, size and orientation as the central portion of the mask, and which contrasts strongly with its surroundings (e.g., white on black or black on white), one of the photomultipliers sees a maximum amount of light while the other sees no direct light at all; the rectified difference of the two video signals is thus a maximum. At the other extreme, if the beam falls on a region which has no correlation with the mask, so that the mean densities of the regions struck by the central and annular portions of the beam are equal, both video signals will be nonzero but their difference will be small; in fact, the photomultiplier gains are adjusted so that this difference is zero for the case of equal densities. The net result is that the output display represents the degree of correlation between the mask shape and the picture.

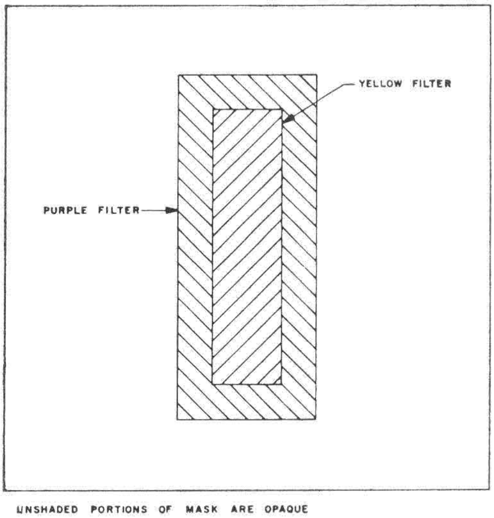

FIG. 3. Example of masks used in optical correlator.

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EXPERIMENTS

When a mask of a given shape is correlated with a terrain image at a given scale, *the resulting correlogram provides a measure of the degree to which "elements" of the given shape and size are present in the image.* Specifically, if the image contains "a lot of" the shape, the correlogram will contain much high contrast detail. The optical correlator can thus be a use-

TABLE 1

MASKS USED IN CORRELATION EXPERIMENTS

Mask No.	*Shape*	*Overall Dimensions*	*Border Width*
1	Rectangle	0.21″×0.59″	0.05″
2	Rectangle	0.14″×1.07″	0.04″
3	Rectangle	0.06″×1.03″	0.01″
4	Circle	0.35″ Diameter	0.05″
5	Circle	0.17″ Diameter	0.02″
6	Circle	0.08″ Diameter	0.01″

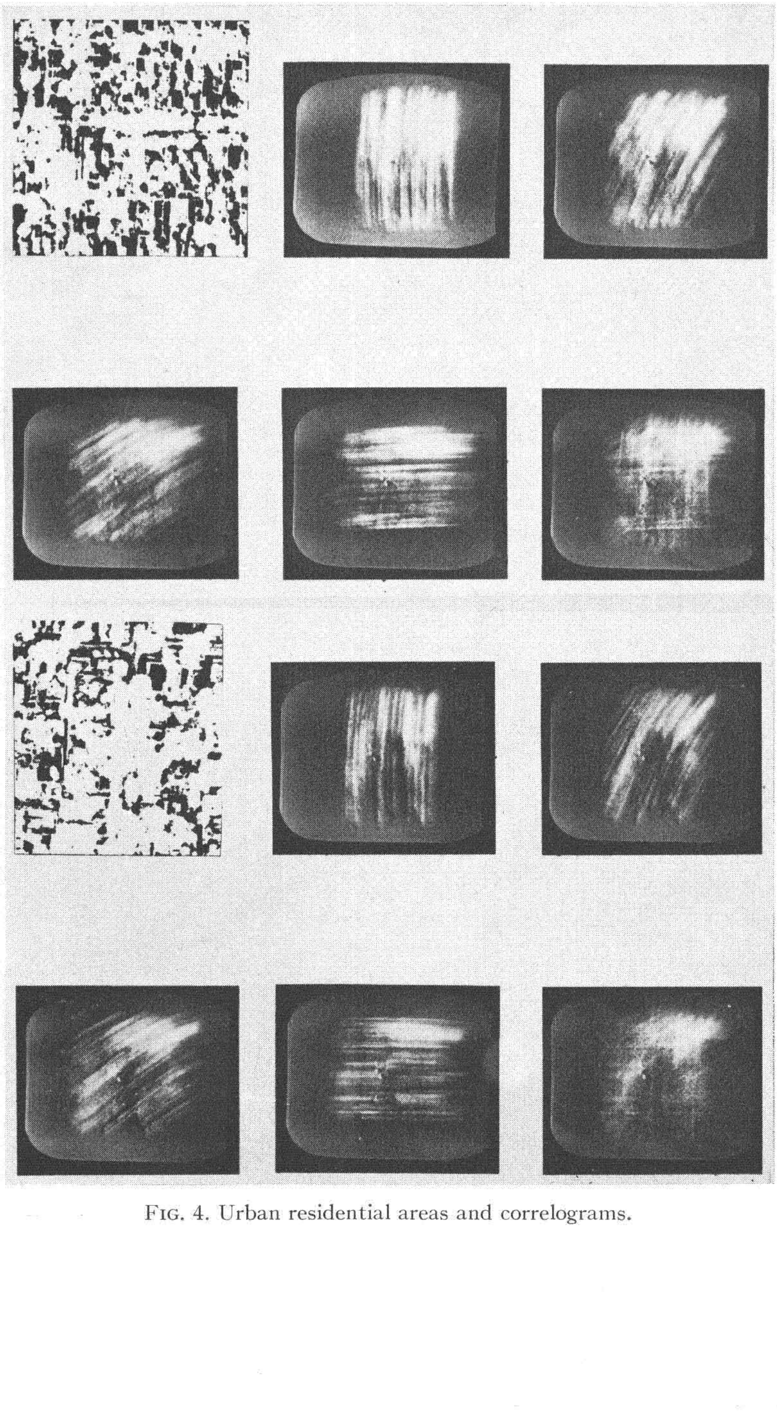

FIG. 4. Urban residential areas and correlograms.

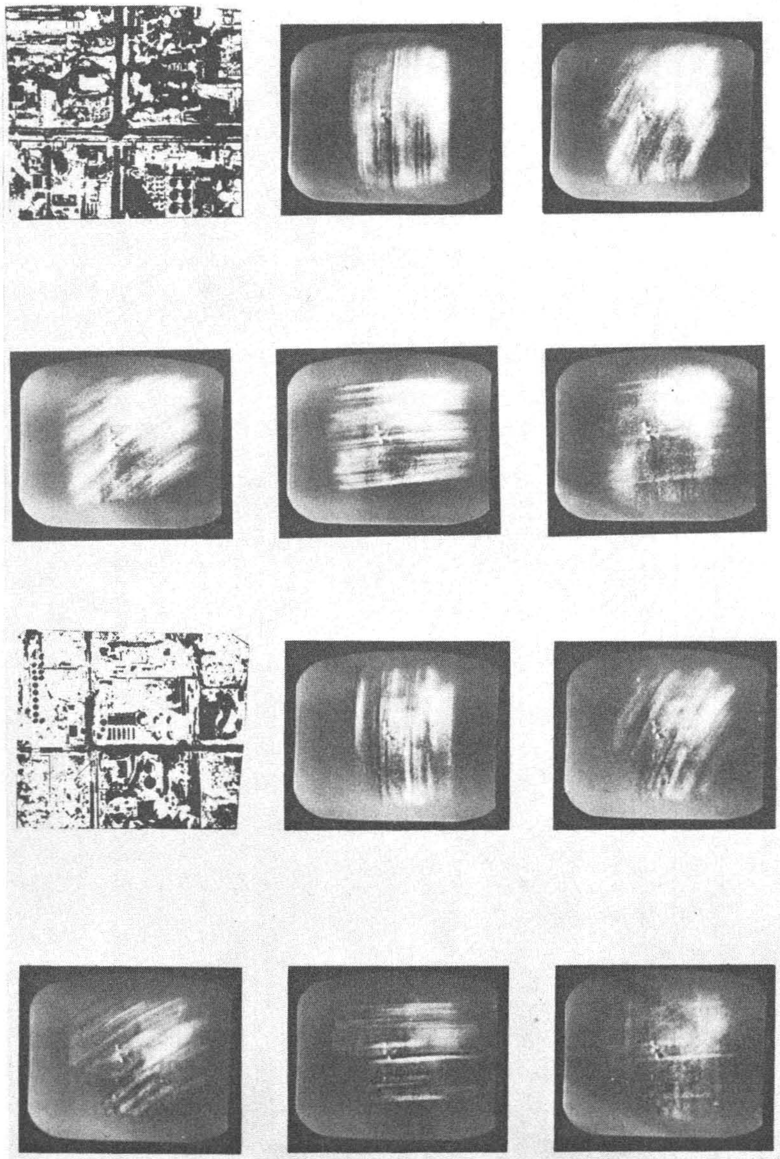

FIG. 5. Urban industrial areas and correlograms.

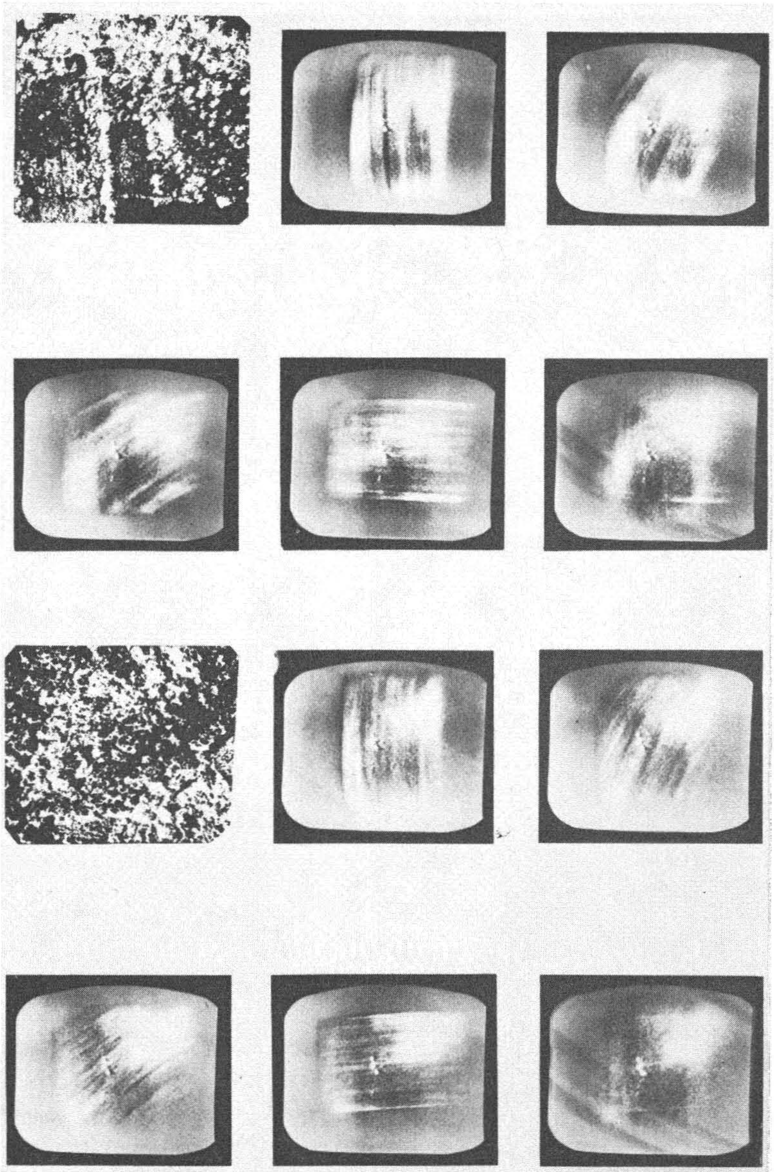

FIG. 6. Wooded areas and correlograms.

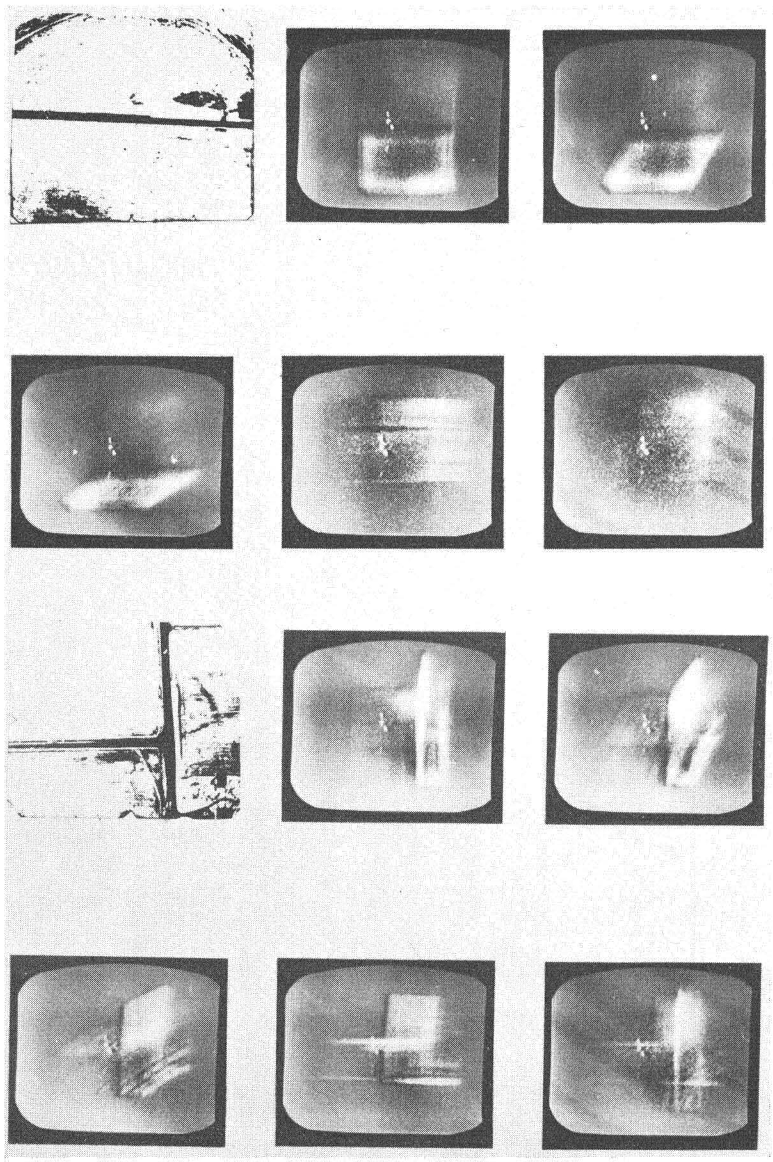

FIG. 7. Cultivated areas and correlograms.

ful tool in automatic terrain type identification.

Eight of the terrain imagery samples used in the experiment of (2) were correlated with masks of various shapes and sizes (primarily circles and rectangles). The masks used are described in Table 1.

The terrain samples, and correlograms corresponding to Mask No. 3, are shown in Figures 4–7. (Space limitations make it impossible to show the other correlograms here.) The terrain samples show two examples each of urban residential, industrial, wooded and cultivated areas. Five correlograms using this mask are shown for each of the eight terrain samples. The first four of these correspond to 0°, 30°, 60° and 90° orientations of the mask long axis with respect to the terrain sample vertical; the fifth is a multiple exposure which shows all four orientations.

It may be seen that the correlograms obtained from the urban terrain samples (Figures 4–5) contain appreciably higher levels of detail than do those obtained from the non-urban samples (Figures 6–7). This is seen in particular if the multiple exposure correlograms are examined. Correlation with a thin rectangle thus makes possible discriminating between the urban and the non-urban terrain types, which could not always be done on the basis of the isotropic spatial frequency analysis of (2).

References

1. "An Approach to Automatic Photointerpretation," presented at the 1962 MIL-E-CON; published in PHOTOGRAMMETRIC ENGINEERING, September, 1962.
2. "Automatic Recognition of Basic Terrain Types from Aerial Photographs," presented at the 1961 East Coast Conference on Aerospace and Navigational Electronics; published in PHOTOGRAMMETRIC ENGINEERING, March, 1962

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