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THE USE OF LINEAR FEATURE DETECTION TO INVESTIGATE THEMATIC MAPPER DATA PERFORMANCE AND PROCESSING

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THE USE OF LINEAR FEATURE DETECTION TO INVESTIGATE THEMATIC MAPPER DATA PERFORMANCE AND PROCESSING

INTRODUCTION

The objective of the work described is to investigate the geometric and radiometric characteristics of Thematic Mapper data through analysis of linear features in the data. The particular aspects considered are:

1. Thematic Mapper ground IFOV
2. Radiometric contrast between linear features and background
3. Precision of system geometric correction
4. Band-to-band registration
5. Potential utility of TM data for linear feature detection especially as compared to MSS data.

MODEL DESCRIPTION

In the context of this investigation linear features are defined as two close, parallel and opposite edges. Examples in remotely sensed data are features such as roads, rivers and bridges.

These features may be detected using a local operator which considers the arrangement of grey levels within a 5 by 5 pixel array. Details are given in Gurney (Ref. 1), and the model is described briefly below. Fourteen possible orientations of the linear feature in the local area are considered, these are illustrated in Fig. 1. For each orientation the sum of values in column B is compared to that in columns A and C. For dark linear features the sum in B must be less than both the sums in A and C by a given threshold. In addition B2 must be lower in value than both A2 and C2. For bright linear features the sums in A and C must be less than those in B. If these conditions are satisfied for any one of the 14 orientations then pixel B2 is considered as linear.

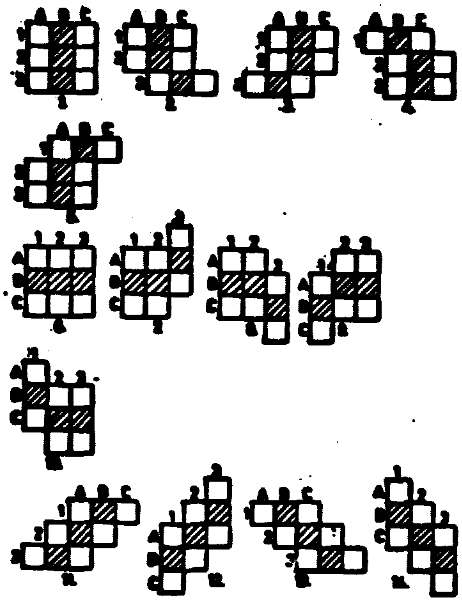

Fig. 1 Orientation of a Linear Feature Three Pixels Long Passing Through the Centre of an Array

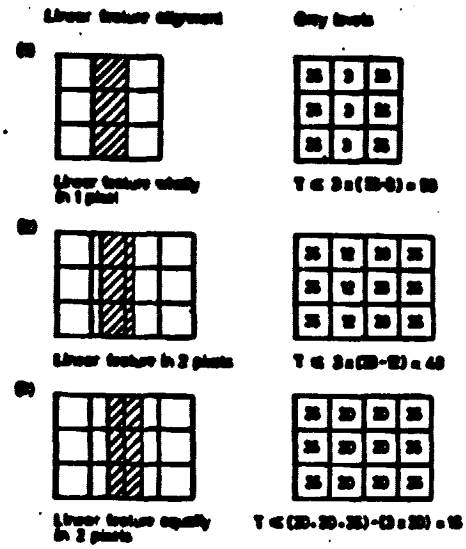

Fig. 2 Variations in Threshold with Linear Feature Alignment with the Pixel Boundaries

Results depend on two factors: the contrast between line material and background material, and the width of the feature. Any given feature may be assumed to be of constant width and contrast over the area of study. Therefore by varying the detector threshold it is possible to vary the accuracy with which the feature is detected. At low thresholds all of a feature may be detected, as the threshold is increased less and less of the feature will be detected.

An additional factor which must be considered is the alignment of the linear feature with the pixel boundaries. A simplified schematic representation is illustrated in Fig. 2. If a feature occupies only a single pixel then a higher threshold may be used to detect it than if it is equally divided between two pixels. Thus there is a wide variability between thresholds required to detect the full range of conditions.

If it is assumed that the present material in a pixel is linearly proportional to its contribution to the reflectance, and if it is assumed that every alignment of the feature with the pixel boundaries is equally probable then it is possible to derive a set of expressions relating detector threshold to detection accuracy, and feature width and contrast. Complete derivations are given in Gurney (Ref. 2).

For lines up to 1 pixel wide:

$$T = 3bW - (3bW - bW/2)\,A \qquad (1)$$

where

T = detector threshold
A = % accuracy / 100
b = contrast = (|mean background - mean line|)/100
W = line width as % pixel width

Similarly for lines 1 - 2 pixels in width:

$$T = 300b - \left[\frac{3b\ (100 - W)}{2}\right] \left[1 + A\right] \qquad (2)$$

Similar expressions may be derived for features up to four pixels in width. Beyond this value detection using this model will not be possible.

Contrast measurements may be made by selecting training areas corresponding to known linear and background materials and using the mean grey level values in these areas. Since the contrast measurement is based upon mean values it is clear that a high variance in a training area will lead to results which conform less closely to the theoretical expectations of the model.

Using this model it is possible to select good thresholds for features of known width and contrast. Also, by applying the procedure at a given theshold and calculating observed detection accuracy then it is possible to estimate feature widths, assuming that the pixel size is known. If all parameters are known then it is possible to obtain an estimate of pixel size. All of these applications have been tested using digital MSS and RBV data with good results.

SCENE CONTRAST AND VARIABILITY

Using MSS data it is generally the case that only one, or maybe two, bands provide sufficient contrast to allow linear feature detection. With TM data there are more bands providing good contrast. This allows the possibility of independent verification from band to band of feature width estimations.

Figs. 3 - 10 illustrate the results of linear feature detection using part of a scene of Iowa for August 1982. Each of Figs. 3-8 corresponds to detection of bright linear features in bands 1, 2, 3, 4, 5 and 7 using the same threshold (9) in each case. Variations between results therefore correspond to variations in contrast and scene variability. Band 6 data, corresponding to the thermal infra-red channel, were not used since no features were detected.

Results indicate that bands 1 and 3 give the best performance, with band 2 providing similar results. Bands 5 and 7 also perform well, but there is evidence of increased 'noise' i.e., pixels detected as linear which do not correspond to any recognizable ground feature.

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Fig. 3 Results of Linear Feature Detection for Iowa Test Area, Band 1

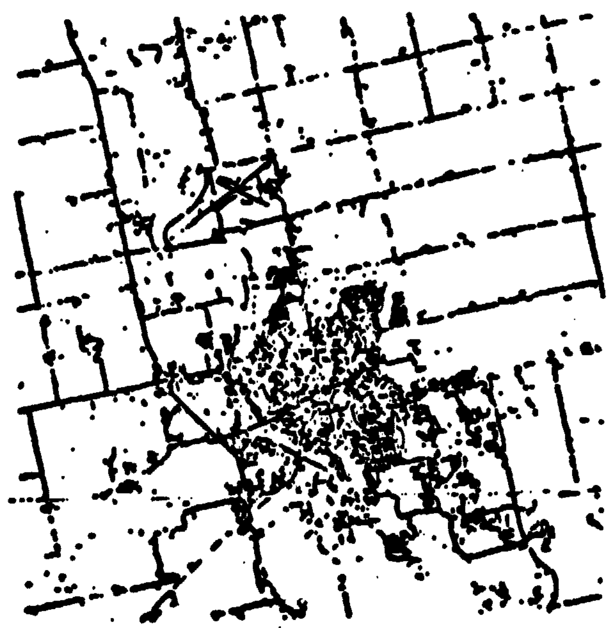

Fig. 4 Results of Linear Feature Detection for Iowa Test Area, Band 2

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Fig. 5 Results of Linear Feature Detection for Iowa Test Area, Band 3

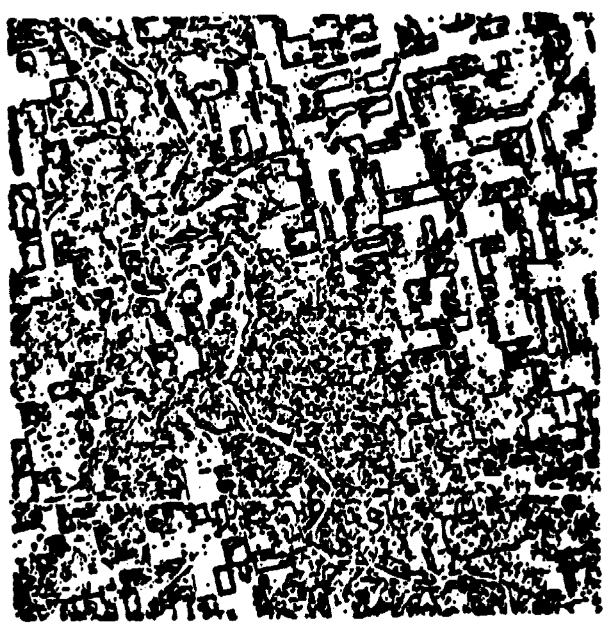

Fig. 6 Results of Linear Feature Detection for Iowa Test Area, Band 4

Fig. 7 Results of Linear Feature Detection for Iowa Test Area, Band 5

Fig. 8 Results of Linear Feature Detection for Iowa Test Area, Band 7

E and 4 results are very different from those for the other bands. The road pattern is not apparent, and the response seems to be driven by a linear effect at field boundaries.

Fig. 9 Results of Linear Feature Detection for Iowa Test Area, Band 4, Dark Lines

Fig. 10 Results of Linear Feature Detection for Iowa Test Area, Band 5, Dark Lines

Figs. 9 and 10 show the results of dark feature detection using bands 4 and 5. Other bands were unable to detect dark features successfully. Band 5 performs best in isolating the rivers without picking up excessive amounts of noise. Band 4 also show an interesting effect of evenly spaced 'dots' along field edges. The reasons for this effect are not known at present and will receive further study.

ESTIMATION OF LINEAR FEATURE WIDTHS

Estimation of feature widths using TM data was carried out in order to establish a lower limit on the width of detectable feature, and to confirm that the data are suitable for application of the model described previously.

Two test areas were selected which had different ground characteristics. The first corresponds to an area in North Carolina with a very homogeneous, flat background traversed by narrow gravel surfaced roads less than a pixel in width. The second corresponds to part of the Washington, D.C. beltway with a width between one and two pixels and traversing a much more variable background.

For each test area training areas were selected to establish line: background contrast. The line detection procedure was then applied at at least three different thresholds to each band of data for which contrast was sufficient to allow some degree of feature detection. For each of these the resulting detection accuracy was then calculated. Results were substituted in equations 1 and 2 in order to obtain an estimate of the feature width as a percent of the pixel width.

Tables 1 and 2 and Fig. 11 show results for the North Carolina area.

Table 1.

LINE: BACKGROUND CONTRASTS FOR NORTH CAROLINA TEST AREA

Band Number	Background		Line		Contrast	Deviation
	$\bar{X}$	σ	$\bar{X}$	σ		
1	64.5	1.5	107.4	14.9	.43	38.4
2	24.6	0.9	54.6	9.9	.30	36.3
3	21.7	2.6	69.3	15.6	.48	38.3
4	62.7	4.0	81.8	10.4	.19	75.4
5	41.8	6.8	139.6	26.4	.98	33.9
6	—	—	—	—	—	—
7	12.4	2.8	79.0	21.0	.67	35.8

Contrast = (|mean background - mean line|) /100.
Deviation = (σbackground + lineσ)/contrast.

Table 1 gives the contrast data and an additional parameter termed the deviation. The deviation is dependent on the amount of variation in the line and background data, and it essentially indicates the degree to which results are likely to accord with model predictions. High variances coupled with low contrast leads to considerable deviation from expected results. From previous experience using MSS data deviation values of 40 or less indicate very close correspondence between observed and predicted results.

Table 2.
RESULTS FOR NORTH CAROLINA TEST AREA.

	Detector Threshold	Observed Accuracy at 95% Confidence Level (%)	Estimated Road Width as % Pixel Size
BAND 1	9	81.7 - 87.5	21.8 - 25.8
	15	55.5 - 63.3	21.6 - 24.6
	18	35.4 - 43.2	19.8 - 21.8
	21	25.4 - 32.6	20.4 - 22.1
BAND 2	9	37.9 - 45.7	14.6 - 16.2
	12	32.5 - 40.1	18.3 - 20.0
	15	16.6 - 23.0	19.3 - 20.6
	18	7.1 - 11.7	21.2 - 22.2
BAND 3	12	75.0 - 81.6	22.2 - 26.0
	15	51.6 - 59.4	18.3 - 20.6
	18	36.8 - 44.6	18.0 - 19.9
	21	26.1 - 33.3	18.6 - 20.2
BAND 4	9	50.8 - 58.6	27.3 - 30.9
	12	34.4 - 42.0	29.5 - 32.4
	18	13.0 - 18.8	35.7 - 37.4
BAND 5	21	69.3 - 76.3	16.9 - 19.6
	24	63.0 - 70.4	17.2 - 19.7
	27	57.4 - 65.2	17.6 - 20.1
	36	45.1 - 53.1	19.6 - 22.0
BAND 7	18	61.1 - 68.7	18.2 - 20.9
	21	48.4 - 56.4	17.5 - 19.7
	24	42.2 - 50.2	18.4 - 20.5
	27	34.8 - 42.6	18.9 - 20.8

	Mean road width (%)	σ	Road width for 28.5 pixel
Excluding Band 4	20.0	2.0	5.7 metres
Including Band 4	21.5	4.7	6.1 metres

Table 2 lists the observed accuracies and calculated range of road widths for all bands and thresholds used. Results show a close correspondence between estimated widths at different bands and thresholds, with the exception of results for Band 4.

Band 4 gives a larger mean width and also shows more variability in the estimates for different thresholds. This is to be expected from the higher deviation value observed for this band. The estimated road width from all these data is about 6 metres assuming a 28.5 by 28.5 metre pixel.

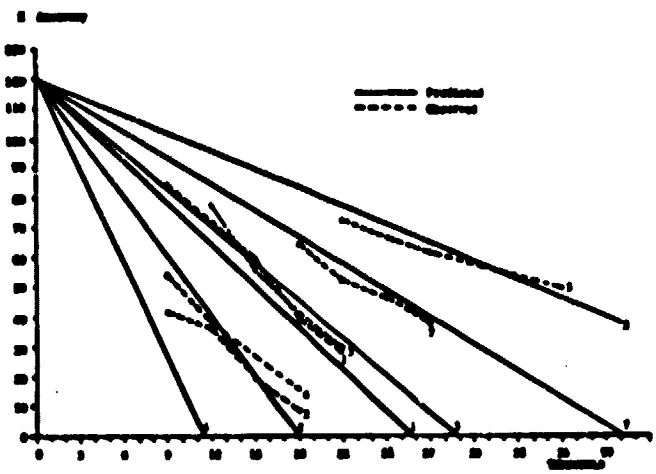

Fig. 11 Predicted vs. Observed Results for N. Carolina Test Area

Fig. 11 shows a plot of predicted results assuming a 6 metre road width, against actual observed results. There is a very close correspondence for all but the Band 4 data. The actual width of the roads in this area is not known at the time of writing, but is believed to be close to the estimate given here.

Table 3.
LINE: BACKGROUND CONTRASTS FOR WASHINGTON, D.C. TEST AREA

Band Number	Background		Line		Contrast	Deviation
	$\bar{X}$	σ	$\bar{X}$	σ		
1	56.6	1.6	73.2	8.5	.17	59.4
2	21.6	0.8	32.1	5.0	.11	52.7
3	22.8	1.96	36.6	7.3	.14	66.1
4	36.4	2.96	43.1	2.4	.07	76.6
5	38.6	5.7	60.7	10.1	.22	71.8
6	115.1	0.8	115.7	0.5	.01	130.0
7	13.1	2.3	28.2	8.4	.15	71.3

Contrast = (| Mean background - Mean line |)/100.
Deviation = (σbackground + σ line)/contrast.

Tables 3 and 4 and Figs. 12 and 13 show results for the Washington, D.C. area. Band 6 and Band 4 were included in the contrast measurement, but were not used subsequently because of the poor contrast levels observed. In general, contrasts are considerably lower than for the North Carolina area reflecting both the difference in materials and the lower sun angle of this November scene. Deviation values are also correspondingly higher.

Table 4.
RESULTS FOR WASHINGTON, D.C. TEST AREA

	Detector Threshold	Observed Accuracy % at 95% Confidence level	Estimated road width as % pixel size
BAND 1	15	83.6 - 94.6	172.5 - 176.9
	18	69.9 - 84.7	170.1 - 176.2
	21	47.9 - 65.3	171.2 - 179.5
	24	45.9 - 63.5	164.8 - 172.6
BAND 2	9	65.5 - 81.2	180.3 - 187.8
	15	31.9 - 49.3	173.1 - 182.1
	18	19.5 - 35.1	167.3 - 176.1
BAND 3	9	87.4 - 97.0	179.8 - 183.9
	15	68.3 - 83.3	170.1 - 176.4
	13	58.9 - 75.5	165.1 - 171.9
BAND 5	9	58.0 - 74.8	198.8 - 209.3
	18	32.7 - 50.1	196.9 - 209.6
	27	17.3 - 32.7	189.1 - 200.8
BAND 7	9	75.2 - 88.8	184.7 - 191.3
	15	31.9 - 49.3	189.3 - 201.1
	18	9.1 - 22.1	198.3 - 210.0

	Mean road width (%)	σ	Road width for 28.5 m pixel
Bands 1 - 3	174.96	5.14	49.9 metres
Bands 5, 7	198.30	6.63	56.5 metres

Estimated road widths are given in Table 4. These show a close correspondence between results in bands 1, 2, and 3 giving a width estimate of 175% of a pixel which is close to 50 metres for a 28.5 m pixel. The true width of the beltway is known to be 48-50 metres in this area so that this result corresponds very closely to the true width. However results for bands 5 and 7 give a width estimate close to 56 metres which is an over-estimate of the width.

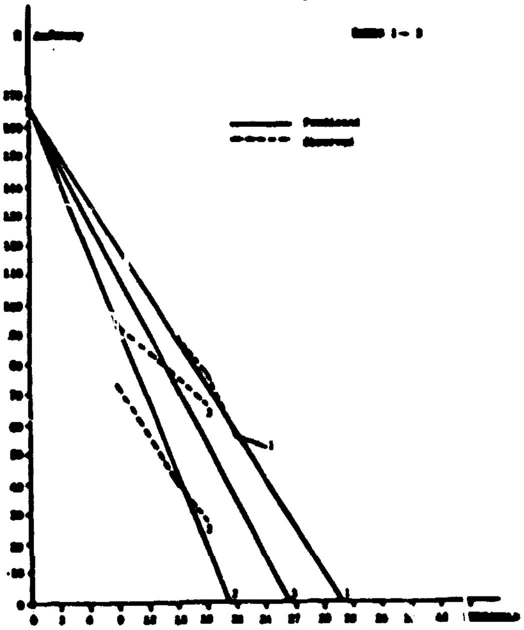

Fig. 12 Predicted vs. Observed Results for Washington, D.C. Test Area

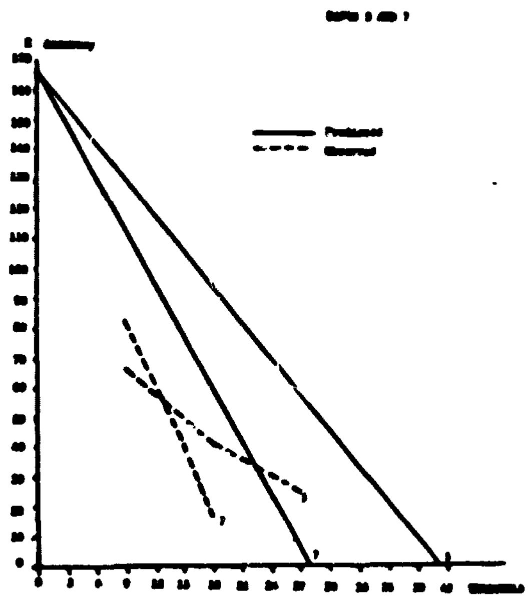

Fig. 13 Predicted vs. Observed Results for Washington, D.C. Test Area

Figs. 12 and 13 illustrate predicted against observed results assuming a road with of 50 metres. The correspondence is less close than for the North Carolina data, and is very poor indeed for bands 5 and 7. The deviation values for these bands are both very high. However, it is also possible that the Band 7 result is due to a mis-estimation of the contrast since the slope of the observed line could intercept the y axis at the same location as all other bands, as required by the model.

It is concluded that the model developed here may be used to estimate the width of unknown features in TM data. In optimum conditions with high contrast and homogeneous materials it appears possible to measure widths as little as one-quarter of a pixel. This has considerable potential for mapping purposes. Contrast levels observed compare favorably with those for MSS data, although variances and hence deviation levels tend to be greater. However, the increased dimensionality of the TM data allows independent verification of results from band to band so that the results may be considered to be more reliable. Pixel size is confirmed by these experiments to be 28.5 metres.

BAND: BAND REGISTRATION

Using linear feature detection results it is also possible to investigate band to band registration. Registration differences will be apparent as shifts in the locations of detected features from band to band.

Fig. 14 I-95 Interchange, Bands 1 and 3 Superimposed

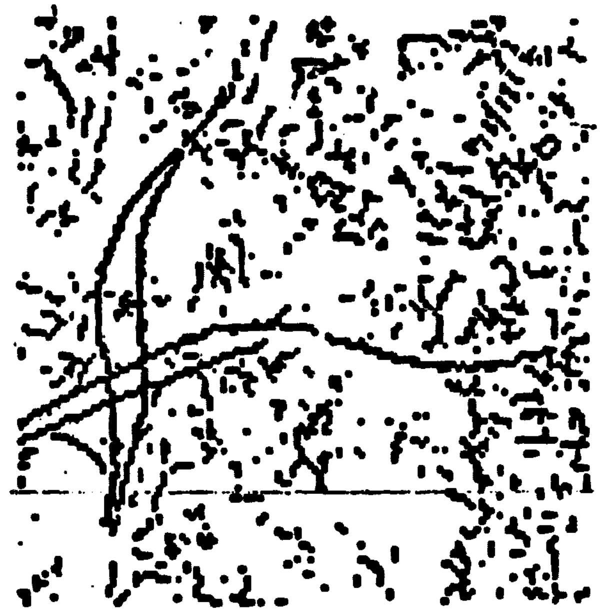

Fig. 15 I-95 Interchange, Bands 1 and 7 Superimposed

Figs. 14 and 15 illustrate the superposition of results of linear feature detection from part of the Washington, D.C. scene corresponding to the I-95: Beltway interchange. Fig. 14 shows bands 1 and 3 together; band 1 results are in black and band 3 in gray. There is clearly a close correspondence between the two. Fig. 15 shows bands 1 and 7 together. In this case there is a clear mis-registration with the band 7 data being shifted both to the right and down with respect to the band 1 data. This result was also observed for band 5 data against band 1. Bands 5 and 7 showed a slight difference that was difficult to assess because of the poor detection rate in band 5.

This method is less suitable for measurement of misregistration than it is for graphically illustrating that it exists. However, it does appear that there is a shift between primary and cold focal planes of less than 1 pixel in both directions that is apparently greater in the x direction than in the y direction.

CONCLUSIONS

It has been shown that TM data may be used to estimate TM pixel size and to illustrate band: band mis-registration. Further, the geometry and radiometry of the data are sufficiently precise to allow accurate estimation of the widths of linear features. In optimum conditions features one quarter of a pixel in width may be accurately measured. These results have considerable potential for applications for hydrological and topographic mapping.

ACKNOWLEDGEMENTS

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REFERENCES

1. Gurney, C.M., Threshold selection for line detection algorithms, Trans Geosci and Remote Sensing Vol. GE-18, 2, 1980, pp 204-211

2. Gurney, C.M., The use of contextual information in remote sensing, Ph.D. thesis, University of Reading, 1980.