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Detection of subpixel woody features in simulated SPOT imagery

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ABSTRACT: A method for detecting small woody features in digital imagery was developed. Woody features, ranging in size from hedgerows to strips or patches several trees wide, were tested. The classification method correctly detected all subpixel woody features larger than hedgerows and identified about 20 percent of the hedges.

1 INTRODUCTION

In Britain, changes in farming practices since the 1940s have resulted in tree, pond, and hedgerow removals, larger field sizes, and less frequent crop rotations (Body 1982, Sturrock & Cathie 1980). Although tree and hedge removals are small land cover changes, they are significant landscape and habitat changes. These changes which decrease habitat diversity affect animal and bird populations. Studies have shown that birds and mammals utilize diverse landscape elements (Pollard & Relton 1970, Wegner & Merriam 1979) and that their distributions are related to the shape, size, and spatial arrangement of these landscape elements (Forman & Godron 1981, Helliwell 1976).

Monitoring and quantifying agricultural change is necessary for effective land use planning and wildlife habitat management. Computer-assisted methods using remotely sensed data could provide timely monitoring of changes in woody vegetation which affect scenic beauty and wildlife.

Since linear woody features are often subpixel targets or features smaller than the pixel size of the image, pixels containing these features are usually mixed pixels or pixels containing two or more land cover classes. Because the spectral values of mixed pixels containing woody features frequently do not correspond to the spectral values of woody vegetation, conventional multispectral classification techniques which operate on single pixels are problematic and repeatedly result in mixed pixels being placed in constituent or extraneous classes. A method for detecting subpixel woody features in digital imagery was developed. Unlike conventional classification techniques, this method incorporates information about adjacent classes and mixture phenomena at the individual pixel level.

2 DATA AND STUDY SITE

As the method developed is concerned with detecting small landscape features, it was appropriate to use digital imagery of a high spatial resolution. Since SPOT data was not available when the project was begun, simulated SPOT data was acquired for the project.

In 1984, the National Remote Sensing Centre (NRSC) in Farnborough, England organized a campaign to investigate the usefulness of SPOT imagery prior to its availability. Simulated SPOT data was collected over a wide variety of sites in the United Kingdom in order to test a number of applications (NRSC 1985). This imagery was also sold to the public and, subsequently, a scene was acquired for this project. Of the 39 test sites imaged, the Winchester data flown on 6 July 1984 was selected because it is representative of agricultural lands in lowland Britain and because it contains numerous linear woody features.

A subscene of the Winchester image was then selected for use in developing and testing algorithms. This subscene, approximately 17 sq km on the ground, is located southeast of the city of Winchester in a gently rolling area of mixed farmland and woodland.

Panchromatic photography, commissioned by the Planning Department of the Hampshire County Council, was used to locate and map woody vegetation within the subscene. This photography was flown by Meridian Airmaps Limited on the evening of 28 July 1984 at 1:10000 scale. Four categories of woody vegetation were mapped: hedgerows, single trees, single rows of trees, and denser woody features. Specific species were not identified. The airphoto interpretation was checked by surveying parts of the study site on the ground.

2.1 Comparison of real and simulated SPOT imagery

The simulated imagery was flown by Hunting Geology and Geophysics Limited with a Daedalus DS-1268 multispectral scanner. Daedalus channels 3 through 7 were used singly or in combination to simulate the SPOT channels (Hunting Geology and Geophysics Ltd. 1984). The wavelengths of these simulations do not exactly match those of the real SPOT bands. The effect of these differences is not known.

Table 1. Comparison of SPOT and simulated SPOT channels.

Channel	SPOT wavelengths in microns	Daedalus channels	Simulated SPOT wavelengths in microns
S1	0.50 - 0.59	3	0.52 - 0.60
S2	0.615 - 0.68	4+5	0.605 - 0.69
S3	0.79 - 0.89	7	0.76 - 0.90
P	0.51 - 0.73	3+4+5+6	0.52 - 0.75

The spatial resolutions of real and simulated SPOT data are the same: 20m in the three multispectral bands and 10m in the panchromatic band at nadir viewing.

Since the simulated SPOT imagery was flown by high-altitude aircraft, it is less map-accurate than satellite imagery. Distortions in aircraft imagery are caused by changes in aircraft altitude and angular orientation during scanning. Since spatial fidelity is not important in this project and since techniques for geometric correction inevitably involve interpolation which further "mixes" the information in the pixels, there has been no attempt to geometrically correct the imagery.

Another difference between real and simulated SPOT data is the sun angle. The simulated imagery was collected at about mid-day and, consequently, shadows are narrow or absent. Real SPOT imagery of the United Kingdom would be recorded in the morning and would contain larger shadows, which are expected to be useful in detecting hedgerows.

2.2 Preprocessing of simulated imagery

The preprocessing of the simulated imagery included two image rectification techniques applied to the raw data recorded by the Daedalus scanner (Hunting Geology and Geophysics Ltd. 1984). One was a linear scaling technique by which the swath was scaled to fit a map. The second technique was an S-bend correction which rectified distortions caused by the radial rotation of the scan mirror. This latter correction is unnecessary in data from push-broom scanners like those on board the SPOT-1 satellite.

During the course of the project, it was discovered that the three simulated multispectral bands were not properly registered to one another. Whether this problem is due to preprocessing or subsequent processing is presently unknown. The misregistration was verified by two methods:

1. By locating the edges of obvious features in printed arrays of DN values and comparing the locations in each spectral band.
2. By visually comparing registered and unregistered colour-composite images on adjacent display terminals.

This misregistration was corrected by shifting band 1 one pixel to the west and by shifting band 3 one pixel to the east.

3 PREVIOUS METHODS FOR CLASSIFYING MIXED PIXELS

In the literature, there are two types of methods for classifying mixed pixels. In the first type, mixed pixels are treated as whole entities and are assigned to a single class. It is assumed that the class assignment corresponds to the dominant constituent class. Textural (Haralick 1979) or contextual information (Gurney & Townshend 1983) may be incorporated into the classification procedure.

The second type of classification method for handling mixed pixels involves pixel splitting, the process of breaking a pixel into its component parts and classifying the fractions. Pixel splitting methods are based on the premise that the gray tone represented by a digital number of a pixel is proportional to the gray tones of the constituent classes. Four statistical procedures for pixel splitting have been found in the literature: weighted averaging (Marsh et al. 1980), linear regression (Nalepka et al. 1972, Richardson & Weigand 1977), maximum likelihood classification (Chittineni 1981, Horwitz et al. 1971), and linear discriminant analysis (Marsh et al. 1980). The first three of these procedures have been or could easily be used in the three-class case, the usual condition for pixels containing narrow woody features.

For a number of reasons, the methods already developed seemed inappropriate for this project. Treating mixed pixels as whole entities was not appropriate because linear woody features are seldom the dominant constituent class. The variances of the major classes in the subscene are significantly different; the variance of woody vegetation is significantly larger than the variance of any other class. Therefore, it seemed unsuitable to use either weighted averaging which does not take variance into consideration or linear discriminant analysis which requires the variances of all classes to be equal. The linear regression method was eliminated since development of the model requires specific information regarding the proportions of component parts within mixed pixels. The small sizes of the features of interest and the geometric distortions in the image make collection of this specific information difficult. Finally, the maximum likelihood method seemed inappropriate because it is the most computationally demanding of the known methods. Since various postprocessing algorithms are planned, it seemed desirable to conserve computer time.

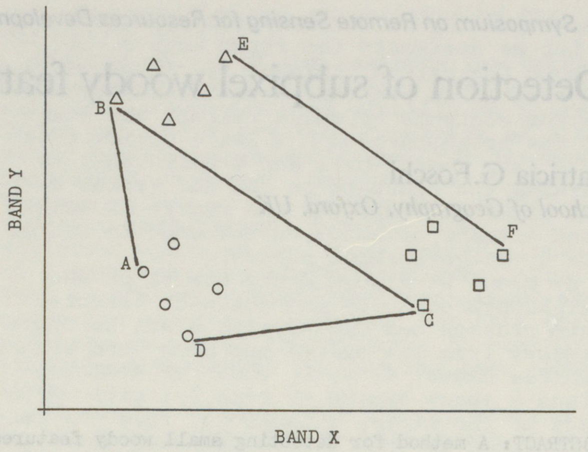

Figure 1. Classification zones in a hypothetical feature space.

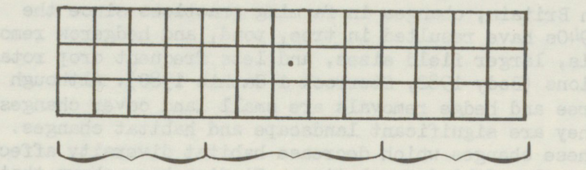

Figure 2. Three parts of the 13 x 3 window.

4 NEW METHOD FOR CLASSIFYING SUBPIXEL WOODY FEATURES

The classification method developed for this project discriminates selected subdivisions of feature space. Figure 1 illustrates the subdivisions of interest in a hypothetical feature space which was constructed using two spectral channels and five pixels from each of three classes. If the triangles and squares represent two crops or any two land covers present in adjacent fields, pixels containing the boundary between the fields are expected to fall between the line joining points B and C and the line joining points E and F. If, however, the boundary between the fields includes a linear woody feature and if the circles represent woody vegetation, pixels containing this boundary are more likely to fall within the polygon circumscribed by points A, B, C, and D. Locating a pixel in one of these two zones is the basis for classifying it in either the class of normal boundaries or the class of small woody features.

Nine major classes present in the study site were plotted in the two-dimensional feature spaces whose axes are pairs of the multispectral bands. The panchromatic data was not used. Visual inspection of the plots revealed that bands 1 and 2 are highly correlated and that the greatest separation between classes occurs when bands 2 and 3 are used. Therefore, only bands 2 and 3 were included in subsequent processing; band 1 was eliminated due to its redundancy.

A training set for woody vegetation, consisting of 80 pixels, was selected from a large patch of deciduous woodland in the subscene and was used in all feature-space calculations.

A 13 x 3 window was employed to locate its central pixels in the two-channel feature space. As shown in Figure 2, the window was divided into three parts: two training sets for the adjacent fields and a central region expected to contain mixed pixels. These two training sets and the training set for woody vegetation were used to construct a feature space for each window. The central pixels in the window were then

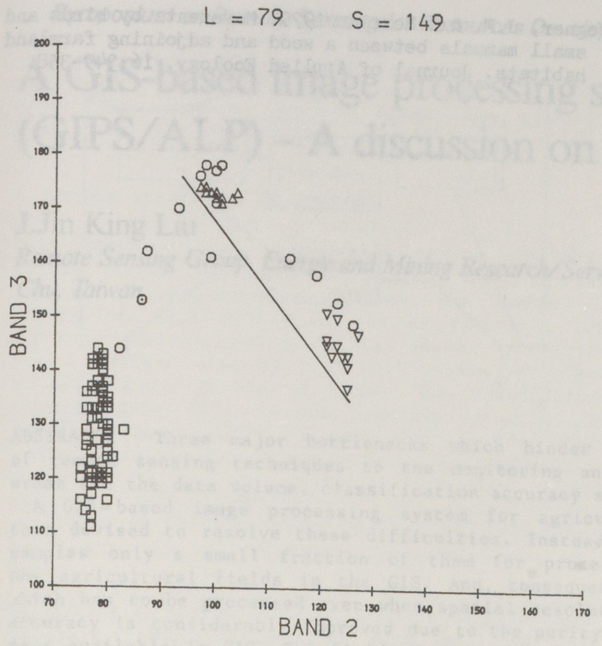

Figure 3. Feature space created from window data.

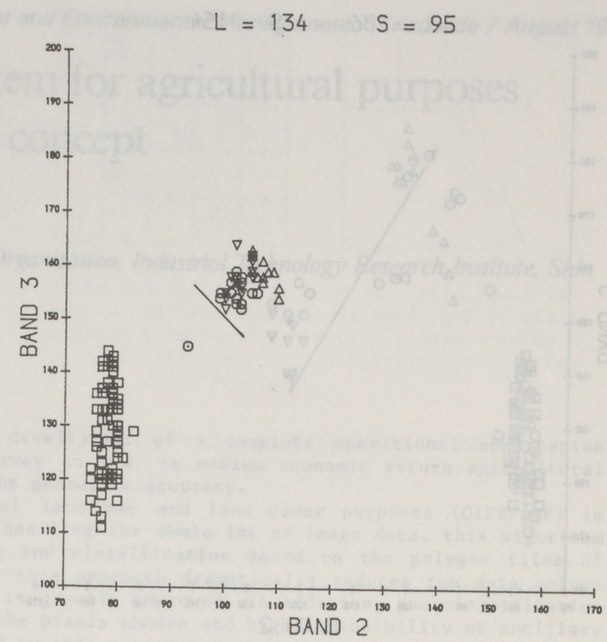

Figure 4. Feature space created from window data.

classified by their locations in this space.

Examples of this classification method are shown in Figures 3-5. In these figures, squares represent woody vegetation, triangles pointing downward and triangles pointing upward represent the two training sets derived from the window, and circles represent the central pixels in the window. The circle with the dot indicates the pixel at the exact centre of the window. L and S refer to the line and sample of the pixel in the centre. In each example, the circles to the left of or below the line are placed in the class of small woody features.

5 RESULTS AND DISCUSSION

Twenty subpixel woody features and two simple field boundaries were selected from the study site for the initial testing of the method. The woody features greatly vary in width and length and include hedgerows, a hedge with one large tree, single rows of trees, and strips or patches two or more trees wide. All of the woody features selected were found to be incorrectly detected by a standard nearest neighbor classification. Most of the features were also unable to be either detected or adequately interpreted by visual inspection of a colour-composite image.

The classification method developed in this project correctly classified all subpixel woody features larger than hedgerows, properly discriminated the simple field boundaries, and identified about 20 percent of the hedges. Further testing is in progress.

Use of the panchromatic band will be incorporated into future classification schemes and is expected to improve classification accuracy for hedgerows.

Figures 3-5 illustrate the three possible ways the training sets may be situated in feature space. The roughly triangular shape, suggested by the training sets in Figure 3, is the most typical arrangement. When adjacent farm fields contain the same land cover, the clusters of their training sets overlap as in Figure 4. In both of these cases, pixels containing small woody features are likely to be pulled toward the woodland cluster. However, when the three training clusters are positioned along a straight line, as in Figure 5, pixels containing small woody features are less likely to be pulled past the middle cluster into the zone designating woody features. This last case only occurred once in the 22 features tested.

Before this method can be completely operational, a

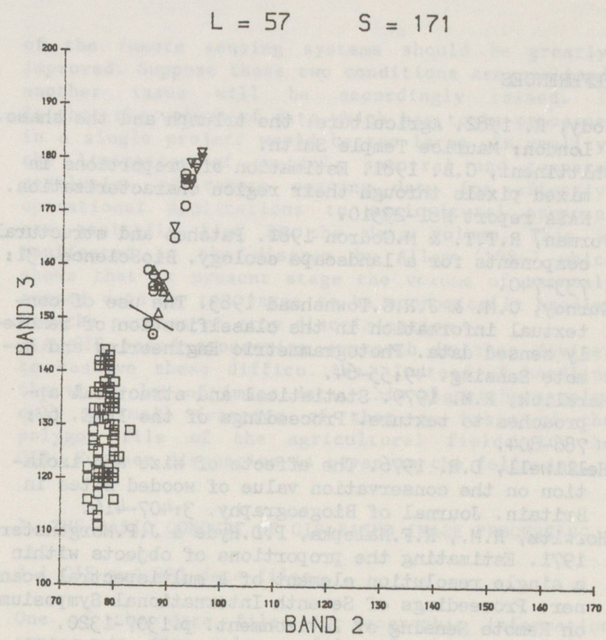

Figure 5. Feature space created from window data.

few practical problems must be addressed. The most important problem is determining an optimal size for the window. The 13 x 3 window is frequently too big to fit into the small corners of farm fields. This inability to fit also contributes to the creation of anomalies in the training sets. Four anomalous training pixels are shown in Figure 6; the correct position of the division line in this feature space is also shown. A smaller window, like a 9 x 1 window, would fit into smaller fields and would create fewer anomalies. A smaller window would also be more efficient since it would less frequently use the same pixels in its calculations.

The automated use of this method could provide an effective means of mapping and monitoring the presence of subpixel woody features in satellite imagery. Also, the use of this method could provide the basis for determining specific quantitative information of use to ecologists and resource managers.

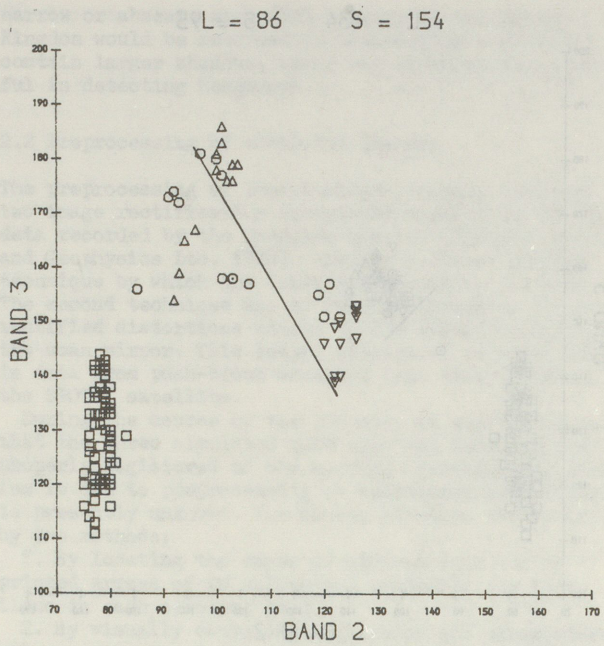

Figure 6. Feature space containing four anomalous training pixels.

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