A CONDITIONAL PROBABILITY AND STATISTICAL STUDY OF CROP DISCRIMINATION USING RADAR IMAGES

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During the last few years a number of studies using radar for the discrimination of natural vegetation and crop types have met with modest success. With the possibility which now arises of obtaining numerous multi-spectral images, there is a pressing need to define both the agricultural systems constraints within which multiband radar sensing must take place and at the same time to develop methods for rapid and accurate analysis of multi-dimensional data. This paper is concerned with both problems.

TEMPORAL AND SPATIAL COMPONENTS OF CROP DISCRIMINATION

First, an outline is given of the complex spatial and temporal variances with which remote sensing must contend in crop studies. Details are given of actual agricultural time tables at selected sites in the United States over several seasons in order to define probabilistic distributions of crop response values for various imaging systems. Since it follows that remote sensor returns for any crop have some probability distribution in both a temporal and spatial sense, probability models of various types must be evaluated. Several such models are explored in the paper.

In addition the contribution of temporal and spatial (statistical) elements to crop discrimination are also explored. As one extreme, a limited number of channels of data may be obtained at several times during the course of a growing season, and the natural variations in crop height, vigor, harvesting and so on may be used to provide a temporal information matrix. Alternatively, multiple wavelengths and/or polarizations obtained at the same time may be able to substitute for temporal information. Various mixes of these two extremes are analyzed and some of the consequences of various probability levels of crop discrimination and identification are discussed.

STATISTICAL CROP DISCRIMINATION

The second portion of the paper consists of a detailed analysis of crop data obtained with radar imagery. Three different methods of crop type discrimination are considered: (1) discrimination using spatial conditional probabilities in conjunction with a nearest neighbor-probability model; (2) discrimination using standard cluster analysis and principal components analysis; and (3) discrimination using a Bayes' decision model.

The data consisted of photographic density values taken from three sets of K-band radar images of a test site near Garden City, Kansas. The type of imagery and the date it was obtained are: (1) Monopolarization (HH, horizontal transmit and receive), August, 1965; (2) Multiple-polarization (HH; HV, horizontal transmit and vertical receive), September, 1965; and (3) Multiple polarization (HH, HV, VV, VH), July, 1966. Information on crop type, height, ground cover, moisture, soil moisture, roughness, and row direction was collected for each run.

Conditional Probability Approach

The conditional probability model is a clustering method which gives priority to the measurement vectors for which the conditional probability of occurrence in the spatial region is higher than the joint probability of its occurrence in measurement space. For example, a multi-spectral image is partitioned into a number of connected spatial regions. The conditional probability distribution for each region is computed and compared with the joint probability distribution for the entire multi-spectral image. All the measurement vectors which have a higher conditional probability in a given spatial region than their probability in the multi-spectral images are given priority in forming clusters. The initial cluster is formed around a center, the measurement vector, with the highest conditional probability. The resulting cluster contains all those measurement vectors which are sufficiently close to the center. Closeness is measured by Euclidian distance and by the difference in probability between the center vector and the measurement vectors being considered for inclusion into the cluster. When there are no more measurement vectors which can be added to the cluster, a new group is started with the center being the next unused measurement vector which has the highest conditional probability. The process continues iteratively until no measurement vector qualifies as a center or all points are included in a cluster.

Using the conditional probability model three clusters were formed. The first cluster consisted primarily of bare ground, wheat stubble, wheat stubble mulch and wheat stubble and weeds. The second cluster was mainly alfalfa, grain sorghum, corn and weeds. Sugar beets formed the third cluster. As a result of this analysis we have been able to discriminate three general categories consisting of (1) idle land; (2) medium intensity crop land (with the exception of weeds); and (3) high intensity crop land.

Cluster Analysis Approach

The second method of grouping the data consisted of cluster analysis using the multiple linkage model. The similarity values used were the Euclidian distance coefficient and simple correlation coefficient. There are two important differences between cluster analysis and the conditional probability approach. First, cluster analysis using multiple linkage does not weigh the measurement sets by conditional probability and, second, the starting points of the groups are not predetermined.

Application to the July data with four polarizations indicates that Euclidian distance is the most powerful similarity coefficient. Little discriminating potential was indicated by the correlation coefficient which suggests that reciprocity holds between the two radar cross-polarization returns. The crop discrimination achieved was slightly inferior to that obtained with the conditional probability model.

For comparison purposes a principal components analysis was also used on the radar imagery. The results suggest that the first two components account for more than ninety-five per cent of the variance. This indicates that the return from the four polarizations analyzed is relatively well correlated.

Bayes' Decision Approach

From statistical decision theory we know a Bayes' decision will give optimum classification when ground-truth is available. Training sets were formed from the ground-truth, each consisting of all measurement vectors of the same category. Bayes' decision classification was used on the July, 1966, data consisting of four polarizations obtained for a single time period, and on the August and September, 1965, data consisting of one polarization (HH).

The results suggest that better discrimination can be obtained using time sequence imagery than can be obtained using multiple polarization imagery at a single time. However, since the model depends on an adequate supply of ground truth, such a system is dependent upon the acquisition of controlled time sequence imagery.

While crop discrimination in this study was confined to radar imagery, the techniques could just as easily be applied to imagery from other remote sensing systems. It is probable that the best discrimination would be obtained by combining imagery from several congruent data sets from a number of sensing systems.