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MAC EUROPE '91 CAMPAIGN: AIRSAR/AVIRIS DATA INTEGRATION FOR AGRICULTURAL TEST SITE CLASSIFICATION

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1. INTRODUCTION

During summer 1991, multi-sensor data were acquired over the Italian test site "Oltrepò Pavese", an agricultural flat area in Northern Italy. This area has been the Telespazio pilot test site for experimental activities related to agriculture applications.

The aim of the investigation described in the following paper is to assess the amount of information contained in the AIRSAR and AVIRIS data, and to evaluate classification results obtained from each sensor data separately and from the combined dataset. All classifications are examined by means of the resulting confusion matrices and Khat coefficients (Congalton et al., 1983). Improvements of the classification results obtained by using the integrated dataset are finally evaluated.

2. DATA SET DESCRIPTION

AIRSAR data were acquired with flight Nr. 91-118 on June 22^{nd}. Four tracks of the area were available. We used the 45-1 track because it was the closest to the area of the ground truth acquisition. Among the three available bands, P band was not used because it was highly disturbed by an interference noise pattern.

AVIRIS data were acquired with flight 910719b on July 19^{th}.

In order to obtain information about the **ground truth**, two "in situ" campaigns were performed. Due to slight errors in the flight tracks, the images do not exactly match the field survey area: in fact, about 45% only of the SAR images are covered by ground truth and this percentage decreases to about 20% in the AVIRIS images.

3. SAR DATA ANALYSIS

3.1. "Per Field" Classification

The discriminant analysis was performed on every combination of the 6 power "bands" (2 frequencies and 3 polarizations); the conclusions can be summarized: **1)** Khat values range from 0.555 to 0.815 as the number of features per observation is increased; the optimized choice is the L-VV, C-HH, C-HV combination, which allows a good classification accuracy (Khat value is 0.805) with a reasonably small amount of data. **2)** Although the results are quite good, problems still arise in the discrimination of alfalfa and corn from wheat. These problems were not solved even by adding more "bands". **3)** The Khat values obtained are quite optimistic since the same data set was used both for training and testing.

3.2 "Per Pixel" Classification

In this case we used all features available for the AIRSAR (that is 6 bands in the NML classifications and 18 for the polarimetric algorithms).

By the examination of the Table 1, we can draw the following conclusions: **1)** the classifiers specifically designed for polarimetric data (Lee et al., 1992; Kong et al., 1987) do not seem to improve the classification accuracy. This could mean that phase information is not vital: in fact, the classification accuracies obtained with the NML classifier are very close to polarimetric ones, but the first uses less information (only the power features). **2)** Speckle filtering is very useful to improve the classification accuracy as denoted by the 9% gain in the Khat values [(the speckle reduction filters that have been implemented are adaptive filters (Lee et al., 1991; Frost et al., 1981)].

4. AVIRIS DATA ANALYSIS

4.1. Data Reduction

From the original 224 AVIRIS bands, we selected 131 between 0.4 µm and 1.75 µm. The radiance to reflectance reduction was performed by means of the "flat field" technique (Crowley, 1990). For this work we identified a suitable flat field examining some sand deposits located near the Po river banks. Although this method is not very reliable, especially in the short wavelengths, it seems to be the best approach in order to retrieve the relative ground reflectance, since no information on local atmospheric parameters (such as aerosols, water vapor, etc.) were available.

We used the reflectance data obtained to draw spectral signatures of agricultural crops and other targets present in the area (an example is given in Figure 1). The analysis of the spectra shows a great agreement with experimental ones (Elvidge, 1990; Martin, 1990; Goetz, 1991).

The spectral analysis allowed us to select 14 significative bands that maximized the differences between crops in the reflectance spectra (see Figure 1). We obtained a further reduction by means of a Principal Components Analysis (Loughlin, 1991; Fung, 1987) performed on these bands; this analysis allowed us to define two combinations of components [PC2, PC3, PC6 (referred to as "refl") and PC1, PC2, PC3 (referred to as "ref2")]. The PC Analysis was also performed on the 14 radiance bands to investigate the effects of calibration on the classification accuracy.Other two combinations of components [PC3, PC4, PC5 ("rad1") and PC1, PC3, PC4 ("rad2")] were thus provided. In both cases, the selection was done by visual examination of the single PC images and by the analysis of the eigenvectors' matrix.

4.2. Data Classification

AVIRIS classifications were performed on the same classes as for SAR data and in a "per pixel" approach. The features used in the analyses are the PC combinations, both in reflectance and in radiance values, described above.

The Khat values obtained (see Table 2) are close to the ones given by the AIRSAR "per pixel" classifications and, though not expected, even the "unsupervised results" are very good. This could be explained as follows: **1)** AVIRIS gives very specific information for each channel: this allows the classifier to recognize different objects without the need of a preliminary training. **2)** In order to reduce the number of generated classes, the clustered image was post-processed by merging those clusters that seemed to belong to the same class.

5. DATA FUSION

5.1. Image Registration

We performed the following operations: **1)** slant-to-ground range projection of the 6 AIRSAR power speckle-filtered images; **2)** re-sampling of AIRSAR images to match the AVIRIS pixel spacing; **3)** image-to-image registration with a cubic convolution filter.

Steps 1 and 2 were executed together with a new projection algorithm developed by Telespazio which allowed us to obtain less than 1 pixel in Mean Squared Error after co-registration.

5.2. Multi-Sensor Classification

For comparison purposes, we used the same classes as in the AVIRIS and AIRSAR "per pixel" classifications. The integrated classification was carried out on the six projected AIRSAR power images and the AVIRIS PC images. Fifteen combinations were classified using the NML and clustering algorithms

From the Table 3, it is evident that the multi-sensor integration gives good results: in fact, these values are generally and significantly higher than those achieved by AIRSAR and AVIRIS separate classifications. The extremely good accuracy obtained by the integrated data is also demonstrated by the absence of "critical pairs" in the best multi-sensor confusion matrix. This absence can be justified by noticing that each sensor data classification was not affected by the same "critical pairs", but in both cases it was very difficult to discriminate alfalfa from other crops (especially from wheat and corn).

6. CONCLUSIONS

In this work a multi-sensor analysis was carried out; first the separate data sets were processed and classified, then their integration and the consequent classification were performed.

The SAR data analysis showed (see Table 1) that polarimetric information does not seem to improve the classification accuracy: in fact, in spite of the great number of features available, the polarimetric classifiers show a little improvement with respect to the NML classifier performed on the power images only (speckle reduction techniques furtherly improve the classification results).

Among the L and C power information, the co-polarizations (HH, VV) seem to be useful for classes identification, while the HV polarization turned out to be useful in "critical pairs" discrimination. It also seems that crops classification is more accurate when using L band.

The great amount of AVIRIS data and its high spectral resolution, which are surely useful in the characterization of green vegetation, imply two major problems: a) reduction of the data, b) accurate atmospheric corrections. Many efforts are being devoted to implement simulation models that will allow us to obtain a more accurate atmospheric correction.

7. REFERENCES

Congalton, R.G., 1983, "Assessing Landsat classification accuracy using discrete multivariate analysis statistical techniques", *PE & RS*, vol. 49, n° 12, pp. 1671-1678

Crowley, S.K., 1990, "Techniques for AVIRIS data normalization in areas with partial vegetation cover", *JPL AVIRIS Workshop*, Pasadena (CA).

Elvidge, C.D., 1990, "Visible and infrared characteristics of dry plant materials", *Int. Journ. of Remote Sensing*, vol 12

Frost, V.S., J.A. Stiles, K.S. Shanmugan, J.C. Holtzman, S.A. Smith, 1981, "An adaptive filter for smoothing noisy radar images", *IEEE*, vol. 69, n° 1

Fung, T., L.E Drew, 1987, "Application of principal components analysis to change detection", *Photogrammetric Engineering and Remote Sensing*, vol 53, n° 12, December 1987, pp 1649-1658

Goetz, A.F.H., 1991, "Sedimentary facies analysis using AVIRIS data: a geophysical inverse problem", *JPL AVIRIS Workshop*, Pasadena (CA), May 20-21

Kong, J.A., H.A Yueh, A.A. Swartz, 1987, "Identification of terrain cover using the optimum polarimetric classifier", *Journ of E.M. Waves & Appl.*, vol 2, pp 171-194

Lee, J.S., M.R Grunes, S.A. Mango, 1991, "Speckle reduction in multipolarisation multifrequency SAR imagery", *IEEE GE 29*, pp. 535-544

Lee, J.S., M.R. Grunes, 1992, "Feature classification using multi-look polarimetric SAR imagery", *Proc. of IGARSS*, pp 77-79

Loughlin, W.P., 1991, "Principal component analysis for alteration mapping", *Proc. of ERIM "Eighth Thematic Conference on Geologic Remote Sensing"*, April 29 - May 2, 1991

Martin, M.E., J.D Aber, 1990, "Effects of moisture content and chemical composition on the near infrared spectra of forest foliage", *Proc. of SPIE*, vol 1298, Imaging Spectroscopy of Terrestrial Environment

Table 1. Khat values and 95% Confidence Intervals for AIRSAR "Per Pixel" Classifications

Classification	KHAT	Δ KHAT (%)
NML on LC bands	0.829	0.9
NML on LC Lee filtered	0.841	0.8
NML on LC Frost filtered	0.899	0.6
Lee's polarimetric	0.861	0.8
Kong's polarimetric	0.859	1.0

Table 2. Khat values and 95% Confidence Intervals for AVIRIS "Per Pixel" Classifications

Classification	KHAT	Δ KHAT (%)
NML on Rad1	0.8108	1.68
NML on Ref1	0.8261	1.62
NML on Rad2	0.8318	1.61
NML on Ref2	0.851	1.53
CLUSTER on Ref2	0.8408	1.61
CLUSTER on Rad2	0.841	1.58
CLUSTER on Ref2+Rad2	0.8509	1.56

Table 3. Khat values and 95% Confidence Intervals for Multi-Sensor "Per Pixel" Classifications

Classification	KHAT	Δ KHAT (%)
NML on Mix 1	0.8264	1.62
NML on Mix 2	0.881	1.39
NML on Mix 3	0.8892	1.34
NML on Mix 4	0.898	1.32
NML on Ref1+PC SAR	0.9284	1.10
NML on Ref2+PC SAR	0.9358	1.06
NML on Ref1+LC	0.9372	1.05
NML on Rad1+PC SAR	0.9403	1.02
NML on Rad2+PC SAR	0.9445	0.99
NML on Rad1+LC	0.9538	0.92
NML on Ref2+LC	0.9583	0.88
NML on Rad2+LC	0.9595	0.87
NML on Mix 5	0.9612	0.85
CLUSTER on Rad2+LC	0.821	1.67
CLUSTER on Ref1+LC	0.9254	1.18

Table 4. Additional combinations referred as "Mix-Y" (Y= 1 to 5) in Table 3

Name	Features used
Mix-1	PC2-Reflect + C-HH + PC1-SAR
Mix-2	PC2-Reflect + PC3-Radiances + PC1-SAR
Mix-3	PC2-Reflect + PC3-Radiances + C-HH + PC1-SAR
Mix-4	PC2-Reflect + PC3-Radiances + C-HH + L-HH + PC1-SAR
Mix-5	PC2-Reflect + PC3-Radiances + C-HH + L-HH + C-HV + PC1-SAR

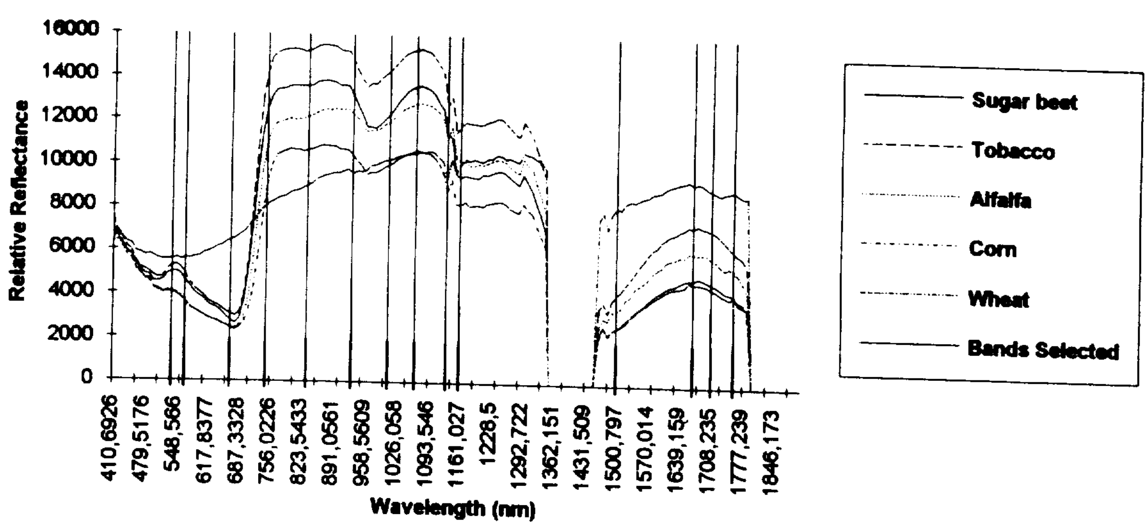

Figure 1. Typical crops spectral Signatures and bands selected for PCA