PRE-PROCESSING AND CLASSIFICATION TECHNIQUES OF SAR IMAGES FOR REMOTE SENSING APPLICATIONS

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Resume

Dans cette communication,on décrit des techniques nu meriques pou le traitment des images et la classifica automatique des radars.Il aussi présenté d'abord les filtres numeriques pour la reduction du bruit derivant des radars et,ensuite,des algoritmes utilisant la ré gle de Bayes ou la distance à blocs pour la classifi cation automatique des récoltes en agriculture. Les images à microondes,obtenues à travers des radars à ouverture synthétique et collectées pendant la campa gne europénne SAR 580,sont employées pou évaluer les pérformance des algoritmes en question.

Summary

In this paper digital techniques for image processing and automatic classification in remote sensing applica tions are described.Digital filters,suitable for radar noise reduction,are first described.Some algorithms using the Bayes rule or block distance for the automa tic classification and discrimination of agricultural crops are presented.Microwave images,obtained by em ploying synthetic aperture radars and collected during the European SAR compaign,are used to evaluate the performance of these processing algorithms.

1.Introduction

The use of multispectral scanners from satellites or aircrafts are quite attractive in crop classifica tions by means of remote sensing .Very promising results have been obtained by using observations in the optical band either by means multispectral scanners.However,in order to achieve satisfactory performance several ob servations during the crop growth cycle are often neces sary.On the other hand,the optical observations are strongly affected by the weather conditions;therefore, the use of radar images can signifiacntly improve the performance of any real method for crop classification. Depending on frequency and observation angle,radar per mits to investigate different vegetation layers and soil surface under plants and to increase the informa tion obtained through the optical data.

At present only few investigations have been car ried out in radar potentials for crop classification and discrimination problems.In this paper,the use of microwave images,obtained by using a Synthetic Apertu re Radar (SAR) in remote sensing is analyzed in a sy stematic way.

The first question,which must be considered for any efficient image processing,is the noise reduction in the SAR images. In these images the noise is essen tially of multiplicative type;in many cases the signal-to-noise ratio is quite low and,therefore,a pre-proces sing operation by means of a digital filtering opera tion,is required.In this paper some different spatial digital filters,suitable for the reduction of the multiplicative noise,are presented.

These filters are used to perform a pre-processing operation on some radar images collected during the European SAR 580 campaign performed in June 1981.Some different classification algorithms are after applied to the pre-processed images in order to separate the different crops in an automatic way.The analyzed classification algorithms use the Bayes rule,the Eucli dean distance or a suitable block distance.

2.Image processing and classification algorithms

The images and the data used in this paper have been collected during the European campaign SAR 580 on June 1981;the surveyed test was located in a farm of southern Tuscany,called Castel di Pietra.The prin cipal crops of this typical mediterranean area were corn,wheat,alfa-alfa,sunflowers and olive trees(Fig.1). About two hours before the SAR flight,a survey with an airborne multispectral scanner was carried out. Many real data were directly collected through an ex tensive ground survey in the farm before,during and after the SAR compaign.

One image at C and X band with HH polarization was recorded during the flight.A small area of the optically SAR images have been digitez and is used in this paper.The original images in band X and C are shown in Figs.2 add 3,respectively.Other four optical and infrared images are also available and have been used to facilitate the classification operation.The noise introduced by the radar sensor is of multiplica tive type and then digital filters suitable for this type of noise must be used.

Two classes of digital filters have been conside red in this paper : the Lee filter /1/ and the Frost filter /2/,/3/.By denoting with $x_{i,j}$ the original pi xel in the i-th row and j-th column,and with $n_{i,j}$ the corresponding noise introduced by the radar sensor,it results :

$$(1) \quad z_{i,j} = n_{i,j}\, x_{i,j}$$

In the Lee filter the filtered signal is given by /1/:

(1) $z_{i,j} = n_{i,j}\, x_{i,j}$

In the Lee filter the filtered signal is given by /1/:

(2) $x_{i,j} = x_{i,j} + k_{i,j}(z_{i,j} - n_{i,j} x_{i,j})$

where $x_{i,j}$ and $n_{i,j}$ denotes the signal and noise mean respectively and $k_{i,j}$ depends on the noise variance. Mean and variance are external parameters, which depend on the radar characteristics.

The Frost filter is defined by an impusive response given by /2/ :

(3) $m(x,y) = k_1\, a \exp(-a(x^2+y^2))$

where

(4) $a = k_2\, \sigma_i^2 / I^2$

and k_1 and k_2 are two constants and σ_i^2 and I^2 the mean and variance of the image. Fig.4 shows the image in the band X after the application of the Frost filter. The quality of the image is significantly improved by the filtering operation. The performance of the classification operation depends strictly on this pre-processing operation. The results obtained by using the previous images show that the Frost filter performs better in many cases than the Lee filter.

Some different classification algorithms using the Bayes rule or the block distance have been analyzed. For all the classification algorithms, it was assumed that the distribution of the gray levels can be assumed as a Gaussian function having mean μ_i and variance σ_i^2, which depend on the particular crop /4/.

In the following it is assumed that k different images of the same area are available and N different crops to be classified will be present in the images. By denoting with (i,j) the element in row i and column j, the values of this element in the k images can be used to form a k-dimensional vector $\underline{x} = (x_I, x_2, \ldots, x_k)$. This vector is used to classify the element (i,J).

By denoting with $\mu_{i,j}$ and $\sigma_{i,j}^2$ the mean and the variance of the i-th crop in the j-th image, the classifier using the Bayes rule computes for each crop the following distance /4/ :

(5) $D_{k,i} = \log P(i) - \frac{1}{2} \log\left|\sum_i\right| - \frac{1}{2} (x-M_i)^T \sum_i^{-1} (x-M_i)$

where P(i) is the a-priori probability of the i-th crop, M_i is the vector of the mean $\mu_{i,j}$ and $\sum_i$ the covariance matrix /4/. The Bayes algorithm gives optimum performance, but requires high computation time.

The minimum distance classifiers permit to reduce significantly the computation complexity. These algorithms computes for each crop the quantities $D_{k,i}$ defined by :

(6) $D_{k,i} = A - \frac{1}{2} (x-M_i)^T \sum_i^{-1} (x-M_i)$

where A is a constant. Moreover, if the different images are not correlated and the noise variance is the same in all the images, the distance $D_{k,i}$ becomes very simple /4/ :

(7) $D_{k,i} = (x-M_i)^T (x-M_i)/2\sigma^2$

In particula for k=2, it results :

(8) $D_{2,i} = (x_1 - \mu_{1,i})^2 + (x_2 - \mu_{2,i})^2$

which is the Euclidean distance, while for k=1, it is obtained :

(9) $D_{1,i} = x_1 - \mu_{1,1}$

In this case the pixel (i,j) is assigned to the crop having the mean value nearest to x_1.

3.Results

The performance of the described classification algorithms have been evaluated by computing the probability of correct classification for each crop. This probability is obtained by using the truth data collected directly in the farm.

First of all, the classification algorithms using only a band (C or X) are considered. Fig.5 shows the results obtained by applying the Bayes algorithm to the X band. The probability of correct classification by using the Bayes rule is given in Table 1 for the same band. Table 1.a refers to the case in which the image is filtered through a Frost filter, while Table 1.b through a Lee filter. Similar results have been obtained by using the band C, which give very poor results.

Fig.6 summarizes the results obtained for the two bands and reportsthe mean probability of correct classification, averaged on the four crops. It can be seen that the Frost filter permits the achievement of a slight improvement in the performance with respect to the Lee filter.

In order to achieve higher performance, it is necessary to use multidimensional classification algorithms. The case of a Bayes classifier using two bands is first considered. The results obtained through this two-dimensional algorithms are shown in Fig.7 (Frost filter). The probability of correct classification is significantly increased by integrating the information derived from the X and C bands, as shown schematically in Fig.6.

Similar results have obtained for other two classification algorithms, based on the distance measure given respectively in (8) and termed D1 algorithm and in (9) and termed D2 algorithm. The probability of correct classification by using these algorithms are resumed in Fig.8.

References

/1/ J.S.Lee,"Digital Image Enhancement and Noise Filtering by use of Local Statistics",IEEE Trans. on Pattern Analysis and Machine Intelligence,March 1980.

/2/ V.S.Frost et Al.,"An Adaptive Filter for Smoothing Noisy Radar Images",Proc. IEEE,January 1981.

/3/ V.S.Frost et al.,"A Model for Radar Images and its Application to Adaptive Digital Filtering of Multiplicative Noise",IEEE Trans. on Pattern Analysis and Machine Intelligence,March 1982.

/4/ R.A.Schowengerdt,"Techniques for Images Processing and Classification in Remote Sensing",Academic Press, 1983.

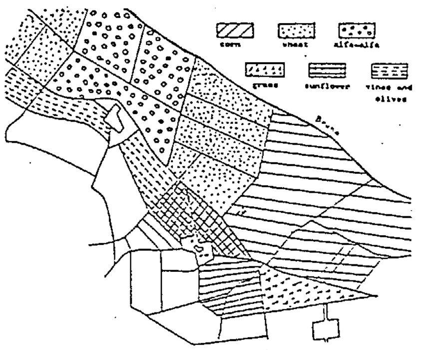

Fig.1

Fig.2

Fig.3

Fig.4

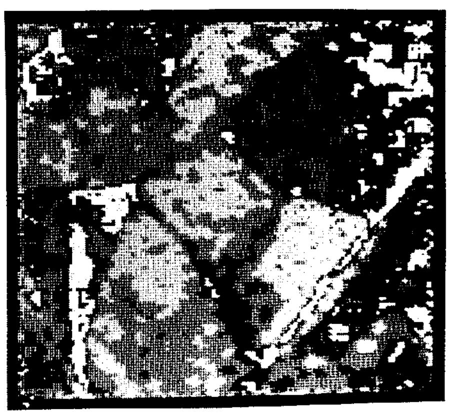

Fig.5

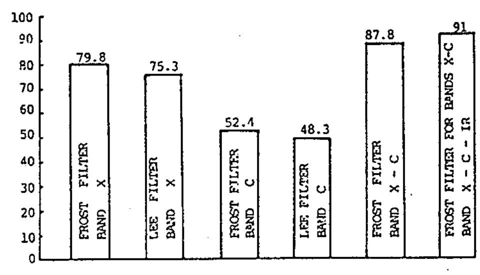

Fig.6

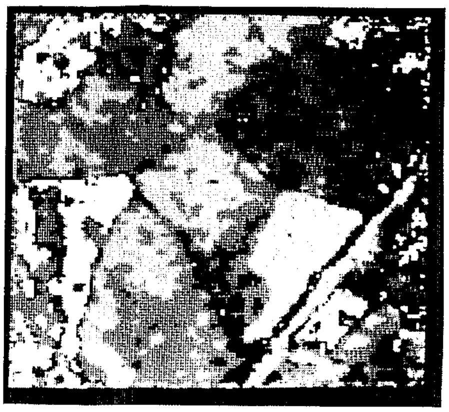

Fig.7

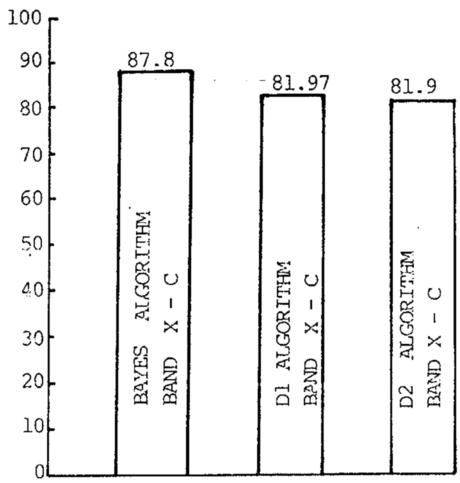

Fig.8

Crops	Probability of correct classification (%)			
	Wheat	Dried Corn	Irrigated Corn	Alfa-Alfa
Wheat	85.7	14.3	0	0
Dried Corn	4.8	70.6	24.6	0
Irrigated Corn	1.0	19.0	80.0	0
Alfa-Alfa	4.7	4.3	0	91.0

Table 1.a

Crops	Probability of correct classification (%)			
	Wheat	Dried Corn	Irrigated Corn	Alfa Alfa
Wheat	87.8	10.7	0	1.5
Dried Corn	5.6	65.3	29.1	0
Irrigated Corn	1.6	27.3	71.1	0
Alfa Alfa	4.8	5.8	0	90.2

Table 1.b