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SEMI-OPERATIONAL IDENTIFICATION OF AGRICULTURAL CROPS FROM AIRBORNE SLAR-DATA

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ABSTRACT

The 1984-airborne SLAR campaign of the Dutch ROVE-team is discussed. Through preprocessing, segmentation and pseudo-hierarchical classification a multitemporal data set of three testsites is treated for identification of potatoes and other agricultural crops.

I. INTRODUCTION

Remote sensing of agricultural crops by means of microwaves has been subject of study in The Netherlands for a number of decades [Ref. 1]. An extensive groundbased measurement programme with tower-based scatterometers, in combination with airborne SLAR data acquisition have provided the Dutch remote sensing community with a large database to rely upon. A multidisciplinary working group (ROVE) was formed in the 1970's to study the microwave backscatter of agricultural crops in relation to crop and soil parameters. This group consists of scientists and technicians from the Agricultural University of Wageningen and its related institutes, Delft University of Technology, Physics and Electronics Laboratory TNO and the National Aerospace Laboratory NLR.

One of the specialized subgroups of ROVE is the working group "Crop identification" which has chosen to undertake two parallel paths of research:

- research of (hierarchical) classification methods for radar data
- execution of semi-operational application programmes

Upon request from The Netherlands agricultural authorities an application programme has been carried out in 1983 and 1984 to monitor crop rotation, especially potatoes, in a number of (ecologically-different) regions within The Netherlands. From crop disease control regulations potatoes may only be grown once every three years on any one field (if no other protective measures are taken), thus it has become desirable to monitor adherence to this practice. The group was asked to devise a method to uniquely discriminate potatoes from all other crops, hence time-consuming ground investigations be reduced. The selected test sites lay in the Flevopolders, Groningen province and Brabant province located in the center, north-east and south-west of The Netherlands respectively. Each test site covers an area of 20*4 km.

II. DATA ACQUISITION AND PREPROCESSING

Sideways-looking airborne radar (SLAR) is an instrument which allows data to be acquired on a line to line basis. The Netherlands digital SLAR (X-band) uses a digital recording system where each line is formed on a point to point basis [Table 1]. The received radar reflections vary widely in a stochastic way when natural surfaces/objects are observed; good estimates of the backscatter coefficient can only be made by combining a large number of independent measurements. The Netherlands SLAR has been designed to do so (Fig. 1).
In order to ensure optimal effectiveness of an airborne campaign it was deemed necessary to incorporate calibration and flight date optimization into the data acquisition programme.

A. CALIBRATION

As the Dutch digital SLAR had not yet been calibrated in 1983 and 1984 corner reflectors were positioned in the selected regions of interest to allow for later calibration and intercomparison between test sites. The results of this activity are expected to become available in 1985.

B. FLIGHT DATE OPTIMIZATION

When investigating the ROVE ground-truth data base it was found that an airborne programme was to be conducted between May and August of the year, as potatoes do not appear above the soil until late May and may be harvested as early as late July in The Netherlands. Furthermore the database and crop growth parameters showed that winter wheat and potatoes tend to exhibit similar backscatter characteristics in all months except May and that potatoes plus winterwheat can be discriminated from most other crops in July (Fig. 2,3).
It was therefore decided to conduct an airborne campaign with the following objectives:

- distinguish potatoes from winterwheat fields in May
- distinguish potatoes from other crops in June/July.

The above objectives can only be achieved with specific viewing angles hence each test site was covered twice from different heights i.e. 500 meters above ground to enable 5°-14° and a second run at 2700 meters above ground for 25°-45° grazing angle.

The selected viewing angles were considered to be essential thus the required flight-accuracy was to be better than 180 meters with respect to the predefined flight track.

C. PREPROCESSING

To overlay and register data from multitemporal airborne sensors may be very difficult due to random deviations from attitude, velocity and position of the aircraft during the execution of the track. These deviations usually distort the resulting dataset sufficiently to disable further multitemporal processing. Also, a lot of effects influence the signal received by the radar antenna, e.g. the antenna gain is a function of the depression angle, and the observed deviations from the ideal flight path distort both radiometric and geometric properties of a SLAR-image.

Hence, in 1980-83 a study was carried out by the National Aerospace Laboratory NLR in close collaboration with the Physics and Electronics Laboratory TNO, Delft University of Technology and the Survey Department of Rijkswaterstaat (Ministry of Public works), to correct acquired SLAR-data for variations in aircraft motion and -attitude through simultaneously recorded INS-parameters (INS = Inertial Navigation System) in the NLR laboratory aircraft. For every acquired radar line its exact position in a terrestrial coordinate system is calculated, thus enabling later multitemporal registration of data via an earth-bound coordinate system. The procedure (called "PARES" for Preprocessing of Airborne REmote Sensing data) includes radiometric system corrections as well to compensate for antenna pattern and other intensity distortions. An additional feature is the optional removal of outliers from the data set that originate from other microwave sources in the test area [Ref. 2,3].
The data first processed through PARES may now be multitemporally processed without further complications due to airborne data acquisition.

III. PROCESSING

Most advanced classification algorithms and user-defined information extraction programmes do not require information on a pixel-by-pixel basis but rather on a field-by-field basis. A field-averaged backscatter coefficient is thus not only more appropriate but also more accurate. This specifically applies to radar data which are contaminated with speckle. Theoretically, the speckle in a radar image is constant and may be determined from the Rayleigh distribution and the number of independent observations. There is no information contained in the variance caused by the speckle, hence a segmentation algorithm may be applied to the data in order to obtain field averages where original pixel values have been replaced by a mean value, without loss of information. A so-called "split-and-merge" algorithm has been implemented on the image processing system RESEDA at the National Aerospace Laboratory NLR based on the Pavlidis-concept [Ref. 4,5].

The algorithm has been designed to process (in parallel) up to 7 multitemporal images with a number of user-identified parameters, like minimum field size and variance, to obtain the required result which can then be classified in a much better way than on speckle-contaminated images. The most important parameter to select, of course, is the variance of a homogeneous area.

As a pixel from PARES represents 15*15 m on the ground (only recently has 7.5*7.5 m become possible through faster digitization-instrumentation (SPEEDIG) developed by NLR) it is evident that fields which contain only a few pixels may easily lead to a questionable segmentation result. Unless appropriate precautions are taken small objects like farms, powerline-masts a.o. will corrupt the image. Therefore a "minimum field size" may be selected. Another source of segmentation-contamination is across-track striping on the PARES-image from yet undetermined causes.

Figures 4, 5, 6 demonstrate that of the three selected test sites the Flevo polders, a region of reclaimed land in the center of The Netherlands, contains the largest fields (most of them are larger than 2 or 3 hectares) and therefore the best segmentation results are obtained there (rectangular fields, perpendicular landmarks like roads and ditches). As can be seen on (Fig. 5, 6) the other two test sites are less ideal. The quality and usefulness of the segmentation result are clearly below that of the Flevo-area. Careful inspection of the Groningen-image (Fig. 6) led to the decision to bypass segmentation in Groningen and use a 5*5 median filter instead to reduce speckle.

IV. CLASSIFICATION OF FLEVO TEST SITE

The input dataset from the segmentation programme consists of 4 images: the high tracks of May and July 1984 (5H and 7H) and the low tracks of May and July 1984 (5L and 7L). The dimensions of the test site have been chosen to contain no more data in across-track direction than acceptable with respect to incidence angle. Most crops show a significant angular dependence with the exception of sugar beets for which the backscatter is nearly independent for a large range of incidence angles.

Image processing facilities at the National Aerospace Laboratory NLR allow for three distinct classification procedures:

- maximum likelihood classification
- unsupervised classification (clustering)
- parallelepiped classification

Due to the operational requirement of (pseudo-) hierarchical classification, the interactive action required by the user and the statistical properties of the data after segmentation, the first two classifiers were not used. This lies among other things in the fact that after segmentation, where field-averages have replaced pixel-values, the standard deviation has been reduced significantly. This diminishes the applicability of classifiers which make use of distances in feature space. Thus the interactive parallelepiped classifier (called DP on the NLR image processing system RESEDA) was applied to the data set. The programme DP allows for interactive classification from data-space into feature space and vice versa. It should be remembered that this type of procedure usually is time consuming when using standard imagery. The preceeding segmentation has already greatly reduced the dynamic range of possible pixel values, so near real time classification is possible.

When in the May imagery (5H and 5L) the winter wheat fields have been identified and labeled as such then the resulting data set can be used as input for classification with July imagery (7H and 7L) where potatoe fields may be identified as such and other crops classified as well. An example of this procedure is given in figure 7. The final classification of the Flevo-area is given in figure 8.

V. ANALYSIS OF RESULTS

The matrix of classification results of the Flevo test site is given in Table 2.

- From Table 2 and previous sections it may be deduced that the choice of incidence angles and flight dates result in good discrimination capabilities between various crop types, especially potatoes.
- Unique identification of the three major crop types (sugar beets, potatoes and winterwheat) was possible in the Flevo test site (and in the other two test sites) with an accuracy of better than 90 %. In the Flevo area an accuracy of better than 90 % could be obtained when using only the July data set (7H and 7L).
- It appears possible to identify more than one species of winter wheat. This also applies to potatoes.
- Oats and barley are difficult to distinguish from other crop types.
- For all practical purposes one appears to be able to obtain the required results with a high and a low track in July and one other run in May.

VI. CONCLUSIONS AND PROGNOSIS

A. CONCLUSIONS

- Calibration of SLAR-data with corner reflectors in the field to allow for cross-comparison is still underway. Its consequence on processing and classification will need further evaluation.
- It appears that identification of a select number of agricultural crops with airborne microwave sensors (SLAR) is possible with a high degree of accuracy (better than 90 %).
- It is essential for obtaining good results that crop growth stages are closely monitored to select optimum flight dates.
- Segmentation of SLAR-images in ecologically noisy regions with small field sizes is problematic. Median filtering of the data may prove to be an acceptable alternative.
- Microwave remote sensing appears to be an efficient tool for agricultural authorities to monitor crops.

B. PROGNOSIS

In order to prepare for future (microwave) satellite programmes the ROVE working group "Crop Identification" will direct its 1985-programme towards:

1. Data acquisition with small incidence angles ($\theta \leqq 40°$) from higher altitudes ($H \geqq 4000$ m) to simulate satellite data.
2. Internal calibration of the SLAR in order to better allow for radiometric comparison of multitemporal and multispatial data.

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Table 1

Specifications SLAR data acquisition and registration chain

Antenna	2,5 m slotted wave guide Polarisation HH Pattern azimuth 16 mrad Elevation: $cosec^2$-pattern (Ref. 2,3)
Transceiver	Modified DECCA 65160 Frequency 9,4 GHz (X-band) Transmitted power 25 kW Pulse length 50 (250)ns PRF 100 Hz (200 Hz) DC coupled IF amplifier and detection circuit type ICLT 6020 from RHG Output: GO-2 V 23.7 mV/dB Dynamic range 80 dB
SLARDIG (SPEEDIG)	Presample filter 3rd order 5MHz,(none) Sample rate 20 MHz , (50 MHZ) Start sampling jitter 0-5 ns , (same) 2048 samples = 15 km range,(4096;12 km) 8 bits/sample , (same) Input 0,01 ± 0,004 V; output 0,(same) Input 2,000 ± 0,004 V: output 255, (same) 7,8 mV/bit ,(same)
Aircraft data	for PARES the data of the Inertial Sensor System (ISS): Litton LTN58 are important True Heading TH North-South Velocity VNS | Digital outputs East-West Velocity VEW | Digital outputs Latitude LAT Longitude LON Angle of roll AR1IS | Synchro outputs Angle of pitch AP1IS | Digitized by RMDU Accuracy: angles better than 0.1° velocity better than 1 m/s position better than 2 mile/hr

Table 2

Classification-matrix of Flevo-area (1984)

NUMBER OF FIELDS ↓	CROP-MAP (GROUND TRUTH)	POTATOES	SUGARBEETS	WINTERWHEAT	ONIONS	BEANS	OTHERS → CLASSIFICATION-RESULT
58	POTATOES	58 (100%)					
58	SUGAR-BEETS	1	54 (93%)				3
92	WINTER-WHEAT	3	–	89 (97%)			
35	ONIONS	14	4	2	9 (25%)		6
9	BEANS	2	1	–		6 (66%)	
	OTHER	9	3	8			

Fig. 1 The NLR laboratory aircraft with SLAR-antenna

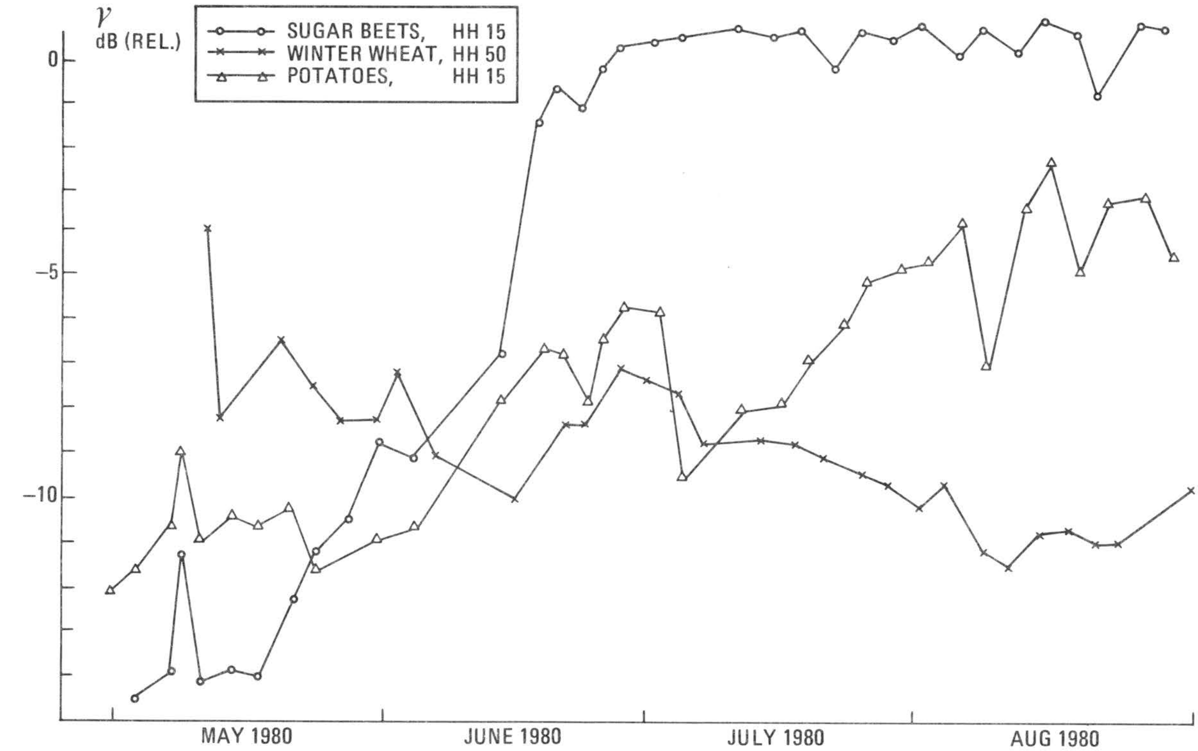

Fig. 2 Backscatter coefficient vs time for three major crops (grazing angles, 10 GHz, HH-polarization) (source: Rove)

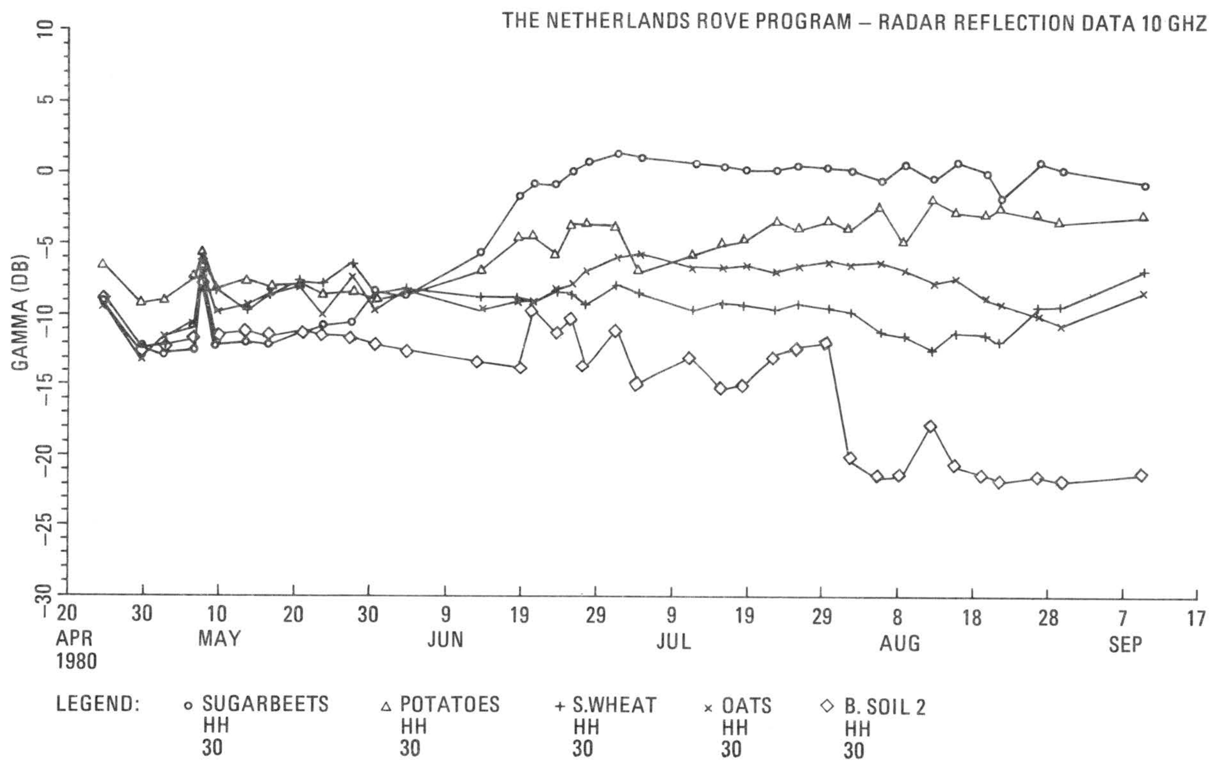

Fig. 3 Backscatter coefficient vs time (grazing angle 30°, HH polarization) (source: Rove; Ref. 1)

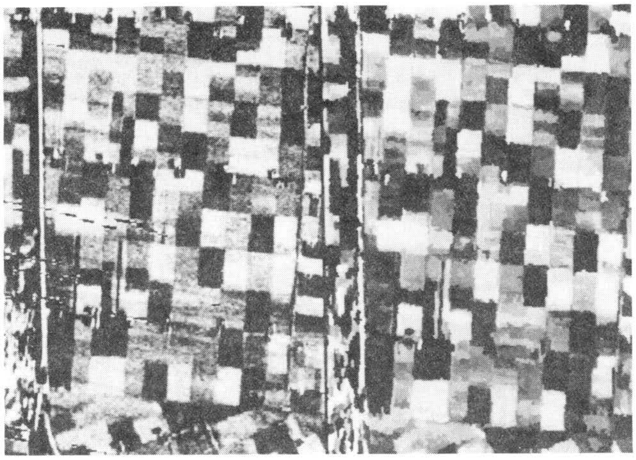

Fig. 4 Flevo test-site (subscene)
left: preprocessed image;
right: segmented image

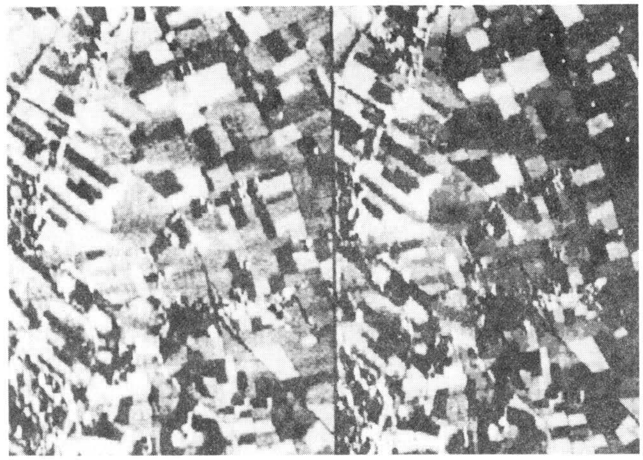

Fig. 6 Groningen test site (subscene)
left: preprocessed image;
right: segmented image

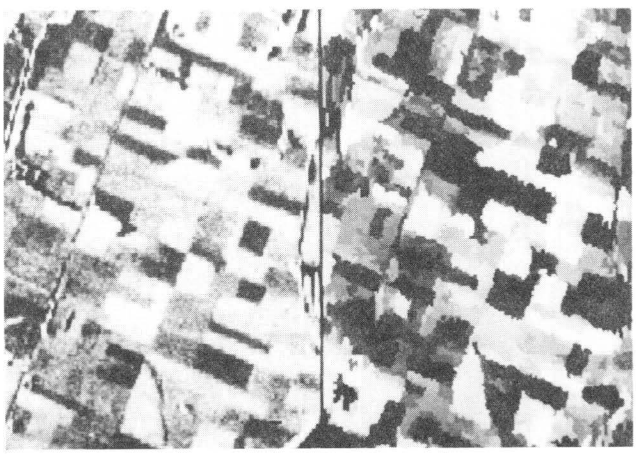

Fig. 5 Brabant test site (subscene)
left: preprocessed image;
right: segmented image

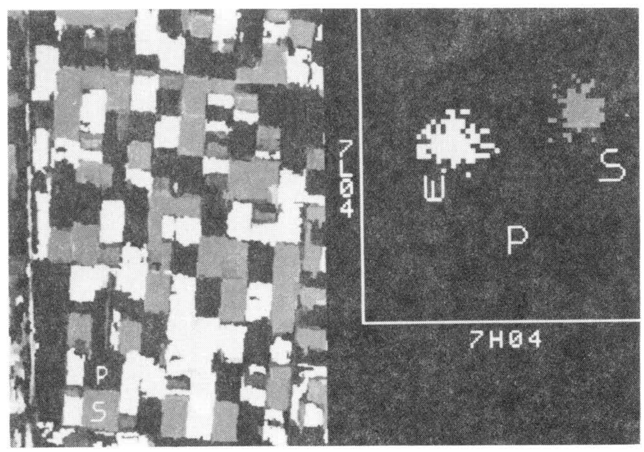

Fig. 7 Interactive, pseudo-hierarchical classification
left: data space; right: feature space

Fig. 8 Classification result of Flevo test site

Peter Binnenkade (1944) was borne in The Hague, The Netherlands. After his secondary education he studied physics and astronomy at the Universities of Hamburg and Munich, Germany. He obtained his doctoral degree (Drs.) from the University of Leiden (The Netherlands) in 1974. He has been employed at the National Aerospace Laboratory NLR in Amsterdam since 1978 where his special interests lie in image processing of remote sensing data and airborne data acquisition.