Session 1A2
Polarimetric Radar Remote Sensing

Principal Component Analysis (PCA) in the Context of Radar Polarimetry

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Abstract| Statistical and computational techniques for revealing the internal structure that underlies the set of random correlated data exists in a great variety at present; and target decomposition theorems, either in the coherent or incoherent formulation, are well established. In spite of this fact a rather innovative and new concept is presented in this contribution. In turn the Principal Component Analysis (PCA) is considered to possibly add value to existing approaches, and it allows for an interpretation of polarimetric synthetic aperture radar measurements using variables obtained via linear transformation. Starting with the Sinclair backscatter matrix S which will be further transformed into the so called target feature vector by stacking column elements of S and generating the covariance matrices averaged over a certain pixel array, we show, how the Sinclair backscatter matrix is decomposed into the sum of a maximum of four 2£2 elementary point scatter matrices which are weighted by the principal components, whereas the variances of these components agree with the eigenvalues of the covariance matrix. This mathematical development de¯nes a decomposition which expresses scattering mechanism from distributed targets in terms of scattering matrices via an incoherent step.

On the Ger¸sgorin Theorem Applied to Radar Polarimetry

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Abstract| This contribution is concerned with the mathematical formulation and theoretical background of the Ger¸sgorin theory in the context of Radar Polarimetry. Named after its founder Semian *A. Ger¸sgorin* the Ger¸sgorin theorem basically states that there are certain regions in the complex plane that can be derived from any $n £ n$ complex matrix by rather simple arithmetic operations. These regions are containing more information, speci¯cally its eigenvalues lying within or at the boundaries of circles, where the radii are obtained by the deleted absolute row and/or column sums of the respective $n £ n$ complex matrices.

Multitemporal C-Band Radar Measurement on Rice Fields

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Abstract| This paper investigates the relationship between C-Band backscatter measurement on the physical structure of rice ¯elds and its growth stages. The study is based on a ground-based scatterometer experiment conducted on rice ¯elds at Sungai Burung site in Malaysia for the year 2005 growing season. Seven C-band scatterometer acquisitions at full polarization, namely Horizontal-Horizontal, Horizontal Vertical, Vertical-Horizontal, Vertical-Vertical polarization with incidence angle from $0^{\pm}$ to $60^{\pm}$, were measured. At the same time, ground truth data

for an entire rice growing season were obtained at 12-day intervals from September to December 2005. The dates were chosen so as to coincide with RADARSAT-1 image acquisitions. The paper describes the experiment and investigates the radar sensitivity to the physical structures of rice at di®erent polarization and incident angles for di®erent rice growth stages. Based on the result, a close agreement of backscattering coe±cient between the scatterometer and RADARSAT-1 was obtained.

An Unsupervised Classi¯cation Using IHSL Transform, FCM Algorithm and XB Index for Fully Polarimetric SAR Data

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Abstract| In this paper, the IHSL transform, the fuzzy C-means (FCM) segmentation algorithm and the Xie-Beni (XB) index are used to perform the unsupervised classi¯cation for fully polarimetric SAR data. We apply the IHSL color transform to the *H*=®=*SPAN* parameter set to get an improved feature space with uniform discrimination. The FCM algorithm is applied to this feature space to perform the classi¯cation. Considering the classi¯cation performance is greatly in dependence of the number of clusters, which is unknown priori, the XB index is introduced to calculate the optimal number of clusters for the input polarimetric SAR data set. The main characteristics of this method are that the *H*=®=*SPAN* space is converted to a space with uniform discrimination to perform the classi¯cation and the clustering validity measurement is used to generate the appropriate number of clusters which is the best ¯t for the data inner structure. The experiments show that this method provides an improved performance than the generally Wishart *H*=®=*A* classi¯cation.

The most widely used polarimetric SAR data classi¯cation is the Wishart *H*=®=*A* classi¯cation [1, 2], which is based on the Cloude-Pottier decomposition [3] of the coherency matrix [*T*]. Three parameters are used during the classi¯cation, which are *H*=®=*A*. There are several disadvantages of this classi¯cation. None of the *H*=®=*A* provides satisfactory interclass resolutions, so the coherency matrix [*T*] has to be used during the segmentation procedure. The *A* contains additional information only when $H > 0.7$ [4], that is to say, the *H* and the *A* are not independent between each other, which is one of the reason that the Wishart classi¯cation has to be performed in a successive way. Furthermore, the number of clusters is ¯xed to a predetermined value (16 clusters), which may not correspond to the groups in the data and will result to clustering errors. In this paper, the *SPAN* is used to improve the interclass discrimination and to replace the dependent parameter *A*, the IHSL transform is performed to the *H*=®=*SPAN* to improve the performance of the FCM segmentation which is based on the distance norm minimization, and the XB index is used to calculate the optimal number of clusters which is the best ¯t for the input data set. The scheme of this proposed classi¯cation is given in the following. Firstly, we calculate the *H*=®=*SPAN* space using Cloude-Pottier decomposition [3], then map the *H*=®=*SPAN* space onto the IHSL color space [6] using the mapping algorithm given in [5], later an improved HSL transform [7] is used to convert the IHSL color space into the RGB color space with an uniform discrimination (which also provides a reference image which can be used to evaluate the classi¯cation result), next the FCM segmentation [8{10] is performed iteratively with di®erent number of clusters, and the Xie-Beni index [11, 12] corresponding to each iteration is calculated to determine the optimal number of clusters for the input data. The segmentation result with the optimal number of clusters is set to be the ¯nal classi¯cation result.

The main advantages of this method are that it transforms the polarimetric feature parameters to the IHSL color space to get a uniform discrimination among the polarimetric parameters, which will improve the performance of the classi¯cation results, and it uses the clustering validity measurement to estimate the optimal number of clusters which is in dependence of the group structure of input data. We use the *SPAN* instead of *A* to improve the interclass discrimination in the classi¯cation result. Since we get a RGB image as a byproduct during the classi¯cation, this method also provides a reference image for further performance estimation. Furthermore, using the IHSL transform, we can easily present the resulting clusters using the corresponding colors of each cluster centers, so this method also provides an automatic way to choose the ¯nal

presentation color in the classi¯cation resulting image. The experimental results show the great improvement of this method. However, the results are still susceptible to the noise of the data. In the future, we prefer to join the model-based segmentation algorithm to this method for further improvement.

A Hybrid Entropy Decomposition and Support Vector Machine Method for Agricultural Crop Type Classi¯cation

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Abstract| This paper presents the development of Synthetic Aperture Radar (SAR) image classi¯er based on the hybrid method of \Entropy Decomposition and Support Vector Machine" (EDSVM) for agricultural crop type classi¯cation. The Support Vector Machine (SVM) is successfully applied to the key parameters extracted from Entropy Decomposition to obtain good image classi¯cations. In this paper, this novel classi¯er has been applied on a multi-crop region of Flevoland, Netherlands with multi-polarization data for crop type classi¯cation. Validation of the classi¯ers has been carried out by comparing the classi¯ed image obtained from EDSVM classi¯er and SVM. The EDSVM classi¯er demonstrates the advantages of the valuable decomposed parameters and statistical machine learning theory in performing better results compared with the SVM classi¯er. The ¯nal outcome of this research clearly indicates that EDSVM has the ability in improving the classi¯cation accuracy for agricultural crop type classi¯cation.

Iteration Based Polarimetric SAR Image Classi¯cation

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Abstract| In this paper, an iteration method is proposed for supervised polarimetric synthetic aperture radar (SAR) image classi¯cation. In this iterative approach, the optimization of polarimetric contrast enhancement (OPCE) is employed for enlarging the distance between the mean values of two kinds of targets and the Fisher method is employed for reducing the variances of two distributions. Using the proposed approach, polarimetric SAR image can be classi¯ed only after a few iterations. For comparison, the authors also use the maximum likelihood (ML) classi¯er for classi¯cation, based on the complex Wishart distribution. The classi¯cation results of a NASA/JPL AIRSAR L-band image over San Francisco demonstrate the e®ectiveness of the proposed approach.

Coherence Enhancement for Polarimetric SAR Interferometry

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Abstract| A new method for coherence enhancement is proposed based on the mathematical model on the relationship between the amplitude and the phase of the complex signals. An optimal projection direction of scattering vectors is derived for maximizing the amplitudes of the master and slave complex images. The experimental results demonstrate the e®ectiveness of the proposed approach.

Initial Polarimetric Calibration Results of ALOS PALSAR

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Abstract| This paper discusses the polarimetric calibration of Advanced Land Observing Satellite (ALOS) Phased Array L-band Synthetic Aperture (PALSAR). PALSAR is the ¯rst spaceborne L-band polarimetric synthetic aperture radar. Since the spaceborne SAR at low frequencies is a®ected by Faraday rotation e®ect which rotates the polarization plane of radar signal in the ionosphere, the scattering matrix which consists of the four polarimetric data (HH, HV, VH and VV) is distorted. Thus, in addition to the estimation of channel imbalance and cross-talk, to estimate Faraday rotation angle and to remove the contribution of Faraday rotation in the scattering matrix are an important problem in the polarimetric calibration of PALSAR. In this paper, we examine the polarimetric calibration of PALSAR. Freeman method is used to estimate the polarimetric calibration parameters including Faraday rotation angle.

Classi¯cation of Targets on Road by Fully Polarimetric and Real-time FM-CW Radar

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Abstract| A real-time and fully polarimetric FM-CW radar system has been developed in the Ku-band. This system has advantages in high resolution, high speed, and mobility. An experiment on the road has been carried out to check the possibility of target decomposition of various types. Figure 1 shows an example of iron pole and bicycle image of Pauli-vectors. Using decomposition results with Span images, possibility of target classi¯cation was evidenced in a real-time.

Polarimetric Observation of the Trees in the X and Ku-band by FM-CW SAR System

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Abstract|A fully polarimetric and a quasi-real-time FM-CW synthetic aperture radar system has been developed [1]. It is operative at the X-band and Ku-band with high resolution, and high speed. We have further improved this system in data acquisition stage, that is, real time display of target decomposition using the four-component decomposition scheme [2], real time polarimetric calibration, as well as scattering matrix representation in the range direction. This real-time system is applied to obtain scattering characteristics of trees of various types. In this presentation, the covariance matrices of various targets are presented.