Государственное образовательное учреждение
высшего профессионального образования
**«Томский государственный университет
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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 9-2

“Radar Target Classification”
(«Классификация РЛ целей»)

Публикации в трудах конференций

Источник: *Digital Library IEEEXplore*
Язык: *английский*
Глубина поиска: *2001 – 2011 гг.*
Дата формирования: *март 2011 г.*
Составитель: *В.И. Карнышев*

Томск – 2011

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"SAR Automatic Target Recognition Based on Classifiers Fusion"

Synthetic aperture radar automatic target recognition (SAR ATR) remains a challenging problem in military and civil field. Much work has been done to improve the performance of SAR ATR systems, both in feature extraction and classifier designing. This paper designs a multiple classifier system to solve the target classification problem in the area of SAR ATR. The proposed multiple classifier system trains three classifiers on different feature sets using three leaning algorithms. The outputs of the three classifiers are combined through evidence combination rule and discounting operation of Dempster-Shafer theory of evidence. Experiments on MSTAR public data set demonstrate that the proposed multiple classifier system significantly outperforms single classifiers and also excels adaptive boosting with RBF network as base learner. [C1]

"Novel short-time MUSIC in non-linear FMCW GPR signal analysis"

A novel windowed FFT MUSIC (W-MUSIC) algorithm is presented in the context of using ground penetrating radar (GPR) to detect closely spaced targets under noisy conditions. It is seen to give a better indication of targets than stand-alone FFT and MUSIC algorithms. Distorted signals are analysed, and with the MUSIC algorithm the reported target positions suffer high degrees of error, with the FFT the main lobe broadens making it difficult to recognise closely spaced targets. The use of the Short-Time Frequency-Transform (STFT) algorithm is examined. A novel Short-Time MUSIC approach is presented, it can be used to obtain higher time-frequency resolution than STFT method. [C2]

"Object tracking via the probability-based segmentation using laser range images"

In this paper, a probability-based segmentation approach is presented for object tracking. The proposed approach uses the Dirichlet process mixture model to describe the probabilistic distribution of observations in a single scan of a laserscanner. Then the number of segments is inferred from the observations by the Gibbs sampling method. Moreover each segment is classified into one of the three predefined classes such that most of non-vehicle-like objects on the roadsides can be filtered out. Then, the tracking algorithm, called Joint Integrated Probabilistic Data Association Filter (JIPDAF), is applied to track the classified objects and manage existing tracks. Simulations based on real traffic data demonstrate that the non-vehicle-like objects on the roadsides are suppressed. Since the number of objects in the tracking step is decreased, the computation load of the tracking step is decreased. [C3]

"Background removal from GPR data using Eigenvalues"

A GPR radargram of an underground scan has reflections not only from the target but many unwanted objects known as clutters. Additionally, the signal is corrupted by the direct wave and coupling effect of the antennas and background noise. In order to successfully extract the target signature, these extra noise effects need to be eliminated. Though the clutters cannot be totally removed from the data, background removal techniques suppress their effect to quite an extent. Usually mean subtraction is used as a background removal technique but the results are just satisfactory and further improvements can be made. In this paper an Eigenvalue based background removal technique in collaboration with mean subtraction is presented. This proposed method decreases the effect of clutters and the output is much more refined. Even though this method takes slightly more time than the traditional background removal methods, the output eliminates major portion of the clutter therefore the segmentation and classification stages in an automated GPR data processing system would be much more efficient hence reducing the overall time consumption for near real time GPR data processing. The method has been implemented on a number of different data sets and the results indicate that the proposed method gives significant improvement in background removal over the existing background removal methods. [C4]

"Feasibility study for IED detection using forward-looking ground penetrating radar integrated with

target features classification"

In this paper, we examined the natural resonance frequency and polarization features of UXO-Like IED target in forward-looking GPR configuration. Based on the simulation results, we confirm that these feature not only exist but also measurable in the case of FLGPR. It is therefore, strongly suggested that these features be included in the target classification algorithms as they are expected to improve detection, increase stand off distance and minimize false alarm rate. [C5]

"Automatic classification of metallic targets using pattern recognition of GPR reflection: a study in the IAG-USP Test Site, Sao Paulo (Brazil)"

In this work, a methodology to automatically classify of metal targets using pattern recognition techniques on GPR reflection data is presented. The methodology consists of designing a multilayer perceptron (MLP) classifier based on features extracted from the targets in the subsoil, and then using it to classify hyperbolas diffraction indicating their position and depth. The classification of reflections allows a high resolution reconstruction of the subsurface with reduced computing time. The system was developed in MATLAB and applied to GPR data obtained at IAG-USP test site, located in the city of Sao Paulo, Brazil, where metallic drums were studied under controlled field conditions. This site contains different targets of variable sizes buried under different depths and it served as a model for the computational experiment. The results indicate that the automatic classification of the metallic targets in the subsoil is efficient, contributing for the reduction of the ambiguities in the geophysical data interpretation, besides having application on the subsoil mapping of utilities. [C6]

"Fast segmentation of 3D point clouds for ground vehicles"

This paper describes a fast method for segmentation of large-size long-range 3D point clouds that especially lends itself for later classification of objects. Our approach is targeted at high-speed autonomous ground robot mobility, so real-time performance of the segmentation method plays a critical role. This is especially true as segmentation is considered only a necessary preliminary for the more important task of object classification that is itself computationally very demanding. Efficiency is achieved in our approach by splitting the segmentation problem into two simpler subproblems of lower complexity: local ground plane estimation followed by fast 2D connected components labeling. The method's performance is evaluated on real data acquired in different outdoor scenes, and the results are compared to those of existing methods. We show that our method requires less runtime while at the same time yielding segmentation results that are better suited for later classification of the identified objects. [C7]

"Object recognition in ground surveillance doppler radar by using bispectrum-based time-frequency distributions"

Performance estimation and comparative study of different kinds of time-frequency distributions (TFDs), especially Wigner-Ville distribution (WVD), as well as bispectrum-based distributions: Wigner-bispecrum (WBD), parametric (PBD) and non-parametric (NPBD) obtained by real non-stationary echosignal measuring in ground surveillance Doppler radar are considered for solving moving object recognition and classification problems. Automatic target recognition (ATR) performance has been examined by using information features contained both in the TFDs and cepstral coefficients. Experimental results performed by ground surveillance radar operating in millimeter wavelength for walking human, group of walking humans, bicyclist, vehicles and vegetation clutter show that bispectrum-based approach seems to be attractive tool for ATR systems comparing to the conventional energy-based approaches. [C8]

"One Example of classing and extracting information from GPR images for the archeology"

Ground penetrating radar (GPR) techniques are based on the possibility of sending electromagnetic pulses and registering of the signals back-scattered by the interface between propagation media of different dielectric permittivity. They had been successfully using to examine structures and materials from inside. In the studying, GPR sounding is practically used for detection and reconstruction of the fortification objects. The software for increase of efficiency of archeological researches and reduction of expenses was developed. The GPR method is practically approved for the undersurface environment monitoring for the archeology-interested zones by results of experimental and practical investigations. The estimation of GPR efficiency at monitoring researches, time and expenses on engineering-archeological works were carried out. As a result of researches, contours of fortifications sites are restored. Contours of the stone bases under dwellings are found out and restored. The investigation aims at expounding some preliminary results drawn by specific algorithms for automatically interpreting, classing and extracting explicit information from radar images. [C9]

"Applying the decision trees to radar targets recognition"

Electronic Support Measure (ESM) systems have been used to passively detect electromagnetic emission from airborne, shipborne, and landborne platforms. The paper describes a method of an automatic radar target recognition based on following principal stages: digital signal processing, feature extraction and selection and applying a combination of decision tree, minimum distance classifier and knowledge base. [C10]

"Analytical sensor data evaluation models for the purpose of evidential inference in electro-magnetic reconnaissance"

This paper describes what particular pieces of information about source should be taken into account to get a reasonable assessment of attribute information based on the sensor data or human originated information. It has been proven that actual sensor weights and hypotheses masses do not change randomly, but they vary in time according to tracked target motion, however not directly to the target position. It is postulated that the knowledge about target position only is insufficient and at least two dynamical coordinates target state vectors are required to reflect the target orientation, which has an influence on actual hypotheses assessment formed, on the basis of the sensor data or visual sightings. [C11]

"Incoherent addition of ISAR images from spatially distributed receivers for classification purposes"

A popular approach for Non-Cooperative Target Identification is the use of 2D Inverse SAR images. To successfully identify a target it is necessary to compare a set of scattering centers in the ISAR image to a data base. In the conventional case of a monostatic radar, however, visibility of scattering centers varies with the target aspect angle. In this paper we show that the visibility of scattering centers can be improved by incoherent addition of images from spatially distributed radars. The main focus lies in the description and relevant results of a multistatic ISAR experiment carried out at Fraunhofer FHR. [C12]

"SAR image target recognition based on NMF feature extraction and Bayesian decision fusion"

In this paper, a new approach of synthetic aperture radar (SAR) image target recognition based on non-negative matrix factorization (NMF) feature extraction and Bayesian decision fusion is presented for recognizing ground vehicles in MSTAR database. First, feature vectors are extracted from image chips by NMF algorithm. Support vector machine (SVM) is used to classify the feature vectors. After multiple views of the same vehicle collected at different aspects are classified by SVM, the outputs are fused by Bayesian decision fusion algorithm and then the final classification decision is generated. We evaluate NMF algorithm and the Bayesian decision fusion approach. Experimental results indicate that there are significant target recognition performance benefits in the probability of correct classification when NMF algorithm is applied and three or more views are used for Bayesian decision fusion. [C13]

"Tracking People with a 360-Degree Lidar"

Advances in lidar technology, in particular 360-degree lidar sensors, create new opportunities to augment and improve traditional surveillance systems. This paper describes an initial challenge to use a single stationary 360-degree lidar sensor to detect and track people moving throughout a scene in real-time. The depicted approach focuses on overcoming three primary challenges inherent in any lidar tracker: classification and matching errors between multiple human targets, segmentation errors between humans and fixed objects in the scene, and segmentation errors between targets that are very close together. [C14]

"A progressive approach for building extraction by fusing LIDAR data and co-registered bands"

In this paper, a progressive approach is presented for building extraction from LIDAR combined with its co-registered bands. Carefully tuned Gabor wavelet filters are applied to LIDAR data for object detection on the earth, and to localize targeted objects in order to minimize hilly terrain effects. Object classification is then carried out in local areas where objects exist. The Dempster-Shafer (DS) theory of evidence is used to conduct initial classification by fusing LIDAR and its co-registered data sets; and a fuzzy Markov random field (FMRF) model takes the output from the DS theory of evidence, and is performed the further object classification to extract buildings. Finally the level set approach is employed for building boundary extraction. The testing experiments under this research have shown the potential of this approach in accurately extracting buildings from airborne LIDAR and its co-registered bands. [C15]

"Impact of flight trajectory on the detection and selection of flowers by nectar-feeding bats"

Echolocating mammals, such as bats, have evolved an excellent ability to detect, select and identify the targets

they depend on for their survival by echolocation even in the most challenging environments. They simultaneously adapt their trajectory and diversify transmission parameters such as waveform, bandwidth and time duration, to obtain high level detection and classification performance that is far better than that obtained by modern radar and sonar systems. This paper exploits the information available to the bat along its in-flight trajectory aiming at assessing the impact of choosing the right trajectory on detection and classification performance. A set of experimental data consisting of HRRPs of one inflorescence of Rhytidophyllum auriculatum is analysed and results are discussed and related to the case of radar and sonar systems. [C16]

"Offshore petroleum exploration from space: A developing capability at Geoscience Australia"

Natural seepage can generate hydrocarbon slicks on the sea surface that may provide petroleum explorers with direct evidence of oil and gas below the sea bed. Remote sensing has the potential to be used as a tool for detecting such sea surface slicks, thereby identifying areas in both producing and frontier basins that are prospective for hydrocarbons. We are developing a two-pronged, remote sensing-based approach for seepage slick studies in the Australian Marine Jurisdiction: 1) building a semiautomated processing and classification system in order to scan large numbers of Synthetic Aperture Radar scenes for potential natural slick targets, and; 2) investigating the potential of optical remote sensing as a diagnostic tool for further, targeted study. Using objected-oriented classification algorithms in a bulk processing environment, large Synthetic Aperture Radar data sets were able to be efficiently screened for potential natural oil slick targets. This processing system offers a range of outputs, including classification statistics for each scene studied, as well as geo-referenced shapefiles ready for analysis in Geographic Information System software, where it can be combined with ancillary data sets for contextual analysis. Our research into the potential for optical remote sensing to enable further diagnostic study of identified, potential targets has shown that there are several commercially available, space borne sensors able to detect the types of oils found throughout the Australian Marine Jurisdiction, but that oil type is critical for this application. Further to this, we have developed an approach for performing a feasibility study of oil type versus sensor sensitivity prior to image data acquisition. [C17]

"Active hyperspectral LIDAR methods for object classification"

We have studied the fusion of active hyperspectral and range (LIDAR) data to investigate the concept of an active hyperspectral LIDAR and its potential applications in the remote sensing of vegetation. We have built two prototype instruments using the newly developed supercontinuum laser technique providing a continuous spectrum, which has then been used both for combined hyperspectral and LIDAR or time-of-flight measurement. The preliminary results point out the potential of active hyperspectral methods in laser-based remote sensing applications: the combined topographic and spectral information, such as the normalized difference vegetation index (NDVI), can be used efficiently in automatic target identification and classification. [C18]

"Advanced through-the-wall radar imaging using spectral and wall estimation techniques"

Two techniques are introduced and combined to improve SAR imaging of TWR scenarios, namely wall estimation and spectral estimation imaging using MUSIC. It was shown that homogeneous walls can be eliminated from SAR images although a significant amount of clutter remains if the wall shows inhomogeneities. Furthermore, applying the MUSIC algorithm can significantly clear up the image and make the targets behind the wall more visible. In conclusion, both the described wall estimation technique and MUSIC imaging can enhance TWR images, allowing a clearer interpretation or building a more reliable basis for further processing like target detection. [C19]

"Comparison between genetic programming and Neural Network in classification of buried unexploded ordnance (UXO) targets"

In this paper, we present the results of our next step effort in comparison of classification performances between the NN and the GP techniques based on the simulated scattering patterns of UXO-like object and non-UXO objects. For this comparative study, 2 dimensional scattering images from one UXO target and four non-UXO objects were generated by numerical simulation tool (FEKO). For non-UXO objects, the most challenging targets to discriminate from UXO, since all these objects produce resonance signal as UXO-like targets do [6], were selected. Classification performances of both techniques (NN vs. GP) in different level of noise and in the case of presence of untrained data were examined and the results and observations are discussed. [C20]

"SAR Target Recognition with Data Fusion"

This paper presents an approach for synthetic aperture radar (SAR) target recognition with data fusion. The data of multi-aspect images of a target are fused by principal component analysis (PCA) or discrete wavelet transform (DWT) after preprocessing. Wavelet domain PCA is used to extract feature vectors from the fused data. Support

vector machine (SVM) is applied to classify the extracted feature vectors. Experiments are implemented with three military targets in MSTAR database for analyzing the effects on recognition rate of targets caused by different number of images and aspect intervals in different fusion algorithms. The experimental results demonstrate the higher recognition rate of the proposed method than that of the method without data fusion. Therefore, the proposed method can be applied in SAR image target recognition effectively and advance recognition rate of targets significantly. [C21]

"Target recognition for marine search and rescue radar"

The key point of marine search and rescue is to find out and recognize the distress objects. At present, the visual search method is usually adopted to detect the ships in distress, and this method can only be used at good sea condition and visibility. In this paper, a new target detection and recognition system is proposed. The parameters of radar transmitter and echo graphics and the invariant moments of radar images are extracted as the system's recognition features, and the system's target classifier is based on BP neural networks. The developed recognition classifier has been tested using three kinds of target images, the target's features are used as the inputs of trained BP neural networks and the outputs of networks are target classification. Sea experimental results show that the proposed method is well-clustering and with high classified accuracy. [C22]

"Assessment of statistical models for clutter and target in SAR images"

Accurate knowledge of statistical properties of SAR data plays an essential role in SAR image processing and understanding. Several studies have been made for discovering the relationship between the physical features and statistical properties of SAR data, and some statistical models for modeling SAR data having been proposed and studied. In this paper, we focused on four often used statistical models: the Weibull, Log-normal, Gamma and K distributions. These models are used to fit target and clutter regions in SAR data provided by MSTAR, and through three different goodness-of-fit tests, we assess the performance of the four statistical models for modeling the clutter and target in the SAR images. The results show that K distribution performs best and Log-normal performs worst for modeling clutter region, on the other hand, Log-normal distribution performs best while K distribution performs worst for modeling target region. [C23]

"Novel side-view imaging of ships at sea for airborne ISAR"

For airborne ISAR imaging of ship targets at sea, both ship's three-dimensional rotation driven by waves in the sea surface and the relative tangential translational motion between the platform and the ship contribute to the imaging. At high sea-state and in long-range and low-altitude observation, the rotation component produced by the relative tangential motion between the radar and the ship is negligible. A well-focused side-view image of a ship formed by utilizing the ship's dominant roll and pitch is always available via a suitable imaging time selection scheme. However, the effect of the rotation due to the platform tangential motion with respect to the ship, which provides much top-view information of the ship, has to be taken into account in some cases, such as when the ship is observed in a relatively close range. In these cases, the resulting image presents a mixture of the ship side-view and top-view that is less valuable than a pure side-view image for further classification. We present a ship side-view imaging method in this paper to solve this issue. The Doppler frequency derivative of each scatterer is shown to approximately only contain the height information and is estimated and utilized for the side-view image formation, with the use of 'CLEAN' technique and a concentration measure that is introduced to increase the estimation accuracy of the Doppler frequency derivative. For a short imaging interval, the Doppler frequency derivative is approximate to a constant chirp rate. The corresponding estimation reduces to a chirp rate estimation. The proposed method is verified by experiments on simulated data. [C24]

"A spatiotemporal model for radar HRRP sequence recognition"

A temporal factor analysis (TFA) model which can describe both the spatial structure and temporal dependency of high range resolution profiles (HRRP) has been proposed for radar HRRP sequence recognition. Variational Bayes method and Bayesian classifier are adopted for model learning and classification task, respectively. The favorable results based on measured data show the effectiveness of this model. [C25]

"A target alignment algorithm for through-the-wall radar imagery classification"

Sensing through the wall using radar is a valuable capability. There is considerable work in generating radar images of the interior of a room by beamforming of the radar backscatter generated in a Synthetic Aperture Radar (SAR) configuration. However, high level interpretation of the scene is a more difficult task. In previous work a minimum distance classifier was successfully used to recognize various targets placed in the scene. The approach suffered from the dependency of target features on target location. This work presents a solution to this problem by bringing the target intensity profiles into alignment with the training data prior to classification. The

alignment is performed by moving the intensity profiles between locations using an Autoregressive Moving Average (ARMA) model. The classification results before and after alignment show a marked improvement. [C26]

"STAP analysis using multi-channel airborne radar data from flight trials"

Flight trials have been performed within the NORA program in order to acquire multi-channel clutter data for different types of terrain, terrain scattered interference, and SAR data. The acquisition of clutter and terrain scattered interference has been made in order to prepare a database for future development of operational space-time adaptive processing (STAP) algorithms applicable to active electrically scanned antenna (AESA) systems employing multiple sub-aperture configurations. In this paper we show some preliminary results that illuminate the benefit of using all four dimensions of multi-channel radar data in a clutter rejection perspective. To illustrate the behavior of multi-channel clutter we employ spatial spectrum estimation methods such as Fourier and MUSIC. We also demonstrate post-Doppler STAP results for the air-to-air case. The results are very promising and indicate that multi-channel processing will indeed enhance the ability to detect targets obscured by clutter. [C27]

"The effect of clutter on the automatic target classification accuracy in FSR"

The clutter influence on the automatic target classification (ATC) accuracy in forward scattering radar (FSR) is presented. To study the ATC at various signal-to-clutter ratios (SCR), a simulated vegetation clutter is artificially added to the real clutter-free targets recorded signals. It is shown that using conventional clutter-uncompensated ATC system can achieve high target classification accuracy at high SCR only, but the accuracy drops significantly with SCR decreasing. The employment of clutter-compensated ATC system is shown to improve significantly the classification accuracy at low SCR. [C28]

"A robust neural network based pulse radar detection for weak signals"

In this paper we develop a neural network capable of detecting targets with weak echoes in a pulse radar. This is possible as the network is designed as a pattern classifier (in contrast to earlier work) together with a suitable but simple pre-processing of the returns. We demonstrate through simulations that such a network exhibits better range resolution and noise tolerance when compared to previous work based on neural networks. In addition, we examine the Doppler tolerance and the overall robustness of the trained network. [C29]

"A radar target recognition method based on wavelet power spectrum and power offset"

Radar high resolution range profile (HRRP) is sensitive to the target aspect and highly overlapped in feature space between different targets, thereby hybrid features are suitable for representing the target's property. In this paper, the quadratic spline wavelet with compact support properties was used to extract the energy spectrum features of HRRP by multi-resolution decomposition, and the power offset was defined to characterize the Structural characteristics of aircraft under different target-aspect. Then the joint features which combine the energy spectrum features and the power offset of HRRP were selected in the kernel space. The simulation results based on support vector machine (SVM) classifier show that the proposed method is effective. [C30]

"Coupling optimal method of segmentation with restoration for target detection in SAR images"

High-quality segmentation is there in a need in SAR images for appropriate target detection. In this paper, the features of Wiener filter are utilized with region of interest and Boundary based segmentation technique in SAR images. The discrete Wiener filter exhibits both linear and nonlinear characteristics. This filter compensates for the blurring due to the linear term and conserves the edges which are mainly used to distinguish the various objects with the gross representation of object of interest. The filter is defined both for edge preserving along with speckle noise cancellation in SAR images. A combination of features from two different types of multi-resolution and multi-channel filters, in general provides superior classification of SAR images. The experimental results show that the proposed boundary based and ROI technique segments the SAR image while the opted filter preserves significant features and noise removal. The fusion performance is evaluated on the basis of Mean square error, time, and signal-to-noise ratio. [C31]

"Scattering Centers Extraction of Radar Target Using Biquaternions"

Scattering centers estimation results are significant for radar target recognition in high frequency section. This paper introduces biquaternion theory into full-polarization scattering centers extraction of radar target. Firstly, we define full-polarization scattering centers as a biquaternion model. It makes a close connection between polarization parameters. Then, we propose Bihan's BQ-MUSIC thought to extract scattering centers' position

parameters. Simulations illustrate that our theory gets better estimation results compared to polarization MUSIC algorithm of complex model. [C32]

"Waveform interference mitigation for a shared spectrum MIMO radar system"

MIMO radars may outperform conventional ones as regards target detection, parameter estimation and classification via spatial and waveform diversities. MIMO radar is a kind of shared spectrum system: the mutual interference among the waveforms may lead to considerable performance degradation, especially with multiple targets. As a result, preserving MIMO radar performance under such conditions via waveform design becomes an interesting research topic. In this paper, we consider the marriage of space time coding (STC) and Golay complementary pairs to mitigate both waveform autocorrelation and cross-correlation effects, and hence to enhance range resolution. The implementation is discussed, and an application for instantaneous polarization is briefly introduced. [C33]

"Sparse representations for automatic target classification in SAR images"

We propose a sparse representation approach for classifying different targets in Synthetic Aperture Radar (SAR) images. Unlike the other feature based approaches, the proposed method does not require explicit pose estimation or any preprocessing. The dictionary used in this setup is the collection of the normalized training vectors itself. Computing a sparse representation for the test data using this dictionary corresponds to finding a locally linear approximation with respect to the underlying class manifold. SAR images obtained from the Moving and Stationary Target Acquisition and Recognition (MSTAR) public database were used in the classification setup. Results show that the performance of the algorithm is superior to using a support vector machines based approach with similar assumptions. Significant complexity reduction is obtained by reducing the dimensions of the data using random projections for only a small loss in performance. [C34]

"AD-MUSIC for jointly DOA and DOD estimation in bistatic MIMO radar system"

In this paper, a MUSIC-based approach named as AD-MUSIC is presented to jointly estimate the directions of arrival (DOAs) and directions of departure (DODs) estimation for the direction finding cross localization of multi-targets in bistatic MIMO radar system. The MUSIC algorithm for the DOD estimation is referred to as the D-MUSIC algorithm. On the other hand, the A-MUSIC, which estimates the DOA, is introduced as well. The proposed AD-MUSIC combines two one dimensional (1-D) MUSICs along with the spatial beamforming technique to jointly estimate the DOAs and DODs. At the same time, the estimated DOAs and DODs is automatically determined. Simulation results are presented to verify the effectiveness of the proposed method. [C35]

"A joint tracking and classification algorithm with improved mutual feedback"

For the joint tracking and classification (JTC) problem in FM-band passive air surveillance radar system, a particle filter approach with improved mutual feedback is presented. Delay and Doppler measurements are used to estimate dynamic state and recognize target class. The improved mutual feedback between tracker and classifier is realized by a classification probability dependent particle assignment technique, which utilizes feedback information completely and increases tracking performance of the higher probability target class. Simulation results show the efficiency of the proposed method. [C36]

"Signal reconstruction as an effective means of detecting targets in a DAB-based PBR"

This paper aims to validate the method of target detection by correlating a surveillance (target) signal with a reconstructed reference signal in DAB-based Passive Bistatic Radar (PBR). Whereas most conventional PBRs condition the surveillance signal by suppressing Direct Signal Interference (DSI) and then correlate this with a similarly measured reference signal to reveal targets, the approach adopted at FHR is to correlate the surveillance signal with a perfectly reconstructed, error-free, copy to the transmitted signal. [C37]

"Classification of air targets including a rejection stage for unknown targets"

In this paper an algorithm for Non-Cooperative Target Identification (NCTI) of airplanes is presented. The advantage of NCTI over Identification Friend-Foe-systems (IFF-systems) is its ability to identify positively not only friendly airplanes but also neutral or hostiles ones. The approach described here uses one-dimensional radar images, so-called High Range Resolutionprofiles (HRR-profiles) for NCTI. However only the locations of the local maxima of the HRR-profiles were used for classification instead of using the whole HRR-profiles. Furthermore a statistical test procedure is presented that is carried out prior to the classification procedure to determine if an airplane belongs to a known or to an unknown class of airplanes without distinguishing the known classes of

airplanes. [C38]

"Analysis of ATR features for non-cooperative ground-based classification of ships"

Measurements were taken at 17 GHz of a ship that was first approaching the coast-based radar and then followed a circular course between 6km and 7km distance. It is demonstrated how the high range resolution profile of the ship and consequently any ATR (automatic target recognition) classification features derived therefrom are modified by multipath as a function of range and aspect angle. For comparison, the TERPEM software is used to simulate the effect and analyse it in a more controlled way. [C39]

"A spectral space-variant approach for structure indexing in Spotlight TerraSAR-X data"

Modern space missions equipped with SAR instruments provide high spatial resolution data. In such data features of urban objects, man-made structures, as well as natural targets can be identified. We propose a descriptive model based on the frequency spectra of the complex signal, that integrates the radiometric, geometric, and texture features, for scene and target indexing, to cope with the problem of large database queries and information retrieval. Considering the properties of the Spotlight imaging mode in particular, a phase correction algorithm is applied to the data, prior to feature extraction. The assignation of a particular scene to a certain class is done using a Bayesian Support Vector Machine classifier. The method allowed for the recognition of more than thirty targets and structures in the scenes. [C40]

"Bat-inspired ultrasound tomography in air"

Classification of targets is of great interest to the radar and sonar community. The development of modern systems has resulted in a drive to improve automatic target recognition in order to be able to identify targets under all weather and clutter conditions. Echolocating mammals, such as bats, have an imperative to identify the targets they depend on for their survival and have evolved an excellent ability to detect, select, and attack prey even in the most challenging environments. They acquire multi perspective information as to construct an image of the target in the way a typical tomographic image is developed. In this paper ultrasound high range resolution profiles of a real scaled target are processed to exploit tomographic images at ultrasound frequencies in air. Results are discussed and related to the radar case. [C41]

"Adaptive polarization processing for improved detection/classification of stationary targets"

A new technique for detection of stationary or slow-moving over-resolved targets on the ground, based upon a Hotelling T-squared test/generalized inner product (GIP) approach to signal analysis is presented. This robust detector separates radar returns from interference via a coherent process. This GIP-based processing can be applied to single-receiver channel systems, multiple spatial channel systems, multiple polarization channel systems or systems with multiple spatial and polarization channels. [C42]

"Robust automatic target recognition using extra-trees"

In this paper, we describe a new automatic target recognition algorithm for classifying SAR images based on the PiXiT image classifier. It uses randomized sub-windows extraction and extremely randomized trees (extra-trees). This approach requires very little pre-processing of the images, thereby limiting the computational load. It was successfully tested on an extended version of the public standard MSTAR database, that includes targets of interest, false targets, and background clutter. A misclassification rate of about three percent has been achieved. In this paper, we describe a new automatic target recognition algorithm for classifying SAR images based on the PiXiT image classifier. It uses randomized sub-windows extraction and extremely randomized trees (extra-trees). This approach requires very little pre-processing of the images, thereby limiting the computational load. It was successfully tested on an extended version of the public standard MSTAR database, that includes targets of interest, false targets, and background clutter. A misclassification rate of about three percent has been achieved. [C43]

"Performance evaluation of multiple-target tracking systems"

To evaluate the performance of real multiple-target tracking systems, instead of their simulative systems, the signal origin of each track should be determined in the different form because the data association in real systems is absolutely unknown. In addition, the calculation of performance indices should be suitable for the case of variable sampling interval. Here the state estimate of each track is projected into measurement space and the statistical distance between this projection and each simultaneous measurement is calculated. Hence the signal origin of that track can be determined via the rule of Nearest Neighbor. Based on the relationship matrix with respect to track and signal origin, a new method to calculate a suit of performance indices for both

TAS and TWS modes is proposed. This method has been adopted in our TrackEnviro-a evaluation system for the multiple-target tracking performance of real phased array radar. [C44]

"Feature extraction in Through-the-Wall radar imaging"

This paper deals with the problem of automatic target classification or Through-the-Wall radar imaging. The proposed scheme considers stationary objects in enclosed structures and works on the SAR image rather than the raw data. It comprises segmentation, feature extraction based on superquadrics, and classification. We present a recursive splitting tree to obtain optimum parameters for feature extraction. Support vector machines and nearest neighbor classifiers are then applied to successfully classify among different indoor targets. The classification methods are tested and evaluated using real data generated from synthetic aperture Through-the-Wall radar imaging experiments. [C45]

"Integrating object-oriented image analysis and decision tree algorithm for land use and land cover classification using RADARSAT-2 polarimetric SAR imagery"

Traditional pixel-based classification methods yield poor results when applied to SAR imagery because of the presence of speckle and limited information in backscatter coefficients. A novel classification method, integrating polarimetric target decomposition, object-oriented image analysis, and decision tree algorithms, is proposed for the classification of polarimetric SAR data (PolSAR). The polarimetric target decomposition is aimed at extracting physical information related to the scattering mechanism of targets for the classification of scattering data. The main purposes of the object-oriented image analysis are delineating objects and extracting various spatial and textural features. The decision tree algorithm provides an efficient way to select features and create a decision tree for the classification. A comparison between the proposed method and the Wishart supervised classification was made. The overall accuracies of these two methods were 89.34% and 79.36%, respectively. The results show that the proposed method is an effective method for the classification of PolSAR data. [C46]

"Detecting depolarizing targets with satellite data: A new geometrical perturbation filter"

Target detectors using polarimetry are often focused on single (coherent) targets, since these are the ones that can be more simply characterized polarimetrically. The new proposed algorithm is aimed at the more difficult problem of partial target detection (i.e. targets with any degree of polarization). A new feature vector is defined starting from the coherency matrix, and then a perturbation method is performed. Starting from the partial target detection, a novel classification algorithm is proposed. The validation is carried out against fully polarimetric satellite data. In particular, X band TerraSAR-X and L band ALOS PALSAR are employed, providing significant agreement with the expected results and the supervised Wishart classifier. [C47]

"A comparison of experimental and modeled results of an active millimeter wave inverse synthetic aperture radar system used to perform standoff detection of person-borne improvised explosive devices"

With the recent rise in casualties resulting from person-borne improvised explosive devices (PBIEDs) or "suicide bombers," there is an urgent need for standoff detection of such threats. An optimum system that fulfills the requirements of standoff detection must be portable, low cost, and have a high probability of detection with low probability of false alarm at a distance of at least 20 meters. Currently there are a variety of modalities being researched to perform standoff detection of PBIED's including: backscatter X-ray imaging, infrared imaging, optical detection, terahertz imaging, video analytics, and millimeter-wave (MMW) imaging. MMW imaging at 94 GHz is a very good modality for performing standoff detection of PBIEDs. MMWs can propagate through the atmosphere and clothing with very little attenuation, while at the same time do not cause damage to human skin tissue. A mono-static linear frequency modulated continuous wave (LFMCW) circular inverse synthetic aperture radar (ISAR) system has been developed and tested. A model of such a system using a two dimensional full wave analysis based on the finite difference method in the frequency domain has been developed and compared with results of the experimental system. Using a two dimensional matched filtering technique in the frequency domain, simulated images have been used as a means of performing target detection and classification. The imaging results of both simulated and experimentally obtained data is presented in this paper. Initial results using the 2D matched filtering target classification technique will also be presented. [C48]

"A mover detection method based on 2-D fuzzy entropy in SAR images"

In this paper, a new technique for the moving targets detection combining incoherent and coherent information of the Synthetic Aperture Radar (SAR) images is proposed based on the measure of a two-dimensional (2-D) fuzzy entropy principle. Firstly, it extracts incoherent and coherent information from images in pixel and builds a 2-D

histogram. Secondly, according to 2-D fuzzy function, image pixels are fuzzy classified into two groups: changed and unchanged then 2-D fuzzy entropy is calculated. Finally, Differential Evolution (DE) algorithm is used to maximize the entropy and the optimal parameters of the fuzzy function are obtained, which procures effective moving target detection results. [C49]

"Parameters estimation of target with precession based on combined feature"

It is beneficial for the recognition and classification of targets to obtain geometrical and motional parameters simultaneously. This paper proposes a new method to estimate parameters of target with precession based on combined feature, which is generated by Doppler feature and high range resolution feature of target from a new radar-OFDM radar. Expanded Hough transform (EHT) is employed to establish the combined feature with range and motion information of scatterers. The paper mainly presents the principle to establish the combined feature and the estimation of precession angle, target posture and target length. Finally, the results from simulations and anechoic chamber data prove the validity of the method. [C50]

"An experiment for oil spill recognition using RADARSAT-2 image"

In this paper, an experiment that is oriented to discriminate between different oil slicks using polarimetric SAR image was introduced. Dark patches which often appear in SAR images such as biogenic slicks, atmospheric front, and crude oil with different chemical composition were identified according to the result of Eigenvector-Eigenvalue based Incoherent Target Decomposition. The experiment demonstrated that polarimetric SAR can be of great help in classifying of oil spills. [C51]

"Evaluation of the influence of the polarimetric calibration process on the H/A/alpha decomposition"

The objective of this article is to evaluate the influence of the cross-talk and channel imbalance calibration on the estimation of the entropy and the alpha images. Few studies can be found in SAR literature concerning the influence of the polarimetric image calibration process on the target decomposition methods and their consequences on the characterization and discrimination of different ground targets. This influence is illustrated here by using a methodology based on an L-band fully polarimetric SAR data acquired by the SIPAM (Amazon Protection System) airborne R99-SAR over two areas of study, located in the Brazilian Amazon Forest and urban area regions. [C52]

"Preliminary result of polarization property analysis using fully polarimetric GB-SAR images"

Korea Institute of Geoscience and Mineral Resources (KIGAM) and Kangwon National University (KNU) ground-based synthetic aperture radar (GB-SAR) team has been developed a fully polarimetric and interferometric GB-SAR system over past several years. The objective of this paper is to investigate an application of the obtained fully polarimetric GB-SAR images and an effective polarimetric analysis method to extract polarization properties from different terrain targets as a preliminary study. We utilized an unsupervised classification method for analyzing of a fully polarimetric GB-SAR image, in particular, Cloude and Pottier's method and a combined H/A/α_ and the complex Wishart classifier method based on the H/A/α_ polarimetric decomposition theorem. [C53]

"Pose estimation for ISAR image classification"

This paper presents aircraft target recognition (ATR) system using Inverse Synthetic Aperture Radar (ISAR) images. Knowing the pose of the target can improve the ATR performance (recognition rate and computational complexity). So, we propose in this paper a new pose estimator from ISAR images, based on the axis of symmetry and the similarity measure. The method proposed is compared with several approaches proposed recently in the literature, such as 2-D Continuous wavelet Transform and Hough transform. Once the pose of target is estimated, the classification if finally performed by K-Nearest Angle (KNA) classifier which insert the pose information into image retrieval task. [C54]

"Log-polar and polar image for recognition targets"

We describe in this paper, data processing algorithms applied on radar image in order to extract feature descriptors and then to perform recognition task. Several kinds of descriptors can be used to acquire information about target characteristics from radar images such as ISAR (Inverse Synthetic Aperture Radar) images. This paper presents two types of vector descriptors extracted via two minds of transformed images so-called polar and log-polar images obtained respectively from the polar and log-polar mapping. In order to guarantee the invariance of some geometrical transformation, additional processing are proposed. In this paper, we present the polar and log-polar transformations and then the classification scheme adapted on correspondent polar and log-

polar templates. In the classification step, log-polar and polar mapping results are compared using adapted classification scheme. [C55]

"Bistatic SAR along track interferometry with multiple fixed receivers"

This paper presents an along-track interferometry (ATI) study for a bistatic or multiestatic SAR configuration with fixed ground receivers. This technique can be useful for sea current estimation or for any problem of Ground Motion Target Indicator (GMTI). The proximity of the ground receivers to the scene allows to be very sensitivite to velocities with small baselines. This paper also proposes a multibaseline approach for ATI able to diferenciate among different velocity contributions in the same resolution cell. At the end of this paper, some results over real acquired bistatic data will be presented and discussed. The data have been acquired using the C-band SAR Bistatic Receiver for INterferometric Applications (SABRINA) and ESA's ENVISAT satellite, as a transmitter of opportunity. [C56]

"A Novel Application of Support Vector Machines to Detect Targets"

In this paper we develop a novel pulse radar detection scheme using Support Vector Machines (SVMs). SVMs are a powerful tool for pattern classification. Exploiting this, we design a SVM for pulse radar detection of targets embedded in noise. An adaptive pre-processing stage is included when the echoes are very weak. It is observed that the signal-to-side lobe ratio obtained is much higher compared to neural network based pulse radar detection schemes. We further examine the noise tolerance, range resolution ability and Doppler tolerance of the new algorithm for pulse compression, and compare it with the ones available in literature. [C57]

"Parallelized Physical Optics computations for Scattering Center Models in radio channel simulations"

Scattering Center Models (SCMs) are an approach to efficiently characterize electromagnetic scattering of complex shaped objects in terms of a distribution of equivalent sources. SCMs have been widely used in the area of radar target modeling, particularly for object characterization and classification. Recently, the SCM approach has been adapted to model the electromagnetic properties of vehicles embedded in a comprehensive environment for the simulation of automotive radar channels. In this paper the application of SCMs for deterministic simulations of communication channels in automotive environments is presented. The main advantage of this concept is a drastic reduction of complexity for the ray tracing simulations. Instead of using a full geometrical description of the scene, the most complex objects are replaced by an equivalent SCM and a strongly simplified surface model. The SCM of an object is determined in advance, independent from the surrounding environment. In order to achieve a precise parameterization of individual Scattering Centers (SC), the Physical Optics (PO) approximation can be applied. Unfortunately, in contrast to a parameterization based on the Geometrical Optics (GO) contribution only, this approach requires field computations for a large number of observation directions. To handle this computational challenge, a parallelization concept is presented, which is based on multi-core architectures and on the utilization of Graphics Processing Units. [C58]

"GMTI tracking using signal strength information"

Signal strength information is a standard output of a modern radar system. Provided the amplitude of the target returns exceeds the false alarm background, the consideration of signal strength may lead to improved target estimates, depending on the scenario. In this paper a Bayesian tracking algorithm is presented which incorporates the signal strength information. In contrast to previous approaches, the knowledge on the target's signal strength is not only used for an improved calculation of the association probabilities, but it enters into the algorithm as a random variable which is sequentially estimated. By this approach it is not only possible to discriminate closely-spaced targets and improve the track continuity, but also to support possible classification and identification tasks. The signal strength fluctuations of the target returns are modeled by the Swerling-I and Swerling-III cases. As a first performance evaluation, numerical results are presented based on a multi-target simulation scenario. [C59]

"Concurrent use of satellite imaging and passive acoustics for maritime domain awareness"

The research being conducted in the Center for Secure and Resilient Maritime Commerce (CSR), a DHS National Center of Excellence for Port Security examines some basic science issues and emerging technologies to improve the security of ports and inland waterways, as well as coastal and offshore operations. This research follows a layered approach utilizing above water and underwater surveillance techniques. The investigated layers include satellite-based wide area surveillance; HF Radar systems providing over-the-horizon monitoring; and nearshore and harbor passive acoustic surveillance. Integration of these systems is aimed at achieving vessel detection, classification, identification, and tracking. In this paper, we present the results of sea tests where

satellite imagery was combined with concurrent passive acoustic surveillance. The wide area sensing was provided by the University of Miami CSTARS facility's electro-optical (EO) and synthetic aperture radar (SAR) satellite imaging capabilities. Satellites detected the ships using a panchromatic EO sensor FormoSat-2 and SAR from the COSMO-SkyMed constellation. The Stevens Passive Acoustic System was used for detecting sound produced by the same ships that were detected by satellites. Concurrent Satellite-Acoustic measurements provide the following advantages: 1. Increasing the probability of small vessel detection and decreasing false alarms. 2. The joint systems can provide redundant detection and classification in conditions where one of the systems fails. For example, EO satellite imaging does not work at night and in fog and cloudy conditions while acoustic detection has limits during stormy weather due to ambient noise. SAR imaging can detect vessels in all weather, but provides less detail about a specific vessel. 3. Acoustics can provide target classification and bearing and satellites can give target localization and heading. SAR data can be used to estimate vessel speed in some cases. 4. Satelli--te imaging is helpful for the acoustic detection of an underwater target in cases when satellite information allows separation of surface and underwater targets. 5. Joint measurements provide more data (information) for target classification. Several tests were conducted in New York Harbor, where the satellite images and acoustic signatures of the same boats were recorded. The satellite registered a number of small boats. The small boats were acoustically detected at distances up to 4 km and the signal generated by a passenger ferry was observed at a distance up to 7 km. [C60]

"Predicted radar/optical feature fusion gains for target identification"

Airborne tracking and identification (ID) of high value ground targets is a difficult task impacted by sensor, target, and environmental conditions. Layered sensing, using a combination of standoff and short-range sensors, maintains target track and identification in cluttered environments such as cities or densely vegetated areas through sensor diversity. Data, feature, decision, or information fusion is necessary for high confidence target classification to be achieved using multiple sensors and sensor modalities. Target identification performance is improved by exploiting the extra information gained from independent sensing modalities through information fusion for automatic target recognition (ATR). Increased target ID has been demonstrated using spatial-temporal multi-look sensor fusion and decision level fusion. To further enhance target ID performance and increase decision confidence, feature level fusion techniques are being investigated. A fusion performance model for feature level fusion was applied to a combination of sensor types and features to provide estimates of a fusion gain. This paper presents a fusion performance gain for Synthetic Aperture Radar (SAR), electro-optical (EO), and infrared (IR) video stationary target identification. [C61]

"Theory and simulation of statistical representation of the Stokes parameters in multilook fields based on polarization basis transformation"

A novel analytical representation of polarimetric Stokes parameters' distributions and their lower-order statistics are derived via the joint Wishart distribution of the covariance matrix of the stochastic multi-look speckle fields by using the polarization basis transformation. The last three Stokes parameters are expressed as a universal form by three parameters of the number samples, the degree of polarization and the polarization weight, which is an extension and generalization of R. Touzi and Y.Q. Jin by considering multiple look radar images, and can be used directly to describe the radiometric data in low resolution radar with polarimetric capabilities. The physical meanings of Stokes parameters via polarization basis transformation bring a short cut for solving the probability density function (PDF) of Stokes parameters. The simulated and experimental data are calculated to justify the expressions derived by us, which provide an excellent match with the novel representation. The conclusion can be useful to speckle reduced, classification and target recognition in complex environments or other applications. [C62]

"Analysis of data structures used for storing and processing 3D LADAR data"

This paper compares the use of a point cloud data storage structure with a voxel based storage structure for 3D data collected with LADAR. The motivation for this work is to support the development of a classification system to model the environment of an autonomous vehicle operating in an unstructured natural setting. The classifier should be able to detect trees, bushes, and ground based on the data. Most LADAR sensors provide accurate 2-D range information in a plane, but we generate 3-D data from the sensor by articulating it using a pan-tilt mechanism. A 3-D grid of voxels is used with each voxel representing a cubic region in space with an associated value to indicate the region's occupancy. We discuss how this voxel representation compares with a point cloud representation in the process of data collection, data storage, and data processing and also look at the complexity of merging new data with old data in the same region. There are two main contributions. The first is comparing a possible voxel based data representation with one possible point cloud data representation. The second is determining reasonable parameters (voxel size, LADAR pitch angular velocity, and distance to the target) to facilitate classification of the voxel data. The scope of this paper is confined to analyzing data size,

scanning time required for accurate classification, and processing efficiency. Experimental data size, density, and classification performance results are presented. [C63]

"Improving target tracking performance by incorporating classification information"

This paper presents approaches for incorporating classification information into target tracking algorithms, specifically in a multistatic active sonar context. In addition, this paper describes the framework designed for simulation and classification of return time series from simulated targets and clutter in a realistic underwater environment. The simulated target and clutter returns are integrated into an existing contact-based tracking dataset (TNO Blind dataset) for which time series are unavailable. Simulations compare the integrating classification of contacts at different stages of tracking algorithms. Results show improvements in some tracking metrics with no degradation of the others. [C64]

"Extraction method of large-scale linear objects from SAR images"

Public safety concerns have been raised by potential safety problems due to deformation of infrastructures such as railways, highways and bridges. Monitoring the deformation of large-scale man-made linear objects (LMLO) by permanent scatters (PS) interferomerty would be critical to prevent this kind of disasters. However, the estimation of LMLO deformation is sensitive to the influence of those random PS from nearby natural objects. Thus, extraction of LMLO from PS images is the necessary condition for an accurate monitoring of LMLO deformation. In this paper, a new procedure of extraction LMLO from SAR images is proposed based on classification, morphological operations and line recognition methods. A preliminary step, merging optical image, would be identification of man-made objects regions from background. Image of permanent scatters (PS) points from PALSAR data will then be masked to remove unrelated PS points. Then a set of morphological operations and line feature extraction methods are performed to connect PS points continuously distributed along the linear target. This method is successfully applied to a PALSAR image to extract the Lantau Link highway (LLH), Hong Kong and the experiment result demonstrates its validity on comparison with the ground truth in optical image. [C65]

"1-D superresolution ISAR imaging algorithm"

A novel 1-D scattering centers extraction algorithm of radar target based on conjugate unitary Root-MUSIC was introduced in this paper. To improve the resolution of 1-D scattering centers, the information of conjugated data was used availably by combining the observation data matrix with its conjugated data matrix. Centro-Hermitian data matrices with hermitian property was constructed by forward-backward(FB) averaging, Unitary transform was applied which convert the FB covariance matrix to a real matrix, and the computational efficiency is improved by real-valued eigendecomposition. Theory analysis and simulation result show that the new approach can improve the resolution and reduce significantly computational complexity. [C66]

"Full polarimetric SAR classification based on Yamaguchi decomposition model and scattering parameters"

The full polarimetric information of the target from polarized Synthetic Aperture Radar (POLSAR) enables us to implement recognition and classification of remote sensing images more effectively. Based on the analysis of typical polarized target decomposition and classification, the issue proposes a new scheme for iterative classification of polarimetric SAR image, which blends the outcomes of Yamaguchi decomposition and H/α decomposition. This technique extracts four decomposition coefficients of four scattering mechanism components through Yamaguchi decomposition, the scattering entropy and angle through H/α decomposition first; then the initial classification of the POLSAR images is done by the combination of the 6 parameters mentioned above. The final result is obtained by iterative classification due to coherence scattering matrix following wishart distribution. The effectiveness of this method plus less computation required is demonstrated by the experimental results of polarimetric SAR data. [C67]

"EM estimation of a generic 2D object model based on a sparse set of incomplete ISAR images"

This paper addresses the estimation of a two-dimensional model of an object, based on measurements with a network of High Range Resolution (HRR) scanning surveillance radars. While considering a dynamic radar scene, the data collected from the multiple radars at multiple scans of the antenna provide a wide, but highly sparse, coverage in 2D space. The multi-radar multi-scan data are treated as asynchronous. Inverse Synthetic Aperture Radar (ISAR) 2D imaging is independently performed within the narrow angular sector which is covered during each single radar scan. Each of the formed ISAR images is a rotated and incomplete version of the 2D profile of an extended object. The multi-look images are aligned and incoherently fused in a common 2D space. Their complementary information content is thus combined in a unique composite image. The Expectation-

Maximization (EM) algorithm is further applied for parametric estimation of a low-dimensional 2D object model. This model constitutes a feature vector, useful for object classification. The local-only use of the phase in this overall sparse, but locally dense, sampling scheme accelerates significantly the de-ghosting of the formed 2D target images. Quicker convergence to an unambiguous estimate of the generic 2D object model is achieved, as compared to a purely incoherent processing of the sparse dataset. [C68]

"A tray based Rotman lens array with beamforming in two dimensions for millimeter-wave radar"

A tray based Rotman lens array is presented, which consists of several low-profile Rotman lenses with beam control circuitry, miniature dual-polarized horn antenna arrays, and tray selection circuitry for elevation beamforming. The array achieves broad bandwidth from 34 to 40 GHz, and beamforming in two dimensions is realized. In azimuth, switched beamforming is implemented with the Rotman lens beam control circuitry. In elevation, adaptive beamforming using MUSIC (multiple signal classification) is implemented with the individual Rotman lens trays. A proof of concept beamforming experiment was conducted, where the locations of targets within a three dimensional space were detected with 2.5 cm range resolution. [C69]

"Target maneuver detection using high resolution Doppler profile"

A novel maneuver detector for radar targets is described. The high resolution Doppler profile is used to detect abrupt variation in attitude as the target maneuvers, which can be extracted within the coherent processing interval. A brief introduction of the detection principle is presented, along with feasibility study results from a back propagation neural network implementation. [C70]

"A refuse-recognition method for radar HRRP target recognition based on mahalanobis distance"

In the radar automatic target recognition (RATR) system using high resolution range profile (HRRP), if a test sample has not been trained in training phase, it would lead to a full miss classification in test phase. In this paper, we design a classifier based on generalized confidence, which can efficiently refuse-recognize a new target. Firstly, principal component analysis (PCA) method is used to extract feature vector from every sample. Secondly, the classifier calculates each feature vector's generalized confidence on mahalanobis distance. Consequently, the distribution of confidence is used to define a refuse-recognition threshold for each training target. In test phase, for each trained-target in the database, we suppose that the test sample belongs to current target, calculate the generalized confidence, judge whether the test sample really belongs to the target or not via comparing the confidence with the target's refuse-recognition threshold. The final class is determined by vote. The experimental results demonstrate the effectiveness of the proposed algorithms. [C71]

"A survey on feature extraction of SAR Images"

The feature extraction is one of the key steps for SAR ATR. It can greatly reduce the amount of information processing by SAR ATR, improve the identification efficiency, reduce the time of recognition and lower resources utilization by means of the feature extraction. In the beginning, the feature extraction methods are classified by target type and then various categories methods are summarized. Finally, some unsolved problems of feature extraction are probed. [C72]

"On the design of integrated HF radar systems for Homeland Security applications"

In this paper, HCAC's research and development efforts on the development of integrated and low cost HF radar for coastal surveillance and other Homeland Security applications are summarized. The proposed design incorporates electrically small antenna for rapid deployment, supports operation on floating platforms by using enhanced DSP algorithms to mitigate clutter, incorporates improved propagation modeling to more accurately select optimum frequency channels based on atmospheric conditions and overcome the errors due to terrain effects, utilizes Genetic Programming for automatic target recognition and classification, and provides for passive radar operation utilizing existing broadcast transmitters to enable covert operation. [C73]

"Track-before-detect algorithms for bistatic sonars"

Track-before-detect (TBD) algorithms can improve track accuracy and follow low signal-to-noise ratio targets. A price paid for this increased performance is the high computational complexity of TBD implementations. In this work, we develop a new TBD approach capable of handling raw hydrophone data. In order to learn more about its performance and feasibility when applied to sonar, we use data from the sea trial PreDEMUS'06 with DEMUS sensor array of NATO Undersea Research Centre. As a first step, we introduce the sensor model for a bistatic sonar based on DEMUS receivers. Then, we formulate the TBD problem at hand as a binary hypothesis testing problem and derive a class of adaptive algorithms by using design procedures based upon the generalized

likelihood ratio test. Remarkably, such detectors guarantee the constant false track acceptance rate property under the design assumptions with respect to the overall spectral properties of the noise. A preliminary performance analysis is presented. Finally, we discuss its potential to implement automatic track continuation and to prepare automatic classification for temporarily weak targets as these tasks are usually the challenges multistatic sonar systems have to overcome. [C74]

"The radar system and information flow"

The information flow through a radar system channel is studied for various component design choices including the radar measurement function, signature feature selection, and classifier decision rule. A simplified target scattering model is used to analyze the application of the information theoretical channel model. [C75]

"Vessel detection and classification: An integrated maritime surveillance system in the Tyrrhenian sea"

In recent years a number of organizations, both national and international, have put significant efforts in developing knowledge-based integrated maritime surveillance (IMS) systems. The final aim is to have a clear picture of the position, classification, identification and movement of cooperative and non-cooperative targets entering and leaving the 200 nautical miles limit of the Exclusive Economic Zone (EEZ). Each sensor (i.e. satellite-based, ground-based, shipborne or airborne) has its own task and, in such a context, high frequency (HF) surface wave (SW) radars are inexpensive tools for long range early warning applications in open waters. They allow maximizing the effectiveness in dealing with fisheries protection, drug interdiction, illegal immigration, terrorist threats, search and rescue tasks. This paper focuses on the possibility of combining automatic identification system (AIS) data with HFSWR data for vessel detection and classification purposes. Three algorithms for target detection in compound Gaussian HF sea clutter are presented and their performance evaluated. The combined use of AIS plots provided by cooperative targets can allow the operator to discriminate non-cooperative targets and possible threats. The concurrent exploitation of AIS and HFSWR data is presented and discussed by means of real data recorded during the NURC experiment in the northern Tyrrhenian Sea in May 2009. [C76]

"A new method of radar target recognition based on time-frequency analysis"

In this paper, focused on three targets with simple structure, such as cone, sphere and cone, cylinder and cone, dynamic RCS echo signals is predicted with the improved Greco software. The Dynamic RCS echo signals of targets with micro-movement are preprocessed by using short time Fourier transform, and high-resolution time-frequency distribution images are obtained. A new radar target recognition method based on time-frequency distribution images is proposed. Pixel scan technique is adopted to extract the feature vector, and the nearest neighbor classifier is used for classification decision. Compared with the target recognition method based on singular value decomposition, the correction probability for recognition of the proposed method is higher. Simulation results verify the correctness and the effectiveness of the proposed method. [C77]

"Target automatic recognition based on ISAR image with wavelet transform and MBLBP"

A novel feature extraction algorithm of Inverse Synthetic Aperture Radar (ISAR) image based on wavelet transform (WT) and multi-scale block local binary pattern (MB-LBP) is proposed in this paper. Firstly, the mathematical morphology method is adopted to enhance ISAR image. Secondly, 2D wavelet transform is used to get the low frequency sub-band image from the enhancement ISAR image. Then, ISAR image is divided into small regions from which block local binary pattern (BLBP) with different weight histograms are extracted and concatenated into a feature vector to be used as an efficient ISAR descriptor. At last the classification is performed by using a nearest neighbor classifier with Chi square as a dissimilarity measure in the computed feature space. The experimental results on three kinds of aircraft targets show that the method performs very well. [C78]

"Fully polarimetric ALOS PALSAR data applications for snow and ice studies"

In this study, the capability assessment of fully polarimetric L-band ALOS PALSAR data has been carried out for snow discrimination from other targets. Eigenvaluve based polarization fraction value has been determined for assessing the capability of PALSAR data for snow discrimination. Radar snow index has been developed using polarization fraction and normalized third eigenvalue of coherency matrix. It has been found that radar snow index is more robust and simple to implement that supervised classification. [C79]

"Potentials of a compact polarimetric SAR system"

The goal of this study is to show the potential of a compact-pol SAR system for vegetation applications. Compact-pol concept has been suggested to minimize the system design while maximize the information and is declined as the π/4, π/2 and hybrid modes. In this paper, the applications such as classification, Faraday rotation and soil moisture estimates are first reminded, then, biomass estimation from CP data is presented and a calibration procedure using external targets is proposed. Finally, the interferometry concept is added to assess the capabilities of a compact-pol system to retrieve vegetation height. [C80]

"A scattering similarity based classification scheme for land applications of polarimetric SAR image"

In this paper, a new classification scheme, which extracts the main scattering mechanism with target scattering similarities, is proposed. This approach not only leads to improved understanding of scattering mechanisms, but also has good performance in discriminating different scattering type of land cover. The NASA/JPL AIRSAR data is used for validating its effectiveness. [C81]

"Optimal sensor positioning for ISAR imaging"

ISAR imaging is a powerful signal processing that allows obtaining images of non-cooperative targets. Such images are often used as input to classification and recognition systems since they contain useful two-dimensional features. Nevertheless, the interpretation of ISAR images remains problematic since the image plane cannot be defined by the user but it depends on the target's own motions and on the relative position of it with respect to the radar. In this scenario, the only degree of freedom that is controlled by the user is the position of the sensor. In this paper, the problem of selecting an optimal position of the sensor to maximise the probability of obtaining a desired image projection plane is addressed. Moreover, mathematical tools are derived that may assist the user in deciding where to place an ISAR sensor given a priori knowledge of the scenario. [C82]

"Advanced classification of UXO using fully polarimetric GPR and frequency-polarization features"

The classification of buried UXO has been a difficult task due to the large amount of false alarms resulted from troublesome clutter objects. This paper closely examined scattering characteristics of such clutter objects by using numerical simulations. From the numerical study, we found that some clutter objects, which mainly causes the false alarms, produce multiple resonances at different frequencies and different polarizations. Based on these observations, we developed new classification algorithms which utilize the frequency-polarization dependent responses of complex targets in order to discriminate UXO-like objects form such trouble some clutters. The developed algorithms were tested by experiments in a test plot. In the test, the new classification algorithms clearly discriminated such clutters from UXO-like targets. In this paper, we present the simulation results for scattering characteristics of complex clutters and the new classification algorithm based on frequency-polarization dependent responses will be discussed. Finally, results from experimental verification will be presented. [C83]

"The database of radar echoes from various targets with spectral analysis"

In this paper we describe a database, noted as RadEch Database, containing radar echoes from various targets. The data has been collected in controlled test environments at the premises of Military Academy-Republic of Serbia. Our goal is to provide a balanced and comprehensive database to enable reproducible research results in the field of classification of ground moving targets (pattern recognition). A time-frequency analysis of radar echoes has been performed, in order to identify the main features of the various targets. The RadEch Database is freely available for download and we hope that our database provides researchers with a valuable tool to benchmark and improve the performance of classification algorithms. [C84]

"An improved signal subspace decomposition method in low SNR case"

The SNR (Signal-to-Noise Ratio) of the targets in HF radar is usually not high enough and the array data length is short. Therefore, the Toeplitz construction method is applied to achieve better azimuth resolution and higher azimuth estimation accuracy than the classic covariance matrix construction method of the spatial spectrum estimation technique. However, its signal subspace and noise subspace could not be separated clearly by the conventional subspace decomposition method. In this paper, an improved signal subspace decomposition method based on the cross-correlation coefficients analysis of the eigenvectors is presented. This method uses an adaptive three sigma rule to select the eigenvectors corresponding to the smaller eigenvalues as the signal subspace. Thus, the signal subspace is divided more clearly. Then, combined with the Multiple Signal Classification (MUSIC) algorithm, the estimate performance for the coherent targets is improved. [C85]

"Multi-Temporal Polarimetric SAR and Optical Data Fusion for Land Cover Mapping in Southwest China"

Zhazuo area located in Guizhou Province of southwest China was selected as the test site of this study. Based on six polarimetric RADARSAT-2 images, this paper presents the analysis on polarimetric and temporal variation backscattering behavior of typical targets such as residential areas, farmlands, forests and water bodies within the test site. The multi-temporal polarimetric SAR data fusion, as well as SAR and optical data fusion was conducted to improve the land cover classification. The analysis shows that there are significant differences of polarimetric backscattering and temporal variation behavior among different land cover types. The fusion of the multi-temporal polarimetric SAR data highlights the significant reduction of speckle noises, better land cover discrimination and improved visual appearance of SAR image. The fusion of SAR images with QuickBird data efficiently improves the land cover classification. This study demonstrates that high-precision land cover thematic mapping with SAR data in combination with optical remote sensing image in cloudy and rainy areas is feasible. [C86]

"Hybrid Method of DOA Estimation for Low-Angle Target Tracking"

In the presence of sea-surface multipath, it is difficult to estimate the direction--of--arrival (DOA) of target for the low-angle tracking problem due to the interference between the direct path and the specular path. We can apply the method of array signal processing to reduce the multipath effect. In this paper, a series of measures are adopted to eliminate the correlation, so one can distinguish the real angle of elevation from the specular, and promote the accuracy and performance of angle measuring, by using MUSIC algorithm. Stimulation results are provided to verify the feasibility of the methods in this paper. [C87]

"Airborne Radar Mode Management Algorithm Based on FDT"

The effect of airborne radar modes varied in different situations of an air combat. Radar mode management technology can reduce the difficulty for the pilot of selecting an appropriate mode. In this paper, an airborne radar mode management algorithm based on fuzzy decision Tree(FDT) is proposed. FDT learning is processed by using a set of training data including air targets data and selected mode instances. FDT reasoning is made aiming at classifying a real time air target data. The classification consists of membership values of different modes. An air combat scenario simulation is carried out. The simulation results indicate that the changing membership value of each mode is coincident with the actual requirements and the algorithm has directive effects on implementing airborne radar intelligent management. [C88]

"On exploring SVDSPM algorithm for more accurate DOA estimation of low altitude target"

There exits SVDSPM (Singular Value Decomposition based on Signal Phase Matching Principle) algorithm for direction of arrival (DOA) estimation. Our aim is to present a different SVDSPM algorithm for more accurate estimation of low altitude target. So a void reference sensor is used to explore the possibility of better performance. In the full paper, VRS-SVDSPM (SVDSPM Using a Void Reference Sensor) algorithm and pertinent experimental research are explained in mush detail; here only a briefing is given. The following two topics are discussed: (1) the time delay formula and VRS-SVDSPM algorithm, with the void reference sensor located on the minus of z-axes; (2) analysis of experimental results. The results show preliminarily that: (1) VRS-SVDSPM algorithm can estimate low altitude target when CBF (Conventional Beamforming) and MUSIC (Multiple Signal Classification) can not; (2) the side lobe with VRS-SVDSPM is lower compared with that with CBF; (3) with VRS-SVDSPM algorithm, the bias of azimuth is 0.6 degree and the bias of elevation is 2.4 degree. [C89]

"New approach of imagery generation and target recognition based on 3D LIDAR data"

Light Detection and Ranging (LIDAR) sensor is an advanced technology of 3D-measurement with high accuracy. The processing of 3D point cloud data collected via LIDAR sensor is of topical interest for 3D target recognition. In this paper, a new approach of imagery generation and target recognition based on 3D LIDAR data is presented. The raw 3D point cloud data are transformed and interpolated to be stored in 2D matrix. The target imagery is generated and visualized by means of height-gray mapping principle proposed in paper. For different poses of target, the affine invariable moments of target imagery are selected as features for recognition because of its invariance in rotation, scaling, translation and affine transformation. BP neural network algorithm and Support Vector Machine (SVM) algorithm are utilized as method of target classification and recognition. The recognition results by two algorithms are compared against and analyzed detailedly. The new method had been applied into target recognition in outdoor experiments. Different types of targets are classified and the rate of correct recognition is greater than 95%. Through outdoor experiments, it can be proven that this new method is applied to the field of 3D target recognition effectively and stability. [C90]

"High-performance pattern recognition system using an improved neural classification chain and decision fusion on multispectral information"

The performance level of pattern recognition (PR) systems can be improved using in a proper way new powerful artificial neural networks inside of its classification chains and respectively, decision fusion techniques on available multispectral information. Consequently, to increase the pattern recognition performances, an improved neural classification chain and respectively, an evolutive version of Sugeno's fuzzy integral based on high-resolution radar (HRR), video and thermal imagery use are described. To confirm the broached theoretical aspects, a real image database was used. [C91]

"SAR Image Target Recognition Based on Hu Invariant Moments and SVM"

Target recognition is a key step in the application of SAR images, but because of the existing of speckles in SAR images, targets can not be recognized well by using traditional methods. According to the advantages of invariant moments extraction and support vector machine (SVM) classification, an efficient method of SAR image target recognition is proposed. First, image preprocessing is performed by using wavelet transform. Second, seven Hu moments, which have the properties of rotation invariability, translation invariability and scaling invariability, are extracted as feature vectors and are normalized. Then a SVM classifier is designed and trained by using normalized feature vectors. Finally, the testing sets of SAR images are recognized by trained SVM. In the experiments of recognizing planes and tanks, better results have been obtained with this new method. [C92]

"A robust W-MUSIC algorithm for GPR target detection in the presence of noise"

When applied to ground penetrating radar (GPR), the multiple signal classification (MUSIC) algorithm is an important frequency estimation method as it can detect very closely spaced targets, particularly when one of the target responses is substantially lower than another. The MUSIC algorithm however must be seeded with the number of targets to find and will indicate that number of targets regardless of the number of targets actually present. In the presence of relatively low levels of noise the MUSIC algorithm is prone to reporting the position of false targets in preference to weaker genuine target responses. In this paper a superimposed MUSIC technique is proposed to suppress false targets. A novel windowed FFT MUSIC (W-MUSIC) algorithm is examined using a linear sweep frequency in noise. It is seen to give a clear indication of targets in the presence of modest noise that prevents MUSIC from working. [C93]

"Exploitation of track accuracy information in fusion technologies for radar target classification using Dempster-Shafer Rules"

The surveillance of the littoral is required by applications in the defence, protection and security area. One might think about anti asymmetric warfare, harbour and coastal surveillance or the prevention of smuggling, illegal fishing, illegal immigration or acts of piracy.To establish situation awareness ground, sea and air targets must be detected and tracked in the littoral simultaneously. Also the detailed classification of targets is of extraordinary importance, e.g. persons vs. vehicles, helicopters vs. planes or buoys vs. ships. This classification can be overtaken by an operator, who listens to the Doppler sound of a target. Unfortunately, obligated to the classification issue an operator gets distracted from the tactical surveillance task. Further, an operator is only able to classify a limited number of targets. Hence, automatic target recognition is an important issue for radar systems applied to the littoral surveillance. Finally, automatic target recognition offers also a synergy with the multi target tracking of such a radar system. In this paper 2 Dempster-Shafer (DS) based fusion methods will be described. Both use tracks and track accuracy information to fuse with Doppler based classified targets, in order to provide a robust classification technique for distinguishes between different kinds of targets. The first classification technique uses a hierarchical tree structured decision method, integrated in a track-based classifier. The second classification technique uses a non-hierarchical decision method also integrated in a track based classifier. In this paper both kinds of DS methods will be compared. The results will be discussed especially with respect to the following performance criteria: track accuracy, classification confusion matrix, targets hit rate, targets rejection probabilities, DS topology requirements, convergence reliability, training duration and generalization efficiency. [C94]

"Combining ICA with LSSVM for Speckle Reduction of SAR Image"

Speckles are inherent defects due to coherent imaging principles in synthetic aperture radar (SAR) systems. An improved polarimetric SAR image filtering method based on ICA (independent component analysis) -LSSVM (least squares support vector machine) was developed to get better results for terrain classification, target detection and other applications. The first step of this method is to apply ICA to LSSVM for feature extraction. By using ICA, the original higher dimensional inputs will be transformed into other lower dimensional features, the

regularized parameter and feature subsets will be geted,These new features are then used as the inputs of LSSVM to process a regularized procedure which defines a cost function to estimate true SAR image.Experiment results using polarimetric SAR data of ERS-1 satellite show that this algorithm attains good despeckling effect and preserves more valuable image details than traditional algorithms. [C95]

"Radar Target Scattering Center Extraction Based on the Full-Polarization GTD Model"

To accurately describe the high frequency electromagnetic scattering of the radar objects, the full-polarization GTD model is established based on the combination of the full-polarization information and the geometric theory of diffraction model. Meanwhile, A novel method, MUSIC based on polarization linear variation method (PL-MUSIC) is proposed. The estimation accuracy is improved and the computational load is greatly decreased compared with the method extracting the parameters from every polarization channel. Compared with the parallel polarization MUSIC method (PP-MUSIC), the proposed method decreases the computational complexity of the smoothing process and has the close accuracy. Moreover, the spatial spectrum estimation method based on eigenspace is utilized to establish the spectrum function. Simulations and computational load comparison show the validity of the full-polarization GTD model and the advantage of the MUSIC based on polarization linear variation method. [C96]

"Flexible ID association-based tracking algorithm"

For robust data association performance, tracking algorithms available in the literature utilize kinematic as well as non-kinematic information. These algorithms, however, do not provide a systematic way to utilize non-kinematic information to resolve severe and prolonged association ambiguities in the past. We propose a novel framework in which kinematic and non-kinematic information of potential targets are stored as different entities, respectively denoted as tracks and IDs. The dynamic association between tracks and IDs provides the mechanism for resolving past ambiguities and reporting any remaining ambiguity to the user. Simulation results are provided to show the effectiveness of the approach. [C97]

"Model-based integrated HRR object tracking and classification"

Radar target classification based on 2D stochastic object model matching is studied in this paper. A network of high range resolution (HRR) radars provides range measurements at multiple time steps, while the extended object is moving in the surveillance area. Alignment of the multi-aspect HRR data in a common 2D coordinate system is required. For this reason, tracking of the extended object is integrated in the classification algorithm. The novelty of this work is the estimation of the object state, conditioned on the object class, by applying the HRR data on a particle filter. A coarse-to-fine multi-resolution data processing scheme is introduced in the filter update step. The reason is the experienced filter degeneracy, when working with HRR data. The proposed processing scheme achieves accurate auto-alignment of the HRR data. The classification system successfully distinguishes between very similar objects, by applying 2D object model matching. [C98]

"De-ghosting of tomographic images in a radar network with sparse angular sampling"

Taking into account sparsity of the reflectivity function of several radar targets of interest, efficient low-complexity automatic target recognition (ATR) systems can be designed. A low-dimensional 2D spatial model, where information on the radar target signature is compressed, can be estimated using high range resolution (HRR) data from a sparse system of view angles. Incoherent tomographic processing of HRR data from a distributed surveillance system, made up of several radar nodes, is studied in this paper. A sparse angular sampling scheme is proposed, which exploits diversity due to both the distributed radar system and the target motion. The novelty is in the exploitation of this locally dense, but otherwise sparse set of viewing angles of the targets, obtained using a sparse network of radars. The de-ghosting efficiency of such a sampling scheme is demonstrated geometrically. This results in identification of minimal information resources for unambiguous estimation of a 2D target model, useful for radar target classification. [C99]

"Unsupervised segmentation of polarimetric synthetic aperture radar data by Markov random field"

An unsupervised segmentation method of polarimetric synthetic aperture radar (POLSAR) data is proposed in this paper. Firstly, this method performs initial classification of the POLSAR data based on polarimetric target decomposition. Then a model for the conditional distribution of the polarimetric coherency matrix is combined with a Markov random field (MRF) representation for the distribution of the region label to obtain the posterior distribution. Finally, iterated conditional modes (ICM) method is used to obtain the final segmentation results. A new MRF model with variable parameter is used in this method. Experiment results indicate that the proposed method achieves improvement over standard MRF method. [C100]

"SAR Target Recognition with the Fusion of LDA and ICA"

In this paper, an approach for synthetic aperture radar (SAR) target recognition with fusion of linear discriminant analysis (LDA) and independent component analysis (ICA) features is presented. We first employ LDA and ICA to extract feature vectors from SAR images. The extracted LDA and ICA features are then imported to two support vector machine (SVM) classifiers respectively. Ranking based decision fusion algorithm is used to fuse the results of two SVM classifiers and the final classification decision is achieved. Finally, we apply the method for various ground vehicles in MSTAR database to evaluate the recognition performance. Experimental results show the higher target recognition performance compared with the methods using LDA or ICA feature. [C101]

"Combining wavelet invariant moments and relevance vector machine for SAR target recognition"

A new method to classify targets in SAR images is proposed in this paper. The method combines both the advantages of wavelet invariant moments and relevance vector machine (RVM). The wavelet invariant moments have the wavelet inherent property of multi-resolution analysis and moment invariants quality. We firstly extract wavelet invariant moments to indicate targets in SAR images, and then select the feature set with principal component analysis (PCA). Finally, the selected feature set is fed to RVM for training and classifying. The RVM can powerfully manage complex classification and regression problems basing on the concept of probabilistic Bayesian learning framework. We perform 2-class and 3-class classification experiments respectively. Test results show that wavelet invariant moments indicate the target effectively, and RVM performs better than K-nearest neighbourhood (K-NN), back propagation neural network (BPNN) and least square support vector machine (LSSVM). [C102]

"Micro-Doppler analysis of high speed moving targets"

Micro-Doppler induced by mechanical vibrating or rotating of structures in a radar target is potentially useful for target detection, classification and recognition. While the Doppler frequencies induced by the target body scatterers are constants after motion compensation, the micro-Doppler due to vibrating or rotating structures of the target is a function of dwell time. Now the characteristic of micro-Doppler has been used in low speed moving targets' recognition widely, but high speed moving targets have different properties from the low speed moving targets. Due to the influence of high speed, the returned signal after stretch processing will appear range profile broadening and range migration. This paper analyzes the micro-Doppler signature of high speed moving targets, and computer simulations are given to prove the validity of the analysis. [C103]

"Recognition of SAR Image Based on SVM and New Invariant Moment Feature Extraction"

Support vector machine (SVM) is regarded as a good alternative of the traditional learning classification. Because of its excellent learning performance, it has become a research hot spot in the field of machine learning. This paper describes the new invariant moment feature extraction of SAR objectives based on shape feature, then classify and train the eigenvectors by using SVM. The excellent recognition rates achieved in experiments indicate that SVM is well suited for SAR image target recognition. [C104]

"Rare Class Mining: Progress and Prospect"

Rare class problems exist extensively in real-world applications across a wide range of domains. The extreme scarcity of the target class challenges traditional machine learning algorithms focusing on the overall classification accuracy. As a result, purposefully designed techniques are required for effectively solving the rare class mining problem. This paper presents a systematic review of the major representative approaches to rare class mining and related topics and gives a summary of the important research directions. [C105]

"Simulation, measurement and validation of amplitude and phase matching performance between transmitter and receiver subsystems in dual-channel high-resolution polarimetric radar"

Stringent requirements for the matching performance between the channels of high-resolution multi-channel radar for superb target detection and classification capabilities have to be met. This paper focuses on the investigation on the amplitude and phase matching performance between two transmitters and two receivers in a dual-channel polarimetric agile radar system. The system will be used to estimate all elements of the polarization-dependent backscattering matrix simultaneously in 3 meters resolution cells. The paper presents breakthroughs in designing such complex radar systems based on very up to date methods used for system level simulations, for measurements and for cross-validation between simulations and measurements. The measurement results of the developed transmitters and receivers demonstrate the validity of our design approach for obtaining the needed matching performance between transmitters and receivers in such a dual-channel radar system. [C106]

"Underwater target detection from multi-platform sonar imagery using multi-channel coherence analysis"

This paper introduces a new target detection method for multiple disparate sonar platforms. The detection method is based upon multi-channel coherence analysis (MCA) framework which allows one to optimally decompose the multichannel data to analyze their linear dependence or coherence. This decomposition then allows one to extract MCA features which can be used to discriminate between two hypotheses, one corresponding to the presence of a target and one without, through the use of the log-likelihood ratio. Test results of the proposed detection system were applied to a data set of underwater side-scan sonar imagery provided by the Naval Surface Warfare Center (NSWC), Panama City. This database contains data from 4 disparate sonar systems, namely one high frequency (HF) sonar and three broadband (BB) sonars coregistered over the same area on the sea floor. Test results illustrate the effectiveness of the proposed multi-platform detection system in terms of probability of detection, false alarm rate, and receiver operating characteristic (ROC) curves. [C107]

"Classifier Design via Projection Approximation"

In the viewpoint of inverse problem and function approximation theory, we set up a framework for pattern classifier design, wherein the classifier is assumed to be an element of a Reproducing Kernel Hilbert Space (RKHS) continuously defined on the pattern feature space. Based on the RKHS metrics, an orthogonal projection criterion is adopted for pattern feature representation so that optimal generalization capability is ensured for the classifier, with respect to minimum error norm. In addition, by orthogonally projecting the outputs of the target class samples onto the null space of an operator defined by the sample outputs of other classes, the target class is optimally discriminated from other classes, with respect to minimum mean output energy. Combination of the above two criteria yields a criterion for optimal representation and discrimination of pattern features, which yields another classifier wherein the balance between representation and discrimination may be controlled by a parameter. Some experimental results on handwritten digit classification, face recognition, and radar target recognition are given to show the feasibility of the presented classifiers. [C108]

"Automatic Target Recognition Based on Rough Set-Support Vector Machine in SAR Images"

An automatic target recognition (ATR) system based on rough set-support vector machine (RS-SVM) for SAR targets is proposed in this paper. The system combines the strong feature selection ability of rough set (RS) with the excellent classification ability of SVM together. The wavelet invariant moments firstly are extracted, then selected by using forward greedy numeral attribute reduction algorithm (FGNARA) as the optimal feature subset to indicate targets and fed to SVM for target recognition. Experiments with neural network (NN) and SVM on both original and selected feature set demonstrate the selection of optimal feature subset is meaningful and RS-SVM is efficient in ATR of SAR. [C109]

"Nonlinear classifier combination for a maritime target recognition task"

This research proposes a nonlinear combination of an ensemble of classifiers to improve pattern recognition performance. A maritime target recognition application is considered. A database of radar range profiles with six ship classes from various aspect angles were created. Five structurally based features are defined on the simulated range profiles. Three kinds of classifiers are used: neural network, Bayes, and nearest neighbor. The proposed nonlinear combination scheme utilizes a neural network combiner. The performance of this combiner is compared to individual classifiers as well as two other combination approaches. [C110]

"Optimal and robust waveform design for MIMO radars"

Waveform design for Target identification and classification in MIMO radar systems has been studied in several recent works. While the previous works considered signal independent noise, here we extend the results to the case where signal-dependent noise, clutter, is also present and then we find the optimum waveform for several estimators differing in the assumptions on the given statistics. Computing the optimal waveforms for MMSE estimator leads to the Semi-definite programming (SDP) problem. Finding the optimal transmit signals for CSLS estimator results in a minimax eigenvalue problem. Finally it is shown that equal power waveforms are the best transmit signals for the SLS estimator. [C111]

"Adaptive digital beamforming for super-resolution angle estimation in jamming"

This paper describes a technique for maintaining angle super-resolution capability of multiple sources in jamming. This technique exploits flexibility provided by digital beamforming (DBF) array to form adaptive sub-

arrays or adaptive beams in canceling jamming, followed by super-resolution processing for determining the number of sources and then estimating the corresponding directions-of-arrival (DOAs). In this arrangement, super-resolution capability in angle estimation of multiple sources can be maintained while jamming is canceled in the sub-array based or the beamspace based pre-processing stage. [C112]

"Extending the frequency matching in linear FMCW radar exploiting extreme frequencies"

Frequency matching is an essential block of the signal processing chain in LFMCW (linear frequency modulated continuous wave) radar. Its task is to associate frequency detections obtained in multiple measurements. Under certain conditions, this association may fail and frequency detections from multiple real targets may be combined to a mismatch. The classification of a frequency association as match (real target) or mismatch (ghost target) is commonly regarded impossible if we only have frequency detections. Yet in this paper we show that even in this case, a reliable classification is possible when special attention is paid to the two outermost frequencies in each spectrum. Furthermore, the radar's modulation can be designed such that the reliable classification can be achieved in the regions of interest of the distance-velocity-plane, i.e. application-specific. [C113]

"Road traffic monitoring using a wireless vehicle sensor network"

With the advancement of micro-electro-mechanical systems (MEMS) technologies, wireless sensor networks have opened new vistas for a wide range of application domains. These sensor nodes usually comprise small, low-power devices that integrate sensors and actuators with limited on-board processing and wireless communication capabilities. One of the most important applications is target tracking and monitoring. Here a novel wireless vehicle monitoring system that is able to detect, classify and determine the direction of travel of vehicles on a two-lane road is proposed. Each vehicle detection node features multiple sensors including magnetometer, accelerometer, infrared and acoustic microphone with a two-node structure for cooperative monitoring. The results show that the system was capable of classifying the vehicle type (using vehicle weight) and their directional of travel with high accuracy. [C114]

"Signal direction finding for low complexity radar"

We propose a novel beamforming algorithm for a three element system that suppresses an interference signal while still being able to measure a target's interferometer phases. Unlike most direction-of-arrival (DOA) estimation algorithms, our algorithm does not use a grid search. Instead the estimates result from a closed form solution, a great advantage in time sensitive applications. The derivation of the algorithm is presented, and its statistical performance is examined with simulations. Additionally, our numerical results demonstrate that our algorithm not only requires lower computation but also is capable of achieving more reliable DOA estimates than those found with the well known multiple signal classification (MUSIC) algorithm. [C115]

"Classification of flowers by bats: comparison with the radar case"

In recent years, with the development of high range resolution radars, the desire to be able to identify targets under all weather and clutter conditions has become of great importance. This is an activity carried out with great success by echolocating mammals such as nectar feeding bats that are able to detect and select flowers of bat-pollinated plants even in a dense clutter environment. In this paper data consisting of acoustically generated high range resolution profiles of four bat pollinated flower heads are analysed. Multi perspective classification performance is assessed and compared with the radar case. There are close parallels that suggest lessons can be learnt from nature. [C116]

"Frequency agile stepped OFDM waveform for HRR"

High range resolution (HRR) is an important feature for radar, aiming at target classification. The range resolution is inversely proportional to the bandwidth of the transmitted signal. Pulse burst waveforms can achieve HRR at low expenses when the carrier frequency increases from one pulse to the next, stepping and synthesizing the wide bandwidth. In such a stepped frequency approach the resolution is determined by the bandwidth of the total pulse burst. With the orthogonal frequency division multiplexing (OFDM) waveform, the time/frequency pattern of the transmitted radar signal is fully flexible while the waveform can be generated easily by IFFT. The novelty of this paper is to demonstrate how the combination of frequency agility and HRR processing into one system can benefit from the OFDM flexibility. An elementary scenario with a single stationary or low speed point target is assumed. [C117]

"Improved waveform design for target recognition with multiple transmissions"

This paper presents a matched waveform technique for target class identification, i.e., a multiple hypotheses

testing (MHT) framework. This technique is shown to improve classification performance of SNR-based matched waveforms derived from a probability-weighted spectral variance (PWSV) approach. The technique, which allows for real-time adaptive waveform transmission, is also shown to be computationally efficient. [C118]

"A novel W-MUSIC algorithm for GPR target detection in noisy and distorted signals"

When applied to ground penetrating radar (GPR), the multiple signal classification (MUSIC) algorithm is an important frequency estimation method as it can detect very closely spaced targets, particularly when one of the target responses is substantially less than another. The MUSIC algorithm however must be seeded with the number of targets to find and will indicate that number of targets regardless of the number of targets actually present. In addition, there is no reliable indication of the magnitude of the responses of the targets. In the presence of relatively low levels of noise the MUSIC algorithm is prone to reporting the position of false target positions in preference to weaker genuine target responses. In this paper a superimposed MUSIC technique is proposed to suppress false targets. A novel windowed FFT MUSIC (W-MUSIC) algorithm is examined using a linear sweep frequency in noise, and it is seen to give a clear indication of targets. In the presence of distortion, FFT is seen to be a more robust approach than the MUSIC algorithm, the latter method becoming very prone to inaccuracy in the presence of distortion. [C119]

"Ground moving personnel indication and tracking from airborne platforms"

Radar is valued for its ability to surveil large areas, day and night, in all weather conditions, with high revisit in order to provide detection and tracking of individuals and groups. Such radars operate either stand-alone or while networked and may generate cues for EO/IR sensors for identification and classification. In the security applications domain radar basing or siting has been predominately, if not exclusively, from fixed, ground-based positions (this includes mobile systems that must be stationary when employed). Airborne radar systems employing phased array antennas and advanced adaptive processing are investigated for their ability to detect and track individuals, in a security application, when integrated with small and medium unmanned air vehicles. Airborne surveillance radar overcomes many of the visibility issues of ground-based systems by operating at steeper grazing angles. We evaluate performance for two operating altitudes and in a variety of surface wind conditions, demonstrating high probability of detection against walking human targets. These results suggest the viability of UAV-based airborne radar as candidates for future surveillance architectures. [C120]

"Improving high range resolution ATR performance with average absolute error metric"

As a complementary mode to synthetic aperture radar (SAR), high range resolution (HRR) is mainly developed to identify moving ground targets automatically. Previous studies have demonstrated many promising solutions in HRR Automatic Target Recognition (ATR). Most of them popularly build on template-based approach and employ mean square error (MSE) metric in matching algorithm to measure the likelihood between test profiles and template profiles. However, discussion about whether MSE works as it is expected is inadequate. This paper represents a preliminary investigation into MSE metric used in matching algorithm. We firstly illustrate MSE metric theoretically, and then indicate its shortcomings such as random coefficients distorting the difference between profiles in mathematical calculation, excessive emphasis on large difference, and lack of reasonable interpretation in physical distance space. An alternative metric named average absolute error (AAE) is utilized to replace MSE. It is directly based on the distance between profiles and is able to provide a clear physical interpretation. The experiment results show that no matter estimated aspect angles are given or not during classification, AAE-based HRR ATR significantly outperforms the baseline MSE-based HRR ATR. [C121]

"Detection of moving intruders from a moving platform using a Ka -band continuous-wave doppler radar"

A scanning-beam Doppler radar has been presented which can detect moving intruders from a moving platform. The limitations of the scanning-beam sensor in terms of platform velocity and rotation rate were discussed for a fixed antenna beamwidth. Targets moving at any velocity relative to the platform can be detected, even when the person is moving along with the platform, producing no Doppler return. Estimation and removal of the clutter return was demonstrated in order to detect slow-moving targets whose response is within the clutter bandwidth. The optimal threshold value was determined using performance metrics for classifiers under imbalanced data sets. [C122]

"Learning a Locality Preserving Subspace for ISAR Target Recognition"

Io order to overcome the instability of Inverse synthetic aperture radar (ISAR) image caused by shift, rotation and scale variation, a new approach based on Locality Preserving Projections (LPP) algorithm of manifold learning is proposed to feature analysis in ISAR target recognition. Firstly, the LPP algorithm is used to reduce the

dimensionality of the ISAR image, and then the reduced feature is classified by k-nearest neighbor classification with rejection recognition capability. Experimental results on four kinds of aircraft target suggest that the LPP algorithm has the capability of finding the low- dimensional manifold structure embedded in the high-dimensional ISAR image space, which is controlled by few parameters, such as attitude angle, scale and position, etc., and the better classification performance is acquired with the low-dimensional feature. [C123]

"Research on target classification for SAR images based on C-Means and support vector machines"

Aim at multiplicative speckle noise and little difference among targets in synthetic aperture radar (SAR) images, a target classification algorithm is proposed based on C-Means and support vector machines (SVMs). Its front part adopts a C-Means clustering method to classify targets and suppress speckle noise in feature space, and its back part adopts an SVM classifier to improve classification accuracy in image space. Experimental results show that this algorithm can reduce the dimension of SVM and have a better classification performance using Ku-band SAR database. [C124]

"Research on Supervised Manifold Learning for SAR target classification"

Nonlinear manifold learning algorithms, mainly isometric feature mapping (Isomap) and local linear embedding (LLE), determine the low-dimensional embedding of the original high dimensional data by finding the geometric distances between samples. This paper proposed an approach to reduce the dimensions of SAR image targets based on supervised manifold learning algorithm. Three steps were done to reduce the dimensions of original data. Firstly take use of a priori information of the sample point to find the k-neighbors. Secondly to build the local reconstruction weight matrix W. Thirdly get the dimension reduction result based on W and the neighborhood of original data. Experiments were done to test the effect of dimensionality reduction to classification results. Three types of targets were used in the experiments. The implementation steps and parameter settings are discussed in details. The results show SLLE is more conducive to SAR image target classification than the traditional LLE. [C125]

"Enhanced multistatic radar resolution via STC"

MIMO radar can improve on conventional target detection, parameter identification, and target classification performance via diversity of, among other things, its simultaneously-transmitted waveforms. However, the mutual interference among the waveforms may lead to considerable performance degradation suppressing clutter near targets. In this paper, we consider the use of space time coding (STC) to mitigate waveform cross-correlation effects in MIMO radar. First, it turns out that a joint waveform optimization problem can be decoupled into a set of individual waveform design problems. Second, a number of monostatic waveforms can be directly used in a MIMO radar system, which offers flexibility in waveform selection. Numerical results demonstrate the effectiveness of STC in MIMO radar for waveform decorrelation. [C126]

"Automatic recognition of man-made objects in SAR images using support vector machines"

Over the past two decades the remote sensing technology is applied in a large scale in environmental research and policy, i.e. water pollution monitoring and conservation of soil, etc. The methods for recognition of man-made objects in remote sensing images are providing capabilities for mapping and monitoring crucial objects or sites in environmental management, i.e. hazardous chemicals storerooms, oil depots, etc. However, the task of recognizing key man-made objects from large images is time consuming and complex. In the paper we aim at developing an automatic and fast image processing method for the recognizing man-made objects in synthetic aperture radar (SAR) images, which is a supervised learning approach based on support vector machines. Firstly, a sample image data set which contains several classes of interested man-made objects is manually extracted from SAR images. Then we train the image data set by least squares support vector machines. After cross-validation and an exhaustive grid search, a model that can predict target label of data instances in the testing set is obtained. Finally we can implement classification in random image set using above prediction model and recognize the man-made objects. This approach needs no a priori knowledge, and only a set of train examples for the learning step is needed. [C127]

"Ship classification by sound signature"

Nowadays, either for supervision or for defense purposes, the transportation is being controlled by RADAR (Radio Detecting and Ranging). RADAR helps us get information about objects of interest by transmitting electromagnetic radio waves to the target and analyzing the reflecting signals. We understand that in order to determine any given object's information (speed, distance etc) the first action is always taken by the control

center. This also tells us that the moving object can also notice the electromagnetic radio waves and hence the control center can also be sensed. It is of great importance in the defense systems that the object under inspection should not notice being recognized. If we could get information about the target by controlling the waves sent by the target rather than sending any signals to it we could be on the advantageous side. In this study the vehicles were classified by the sounds they make while operating. Working units of the marine vehicles (engine, fan, the generator and etc) analyzed and the sounds they diffuse to the environment while operating were characterized. In the characteristics determination the MFCC (Mel Frequency Cepstral Coefficients) method used to determine the features of the vehicles and by the k-means method, the defined features degraded to a specific number, k-NN (k-Nearest Neighbor) method selected for the classification and recognition of the vehicles. [C128]

"Forest type discrimination using polarimetric Radarsat 2 data"

In the south of China, synthetic aperture radar (SAR) provides a powerful tool for forestry inventory because of its all-weather and all-day capabilities. Nevertheless previous single or dual polarization SAR data cannot meet the requirements of forest type classification. Polarimetric SAR data contained more information of targets and in this paper we investigated the capability of polarimetric Radarsat 2 data for forest type discrimination. Taking Zhazuo forest farm of Guizhou Province as study area, an 8-temporal field experiment was designed and used for polarimetric backscattering signatures analysis based on MIMICS model. Then two-temporal polarimetric Radarsat 2 data was analyzed to extract polarimetric variables for forest species discrimination, and then polarimetric decomposition and classification were carried out. Experiments prove that forest type can be discriminated using polarimetric Radarsat 2 data, but it is not very effective for forest species identification mainly due to the spatial resolution limitation. Polarimetric SAR data with higher resolution and more complicated classification methods are needed in the future. [C129]

"Karst forest type discrimination in southwest China using spaceborne polarimetric SAR data"

Karst forest physiognomy occupy a large area of Guizhou, southwest China. It is a rare forest resource in the earth and urgently needed to carry out protection. Due to synthetic aperture radar (SAR) data's ability to acquire images through clouds, it was tested as an alternative to optical data to map changes of land use/land cover, to estimate biophysical parameters of vegetation types, and to detect deforestation. The main goal of this paper is to analyze the potential of the spaceborne full polarimetric data in distinguishing the different types of forest in southwest China. Different polarimetric target decompositions, such as eigenvetor-based decomposition (Cloude-Pottier's decomposition and Touzi Decomposition) and scattering model-based decomposition (Freeman decomposition), were used in this paper to extract forested areas from the scene. To further divide the extracted forested area into deciduous and coniferous forest., Supervised polarimetric classification procedures based on Freeman decomposition is presented in this paper. [C130]

"Statistics of SDH target decomposition theorems in radar polarimetry"

The comparisons between different decompositions show that the SDH (sphere, deplane, helix) target decomposition gives the best overall performance with other automatic classification algorithms. In this paper, we emphasize that the different decompositions include the equal information while they decompose the information to different sub-scattering matrices indeed. The statistics of the SDH target decomposition theorems in radar polarimetry is given for the stochastic target fluctuation. Many classification algorithms almost ignore the important decomposed phases, therefore they make some useful information lost, which lead to the worse performance of classification. The results of this work are helpful to enhance the performance of classification. [C131]

"Polarimetric scattering feature estimation for accurate vegetation area classification"

This paper proposes an accuracy improvement of the vegetation area classification based on the POLSAR image analysis, when vegetation and man-made areas are both included in the radar target region. Here we introduce a simple compensate polarimetric marker, T13or T31, to accurately distinguish the unexpected scattering from the obliquely oriented man-made targets and the complex volume scattering generated from vegetation area. T13or T31is the (1, 3) or (3, 1) elements of the 3Г‑B—3 averaged coherency matrix ([T]), and has not been effectively utilized in the general scattering power decomposition scheme. By appropriately utilizing T13(T31), one can extract only the vegetation area from the mixed target region. It is verified from the detailed analysis that the proposed marker T13(T31) works well not only for Pi-SAR data but also for ALOS/PALSAR data. [C132]

"Polarimetric signatures and classification of tropical land covers"

Polarimetric signatures for different tropical land covers were extracted from RADARSAT-2 data. Subsequently, the data were classified. The objective of this work was to assess the potential of RADARSAT-2 polarimetric C band data on land cover mapping. RADARSAT-2 data were acquired over Tapajos National Forest, a tropical forest reserve in Brazil, and surroundings, in September 2008. A field campaign was conducted during the same week of the SAR data recording. Polarimetric signatures for the different land covers were extracted for co- and cross-polarised bands and results indicated the variety of scattering mechanisms in the study area. Following that, the coherence and covariance matrices were used for the Freeman-Durden target decomposition, which decomposed the image targets in new bands representing the main scattering mechanism in the resolution cells-corner reflection, volumetric and superficial. Data were later classified by a k-means-Wishart classifier. The bands representing volumetric and superficial scattering helped discriminating vegetated and non-vegetated areas. Classification accuracy reached around 80% for forest and pasture/bare soil classes. For the remaining classes, the classification accuracy results did not reach 50%. [C133]

"A preliminary study of target contour extraction based on scattering mechanism using polarimetric SAR images"

Finding the target contour information from a remote sensing image is one of the fundamental steps for image analysis. Conventional target contour extraction methods are usually based on the statistics information of the image. In this paper, using the maximum return value of the normalized scattering matrix derived from full-polarized Synthetic Aperture Radar (PolSAR), the relationship between the contour of targets and their corresponding dominate scattering type is preliminary researched. Then a novel target contour information extraction method based on the physical scattering mechanism of terrain targets is proposed, which is more effective and adaptable due to the scattering mechanism of terrain targets do not depend on the radar backscattering intensity, but its proportion among different polarizations. After applying to E-SAR airborne data, the results show that this method has a good capability to extract the target contour information. [C134]

"Supervised classification by neural networks using polarimetric time-frequency signatures"

In radar imaging, the assumption is made that scatterers are white in the emitted frequency band and isotropic for all direction of observation. Nevertheless, new capacities in radar imaging, using a wideband and a large angular excursion, make these hypotheses not valid. Time-frequency analysis highlight this point of view and show some scatterers are anisotropic and/or dispersive. This information source can be completed by radar polarimetry. This paper suggests a supervised classification of scatterers using neural networks based on polarimetric time-frequency signatures. This method is applied here on anechoic chamber data, however can be generalized to SAR or circular SAR imaging. [C135]

"Operational approach for ship detection and classification"

The necessity to control all the activities within the marine environment is nowadays vital for most official authorities. Besides protecting the ecosystem and providing safety and surveillance along the transportation corridors, illegal immigration and sustainable economic activities are also issues to cover. Since early nineties, a lot of efforts have been devoted to develop monitoring systems based on transponders (VMS or AIS). Such systems use active on-board devices to track ship positions via satellite communications. Despite of their great performance, the experience has shown, however, that this approach does not have the required independency and other alternatives are necessary. Among them, the one gathering more benefits is the integration of remote sensing, specially Synthetic Aperture Radar (SAR), with operational transponders. Certainly, this solution provides redundancy, 7/24 and all-weather monitoring capability, independently from the targets to track. [C136]

"Automatic target recognition of aircraft models based on ISAR images"

In this paper, we present a system for aircraft automatic target recognition (ATR) using inverse synthetic aperture radar (ISAR) and based on knowledge discovery from data process adapted to radar domain. We propose a method for target shape extraction from ISAR images based on the combination of two methods, SUSAN modified and active deformable contours via level set. In the second part of this work, we propose to fuse two commonly used shape descriptors algorithms based on moments invariant and Fourier descriptors. We have investigated the impact of the information fusion on the recognition rate. The classification scheme is ensured using support vector machine (SVM) classifier. Several combination strategies are compared at score/decision/feature level. Experimental results of the proposed method are provided and discussed. [C137]

"Target coherence analysis using canonical correlation decomposition for SAS data"

This paper analyzes the connection between the canonical correlations of sonar signals captured using two linear hydrophone arrays and the spatial coherence of the sources that are observed. Analysis of this connection

allows for the use of a canonical correlation decomposition (CCD) framework for performing synthetic aperture sonar (SAS)-like processing. In particular, it can be used to extract correlation features of the targets in the frequency domain, which can then be used as a measure for target detection and classification. Results on real and simulated data indicate that coherence patterns are different in the presence of a target when compared to background clutter, and this pattern also changes as a function of the number of sensors on the array. [C138]

"Multiple target Doppler estimation under possibly moving radar clutter"

Multi-target detection for pulsed Doppler radars under land/moving clutter characterized by antenna scanning modulation is analyzed using linear prediction based Tufts-Kumaresan's method. Comparison between this method and other line spectra estimation algorithms such as MUSIC and ESPRIT is performed. A technique to determine the model order required by the frequency estimation algorithms, which does not distinguish between targets and clutter, is presented. The clutter region concept is then introduced to identify targets from the clutter. [C139]

"Bat-pollinated plants: feature extraction for target recognition in the natural world"

In recent years, with the development of high range resolution radars, the desire to be able to identify targets under all weather and clutter conditions has become of great importance. Bat-pollinated plants have evolved flowers to ease classification by nectar feeding bats even in a dense clutter environment. In this paper we analyze three real images of a Cobaea scandens corolla. These were collected by means of an acoustic radar capable of very high range resolution. The features of these flowers that allow high classification performance by bats are exploited. Results are discussed and related to the task of classification in radar systems. [C140]

"Spectral estimation for clutter processing in digital radars by Dimension-Adaptive Particle Swarm Optimization (DA-PSO)"

Power spectrum estimation from radar data is essential for target detection. For instance, microburst causes detrimental effects on airplane performance, and hence its detection is critical. We compare auto-regression (AR), Periodogram, Kaiser windowed Periodogram, and multiple-signal-classification (MUSIC) methods for microburst clutter spectrum estimation. Given a long train of returned signal, we are able to segment the signal to obtain multiple estimations of the parameters, which leads to a more accurate estimation after coefficient averaging. The estimated power spectrum is then integrated for clutter magnitude calculation to determine whether a target is present at certain cell. The magnitude of clutters in an ensemble from a wide region spatially or through time temporally is used to estimate the clutter map. We choose a K-distribution mixture model over the traditional Rayleigh distribution to better approximate the tail structure of the distribution to minimize the false alarm rate. We show that Dimension-Adaptive Particle Swarm Optimization (DA-PSO) is robust to sample size in estimating the K-distribution mixture model, which is desirable for real-time implementations. [C141]

"Moving target detection with MUSIC for the bistatic radar using digital broadcasting signals"

In the bistatic radar using broadcasting signals, the delays between signals propagated directly and scattered by the target are measured to estimate the target position with cross-correlation. This results in the delay profile with the width limited by the bandwidth of the signal. To get better resolution, larger bandwidth is required, however, the bandwidth of broadcasting signals can not be increased by the receiver. In this paper, we propose a new method of the moving target detection with MU-SIC (MUltiple SIgnal Classification), processed at only receiver. That offers much narrower width than that of cross-correlation. The proposed method can distinguish the moving targets from the stationary targets, though the conventional MUSIC can not. This is realized by the decorrelation of the time delay-derived phase rotation factors caused by moving targets. The performances using ISDB-T (Integrated Service Digital Broadcasting -Terrestrial), the bandwidth of which is 5.57 MHz, are evaluated by the computer simulations. The results show that two close moving targets, separated by 0.1 Г‚Вїs, with SNR=-10 dB each can be resolved even if the stationary target is located around the one moving target. [C142]

"Application of the multiresolution wavelet representation to Non-Cooperative Target Recognition"

In this paper, the problem of efficient representation of large database of target radar cross section is investigated in order to minimize memory requirements and recognition search time, using wavelet representation. Synthetic RCS of large aircrafts, in the HF-VHF frequency bands, are used as experimental data. Many parameters are evaluated like mother wavelet, decomposition level, and classification parameters. Criteria used to determine the efficiency of multiresolution representations are compression scores, false identification rate and search time. [C143]

"An extra-trees-based automatic target recognition algorithm"

In this article, we describe a new automatic target recognition algorithm for classifying SAR images. It is based on the PiXiT image classifier, already used in several applications, which uses randomized sub-windows extraction and extremely randomized trees (extra-trees). This approach requires very little pre-processing of the images, thereby limiting the computational load. It was successfully tested on the public standard MSTAR database, achieving a misclassification rate of about one percent. [C144]

"Investigation of 1D and 2D PCA for SAR ATR"

Principal component analysis (PCA) has been used in many applications ranging from social science to space science, for the purpose of data compression and feature extraction. Usage of PCA for synthetic aperture radar (SAR) image classification, have recently been exploited by the automatic target recognition (ATR) community. PCA can be used in one dimensional as well as two dimensional mode. These different modes have recently been studied for face recognition. Following similar trends, 1D and 2D PCA has been exploited in the present paper for SAR ATR. 2D PCA based algorithm has been fine-tuned for the current usage. Contrary to the conclusions in face-recognition research, here it has been concluded that both 2D and 1D PCA perform equally well for SAR ATR. And both the algorithms outperform the conventional SAR ATR algorithms. [C145]

"2D parametric target model estimation using HRR data from a radar network"

Estimation of a parametric 2D spatial target model is proposed in this paper, with ultimate goal to support radar target classification. Limited number of multi-aspect High Range Resolution (HRR) data from a radar network are used as source of information. Back-projection in 2D space and mixture model fitting is applied for the estimation. The ghosts are progressively resolved and unambiguous retrieval of the 2D target model is achievable using data at consecutive time steps, while the target is moving. [C146]

"Aircraft Target Recognition: A novel approach for features extraction from ISAR images"

In this paper, we present a system for Automatic Target Recognition (ATR) based on ISAR images. The methodology used is based on knowledge discovery from data (KDD process) process adapted to radar field. The shape extraction is the most important step in recognition system. However, we propose a new approach for Target shape extraction based on combination of Smallest Univalue Segment Assimilating Nucleus (SUSAN) method and Variational Level Set (VLS). The feature vector is then represented by Fourier descriptors of each target shape. Finally, recognition scheme is achieved by both: Support Vectors Machine (SVM) and K Nearest Neighbors (KNN) classifiers. [C147]

"Hyperimage concept: Multidimensional Time-Frequency Analysis applied to SAR imaging"

This paper deals with the analysis of non-stationary scatterers in SAR images. Indeed, SAR imaging makes the assumptions that the scatterers are isotropic and white in the emitted frequency band. However, new SAR applications use a large bandwidth and a strong angular excursion. These assumptions become obsolete and the behavior of scatterers becomes non-stationary. The basic tool to study non-stationary signals is the time-frequency analysis. Recent studies based on multidimensional Time-Frequency Analysis describing the angular and frequency behavior of scatterers has highlighted anisotropic and dispersive behavior of bright points. This paper generalizes the hyperimage concept to study scatterers. Multidimensional Time-Frequency distributions are tested on simulations, then they are applied to very high resolution SAR images and show some scatterers are anisotropic and dispersive. [C148]

"Texture feature coding method for SAR automatic target recognition with adaptive boosting"

In this paper, the applicability of texture feature coding method (TFCM) to synthetic aperture radar (SAR) automatic target recognition (ATR) is studied. The TFCM cooccurrence matrix (CM) is used as an additional image feature for adaptive boosting (AdaBoost) algorithm which uses originally 2D-DFT coefficients as an image feature. The TFCM CM extracts the connected texture information from the image while 2D-DFT gives the value of the spatial frequency components. The TFCM CM is invariant under the rotation of images. With these characteristics, the TFCM CM can discriminate a confused target which is not classified properly using 2D-DFT. The TFCM CM is combined with 2D-DFT in fusion process of the AdaBoost algorithm. In experimental results, it is shown that the correct-classification probability of the proposed scheme is larger than that of the conventional scheme which uses only 2D-DFT and raw image as image features. [C149]

"An iterative segmentation algorithm of SAR image based on support vector machine"

In this paper, an iterative algorithm, which is based on support vector machine (SVM), is proposed for synthetic

aperture radar (SAR) image segmentation. The proposed method considers the SAR image segmentation as the pixel classification. The pixels of the previous segmented image are regarded as the training samples for SVM, which is used to re-segment the image. These iterations are repeated until the convergence, which is determined by checking the relative change of the entropy between two consecutive segmented images. Experimental results show that compared with, the proposed algorithm can achieve much better segmented results than the Markov random field (MRF) algorithm, and the proposed method dramatically reduces the influence of initial segmentation on the final result. [C150]

"Novel approach of SAR target classification utilizing aspect information"

Aiming at the computational burden of template-based SAR target classification, an approach of SAR target classification utilizing aspect information is presented. First, estimate target aspect from peaks. Then consider the aspect as cueing information to reduce the search space. Finally the candidate target is declared by matching against those templates under aspect constraint. The proposed method is evaluated on MSTAR SAR target imagery, and the experimental results indicate that it achieves improved efficiency as well as comparable performance, compared with direct correlation method. [C151]

"Effectivenessand uniqueness conditions for 2-D MUSIC algorithm used in ISAR imaging"

This paper discusses the applying of 2-D MUSIC spectral estimation algorithm used in ISAR imaging. The motivation for applying 2-D MUSIC algorithm is to improve resolution and remove side-lobe effects compared to the conventional imaging techniques based on Fourier transform. This paper makes two principal contributions to the 2-D MUSIC algorithm. First, it proved that 2-D MUSIC algorithm using spatial smoothing technique is equivalent to 1-D MUSIC algorithm. Second, the effectiveness and uniqueness conditions for 2-D MUSIC algorithm are derived and demonstrated. Simulations illustrate that only when the effectiveness and uniqueness conditions are met can the unique imagery of target using 2-D MUSIC algorithm be obtained; otherwise there will be Г‚ВїartifactsГ‚Вї. [C152]

"Analysis of the polarimetric parameters of representative targets and its application to land use classification"

Polarimetric SAR (POLSAR) data contains both phase and amplitude information from radar returns transmitted in four different polarizations. Thus it is necessary that we place strong emphasis upon extracting physical information from the observed scattering of microwaves. In this paper, we studied the Freeman decomposition method as well as some feature parameters that can represent targets' characteristics. Further more, we made an in-depth investigation on applying these parameters to discriminate several representative terrain cover types. [C153]

"Ultra wideband impulse radar calibration"

Sensing and locating with Ultra Wideband is a quickly evolving technology in automation and disaster monitoring. Features are the high resolution, extremely fast measurements and the moderate cost. For target and object classification these UWB impulse Radars require a full polarimetric calibration. Only by this, the correct target features can be assigned. A complete mathematical description by scattering and transfer matrices is derived. Proper calibration targets and procedures are discussed and evaluated. [C154]

"ISAR target recognition based on manifold learning"

In this paper, the idea of manifold learning is introduced into inverse synthetic aperture radar (ISAR) target recognition, a new method based on Locality Preserving Projections (LPP) algorithm and k-nearest neighbour classification for ISAR target recognition is proposed. Firstly, the LPP algorithm is used to reduce the dimension of ISAR image, and then three kinds of aircraft target are classified by k-nearest neighbour classification in the low-dimensional subspace. The simulated experimental results suggest that the proposed method has the capability of finding the low-dimensional manifold structure embedded in the high-dimensional ISAR image space controlled by few parameters, such as attitude angle, scale and position, etc., and better classification performance is acquired comparing to PCA and LDA. [C155]

"Study on Polarimetric measurement and radar target identification in instantaneous polarization radar system"

Instantaneous polarization radar can obtain radar target polarization scattering matrix (PSM) by taking advantage of single pulse echo signal. The Polarimetric measurement properties and weak target detection of this system is verified by external field experiment. The actual measured data is used to target classification by applying

polarization statistical properties and transformation of target polarization scattering matrix or decomposition. Two different radar target identification subject to its polarization properties has been demonstrates the effectiveness of using Polarimetric data and motivates the use of polarimetry for target detection in clutter and interference environment. The back-scattering power and optimized transmission polarization of the system is also involved. [C156]

"Particle filter based approach to road detection in multiband SAR images"

Synthetic aperture radar (SAR) images are widely used for aerial and spatial image applications, such as terrain classification, target detection, etc. SAR images in different bands can provide multi-spectrum information, which is beneficial for more accurate target observation. In this paper, a new method is proposed for joint detection of roads in multiband SAR images. First, the multi-segmented polyline model is introduced to provide a more accurate description of road curve. Then, the roads in SAR images are extracted in a Bayesian tracking framework, and the particle filtering algorithm is employed to implement the tracking. Finally, a joint detection method is proposed to determine the optimal weights of particles based on the maximum likelihood (ML) criterion. The effectiveness of the proposed method is demonstrated by experimental results with real multiband SAR data. [C157]

"Forward scattering micro radars for situation awareness"

In the paper a progress in the netted forward scattering radar research is presented. A special attention is paid to the optimal and sub-optimal signal processing algorithms. These algorithms are assumed to be efficient when the signal is received at a background of Doppler clutters and AWGN. [C158]

"Study on SAR target recognition based on Support Vector Machine"

This paper studies MSTAR SAR target recognition with Support Vector Machine (SVM) classifier by using Principal Component Analysis (PCA) features, without consideration of errors in target aspect angle estimation. A good strategy is proposed to avoid errors in classifier selection for the errors in estimation of aspect angle. The experiments based on MSTAR data set show perfect results. [C159]

"A new fast 2-D superresolution imaging algorithm"

A novel method is proposed for reconstructing the 2-D scattering centres of radar target, research the frequency scatter model of electromagnetic scattering, we resolve the problem by extracting two 1-D scattering centres parameter instead of extracting directly 2-D scattering centres parameter, separately estimate the 1-D scattering centres in range dimension and cross dimension using conjugate unitary Root-MUSIC algorithm, group them and attain all possible spatial frequency pairs, then the unveracious frequency pairs are eliminated by spatial filtering, achieve the 2-D scattering centres parameter. [C160]

"Effects of amplitude and phase errors on 2-D MUSIC and 2-D ESPRIT algorithms in ISAR imaging"

We investigate the effects of amplitude and phase errors on 2-D MUSIC and 2-D ESPRIT algorithms in ISAR firstly with ideal point-targets model, and then with a full-wave electromagnetic simulation of ISAR real-targets model by using 2-D finite difference time domain method (FDTD). The 2-D MUSIC and 2-D ESPRIT algorithms are implemented to form the ISAR imageries of the targets with different amplitude and phase errors, and the imaging results are compared and analysed. [C161]

"Characteristic study of ionospheric clutter in high-frequency over the horizon surface wave radar"

The presence of ionospheric clutter in high-frequency over the horizon surface wave radar may extremely affect the performance of radar system and degrade the capability of detecting target. The characteristic analysis of ionospheric clutter is the foundation of studying method to suppress ionospheric clutter. By using the MUSIC algorithm to analyze plentiful radar echoes data, directivity characteristic of several major kinds of ionospheric clutter has been summarized and the superposition situation that two kinds of ionospheric clutter exist at the same altitude has been discussed, moreover, the pertinence between directivity characteristic of ionospheric clutter and the working frequency has been studied. All these works provide convenience for advancing and realizing ionospheric clutter suppression methods based on directivity characteristic of ionospheric clutter. [C162]

"Situation assessment via multi-target identification and classification in radar sensor networks"

DoD has defined three levels of data fusion for network centric warfare (NCW). Level 1 data fusion combines

data from single or multiple sensors and sources to provide the best estimate of objects and events in the battlespace. Level 2 data fusion focuses on situation assessment. Level 3 data fusion is threat assessment. To facilitate situation assessment, we investigate the problem of jointly classifying and identifying multiple targets in radar sensor networks where the maximum number of categories and the maximum number of targets in each category are obtained a priori based on statistical data. However, the actual number of targets in each category and the actual number of target categories being present at any given time are assumed unknown. It is assumed that a given target belongs to one category and one identification number. The target signals are modeled as zero-mean complex Gaussian processes. We propose a joint multi-target identification and classification (JMIC) algorithm for radar surveillance using cognitive radars. The existing target categories are first classified and then the targets in each category are accordingly identified. Simulation results are presented to evaluate the feasibility and effectiveness of the proposed JMIC algorithm in a query surveillance region. [C163]

"Unsupervised polarimetric SAR image classification using fisher linear discriminant"

How to use the POLSAR data to classify and interpret the conditions of the earth is a very important research field of POLSAR. In this paper, we propose an improved algorithm on the basis of studying and analyzing some common algorithms. This technique introduces the fisher criterion in the feature selection and the hierarchical method in the classification of POLSAR image, which can improve Lee's combination method of the unsupervised classification based on polarimetric target decomposition and the maximum likelihood classifier based on the complex Wishart distribution. The effectiveness of this algorithm is demonstrated using a polerimetric SAR image. [C164]

"Radar target recognition based on combined features of high range resolution profiles"

This paper is focused on the feature extraction techniques of radar high range resolution profiles (HRRPs). In order to release the translational sensitivity of HRRPs, two translation invariant features, the central moments and distribution entropy, are extracted from the HRRPs and combined to form a new feature vector. Experiment on real data of three airplanes in flight is implemented to evaluate the recognition performance of the combined feature, using the nearest neighbour (NN) classifier and the support vector machine (SVM) classifier, respectively. Experimental results demonstrate that the combined feature can significantly enhance the separability of different targets and improve the average recognition rate of HRRP target recognition. [C165]

"Performance comparison of target classification in SAR images based on PCA and 2D-PCA features"

Feature extraction is an important step for target classification in SAR images. Principal component analysis (PCA) is common in pattern recognition, and has been used widely for target classification in SAR images. In order to utilize PCA, two-dimensional image has to be arranged to an observation vector. However, two-dimensional PCA (2D-PCA), which is developed from PCA, can extract features from two-dimensional SAR image directly. Although 2D-PCA is consistent with PCA in theory essentially, which represents original data by extracting principal components with high variance values by linear transformation, they perform distinctly due to the difference of data processing methods. Based on the theoretical analysis and classification experiment using MSTAR data, this paper compares PCA and 2D-PCA systematically and roundly. [C166]

"A new method for polarimetric SAR image classification"

In this paper, the authors propose a new method for supervised target classification of polarimetric synthetic aperture radar (SAR) image, by using the optimization of polarimetric contrast enhancement (OPCE). First, using the idea of the generalized optimization of polarimetric contrast enhancement (GOPCE), the authors modify the model with three polarimetric parameters which are related to the physics of the scattering mechanisms. It leads to enlarge the difference between two categories and improve the classification results. A new classification approach is then proposed, it is similar to a single binary tree, which the misclassification between the classes with a big power difference is minimal. After the classified results are obtained by the combination of Fisher-OPCE and polarimetric parameters, the coefficients of the scattering parameters information of every two adjacent classes will be used as the last discrimination for final classification results. The effectiveness of the proposed algorithm is demonstrated by using a NASA/JPL AIRSAR L-band image over San Francisco. [C167]

"Radar target classification in littoral environment with HMMs combined with a track based classifier"

One of the challenges of maritime radar applications is to address new kinds of threats, the so called anti asymmetric warfare role, which happens in the littoral environment. Besides the asymmetric warfare also the

symmetric warfare is transformed more and more from the blue sea scenario into this environment. To realize information superiority one has to be able to deal with air, sea and land targets simultaneously. To fulfil the operational requirements (proportionality of counter measures, prevent collateral damage, etc.) the capability for a detailed classification of sea, land and air targets is of extraordinary importance (persons vs. vehicles, buoys vs. ships). [C168]

"Naпve Bayesian radar micro-doppler recognition"

A comprehensive evaluation of a naive Bayesian classifier used for micro-Doppler signature (mu-DS) radar automatic target recognition has been performed. An initial estimate of performance is made using the Bhattacharyya bound on the error probability that gives results of approximately 60% of the measured value. The classifier input data is pre-processed using the CLEAN algorithm, the Fourier transform and principal component analysis to provide feature vectors exhibiting only mu-DS information. The classifier includes ldquounknownrdquo input rejection that falsely declares known targets with a probability of just 0.07. The probability of correct classification is 0.94. [C169]

"Research of radar automatic target recognition in practical high resolution range profile"

Radar target automatic recognition is a comprehension problem. We have researched the practical radar data and concluded some valuable viewpoint. With it we put forward a whole scheme to achieve radar automatic target recognition. First the OS CAFR and binary accumulation algorithm is taken to accurately detect target. Here we lower self-adapt threshold to get more targets which maybe be false target. Then we use target trace management to remove the illusion target. The novel algorithm, called as endpoint detection based on moving window, can get more valuable data to classification. For 3D target we must build more templets in classification. So we use Neural Net as classification algorithm to reduce memory space. The simulation results prove that this scheme can get better recognition results. [C170]

"A Target Recognition Method of Multi-radar"

A target recognition method of multi-radar is proposed based on the kinematical information from multi-radar. The process of target recognition can be divided into three levels. First, air/sea target classification can be obtained based on the information from single radar including target height, velocity, acceleration, elevation rate and azimuth rate by using fuzzy synthetic evaluation. Then, type recognition of the air target classified from first level can be accomplished only by the target height information. Finally, the recognition results of multi-radar are obtained by the fusion of recognition results from single radar. The simulation results show that the method proposed in this paper is effective and can be facilitated to engineering. [C171]

"Application of Improved FCM on Classification of Multi-target Guided by AWACS"

An improved FCM (fuzzy C-means) algorithm is applied to classify the multi-target in the air combat, and divides them into several colonies averagely according to the simulation in different targets compared to traditional FCM algorithm. Meanwhile, this method reduces the computational complexity, and raises the operating speed by considering multi-target as a whole. Finally, multi-target colonies mathematical model has been established, the simulation result indicates that this improved algorithm is reasonable and effective. [C172]

"A whole scheme for aircraft target identification in HRRP"

This paper describes the authorspsila efforts in practical high resolution range profile target automatic recognition. The practical high resolution range profile has more difference to simulation results, so this paper presents a novel algorithm to detect and extract the target range profile data and also create a whole scheme to deal with this difference. First it takes OS CAFR and binary accumulation algorithm to detect target. Here we lower self-adapt threshold to get more targets which maybe be false target. Then we use target trace management to remove the illusion target The novel algorithm, called as endpoint detection based on moving window, can get more valuable data to classification. Practical data has more noise and low PSN, so K-mean algorithm can remove the bad data. Due to variation of target high resolution range profile we build a suffice sample set, which require us to use PCA algorithm to reduce the computer time and memory. Classification is N near classifier, which can get a nonlinear classification effect. The test results prove that this scheme can get better recognition results. [C173]

"An intelligent through-the-wall recognition system for homeland security"

The increasing demands for homeland security boost the development of an intelligent recognition system for through-the-wall sensing. A novel intelligent through-the-wall life recognition engine based on support vector

machine (SVM) is provided herein. In this system, micro-Doppler signatures detected from through-the-wall radar are extracted and fed into a SVM classifier. Micro-Doppler effect has great potential for life recognition of human activities, nonhuman but vital subjects, and lifeless targets. Due to time-varying non-stationary characteristic of micro-Doppler feature and its high dimensionality, the SVM classifier is found effective in achieving both computation efficiency and accuracy for this application. Simulation results show that high classification performance is achieved using the proposed recognition system. [C174]

"Coherent Ka-band radar with a semiconductor transmitter for airport surface movement monitoring"

The paper outlines the operation principles, technical characteristics and the field tests results of the innovative Ka-band radar for airport surface monitoring. Advantages and disadvantages of operation in the Ka-band with respect to a shorter one, i.e. the W-band, are discussed. It is shown that in the Ka-band the coherent operation regime can be realized. This regime enables one not only to essentially reduce the radiation power to the level provided by the available semiconductor devices, but also to perform moving target detection on a interference created by reflections from surface objects and rain as well as to perform automatic classification of targets according to their radial velocity of movement. Main performance specifications, principle of operation, and design of the innovative antenna developed for the radar are described in details. The results of the field tests confirm the predicted radar operation characteristics. The radars of the proposed type can find use as radar-sensors for systems of airport surface monitoring. [C175]

"Evaluation of some features for extended target extraction in polarimetric radar"

Detection in most surveillance radars is based on the condition of point targets against a more or less homogeneous background. Currently, the resolution of many new types of radar is increasing, at least in the range dimension. Therefore many objects no longer can be considered as points. Also as a consequence, the background is getting more diverse, in statistical terms. The scene addressed in this paper concerns a ground clutter environment, and extended objects observed with a polarimetric radar with modestly high resolution (i.e. 6m resolving power in range). A staged approach is proposed to detection and parameter assessment of extended objects and adding classification based on polarimetric features. The evaluation of this approach is based on recordings of real natural scenes and artificially inserted extended objects. It has been observed that in the multi-stage detection the object classification benefits from several features, amongst which polarimetric ones. It is proposed that the quality of the contour circumscribing the object is the prime factor for quality of the features next to the polarimetric features. Clutter is affecting the edges of the contours, and therefore may have a major impact on features that are dependent on these contours. [C176]

"Analysis of ISAR images of a helicopter by a facet model"

A triangular facet model of targets is proposed to generate ISAR images. Targets are composed of solid objects which are modeled by triangular facets. It is shown that the facets have an equivalent point-scatterer whose radar cross section and position depend on the shape of the triangle, the frequency and the angle of incidence. It is developed a shadowing algorithm to detect the facets which actually have influence on the signal received by the radar. This model is applied to study the ISAR images of a helicopter with two different transmitted signals, a rectangular pulse waveform and a linear frequency modulated waveform to identify the main features of the ISAR images for future classification purposes. [C177]

"Automatic Target Recognition by means of polarimetric ISAR images: a model matching based algorithm"

Automatic target recognition (ATR) is generally the reason why ISAR imaging systems are employed. Moreover, the use of fully polarimetric radar systems in radar imaging applications such as SAR and ISAR has enhanced both image quality and classification capabilities. In this paper, the authors propose a novel technique for ATR by using Polarimetric ISAR (Pol-ISAR) images. The proposed method is based on a model matching approach. Results are obtained by using real data that show the effectiveness of such technique. [C178]

"A technique to predict the time-of-arrival of a tumor response corrupted by clutter"

Radar-based microwave imaging has been proposed as a complementary modality for early stage breast cancer screening. A considerable challenge for the successful implementation of this technique is the reduction of clutter, or components of the signal originating from objects other than the tumor. To remedy problems that arise due to the breast shape, size and tissue variations, a novel technique is presented that identifies and localizes the source of a target response. The ability of the algorithm to predict the time-of-arrival of a tumor response in

a signal corrupted by clutter is demonstrated. [C179]

"High Resolution Radar Automatic Target Recognition Based on an Improved LDA Method"

A novel improved linear discriminant analysis (ILDA) method is presented. Comparing with LDA, under the condition of d < c -1, d and c are the dimensionality of feature subspace and the number of classes respectively, ILDA uniformly preserves the class distances of classpairs by rearranging the contribution of each class-pair to the generalized between-class scatter matrix after whitening within-class scatter matrix. Experiment results based on simulating data and measured radar data both show that, under the condition of d < c -1, the features extracted by ILDA are more efficient for multi-class classification than those extracted by LDA. [C180]

"Measuring time between peaks in helicopter classification using Continuous Wavelet Transform"

Helicopter classification capability is a desirable feature on air defense radars, as a way of distinguishing friends of foes. However, it is still a challenging task for any radar system. The classical method for helicopter classification is the L/N-quotient method, where two signal features are measured: time between peaks and blade tip velocity. Unfortunately, these features are difficult to measure on actual target echoes with high noise levels. This paper shows the difficulties for measuring these features and presents a way of measuring time between peaks using continuous wavelet transform (CWT). [C181]

"Subspace methods and spatial diversity in radars"

The utilization of diversity in radar systems has shown improvements over conventional beamforming phased array radars in many aspects of the system performance including target detection probability, the number of identifiable targets, and beam-pattern synthesis. When linearly independent signals are transmitted, the signals received from targets at different locations are also linearly independent. In using subspace methods such as MUSIC, this presents an advantage as spatial smoothing is no longer required. We present here a comparison of the performance of a MIMO radar system, with that of a phased array requiring spatial smoothing. The behaviour of the eigenvalues of the received data covariance matrix for radars with and without spatial diversity is presented, and the characteristics of the MUSIC spectrum of the two systems is compared. [C182]

"Multiple-target localization and estimation of MIMO radars using Capon and APES techniques"

The concept of multiple-input multiple-output (MIMO) radar is recently proposed inspired by recent advances in MIMO communications. A recently proposed statistical MIMO radar configuration is considered here, in which the transmit array antennas are widely spaced to enable spatial diversity with respect to the targets, while the receiver is an uniform linear array with the elements spaced half a wavelength apart to enable direction finding. In this proposal, this signal model is extended to the multiple-target case, and the problem of multiple-target localization and estimation is considered. The Capon and APES techniques for multiple-target localization and estimation of MIMO radar systems are proposed in this paper. The performance of the proposed method is validated by numerical simulations. [C183]

"High Range Resolution (HRR) profiling within low elevation search mode"

In this paper, we describe the high range resolution (HRR) profiling technique for generating the target range profile while the radar is in the low elevation search mode. The major advantage of this concept is reuse of the moving target detection (MTD) radar data for formulating the target range profile to provide the early target classification, discrimination, and identification (CDI) decision for all targets. This technique is developed for air missile defense pulse Doppler radar in which transmitting frequency is changing within the transmit pulse width. Here, we also discuss the effects of phase variation introduced by radial target motion and address how to compensate those effects. [C184]

"Real-time signal processing system for high resolution CWLFM millimeter-wave radars"

An FPGA-based real-time signal processing unit has been developed to perform Doppler processing in a high resolution CWLFM (continuous wave linear frequency modulated) millimeter-wave radar demonstrator. The article focuses on the strategies followed in order to achieve the required throughput as well as on the measures taken to guarantee coherency. Doppler processing is accomplished to output Range-Doppler radar images and transfer them to a PC application for display. Two different experimental setups have been used to verify the correct operation of the processing flow. The system has been designed so as to allow for future addition of complex target detection-classification schemes. [C185]

"A new approach to moving terrestrial targets recognition using ground surveillance pulse doppler RADARs"

In this paper we propose a new automatic target recognition algorithm to recognize and distinguish of three classes of targets: personnel, wheeled vehicles and animals, using a low-resolution ground surveillance pulse Doppler radar. Using the chirplet transformation, a time-frequency signal processing technique, the parameterized radar signal is then used by the Zernike moments (ZM) for the pertinent features of the targets. The current work provides a new approach for multiresolution analysis and classification of non stationary signals with the objective of revealing important features in noisy and cluttered environment. The algorithm is trained and tested on real radar signatures of multiple examples of moving targets from each class. The results shows the proposed algorithm invariancy against speed and orientation of the targets. [C186]

"Classifying HRRP by AdaBoostSVM"

Radar target identification by using high resolution range profile (HRRP) have been studied extensively. Effective way of HRRP classification by support vector machine (SVM) was studied in this paper. In order to improve the classification performance of SVM, the approach of improving the classification performance of AdaBoostSVM was studied. A new variable sigma-AdaBoostSVM was given, it improves the classification performance by making a balance between the accuracy and diversity of base classifiers. The scheme of using the improved algorithm for AdaBoostSVM to classify HRRP was studied. Experiments using the measured range profile datasets prove the effectiveness of the scheme. [C187]

"ESPRIT method for multiple-target localization using MIMO array"

A subspace-based method for multiple-target localization by multi-input multi-output (MIMO) array is presented in this paper. Because the covariance matrix of reflected signals from targets at different locations is always nonsingular as a result of mutual orthogonality among the signals transmitted by MIMO array, estimation of signal parameters via rotational invariance technique (ESPRIT) algorithm can be directly applied to the direction of arrival (DOA) estimation problem of the MIMO array without spatial smoothing (SS) techniques beforehand. Simulation results verify the effectiveness of the proposed method. [C188]

"Time Frequency Representations for Classification of Landmine Using UWB Impulse GPR"

In this paper, Time Frequency Representations (TFRs) for classification of landmine using Ultra Wideband (UWB) impulse Ground Penetrating Radar (GPR) is presented. GPR signal is composed of three parts: ground bounce, clutter and target echo signal, the target signal is seriously deteriorated by ground bounce and clutter. To extract intricate structures of target signal, wavelet packet transforms (WPT)-based algorithm is used to ground bounce removal and clutter reduction. Then the Fisher Dsicriminant Ratio (FDR) for feature subset selection method is used to select the suboptimal feature subset of target signal, thereby a Learning Vector Quantization (LVQ) classifier is designed. Experimental results based on GPR measured data are presented, showing that the feasibility and advantage of the presented algorithm. [C189]

"Study of the classification task into an integrated multisensor system for maritime border control"

This work focuses on the classification task performed into a multi-sensor system for the coastal surveillance. The system is composed of two platforms of sensors: a land based platform, equipped with a land based radar, an automatic identification system (AIS) and an infrared camera (IR); an airborne platform, carrying an airborne radar that can operate in a spotlight synthetic aperture radar (SAR) mode, a video camera, and a second IR camera. The tasks performed by the system are the detection, tracking, identification, and classification of multiple targets, the evaluation of their threat level, and the selection of an intervention on them. The classification algorithm implemented inside the system exploits an analytical approach based on the confusion matrix (CM) of the imaging sensors that belong to the system. Some measures of effectiveness (MoE) of the system are evaluated, considering both the cases where an ideal error free classification process and a non-ideal classification process are performed. [C190]

"High resolution through-the-wall radar imaging using extended target model"

Through-the-wall radar imaging attempts to image complex scenes within enclosed structures. While most of the high-resolution imaging techniques assume point targets, indoor imaging requires dealing with single or multiple walls which are extended targets in nature and violate the point-target assumption. In order to provide high quality imaging, we need to consider point targets and extended targets separately. In this paper, we model extended targets and apply signal subspace methods for target localization. By combining two separate images, one with point target model and the other with extended target model, both types of targets can be identifiable.

Imaging results are shown with both synthesized and experimental data. [C191]

"Automatic target recognition of aircrafts using translation invariant features and neural networks"

Automatic target recognition (ATR) of aircrafts using translation invariant features derived from high range resolution (HRR) profiles and multilayered neural network is presented in this paper. The HRR profile sequences are translation variant in the range resolution cell because of the non-cooperative target maneuvering. The differential power spectrum (DPS) is introduced to extract the translation invariant features. Several learning algorithms of feed-forward neural network are implemented to determine an optimal choice in the recognition phase. The range profiles are obtained using the two-dimensional backscatters distribution data of four different scaled aircraft models. Simulations are presented to evaluate the classification performance with the DPS based features and neural networks. The results show that this method is effective for the application of radar target recognition. [C192]

"Smart beamforming and wideband signals for ground surveillance"

In this paper, dealing with long range ground surveillance radars, it is shown that the simultaneous requirement for wideband waveforms and multiple channels opens the way to new space-time signals and processing techniques, thus improving the detection and classification of multiple ground (and low-flying) targets. [C193]

"Target recognition of MMW radar based on FSVM"

The choice of fuzzy membership relates to the classification results of fuzzy support vector machine (FSVM). In this paper, membership based on distance and affinity among samples is researched. Aimed at the disadvantage of membership based on affinity among samples that can not reflect the distribution of radar echo in feature space, super-ellipse is introduced to improve the membership and applied to FSVM to distinguish support vectors with outliers or noise. The results of experiments show that the fuzzy support vector machine, based on the improved affinity among samples, is more robust than others. [C194]

"Colorization for Polarimetric SAR Image Based on Scattering Mechanisms"

Polarimetric synthetic aperture radar (POLSAR) images are widely used for aerial and spatial image applications, such as terrain classification, target detection, etc. However, only monochrome gray images can be derived from SAR data due to the imaging mechanisms of SAR, which limits image presentation and visual appeal. In this paper, we proposed a new approach to colorization for POLSAR images. The basic principle is that pixels with the same scattering characteristics should have similar colors. To achieve this, the algorithm first utilizes the Cloude and Pottier's decomposition to separate pixels into eight scattering categories, and then unsupervised classification is applied for further iteration. Colorization is performed in Lab color space using the classification result, which assigns a color to each class according to the self-defined entropy-alpha color map. In this semiautomatic method, an operator only needs to define a color map, and then the indicated colors are automatically transferred to produce a fully colorized image. The effectiveness of this algorithm is demonstrated by a JPL/AIRSAR POLSAR image. [C195]

"Classification of ground moving targets in the exoclutter region of airborne radar signals"

An airborne radar sensor operating in ground moving target indicator (GMTI) mode is able to distinguish between airborne targets and ground moving targets. Further it is possible to separate stationary from moving ground targets. For military radar applications, it is desirable that the GMTI mode be extended to allow classification of detected ground targets. In addition, such an extension should permit classification of Helicopters. A model-based classification algorithm suitable for GMTI processing as well as for Doppler signal evaluation is presented, using only signals in the exoclutter region (clutter-free region of the range-Doppler domain) and not requiring STAP processing. [C196]

"Impact of Wavelet based signal processing methods in radar classification systems using Hidden Markov Models"

A classification technology is presented that uses a Wavelet based feature extractor and a Hidden Markov Model (HMM) to classify simulated and real radar signals from six classes of targets: person, tracked vehicles, wheeled vehicles, helicopters, propeller aircrafts and clutter (no match). Similar to techniques that have been well proven in speech and image recognition, the time-varying nature of radar Doppler data is exploited. The method classifies the targets by their different Doppler characteristics. The Wavelet technique has been tested on radar data where the classical signal processing methods failed. The purpose of this paper is to demonstrate the ability of Wavelet methods combined with a Discrete Hidden Markov Model (DHMM) in radar target recognition tasks.

[C197]

"Extended object detection and extraction in a high resolution polarimetric surveillance radar"

Detection in most surveillance radars is based on assumptions on point targets against a more or less homogeneous background. Currently, the resolution of many new types of radar is increasing, at least in the range dimension. Therefore many objects no longer can be considered as points. Also, the background is getting more diverse, in statistical terms, since many individual objects in the background are no longer mixed coherently. The current paper proposes as staged approach to detection and parameter assessment of extended objects and adds classification based on the polarimetric features. The evaluation of the approach is based on recordings with a polarimetric radar of real natural scenes and both real and artificially inserted extended objects. It has been observed that a multi-stage detection outperforms a classical method, in terms of the ratio between wanted and unwanted alarms. [C198]

"Improved Tracking Algorithm for Multiple Targets"

In this paper, a novel algorithm for tracking multiple targets is proposed. The algorithm incorporates subspace tracking with Kalman filtering to improve tracking performance. At each recursive step of the Kalman filter, subspace tracking is first combined with the MUSIC spectrum to provide angle estimates which are used as measurement data. To avoid abnormally large errors caused by crossing trajectory, the estimated angles are updated through a decision mechanism. Finally, the angle estimates are smoothed and then predicted for accuracy improvement and correct association, respectively. Simulation results are furnished to demonstrate the effectiveness of the proposed algorithm. [C199]

"Classification of non-Rayleigh echoes from patches of fish"

Echoes from patches of fish fluctuate significantly from ping to ping as the sonar beam is swept across the patches. The fluctuations can be strongly non-Rayleigh because 1) there can be a small number of targets in the beam at a time, 2) the distribution of fish can be inhomogeneous, or "patchy", and 3) the echoes are weighted by the non-uniform response of the sonar beam. We have previously identified several distributions to describe the statistical behavior of non-Rayleigh echoes from fish-the K-distribution for multiple patches of unresolved fish, a mix distribution composed of two Rayleigh distributions for the patches, and a distribution that explicitly accounts for the beampattern when the fish are resolved. We have demonstrated good agreement between these PDF's and corresponding sets of data. In this new study, we investigate classification approaches and how they best suit the problem specific to patches of fish. In particular, we apply standard classifiers to fish echo data using our theoretical PDF's. We compare the performance of the different classifiers and make recommendations as to which type of classifier might best be suited to the fish application. Our initial results show that a classifier using the Kullback-Leibler (KL) distance is better than a L-2 norm approach, as the KL approach emphasizes differences in the tail of the distribution. One key aspect to this problem is that parameters of the theoretical PDF's are physics-based. [C200]

"Naval Target Classification Based on the Confusion Matrix"

In this paper, we propose an algorithm for the classification of naval targets, which is based on the fusion of the class information provided by three imaging sensors: a video camera, an infrared (IR) camera, and an airborne radar operating in spotlight Synthetic Aperture Radar (SAR) mode. The purpose of the fusion process is to elaborate the outputs of these three imaging sensors in order to obtain an accurate and reliable estimate of the target class. The performance of each imaging sensor is modelled by means of its confusion matrix (CM). The entries of the matrix are used to make the decision on the target class by each sensor. Then a final decision on the class is made, using an appropriate fusion rule in order to combine the decisions coming from the three sensors. Two decision rules are compared: a majority voting rule and a maximum likelihood rule. The overall performance of the classification process is evaluated by means of the "fused" confusion matrix, i.e. the matrix pertinent to the final decision on the target class. The main contribution of this approach is the development of a methodology that allows to easily include the classification process inside the Monte Carlo simulator of a large integrated system, without increasing its overall computational load. [C201]

"Radar Target Recognition Using LVQ Network and Majority Voting"

This paper describes a novel method for radar target classification based on high range resolution profile (HRRP). In view of the non-stationary characteristic of radar signal, adaptive Gaussian basis representation (AGR) is utilized to extract features from raw HRRP signatures to fully retain the physics information of target. Then learning vector quantization (LVQ) network is adopted to tackle the classification of single echo (after features extraction) with complicated space distribution. Finally ,a combined classification scheme combining

LVQ networks with the majority voting rule is designed to circumvent the sensitivity of HRRP to target aspects based on sequential echoes. A actual example using three scaled aircraft model data collected in microwave anechoic chamber is presented to demonstrate the effectiveness of proposed scheme. [C202]

"Incremental object part detection toward object classification in a sequence of noisy range images"

This paper presents an incremental object part detection algorithm using a particle filter. The method infers object parts from 3D data acquired with a range camera. The range information is quantized and enhanced by local structure to partially cope with considerable measurement noise and distortion. The augmented voxel representation allows the adaptation of known track-before-detect algorithms to infer multiple object parts in a range image sequence even when each single observation does not contain enough information to do the detection. The appropriateness of the method is successfully demonstrated by two experiments for chair legs. [C203]

"Radar target recognition based on a kernel double discriminant subspaces method"

Kernel Fisher discriminant analysis (KFDA) is a very effective tool used for dimensionality reduction and feature extraction in pattern recognition. However, KFDA also suffers from the so-called small sample size problem (SSS) which often exists in high-dimensional pattern recognition data. In this paper, we present a complete KFDA method, namely kernel double discriminant subspaces (KDDS). The new algorithm views the optimal discriminant vectors as a global transform in the feature space to some extent, and it makes full use of the discriminative information within both null and non-null subspace of the within-class scatter matrix, which makes KDDS a more powerful dicriminator. Experiments based on the measured airplanes database are conducted to evaluate the effectiveness of the proposed method, and the results show that it can obtain better classification performance. [C204]

"Detecting targets of variable acceleration with High Frequency Surface Wave Radar"

According to the conventional hypothesis, the velocity of target in the coherent integration time (CIT) is invariable in the application of utilizing high frequency surface wave radar to detect target. First, this paper proposes a more proper hypothesis in which the velocity and acceleration of target are treated as time-varying. However the acceleration of target can be regarded as invariable within the small fraction of coherent integration time. Then the model of echo signal in the hypothesis is analyzed. Considering the disadvangtages of some conventional methods of time-frequency analysis such as short-time Fourier transform (STFT) and Wigner-Ville distribution (WVD), the paper proposes the method of time-frequency analysis based on chirplets signal decomposition which can improve the time and frequency resolution simultaneously and solve the cross-term problem in WVD method. Firstly, we process the small fraction of coherent integration time with the chirplets signal decomposition. Then according to the differences between target signal and ocean clutter echo, the BP neural network classifier can be exploited to suppress ocean clutter. The different fractions of coherent integration time are composed together with the method of the nearest correlation. Lastly, the feasibility of the method for detecting targets of variable acceleration is proved by its processing the actual data. [C205]

"Statistical evaluation of decision-level fusion methods for non-cooperative target identification by radar signatures"

A promising method of non-cooperative identification is the classification of a target by high-resolution radar signatures. By simultaneous tracking and classification one obtains a set of successive radar range profiles which contain information on the target from different aspect angles. At this point data fusion of the declaration series can help to stabilize the identification against misclassifications by putting it on a broader basis. In this paper we use an experimental data base filled with radar range profiles of eight different aircraft types of similar size for a statistical analysis and comparison of fused and unfused declaration series. As fusion methods we consider the simple voting algorithm as well as more advanced techniques as the Bayes and the Dempster-Shafer approach. [C206]

"Robust multi-look HRR ATR investigation through decision-level fusion evaluation"

Simultaneous tracking and identification (STID) is impacted by sensor and target dynamics especially in move-stop-move type scenarios. For most scenarios, both moving and stationary targets can be processed into 1D High-Range Resolution (HRR) radar profiles which contain enough feature information to discern one target from another to help maintain track or to identify the vehicle. To meet mission objectives, different decision-level and feature-level classifiers can be designed to achieve performance requirements such as the sensitivity of the

number of features for a given location accuracy, identification confidence, timeliness (revisit rate and track length), and throughput of the number of targets tracked. For robust STID evaluation, repeatable scenarios, metrics, and data support is recommended for comparisons. This paper compares the ATR performance of a baseline single-look algorithm to the performance of decision level and feature level fusion ATR algorithms through multilook assessments to assess relative fusion performance gains. [C207]

"Sound and dynamics of targets-Fusion technologies in radar target classification"

The challenge of modern sensor systems is besides the tracking of targets more and more their classification. The knowledge of the target class has significant influence on the identification, threat evaluation and weapon assignment process of large systems. Especially, considering new types of threats in anti asymmetric warfare the knowledge of a target class has an important drawback. Also the target class is used to optimize track and resource management of todaypsilas agile sensor systems. A technology is presented that fuses different classifiers to decide between persons, tracked vehicles, wheeled vehicles, helicopters, propeller aircrafts and clutter for a 2 dimensional, electronically scanned radar system. A first classifier analyses the Doppler sound of the target to decide its target class. Therefore, a cepstrum based feature extractor and a hidden Markov model (HMM) is applied. Similar to techniques that have been well proven in speech and image recognition, the time-varying nature of radar Doppler data is exploited. A second type of classifier extracts dynamic features of the target found by the underlying target tracking methodology. Through a fusion of these classifiers a highly reliable classification result is established. [C208]

"An adaptive ground penetrating radar imaging system based on complex-valued self-organizing map-recent progress and experiments in Cambodia -"

This paper reports recent progress in an adaptive ground penetrating radar imaging system based on a complex-valued neural network (CVNN), i.e., a complex-valued self-organizing map (CSOM). In the CSOM processing, we deal with feature vectors that represent complex-amplitude texture in space and frequency domains. We developed a switched walled linearly tapered slot antenna (walled-LTSA) array for the front-end. A higher resolution results in a better classification quality. To realize a high resolution in range and azimuth directions, we utilize a wide frequency bandwidth in frequency stepping operation, and a special switching scheme for the walled LTSA. We conducted experiments in Cambodia. In this paper, we report successful plastic landmine visualization, not only for targets buried in normal sand but also for those in wet laterite soil at the Siem Reap test site. Adaptive coherent radar imaging is one of the most potential application fields of the CVNNs. [C209]

"Automatic target recognition of aircrafts using neural networks"

The multilayered feed-forward neural network was applied to automatic target recognition using the high range resolution (HRR) profiles in this paper. To extract effective features from the HRR profiles, the product spectrum originally proposed for the speech signal processing was introduced to the radar target recognition community. The product spectrum was defined as the product of the power spectrum and the group delay function, which could combine the information contained in the magnitude spectrum and phase spectrum of the HRR profiles and carry more details about the shape of the aircrafts. A multilayered feed-forward neural network was selected as classifier. The HRR profiles were obtained using the two-dimensional backscatters distribution data of four different scaled aircraft models. Simulations were presented to evaluate the classification performance with the product spectrum based features. The results demonstrate that the product spectrum based features outperform the original HRR profiles and the multilayered feed-forward neural network is effective for the application of automatic target recognition of aircrafts. [C210]

"The theory and application of an electromagnetic target recognition method based on natural-resonance for multi-targets"

This paper presents the application of an electromagnetic target recognition method based on natural resonance mechanism and MUSIC algorithm to the target sets containing single amd multi-targets. The simpler case of the proposed method was applied to single targets previously and successful results were obtained [1]. However, when multi-targets are added to the test target set, the method needs crucial modifications and these modifications are mentioned in detail in this study. Owing to these modifications, the method becomes highly invariant to aspect angle and the distance between the multiple targets observed at once. The final version of the mentioned method is applied for the recognition of a target set containing single and multiple perfectly conducting spheres and sufficient accuracy rates are obtained even for low signal-to-noise ratios. [C211]

"Chirplet-based target recognition using RADAR technology"

In this paper, q-chirplet based signal processing is applied to data from a low-resolution ground surveillance pulse Doppler RADAR, to classify three classes of targets: personnel, wheeled vehicles and animals. We utilize Zernike moments (ZM) over the chirplet parameters to determine the pertinent features. Our work provides a new approach for multiresolution analysis and classification of non-stationary signals with the objective of revealing important features in an unknown noise and clutter environment. The algorithm is trained and tested on real RADAR signatures of multiple examples of moving targets from each class. The results show the proposed algorithm invariancy against speed and orientation of the targets. [C212]

"Monte-Carlo-based partially observable Markov decision process approximations for adaptive sensing"

Adaptive sensing involves actively managing sensor resources to achieve a sensing task, such as object detection, classification, and tracking, and represents a promising direction for new applications of discrete event system methods. We describe an approach to adaptive sensing based on approximately solving a partially observable Markov decision process (POMDP) formulation of the problem. Such approximations are necessary because of the very large state space involved in practical adaptive sensing problems, precluding exact computation of optimal solutions. We review the theory of POMDPs and show how the theory applies to adaptive sensing problems. We then describe Monte-Carlo-based approximation methods, with an example to illustrate their application in adaptive sensing. The example also demonstrates the gains that are possible from nonmyopic methods relative to myopic methods. [C213]

"Clustering of fully polarimetric SAR data using finite Gp 0 mixture model and SEM Algorithm"

This paper presents a novel method for clustering multilook polarimetric SAR images by combining the stochastic expectation-maximization (SEM) algorithm with the mixture of Gp0distributions, using the method of moments for parameter estimation. The pixel values of multilook SAR data are complex covariance matrices, and they are described by mixtures of gp0laws. This distribution can describe different type of targets; like urban areas, forest and pasture. The proposed clustering technique can be applied to unsupervised classification and segmentation process. Experiments with real image data provide good results. [C214]

"2D spatial model matching using HRR multi-radar data"

In this paper, the problem of target classification from multiple high range resolution (HRR) radars data is studied. The use of multi-sensor angle-diverse data aims at shortening of the required time before a decision is made, as compared to using single-sensor data. In order to avoid the high-dimensional HRR profile databases, involved in the classic automatic target recognition (ATR) approaches, the classification is based on 2D spatial target profile matching. Stochastic target modeling is further applied, as a more robust way to deal with more realistic target scattering behaviors at variant aspect angles. Raw video measurements are used, with the objective to circumvent problems due to missed detections and false alarms in the thresholded profiles. This paper proposes a new method, where the above elements are combined. Some first encouraging simulation results are given. [C215]

"Laser-based vehicles tracking and classification using occlusion reasoning and confidence estimation"

In this paper, we present a robust approach for the detection, tracking and classification of multiple vehicles using a vehicle mounted laser scanner working independently in highways an urban centers. Our classification is based on different criteria: geometrical configuration, occlusion reasoning, sensor specifications and tracking information. The estimated confidence level is thus computed accounting the classification, the geometrical configuration and the tracking duration. Our system has been validated under various conditions (highways, urban centers) with three different laser scanners and proved is robustness on real data and with real time constraints. [C216]

"Constructive neural network for landmine classification using ultra wideband GPR"

In this paper, constructive neural network for landmine classification using ultra wideband (UWB) ground penetrating radar (GPR) is presented. GPR echo signal is composed of three parts: ground bounce, clutter and target echo signal, the target echo signal is deteriorated by the clutter. Firstly WP-based preprocessing algorithm is used to ground bounce removal and clutter reduction and feature extraction of GPR echo signal. Then wrapper based approach is adopted to feature subset selection of GPR echo signal using genetic algorithm(GA) in conjunction with constructive neural network learning algorithm, and at the meanwhile, the result of classification of landmine is obtained. Experiment result based on GPR measured data shows that the feasibility

and advantage of the presented algorithm. [C217]

"A DCT-based Change Detection Method for Multi-Temporal SAR Images"

This paper aims at effectively detecting the changes in multi-temporal synthetic aperture radar (SAR) images. Since pixel-based method does not sufficiently utilize the correlation between pixels, it usually may only be used in some specific applications. We propose a change detection method that is based upon discrete cosine transform (DCT) classification. It can utilize the correlation between pixels and eliminate unimportant or nuisance forms of changes. It generates a threshold automatically in DCT classification according to the relationship between DCT coefficient and pixel's gray level. In order to eliminate the block effect, we check pixels not only within the target block, but also inside the neighborhood window around the target block. Experimental results show that the proposed method outperforms some recently published pixel-based methods. [C218]

"SAR Target Recognition Based on MRF and Gabor Wavelet Feature Extraction"

This paper presents a method for synthetic aperture radar (SAR) target recognition based on Markov random field (MRF) segmentation and Gabor wavelet transform feature extraction. ICM algorithm which based on Markov random field is used to segment a SAR target chip into target and background two fields and generate a two-value figure. Gabor wavelet transform is applied to extract feature vectors from the two-value figure. The method is verified by recognizing three-class targets in MSTAR database. The highest average probability of correct classification arrives at 93.11%, which indicates that the approach proposed in this paper is an effective method for SAR target recognition. [C219]

"Scattering type phase for wetland classification using C-band polarimetric SAR"

The Touzi decomposition is investigated for wetland characterization. Like the Cloude alpha scattering type, the magnitude alphasof the symmetric scattering is not effective for vegetation type discrimination. The phase Phialphasof the symmetric scattering type has to be used for enhanced characterization of wetland vegetation species. A new tool is introduced for assessment of the scattering type phase coherence, and the phase of the dominant scattering type is shown to be very promising for wetland target classification. The unique information provided by Phialphasfor enhanced wetland class discrimination is demonstrated using Convair-580 polarimetric C-band SAR data collected over the Mer Bleue wetland in the East of Ottawa, Canada. The use of Phialphasmakes possible the discrimination of shrub bog from sedges fen, and permits even the discrimination between conifer dominated treed bog from upland deciduous forest under leafy conditions. [C220]

"Region Feature Extraction Based on Improved Regularization Method in SAR Image"

The noise existed in Synthetic Aperture Radar (SAR) image weakens the detailed features of region of interest (ROI) such as target and shadow. It also leads to the serious performance reduction of subsequent target detection, classification and recognition. The conventional regularization method could enhance target features in SAR image; however, the high computation complexity limits the real-time application of it. An improved regularization method is introduced in this paper, which increases processing speed of region feature extraction for SAR image significantly. It is theoretically proved that, by optimizing SAR projection operator, computation complexity could be reduced from O(M3N3) to O(MN) without ability losing of the region-based feature enhancement. MSTAR SAR image data is employed for algorithm experiment. The result shows that our method can increase target-to-clutter ratio significantly while restraining the noise in ROI, and then extract target and shadow from background clutters in SAR image more accurately. [C221]

"Signal Processing Techniques for Feature Extraction and Classification using Small-Footprint Full-Waveform Airborne LIDAR"

Full-waveform digitizer hardware integration within discrete return LIDAR systems provides an enhanced capability to resolve vertical structure within the laser line of sight and potentially classify specific surfaces or objects. However, the subject of waveform signal processing as it applies to surface classification is fairly underdeveloped. This research includes the examination of LIDAR waveform pulse characteristics for known targets and vegetation types. Using these data, a number of signal processing techniques were investigated as precursors to classification engines without prior knowledge of surface slope, or obscuration density. Relevant waveform features were extracted using both Gaussian decomposition method and raw waveform features revealing surface classification distinctions. Preliminary results from this data set indicate that the total integrated waveform energy provides an efficient and rapid methodology for discrimination of vegetation from built surfaces. These results indicate that metrics derived from the full waveforms can be utilized to characterize and classify (to a limited degree) an environment without prior knowledge. [C222]

"Polarimetric BISAR Image Simulation and Analysis"

Employing three-dimensional mapping and projection algorithm (MPA), imaging simulation of bistatic SAR (BISAR) observation over complex scenario is developed. Based on the explicit expression of point target response of stripmap BISAR imaging, raw data is efficiently generated from the scattering map pre-calculated by MPA. Some examples of BISAR image simulation are studied. Polarimetric characteristics of BISAR image are then discussed. A transform of unified bistatic polar bases for BISAR image is proposed. Analysis of simulated images shows that the redefined parameters by the unified bistatic polar bases transform well describe different scattering mechanisms in BISAR imaging. It provides a primary tool for BISAR image interpretation and terrain classification. [C223]

"Classification of polarimetric synthetic aperture radar images from SIR-C and ALOS PALSAR"

SIR-C quad-pol MLC data and ALOS PALSAR quad-pol and dual pol SLC data over Indian sites have been processed using PolSARpro software for classification of various land features. The land features include ocean, clear water, settlements, agriculture fields, arid lands, grown and young forest, hilly terrain, mangrove forest, etc. The test sites used are SIR-C L-band and C-band Kolkata city and its surroundings, ALOS PALSAR data over West Bengal, Haryana, Rajasthan, Uttar Pradesh, and Mumbai. For Kolkata city we observed that classification results for L- and C-bands are slightly different. For Mumbai dual pol data classification accuracy is poor due to overlap of backscattering values for bare ground and mangrove vegetation with ocean backscattering values. [C224]

"SOSTAR-X system integration and flight trials"

The SOSTAR-X system is an advanced airborne ground surveillance radar system. This multi-mode radar demonstrator allows the acquisition of highly squinted and long range data in several SAR, classification and MTI modes, as well s in simultaneous SAR/MTI modes. Furthermore, tracking functionalities are included. The radar development was shared between the SOSTAR-X companies Dutch Space (NL), EADS (D), Galileo Avionica (I), Indra Sistemas (E) and Thales (F). flight trials on a Fokker F100 aircraft were performed in 2006 and 2007. This paper presents a description of the SOSTAR-X prime item and radar sensor integration, the radar system integration and tests as well as the aircraft installation and flight trials. [C225]

"Spectral target classification with SOSTAR-X"

The SOSTAR-X project has developed a demonstrator dedicated to the surveillance of both fixed and moving targets on large coverage areas, target activity analysis on dedicated areas and classification on designated targets. In this project, The Netherlands contribution has been in the areas of Spectral Classification (SPC mode), SAR SPOT mode autofocus, antenna harness, and ground target coordination during the flight campaign in the Netherlands. This paper focuses on the topic of Spectral Classification. The so-called SPC mode is a dedicated mode activated on a designated target, which classifies the target as wheeled, tracked (treaded), rotary wing, or rotating antenna. This is achieved by producing a high resolution Doppler profile, containing modulations caused by moving parts of the vehicle, and classifying on the basis of this profile. The SPC mode has been designed, implemented in the sensor and the Radar Processing Unit, and validated during extensive flight trials, in the Netherlands, Germany, and France. [C226]

"Optimized Multilooking for Robust SAR Image Indexing"

Compared to conventional optical images, the classification of remote sensing SAR images represents a rather difficult task. As a rule, the various SAR imaging and product options, the high dynamic range of SAR images, and the presence of speckle noise prevent us from obtaining robust classification results. In the following, we try to circumvent these difficulties by proper pre-processing and despeckling of high resolution SAR images. Our approach aims at adapting the radiometry and the resolution of the scenes to the optimal target recognition capabilities of a classification algorithm. To this end, we have to apply systematic adaptations that provide optimized multilooking of our input data. Then these adapted data can be fed into a scene classification system. [C227]

"Optimizing Estimation of Target's Direction of Arrival after Disturbance Suppression by Exploiting Far Distance Cell's Data"

The paper proposes one processing method of optimizing estimation of direction of arrival (DOA) by utilizing long distance cell's data to suppress radio frequency interference (RFI). After exploiting long distance cell's data to acquire the eigenvector of RFI signal and construct the subspace of RFI signal, we can project the data of distance cell to be tested onto the subspace of RFI signal. Then the result of projection is subtracted from the

data of distance cell to be tested. So RFI signal can be suppressed. We utilize the method of DOA estimation based on MUSIC algorithm to process the data in two cases, i.e. one without suppressed RFI and the other with suppressed RFI, and compare the results of the DOA estimation in the two cases. The feasibility of the processing method is proved by the results of simulation. [C228]

"Validation of PCA and LDA for SAR ATR"

Both principal component analysis (PCA) and linear discriminant analysis (LDA) have long been recognized as tools for feature extraction and data analysis. There has been reports in the open literature regarding the performance of both LDA and PCA as feature extractors in various types of classification and recognition problems. Many of the reports claim a better performance with LDA than with PCA. However, the grounds of comparison have mostly been quite narrow. In the current paper PCA and LDA based classifiers are evaluated for the problem of synthetic aperture radar based automatic target recognition problem. The results show that in terms of absolute performance, PCA outperforms LDA. Results of PCA based classifier are also found to be of higher confidence than those from LDA based classifiers, as observed from the error-bar analysis of the classifiers.With decreased amount of training dataset, the degradation in the performance of the classifiers are almost similar in nature. The current work concludes that LDA is not suitable for radar image based target recognition task. This is in line with reports from some works in the open literature which claim that the success of LDA will depend on the type of data and whether there is exhaustive data available during the training phase or not. [C229]

"A New Method of SAR Image Target Recognition based on AdaBoost Algorithm"

We propose a novel target recognition algorithm for classification of three types of ground vehicles in the moving and stationary target acquisition and recognition public release database. Algorithms that produce classifiers with large margins, such as support vector machines (SVMs), AdaBoost, etc. are receiving more and more attention in the literature. A real application of AdaBoost for synthetic aperture radar automatic target recognition is presented and the result is compared with conventional classifiers. And we also describe how AdaBoost algorithm can be used as a multiclass classification method as well as a feature fusion method. Results are presented to verify that, the performance of the recognition system is improved significantly, and the method presented in this paper is an effective method for SAR images feature fusion and target recognition. [C230]

"ROEWA based detector for SAR automatic target recognition"

Edge detection is a fundamental issue in automatic target detection using synthetic aperture radar (SAR) images. Edges are associated with intensity changes in the image and are efficient descriptors of the image structure. Due to the presence of speckle, edge detection in SAR images is extremely difficult. Several detectors have been developed for the detection of isolated step edges in speckled images like MRoA and RGoA edge detectors which use predefined thresholds. The modified RGoA detector defines an automatic threshold determining method. But all these edge detectors, apart from detecting the target edges, detect a number of false edges. In this paper we have proposed a new ROEWA based algorithm that automatically discriminates the object boundaries and the false edges. The principle of entropy is introduced in this classification process. Real SAR images are used to verify our method and the results are compared with the modified RGoA and entropy based MRGoA edge detectors. Experimental results show that the proposed method is robust and efficient. [C231]

"MMSE based waveform design for MIMO radars"

Waveform design problem for MIcircldquoMO radars has been studied in several recent works. Although signal dependent noise (clutter) is considered in some works aiming to design waveform to improve target detection in MIMO radars, there are less works on waveform design problem for target classification and estimation in the presence of clutter. Thus, here, we investigate this problem In contrast with previous works, our design leads to the convex optimization problem which can be efficiently solved through numerical methods and it can be guaranteed to converge to optimal solution. Optimal waveforms are found for two scenarios. In the first scenario it is assumed that different transmission antennas see uncorrelated aspects of the target and we consider the correlated target aspects (owing to the closed space anttenas) in the second scenario. Due to the interdependence of signal and clutter, target estimation error of the first scenario will not zero even if the transmit power tends to infinity, i.e., clutter power also increases by increasing the transmission power. This is the major problem in target detection and estimation in the presence of clutter in radars. We show that in the second scenario the MIcircldquoMO radar receiver can nullify the clutter subspace. Thus by increasing the transmission power, estimation error becomes zero in the second scenario. Waveform design for MMSE estimator under both scenarios, leads to the Semi-definite programming (SDP) problems. [C232]

"Applications for remote laser vibration sensing"

Laser vibrometry based on coherent detection techniques allows to measure vibration characteristics of objects due to the high Doppler resolution. Examples for applications in the field of defense and security such as target classification and identification including camouflaged or partly concealed targets as well as the detection of buried land mines are presented. [C233]

"Buried underwater target classification using frequency subband coherence analysis"

This study introduces a new feature extraction method for detection and classification of buried underwater mine-like objects. Multiple sonar returns off an object are used, where each sonar return is characterized by its specific frequency subbands, which contain valuable discriminatory information that can be used to correctly determine the type of object encountered. Features are extracted from the data using canonical correlation analysis (CCA) between the selected frequency subbands of two sonar returns and are subsequently used to classify mine-like and non-mine-like objects using a simple classifier. This method offers a more rigorous way of performing acoustic color processing where ping-to-ping coherence between sonar returns is also exploited in extracting acoustic color features. This method will be tested against a previously developed time domain multiple aspect feature extraction method on a database that contains sonar returns from various buried or proud mine-like and non-mine-like objects in different operating and environmental conditions. Results will be presented in terms of the receiver operating characteristic (ROC) curve for each system and overall detection and classification performance in different operating and environmental conditions. [C234]

"Quad Polarimetry SAR Target Recognition Based on Parametric Statistics and Multidimensional Analysis"

Diverse parameters decomposed from quad-polarimetric SAR could become the important basis in target recognition, classification and other applications.During the target recognition, due to the sidedness of single parameter or two parameters decomposed by same algorithm, obvious differences exist among the results extracted by different parameters. In this paper, a parametric statistics and multidimensional analysis algorithm will be applied in target recognition from quad-polarimetric SAR image. The proposed algorithm looked the backscattering characters of land cover targets as the basis of analysis. Through parametric statistics, the dominant scattering mechanisms of every decomposing algorithm would be picked out such as volume scattering and sphere scattering of paddy. They become the data of multi dimensional analysis. In the multi-dimensional analysis, the targetpsilas location of parametric space will be the basis of target recognition. The application on land cover and land use by the proposed algorithm improved the monitoring capability of quad polarimetric SAR. [C235]

"Improved support vectors machine for signal detection in non-reverberation"

Active sonar system have developed using large arrays and broadband transmitted signals for improving the signal to reverberation power ratio after beam forming and matched filter. While the size of the range bearing resolution cell is reduced resulting in the reverberation becomes non-Gaussian distribution. The performance of matched filter is reduced. We proposed two methods to modify the kernel function of SVM for improving the performance of detection in non-Gaussian reverberation. The first method is to use mixture kernel function. And the experiment results show the performance is as good as SVM with Gaussian kernel and better than RBF and matched filter in non-Gaussian reverberation. The second method is to use the kurtosises of reverberation and targets echo to drive the kernel. The experiment results show the performance is better than matched filter and SVM with Gaussian kernel in non-Gaussian reverberation. When detection probability is 0.5, the input signal to reverberation power ratio is respectively reduced 1.5 dB and 7 dB than conventional SVM and matched filter. [C236]

"Analysis of Simulated Polarimetric SAR Images Generated by a Multilayer Electromagnetic Scattering Model"

The evaluation of a polarimetric SAR image, which is generated by means of computation of far electric field scattered by multilayer structure, is carried out. The image analysis consists on the study of statistical properties of amplitude data and the investigation of the information gathered by alpha and szlig angles derived from the standard Cloude-Pottier's target decomposition and the orientation angle induced by azimuthal terrain slope. The discriminatory power capability of these three angle features is assessed through a simple threshold polarimetric classification procedure. The results show that the simulation process is working properly and that the SAR return is extremely sensitive to scatter local orientation. [C237]

"A study on the classification of urban region using Hyper-spectrum data at AVIRIS"

The purpose of this study is to improve accuracy of land cover classification in urban area. This study used Quick bird and airborne hyper spectrum sensor AVIRIS. Land cover survey was attempted at residential area. There were houses, road, pond, park and vegetations. There were many kinds of vegetations, broad leave trees as Ash, Elm, Willow, Maple, Cotton tree, Needle leave trees as Pine, Tsuga, Spruce. In the study in the past, about Quick Bird analysis, supervised classification (Maximum likelihood algorithm) was executed with some supervisors obtained from field study. 6categories were classified. The results show that with Quick Bird analysis, distribution of vegetation is comprehended well, but timber species are not comprehended well. About AVIRIS analysis, SAM (Spectral Angle Mapper classification) was executed with some supervisors obtained from field study. About broad leave trees, there were five species which spectrums were classified to categories. About grass, 3 categories were classified with conditions of land coverage condition. The accuracies of classification were 26% to 84%. It is confirmed that better results were obtained with AVIRIS. In this study, the classification of the material was tried. There were many kinds of roof materials at residential area, for example, Onix black, Shasta white, Desert tan, Siera gray, Terra cotta, Tile, Wood, Concrete, Asphalt. About AVIRIS analysis using measured spectrums, 7categories were classified. Target area was 2residential areas and Site of university. Target area size was 360 m by 360 m. The accuracies of classification were 44.4% to 100%. [C238]

"Polarimetric Scattering Analysis for Simplified Man-Made Structure Model on Rough and/or Inclined Ground Plane"

This paper analytically examines polarimetric scattering for a simplified man-made structure model, by utilizing the finite-difference time-domain (FDTD) method. The model considered here simulates a building in mountainous environment and is composed of a dielectric rectangular parallelepiped on finite rough and/or inclined plate. The statistical FDTD analysis on two polarimetric indices, the scattered power decomposition and the polarimetric correlation coefficient, with respect to squint angle change is carried out. It is found from the detailed analysis that the considered polarimetric indices are valid even when the surface of the ground plate has small roughness and gentle slope. This result contributes to the development of Polarimetric Synthetic Aperture Radar (POL-SAR) image analysis for detecting or classifying man-made residential houses in mountainous region. [C239]

"Land Cover Characterization and Classification using Polarimetric ALOS PALSAR"

In this study, the Touzi and Cloude-Pottier decompositions are compared for land cover characterization using ALOS/PALSAR polarimetric data collected at September, 4, 2006, over the Weinan region of Shanxi Province in China, the most useful parameters are combined for land cover classification. The classification results are assessed and validated using Landsat TM image of Weinan area acquired at August, 9, 2006. [C240]

"Synthetic Aperture Radar Image Processing using the Supervised Textural-Neural Network Classification Algorithm"

Synthetic Aperture Radar (SAR) satellite images have proven to be a successful tool for identifying oil slicks. Natural oil seeps can be detected as elongated, radar-dark slicks in SAR images. Use of SAR images for seep detection is enhanced by a Texture Classifying Neural Network Algorithm (TCNNA), which delineates areas where layers of floating oil suppress Bragg scattering. The effect is strongly influenced by wind strength and sea state. A multi orientation Leung-Malik filter bank [1] is used to identify slick shapes under projection of edges. By integrating ancillary data consisting of the incidence angle, descriptors of texture and environmental variables, considerable accuracy were added to the classification ability to discriminate false targets from oil slicks and look-alike pixels. The reliability of the TCNNA is measured after processing 71 images containing oil slicks. [C241]

"Automatic Target Recognition by Means of Polarimetric ISAR Images and Neural Networks"

Inverse Synthetic Aperture Radar (ISAR) images are often used for classifying and recognising targets. Moreover the use of a fully polarimentric ISAR image enhances classiication capabilities. In this paper, the authors propose a novel ATR technique based on the use of fully polarimetric ISAR images and Neural Networks. In order to reduce the amount of data processed by the classifier, the brightest scattering centres are first extracted by means of the Pol-CLEAN technique and then their scattering matrices are decomposed using Cameron's decomposition. The proposed ATR algorithm is finally tested on real data. [C242]

"Estimation of the lateral target length by generalised power estimation: Clutter-free case"

Knowledge about the lateral target length may be useful in several applications such as convoy tracking and alerting a high resolution imaging mode for classification. We focus on the estimation of the apparent length of an extended target with particular emphasis on convoys of ground vehicles. The estimation is done by applying generalised power estimators to the output signals of an array antenna. These estimators take into account that the signal vector is random and characterised by a covariance matrix. A clutter-free environment is assumed. [C243]

"Hidden Markov models for multi-perspective radar target recognition"

This paper presents a novel fusion technique for automatic target recognition from high range resolution radar profiles when observations from multiple viewpoints are available. The fusion technique entails only a straightforward modification of the transition probabilities of a single-viewpoint target model in which a Hidden Markov Model is used to represent the unknown target orientation. Evaluations using the MSTAR database indicate that the new technique can reduce classification errors by about two orders of magnitude when compared to single viewpoint observations and, in a 10-target classification experiment, gave almost perfect recognition. [C244]

"H/α polarimetric features for man-made target classification"

Entropy (H)/ Alpha (alpha)/ Anisotropy (A) polarimetric features are largely employed in polarimetric SAR for supervised and/or unsupervised land classification. Can these features be exploited for classifying man-made targets? This paper answers this question by proposing: 1) A technique for extracting H/alpha/A parameters from High Resolution Range Profiles (HRRP) of the target 2) A MAP classifier based on such parameters 3) A performance analysis of such classifier based on simulated polarimetric radar data of ships. [C245]

"Radar target classification based on support vector machines and High Resolution Range Profiles"

In this study, the support vector machine (SVM) was used as a classifier to identify aerospace objects. Radar target identification based on high resolution range profiles (HRRPs) received much attention because of its reduced complexity than those using two-dimensional (2-D) ISAR images. Therefore range profiles were used as feature vectors to represent radar data. Data sets which are for training and testing were generated by using a program called radar target backscattering simulation (RTBS) for three different target types. The performance of the SVM was compared with other classification algorithms including statistical classification techniques such as maximum likelihood (ML) and fisher linear likelihood (FLL). [C246]

"Automatic Target Recognition in Synthetic Aperture Radar image using multiresolution analysis and classifiers combination"

Automatic target recognition (ATR) is an important capability for defense application. ATR removes the human operator from the process of target acquisition and classification, reducing the reaction time to possible threats and can be used to gun target engagement. This paper presents one technique used to solve the automatic target recognition problem in synthetic aperture radars (SAR) images, that is independent of target pose in the images. The classification is performed by a combination of three different classifiers the minimum distance classifier (MDC), the quadratic Gaussian classifier (QGC) and a multilayer perceptron (MLP) neural network, using a voting architecture. [C247]

"Radar target recognition method with MUSIC algorithm: Application to aircraft targets with measured scattered data"

This paper demonstrates the usefulness of an ultra wideband target recognition method in the case of realistic and complicated target geometries at resonance region. The method utilizes the MUSIC algorithm to extract the natural resonance-related scattering features of targets. The resulting features give the power distribution maps of targets. These maps are called as fused MUSIC spectrum matrices and used as the main target recognition feature in the method. The fusion process is needed to reduce the aspect dependency of target features, which increases the accuracy rate of the classifier. In this paper, the method is applied to classify three small-scale aircraft targets. It is demonstrated that the method provides high accurate classification rates although the target geometries are highly complex, the measured scattered data is incomplete and only a few different reference aspects are used in recognition design process. [C248]

"Classification of landmines using GPR"

This paper describes a study carried out into the discrimination and classification of anti-personnel landmines using the MINEHOUND GPR. Other techniques, well reported in the literature, are not considered in this study.

The techniques investigated enabled the classification of landmines to be achieved on a restricted set of targets. The approach proposes a method whereby a library of radar signatures of landmines is acquired under controlled conditions and then used to classify unknown signatures. Initial results show that this method enables clutter targets to be well separated from landmine targets, with the exception of air voids, such as pipes. The technique offers the potential of a reduction in false alarm rate to 10% of the current performance. [C249]

"Multistatic target classification with adaptive waveforms"

Traditional radar systems rely on a predefined suite of waveforms and post-measurement signal processing to achieve such goals as target detection, classification, and tracking. Cognitive radar (CR) is a newly proposed framework in which the radar actively interrogates the propagation channel and adapts its operating parameters in order to maximize performance. We apply CR to a target classification problem by calculating custom waveforms that maximize the information received from the target echoes. A new MIMO waveform is proposed which maximizes the mutual information between a Gaussian random target and the received data under AWGN. The results indicate that the new frequency-domain formulation offers superior performance compared to both a non-adaptive approach and an ad hoc application of spectral waterfilling to the MIMO setting. [C250]

"Detection of snow clutter in ATC ground radar signal"

The use of adaptive techniques may prove useful in the processing of radar signals. The proposed radar clutter classificator is aimed to improve the detection of snow clutter presence in data acquired by a ground radar system in an air traffic control environment. The classifier receives as input a set of features which describe the appearance of the same plot in two consecutive scans of the ground radar. The feature set includes two group of parameters, which respectively represent the shape of the plot in each scan, and the displacement of the center of mass of the plot between the two scans. The data set used in simulations has been extracted from a measurement campaign carried out in presence of snow in Italian airports, with the help on an expert operator who manually classified a set of plots as target, or clutter. The performance of the classifier, a multilayer perceptron trained with the backpropagation rule, indicates a correct classification rate of about 98%. [C251]

"Multipolar SAR ATR: Experiments with the GTRI dataset"

Multipolar radar data is a rich source of information. Even though multipolar synthetic aperture radar (SAR) images have been used extensively for remote sensing applications, the use of the same for airborne radar systems has been limited. With the release of the GTRI turn table multipolar data in public domain, the scopes to experiment with real multipolar data has increased. The current work reports the experiments done with the GTRI dataset to examine the effect of using multipolar data for SAR based target classification. The results indicate that multipolar data may give better classification performance and may also be useful to make the classifier less sensitive to minor variations between the training and test target images. [C252]

"Radar classification evaluation"

In this paper five parameters for classifier performance evaluation are introduced. They are the probabilities of correct classification, declaration, and false alarm along with the reliability and generalisation capability. The use of Receiver Operator Characteristic (ROC) curves is also considered. These parameters are not always accepted or acknowledged in literature, yielding ambiguous and non exhaustive classification performance analysis. This paper gives a definition of the classification requirements and provides for an interpretation of the output of a classifier. [C253]

"Interleaved tracking and classification strategy (ITCS) using Medium Range Resolution (MRR) features"

Scope of the paper is to describe a technique to improve the multifunctional radar capabilitiesof tracking and classification of non-cooperative targets. The result is achieved by joining together the following two functions: (i) a tracker architecture based on Interacting Multiple Model approach and (ii) the processing of large bandwidth (either synthetic or instantaneous) signals to form Medium Range Resolution (MRR) profiles. The novelty of the approach consists in the interleaving of the two techniques with the aim of using features extracted from the MRR profiles both for classification and for tracking. Simulation results concerning a ballistic target trajectory are included for testing purpose. [C254]

"Target recognition and polarimetric SAR"

This tutorial presents a state-of-the-art survey of advanced applications of Synthetic Aperture Radar (SAR). Applications include: the detection and recognition of targets in SAR imagery, and the detection of targets under

trees (and in the open) using change detection (coherent change detection, full-polarization change detection, etc). A fully polarimetric SAR sensor is described. Models of clutter and targets are developed from analysis of full-polarization SAR imagery. Algorithms for optimum (GLRT) processing of full-polarization data are derived, including the polarimetric whitening filter (PWF) and the polarimetric matched filter (PMF). Polarization-based discrimination features (polarization entropy, anisotropy, etc.) are developed and applied to SAR image terrain classification. Model-based and template-based target recognition systems are described and classifier performance results versus resolution and polarization are summarized for 10-and 20-target classifiers. Super-resolution algorithms are applied to SAR imagery and target recognition performance improvements demonstrated. Multi-polarization and multi-pass change detection algorithms are developed and demonstrated using UHF SAR imagery of targets under trees; fusion of multi-polarization coherent and non-coherent change detection algorithms is demonstrated. The effect of SAR image compression on change detection performance is quantified. Change detection performance using multi-pass VHF SAR imagery of targets under trees is demonstrated using data gathered by the Swedish CARABAS SAR system. [C255]

"Edge Detection in Speckled SAR Images with Improved ROEWA"

Automatic detection of sustained intensity changes (edges) in SAR images for applications requiring localization and identification of objects is complicated by the nature of the speckle. The speckle is characterized by a high degree of correlation and multiplicative signal dependence. Ratio based detectors like MRoA and RGoA edge detector use predefined thresholds. The modified RGoA detector defines an automatic threshold determining method. But all these edge detectors, apart from detecting the object edges, detect a number of false edges. In this paper, a new ROEWA based algorithm that automatically discriminates the object boundaries and the false edges is proposed. Otsupsilas nonparametric and unsupervised principle for automatic threshold selection is introduced in this classification process. An optimal threshold is selected by maximizing the seperability of the classes in gray level. Real SAR images are used to verify our method and the results are compared with the existing methods for edge detection. Experimental results show that the proposed method is robust and efficient. [C256]

"Time reversal: Algorithms for M-ARY target classification using array signal processing"

An M-ary time reversal (TR) maximum likelihood classifier for a single pair of transmitting and receiving transducer element was derived in for underwater acoustic target detection applications. This paper considers a more general TR setup consisting of a P-element transmitting array and an N element receiving array and derives the M-ary conventional and TR classifiers for the multielement case in an electromagnetic communication environment. We show that the TR algorithm provides a classification gain of over 3 dB at low signal to noise ratios as compared to the conventional classifiers. [C257]

"Spectral target classification with SOSTAR-X"

The SOSTAR-X project has developed a demonstrator dedicated to the surveillance of both fixed and moving targets on large coverage areas, target activity analysis on dedicated areas and classification on designated targets. In this project, The Netherlands contribution has been in the areas of Spectral Classification (SPC mode), SAR SPOT mode autofocus, antenna harness, and ground target coordination during the flight campaign in the Netherlands. This paper focuses on the topic of Spectral Classification. The so-called SPC mode is a dedicated mode activated on a designated target, which classifies the target as wheeled, tracked (treaded), rotary wing, or rotating antenna. This is achieved by producing a high resolution Doppler profile, containing modulations caused by moving parts of the vehicle, and classifying on the basis of this profile. The SPC mode has been designed, implemented in the sensor and the Radar Processing Unit, and validated during extensive flight trials, in the Netherlands, Germany, and France. [C258]

"Use of HRR data for target acceleration estimation: A simple but effective approach"

Scope of this paper is to jointly estimate and compensate the radial velocity and the radial acceleration of noncooperative targets in the HRR (high range resolution) processing for frequency stepped radar. The single velocity compensation has been studied [1]. The estimation of the acceleration throughout the proposed algorithm is derived ldquofor freerdquo from the HRR data already processed by the radar for classification purpose. The joint estimation of velocity and acceleration is performed using different approaches mainly based on the maximization or the minimization of a proper functional (contrast, correlation-like or entropy) of the reconstructed profile. Comparison between these functions with respect to signal to noise ratio (SNR) is evaluated by Monte Carlo simulations. [C259]

"Automatic target classification in a low frequency FSR network"

This paper presents the evaluation of a low-frequency forward scattering radar (FSR) network for the classification of ground targets. The experimental results of automatic targets classification for different operational frequencies are presented and discussed. The possibility of target recognition is shown for system operating frequencies in the VHF band. [C260]

"Incoherent Polarimetric ISAR Decomposition for target classification"

The incoherent target decomposition theorem (ICTD) has been largely used when dealing with the problem of classifying distributed targets by using polarimetric synthetic aperture radar (PolSAR) images. In this paper, a method based on the use of the ICTD and the nearest neighbour classifier is proposed and applied to man made point-like targets in an ISAR-like scenario. the algorithm is tested by using real data in several signal to noise ratio (SNR) scenarios. [C261]

"A Novel Radar Target Recognition Algorithm Based on SVM"

To solve the problems and defections of existing methods of support vector machine (SVM) classification, an improved Gaussian kernel based on SVM is proposed and a improved SVM model selection scheme combining leave-one-Out method with one-validation method is presented in this paper, Based on the high resolution range profile (HRRP) of three types of target, a preprocessing method is introduced, the novel classification algorithm for HRRP based on the improved SVM is applied. Finally, experimental results prove that the improved SVM classifier has better performance on target-aspect stability, training set-size stability and anti-noise ability than traditional SVM. [C262]

"Fusion of multiple-look synthetic aperture radar images at data and image levels"

Synthetic aperture radar (SAR) and inverse synthetic aperture radar (ISAR) have proven capabilities for non-cooperative target recognition (NCTR) applications. Multiple looks of the same target (at different aspect angles, frequencies, etc.) can be exploited to enhance target recognition by fusing the information from each look. Such fusion can be performed at the raw data level or at the processed image level depending on what is available. At the data level, physics based image fusion techniques can be developed by processing the raw data collected from multiple inverse synthetic aperture radar (ISAR) sensors, even if these individual images are at different resolutions. The technique maps multiple data sets collected by multiple radars with different system parameters on to the same spatial-frequency space. The composite image can be reconstructed using the inverse 2-D Fourier transform over the separated multiple integration areas. An algorithm called the matrix Fourier transform (MFT) is proposed to realize such a complicated integral. At the image level, a persistence framework can be used to enhance target features in large, aspect-varying datasets. The model focuses on cases containing rich aspect data from a single depression angle. The goal is to replace the datapsilas intrinsic viewing geometry dependencies with target-specific dependencies. Both direct mapping functions and cost functions are presented for data transformation. An intensity-only mapping function is realized to illustrate the persistence model in terms of a canonical example, visualization, and classification. [C263]

"Minimum Distance Texture Classification of SAR Images in Contourlet Domain"

Contourlet has shown good performance in different aspects of image processing. Because of its charming multi-resolution and multi-direction characteristics, Contourlet is especially efficient in the processing of images with abundant texture. In this paper, a texture classification method is presented for the SAR images based on the Contourlet transform and a minimum distance classifier. The interested image is firstly decomposed with Contourlet transform. Then, the texture feature vector is constructed with only the significant first order statistical features of Contourlet coefficients for the concern of computational complexity. In the classification procedure, the Euclidean distance is used as the measurement of the texture similarity between two feature vectors. Finally, the minimum distance classifier is applied for the classification of the target images. The proposed texture classification method is implemented with the SAR image of the Cairo city. Numerical results show that the proposed method has good performance for the classification of areas with distinctive texture features. [C264]

"Optimal signals for MIMO RADAR in the presence of clutter"

Waveform design for target identification and classification in MIMO radar systems has been studied in several recent works. While the previous works considered signal independent noise and found optimal signals, here we extend the results to the case where clutter is also present and then we will find the optimum waveform for MMSE estimator. Choosing optimal waveform for MMSE estimator leads to the Semi-definite programming (SDP)problem, a convex optimization problem which can be efficiently solved through numerical methods. Explicit solution is developed for this SDP problem in two cases. In the first case, target and clutter covariance matrices are jointly diagonalizable and in the second one, signal to noise ratio (SNR)is sufficiently high. [C265]

"Convex optimization and MIMO RADAR waveform design in the presence of clutter"

Waveform design for target identification and classification in MIMO radar systems has been studied in several recent works. While the previous works considered signal independent noise and found optimal signals for an estimation algorithm, here we extend the results to the case where clutter is also present and then we will find the optimum waveform for several estimators differing in the assumptions on the given statistics. Several different approaches to the optimal waveform design are proposed, including minimizing the error of MMSE estimator, minimizing the maximum error of the covariance shaping least square (CSLS) estimator and minimizing the MSE error of scaled least square (SLS) estimator. Choosing optimal waveform for MMSE estimator leads to the semi-definite programming (SDP) problem. Finding the optimal transmit signals for CSLS estimator results in a minimax eigenvalue problem. Finally it is shown that equal power waveforms are the best transmit signals for the SLS estimator. [C266]

"Electromagnetic modelling of ship classification in OTHR"

Because of the Faraday rotation effect in the ionosphere, the elliptical polarization high frequency electromagnetic wave is used to simulate the sky wave to illuminate the ship targets. The half space FDTD method is utilized to model the ship targets on ocean which have the similar structures. The backscattered instantaneous polarization information of the targets can help to classify targets. The computer simulation results show this method not only can classify them, but also can distinguish the targets motion direction. [C267]

"HRR Signature Classification using Syntactic Pattern Recognition"

An automatic target classification system contains a classifier that maps a vector of real numbered features characteristic to a specific target onto a class label. Other features can be a string of symbols or alphabets that may not involve real numbers at all. There are certain orderings of the symbols in the strings governed by syntax rules, thus, generating a language, (that is, a collection of strings). Thus, a classifier would map a string to a class label. Such a classifier is called a syntactical classifier and varies greatly from its vector space counter part. This paper will give an overview of the construction of a grammar that generates a language then shows how they fit into a syntactical classification system. The performances of two syntactical classification systems with two and ten labels respectively are presented via confusion matrices. Experiments performed on public release DCS database indicate this approach has sufficient power to perform target detection using HRR signatures. [C268]

"Future Concepts for Wideband Antenna Radar Systems"

Array based radar sensing systems are set to become the norm in future systems. Current array based systems tend to operate at the sub-array level often condensing the received echo information into one or two channels only. Processing of the received data is often relatively simple with a few fixed modes of operation. Future trends are largely two-fold. Firstly there is a move from a small number of sub-arrays towards operation at the element level and second there are more output channels available for more sophisticated processing. Wideband arrays are increasingly necessary to support more demanding modes of operation required for capability such as target classification. This requires bandwidths of the order of 2-4GHz around a centre frequency of 10GHz. Examples will be given of methods used to synthesise such bandwidths, thus avoiding the limitations of array techniques and of the resulting target signatures and classification performance. [C269]

"Non-iterative exact inverse scattering using simultaneous orthogonal matching pursuit (S-OMP)"

Even though recently proposed time-reversal MUSIC approach for inverse scattering problem is non-iterative and exact, the approach breaks down when there are more targets than sensors. The main contribution of this paper is a novel non-iterative exact inverse scattering algorithm that still guarantees the exact recovery of the extended targets under a very relaxed constraint on the number of source and receivers, where the conventional time-reversal MUSIC fails. Such breakthrough was possible from the observation that the induced currents on the unknown targets assume the same sparse support, which can be recovered accurately using the simultaneous orthogonal matching pursuit developed for multiple measurement vector problems. Simulation results demonstrate that perfect reconstruction can be quickly obtained from a very limited number of samples. [C270]

"Using Measured RCS in a Serial, Decentralized Fusion Approach to Radar-Target Classification"

A decentralized fusion problem is a hypothesis-testing problem where the decision algorithm is not provided with raw measurements but rather is provided only with results from so-called local decision functions. In a serial decentralized fusion problem, these local decisions are fused into a global decision one-by-one until all local

decisions have been included or until a stopping criterion is achieved. In this paper, we consider serial decision fusion with a single radar sensor using a local decision function based on the radar cross section (RCS) characteristics measured across multiple dwells. In a single-sensor situation, the serial topology is convenient because local decisions are naturally sequential in time. A serial topology also supports the calculation of system performance measures and adapts easily to a distributed or multi-sensor situation. From dwell to dwell, measured RCS fluctuates due to noise, errors, and target scintillation. By examining the results from multiple dwells, the measured RCS can be separated into fixed-amplitude and Rayleigh components. The relative magnitudes of these components vary depending on both target type and sensor-to-target geometry. Spreading measurements and local decisions in time allows the sensor to observe a moving target from different aspect angles and thus introduces changing geometry into the decision data. In this way local decisions at different times are based on observations of different fixed to Rayleigh-amplitude ratios. Results based on a high-fidelity radar simulation along with different fixed- versus-Rayleigh RCS profiles are used to investigate issues related to serial multi-hypothesis decentralized fusion. Simulation results and performance measures demonstrating the efficacy of the proposed method are presented and sensitivities with respect to RCS profiles and to local-decision rates are investigated. [C271]

"Classification of Cylindrical Targets above Perfectly Conducting Flat Surfaces by Statistical Neural Networks"

This paper evaluates the radar target classification performance of neural networks. A set of features are derived from scattered fields calculated by using the image technique formulation and Moment Method (MoM). Statistical neural networks that utilize the feature set are proposed for target classification. The database contains a finite number of samples of three cylindrical targets at certain angles. A portion of the database is used to train the network and the rest is used to test the performance of the neural network for target classification. This work aims to find the right target above a perfectly conducting (PEC) flat surface from the scattered .field values. [C272]

"Minimax Robust Waveform Design for MIMO Radar in the Presence of PSD Uncertainties"

In this paper, we consider the problem of mini-max robust waveform design for multiple-input multiple-output (MIMO) radar based on mutual information (MI) and minimum mean square error (MMSE) estimation for target identification and classification. Recognizing that a single, precise characterization of target power spectral density (PSD) is rare in practice, we assume the PSD lies in an uncertainty class of spectra bounded by known upper and lower bounds, which markedly relaxes the required target a priori knowledge. Based on this band model, we develop minimax robust waveforms for MIMO radar under both MMSE and MI criteria. These robust waveforms bound the worst-case performance at an acceptable limit, and also could insure performance will be sufficiently good for any PSD in the uncertainty class. Our findings also indicate that the MI and MMSE criteria lead to a different minimax robust waveform solutions, which is in contrast to the case of the perfectly known target PSD. [C273]

"Electromagnetic Target Recognition with the Fused MUSIC Spectrum Matrix Method: Applications and Performance Analysis for Incomplete Frequency Data"

The aim of this paper is to apply an electromagnetic target recognition method, which is based on the use of fused MUSIC spectrum matrices, to the case of incomplete frequency domain data. The aforementioned method was suggested recently and succesfully applied to both canonical and complicated targets in the presence of complete frequency domain data [1]. However, most of the real world applications involve the use of severely incomplete frequency data, especially missing low frequency information. In this paper, the performance of mentioned target recognition method is investigated for various incomplete frequency bands and for a group of five small-scale aircraft targets. As a result, the mentioned target recognition method is demonstrated to give still high correct decision rates even when the frequency band is reduced by 300 MHz at low frequency end and at the signal-to-noise ratio is decreased down to -5 dB level. [C274]

"MIMO Radarwaveform Design"

Recently the radar community has been discussing "multiple-input multiple-output (MIMO) radar" that utilizes multiple transmitters to transmit independentwaveforms. MIMO radar offers the potential for significant gains, e.g., diversity gain and spatial resolution gain. Since the employed radar waveform plays a key role in determining the accuracy, resolution, and ambiguity in performing tasks such as determining the target range, velocity, shape and so on, it is meaningful to investigate waveform design specially for this newly proposed MIMO radar. This paper summarizes some of our recent results on MIMO radar waveform design, mainly for identification and classification of extended radar targets. Our waveform design considers optimizing two criteria:

maximization of the mutual information (MI) and minimization of the minimum mean-square error (MMSE). In this process, we are also interested in identifying the relationship between the waveforms obtained under the two criteria, given different a prior knowledge of the target's second-order statistics. [C275]

"Time Reversal Target Classification from Scattered Radiation"

This paper proposed the M-ary hypothesis testing algorithm for classifying radar backscatter signals from hidden targets in a rich scattering environment using time reversal. The target recognition algorithm is to be designed to distinguish measurements of the radar backscatter from an unknown object as belonging to one of a set of M classes. The proposed time reversal target classifier is, in essence, a correlator that calculates the cross-correlation of the normalized target signature waveforms with a data dependent quantity obtained from measurements. The algorithm requires a priori empirical statistical knowledge of the scattering channel, which is dependent of configurations of the scatterers in the environment. By incorporating time reversal, the proposed algorithm provides a significant performance improvement compared with the conventional method. Proof of concept is provided using electromagnetic data collected in a laboratory environment. [C276]

"Modified Generalized Discriminant Analysis For Radar HRRP Recognition"

Generalized discriminant analysis (GDA) is a nonlinear extension of the classical linear discriminant analysis (LDA) via kernel trick. As a feature extraction method, it has been proven successful in many applications such as radar high-range-resolution profiles (HRRP) recognition. However, GDA often suffers from the so-called small sample size problem (SSS) which exists in high-dimensional pattern recognition data. To overcome this weakness, we present a new algorithm for solving GDA by utilizing the idea of direct-LDA (DLDA) in this paper. Experiments based on three measured airplanes data are conducted to evaluate the effectiveness of the proposed method. From the results we can see that the new algorithm is more transparent and easier to be implemented than the traditional one, while keeping competitive classification accuracy. [C277]

"Optimising bistatic HF radar configurations for target and environmental signature discrimination"

HF radars are large and expensive systems whose performance is strongly dependent on the scattering geometry. There have been several cases where such radars have been poorly deployed, with consequent failure to achieve the surveillance objectives. This paper formulates the problem of radar site configuration in terms of objective mission-related metrics and outlines the optimisation procedure. [C278]

"Multipath Effects Cancellation in ISAR Image Reconstruction"

When radar illuminates targets at low elevation angles, radar returns will change due to multipath interference. For inverse synthetic aperture radar (ISAR), the multipath effects introduce two artifacts in its reconstructed images, which greatly hinder radar target recognition and classification. A novel technique requiring no apriori knowledge of target motion parameters is developed in this paper for multipath effects cancellation in ISAR image reconstruction. This technique is based on a parametric estimation method using two-dimensional image entropy as its cost function and realized via simulated annealing (SA) algorithm to search the optimum parameters corresponding to the minimum image entropy. Simulation results shows encouraging qualities of ISAR images after multipath effects cancellation, which also confirms the feasibility of this technique. [C279]

"Long-Range Target Classification in a Cluttered Environment Using Multi-Sensor Image Sequences"

Visual surveillance has been an active research area in computer vision and image processing, due to its crucial role in helping military intelligence and law enforcement agencies to fight against crime and terrorist activities. The goal of a visual surveillance system is to detect abnormal object behaviors and to raise alarms when such behaviors are detected. After moving objects are detected, it is essential to classify them into predefined categories, so that their motion behaviors can be appropriately interpreted in the context of their identities and their interactions with the environment. Consequently, object classification is a vital component in a complete visual surveillance system. RADAR (Radio Detection and Ranging) images are often undesirable in military applications because they reveal the location of the imaging system. So we explore visible and infrared images of ships which are generally more consistent than RADAR images and for which it is easier to compensate for environmental effects. Recent advances in visible and IR imaging technology improves its ability to observe objects at very long distances, but it is still militarily desirable to stay away as far as possible from potential enemy ships, which may be observed at different viewing angles. Several methods have been described in literature to perform the automatic classification of big ships (e.g. aircraftcarriers, combat ships, transportation ships, etc) from images, but none of them are based on small boat classification. A Principal Component Analysis (PCA) based target classification system is implemented for visible and IR small boat images which are

captured in a highly cluttered background environment. Two robust segmentation algorithms were implemented, Graph-cut for grayscale IR small boat images, and Adaptive Progressive Thresholding (APT) for visible small boat images. These algorithms are tested for images captured in a highly cluttered background. [C280]

"Time-frequency domain signature analysis of GPR data for landmine identification"

In this paper, the problem of detecting buried antipersonnel (AP) landmines is tackled in the broader context of target identification: determining relevant features, extracted from impulse ground-penetrating radar (GPR) signals, which can be used to classify landmines. These features are extracted in the time-frequency domain using the Wigner-Ville distribution (WVD) and the wavelet transform (WT). Radar data are collected using the MINEHOUNDTM hand-held dual-sensor system over two types of soil and for different landmines and objects. The Wilk's lambda value is used as a criterion for optimal discrimination. Results show that time-frequency signatures from WVD contain more valuable information than the features extracted using WT. Therefore, they could improve landmine and false alarm classification and help to differentiate between two different landmines. [C281]

"Genetic-Based EM Algorithm for Classification of SAR Imagery"

A valid unsupervised and multiscale classification method of synthetic aperture radar (SAR) imagery is proposed based on the Expectation Maximization and the genetic algorithm (GA-EM). This algorithm is capable of selecting the number of classification of SAR image using the Bayesian information criterion (BIC) for Gaussian mixture model. Our approach benefits from the properties of Genetic algorithms (GA) and the EM algorithm by combination of both into a single procedure. The population-based stochastic search of the GA explores the search space more thoroughly than the EM method. Therefore, our algorithm enables escaping from local optimal solutions since the algorithm becomes less sensitive to its initialization. Some experiment results are given based on our proposed approach, and compared to that of the other algorithms. The experiments on the SAR images show that the method based on the GA-EM outperforms the other method. [C282]

"A Radar Guided Vision System for Vehicle Validation and Vehicle Motion Characterization"

This paper describes a radar-guided monocular vision system that detects, validates, and tracks the preceding vehicle and thus predicts its lane-change intentions. A vision-based lane tracking process is developed to create a stable motion model in order to map the radar targets to image coordinates and consequently generate the region of interest (ROI) to search for a potential preceding vehicle. Model-based object classification algorithms are then applied to validate the existence of a vehicle in this ROI. Once the detected primary target vehicle, which is in the same lane as the host vehicle, is validated, it will be continuously tracked until it leaves the host lane. The spatial-temporal tracking history of the primary target vehicle is used to infer its intention of changing lanes. This prediction results from a characterization process for the primary target motion vector. The radar-vision integrated system has been evaluated on real-world data collected using a test vehicle equipped with a radar sensor, vision sensor, and a host processor. [C283]

"Application of neural network in Infrared-Radar Dual-mode Guidance System"

In this paper a novel target tracking information differentiating system with the capability of real time tracking and accurately identifying is developed in infrared-radar dual-mode guidance system. We take advantage of neural network's well known capability of learning to perform the required classification without the assumption of probabilistic models for the input models to substitute the fuzzy rules in the information differentiating system. Since the neural network training based on expert knowledge database is conducted off-line, significant benefits of developing real time tracking capabilities are possible. Her supervising trained neural network is applied in the dual-mode guidance system, which outputs the confidence degree denoted as the weight value of target information in data fusion center according to the two input variables of measure noise and tracking error. The validity of this method is proved by simulation. [C284]

"Closed-Loop Radar with Adaptively Matched Waveforms"

Adaptive and knowledge-based radar focus on improving the performance of the radar receiver through signal processing However, rather than develop transmission waveforms and signal-processing techniques independently, it is useful to consider a closed-loop system complete with an adaptive radar transmitter. In this paper, we summarize and demonstrate a framework being developed at the University of Arizona for implementation of closed-loop radar with adaptive waveforms. This framework integrates a Bayesian channel representation, matched illumination techniques, and sequential hypothesis testing. The result is a closed-loop system that modifies its understanding of the channel based on measured data, customizes waveforms to hasten understanding of the channel, and draws conclusions (such as target classification) when sufficient

understanding of the propagation channel is achieved. [C285]

"Simple and Collected Targets Radar Cross Section"

The goal of this paper is to analyze the scattering properties of different kind of targets, from simple shapes to collected targets made up of several objects, from 400 MHz to 7400 MHz to be used as patterns in a Ground Penetrating Radar in the classification stage. The data have been collected in an anechoic chamber with a vector network analyzer (VNA) set to work as a stepped frequency continuous wave radar (SFCW). The data are analyzed in frequency and time domain in order to picture the radar cross section dependency of frequency, incident angle, polarization and target's shape. The measurement have been carried out using a bistatic arrangement with two TEM horns for linear polarization and two spiral antennas for circular polarization. [C286]

"Target classification by echo locating animals"

In this paper, the principal mechanisms by which bats are assumed to classify targets are reviewed. Particular attention is paid to the ways in which bats might extract information from echoes. Classification mechanisms differ fundamentally according to signal design. It is shown how bats design their emitted waveforms according to whether they need to classify on the basis of micro-Doppler or range profile information. Throughout, analogies are made with radar (and sonar) systems, drawing attention to some ways in which engineers might learn from the classification mechanisms proposed for echo locating animals. [C287]

"A Structured Approach to Passive Sonar Track Association"

The presence of multiple, apparently independent track segments originating from the same target complicates the track-level passive sonar picture. If some of these segments can be shown to have common origin, they can be associated into a single composite track, simplifying that picture. The process could also provide additional information about the target, such as range or classification. Track association is typically a manual process, relying on the expertise of a human sonar operator. If a method could be found to reliably apply numerical scores to the degree of apparent relationship between pairs of tracks, those scores could be used to assist an operator in the track association process or as inputs to a fully automated track association process. This paper outlines the construction of a test based on the sample correlation coefficient and describes the result of its application to tracks produced by a probabilistic data association filter (PDAF) from a set of towed array sensor data. [C288]

"The Research of Network Planning Risk Element Transmission Theory Model Based on Neural Network"

In order to solve the network planning problem considering risk elements efficaciously, we redefine the network planning in this paper and transform the classical network chart to the new network chart based on combining neural network theory. On this basis, a risk classification is listed for the construction project, and we give the evaluation activity indexes using the expert assessment. Then, a risk classification is listed for the construction project. In order to get the total risk degree of all the network routes, after setting a certain weight and threshold value, we regard the indexes as the neural network input vector and calculate the risk degree of various activities. Thus, the total risk degree of all the network routes can be got. Finally, the model algorithm is illustrated with a case study. [C289]

"A Novel Proximal Support Vector Machine and Its Application in Radar Target Recognition"

The samples are assumed to distribute normally in the solution of the standard proximal support vector machine (PSVM). But in many application problems, the data set for each class is generally unbalanced, where a poor performance can be gotten by PSVM. For this, a novel PSVM is presented, namely the modified PSVM (MPSVM). By adding a new diagonal matrix in the primal optimization problem, the new algorithm assigns the different penalty coefficients to the positive and negative samples respectively. Therefore the samples in different classes can make different contributions to the learning of the decision surface. Based on the sufficient experimental results on the UCI datasets, MPSVM is also applied to the measured radar range profile images and the results illustrate the effectiveness of the proposed method. [C290]

"Unsupervised Classification of Polarimetric SAR Images Based on ICA"

Polarimetric SAR image classification is an important research area. Various classification methods continue to be developed for specific applications. In this paper, A new unsupervised classification method for polarimetric SAR images is proposed. It is based on independent component analysis (ICA). By ICA processing, several independent components are extracted from the channels of the SAR images. One of the independents is

regarded as speckle noise and thrown away. By taking each remained independent as a kind of target, a classified SAR image with higher classification accuracy can be obtained. [C291]

"Model-Based Classification of Aircraft Range Profiles using Data Association Algorithms"

This paper deals with aircraft recognition from an airborne platform. The data available are high-resolution radar range profiles. The classification method is probabilistic and supervised. It consists in modelling targets by scattering centers and a further association of peaks from the measure to these scattering centers. The global nearest neighbour algorithm performs the association. [C292]

"Investigating the effect of a target's time-varying Doppler generating axis of rotation on ISAR image distortion"

ISAR imaging has potential in assisting with the classification of non-cooperative targets. Blurred ISAR imagery may however lead to misleading classification results. Much research has been done to understand some of the causes of distortion in ISAR imaging mostly under the limited assumption that a target's axis of rotation is constant over the CPI. This paper investigates how the target's time-varying Doppler generating axis of rotation, caused by the complex 3D motion of a target at sea, contributes to ISAR image blurring. Quaternion algebra is used to aid the characterisation of a time-varying Doppler generating axis of rotation on the migration through cross-range cells. Real motion data of a sailing yacht is used to examine the effects of 3D rotational motion on ISAR imagery of point scatterer like simulated targets and the associated blurring. Simulation results show that small yaw rate perturbation during side-view ISAR imaging intervals gives rise to significant changes in the direction of the Doppler generating axis which results in scatters migration through cross-range cells. [C293]

"The effect of land clutter statistics on automatic gain control"

Modern radars are rarely able to sample the full dynamic range of observed land clutter. Therefore designers must employ gain control to make best use of the receiver hardware. This paper considers suitable land clutter models for use in the development of automatic gain control for high-resolution radar. The clutter statistics observed by the radar also have an impact on other areas including detection and target classification, but this paper concentrates on the problem of controlling the front-end gain of the radar receiver. [C294]

"Shadow enhancement in SAR imagery"

Shadow cast by features on ground can be an important aid in object classification in synthetic aperture radar (SAR) images. Synthetic aperture imaging causes a fundamental limitation to shadow clarity due to the fact that the illuminator is moved during the data collection. This leads to a blend of echo and shadow, or geometrical fill-in in the shadow region. The fill-in is most dominant for wide beam synthetic aperture imaging systems. By treating the shadow as a moving target and compensating for the motion during the synthetic aperture imagery, we avoid the geometrical shadow fill-in. This new technique, referred to as the fixed focus shadow enhancement (FFSE) can be used directly as an imaging method on raw SAR data or as a post processing technique on the complex SAR image. In this paper, we demonstrate the FFSE technique on publicly available SAR data. [C295]

"A ground vehicle classification approach using unmodulated continuous-wave radar"

Vehicle classification is of great importance to the development of Intelligent Transportation Systems. In this paper, a novel ground vehicle classification approach using unmodulated CW radar is proposed. The radar is set up to look forward down to the road; vehicles are modelled as body targets composed of multiple scattering centers. Analysis shows that the spatial distribution of scattering centers can be derived from the Doppler signature of radar echo. Hough Transform is performed to estimate the distribution which is then used for classification. In experiments, vehicles are classified into three types at an average accuracy of 94.8%. [C296]

"Radar detection and classification of jamming signals based on cone classes"

This paper deals with the problem of detecting and classifying a radar signal (target signal or jamming) in the presence of Gaussian disturbance. The jamming signal is modelled as belonging to a cone whose centre vector is the true target steering vector. Two different detection/classification approaches are analysed (the well-known ACE and GLRT approaches), yielding both to a two block device. The performance of the two decision algorithms are evaluated analytically, where possible, and by Monte Carlo simulation, otherwise. Some numerical results are reported along with some concluding remarks. [C297]

"Hidden Markov Models in radar target classification"

A classification technology is presented that uses Hidden Markov Models (HMMs) to classify simulated and real radar signals from five classes of targets: personnel, tracked vehicles, wheeled vehicles, helicopters and propeller aircrafts. Similar to techniques that have been well proven in speech recognition, the time-varying nature of radar Doppler data is exploited. The method classifies the different targets by their different Doppler characteristics. The purpose of this paper is to make a comparison between three kinds of HMM Methods: 1. HMM with continuous outputs (CHMM) 2. HMM with discrete outputs (DHMM) 3. Semi-continuous Hidden Markov Models (SCHMM) [C298]

"Impact of measurement-to-track data association errors on RCS-based target classification"

This paper develops a method for quantifying the impact of measurement-to-track data association errors on the performance of RCS-based classification schemes. First, it develops a means for assessing the impact of misassociations on the estimated mean and variance of the track SNR. This is done for both single-target and multiple-target tracking scenarios. Then, it develops an approach for quantifying the impact of errors in the estimated mean and variance on classification performance. As such, the user can easily relate the number of misassociations to the probability of error in the classification scheme, given specific target information and a particular decision region. Furthermore, this approach could prove useful to those designing RCS-based classification schemes. For example, the decision region could be intelligently modified to reduce the overall probability of error if certain types of misassociations are anticipated. Future work will explore revisions necessary to accommodate multi-modal SNR distributions and more sophisticated SNR estimators. [C299]

"Fractal feature based radar signal classification"

Automatic target recognition (ATR) using radar, is a much researched area with a demand for better and more accurate classification algorithms. In the present work, the local fractal dimensions of a synthetic aperture radar image have been used as features to classify ground targets. The performance of the fractal feature based ATR algorithm was compared with that of three other established ATR algorithms, viz. the simple yet powerful template matching ATR algorithm, the Gaussian model based Bayesian classifier, and the recently proposed principal component analysis based nearest neighbour algorithm. The fractal feature based classifier was shown to outperform all the other algorithms. [C300]

"Polarisation filtering for small target discrimination in ground clutter"

The Electronic Warfare and Radar Division (EWRD) of the Defence Science and Technology Organisation (DSTO) has initiated a number of studies investigating the exploitation of polarimetric analysis for the detection of small targets in strong ground clutter. This paper presents the results of experimental trials and associated signal processing research where an understanding of the scattering mechanisms present is used to design discrimination filters in the polarisation domain. It is shown that these physics-based filters provide highly efficient detection and identification of a variety of manmade targets immersed in strong clutter environments. [C301]

"Features influence on targets classification performance using the high range resolution profiles (HRR profiles)"

In this paper, we propose the aircrafts supervised classification using the high range resolution profiles (HRR Profiles), extracted from ISAR images. [C302]

"Detection and classification of urban structures based on high-resolution SAR imagery"

In this paper, several advanced methods for detecting and classifying urban structures in high-resolution SAR imagery are presented. The detection of man-made structures resp. the suppression of clutter, for example natural surfaces, can be accomplished by a coherent time-frequency analysis. These techniques can detect targets in the scene that behave like point-scatterers (such as edges, poles, etc.) by their high degree of correlation across sub-apertures of the scene. If polarimetric data are available, this approach can be extended by taking into account the frequently anisotropic polarimetric backscattering of man-made targets. As a third approach, a simple but powerful operator for detecting urban structures by analysing texture inhomogeneity in SAR images is developed. A second objective of this paper is the segmentation and classification of the detected urban structures. Based on the detected man-made structures, the characteristic structure size is investigated, using several approaches, to distinguishing between residential areas, industrial areas and dense city centres. The methods are evaluated using several real airborne SAR datasets. [C303]

"Development of an Experimental Prototype Multi-Modal Netted Sensor Fence for Homeland

Defense and Border Integrity"

Potential terrorists/adversaries can exploit a wide range of airborne threats against civilian and military targets. There is no effective, low-cost solution to robustly and reliably detect and identify small, low-flying airborne vehicles such as fixed-wing aircraft or unmanned aerial vehicles (UAVs) that might be carrying out chemical, biological or nuclear attacks, or smuggling drugs or illegal immigrants across the border. This paper presents a low-cost and low-power methodology for performing key 24/7 sentry functions that can be used for the protection and the surveillance of critical infrastructure from airborne threats. The methodology is based on joint multi-sensor fusion technology. It consists of a forward-based fence comprised of a mixture of selected low cost, low power, netted sensors including a simple radar, acoustic microphone array and optical (infrared and visible) cameras to detect, track and discriminate potential airborne targets. An experimental prototype end-to-end proof of concept system with deploy able software, hardware and connectivity is built using COTS component. Multi-modal senor fusion algorithms employing Kalman filter for target tracking and acoustic and image recognition algorithm for target classification are implemented. Results from field tests reveal reasonable detection and discrimination among candidate aircraft. [C304]

"Applications of Multi-source Remote Sensing Information to Urban Environment Monitoring in Mining Industrial Cities"

Remote Sensing (RS) has been viewed as the one of the most effective tools for environment monitoring, urban resources and environment investigation, change detection and urban growth analysis in mining industrial cities. Firstly, the framework and structure of applying multi-source RS information to environment monitoring of mining industrial cities is proposed based on the general methodologies of RS applications and the characteristics of mining industrial cities. RS can be used to monitor land use/cover change, extract subsidence land because of underground mining, analyze the dynamic change and simulate the trends of mining industrial city growth, monitor the extension of mining contamination, analyze the impacts of mining to farmland and ground buildings, assess the feasibility and performance of land reclamation and ecological reconstruction, and so on. Land subsidence is a very serious environmental damage caused by mining, and that leads to more negative impacts to ecological system, even leads to geological disaster. Three methods to extract subsidence land from RS image: thematic information based on decision tree, object-oriented subsidence land extraction and target identification based on RS information, geographical data and domain knowledge are experimented. Multi-source and multi-temporal RS information fusion is used for environmental analysis in mining areas. By the fusion of Landsat TM and SAR image, both high spatial resolution and multi-spectral information can be integrated so high classification and target extraction accuracy can be got. IHS fusion algorithm is improved by considering the image content and adaptive IHS fusion is experimented. Multi-temporal RS information fusion is used for change detecting and dynamic monitoring. By the case study in Xuzhou city, it proves that remote sensing can play important roles in environmental analysis and assessment in mining industrial cities and serve as the efficient decision-making support tool f- or regional sustainable development. [C305]

"An Adaptive Beamforming Technique for Countering Synthetic Aperture Radar (SAR) Jamming Threats"

In a hostile environment synthetic aperture radar (SAR) is likely to be subjected to electronic countermeasures (ECM) to prevent target detection and classification. In practice, noise jamming may not always provide an effective ECM against the SAR because of the large power output required to obscure the SAR image. A potentially more potent threat is presented by deception or repeater jamming, which can exploit the SAR processing gain and prevent target identification and classification using relatively low power output. Such jammers are likely to be light, inexpensive and readily deployable. This paper presents an adaptive beamforming (ABF) for SAR technique which can provide robust and efficient suppression of both noise and deception jamming. The paper also includes results from experiments with SAR trials data containing jamming which demonstrate the effectiveness of the technique in a system offering using two spatial channels. [C306]

"UWB Radars: Recent Technological Advances and Applications"

A number of challenging radar applications (such as anti-personnel mine detection and human being detection) is discussed. In these applications UWB technology has multiple advantages over the traditional narrow-band approach, in particular very high positioning accuracy, rigidity to multi-path propagation and target classification abilities. On a number of examples recent advances of UWB technology in radar have been demonstrated and remaining challenges have been discussed. [C307]

"Multiperspective micro-Doppler signature classification"

Multiperspective automatic target recognition is considered to assist underlying classifiers by providing more

views of the target. For the first time data from netted radar has been analysed for micro-Doppler signature content and a multiperspective dynamic time warping classifier developed. Despite limitation in the multiperspective data, identification is achieved with a probability of correct classification of 0.99. The results are contrasted with a monoperspective approach. [C308]

"Neural network based for automatic vehicle classification in forward scattering radar"

The paper is dedicated to the continuation and improvement of the vehicle classification method of SISAR micro-sensors for ground vehicles previously presented in RADAR2004 and RADAR2005 [1-2]. In spite of a number of theoretical research efforts in the application of SISAR for target classification [1-4], there are only few research concentrate on the classification processing to confirm the feasibility of SISAR's practicality. This paper begins with an overview and summary of the authors' previous research. Then a new research topic in the improvement of the classification performance for various scenarios using Neural Network is proposed. Finally experimental results, conclusions and recommendations are presented. [C309]

"The architecture and operating characteristics of a multi-frequency HF surface wave radar-part two"

The HFSWR described in part one of this paper [1] uses simultaneous multi-frequency operation to obtain robust performance during its normal operation. To examine the nature of the radar and its environment, the high quality multi-frequency data generated and then stored, is analysed in more detail, particularly to generate measured target HF RCS profiles which are presented in this paper. The results suggest there is an ability in part to distinguish different target categories. This, and the supporting evidence, is commented on. [C310]

"Sparse Manifold Learning with Applications to SAR Image Classification"

Nonlinear data-driven dimensionality reduction techniques have recently gained popularity due to the emergence of high dimensional data sets. The algorithmic complexity and storage requirements of these techniques, however, can make them prohibitive in resource-limited applications. It is therefore beneficial to reduce the number of exemplar samples required for performing an out-of-sample extension to a test point. In this paper, we propose a novel method for selecting a minimal set of exemplars and performing the out-of-sample extension. In the case of two-class target recognition with synthetic aperture radar (SAR) data, we compare the efficacy of the proposed approach with other approaches for selecting a subset of the available training samples. We show that the proposed algorithm outperforms the existing methods by providing low-dimensional embeddings that maintain interclass separability using fewer retained exemplars [C311]

"Clustering Polarimetric SAR Image Under Deorientation Theory"

In natural complex terrain surfaces, scattering targets with random orientations produce random fluctuating echoes which lead to confused classifications by directly using target decomposition on polarimetric SAR (PolSAR) image. In order to reduce the influence, the target vector is transformed into the state with minimization of cross-polarization. Then a set of new parameters u/v/w are used to characterize scattering mechanisms under the deorientation theory, and the fuzzy membership is adopted instead of "hard" division of parameter plan. Characterizing the sample coherency matrices as complex Wishart distribution, the PolSAR image is clustered based on Bayes maximum likelihood (ML) criteria. Experiment is carried out on an L-band NASA/JPL SIR-C PolSAR image over Danshui town, Guangdong, China. Comparison results with the popular used methods show that the proposed method provides a significant improvement in classification and the associated scattering mechanism of class is more accurate and beneficial for automatic terrain recognition. [C312]

"A Geometrical Feature Based Sensor Fusion Model of GPR and IR for the Detection and Classification of Anti-Personnel Mines"

The Ground penetrating radar (GPR) and Infrared (IR) imaging have become two established sensors for detecting buried anti-personnel mines (APM) which contain no or a little metal. The paper introduces the GPR and IR techniques briefly and compares the two sensors with respect to their strengths and weaknesses for target detection and emphasizes the necessity of fusion to harness the advantages of each of the methods. We propose a geometrical feature based sensor fusion framework, combining GPR and IR, as an effective technique for detection and classification of APM, which will reduce the false alarm rate significantly. We consider the basic geometrical shape descriptor features of an object and construct a feature vector for each of the objects. These feature vectors are used to train a Probabilistic Neural Network (PNN) for the classification of APMs. The method gives almost perfect detection accuracy. [C313]

"Collaborative Multi-Target Detection in Radar Sensor Networks"

In many military and civilian applications, estimating the number of targets in a region of interest plays a primary role in performing important tasks such as target localization, classification, recognition, tracking, etc. Such an estimation problem is however very challenging since the number of targets is time-varying, targets' states are fluctuating, and various kinds of targets might appear in the field of interest. In this paper, we develop a framework for estimating the number of targets in a sensing area using Radar Sensor Networks (RSN): (1) the multi-target detection problem is formulated; (2) signals, interference (e.g., clutter, jamming, and interference between radars), and noise at radar sensors are modeled; and (3) a Maximum Likelihood Multi-Target Detection (ML-MTD) algorithm is proposed to combine received measurements and estimate the number of targets present in the sensing area. We evaluate multi-target detection performance using RSN in terms of the probability of miss-detection Pmd and the root mean square error (RMSE). Simulation results show that multi-target detection performance of the RSN is much better than that of single radar systems. [C314]

"Demonstration of a Novel Man-Portable Magnetic STAR Technology for Real Time Localization of Unexploded Ordnance"

We report results of field tests of the first prototype of a novel man-portable Magnetic Scalar Triangulation and Ranging (STAR) technology. The new magnetic sensor system technology is being developed with support from the Strategic Environmental Research and Development Program (SERDP) to provide an easily deployable magnetic sensor system for real-time, point-by-point Detection, Localization and Classification (DLC) of magnetic targets such as Unexploded Ordnance (UXO) and buried mines. The STAR technology is based on a multi tensor gradiometer approach that uses magnetic gradient tensor magnitudes, i.e., "gradient- contraction-type" parameters to perform DLC of magnetic targets. The magnetic STAR sensor uses the scalar functions to triangulate a magnetic UXO-type target's position vector and to calculate the target's magnetic signature vector. The vector components of an object's magnetic signature provide a basis for real time classification of its type, i.e. UXO-like or not. In order to provide proof of principle of the STAR concept and demonstrate its advantages for high mobility magnetic sensing applications, we designed, constructed and field-tested a prototype man-portable STAR Gradiometer. The portable gradiometer's hardware and software are completely self- contained and provide a practical and user friendly capability for real time DLC of magnetic targets. Target DLC parameters: e.g., range, bearing, elevation and magnetic signature are correlated with Global Positioning System time and position data and displayed in near real time (total delay < 3 seconds) on a heads-up display that clips onto the operator's safety glasses. Interactive software controls data acquisition, performs signal processing to remove residual motion noise effects and runs the STAR Algorithm to generate and display the target's DLC parameters. Field tests have demonstrated proof-of-principle of the STAR concept and conclusively demonstrated that the technology has uniqu- e advantages for DLC by highly mobile sensing platforms. While being carried and operated by a single individual, the portable sensor has demonstrated very robust, motion noise resistant performance even while undergoing rotational motion of more than 40 degrees per second. The field test results very strongly indicate that the man-portable STAR technology can provide a wide variety of highly maneuverable sensing platforms (including Autonomous Underwater Vehicles) with uniquely effective, motion-noise-resistant magnetic sensing modalities for DLC of magnetic targets such as UXO and underwater mines. [C315]

"Improvements of radar clutter classification in air traffic control environment"

The use of adaptive technologies may prove useful in the processing of radar signals. The proposed radar clutter classificator is aimed to improve the detection of snow clutter presence in data acquired by a ground radar system in an air traffic control environment. Each plot detected in the radar image is processed in order to extract a series of features which are then used to discriminate between targets or snow clutter. The data set used in simulations has been extracted from a measurement campaign carried out in presence of snow in Italian airports, with the help on an expert operator who manually classified a set of plots as target, or clutter. Two sets of features have been tested, one of which is derived from moments of inertia, and the second one is a specifically designed feature vector, which has been selected as to follow the reasoning scheme of a trained human observer. Three different classifiers have been tested and compared in the final stage: a Bayes classifier, a multilayer perceptron and a radial basis function network. Results indicate the best configuration exhibits a correct classification rate of about 95%. [C316]

"The use of multidimensional copulas to describe amplitude distribution of polarimetric SAR data"

The paper focuses on a flexible model of multidimensional probability density function (pdf) dedicated to describe amplitude distribution of polarimetric SAR data. The model is based on the copula theory for characterizing the dependency between polarimetric channels (HH, VV, HV/VH or the target vector components). The benefit in

using copula theory is to extend correlation concept to a wider dependence one, which may not be linear. From this point of view, the model is more flexible than the classical Wishart distribution. But it may include it. The other benefit in using the copula model is to separate the dependence concept from the shape of the marginal pdfs. Hence, this multidimensional characterization may be linked to classical 1D gamma pdf, or to a more flexible Pearson system of distributions. In the case of high resolution data, pdf shapes are becoming of heavy tailed and the Fisher system of distributions seems to be an interesting alternative for such a model. Any parametric 1D model may be used. The paper mainly focuses on the model itself and more precisely on the technique required to construct such multidimensional dependence function. The difficulties arise for copula on 3D in which the dependency is not homogeneous between the components (the link between HH and VV may not be of the same behavior as the one between HH and HV). Illustrations are given on classification and despeckling. Classification will be performed by a stochastic estimation maximisation (SEM). Despeckling will be achieved by a maximum A posteriori technique. [C317]

"The value of SAR Multi-polarization data in delivering annual crop inventories"

The outcome of a multi-year project carried out across sites within Canada has been the development of a method to deliver crop inventories using the integration of SAR and optical satellite data. Although multi-temporal optical imagery can classify crops at the target accuracy, SAR data will be valuable in boosting accuracies and ensuring operational delivery of this annual inventory. [C318]

"The equivalence of Cameron's unit disc and Poincarй's sphere for symmetric scattering characterisation and classification"

Cameron's coherent target decomposition and classification is able to represent a symmetric scatterer onto a unit disc in the complex plane, and assign it to one of the six symmetrical elemental scatterer classes. Recently, Touzi et al. proposed a variation of Cameron's method by introducing a coherent analysis. Moreover the Poincare's sphere, was used instead of the unit disc for representing symmetric scattering because it was considered a more suitable domain. The aim of this work is to demonstrate the equivalence of using Poincare's sphere domain and Cameron's unit disc, in term of characterisation and classification of symmetric scattering types. [C319]

"Target separation in SAR image with the MUSIC algorithm"

The aim of this work is to exploit the MUSIC algorithm performance in order to enhance target separability in range and azimuth, i.e. achieve point targets separation inside a resolution cell. Simulations have been done in order to plan and check the feasibility of a super-resolution experiment that took place in September 2006 on the test site of Oberpfaffenhofen (Germany). The data set has been acquired with the E-SAR system of the DLR in X-band. The targets to be separated were seven small corner reflectors that have been placed in a way that their response falls in one or, at maximum, two resolution cells of the standard Fourier SAR image. A post-processing implementation of the MUSIC algorithm has been proposed allowing, in the already focused SAR image, to retrieve the targets geometry. Conditions and analysis of the results have been carried out. [C320]

"Clutter analysis of high resolution millimeter-wave SAR-data in the spatial and wavelet domain"

This paper presents the analysis of high resolution millimeter SAR clutter data, measured in a joint Swiss-German flight campaign. The generalized Gaussian function and the Kolmogorov-Smirnov test are considered to test the hypothesis of Gaussian clutter process. 35 GHz and 94 GHz data are compared. The results are presented in the time and wavelet domain, as the wavelet domain is an import transform domain for the development of terrain classification, target recognition and data compression algorithms. [C321]

"Wrapper approach for feature subset selection using GA"

In this paper, wrapper based approach is presented to feature subset selection of ground penetrating radar (GPR) echo signal using genetic algorithm in conjunction with constructive learning algorithm. GPR echo signal inherently has the non- stationary characteristic and the target echo signal is deteriorated by the clutter. Firstly, WP-based preprocessing algorithm is used to clutter reduction and feature extraction. Then wrapper based approach is adopted to find optimal feature subset, and at meanwhile obtain the result of classification. Experiment result based on GPR landmine data shows the feasibility and advantage of the presented algorithm. [C322]

"Region feature extraction based on improved regularization method in SAR image"

The noise existed in synthetic aperture radar (SAR) image weakens the detailed features of region of interest

(ROI) such as target and shadow. It also leads to the serious performance reduction of subsequent target detection, classification and recognition. The conventional regularization method could enhance target features in SAR image; however, the high computation complexity limits the real-time application of it. An improved regularization method is introduced in this paper, which increases processing speed of region feature extraction for SAR image significantly. It is theoretically proved that, by optimizing SAR projection operator, computation complexity could be reduced from O(M3N3)to O(MN) without ability losing of the region-based feature enhancement. MSTAR SAR image data is employed for algorithm experiment. The result shows that our method can increase target-to-clutter ratio significantly while restraining the noise in ROI, and then extract target and shadow from background clutters in SAR image more accurately. [C323]

"Subspace-Based Method for Multiple-Target Localization Using MIMO Radars"

The concept of multiple-input-multiple-output (MIMO) radar is recently proposed inspired by recent advances in MIMO communications. The subspace-based method for multiple-target localization is proposed in this paper. It is shown that the "effective source" covariance matrix is almost always nonsingular under mild conditions in the MIMO radar configuration. The performance of the proposed method is validated by numerical simulations. [C324]

"A Comparison of MIMO and Phased Array Radar with the Application of Music"

The utilization of diversity in radar systems has shown improvements over conventional phased array radars in many aspects of the system performance including target detection probability, number of targets, and beam-pattern. We present here the application of the MUSIC algorithm to MIMO radar and the associated benefits of increasing the diversity to its performance for a single target and two closely spaced targets, but also show that a system with diversity can perform worse than that of a phased array system due to the directional transmit beamforming gain available to the phased array. [C325]

"A 94GHz FMCW instrumentation radar"

We report on the use of a versatile 94GHz FMCW instrumentation radar to assess optimum hardware configurations for a variety of co-polar and cross-polar target classification studies. Phase noise and sweep linearity are critical parameters in FMCW radars and optimising them is a key objective of any high performance radar system. We have made a systematic comparison of fundamental sources (bias tuned Gunn, varactor tuned Gunn) and multiplied sources (commercial YIG based sweeper, YIG tuned oscillator, permanent magnet YIG tuned oscillator) to ascertain their relative phase noise contributions and FMCW sweep linearities at 94GHz. The radar will also be used to investigate the effect on target return signal coherence as a function of time for different sources. We present details of the calibration against the radar range equation and the effects of variable sweep bandwidth (and hence range resolution). The radar can also be configured for arbitrary polarisation (V, H, +45, -45, RC, LC) and demonstrates high polarisation isolation (33dB) which is required for the accurate assessment of cross-polar radar cross section (RCS), and we will present preliminary results for standard targets and clutter. [C326]

"High-resolution walled-LTSA-array ground penetrating radar system using adaptive complex-valued self-organizing-map processing"

We present a newly developed high-resolution adaptive imaging system using switched walled linearly tapered slot antenna (walled-LTSA) array and complex-valued self- organization-map (CSOM) processing. In the CSOM processing, we deal with feature vectors that possess complex-amplitude texture in space and frequency domains. A higher resolution results in a better classification quality. To realize a high resolution in range and azimuth directions, we employ a wide frequency bandwidth in frequency stepping operation, and a special switching scheme for the walled LTSA. We have realized successful plastic landmine visualization not only for targets buried in normal sand but also for those in wet laterite soil. [C327]

"Urban target classifications using time-frequency micro-Doppler signatures"

Moving target indicators (MTI) find important applications in urban sensing. While motion detection can be achieved using simple CW radars, characterization of moving targets can be provided by estimating the key parameters of the target micro-Doppler signature. For indoor sensing, this signature has underlying instantaneous frequency features, which may depend on the radar viewing angle. This paper considers typical animate and inanimate moving objects and presents time-frequency motion classifiers using quadratic time-frequency distributions. The distinctions between the different target micro-Doppler parameter values and bounds are delineated. [C328]

"Polarimetric SAR observation by ALOS"

The Japanese microwave remote sensing satellite ALOS/PALSAR was launched successfully in January 2006. We are carrying out polarimetric calibration of the PALSAR sensor, which has the full-polarimetric function of L-band SAR. We set corner reflectors in Ulaanbaatar in May and August 2006, and the acquired data was used to confirm the polarimetric calibration coefficients, which will be used for the data sets delivered from October 2006. In addition, the acquired polarimetric SAR data will provide new possibility in remote sensing. Since this is the world first satellite borne full-polarimetric SAR system, we cannot show many examples in this moment, but from airborne SAR data, which we have studied, we show some examples of polarimetric SAR, which include tree type classification, and estimation of the orientation angle of scattering targets. [C329]

"Optimal radar bistatic angle by statistical analysis of scattering patterns"

In this work, we introduce the concept of optimal bistatic angle such that the scattered radar target signal has a robust strength level irrespective of the target aspect. The concept involves statistically analyzing the scattering patterns as a function of the target aspect to a fixed and known incident radar direction. Henceforth, statistical quantities like mean and standard deviation are used to obtain statistics patterns for radar scattering patterns of an ellipsoid, a cylinder, and a square shape targets. Since different targets are likely to have different optimal angles, we propose using the optimal angle concept to improve the signal-to-noise ratio of a target of interest. This benefit can be further exploited in a radar target classification process. [C330]

"Corn monitoring and crop yield using optical and RADARSAT-2 images"

In agriculture, soil and crop conditions change from day to day and throughout the growing season. Agricultural targets also vary spatially with differences observed from field to field, as well as within individual fields. The heterogeneity of corn-growing conditions in Mexico makes accurate data for crop type, crop condition and crop yield prediction difficult to obtain. Yield predictions are needed by the federal government to estimate, ahead of harvest time, the amount of corn required to be imported in order to meet the expected domestic shortfall. In this project a methodology for the estimation of corn yield ahead of harvest time is developed which uses radar and optical remote sensing and which specifically considers the corn-growing situation in Central Mexico. Radar based crop type classification requires data sets with multiple polarizations. Recent research to assess relative classification accuracies of multi-polarized combinations for target crops using airborne data has been reported. In addition to identifying crop type and variety, identifying crop growth stage is valuable. Crop condition, loosely defined as the vigor or health of a crop in a particular growth stage, is related to crop productivity and yield; however, the relationship is complex. Main crop condition indicators include biomass, height, leaf area and contents of plant water, chlorophyll and nitrogen. Crop-type and crop-condition mapping are among the applications that are expected to benefit the most from the technical enhancements embodied by RADARSAT-2. The potential of RADARSAT-1 data for these applications has been rated as "limited", whereas for RADARSAT-2 data this potential is anticipated to be "strong". The Science and Operational Applications Research for RADARSAT-2 Program (SOAR) is promoting the evaluation of Synthetic Aperture Radar (SAR) capabilities by providing images to selected research projects which include the present one.objectives of this project are: a) use RADA- RSAT-2 data and optical data to determine cultivated areas and monitor crop condition for obtaining better estimations of crop yield; b) obtain polarization signatures from RADARSAT-2 data for corn and relate these to Leaf Area Index and photosynthetic active radiation (PAR) crop parameters and vegetation indexes, to establish indicators of crop condition and produce estimates for crop yield; c) use field data collected for three key corn crop growth stages over 300 pilot plots during 2001-2006, and increase the number of plots to build a database to support accuracy studies using RADARSAT-2 data.The expected benefits of this project are: to obtain knowledge about crop type, crop condition and crop yield with better accuracy than with current methodologies; to support national corn farmers associations; to design agriculture related activities within State agriculture plans; to support the corn product industry and aid government decision making. Relevant results and economical impact will imply operational usage of RADARSAT- 2 data in the agricultural sector in Mexico. [C331]

"Reconstruction of Super-resolution Spectra for the Beamformed Data in HF Skywave Radar"

For economy, the digital beamforming(DBF) is used to transform a huge array outputs into the bearing ones at several expectable directions in HF skywave radar. However, as the target signal phases on the different array elements are mixed in the beamformed data, the resolvable super-resolution spatial spetra of the coherent targets within a beamwidth can not be directly constructed by the existing algorithms any more. Therefore, in this paper, an improved method for the reconstruction of these spatial spectra is investigated to solve the underlying problem. A so-called pseudo-inverse processing is used to transform the beamformed data to the equivalent array data on the peak of the detected target range-velocity spectra. Then, combined with the Toeplitz

construction and the multiple signal classification (MUSIC) algorithm, the coherent targets are resolved and the azimuth estimates are improved. Since the window weighting is usually used in the beamforming, the different weighting effect on the pseudo-inverse processing is also discussed. [C332]

"In Situ Adaptive Feature Extraction for Underwater Target Classification"

This research compares the performance improvements of image-based sonar target classification algorithms when they are adapted to changing clutter environments. The distribution of seabed pixels in the sonar imagery is modeled as a correlated, K-distributed random variable allowing for a quantitative representation of seabed environments in the various testing scenarios. Parameterized environments comprising various target-like seabed textures are generated synthetically and used to examine adaptive classification performance. Results demonstrate that optimizing classifier parameters respective to specific environments improves overall classification performance compared to optimizing classifier parameters against a pooled dataset that includes all possible environments. [C333]

"Extracting information from shadows in SAR imagery"

The presence of speckle noise presents considerable challenges in interpreting SAR imagery. Despite the very high resolution that is on offer with modern SAR systems, the extraction of reliable intelligence from SAR imagery in an automated and robust manner has faced considerable difficulties. Shadow regions in SAR imagery are unique in terms of absence of speckle and any distortion from imaging artefacts. This paper presents a series of work that has aimed at exploiting the information in SAR shadows. Earlier work looked at combining shadow features with target features obtained with single look imagery. This provided for better target classification and led to a technique for estimating heights for urban structures. However, it is with multiple perspective imagery that SAR shadows have proved really effective. Using shadow delineation alone, information from different look angles over a sequence of SAR images is combined together to provide very reliable and unambiguous estimates of building dimensions. Another remarkable success has been the detection of moving targets from their shadows over a sequence of SAR images. The images of moving targets are blurred and distorted making it difficult, if not impossible, to detect the moving targets in SAR imagery. However, the target shadows are undistorted. Initial results with short-range data have been successfully replicated with detecting moving targets at much longer ranges. In all of these cases performance will be affected where clutter background is weak, dynamic range is poor or shadows from different objects overlap. Nevertheless, this paper has highlighted a range of applications from target detection and location to urban scene analysis where SAR shadows have been shown to provide a highly effective way of extracting information from the imagery. [C334]

"Joint estimation of target Doppler frequency and azimuth angle of scanning system radar"

A space-time joint estimated algorithm, SAFE algorithm, is developed to estimate azimuth angle and Doppler frequency of targets within one beam width in this paper. The algorithm applies the multi-channel super-resolution technique to the single-channel scanning system radar in order to improve the estimated precision of azimuth angle. Theory and simulation analysis verifies the validity of the algorithm. A frame is built to describe how to apply the classic super-resolution spatial spectrum estimation algorithm to the Doppler frequency and azimuth angle joint estimation of scanning system radar. [C335]

"Statistical distribution for scattering mechanism of targets based on eigenvector decomposition in Polarimetric Radars"

In this paper a decomposition scheme for analysis and classification of statistical radar targets is presented. For this purpose eigenvector target decomposition (ETD) analysis method is used for calculating coherency eigenvalues. Also a simulation scheme is developed for calculating entropy, scattering mechanism for discrimination of several surface scattering objects within distributed targets. As results, radar image data set have been used for compare. [C336]

"Optimal bayes joint decision and estimation"

Many problems involve joint decision and estimation, where qualities of decision and estimation affect each other. This paper proposes an integrated approach based on a new Bayes risk, which is a generalization of those for decision and estimation separately. Theoretical results of the optimal joint decision and estimation that minimizes the new Bayes risk are presented. The power of the new approach is illustrated by applications in target tracking and classification. [C337]

"Motion compensation for SISAR based on contrast maximization"

The shadow inverse synthetic aperture radar (SISAR) can obtain the shadow image of the object for target detection, classification and identification. The precise motion compensation is the key problem for the accurate shadow image. A novel method for motion compensation based on the contrast maximization is proposed in this paper. The value of the estimated motion parameter is adjusted continuously until the contrast of the image is maximized. This method is simple and apt for actualization as well as precise motion compensation. Computer simulations are given to illustrate the effectiveness, and the performance of the proposed method with different SNR is also discussed. [C338]

"Vibrometry classification of moving vehicles using throttle signature analysis"

Any operating vehicle will emanate a degree of vibration due to the running engine and other machinery. These vibrations differ based on engine type, throttle-level, and vehicle structure and as such they constitute a unique signature for a given vehicle. The availability of remote vibrometry sensors, such as pulse laser radar, makes it possible to utilize this signature for remote automatic target identification. We propose a novel classification technique that is specifically tuned to identify vehicles whose engines have a variable amount of applied throttle based on a limited training set with known idle and full throttle values. The presented algorithm is real-time and operates reliably with short time duration samples of input data. Other benefits include a small training set and simple implementation based on linear algebraic techniques. It is also possible to adjust the technique to indicate the degree of confidence in the result. We have achieved classification accuracy for a two class problem of 90% to 98%. [C339]

"A multi-band UWB radar for sensing objects"

Development of a new multiband UWB radar for object-sensing is described. The radar transmits pulses with duration varying from 450 to 1170 ps and peak power from 200 to 400 mW and detects signals with a conversion gain of 6.5-9.5 dB over a 5.5-GHz bandwidth. It has a range resolution of around 1 inch. The radar performs well through tests of various samples, demonstrating its success for sensing objects. The multi- pulse/multi-band feature allows the radar to achieve both fine range resolution and long operating range, and enhanced target detection and classification. [C340]

"The music algorithm-based electromagnetic target classification for isolated targets from incomplete frequency domain data"

This paper investigates the performance of a new electromagnetic target classification method to recognize isolated targets in the presence of scattered frequency domain data which may be severely incomplete at low frequencies. The suggested method utilizes multiple signal classification (MUSIC) algorithm to construct approximate pole location maps of the targets without determining the exact pole values. In this work, this method is validated for small-scale aircraft targets modeled by thin, conducting wires with incomplete data, which brings additional difficulty in target classification problems. It is shown that the method provides high accurate classification rates even when incomplete frequency domain data with low signal-to-noise ratio values are utilized while it needs only a few different reference aspects and small memory storage in classifier design. [C341]

"Ultra-wideband radars for high-resolution imaging and target classification"

UWB technology in radar allows for a very high accuracy ranging, rigidity to multi-path propagation and external EMI. If added to high-cross range resolution capabilities, ultra-wide operational bandwidth can be also used to obtain high-resolution images of targets. As a next step, image-based classification of detected targets can be done. In this paper different approaches to high-resolution imaging with UWB radars are discussed and compared. Examples of system architecture are given. Possible image-based features of targets are discussed and examples of image-based target classification are presented. [C342]

"Joint estimation of target doppler frequency and azimuth angle of scanning system radar"

A space-time joint estimated algorithm, SAFE algorithm, is developed to estimate azimuth angle and Doppler frequency of targets within one beam width in this paper. The algorithm applies the multi-channel super-resolution technique to the single-channel scanning system radar in order to improve the estimated precision of azimuth angle. Theory and simulation analysis verifies the validity of the algorithm. A frame is built to describe how to apply the classic super-resolution spatial spectrum estimation algorithm to the Doppler frequency and azimuth angle joint estimation of scanning system radar. [C343]

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"A kind of trading off algorithm of object classification based on intelligent data fusion"

A kind of trading off algorithm of target classification combined with double mode intelligent fusion is presented, Applying neuron-fuzzy technique to the synthesis of the complementary information between radar and infrared, through combining neuron-fuzzy technique with D-S evidence fusion theory, the ability of target classification could be improved. At the same time, according to the effective detection range of sensors, reasonably select the target features that can ensure the accurate target classification so that the computation load of the algorithm can be largely decreased compared to the infrared single model fusion. Simulation results illustrate that the trading off algorithm is effective. [C345]

"Automatic extraction of power transmission tower series from PolSAR imagery based on MRF model"

This paper describes a three-step algorithm for automatic extraction of power transmission tower series in full polarimetric SAR imagery. Firstly, the method uses a polarimetric whitening filter to combine the information in different polarimetric channels and reduces the speckle. Then the point-like targets are detected by an adaptive region classification CFAR detection approach, among which only a few are the potential power transmission towers. Finally, a graph linked the potential point targets is constructed and a Markov random field is defined on the constructed graph, the extraction result is obtained through an energy minimization process. The experimental result verifies the effectiveness of this algorithm. [C346]

"Algorithm of target classification based on target decomposition and support vector machine"

Since Huynen's original work, there have been many other proposed target decomposition theorems. In this paper, we provide a review of the different approaches used for target decomposition theory in radar polarimetry and classify three main types of theorems: those based on Mueller matrix, those using an eigenvector analysis of the coherency matrix, and those employing coherent decomposition of the scattering matrix. Support vector machine (SVM), as a novel approach in pattern recognition, has demonstrated a success in many fields. Here we first extract scattering mechanisms of radar targets by target decomposition and color composite. Then we propose a new algorithm of target classification by combining target decomposition and support vector machine. We conduct the experiment on the polarimetric synthetic aperture radar data. Experimental results show that: it is feasible and efficient to target classification by designing SVM classifiers using target decomposition, and the effects of kernel functions and its parameters on the classification efficiency are significant. [C347]

"Target recognition in SAR images with Support Vector Machines (SVM)"

This paper addresses object recognition problem in SAR images with SVM classifier; the work has been mainly focused on feature vector definition. Actually, each object is represented by a feature vector and SVM aims to estimate the best hyperplanes that separate classes in the feature space. Very robust definition of feature vector is proposed and tested on real data (MSTAR database). Confusion matrices prove that a very good recognition rate is reached, even for mixed incidence angles configuration. [C348]

"Classification of stricken residential houses by the mid niigata prefecture earthquake based on POLSAR image analysis"

This report attempts to apply a hybrid classification technique based on POLSAR image analysis to detect the man- made residential houses in a local mountainous area stricken by the Mid Niigata Prefecture Earthquake. The present hybrid scheme includes the scattered power decomposition method based on physical scattering nature and the scattering feature extraction method using polarimetric correlation coefficient. From the results of the image analysis for actual POLSAR data, it is verified that the present hybrid scheme provides us accurate classification of the man-made targets even in the severe mountainous [C349]

"Polarimetric phase gradient autofocus"

In the past decade the use of fully polarimetric SAR (polSAR) systems has increased significantly due to their

effectiveness in target classification and detection applications. While polSAR imagery has been extensively used to distinguish between different scattering mechanisms in a scene, there has been a lack of research in the exploitation of polarimetry to assist in image formation and in particular autofocus for fine resolution SAR. In this paper an extension of the phase gradient algorithm (PGA) for polSAR imaging is proposed and its effectiveness is tested on simulated and real data. [C350]

"Two-dimensional PCA for SAR automatic target recognition"

In this paper, a new technique for synthetic aperture radar (SAR) automatic target recognition (ATR) is developed, which is builded upon two-dimensional principle component analysis (2DPCA). First, 2DPCA is applied to extract features in frequency domain, which is based on image matrix directly. Then support vector machine (SVM) is used for classification. Experimental results on MSTAR dataset show that the 2DPCA method both gives higher recognition rate, and are computationally more efficient than PCA. [C351]

"Analysis of PC number selection in SAR ATR"

The effect of PC (principal component) number upon SAR ATR (synthetic aperture radar automatic target recognition) performance based on PCA (principal component analysis) is analyzed. First, PCA features are extracted with different PC number, and then SVM is used to classify. Experimental results based on MSTAR data sets show that the performance is optimized when the accumulative contribution rate of the selected PC is 70%. Compared with the common selected method of PC number, the new selection method improves recognition performance and also reduces computational complexity. [C352]

"Electromagnetic simulation of ISAR imaging with supper-resolution"

A full-wave electromagnetic simulation of inverse synthetic aperture radar (ISAR) using two-dimension (2-D) finite difference time domain method (FDTD) is presented with multiple signal classification (MUSIC) method used to investigate the scattering center in radar image. Full-wave electromagnetic simulation can account for multiple scattering effect usually exists in real case, but ignored when ideal point-targets are treated as scattering centers, so it can help us understand the scattering mechanism of complex target. Fourier-based imaging algorithms are fast and robust, but they are limited in resolution and dynamic range. Subspace eigen-value analysis based methods, such as MUSIC, is able to provide superresolution and accurately recover the scattering center locations even for a small number of correlated samples. Simulations show that with techniques of full-wave electromagnetic calculation and superresolution, one can get an insight into the relation between multiple scattering effects and scattering centers formed in ISAR imagery. [C353]

"UWB Radars for Chalenging Applications"

A number of challenging radar applications (such as antipersonnel mine detection and human being detection) has been discussed. In these applications UWB technology has a number of advantages of over the traditional narrow-band approach, in particular very high positioning accuracy, rigidity to multi-path propagation and target classification abilities. On a number of examples recent advances of UWB technology in radar have been demonstrated and remaining challenges have been discussed [C354]

"Intelligent Identification Software Module (IISM) for the US Navy's Combat Centers"

We have developed and continue to enhance our automated intelligent software, which performs the tasks and decision making currently handled by the personnel manning the watch stations in the Combat Direction Center (CDC), the Task Force Combat Center (TFCC), on-board aircraft carriers, and other Navy ships. Integration of information from a variety of sources in a combat station is a complex task; surveillance guards can receive divergent information from on-board radars, sonar, and other sensors, and must assimilate and interpret even conflicting information in a timely manner to relay it up the chain of command. The intelligent identification software module (IISM) alleviates some of the burden placed on battle commanders by automating certain tasks, such as the management of historical data, disambiguating multiple track targets, assessing the threat level of targets, and even rejecting improbable data. IISM is interfaced to the Advanced Battle Station (ABS). Given tracking data and time stamps from ABS, IISM updates the history list of tracking and identification data, rejects nonsense tracks, compares recent history to past patterns of activity, alerts the commander via ABS when necessary, and provides customizable identifications of targets, as well as the threat level of each of these targets. IISM is also capable of correcting errors and recovering snap-shot and history data after unforeseen catastrophes. On a highly conceptual level, IISM is able to perform these tasks by viewing the target tracking as a classification problem of the threat levels that it assigns to the individual entities present in the situation. It maintains a consistent and reasonably approximate model of several entities' attributes that are only partially perceivable. This, fundamentally, is the task of track handling and analysis currently being handled by human

decision-makers. Put simply, IISM 1) determines, to a degree of certainty, the identity of an entity, 2) performs a path-- analysis of the entities, and 3) infers abstract conclusions regarding the behavior of entities based on their movement over time. Stated another way, both positive and negative evidence is tracked to form multiple, possibly competing hypothesis, and conclusions of these tracks are made through a process of elimination reasoning. IISM is able to perform this complex task by utilizing certain AI-based solutions. IISM uses SimBionic, a visual authoring tool that outputs C++ code for fast execution. IISM also mimics the intelligent memory provided by current human track-watchers, including all track attributes (position, velocity, ID information, etc.), along with a time stamp for each. IISM also has system independence and will continue to remember the current tactical picture even if a tactical decision system go down, is very robust, has an automated system backup and restore function, and can even be saved to a file server to diminish physical vulnerabilities. IISM is an AI module that alleviates many of the burdens placed on battle commanders. It is a seamless enhancement to the current Advanced Battle Station, providing enhanced reasoning without the need for users to learn a new system [C355]

"Integrated Marine Mammal Monitoring and Protection System (IMAPS): Gray Whale Target Strength Measurements and the Analysis of the Back-Scattered Response"

The central IMAPS objective is to establish a global solution for systematic assessment and protection of the marine environment for the Navy, offshore industry, and scientific research community, through the development and implementation of a comprehensive, modular tool. The limitations of current technologies are that they are individually inadequate to fully achieve mitigation objectives. Visual monitoring, passive location, high frequency active sonar, and radar all have their inherent limitations such as weather conditions, a necessity for vocalizations, maximum detection range, and sea state limitations. Therefore, there is a need for all the sources of information related to the detection and classification of marine mammals to be fused and to operate in real-time in order to provide a robust protection, assessment, and research system. The other IMPAS direction is concentrated on the design and development of the active sonar modality representing just one component of the global system. The active sonar was designed, built and tested during the Marine Mammal Active Sonar Test (MAST 04), producing whale detections and whale tracks. The experiment was conducted in January 2004 off the coast of California. One of the objectives is to distinguish whale backscattered responses from the ones generated by the environmental clutter in a waveguide. Furthermore, it aims to identify and analyze the target signature features that are necessary for enhanced active sonar detection and classification of marine mammals. Over the years there have been very few documented attempts to capture and analyze the backscattering response of whales using an active sonar system. Nevertheless, whales, mostly owing to their size, their motion, and the aspect dependence of their backscattered field, possess desirable properties that help distinguishing their scattered response from clutter and other environment related false alarms. As an initial step, data collected during the MAST04-- experiment is presented, and gray whale target strength measurements are obtained. Results are compared to the previously published whale target strengths. Additionally, an investigation is conducted in an effort to provide whale feature identification points suitable for automated detection and classification, as means of relating gray whale active acoustic signatures to their inherent characteristics and their motion. During the MAST04 experiment, the active sonar component feasibility has been demonstrated, while the second generation system is being developed for the MAST 07 experiment. Tracking and classification algorithms are being further developed and they will be implemented and tested during the upcoming MAST 07 experiment. MAST 07 will feature a lighter, autonomous, fuel cell powered active sonar system, implementing real time marine mammal detection, tracking and classification algorithms [C356]

"Automatic Target Recognition: The Problems of Data Separability and Decision Making"

This paper treats the problem of target recognition as a decision process. The nature of the decision to be made has a bearing on the data gathered and the subsequent processing. A key factor in the processing is the separability, i.e., the ability to distinguish, of radar images of similar but distinct objects. A number of recognition algorithms are considered and their suitability for data sets of various types is discussed. In addition some simple measurements of the transfer functions of two targets are considered. Observation suggest that the examples have characteristics that may make them readily separable. As with all recognition techniques the quality and quantity of training data available will place a limit on the performance of any recognition technique and this discussed in the text. The view is formed that a single technique is unlikely to be successful and several techniques cued by gross-features of the image may be more appropriate [C357]

"Target Classification by Radar"

Target classification by radar has enormous potential with many important applications. So far, with a couple of notable exceptions, this has proved to be an extremely challenging problem with no obvious solution. The chief method for improving the quality of information gathered has been to improve resolution in both range and cross-range dimensions. Recent advances, chiefly in digital technology means that radar systems are now able

to operate varying parameters such as frequency, waveform, PRF, bandwidth on a pulse by pulse basis. Additionally, there is emerging evidence that geometric diversity when gathering measurements to be used for classification is an equally important factor. This paper will examine the relationship between radar design parameters and data collection strategies as a basis for solving the problem of radar target classification [C358]

"High Resolution Radar Imaging of the Sea Surface"

Applications are reviewed of high resolution radar sea surface imagery to remote sensing, wide area surveillance, target detection and tracking. The limitations imposed by sea surface motion on SAR imaging are discussed and illustrated, along with methods to exploit the motion such as along track interferometry. Ships on the sea are subject to roll, pitch and yaw motions, which defocus SAR imagery; analysis and signal processing to characterise and overcome the difficulties are described. Real aperture images of the sea are shown to contain detailed information on the propagation of surface waves, which may be used in algorithms to detect anomalies such as small surface vessel; these are also described and demonstrated [C359]

"Flash and Persistent Point Scatterer Feature Extraction from Radar Images"

The talk will discuss the modelling of flashes buried within radar range compressed, or raw data. It will be shown how variants of the CLEAN algorithm can speedily efficiently extract all the flashes. Persistent point scatterers are regarded here as a special case of flashes, of long duration in the time/angle domain. A `flash representation' of a target closely related to its ISAR image is shown. The talk will discuss efforts to validate the flash representation against flashes direct from CAD models, or from electromagnetic prediction codes such as QinetiQ's SPECTRE. Implications for feature-based ATR, scatterer interpretation, and human interpretability of radar images will be discussed [C360]

"SAR 3D Scene Reconstruction Using Fourier Imaging Techniques"

Synthetic aperture radar (SAR) images are conventionally collected from platforms following a straight and level flight path. The resulting Fourier domain data exist on a 2D plane which is projected onto the ground plane for imaging, producing a 2D image of the target scene. To obtain a 3D image of the target scene interferometric SAR is typically employed, this involves determining the phase difference between two independent SAR images. However if the SAR data is collected from a nonlinear 3D flight path then the Fourier domain data exist on a 2D surface with extent in all three dimensions. Scene reconstruction from this type of flight path has been covered in the literature previously; however the algorithms used for scene reconstruction are computationally intensive. This paper covers 3D scene reconstruction using Fourier imaging techniques. A 3D equivalent to the polar format algorithm (PFA) is used for scene reconstruction, where the 2D data surface is resampled onto a regular rectangular 3D grid of points to allow use of the fast Fourier transform (FFT). The irregularly sampled 2D surface is mapped to another domain where resampling to the regular rectangular 3D grid points near the surface is a simpler operation. The FFT is then performed in each direction to reconstruct the target scene. This method of scene reconstruction has been simulated in MATLAB and the results obtained have been compared to results obtainable from the same data using a matched filter (MF) based approach. The results from two different nonlinear 3D flight paths are discussed to demonstrate the algorithm, an orthogonal aperture and a circular curved arc. The results of the simulations show that Fourier imaging methods can provide a less computationally intensive alternative to the methods discussed in the literature [C361]

"Semi-Supervised Image Classification in Likelihood Space"

This paper studies the problem of using limited amount of labeled data and large amount of unlabeled data in the training of a generative model for image classification, and proposes a likelihood space approach to improve the classification performance. Frequently when labeled data is limited, unlabeled data can help to improve classification performance if the assumption of the generative model structure in the classifier is correct. But classification accuracy can be degraded if the model structure assumption is incorrect. In this paper, we compare raw data space classification and likelihood space classification in semi-supervised learning framework, and we show that the classification performance can be improved in likelihood space when model is misspecified. We apply this likelihood space semi-supervised learning method in automatic target recognition on SAR images, and experimental results demonstrate the effectiveness of this proposed approach [C362]

"Decision Tree Based FPGA-Architecture for Texture Sea State Classification"

The target detection process in sea clutter background involves the use of different types of CFAR (constant false alarm rate) algorithms. These algorithms and their parameters should be configured to obtain the maximum detection probability and minimum false alarm probability at the current sea state (Beaufort scale). This paper present an FPGA-architecture for automatic classification based on texture recognition of sea states. The sea

state texture classification allows select the appropriate CFAR algorithm and its parameters for the target detection process. The paper is centered in the hardware implementation for sea state texture classification, based on decision tree. The rules for decision tree are obtained from the analysis of the grey levels co-occurrence matrix features applied in an image of the sea state obtained in a radar scan. Results with simulated and real data are presented and discussed [C363]

"Enhanced SVM versus Several Approaches in SAR Target Recognition"

This paper presents a comparative study between different automatic target recognition (ATR) approaches in the application of synthetic aperture radar (SAR) target recognition. Four different categories of approaches are investigated and compared. The first is distribution-based where a statistical data model is assumed for the SAR image data. The second category contains one approach that is based upon principal component analysis (PCA). The third category employs different neural network architectures. The last category utilizes support vector machines (SVM). It contains the classical SVM implementation and an enhanced implementation proposed elsewhere by the authors in which the traditional Euclidean kernel is replaced by a new one that is more suitable for the application in question. Experimental results are presented. It is shown that the enhanced SVM approach outperforms all other investigated approaches in both the classification performance and the confuser rejection [C364]

"Target Classification for Air Defence Radars"

Radar is evolving rapidly from being a sensor which detects and tracks targets to a high resolution imaging sensor with target classification capabilities. This paper addresses the techniques being developed for air defence radars. The application of target classification functions in fire control radars which support missile systems and multi-function phased array radars is discussed. The main high resolution techniques employed are range profiling, ISAR, frequency/spectral analysis and range-frequency imaging. Typical aircraft images measured are presented. The level of maturity of the hardware and signal processing technology to support these modes is discussed. The key technical, operational and practical issues which drive the design and application of high resolution modes for these types of radars are presented. Factors which determine the type of target classification mode which can be employed include the: operational frequency of the radar, time available for the application of the high resolution waveform, pulse repetition frequency, radar bandwidth available, basic architecture of the radar, and mission of the radar system. The other critical issue for the practical employment of target classification modes is that of the target signature database. Classifier algorithms are used to provide the match between the signature measured by the radar and reference signatures of targets of interest held in a database to provide an estimate of the target class. The assembly and maintenance of the target signature database is discussed and techniques employed are presented [C365]

"The Institution of Engineering and Technology Seminar on High Resolution Imaging and Target Classification"

The following topics were dealt with: high resolution imaging; target classification; radar imaging; sonar; military radar; speech recognition; SAR; and Doppler radar [C366]

"SeeCoast: Automated Port Scene Understanding Facilitated by Normalcy Learning"

SeeCoast is a prototype US Coast Guard (USCG) port surveillance system that provides automated scene understanding support for watchstanders. A major SeeCoast objective is to reduce operator workload while maintaining optimal domain awareness by shifting operators' focus from having to detect events to being able to analyze and act upon the knowledge derived from automatically detected anomalous activities. Analyst-defined vessel activities are recognized from pre-scripted patterns and anomalous vessel activities are detected using machine learning techniques. The baseline SeeCoast system interfaces to the USCG Hawkeye prototype and uses (a) machine vision technology to produce target tracks from streaming video data; (b) multi-INT fusion technology to correlate radar, automatic identification system (AIS), and/or video track data into a single coherent track picture; (c) vessel activity analysis and learning technology to provide alerts for events of interest according to user-defined criteria; and (d) visualization of those alerts embedded within the common operating picture. The video processing component tasks and controls Hawkeye cameras to detect vessels in motion and generates vessel track and classification (based on vessel length) information. SeeCoast detects unsafe, illegal, and threatening vessel activities using a rule-based pattern recognizer and detects anomalous vessel activities on the basis of automatically learned behavior normalcy models. Operators can optionally guide the learning system in the form of examples and counter-examples of activities of interest, and refine the performance of the learning system by confirming alerts or indicating examples of false alarms. This paper focuses on the learning-based activity analysis capabilities of SeeCoast [C367]

"Medeling of propagation of electromagnetic waves in forest media Application to detection and localization of targets"

In this paper, we study the propagation of electromagnetic waves in forest media in UHF and VHF frequency bands. We propose a full wave coherent method that allows computing the electric field everywhere in the medium and for any kind of transmitting antenna. Using the data given by the model, we develop two methods in order to detect and localize a metallic target in the medium. The first one is based a monostatic SAR imaging algorithm, the second one is based on a DORT method associated with MUSIC algorithm [C368]

"Target Detection and Characterization using H/alpha Decomposition and Polarimetric Signatures"

Recently, the characterization and classification of terrain-cover using polarimetric SAR data has been extensively investigated and reported on (J.S.Lee, 1994). In this paper we re-examine the entropy-alpha approach (J.S.Lee, 1999) to radar polarimetry and show how the basic method may be augmented by the addition of the polarimetric signature parameters (F.T. Ulaby and C. Elachi, 1990), the propagation and helicity phase angles and the backscattering cross section. The method has been tested using the full polarimetric airborne data sets acquired with DLR's experiment SAR (E-SAR). The test region is the area of Oberpfaffenhofen, Germany acquired in the P-band. The results agree with the accepted understanding of radar backscatter and show that the use of the polarimetric signatures deliver complementary information to the entropy/alpha decomposition [C369]

"ISAR image segmentation by non linear diffusion equation"

This paper describes a non linear spatial filtering for the target radar segmentation of ISAR/SAR images. Since such images are usually corrupted by speckle noise and clutters, image processing technique are required in order to obtain a more clear image. We have implemented a spatial technique based on the non linear diffusion equation, also known as the Perona-Malik equation. Our model is based on an calculation of the spatial gradient on a 5Ч5 stencil in order to increase the merging of target corresponding regions. By suitably estimating a diffusion coefficient related parameter, the gradient threshold, target segmentation is done into few integration steps of the equivalent explicit scheme. The resulting images maintain most of the original details also visible in converting the filtered image in a binary format. The proposed method can be the first step of target classification by matching correlation of more advanced techniques. [C370]

"Radar Signal Classification Using Pca-Based Features"

Principal component analysis (PCA) has been used in many applications ranging from social science to space science, for the purpose of data compression and feature extraction. Usage of PCA for synthetic aperture radar (SAR) image classification, though widely reported by remote-sensing researchers, has not been exploited much by automatic target recognition (ATR) community. In the present paper, PCA has been used in SAR-ATR using the MSTAR data base, and comparison has been made with the conventional conditional Gaussian model based Bayesian classifier (M.D. DeVore and J.A. O'Sullivan, 2002). The results have been compared based on percentage of correct classification, receiver operating characteristics (ROC), and performance with limited amount of training data. By all standards of comparison, the PCA based classifier was observed to outperform the conditional Gaussian model based Bayesian classifier (CGBC) or at the worst it performs at par. And given the computational and algorithmic simplicity of PCA based classifier, the new algorithm was concluded to be a highly prospective candidate for real time ATR systems [C371]

"A New Hybrid Approach to Radar Target Classification for the Estimation of Scattering Centers"

Radar images, range profiles and scattering centers are used as feature parameters in radar target classification applications. Scattering center parameters, when used as feature parameters, enable an efficient compression of feature space compared to classical target classification methods based on radar images and range profiles. A method used for the estimation of scattering centers via cancellation of side lobes is the CLEAN algorithm. In this work, model based Prony, MUSIC, ESPRIT and evolutionary based CLEAN methods are applied for the estimation of scattering centers. A hybrid method is proposed which improves the convergence of evolutionary based CLEAN. Scattering centers which are estimated by aforementioned methods are classified using correlation based matching score method, Bayes classifier and artificial neural networks. Classification is accomplished using simulated data of four different aircraft models created by the point target model at different frequency bands and aspect angles [C372]

"Target Classification and Pattern Recognition Using Micro-Doppler Radar Signatures"

Micro-motions, such as vibrations or rotations of an object or structures on the object, induce additional frequency modulations on returned radar signal, which generates sidebands about the object's Doppler frequency, called micro-Doppler by V.C. Chen et al. (2002). In this paper, we investigated statistical classification methods for target classification using their micro-Doppler signatures. At this stage only simulated data are studied, and two models are used to generate simulation data: point scatter model and RCS model. Both models are tested and compared for their performance on target classification [C373]

"Study of dispersive and anisotropic scatterers behavior in radar imaging using time-frequency analysis and polarimetric coherent decomposition"

A fully polarimetric time-frequency analysis is proposed for radar imaging (SAR, ISAR) to analyse the anisotropic and dispersive behavior of deterministic target illuminated by a radar sensor. This method is based on the hyperimage concept which describes the response of scatterers as a function of the observation angle, of the emitted frequency and of the polarimetric decomposition. New polarimetric hyperimages point out a non-stationary behavior which can be interpreted by the physics parameters of the target (geometrical shape, relative orientation). They allow a best understanding of the scattering mechanisms. Basic statistics extracted from these representations show that they are tools to detect non-stationary scatterers and are the first step to a new classification. [C374]

"Target track classification for airport surveillance radar (ASR)"

The aim of this paper is to identify false tracks that arise from weather and biological targets, and to increase the air traffic security and safety level by detecting aircrafts lacking secondary surveillance radar (SSR) data. In this paper a single-source target classification after tracking using support vector machines (SVM) is introduced, which gives each track an updated probability value based on its likelihood behavior to conform to aircraft and non-aircraft targets. We introduce various features and evaluate different combinations in order to achieve the highest clustering index. The experimental classification results with real radar data provide good evidence that machine target classification is viable, with the capability of being implemented in real time. [C375]

"Fuzzy Logic Applications to Fire Control Systems"

The paper objective is to study and solve one of the problems encountered in the development of a fire control system. Fire control encompasses all operations required to apply fire on a target. We can not cover in this paper the whole set of mathematical problems in which fire control applications can be divided. Therefore, we will focus in one of the initial phases, the target detection problem. In general, the application of a segmentation algorithm to a data set as a preprocessing of the data previous to an unsupervised classification algorithm improves the probability of detection. The paper presents such a combination. Expert information about the encounter classes will be used for a supervised classification of the example picture. In the first place, we will use a segmentation algorithm to found the natural homogeneous classes in the data. These classes will be explored by an unsupervised clustering algorithm. The unsupervised classification will be performed on the segmented image. Once the classes have been determined that way the classification will be done over the original image. [C376]

"Classification and launch-impact point prediction of ballistic target via multiple model maximum likelihood estimator (MM-MLE)"

The paper deals with the problems of (i) launch and impact point prediction (LPP, IPP) of ballistic targets (BT) and (ii) BT classification by processing measurements acquired either by 3D surveillance or multifunctional phased-array radars. It is assumed that the radar acquires a limited number of measurements (plots) that do not encompass the whole target trajectory; thus, the established target track has to be extrapolated ahead in time in order to predict the coordinates of the impact point. A procedure based on multiple model maximum likelihood estimator (MM-MLE) has been conceived and tested using a Monte Carlo simulation approach; the parameters selected for testing are the probability of BT correct classification (Pcc), the IPP and the LPP. The new procedure is compared with the estimator described in A. Farina et al. (2004). [C377]

"Maximum a-posteriori adaptive masking for clutter suppression in automatic radar target recognition"

To suppress the effect of clutter in automatic target recognition we propose a maximum a-posteriori adaptive mask that isolates the target scattering centres in the data. This improves the quality of the construction of the target feature vector which results in an improved classification performance. We evaluate the technique on a closed-set identification task using targets from the MSTAR database and, on a 10-target forced-choice

experiment, obtain a recognition error rate of only 1.2%. We also conduct an open set identification experiment and show that the technique can achieve an equal error rate of 1.82%. [C378]

"Aspect dependent drivers for multi-perspective target classification"

In this paper, a 2-D classifier using radial basis function neural networks (RBFNNs) has been implemented combining two imageries collected by different locations to prove the classification rates enhancement given by aspect diversification. Principal components analysis (PCA) is applied to features extracted from a masked version of the SAR image using the sole target's backscattering and shadow information. The classification performance, examined in terms of receiver operator characteristic (ROC) curves is presented using MSTAR data for a population formed by six classes plus two unknown and two independent targets. The resulting performance shows a reduction of the probability of false alarm, related to an improvement of probability of declaration and correct classification in comparison with the traditional single aspect case. [C379]

"Radar Waveform Design using Minimum Mean-Square Error and Mutual Information"

This paper addresses the problem of radar waveform design for target identification and classification. Both the ordinary radar with a single transmitter and receiver and the recently proposed multiple-input multiple-output (MIMO) radar are considered. A random target impulse response is used to model the scattering characteristics of the extended (nonpoint) target, and two radar waveform design problems with constraints on waveform power have been investigated. The first one is to design waveforms that maximize the conditional mutual information (MI) between the random target impulse response and the reflected waveforms given the knowledge of transmitted waveforms. The second one is to find transmitted waveforms that minimize the mean-square error (MSE) in estimating the target impulse response. Our analysis indicates that under the same total power constraint, these two criteria lead to the same solution for a matrix which specifies the essential part of the optimum waveform design. The solution employs water-filling to allocate the limited power appropriately. We also present an asymptotic formulation which requires less knowledge of the statistical model of the target [C380]

"Comparison of Fusion Methods for Successive Declarations of Radar Range Pro les"

Classification of high-range-resolution profiles is a viable method of non-cooperative target identification. In order to increase the reliability and robustness of the classification result, methods of decision-level identity fusion can be applied. Different approaches have been used for a cumulative fusion of declarations of successively recorded radar range profiles. Besides probabilistic techniques such as the Bayesian fusion, non-probabilistic methods based on Dempster-Shafer or voting algorithms have come into focus. In this paper these different approaches are compared for typical situations which can arise in aircraft identification scenarios [C381]

"Remote Sensing Target Recognition Based on Contourlet and Kernel Fisher Discriminant"

An efficient feature extraction method for remote sensing target recognition was proposed in this paper, which was based on contourlet and kernel Fisher discriminant (KFD). After the contourlet decomposition, the contourlet features are fused (the weight for fusion is chosen by cross validation), and then KFD was used for further feature extraction, finally k-nearest-neighbor (KNN) was used for classification. Experimental results show that the proposed feature extraction method reach a higher correct rate than KFD and the method which use KFD on the lowpass filtered images. Moreover, when dealing with large scale images our method achieves a lower computation complexity than KFD [C382]

"Radar Target Recognition Method Using Improved Support Vector Machines Based on Polarized HRRPs"

Target recognition based on high range resolution (HRR) polarized radar using support vector machines (SVMs) was studied in this paper. A fuzzy membership function was constructed based on SVM decision-making function in order to improve the performance of OAA and OAO classifiers for multi-class target, and HRR radar target recognition method using improved SVM was proposed: First, the polarized radar backscatter echoes were processed by incoherent integration and power-normalized, the location and length of target in echoes were estimated and range profiles of target were interpolated to certain radial length, then polarized profiles were integrated considering the relevancy of range profiles of same target in different polarization state, at last, the improved OAA and OAO classifiers were used for target classification. Simulation experiment results show that the proposed method has the advantage of little capacity of computation and can improve the performance of classifiers effectively [C383]

"Joint IMM/MHT Tracking and Identification for Multi-Sensor Ground Target Tracking"

After giving an overview of the design of the IMM/MHT tracker, this paper discusses a joint tracking and identification approach to the multi-sensor ground target tracking problem. It is widely recognized that the requirements for the continuous tracking of important targets can only be achieved by incorporating feature data and behavioral information. Consequently, a Dempster-Shafer approach has been applied in the integration of multi-sensor classification with the target behavior so that an estimate of target type may included in the data association decision process. The ID information that may be potentially derived from HRR profiles may be combined with conventional IMM/MHT tracking techniques in order to aid the track-observation association process. Issues such as the inevitable loss of track identity due to track switching as well as the presence of confusers must be addressed. Thus, the paper discusses methods to include the effect of confusers and to efficiently reestablish track identity after a track-switch [C384]

"Interpretation of high-resolution optical imagery with evidential fusion of spectral information and object attributes"

Since the past five years Lockheed Martin Canada is developing an advanced image interpretation system integrating classification tools and target detection operators for multispectral, hyperspectral and polarimetric SAR imagery. Improved classification maps and superior object detection and identification performances have been obtained with a pixel-driven evidential fusion of textural measurements and end-member respectively extracted from polSAR and HIS imagery. As in many applications objects to be extracted occupy several pixels in the image, the objective of current developments is to supplement the pixel-based fusion already performed with radiometric, textural, spectral features by adding specific object topological attributes (shape, size) and contextual description (spatial relationships). This paper presents a description of the new primitives and the results obtained on Ikonos imagery [C385]

"A Model for a Human Decision-Maker in a Command and Control Radar System: Surveillance Tracking of Multiple Targets"

This work presents a deterministic approach to the problem of modelling the human behaviour in a command and control radar system and it considers the fusion of information between the operator and the system. The implementation and the results of a case study are presented where a human operator performs a tracking operation of multiple targets in a sea region. The mission performed by the operator is the surveillance of a coast area and the selection of a system action against possible threat targets, in order to check their identity. An analytical model of human memory has been investigated where the human decision maker is represented as a subsystem involved with two operational blocks, corresponding to the situation assessment process and the response selection process that he performs. The operator performance is evaluated by mean of his error probability in these two processes [C386]

"Performance analysis of meter band radar height-finding approach for low-angle tracking"

In this paper, a new meter band radar superresolution height-finding approach under clutter environments is presented in the presence of multipath, which cascades moving target indication (MTI) method and forward spatial smooth MUSIC (FSS-MUSIC) algorithm, the MTI$FSS-MUSIC approach for short. The numerical simulation analysis of the presented approach is performed and the root-mean-square-error (RMSE) of target height estimation is given. It is demonstrated that clutter suppression method i.e., MTI cascaded superresolution height-finding approach is available for VHF array radar low-angle tracking applications [C387]

"Vehicle identification and GPS error detection from a LIDAR equipped probe vehicle"

When detecting and tracking vehicles in LIDAR data it is important to differentiate between the measurements from vehicles and the measurements from fixed objects such as road boundaries. In this paper we present our approach to classify the LIDAR targets as vehicles and non-vehicle objects, and detect GPS positioning errors from a probe vehicle equipped with LIDAR and DGPS. The classification approach is developed based on a world space density image generated by averaging over historical LIDAR measurements. A correlation approach is used to detect GPS positioning errors and prevent incorrect classifications of the targets caused by erroneous projections between the vehicle coordinate system and the world coordinate system. The classification approach is then modified accordingly and becomes robust to these GPS errors [C388]

"A Novel Non-Linear Approximation to the Huygens-Fresnel Diffraction Patterns for Reconstructing Digital Holographic SAR Images"

Based on the nonlinear approximation of Huygens-Fresnel diffraction patterns, the SAR images of a target can be made up from a knowledge of a hologram for all frequencies and all aspects angles to provide a complete

description of the target. In this paper we reconstruct the image of hologram employing the multiresolution Fresnelet transform to approximate the Huygens-Fresnel diffraction patterns in an off-axis geometry from the simulated test pattern (3bar). Fresnel transform is a wavelet-like transform, very close to Gabor functions (M. Unser et al., 1992) and well localized with respect to the holographic process. This method allows us to generate and reconstruct hologram on a digital computer, and apply multiresolution wavelet base analysis and special filtering on it. Since images are nonstationary process, we use fractional Brownian motion (fBm) method to describe texture in SAR images. It is known as a suitable model to classify a vast number of natural phenomena and shapes, such as the range of rivers, terrain surfaces, mountains ripples of water, coastlines and etc. The novelty of this technique lies in the use of Fresnel transform in reconstruction of holographic SAR images and fBm model for classifying them [C389]

"Template Based Micro-Doppler Signature Classification"

The micro-Doppler signature of a target is a time varying frequency modulation imparted on the radar echo signal by moving components of the target. Battlefield radar output the baseband signal as audio and soldiers listening on headphones are able to identify the target from its micro-Doppler signature. Automation of this capability is desirable for improved reliability and reduction in classification time. For the first time dynamic time warping (DTW), a speech recognition technique, has been applied to the problem. Its performance has been compared with the common k-nearest neighbour (k-NN) classification method since both approaches utilise a template library [C390]

"The Intelligent Identification of Air and Sea Targets in Coastal Radars"

Target identification is important in coastal radars to separate air and sea targets. In this paper a novel algorithm for identification of air and sea targets in coastal radars is presented. For this purpose, a multiple PRF technique along with a maximum likelihood frequency estimation method has been used. Then an intelligent algorithm, based on artificial neural networks, or a simple and efficient algorithm are utilized for resolving the Doppler frequency ambiguity and the classification of sea and air targets. Our simulation and practical results have shown that this method has an excellent performance to identify air and sea targets in coastal radars, even in low SNRs [C391]

"Automatic Target Recognition Based on High-Resolution Range Profiles with Unknown Circular Range Shift"

In this paper, an automatic aircraft target recognition (ATR) framework is presented, which is based on the high resolution range profiles (HRRP) of aircraft targets. This work is divided into two major parts. First, we consider the generation of the HRRP, which includes the modeling and simulation of radar cross section (RCS), the design of step frequency waveform (SFW), and IFFT processing for HRRP synthesis. In practice, a possible circular shift of the received HRRP relative to the template HRRPs in target library may exist. In such a situation, we resort to the statistical classification technique to develop an ATR algorithm, which begins with using the Neyman Pearson criterion to determine whether a target is present or not, under a constant false alarm rate constraint. Then the circular correlation is used to estimate possible circular range shift, as well as the unknown phase shift and attenuation. Moreover, we adopt the Gram-Schmidt orthogonalization (GSO) procedure to construct a signal space, and then project the received HRRP onto the signal space. Finally, the target classification can be done in terms of maximum a posteriori (MAP) decision rule. Simulation results are also included to demonstrate the feasibility of this approach [C392]

"Database Generation for Non-Cooperative Air Target Identification"

Summary form only given. In this paper we will discuss the approach that we have evolved for populating a database with representative training data for the purpose of non-cooperative target identification (NCTI) of air targets by radar. Such NCTI should help to augment procedures like IFF to reduce the risk of fratricide and allow early designation of targets such that threats can be engaged before significant risk to vulnerable assets. This paper will focus on the use of synthetic data generated from limited information, such as photographs, to represent target types for which we don't have access to real radar measurements over any or a sufficiently representative range of aspects and configurations. This can often be the case for hostile aircraft types. Subscale models and computer electromagnetic predictions are both common methods that researchers have explored to simulate the radar returns from real aircraft. Both have advantages and disadvantages but the former is thought to be a feasible approach with current technology. We will discuss the methodology required for subscale model generation and subsequent use of the data to populate classifier databases and how to quantify the fidelity of the data such that confidence in classification result can be quantified and thus classifier performance as a whole estimated [C393]

"SAR ATR based on Support Vector Machines and Independent Component Analysis"

In this paper, a SAR (synthetic aperture radar) ATR algorithm based on support vector machines (SVMs) and independent component analysis (ICA) is proposed. Features of SAR images are extracted using ICA firstly, then we test our method on MA STAR database by using support vector machines classifier. The experiment result shows that the performance of this method is superior to other methods [C394]

"Research on Ship Target Auto-Recognition Technique for Low Resolution Radar"

An auto-recognition method of ship with low resolution radar is presented in the paper using multi transform technique. The radar target echo is sampled and preprocessed to suppress clutter first. Then characteristic vectors of the target are extracted with FFT transform, Mellin transform, wavelet transform and frame correlation processing. Experiments are carried out for the proposed method with three kinds of real radar echo data of ship target, the results indicate that the characteristics vector extracted by the proposed method in this paper is valuable for target classification [C395]

"Research on Typical Millimeter Wave Radar Target Characteristic"

The advantage of millimeter wave radar, radar cross section (RCS) and one dimension range profile are presented at this paper. With the high frequency approximate method, the typical millimeter wave (35 GHz, 94 GHz) radar target characteristics are simulated. With the comparison, it is found that the target's radar cross section at 94 GHz has more details and evident scattering centers, but the range profiles have similar scattering centers with the same band. [C396]

"Study on Distinguish of Two Overlapped Target Signals in DBF"

This paper studies the method how to solve for the real azimuths of each target when two targets are in the same beam so as to distinguish the two targets using the same phase property. By means of the directly calculation according to a formulas, this method possesses the merit of easy and convenient to realize [C397]

"A New Algorithm of Target Classification Based on Maximum and Minimum Polarizations"

The polarization signature of a given pixel in a radar image represents scattering mechanisms from various scattering elements. This paper presents an analysis of maximum and minimum polarizations of five kinds of polarization signatures: co-polarized, cross-polarized, completely polarized, completely unpolarized, and total available power signatures. We propose a new algorithm of target classification based on these maximum and minimum polarizations, then, conduct the experiment on the measured polarimetric SAR data. Experimental results show that this algorithm is robust to pixel-by-pixel target classification in radar images [C398]

"Automatic Target Recognition Using Multiple Radar High Range Resolution Profiles"

Radar automatic target recognition (ATR) based on multiple high range resolution profiles (HRRPs) is concerned. To relax the target aspect sensitivity and use more statistical information of the HRRPs, in this paper we extract the average range profile and the variance range profile together as the feature vectors for both training data and test data representation. And a decision rule is established for ATR based on the minimum Kullback-Leibler distance (KLD) criterion. The recognition performance of the proposed method is comparable with that of adaptive Gaussian classifier (AGQ with multiple test HRRPs, but the proposed method is much more computational efficiently. Experimental results based on the measured data show the minimum KLD classifier is effective [C399]

"Simulations for Evaluation of Sensor Systems Exposed to Countermeasures"

A methodology for simulation of multi-sensor systems exposed to countermeasures has been developed with the aim to investigate how multi-sensor systems are affected by different types of countermeasures and deployment tactics. The target recognition function of a combined radar/IR-seeker exposed to countermeasures is studied. Features extracted from simulated high range resolution radar data and IR images are fused. Sensor data are simulated for a seeker approaching ground vehicle targets moving on a grass field. The countermeasures consist of IR and radar attenuating smoke. The rate of correct classification is always higher for fused sensor data than for a single sensor as long as the proper confidence level of the data is considered [C400]

"The Performance Comparison of Adaboost and SVM Applied to SAR ATR"

In this paper, Adaboost and SVM are applied to SAR ATR (synthetic aperture radar automatic target recognition)

respectively. The performance of these two classifiers is analyzed and compared in target aspect window with different size. First, PCA (principal component analysis) features are selected as target feature, and then Adaboost.MI and SVM are used to classify, respectively. Experimental results based on MSTAR data sets show that Adaboost classifier has better robustness than SVM classifier [C401]

"An Efficient Kernel Optimization Method for High Range Resolution Profile Recognition"

A kernel optimization based on fusion kernel for HRRP is proposed in this paper. Based on the fusion of the 1-norm and 2-norm Gaussian kernels, our method combines the different characteristics of them so that not only is the kernel function optimized but also the speckle fluctuations of HRRP are restrained. Then on the radar measured data the presented method is employed to the kernel optimization of KPCA and the classification performance of the extracted is evaluated via a SVM classifier. Finally, experiment results are compared and analyzed, which prove our method effective [C402]

"Performance Analysis of Meter Band Radar Height-Finding Approach for Low-Angle Tracking"

In this paper, a new meter band radar superresolution height-finding approach under clutter environments is presented in the presence of multipath, which cascades moving target indication (MTI) method and forward backward spatial smooth MUSIC (FBSS-MUSIC) algorithm, the MTISFBSS-MUSIC approach for short. The numerical simulation analysis of the presented approach is performed and root-mean-square-error of the target height estimation is given. It is demonstrated that clutter suppression method i.e., MTI cascaded superresolution height-finding approach is available for VHF array radar low-angle tracking applications [C403]

"A Case Study on the design of a cluttermap based plot classification mechanism"

Many fielded state-of-the-art radars suffer occasionally from excessive false alarm rates. Various mechanisms have been devised in order to improve the signal-to-clutter ratio in general, but control of false alarms remains to be an issue of concern for the designers. This paper discusses a post-detection mechanism that splits the total offer of plots into four classes, such that each of these classes may be utilized by the tracking algorithm in order to have control over the false track rate. The mechanism has been developed for maritime sea-surveillance radar having a logarithmic receiver and a sliding window video extractor. It is basically a plot map performing a two-dimensional feature based classification. The features exploited are the signal-to-noise ratio and the target extent. The parameters in the algorithm are tuned based on a learning set from the radar operating in real life and tested using the same parameter values on a test set, also recorded during real life operation. The results suggest that a mechanism like proposed can be effective in controlling the false alarm rate', however sometimes at the expense of loosing some detections of real targets. [C404]

"Wetland Characterization using Polarimetric RADARSAT-2 Capability"

Wetlands play a key role in regional and global environments and are critically linked to many major issues such as climate change, water quality, the hydrological and carbon cycles, and wildlife habitat and biodiversity. Mapping wetlands and monitoring their change in a systematic and repeatable manner for the Canadian Wetland Inventory (CWI), led by the Canadian Wildlife Service of Environment Canada (EC), are important in order to manage and protect significant wetland areas in Canada. The use of RADARSAT-1 Synthetic Aperture Radar (SAR) data has been shown to be important for wetland water extent characterization. However, the limited capability of RADARSAT-1's single-polarization C-band SAR in vegetation type discrimination makes the use of clear-sky- dependent visible near-infrared (VNIR) satellite data necessary for wetland mapping. In this paper, the unique polarimetric capability of RADARSAT-2 is investigated for wetland classification. The roll invariant incoherent target decomposition, the TSVM-ICTD [11], is used for optimum characterization of wetland target scattering. It is shown that like RADARS AT-1 HH polarization, the magnitude of the complex symmetric scattering is not effective for vegetation type discrimination. The phase of the symmetric scattering type has to be used for a more complete characterization of wetland vegetation species. This new phase scattering parameter introduced in [11] has been shown to be very promising for wetland classification using Convair-580 polarimetric SAR data. [C405]

"Radar cross section of some simple and collected targets to be used for classification"

The goal of this paper is to analyze the scattering properties of different kind of targets, from simple shapes to collected targets made up of several objects, from 400 MHz to 7400 MHz to be used as patterns in a Ground Penetrating Radar in the classification stage. The data have been collected in an anechoic chamber with a vector network analyzer (VNA) set to work as a Stepped Frequency Continuous Wave Radar (SFCW). The data are analyzed in frequency and time domain in order to picture the radar cross section dependency of frequency, incident angle, polarization and targetГ‚Вїs shape. The measurement have been carried out using a bistatic

arrangement with two TEM horns for linear polarization and two spiral antennas for circular polarization. [C406]

"High resolution DOA automotive radar with four receiving antennae"

Current research activities in the automotive industry focus on the improvement of the perception capabilities of radar sensors. A radar sensor with four receiving antennae and its LFMSK transmit signal are introduced. To determine the DOA (Direction Of Arrival, azimuth angle) of the targets in the range of the radar sensor spatial samples of the antennae are chosen and processed using the high resolution frequency estimation technique MUSIC (MUltiple SIgnal Classification). Results of simulations and practical measurements are presented and compared. [C407]

"A New Set of the Parameters for the Terrain Surface Classification in Polarimetric SAR Image Based on Deorientation of Polarimetric Scattering Vector"

Deorienation theory of polarimetric scattering targets is developed, which transforms the scattering vector of spatially oriented targets into a certain status with minimization of cross polarization. A new set of the parameters u,v,w,Psiis defined to describe and classify different terrain surfaces. Based on the vector radiative transfer (VRT) model of non-spherical particles above a rough surface, numerical simulations illustrate the parameters u,v,w,Psiand the entropy H. These parameters are applied to the unsupervised classification in polarimetric images. The terrain surfaces of polarimetric SIR-C and airborne SAR images are classified and orientation-analyzed. [C408]

"Detection and Recognition of Target Signals in Radar Clutter via Adaptive CFAR Tests"

In this paper, adaptive CFAR tests are described which allow one to classify radar clutter into one of several major categories, including bird, weather, and target classes. These tests do not require the arbitrary selection of priors as in the Bayesian classifier. The decision rule of the recognition techniques is in the form of associating the p-dimensional vector of observations on the object with one of the m specific classes. When there is the possibility that the object does not belong to any of the m classes, then this object is to be classified as belonging to one of the m classes or to class m+1 whose distribution is unspecified. The tests are invariant to intensity changes in the clutter background and achieve a fixed probability of a false alarm. The results obtained in this paper agree with the simulation results, which confirm the validity of the theoretical predictions of performance of the suggested adaptive CFAR tests. [C409]

"Utilization of Support Vector Machine based on Neural Network to Suppress Ocean Clutter and Zero Frequency Disturbances"

The paper proposes a new multi-classifier for pattern recognition by combining neural network with SVM (support vector machine). The multi-classifier has the advantages of SVM and NN (neural network). According to the properties of Bragg peak, zero frequency disturbance and the target of moving with time-varying velocity among the echo signal of HFSWR (high frequency surface wave radar), the multi-classifier is utilized to process the result of decomposing radar echo with chirplet atom and separate them. Then the ocean clutter and zero frequency disturbances can be suppressed according the result of classifying. A new means by utilizing HFSWR to detect the target moving with time-varying velocity is provided in the paper. [C410]

"Target Classification by Means of Fully Polarimetric ISAR Images"

In ISAR systems, fully polarimetric capabilities have not been fully exploited for target classification or recognition. In this paper, a full system that reconstructs the polarimetric ISAR image and classifies the target is proposed and tested on simulated data. [C411]

"Study of the Influence of Vessel Motions and Sea-Ship Interaction on Classification Algorithms Based on Single-Pass Polarimetric SAR Interferometry"

This paper analyzes the worsening effects the sea surface can induce on vessel classification algorithms working with SAR imagery. Two issues will be tackled, the complex motion history of ships and the polarimetric scattering mechanisms generated by the sea-hull interaction. Both can modify the information that allows to infer the geometry of ships dropping the classification capability. The current analysis will introduce a new classification approach based on polarimetric SAR interferometry that presents a low sensitivity respect the main distortions caused by the sea surface. Simulated SAR images obtained from GRECOSAR, a SAR simulator of complex targets, will show trustworthy vessel classification almost independent on the environmental conditions could be possible for incoming system configurations as Tandem TerraSAR-X. [C412]

"RSOM Algorithm for Radar Target Recogniton"

A number of general neural networks have several drawbacks such as how to decide their structures and scales, how to design their self-learning procedure and how to cope with a bulk of computation for the case of large data set classification and complex patterns recognition. In order to solve these problems, this paper proposes the RSOM tree classifier based on discrimination criterion approach. The RSOM tree classifier is composed of topology-preserved sub-SOM nets, and its scales is determined by discrimination criterion. The main advantage of this new neural network is that it adjusts structure and scale automatically with the large training data set, therefore, it maps the training data set very well. This makes it achieve high right classification rate in radar ship target recognition. The experiments in the end are very good proofs for this new network [C413]

"Radar Target Recognition Based on Micro-Doppler Effect"

Micro-Doppler effect is of great potential for radar target recognition since the micro-dynamics of structures on the target can be detected with it. The recognition process includes time-frequency analysis of the returned radar signal, feature extraction from time-frequency distribution images, and classification according to the feature set. In this paper, the time-frequency distribution images of four different types of micro-dynamics, which are vibration, rotation, coning and tumbling, are given and analyzed first. Then a method is proposed for feature extraction from time-frequency distribution images of micro-Doppler dynamics. Simulated experimental results have shown that high classification performances for different classifiers have been achieved [C414]

"50 Million Years of Waveform Design"

Echo locating mammals such as bats, whales and dolphins have been using waveform diversity for over 50 million years. They vary the PRF, the power and the frequency content of the transmitted waveforms. This has enabled them to evolve highly sophisticated navigation techniques and the ability to forage for food. Moreover, recent developments in technology means that it is now possible to replicate many of the methods employed by mammals in synthetic systems such as radar and sonar. Thus echo locating mammals potentially offer valuable insights that might allow improvements in these synthetic sensor counterparts enabling autonomous navigation of platforms and automatic target classification. In this paper the authors examine the waveforms used by bats as a function of orientation and intent. The information is presented in terms forms well known to the radar community and includes, power spectra, ambiguity functions. From this analysis the authors are able to derive understanding as to how bats are exploiting waveform diversity and how this can be copied in radar and sonar systems [C415]

"A HRRP Recognition Method Based on KFD"

High resolution range profiles (HRRP) could accurately reflect the structure of target, so it is an important method for radar target recognition. Kernel Fisher discriminant (KFD), which is a machine learning method based on kernel function, is suitable for classification of high dimensional samples which couldn't be separated by linear classifier. In this paper, KFD were used for HRRP classification with KMOD kernel function. A multiple classifier was proposed, and better anti-noise performance was achieved with phase-subtraction alignment and a special rejecting method. The experimental results by three classes of measured HRRP data proved out the effectiveness of KFD [C416]

"SVM Enhancement with Application to SAR Imagery Classification"

This paper investigates enhancing the performance of support vector machines (SVMs) in the application of synthetic aperture radar (SAR) imagery classification. The approach is to replace the conventional Euclidean distance in the SVM kernel with a new similarity measure that is less sensitive to perturbations. Same-target SAR images show perturbations, in part due to the presence of speckle and in part due to small variations in radar depression angle and target orientation. It is expected that SVMs with the proposed new kernel will outperform those with the conventional Euclidean kernel. Experimental results are presented to validate this expectation for both batch and iterative implementations of SVMs. The paper also argues that the proposed approach is well-founded theoretically by demonstrating that the new kernel is still a Mercer kernel [C417]

"The Application of Speech Recognition Techniques to Radar Target Doppler Recognition: A Case Study"

This paper reports some preliminary results of an examination into the feasibility of recognising the Doppler signatures of targets using speech recognition processing techniques. The rationale is that human operators typically listen to the Doppler audio output from the surveillance radar to detect and possibly identify targets. A feature of speech recognition is that pre-processing is used that takes account of the voice mechanisms that

produce speech and the characteristics of the human ear. Three different recognition techniques, with identical pre-processing, were implemented. After validating the recognition algorithms with speech the recognisers were retrained with Doppler signals from a number of sources. It was found that the best of the speech recognisers, HMM-GMM, was also the best of the Doppler recognisers with 88% recognition. The work has been compared with that of others using a similar technique and a good agreement has been found. Some recent discoveries in neuroimaging are quoted that suggest that the human brain and that of several other mammals performs visual recognition in a manner common in speech recognition [C418]

"Target Recognition in Synthetic Aperture and High Resolution Sidescan Sonar"

The accurate detection and identification of underwater targets continues as a major issue, despite, or perhaps as a result of, the promise of higher resolution underwater imaging systems, including synthetic aperture sonar and high frequency sidescan. Numerous techniques have been proposed for computer aided detection to detect all possible mine-like objects, and computer aided classification to classify whether the detected object is a target or not. The majority of existing techniques employ supervised classification systems which are reliant on training data. The success of these systems can be highly dependant on the similarity of the test data to the training data, which includes the effect of the background region on which the target was located. This paper will briefly discuss and compare two possible solutions to this problem. The first is a model based system for classification and the second utilises an augmented reality simulator to produce training data [C419]

"Target Classification Using Bistatic SAR Images"

In a radar system, a bistatic configuration is the more generic version of a monostatic configuration. Hence, it is expected and has also been verified to a large extent, that bistatic configuration can increase the range of applications of radar systems. This has given rise to the recent thrust in research activities in bistatic radar development. However, it is an established convention that the new version of a system should be able to perform all the tasks, that its older version could perform 1. Hence, the applications that are currently possible using a monostatic system 2, should be achievable using a bistatic system. One such application is that of automatic target recognition (ATR), for which monostatic radars have proved to be quite effective. The present paper would present some experimental results, which in turn would establish the feasibility of bistatic ATR. In the present paper, ATR exercises have been performed on bistatic synthetic aperture radar (SAR) images. These SAR images have been generated synthetically, using an electromagnetic simulator. In the main paper, few sets of experiments along with their results would be discussed, to analyse various aspects of the bistatic ATR problem. First of all, the dependence of bistatic ATR performance on the bistatic angle of imaging, would be analysed. Bistatic ATR performance decreases with an increase in the bistatic angle of imaging. The reason behind this would also be expounded. In the second set of experiments, the performance of monostatic and bistatic ATR would be compared. It would be shown that contrary to held reserves, bistatic ATR performance is not drastically worse than the monostatic ATR performance. Lastly, the effect of multi-polar bistatic data on ATR performance would be looked into. Even though, multipolar data analysis in bistatic domain is more complicated, still multipolar data do give more information (than single polarisation data) about the target and help in improving the bista- tic ATR performance. Conclusions from the work presented in the paper, are quite encouraging. Even though bistatic data handling is more complicated, still a good ATR performance can be achieved by using bistatic radar. Bistatic multi-polar data is also exploitable. These conclusions in turn make a case for further research into bistatic radar systems [C420]

"Template Based Micro-Doppler Signature Classification"

The micro-Doppler signature of a target is a time varying frequency modulation imparted on the radar echo signal by moving components of the target. Battlefield radar output the baseband signal as audio and soldiers listening on headphones are able to identify the target from its micro-Doppler signature. Automation of this capability is desirable for improved reliability and reduction in classification time. For the first time dynamic time warping (DTW), a speech recognition technique, has been applied to the problem. Its performance has been compared with the common k-nearest neighbour (k-NN) classification method since both approaches utilise a template library [C421]

"A Doppler-Based Target Classifier Using Linear Discriminants and Principal Components"

This paper describes the design of the automatic target classifier which has been introduced into the AMSTAR battlefield surveillance radar. It discusses the requirements which have driven the design of the classifier, the data which is used to make the classification, the choice of linear discriminant analysis as one of the classification techniques used and the use of principal components analysis to simplify the training of the discriminator. It also discusses the addition of other classes by the use of other data about the targets. It

includes a discussion of the testing of the classifier and the performance achieved [C422]

"SAR Imagery Scattering Center Extraction and Target Recognition Based on Scattering Center Model"

Based on a scattering center parametric model derived from the geometric theory of diffraction, main characteristic scattering center Fisher optimal discriminator is presented in this paper for the problem of multi-class ground targets. All aspect main characteristic scattering center recognition model and target outline characteristic curve recognition model are presented in this paper. Four-class targets (Sandia Laboratories Implementation of Cylinders II, BTR70 armored transport, T72 main battle tank and BMP2 infantry tank) in MSTAR public database are adopted in our experiments and the results are presented [C423]

"A Real Time Test Bed for 2D and 3D Multi-Radar Tracking and Data Fusion with Application to Border Control"

This paper describes part of the activities required to model and assess the performance of a national integrated system (NIS) in the context of homeland security and in particular on border control issues. The border control requires an accurate surveillance of the terrestrial, maritime and overland boundaries, thus involving a wide number of heterogeneous sensors, command and control centres, platforms and communication networks. One of the layers of the integrated system is composed by radar sensors; these sensors can be ground or ship based, 1D or 3D. The paper deals with the problem of correlation and fusion of track data pertaining to ground and ship based, 2D and 3D radar sensors directly in the radar sites. Then, the improved (i.e. more accurate) information can be soon made available for a number of radar functions, such as: (i) re-pointing of the beam along the threat direction of arrival, (ii) energy and time management, (iii) cue of other sensors (i.e. infrared) or proper reaction means (patrol boat), (iv) preliminary classification of potential hostile targets. The updating and testing of the data extractor (DE) of a notional surveillance radar system is presented; the modified hardware and software is capable of acquiring, managing and fusing tracks pertaining to the radar system housing the DE and to other systems connected to the DE itself [C424]

"Radar HRRP Target Recognition using influence region of samples"

The k-nearest neighbour (KNN) rule using Euclidean distance is actually the same as template matching method under the maximum correlation coefficient criterion (MCC-TIMM), which has been widely used in high resolution rang profiles (HRRPs) based radar automatic target recognition (RATR). The nearest neighbor rule treats each training sample equally without consideration of different recognition performances due to its congregation around the other samples coming from the same class and segregation from those of the rest classes. In this paper, we propose an adaptive method that takes into account the effective influence size of each training sample and the statistical confidence with which the label of each training sample can be trusted. The experimental results confirm the effectiveness of the proposed method [C425]

"A New Radar Emitter Recognition Method Based on Variable Precision Rough Set Model"

Radar emitter information detected by multisensor system takes on uncertainty, illegibility and contradiction. In real reconnaissance environment, the patterns of radar classes often overlap, the accurate classification of the Pawlak rough set model restricts its application in the real world. In order to solve emitter recognition problem, a new method of finding decision rules is presented to classify radar emitter from the new point of view of variable precision rough set. This method is according to dependent degree of decision attributes on condition attributes. The decision rules proposed are more straightforward. At last, example of recognizing the radar emitter purposes is selected. During the experiment, discretization is conducted on extracted index data of radar emitter and metrical radar characteristic parameter firstly. Then, positive region of each condition attribute are calculated under the given error parameter, which is the basis of decision rules. Experimental results demonstrate this new radar emitter recognition method by finding decision rules based on variable precision rough set model is effective and feasibility [C426]

"Micro-Doppler Signature Classification"

The micro-Doppler signature of a target is a time varying frequency modulation imparted on the radar echo signal by moving components of the target. Battlefield radar output the radar's baseband signal as audio and soldiers listening on headphones are able to identify the target from its micro-Doppler signature. Automation of this capability is desirable for improved reliability and reduction in classification time. For the first time dynamic time warping (DTW), a speech recognition technique, has been applied to the problem [C427]

"Outline Structural Representation for Radar Target Classification Based on Non-Radar Templates"

Automatic target recognition (ATR) is often based on statistical methodologies rather than using symbolic information relationships and properties. In this paper, a possible approach for the syntactic outline representation for radar target classification based on non-radar templates is presented, describing the outline extraction and tine detection algorithms to define a code-book of structures representing the target radar shape. The outline target recognition is attempted from a multi-perspective point of view: only the illuminated side of the target is preserved and then combined with other partial shapes collected from different nodes of a hypothetical radar network [C428]

"Radar Target Recognition Using A Modified FastICA Algorithm plus GAs"

Independent component analysis (ICA) is a statistical method developed from the separation of blind signal, and now it has been successfully used in many fields. In this paper, we present an effective technique combined with a modified fastICA (M-FastICA) algorithm plus genetic algorithms (GAs) for radar high-resolution range profiles (HRRPs) feature extraction. As we all know that the most time-consuming course in fastICA is to compute the Jacobian matrix. So in this modified version, several iterations of fastICA are merged into one iteration but only needs to compute the Jacobian matrix once time. Thereby the convergence velocity of fastICA is accelerated while the performance is not degraded. To demonstrate the above feature extraction algorithm, the classification experiment on three types of radar targets are evaluated. First M-fastICA is applied to extract the independent components from the HRRPs. Then GAs is used to select the optimal basis vectors and thus build a feature subspace. The results show that the introduced method can achieve better classification performance than both PCA and ICA [C429]

"Modeling of Target Shadows for SAR Image Classification"

A recent thrust of non-cooperative target recognition (NCTR) using synthetic aperture radar (SAR) has been to complement the extraction of scattering centers by incorporating information contained in the target shadow. When classifying targets based on the shadow region alone, it is essential that an image be well clustered into its respective shadow, highlight, and background regions. To obtain the segmentation, the intensity and spatial location of a pixel are modeled as a mixture of Gaussian distributions. Expectation-maximization (EM) is used to obtain the corresponding distributions for the three regions within a given image. Anisotropic smoothing is applied to smooth the input image as well as the posterior probabilities. A representation of the shadow boundary is developed in conjunction with a Hidden Markov Model (HMM) ensemble to obtain target classification. A variety of targets from the MSTAR database are used to test the performance of both the segmentation algorithm and classification structure. [C430]

"Geometric Hashing Classifier Based on Modified D-S Theory in SAR Target Recognition"

Geometric hashing technology can effectively recognize targets with partially changed shape. But when the known targets in training data set don't satisfy with the condition of 360 azimuths, the effect of recognition degrades. The reason is that the imperfect training set and partially changed shape make the uncertain information increase. Dempster-Shafer theory can deal with the uncertainty successfully. However, Dempster-Shafer theory does not model well evidences with a high degree of conflict. In order to overcome the aforementioned problems, in this paper, a modified D-S theory combined with geometric hashing is proposed and used in SAR images recognition. Experimental results with MSTAR dataset show that this fusion method is feasible, and it can correctly recognize the targets with partially changed shape [C431]

"HF Radar Target identification Based on Optimized Multi-frequency Features"

In this paper, multi-frequency target radar cross section (RCS) of high frequency surface wave radar (HFSWR) is used for airplane target identification. Radar working frequency optimization selection is investigated for an optimization selection method based on the minimum classification error (MCE) rule in order to improve airplane target identification performance; Target RCS is compensated with the consideration of the influence of ground wave propagation attenuation and ocean wave additional loss. By using this method, identification results of ten types of airplane targets are given with different working frequency numbers in different signal to noise ratio (SNR). Simulations indicate that identification performance of frequency optimization is improved remarkably compared with the performance of random frequency selection, and the reliable airplane target identification using this method can be realized at lower SNR with fewer working frequency numbers [C432]

"Radar shadow and superresolution features for automatic recognition of MSTAR targets"

Automatic target recognition from high range resolution radar profiles remains an important and challenging

problem. In this paper, we present a novel feature set for this task that combines a noise-robust superresolution characterisation of the target scattering centres derived using the MUSIC algorithm with a representation of the target's radar shadow shape. To obtain the shadow shape features, three alternative spectral estimation methods are investigated. Using a hidden Markov model to represent aspect dependence, we demonstrate that the inclusion of the shadow features results in a significant improvement in recognition performance. Using azimuth apertures of 3° and 6° in a 10-target classification task from the MSTAR database, we obtain overall classification error rates of 1.3% and 0.2% respectively. These results are significantly better than those obtained by other published methods on the same database. [C433]

"Nearest neighbor classifier based on Riemannian metric in radar target recognition"

A successful design for a nearest neighbor classifier based on Riemannian metric in radar target recognition is presented. In Riemannian space, obtaining feature coefficient using subspace methods can be regarded as an affine transformation, and the classifier can be deduced easily from the distance formula in Riemannian space. The classifier is compared with other classifiers and good performance is reported. This design for the classifier may serve as a guideline for dealing with the puzzle that how to combine feature extraction with classifiers reasonably in radar target recognition using range profiles. [C434]

"Multipath signal resolving and time delay estimation for high range resolution radar"

High range resolution radar target signature is a promising signature for radar automatic target recognition (ATR), and the multipath time-delay is used for height finding in high range resolution radar recently. We address multipath time-delay estimation under the scenario of closely spaced multipath for high range resolution radar, the target scattered signature can be resolved via the estimated channel parameters. By using the prior information of the typical multipath channel structure in radar application, a channel constrained MODE-RELAX algorithm is proposed to estimate the channel parameters. The resolved target signatures are used to evaluate the classification performance. Numerical results show that the proposed algorithm can estimate the time-delay very well for many cases, and the classification performance can be improved via the resolved signal. [C435]

"PCA and kernel PCA for radar high range resolution profiles recognition"

Radar high range resolution profile (HRRP) contains target structure information. It is shown to be a promising signature for radar automatic target recognition. As a method for data dimension reduction and feature extraction, principle component analysis (PCA) and kernel PCA have found wide applications in pattern recognition field. According to the characteristics of target pose sensitivity and shift sensitivity, a localized PCA and a modified KPCA are proposed for radar HRRP recognition. Also the methods for selecting the kernel basis vectors and handling the range-shift alignment are carefully addressed. Finally, support vector machine (SVM) classifier is used to evaluate the classification performance based on measured data. Experimental results show the proposed methods are effective and KPCA outperforms PCA. [C436]

"Multi-perspective target classification"

Traditional radar classification is based on a single aspect view of the target. It is remarkably sensitive to the particular direction under which the target is sensed. A network of radars offers means of collecting backscattered radiation of a range of viewing angles. This offers multi-perspective data sets as an aid to improve radar target classification. By definition, this will provide a data set with higher information content. In this paper we examine whether this approach is useful for classification purposes. Results using full scale turntable demonstrate significant improvements in performance over and above the monostatic case. [C437]

"Database generation of bistatic ground target signatures"

Automatic target classification has been an area of active study due to many of its significances. With there advent of bistatic technology in radar, the research into target classification in bistatic scenario seems quite timely. But the study of any classification algorithm demands for a suitable database. Due to the unavailability of suitable field collected bistatic database, computer simulation of such a database is quite pertinent. The present work discusses the approach towards the generation of a similar database, using FEKO as the electromagnetic simulation tool. Various special needs of such a project and the answers of FEKO to those needs, have been discussed. The results conclusively show the suitability of FEKO for the project. [C438]

"Classify of Underwater Target Utilizing Audio Fingerprint"

As well known, because of the complicated watery environment and the limitation of the detecting method, recognizing the underwater target precisely is always a Gordian knot to all countries. In this paper, we designed

a genetic-based classifier system (CS) which recognizes a target utilizes audio fingerprints. Audio fingerprint technology extracts some unique feature from a given sound clip, and the classifier system does some classifying and recognizing works according to those features. In order to improve the performance of the classifier system, we designed some techniques: the comparing and matching algorithm would give the fitness value more explicitly statistical meaning; the hyperplasia operator gives the system persistent learning abilities, the refining classifier merges redundant rules and shrinks the rule set, and an alterable mutation probability increases the speed and the accuracy of the classifying operation. Experiments show that it's competent for the recognition [C439]

"Empirical mode decomposition of micro-Doppler signature"

Micro-Doppler induced by mechanical vibration or rotation of structures in a radar target is potentially useful for target detection, classification and recognition. In order to exploit the time-varying micro-Doppler signature, time frequency analysis techniques are used. However, they can not represent this useful information clearly all the time. In this paper, we introduce a novel algorithm to extract the micro-Doppler signature using a technique called empirical mode decomposition. Both simulation and the experimental results indicate that EMD provides us an effective way to give better time frequency representation of the micro-Doppler signature. [C440]

"Target classification using Gaussian mixture model for ground surveillance Doppler radar"

An automatic target recognition (ATR) algorithm, based on greedy learning of Gaussian mixture model (GMM) is developed in this work. The GMMs were obtained for a wide range of ground surveillance radar targets such as: walking person(s), tracked or wheeled vehicles, animals and clutter. Maximum-likelihood (ML) and "majority voting" decision schemes were applied to these models for target classification. The corresponding classifiers were trained and tested using distinct databases of target echoes, recorded by ground surveillance radar. ML and "majority voting" classifiers obtained classification rates of 88% and 96%, correspondingly. Both classifiers outperform trained human operators. [C441]

"Automatic recognition of MSTAR targets using radar shadow and superresolution features"

Automatic target recognition from high range resolution radar profiles remains an important and challenging problem. In this paper, we present a novel feature set for this task that combines a representation of the target's radar shadow with a noise-robust superresolution characterisation of the target scattering centres derived from the MUSIC algorithm. Using an HMM to represent aspect dependence, we demonstrate that the inclusion of the shadow features results in a significant improvement in recognition performance. We evaluate our proposed feature set on a closed-set identification task using targets from the MSTAR database and show that it results in lower recognition error rates than previously published methods using the same data. [C442]

"Automatic Target Classification — Experiments on the MSTAR SAR Images"

SAR (Synthetic Aperture Radar) can produce target images in range and cross-range with sufficient resolution for recognition. In this paper, we did an experimental test on three different feature extraction techniques (Principle Components Analysis PCA, Independent Components Analysis ICA, and Hu moments) by using different target SAR images taken from the MSTAR database. The performance of these techniques is analyzed. A number of classification techniques, such as Linear (LDC), Quadratic (QDC), K-nearest Neighbor (K-NN), and Support Vector Machine (SVM) are tested and compared for their performance on the target classification. Our experimental results provide a guideline for selecting feature extracting techniques and classifiers in automatic target recognition using SAR image data. [C443]

"Transmission diversity smoothing for multi-target localization [Cradar/sonar systems]"

A new method for target localization by radar or sonar systems based on spatially coded signal transmission is proposed. Recently, it has been shown that spatially-coded signal transmission allows us to obtain virtual sensors. We show that for any array geometry, these virtual sensors are grouped into subarrays with identical structures. The transmission diversity, embedded in the spatially-coded signal model, is used to spatially smooth the signal covariance matrix in order to enable the use of eigenstructure-based methods for multiple coherent target localization. Unlike conventional spatial smoothing and forward-backward averaging, the proposed transmission diversity smoothing (TDS) algorithm is not limited to uniform or symmetric arrays, and does not decrease the array aperture. The performance of the algorithm implemented with MUSIC is tested using simulations and compared to the spatial smoothing method. The results show that the TDS algorithm is consistent and outperforms the spatial smoothing method. [C444]

"Radar high range resolution profiles recognition based on wavelet packet and subband fusion"

Radar automatic target recognition (ATR) using high range resolution profiles (HRRPs) is addressed. A subband fusion structure is proposed based on wavelet packet transforming. Multiple adaptive Gaussian classifiers (AGCs) are built for each subband, and the outputs of each of the subband classifiers are combined to make a final decision. Compared with the traditional wideband recognition approach, i.e., single band approach, the proposed approach can achieve better recognition performance, and is more robust to noise as well. Example results, based on the measured data, show the efficiency of the proposed method. [C445]

"Pattern recognition based on time-frequency distributions of radar micro-Doppler dynamics"

Radar micro-Doppler signatures are of great potential for identifying properties of unknown targets. An effective tool to extract information from the signatures is time-frequency analysis, based on which target identification and object recognition can be extended. In this paper, a method has been proposed for feature extraction and selection from simulated time-frequency distribution of micro-Doppler dynamics. Experimental results have shown that a highly discriminative feature set can be established by using this method. With this feature set, high classification performances both in training and testing stages for different classifiers have been achieved. [C446]

"Analysis of Doppler measurements of ground vehicles"

A moving ground vehicle reflects a coherent radar signal depending upon its range rate, rotations and deviations from a rigid body during the integration time of the radar. The time and frequency representations of the received signal present modulations that in some cases are possible to utilize for classification of different vehicles. The experimental work comprises radar measurements including Doppler registrations from a stationary radar observing moving ground vehicles. The data analysis indicates that essential parts of the Doppler fine structure, visible in front and aft aspects, are related to the dimensions of the track of a tracked vehicle and thereby present the possibility to use this structure for discrimination or classification. The interpretation of the Doppler signature requires the target heading relative to the target direction to be known. [C447]

"Technique for selection of optimum polarimetric angles in radar signature classification"

In this paper an automated technique for adaptive radar polarimetric pattern classification is described. The approach is based on a genetic algorithm that uses probabilistic pattern separation distance function and searches for those transmit and receive states of polarization sensing angles that optimize this function. Seven pattern separation distance functions, the Rayleigh quotient, Bhattacharyya, divergence, Kolmogorov, Matusta, Kullback-Leibler distances, and the Bayesian probability of error, are used on real, fully polarimetric synthetic aperture radar target signatures. Each of these signatures is represented as functions of transmit and receive polarization ellipticity angle and the angle of polarization ellipse. The results indicate that based on the majority of the distance functions used; there is a unique set of state of polarization angles whose use leads to improved classification performance. [C448]

"Non-cooperative target identification of battlefield targets-classification results based on SAR images"

Non-cooperative target identification (NCTI) has become more and more important during the last years. So it is essential to develop robust classification schemes, which can be applied reliably in military operations. The major problems are the clutter (which is not present in air), the unknown target orientation (aspect and elevation angle), the high variability of the target scatterers and the possible multiple variants of the target. In this paper we concentrate on analysis and comparison of classification rates for target identification, the former detection process of the targets in the observed SAR scene will not be discussed. We focus on SAR images of single separated stationary and moving ground targets. To be able to compare our classification results with results published in literature we start our evaluation with the public MSTAR dataset, which is used since many years for ATR evaluation and identification. In addition to this we worked with a second dataset from another field measurement campaign which was performed by QinetiQ, UK. We quantify the influence of some fundamental key aspects on the classification rate. These subjects are target centering (using center of mass algorithms), image segmentation (target, clutter, target shadow), different applied classifiers (nearest neighbour classifier, support vector machines, SVM), the image resolution and the target orientation (knowledge of the aspect angle). Additionally we analyse the influence of clutter and target shadow on the classification rate when using again the MSTAR and QinetiQ datasets. For this purpose the data were segmented in a part containing the target (or target shadow) and another part containing only the surrounding clutter. For the QinetiQ dataset the classification rates drop from 79% to 70% when only the target (separated from the clutter) was used as a feature. The MSTAR dataset shows similar results. Thus obviously the identical background of each of the targets in the test and reference database contributed a lot to the reported high classification rates. That again

shows that realistic expressions on the capabilities of target classification can only be based on independent test and training data. By introducing the image clutter content, ICC, we quantify the influence-of the separated clutter on the classification rate. Furthermore the target shadow can be used for additional information dependent on the depression angle. Finally we come to the conclusion that the main work is not only choosing and applying the classifier, but concentrate on the data collection (that means good data quality), preprocessing and feature extraction processes. [C449]

"Target classification based on micro-Doppler signatures"

In this paper, we propose a Gabor filtering method to extract localized micro-Doppler signatures represented in the time-frequency domain. The dimensionality of the extracted Gabor features is further reduced by using the principal component analysis (PCA) method. Therefore, a suitable classifier can be used for target classification based on their different motion dynamics. In our study, we use simulated radar data. Three different classifiers (Bayes linear, k-nearest neighbor, and support vector machine) are compared and tested. Our experiments show that Gabor features are robust in discriminating micro-Doppler effects of different types of micro-motions, and SVM classifier provides the best performance. [C450]

"Multidimensional superresolution ISAR reconstruction techniques in sea-cluttered environnement"

For high-resolution radars (as the ones used for radar imagery tasks are), sea clutter is difficult to characterize, especially for low grazing angles. According to the physical model of sea surface, the echo signal is best described as the product of a Gaussian process, with rapid variation (the speckle component), and of a slow varying component (the underlying component). The K-compound distribution is used for the statistical characterization of the clutter echo. Standard target complex signature simulations techniques (based on the well-known scattering center model or using geometric primitives) are combined with synthetic sea clutter, allowing us to generate realistic signals. The MUSIC 2D super-resolution reconstruction method, presented in the paper, is used to generate ISAR target images. A comparative study of robustness of MUSIC and Fourier type images is then performed. The obtained results show the validity of both clutter simulation engine and super-resolution reconstruction methods. The problem of naval targets, subject to particular simulation conditions, is also discussed in detail. [C451]

"Vehicle classification by vibration analysis using millimeterwave sensors"

Vibration signatures of battlefield vehicles are strong criteria to discriminate real targets and decoys (Ebert, 2002). To implement vibration detection in a fire control radar system, it is important to analyse the behaviour of vibration signatures over a respective frequency range. This paper shows the first results of a pilot study which analyses vibration signatures of real battlefield targets at 10 GHz, 35 GHz and 94GHz. [C452]

"Pose angular-aiding for maneuvering target tracking"

With high-resolution radar sensors such as HRRR and SAR, ground targets become visible more as a rich set of radar signatures corresponding to the target geometrical details than as a single reflector with an equivalent RCS. This has enabled target classification and identification (ID). As a "by-product" of the target ID process, the pose angles are available. For ground targets, which are constrained to move on the earth surface, their velocity vector direction is aligned most of time along the body's longitudinal axis. As a result, the pose angles carry kinematic information that can be used to aid target tracking particularly during the maneuvering periods. In this paper, we investigate the potential benefits of pose angular aiding and the requirements on pose angular measurements in order to realize such benefits. Simulation results are presented to illustrate the concept and performance. [C453]

"CRLB with Pd"

This paper presents mathematical procedures to calculate the Cramer-Rao lower bound (CRLB) for a target track obtained by fusing two tracks given by two interactive multiple model (IMM) trackers filtering the plots received by two radars. The target under tracking is a ballistic target (BT) in reentry phase and it is assumed that the two sensors could have a detection probabilities Pd less than 1. Accurate BT tracking is required for: (i) impact point prediction, (ii) support to the kill assessment, and (iii) threat classification. Note that, to improve the performance, the method can be extended to the fusion of more than two sensor tracks. The paper is organized as follows: the problem is introduced in section 1; section 2 briefly recalls the models of BT dynamic and of the radar measures. Section 3 presents the tracking algorithm based on the IMM approach; section 4 contains the description of the CRLB evaluation problem and section 5 the results achieved in comparing the fusion of two BT tracks (each track is obtained from the IMM algorithm described in section 4) with the CRLB; Monte Carlo simulations is also used to quantify the fused track accuracies. Section 6 is pertinent to conclusions and follows

on of the activity while references are reported in section 7. [C454]

"Single snapshot signal subspace method for target location"

A signal subspace approach is developed for the passive sensing problem of locating radiation-emitting point sources from a single statistical realization or snapshot of the superposed radiation as detected at a receiving antenna array, and for the active sensing problem of locating point scatterers or "targets" from the multistatic response matrix (MRM) of the targets as measured either by a coincident array of "same transmit/same receive" antennas or by a non-coincident array where different elements are used for transmit and receive. Two applications are emphasized: (1) passive location of M [C455]

"Enhanced detection and classification of buried mines with an UWB multistatic GPR"

We present a resonance-based classification technique for the identification of plastic-cased antipersonnel (AP) land mines buried in lossy and dispersive soils under rough surfaces by a stepped-frequency ultra-wideband (UWB) downward-looking ground penetrating radar (GPR) with an array of receivers. For this application the multistatic ground probing sensor is positioned just above the ground surface and operates from UHF to C-band frequencies. Novel physics-based models based on the finite difference frequency domain (FDFD) technique simulate the characteristic resonating multi-aspect target frequency responses for several realistic buried land mine detection scenarios. Matched filter detection results are presented which assess the GPR's performance in identifying a simulated mine buried under a rough surface at varying depths in dry sand and a dispersive clay loam soil and distinguishing them from false targets such as buried rocks. [C456]

"Reduced-rank signal-dependent classification of training data for space-time adaptive processing"

Nonhomogeneous and nonstationary training data are two of the key technical challenges facing space-time adaptive processing (STAP) for target detection using space-based radar. We describe a technique for training data selection that seeks to classify the available data in a reduced-rank subspace based on the multistage Wiener filter (MWF). The method builds on previous work by allowing each data sample to associate with multiple covariance classes within the separate subspaces defined by the signal and the class, thereby enabling larger sample support for each class. Performance of the new method is assessed using simulated data based on a monostatic space-based radar scenario. Comparison is made with conventional training data selection techniques [C457]

"Time-frequency analysis of polarimetric SAR images"

This article demonstrates the usefulness of time-frequency tools in SAR imagery through two applications. A new method is proposed to analyse moving targets. It uses a two dimensional matching-pursuit algorithm, over a time-frequency dictionary. Point targets speed and scattering characteristics (frequency comportment, angular and polarimetric behaviour) can be retrieved, thus permitting a better knowledge of the target. Urban areas analysis is carried on in a time-frequency framework. The behaviour of pixels in the frequency domain is studied and employed as an input for two new indicators, allowing a classification of urban areas pixels [C458]

"Integrated Marine Mammal Monitoring and Protection System (IMAPS)"

The IMAPS mission is to establish a global solution for protecting the marine environment through the development and implementation of a modular assessment and protection system. The limitations of current technologies are based on them being individually inadequate to fully achieve the mitigation objectives. All the sources of information related to the detection and classification of marine mammals such as active sonar, passive sonar, radar, visual and distribution databases need to be fused to provide a robust protection system. In order to successfully standardize, transport, interface and fuse the information being supplied and requested by the diverse sensor modalities, two essential took of the IMAPS global system are being developed: the Integrated Tracker and the Integration Architecture. The Integrated Tracker employs a data fusion algorithm that combines sensor information to refine estimates of target position, velocity, identity to provide integrated tracking and classification. A data fusion architecture has been chosen and a Bayesian approach for fusion and classification is developed. A data fusion and transport approach has been taken to develop a set of IMAPS prototypes that consist of simulated active sonar, passive sonar, radar and visual modalities communicating in real-time via the Integration Architecture, and to supply the sensor data, and other information necessary for the fusion, to the Integrated Tracker. The main functionality of the Integration Architecture is to provide information transport and common services in the form of a 'plug and play' capability, implemented with a software framework developed upon the Test & Training ENabling Architecture (TENA). The TENA software framework provides for the implementation of common software interfaces to disparate sensor modalities, thereby enabling the integration of different data sources using a common data representation and transport medium. Sensor

outputs such as target detections and environmental information are being transformed in object-orientated data representations that are easily interpreted, manipulated, and interfaced. In addition to the Global IMAPS initiative, the active sonar modality was designed, built, and tested during the MAST 04 experiment producing detect- ions of whales and preliminary synthesis of whale tracks. [C459]

"Emitter Recognition using Fuzzy Adaptation of ARTMAP Neural Networks"

Emitter recognition is the problem of classifying the radar type from intercepted radar signals. This capability is crucial for classifying approaching enemy ships and aircrafts. The sensed parameters may vary from their actual or reported values because of man-made variations in the form of agility or staggering. Another cause of variation could be dispersion because of atmospheric effects and equipment noise. Associating the measured radar parameter set with a known sighting is a pattern recognition problem in a multi-dimensional space. Several authors have attacked the problem with various data association tools with different merits and de-merits. Most of them are marred by the massive computing power required and unrealistically large training data requirements. In this paper a simple but elegant technique is proposed to solve the above problem using well-established framework of fuzzy logic and neural networks [C460]

"The impact of tropospheric propagation on data fusion from multiple radars"

Data fusion from spatially separated radars is increasingly being considered within network centric warfare to mitigate complex threats. Propagation of signals from spatially separated radars through differing atmospheric environments, however, can introduce significant errors in target positioning and ranging. For example, simulations illustrate that two radars separated by 100 km viewing the same single target through different tropospheres could place the single target in positions separated by over 200 m. Attempts at fusing the data and resolving the information into a single object could result in operational deficiencies due to classification and discrimination errors. Additionally, anomalous propagation conditions such as tropospheric ducting can lead to radar coverage holes and hence the perception of faulty radars and system level fusion errors. These errors must be characterized and, as far as possible, eliminated if the operational effectiveness of cooperative radar engagements and capabilities are to be optimized. This paper illustrates the type and magnitude of these errors, and their likely impact on system level fusion. The architecture of a potential correction system is outlined. [C461]

"An evidential model of multisensor decision fusion for force aggregation and classification"

This paper describes airborne sensor networks for target detection and identification in military applications. One challenge is how to process and aggregate data from many sensor sources to generate an accurate and timely picture of the battlefield. The majority of research in data fusion has focused primarily on level 1 fusion, e.g., using multisensor data to determine the position, velocity, attributes, and identity of individual targets. In this paper we present a novel approach to military force aggregation and classification using the mathematical theory of evidence and doctrinal templates. Our approach helps commanders understand operational pictures of the battlefield, e.g., enemy force levels and deployment, and make better decisions than adversaries in the battlefield. A simple application of our approach is illustrated in the simulated testbed OTBSAF and RETSINA system. [C462]

"Vehicle control classification and identification through ISAR imaging"

The great advantages arisen in millimeter-wave frequencies have made possible the development of high range resolution radars. The capability of using high bandwidths (Gigahertzs) increases the range resolution allowing the obtaining of target's radar signatures. Through these signatures some patterns of the targets can be extracted like its size, velocity or maybe some specific features which facilitates its recognition, classification and even identification. The increase in azimuth dimension obtained, like it is explained in this paper, thanks to Doppler processing, allows to get better estimations of the targets characteristics [C463]

"Influence of the magnitude and phase errors on the reconstructed radar images"

Our research work has been focused for several years on ISAR techniques and ATR using superresolution radar imagery. The anechoic chamber of ENSIETA at Brest and the associated measurement facilities allow us to obtain radar signatures for various scale reduced targets and to reconstruct their radar images using a turntable configuration. The paper investigates an aspect which has a great influence on the quality of the reconstructed images. We use two canonical targets, a single sphere and a set five spheres, in order to have perfect control of the target configuration and to make the interpretation of the obtained results easier. The idea of the paper is quite simple and was suggested by some errors in the scattering center positioning we detected on the reconstructed images. Hence, we decided to investigate the influence of the magnitude and the phase of

acquired signatures on the scattering center position estimation. [C464]

"Ground Surveillance Radar Target Classification Based On Fuzzy Logic Approach"

The fuzzy logic approach to the automatic classification of moving target detected by ground surveillance radar is presented in this paper. The real audio Doppler signatures of various targets are analyzed by spectrogram. As a result of analysis, input and output variables with corresponding membership function are defined. The set of fuzzy rules is established. The defuzzification of the output fuzzy set is performed by computing the "fuzzy centroid". The three target classes (walking man, running man and wheeled vehicle) are successfully classified [C465]

"Sonar processing for short range, very-high resolution autonomous underwater vehicle sensors"

In an attempt to improve manual and automated sea mine classification results, autonomous underwater vehicles (AUV) are being outfitted with short-range, very high-resolution sonar sensors. To improve pattern classification results in this regime, artifacts caused by platform motion, sonar beam pattern, and the ocean bottom clutter are first removed from the image. Several preprocessing steps for high-resolution imagery are developed and integrated to help isolate and discover the enduring features of high value targets. Classical denoising, segmentation, and feature-based equalization preprocessing techniques for target localization are adapted and demonstrated. [C466]

"Speckle filtering of polarimetric SAR image and the enhancement for classification"

In this paper, a new approach to speckle filtering of synthetic aperture radar (SAR) data is presented. We define a parameter space consisting of two orthogonal subspaces-the signal subspace and the noise subspace. Then, the full polarimetric information from the signal subspace is obtained after speckle filtering. Moreover, edges of different kinds of targets are preserved. Using polarimetric SAR data, the effectiveness of the proposed method is not only validate by the standard-deviation-to mean ratio, but also by target classification [C467]

"Vehicle detection combining gradient analysis and AdaBoost classification"

This paper presents a real-time vision-based vehicle's rear detection system using gradient based methods and Adaboost classification, for ACC applications. Our detection algorithm consists of two main steps: gradient driven hypothesis generation and appearance based hypothesis verification. In the hypothesis generation step, possible target locations are hypothesized. This step uses an adaptive range-dependant threshold and symmetry for gradient maxima localization. Appearance-based hypothesis validation verifies those hypothesis using AdaBoost for classification with illumination independent classifiers. The monocular system was tested under different traffic scenarios (e.g., simply structured highway, complex urban environments, varying lightening conditions), illustrating good performance. [C468]

"One-dimensional model-based approach for ISAR imaging"

In this paper, we extend the estimation of scattering centre parameters to the case of ISAR imaging. The representation of a target by a set of individual scattering centres has shown promising results for applications where high resolution is needed (high-resolution imaging, classification, NCTR). In practice, methods extract time-delay and amplitude parameters associated with strong scattering sources from complex-valued reflectivity samples in the frequency domain. The principle has been successfully applied with samples from one or several segments. We show that a one-dimensional model can be used to create a two-dimensional ISAR image. After presenting the principle of ISAR matrix data collection and processing, we propose two methods for building the ISAR model matrix. We show that the technique processing the Doppler information first is more suitable for building ISAR-Model. As an example, we consider the case of a corrupted data matrix, which can be restored by coherently processing sparse sub-bands. Samples from a simulated Mig25 are used to illustrate the technique. [C469]

"Using improved SVM decision tree to classify HRRP"

Radar target classification by using high resolution range profile (HRRP) as features has been studied in this paper. Support vector machine (SVM) has been used in range profile classification for its good generalization ability for the pattern classification problem with high feature dimension and small training set. In order to perform multi-class classification, decision-tree-based SVM has been studied. Based on the analysis of the structure and the classification performance of the SVM decision tree, and by introducing the defined separability measure that based on the distribution of the training samples into the formation of the decision tree, an improved algorithm for SVM decision tree has been proposed. The scheme of using the improved algorithm for SVM decision tree to

classify HRRP has been studied. Experiments using the simulated range profile datasets prove the effectiveness of our scheme. [C470]

"A new method of SAR image target recognition based on SVM"

{no data available} [C471]

"An effective method for underwater target recognition"

To recognize the underwater target precisely is always a hard problem to all countries. In this paper, we designed a genetic-based classifier system which recognizes targets utilize sonar fingerprints. Exceptionally some improvements have been designed on it. The proposed Comparing and Matching algorithm would give the fitness value more explicitly statistical meaning, which would make user easier to explain the rules with background knowledge. The proposed hyperplasia operator can handle those instances which were not emerged before. It gives the system persistent learning abilities, so the system may be more compatible with the surroundings. The proposed refining classifier merges redundant rules and shrinks the rule set In addition, an alterable mutation probability is set in the genetic algorithm, experiment shows that this strategy increased the speed and the accuracy of the classifying operation. Sonar fingerprint technology extracts unique feature from an echo, it is similar to that one's fingerprint can identify a unique person himself, dissimilar echo leads to different fingerprint. And all these have none business with the echo's store way (analog or digital) or format (WAV, MP3, WMA, RM, and etc). The proposed underwater target classifier system is highly automatic, with quite finite hardware requirements in operating. [C472]

"Dual-use bistatic multi-frequency HF radar for ship classification and mapping of oceanic currents and vector winds"

We discuss a dual-use bistatic HF radar design using multi-frequency operation over the HF band for ship classification and mapping of ocean current shear. The radar is based on a digital transceiver PCI card family that supports antenna arrays of four to 32 elements in a single PC computer, with larger arrays possible using additional PC. We show measurement and modeling examples of multiple frequency HF radar cross section (RCS) of ships to demonstrate target classification. Results of using 32 frequencies to measure the fine structure in ocean current vertical shear are also shown. [C473]

"On SVM for classification of real and synthetic radar signatures"

This paper focuses on radar target identification using support vector machines (SVM). The radar features used in this study are impulse response features representing the down range profile of the target as seen by stepped frequency radar. The purpose of this paper is to shed additional light on the benefits of SVM in radar target identification (RTI) under various scenarios of adversity that are commonly addressed in the RTI literature. This paper attempts to maximize the performance of SVM in RTI but does not introduce new SVM kernels, or SVM training methods. The focus is on defining the rewards of SVM in target identification assuming a classifier that is presented with time domain signatures representing the target impulse response at a certain azimuth angle. In particular this paper focuses on assessing the SVM classifier performance in different scenarios, which are discussed in this paper [C474]

"Airborne scan mode ISAR imagery of ships using high resolution spectral methods and particle filter"

The basic principle of Inverse Synthetic Aperture Radar (ISAR) imaging consists of performing a Doppler analysis of the signal returned by the target. In the context of maritime surveillance mission, the Doppler analysis, which is usually performed via FFT-based methods, enables to form a profile view of the ship. We propose to form the ISAR image while antenna is scanning via high resolution spectral estimation methods. The goal of using superresolution algorithms instead of Fourier methods is to improve resolution and to remove sidelobe, especially in our context where the rotation of the antenna implies a shorter dimension of the processed signals. We present in this article results of the application of such methods on both synthetic and real data. Next, this paper considers the possibility to track the scattering centers of the ISAR image along the different antenna scans. This technique will allow a better estimation of discriminating parameters in an additional classification step. We propose to use particle filter methods to perform tracking because they are more adapted to the context than Kalman filtering which imposes a linear state-space modelling and a necessarily white Gaussian noise. Preliminary results of these methods will be presented in this paper. [C475]

"Sea SAR image analysis by fractal data fusion"

SAR images from space-borne platforms have proved to be helpful data for identification of oil spills and other surface anomalies, such as low wind areas, man-made targets, and natural films. The use of fractal dimension, which is related to the concept of surface "roughness", as a feature for classification, improves the detection of anomalies, since enhances texture discrimination. In the particular case of oil slicks, the surface tension of seawater is increased and the surface wave motion is significantly depressed. This effect relatively reduces the sea surface roughness, decreases the radar backscattered energy and enables oil slicks to be discernible from the radar image. Several algorithms may be applied for local fractal dimension estimation, but most solutions are tailored for specific applications and are characterized by estimation accuracies depending on the adopted image model and also on the value being estimated. This paper describes a decision-based fusion approach for local fractal dimension estimation of SAR images of the sea surface. Three different estimation algorithms are considered and the three resulting fractal maps are fused by means of a weighted average. The weights are calculated from the performance characteristics of the three algorithms measured on synthetic fractal surfaces. The experimental results carried out on ERS-2 SAR images prove the effectiveness of the proposed decision-based fusion approach [C476]

"Automated texture recognition system based on 2D minimum variance spectral estimation"

The primary feature of any image texture is the spatial frequency content. This paper proposed the use of a 2D minimum variance spectral estimation (MVSE) method for recognizing target multispectral image textures. The power spectral density of the target texture is estimated via MVSE. This estimate is then used as a feature to discriminate between target and nontarget textures. A remotely sensed multispectral image of a row crop agricultural field is analyzed and, the corresponding results are presented to illustrate the applicability of the proposed technique. [C477]

"A hybrid approach for target detection using CFAR algorithm and image processing"

In ship detection, a key aspect is to keep a low level constant false alarm rate combined with a high detection probability in presence of clutter background, caused by reflections from wave tops on the sea, rain, snow or fog. Generally, the constant false alarm rate (CFAR) algorithm is applied, which is based on the assumption that clutter background can be modeled using a Gaussian distribution, generating a high level of false alarms in presence of non Gaussian clutter. This problem has been addressed under two independent approaches: modeling the environment noise (sea clutter) with independent non Gaussian models or using variations of CFAR detection algorithm. Both approaches provide good results only for specific characteristics of clutter. We discuss a hybrid approach for target detection that use three probabilistic models of clutter associated to sea state (Gauss, Weibull and K distributions), detection algorithms with adaptive threshold for CFAR, classification algorithms that associate a noise model with a specific CFAR algorithm according to the sea state, and low level morphological operations to generate an image of targets. The goal of this approach is provide an automatic mechanism to associate a clutter model with a specific CFAR algorithm according to sea state in order to obtain radar images without clutter. The proposed detection approach is evaluated by high level simulation. Results are presented and discussed. [C478]

"Both direction and time of arrival estimation by using beamforming and MUSIC algorithm for stepped FM array radar"

In this research, we propose a method to estimate both direction of arrival (DOA) and time of arrival (TOA) using stepped FM radar system. The method uses beamformer and MUSIC algorithm with respect to time and space. The multiple target f s directions and distances are estimated accurately, and they are combined to represent the parameter of each target. Some simulations are performed and they show the validity of our method. [C479]

"Detection of sea targets from thermal images"

The sea target detection problem from thermal (IR) images is solved by using statistical classification methods. Background modelling is achieved via principle component analysis (PCA) followed by a two-class Bayes classification step, i.e., target or sea. A wavelet-denoising block is added to the system resulting in a significant increase in the detection performance. K-means clustering is also implemented to explore the target detection accuracy without training. It is concluded that the PCA training provides high detection accuracy while the K-means clustering mostly fails to classify sea targets. [C480]

"Estimation of vector miss distance based on source localization"

A vector miss distance estimation algorithm based on source localization is presented. A small antenna array is used for measuring the movement of a target. Phase differences among antennas and range from the target to the origin can be estimated by some modern spectral analysis method, such as ESPRIT or MUSIC. A closed-

form source location estimate is given by the solution of a set of linear equations constructed from the estimates of phase differences and range. Then, by utilizing all source locations estimated from different samples, another set of linear equations is formed and unknown vector miss distance parameters can be estimated. Simulation results are provided to demonstrate the effectiveness and feasibility of the proposed method. [C481]

"Classification of training data with reduced-rank generalized inner product"

Selection of training data for space-time adaptive processing in radar systems remains one of the critical problems to be solved. The practical application of optimal detection theory relies on a large number of i.i.d. training samples. The required homogeneity is typically assumed to be satisfied by range cells adjacent to the cell under test. This is typically not valid in real-world applications. The generalized inner product has previously been proposed to assist in training data selection. This paper introduces two innovations: (1) the generalized inner product in the data-adaptive reduced-rank subspace of the multistage Wiener filter; and (2) classification of the available data into distinct, self-homogenous sets. Injected targets in recorded data from the MCARM program are used to assess performance. Training with data classified within the multistage Wiener filter subspace, also known as the Krylov subspace, is shown to outperform the conventional technique of selecting adjacent training cells. [C482]

"A multiple hypotheses testing approach to radar detection and pre-classification"

This work presents a single-scan-processing approach to the problem of detecting and pre-classifying a radar target that may belong to different target classes. The proposed method is based on a hybrid of the maximum a posteriori (MAP) and Neyman-Pearson (NP) criteria and guarantees the desired constant false alarm rate (CFAR) behavior. The targets are modeled as subspace random signals having zero mean and given covariance matrix. Different target classes are discriminated based on their different signal subspaces, which are specified by their covariance matrices. Performance is investigated by means of numerical analysis and Monte Carlo simulation in terms of probabilities of false alarm, detection and classification. The extra signal-to-noise power ratio necessary to preclassify a target once a detection has occurred is also derived. [C483]

"An M-ary KMP classifier for multi-aspect target classification"

The kernel matching pursuit (KMP) algorithm is re-formulated in the framework of the theory of optimal experiments, using a weighted sum of squared errors as the loss function, and it is extended to the case of M-ary target classification and kernel optimization. The M-ary KMP classifier is applied to the multi-aspect classification of moving targets based on high-range resolution (HRR) radar signatures, for which the target-sensor orientations are assumed approximately known. A multi-aspect processing method is presented based on the use of the estimates of target-sensor orientation angles. The KMP classification results for ten MSTAR targets are presented, with a comparison to corresponding results using the relevance vector machine (RVM). [C484]

"Solid or not solid: vision for radar target validation"

In the context of combining radar and vision sensors for a fusion application in dense city traffic situations, one of the major challenges is to be able to validate radar targets. We take a high-level fusion approach assuming that both sensor modalities have the capacity to independently locate and identify targets of interest. In this context, radar targets can either correspond to a vision target- in which case the target is validated without further processing- or not. It is the latter case that drives the focus of this paper. A non-matched radar target can correspond to some solid object which is not part of the objects of interest of the vision sensor (such as a guard-rail) or can be caused by reflections in which case it is a ghost target which does not match any physical object in the real world. We describe a number of computational steps for the decision making of non-matched radar targets. The computations combine both direct motion parallax measurements and indirect motion analysis- which are not sufficient for computing parallax but are nevertheless quite effective- and pattern classification steps for covering situations which motion analysis are weak or ineffective. One of the major advantages of our high-level fusion approach is that it allows the use of simpler (low cost) radar technology to create a combined high performance system. [C485]

"Target classification based on near-distance radar sensors"

Automotive radar systems offer the capability to measure very accurately target range, relative velocity, and azimuth angle of all objects inside the observation area. For future automotive applications like pedestrian safety systems, collision warning, turning-off and lane-changing assistance it will be necessary to have more detailed information about the target type. Therefore, a target classification technique, which is purely based on the range profile measured by a near-distance radar sensor, is presented in this paper. [C486]

"Joint Doppler and polarization characterization of moving targets"

In through-the-wall imaging radar systems, the synthesized images may not provide sufficient range and cross-range resolution for visual classification and identification of the targets. Target movement and target Doppler characteristics can be used to combat resolution limitations and improve object discrimination. However, slowly moving targets and targets moving perpendicular to the incident waves render target motion ineffective in high-resolution imaging. We utilize the target's polarization properties and introduce time-varying polarization signature estimation based on polarization time-frequency distribution. [C487]

"Ocean clutter suppression using one-class SVM"

This paper presents a new algorithm based on pattern classification technique to suppress ocean clutter of high frequency ground wave radar (HFGWR). We first decompose radar returns as weighted sum of several chirp-like signals and then extract chirp rates and initial frequencies of these chirps to construct the feature space. The support region of ocean clutter in this feature space is calculated by one-class support vector machine (OCSVM). New data that falls inside this support region are labelled as ocean clutter and are discarded. We validate our method by conducting experiments on real radar data. The result shows that the selected features can discriminate between ocean clutter and target echo effectively and our classifier can suppress ocean clutter successfully by defining a fine support region of ocean clutter in that feature space [C488]

"Performance analysis of NNF-class target tracking algorithms applied to benchmark problem"

In target tracking system, accurate target state estimation is required to accomplish efficient radar beam pointing control even in a cluttered environment. State estimation accuracy is degraded by false alarms due to clutters and jamming by intelligent targets. The NNF (nearest neighbor filter) is widely used for tracking a target in a cluttered environment for its computational simplicity. One drawback of the NNF stems from the fact that the selected NN is a false measurement. To improve the performance of the NNF, the PNNF is suggested to consider the probability of the event that the selected NN is the target-originated measurement. The PNNF-m is a new data association with the NN by incorporating the number of validated measurements into design of the PNNF. In this paper, tracking filter algorithms combined with nearest neighbor data association have been applied to the benchmark problem of target tracking algorithms for MPAR (monopulse phased array radar) to compare the tracking performance in the realistic situation where the spatial density of false measurements in the validation region is unknown. Also the performance comparison of the NNF-class filters and the PDAF is included. [C489]

"Minimizing uncertainty in determinants and ratios of determinants for invariant relationships employed in SAR imagery pattern recognition"

Invariant relationships involving ratios of determinants have been proposed for the classification of an object in SAR imagery. The target detection decision-making process depends on the uncertainty involved in the measurements. At fixed experimental resolution, some determinants are simply better than others because they are much less sensitive to uncertainty. A geometrical interpretation of determinants is applied to assess the minimum relative uncertainty expected for a determinant employed in invariant relationships. Because much larger relative uncertainties can occur in some determinants, a method based on the perturbation of eigenvalues is proposed to identify determinants that are less sensitive to element errors. Symmetric alpha-stable probability distribution functions are employed to characterize error distributions in ratios of determinants. [C490]

"A method for characterizing a target in polarimetric radar remote sensing"

A method for characterizing a target is proposed in this paper, based on the eigenvalue decomposition of a scattering matrix. From this method, a set of parameters is derived. The parameters are not only independent of the spans of the scattering matrices, but also independent of the target orientation angles. With these parameters, we enhance the contrast between the road and forest of a SAR image, demonstrating the effectiveness of the proposed parameters. [C491]

"Feature extraction and selection based on ATR of ISAR image"

In this paper, based on auto target recognition (ATR), two kind of feature in ISAR images are extracted: Fourier-transform coefficients feature and wavelet-transform coefficients feature. Three kinds of targets ISAR images were done some recognition study based on the exact nearest neighbor algorithm and those extracted features. Experimental results show these two methods are effective. [C492]

"Influence of magnitude of target range profile on discrimination of baseline-based classifier"

The influence of the magnitude of radar target range profiles on the performance of the classifier based on the baseline method is studied. Then, a novel conception of the factor for magnitude registration is introduced with its formulation presented by the optimization. The computer simulation results show that employing the factor of magnitude registration apparently reduces the matching error and improves the performance of the baseline method. [C493]

"Unsupervised segmentation of the POL-SAR image using similarity parameters in sequential projection pursuit model"

A sequential projection pursuit model (SPPM) for unsupervised segmentation of the polarimetric synthetic aperture radar (POL-SAR) image is proposed in this paper. The features of the high dimension data are extracted out via orthogonal projection and the classification is accomplished by the Bayesian decision rule. Also the similarity parameters of POL-data are expressed as the characters of a target and form new target data. The SPPM utilizes new target data to classify the target into various subclasses. Good-segmented results have been obtained for the POL-SAR image processing. The segmented results using the SPPM are better than that of using entropy-alpha plane. [C494]

"Confusion relationship between patterns and its application in adaptive construction of hierarchical classifiers"

The hierarchical relationship and the objective patterns of subclassifiers is the primary difficulty to construct a hierarchical classifier. In order to solve this problem, firstly, the confusion relationship between patterns has been defined to describe the interweaving effects of patterns in the decision domain. Then a measurement of the relationship has been proposed by utilizing the confusion matrix. Abiding by the Fisher Principle, a multipattern confusion relationship analysis machine (MPCRAM) has been designed to adaptively construct the structure of a hierarchical classifier. Various data scenarios have been used to compare the hierarchical structures generated with the MPCRAM and the conventional ways. The results have testified that MPCRAM was effective, and it could prominently improve the performance of a hierarchical classifier. [C495]

"An efficient Bayesian algorithm for joint target tracking and classification"

It is pointed our in this paper that a more appropriate description of the joint target tracking and classification (JTC) problem would be the simultaneous probability density function (pdfs) of target state and target class instead of the joint target state-class pdf. In this paper, models of different classes are combined info a unified set. The Bayesian optimal JTC algorithm based on pdfs of target state and target class is derived, which integrates a Bayesian multiple-model filter and a Bayesian classifier. Also given is a suboptimal JTC algorithm with much lesser computational complexity, which is suitable for real-time application. Simulation results reveal that the proposed JTC algorithm provides a theoretically attractive solution to a class of joint target, tracking and classification problems. [C496]

"Characteristics of permanent scatterer in coastal area"

We have succeeded in estimating tide height in the coastal area with an r.m.s. error of 5.7 cm by exploiting interferometeric phase and image intensity of JERS-1 SAR data in our previous work. We used an array of oyster farming frames, composed of two vertical poles and one horizontal pole for each frame, as permanent scatterers. In this paper, we investigate the backscattering characteristics of the structure using AIRSAR data and results of experiment in laboratory. AIRSAR polarimetric images show L-band HH- and VV-polarization produce strong returns from the target structures. Classification of L-band polarimetric AIRSAR data confirms the double-bounce scatter is dominant scattering mechanism. Odd-number scatter is, however, not negligible. The ratio of single-bounce to double-bounce scattering depends of the relative radar look direction to the target array and sea surface conditions. Laboratory experiments were carried out using Ku-band according to the target scale. The results of the experiments can be summarized as: i) the structures produce a mixed signal of double-bounce and odd-bounce scatter; ii) the backscattering from horizontal pole is very sensitive to radar look direction; iii) the signals from vertical poles are stronger than that from horizontal pole. From the results, it is concluded that water level change can be most effectively estimated when vertical poles in the water are observed by L-band HH- or VV-polarization [C497]

"Exploration assessment in a petroleum frontier area offshore the Amazon River mouth using RADARSAT-1 images"

The study discusses the use of RADARSAT-1 images to identify oil seepage in the Foz do Amazonas Basin, an oil and gas exploration frontier in the Brazilian Equatorial margin. An unsupervised semivariogram textural classifier algorithm was used to enhance areas of smooth texture and low radar backscatter, indicative of these targets. Complementary information related to cloud top temperature, wind velocity, and modelling for the tidal regime (all obtained as close as possible to the RADARSAT-1 images acquisition) was used to support image interpretation and to exclude false-targets. Together with previously discovered sub-commercial shallow water oil accumulations, the detection of seepage slicks an additional evidence of oil generation in the study area. Results also indicate that radar remote sensing can be used as a tool to reduce risks in the exploration of frontier areas like the Foz do Amazonas Basin [C498]

"Iceberg and ship discrimination with ENVISAT multipolarization ASAR"

Spaceborne synthetic aperture radar (SAR) can provide wide area and all-weather surveillance for iceberg and ship targets. However, the discrimination between icebergs and ships in SAR imagery, especially in the single polarization imagery that has been available over the past decade, is not always reliable. This is especially true when vessel and iceberg size are on the order of the pixel spacing. Present requirements for ocean surveillance with SAR data include a high detection and classification accuracy due to the necessity of comparable performance with other reconnaissance methods, such as aerial. ENVISAT advanced SAR (ASAR) data offers a potential solution to the iceberg-ship discrimination problem. ASAR data has comparable swath and resolution to other operational SAR systems and in addition offers an alternating polarization (AP) mode. AP targets offer more information than single polarization with respect to radar scattering mechanisms. The AP ship and iceberg targets in this study were observed to have considerably different polarization responses. In particular, ship targets in the HH and HV channels were comparable. In contrast, iceberg targets had at best, weak HV responses compared to the HH channel. Two methods for target discrimination were investigated: a multipolarized area ratio and HV signal-to-clutter ratio (SCR). [C499]

"Improvement of polarimetric SAR calibration based on the Quegan algorithm"

The polarimetric cross-talk calibration algorithm proposed by Quegan, which is more general than the one proposed by van Zyl, is modified to improve polarimetric SAR calibration. L-band polarimetric SAR data acquired by the JAXA/NICT airborne Pi-SAR, including a variety of natural and artificial targets, are calibrated introducing noise imbalance of cross-polarized channels into the Quegan algorithm and deriving the cross-talk parameters from areas with low correlation between like and cross-polarized observed echoes. The achieved enhancement in stability of cross-talk parameter estimation and removal over is demonstrated in terms of CR response analysis and polarimetric classification result [C500]

"Multilayer perceptron classification for ENVISAT-ASAR imagery"

This paper describes the application of neural networks to targets classification from multi-polarization ENVISAT-ASAR imagery. The used neural network is multilayer perception (MLP) with fast learning (FL), which is fully interconnected network. Accordingly, the training data sets may be taken from a known truth data in the ground. And finally, the results of proposed method are compared with that of the other classification ones, the in situ test data are from Zhaoqing in Guangdong Province of China [C501]

"Detection and tracking of multiple targets within a three-dimensional medium"

One of today's problems in signal processing is the identification of direction of arrival (DOA). The need for estimating direction-of-arrival (DOA) of energy wave fields within a three-dimensional medium has led to great interest in areas outside of military use. For most real-world applications however, a target tends to lie within three-dimensional medium. A method for detection and tracking of multiple moving targets within a three-dimensional medium has been developed. [C502]

"Proceedings. 33rd Applied Imagery Pattern Recognition Workshop"

{no data available} [C503]

"Application of texture feature classification methods to landmine/clutter discrimination in off-lane GPR data"

Recent advances in ground penetrating radar (GPR) fabrication and algorithm development have yielded significant performance improvements for anti-tank landmine detection in government sponsored blind tests. However, these blind tests are typically conducted over well-maintained homogeneous testing lanes specifically designed to test landmine detection performance in low-clutter population situations. New GPR data collections

over targets emplaced in un-maintained off-lane soils have much higher GPR anomaly populations and provide more stringent tests of landmine detection algorithms. In this work, we focus on the application of feature-based class separation techniques to lower false alarm rates in heterogeneous off-road soils. In particular, we explore the application of texture feature coding methods (TFCM), which have previously shown promise in fields like tumor detection [C504]

"A highly automatic underwater target classifier system"

Due to the complicated watery environment and the limitation of the detecting method to the underwater target, recognizing them precisely is always a hard problem to all countries. In this paper, we design a genetic-based classifier system (CS), which recognizes a target utilizing audio fingerprints. Audio fingerprint technology can extract some unique feature from a given sound clip, and it is similar to that one man's fingerprint can identify a unique person himself, dissimilar sound leading to different fingerprint. All these have none business with the sound object's store way (analog or digital) or format (MP3, WAV, WMA, etc.). Compared with traditional CS, the proposed comparing and matching algorithm would give the fitness value more explicitly statistical meaning, which would make us easier to explain the rules with background knowledge. The proposed hyperplasia operator can handle those instances, which have not been emerged before. It gives the system persistent learning abilities, so the system may be more compatible with the surroundings. The proposed refining classifier merges those redundant rules and shrinks the rule set. In addition, we set an alterable mutation probability to the genetic algorithm in the CS, and the experiment shows that this strategy increases the speed and the accuracy of the classifying operation. We propose a highly automatic underwater target classifier system, and we keep improving it. We expect it can be competent in the recognition with minimum hardware requirements. [C505]

"Support vector machine for HRRP classification"

Radar target identification schemes by using high resolution range profile(HRRP) as features have been studied extensively. In practical systems we usually have only a very limited amount of training data. Therefore how to train a classifier with good generalization performance based on the training set is obviously a challenging task. This paper introduce the newest branch of statistic learning theory, support vector machine(SVM) to range profile classification. The range profiles of two targets were classified by SVM and LVQ (Learning Vector Quantization). Experiment results show that applying SVM to range profiles classification can get higher correct classification rate and better generalization performance. [C506]

"Time-frequency analysis for maneuvering target detection in over-the-horizon radars"

A novel linear time-frequency representation method is proposed for source detection and classification in over-the-horizon radar (OTHR) systems. Of particular interest is the estimation and identification of the multipaths of maneuvering targets described as multicomponent time-Doppler signatures in the presence of strong clutter. By approximating the time-Doppler signatures as chirp signals in each block of time period, chirp signal analysis is used to estimate the chirp parameters (chirp rates and center frequencies) of the clutter and target signal components. Clutter components, which are localized around the low chirp rates and frequencies, are effectively suppressed through subspace projections. The target signals are then dechirped, which is followed by either conventional DFT transform or high-resolution spectrum estimation methods for center frequency estimation. [C507]

"Intelligent target recognition based on hybrid support vector machine"

In this paper we presented a new method of adaptive projective algorithm to improve the speed of SVM classifier. The idea is to pre-extract support vector from training pattern, so that the classification speed is increased with the same performance. Besides this method, the modifying kernel function method is used to achieve high precision approximation. Therefore a novel hybrid support vector machine based on adaptive projective algorithm and modifying kernel functions method for the intelligent target recognition can increase the generalization ability and the speed. It is shown that the radar target data can be classified, and consequently the separability between classes is increased and speed is well improved with this hybrid support vector machine. [C508]

"An application of MUSIC algorithm in no-cooperative passive location"

In this paper, the use of a non-cooperative FM broadcasting transmitter as illuminator for the bistatic radar system was investigated. A signal processing scheme is developed that allows airborne targets to be detected and tracked using the sound carrier of the FM broadcast. This scheme requires no synchronization with the transmitter, and uses MUSIC algorithm to estimate the directions and time delays of several targets from received echoes. The simulation results show that targets can be detected correctly. [C509]

"Multi-targets for high-resolution range profile of radar based on fuzzy support vector machine"

Multi target recognition of high-resolution 1D radar image is proposed in this paper based on the fuzzy support vector machine. The four classes of finite real measured data of radar range profile image are recognized. Better simulation results were obtained compared with the traditional support vector machine approach. It is showed that the improved fuzzy support vector machine has the characteristics of simpler calculation and better testing correctness. [C510]

"Numerical determination of ISAR images of objects modeled with NURBS surfaces"

An application to obtain ISAR images of real targets is presented. ISAR images are obtained by means of two different algorithms FFT and MUSIC. Targets are modeled using NURBS surfaces, which guarantee the use of geometrical realistic models to describe the bodies. [C511]

"High resolution time-frequency distributions for maneuvering target detection in over-the-horizon radars"

A novel high-resolution time-frequency representation method is proposed for source detection and classification in over-the-horizon radar (OTHR) systems. A data-dependent kernel is applied in the ambiguity domain to capture the target signal components, which are then resolved using the root-MUSIC based coherent spectrum estimation. This method is particularly effective to analyze a multi-component signal with time-varying time-Doppler signatures. By using the different time-Doppler signatures embedded in the multipath signals, this proposed method can reveal important target maneuvering information, whereas other linear and bilinear time-frequency representation methods fail. [C512]

"SAR image enhancement for small target detection"

The paper investigates the impact of SAR image enhancement on the performance of small target detection in SAR images. Three SAR image enhancement algorithms are evaluated on large SAR image data-sets. The evaluation results show that image enhancement can greatly improve the performance of false alarm mitigation, and that the level of performance improvement is correlated with the resolution and background suppression of the enhanced images. The higher the resolution and the level of background suppression, the higher the level of performance improvement. [C513]

"Improved HRR-ATR using hybridization of HMM and eigen-template-matched filtering"

A new 1-D hybrid automatic target recognition (ATR) algorithm is developed for high range resolution (HRR) profiles. The proposed hybrid algorithm combines eigen-template based matched filtering (ETMF) and hidden Markov modeling (HMM) techniques to achieve superior HRR-ATR performance. In the algorithm, each HRR test profile is first scored by ETMF which is then followed by independent HMM scoring. The first ETMF scoring step produces a limited number of "most likely" models that are target and aspect dependent. These reduced number of models are then used for improved HMM scoring in the second step. Finally, the individual scores of ETMF and HMM are combined using maximal ratio combining to render a classification decision. The results demonstrate that the hybridization technique achieves improved recognition performance when compared to the independent performances of either ETMF or HMM. [C514]

"STW project "Advanced relocatable multisensor system for buried landmine detection""

Delft University of Technology has just finished its major efforts in a most challenging project, supported by the Dutch Technology Foundation STW. This four-year project entitled "Advanced relocatable multi-sensor system for buried landmine detection" was the largest project in STW history. Within the scope of this project we have built up a unique expertise and knowledge in the whole GPR chain starting from all aspects in GPR technology and finishing with target classification and soil characterization. The paper describes the goals and results within this project. [C515]

"An efficient SAR ATR approach"

Automatic target recognition (ATR) based on synthetic aperture radar (SAR) imagery (denoted as SAR ATR for simplicity) is very important for battlefield awareness. Since SAR images are very sensitive to pose variation of targets, SAR ATR is a well-known very challenging problem. An efficient SAR ATR algorithm is given, which uses KFD (kernel Fisher discriminant) as feature extractor and linear SVM (support vector machine) as classifier. Experimental results evaluated with the MSTAR (moving and stationary target automatic recognition) public data

sets provided by the DARPA/AFRL (Defence Advanced Research Project Agency/Air Force Research Laboratory) show that the proposed scheme performs much better than the conventional template matching and SVM methods, especially when the target pose uncertainty is large, which is desirable for SAR ATR. [C516]

"2003 Proceedings of the International Conference on Radar (IEEE Cat. No.03EX695)"

First Page of the Article [C517]

"The SSCM for ship characterization using polarimetric SAR"

Ship characterization is investigated using the symmetric scattering characterization method (SSCM), which was introduced by Touzi and Charbonneau (2002). The SSCM method appears to be very promising for ship identification. Identification of ship targets with significant symmetric scattering is shown to lead to accurate pitch measurement, under certain conditions. [C518]

"Radiometric normalization of optical remote sensing imagery"

Sensor viewing angle effects, which are caused mainly by an atmosphere and a sun-sensor-target geometry, are observed quite often in images acquired by optical remote sensing sensors, especially airborne sensors with a wide field of view. We propose an image-based empirical radiometric normalization method, which is based on a linear regression applied over linear models between the observed radiance and the target radiance for each surface class separately. The experiments for data acquired by airborne multispectral scanner DAEDALUS AADS 1268 ATM show the effectiveness and potential of the proposed method especially for the mosaicking and classification applications. [C519]

"Dual use multi-frequency radar for current shear mapping and ship target classification"

A new radar is in final stages of development and testing by Imaging Science Research (ISR), Inc., sponsored by the Office of Naval Research. The system is based on digital receiver technology incorporated into a PC operating environment. A digital receiver eliminates the need for many radio frequency analogue components, providing more robust temperature-insensitive operation and lowers hardware costs. The digital approach allows operation beyond the High Frequency (HF) band, which occupies 3-30 MHz, and our current plan is to cover 2-55 MHz with a single system. The system can be tied to our ISR Rubidium Clock option, allowing bistatic operation using a single receive array and processing station with multiple transmit sites, for vector measurements of velocity. Here we provide a description of our digital transceiver, our radar block diagram, and our transmit and receive antenna arrays. Measurements of the radar cross section (RCS) of small boats are presented, based on work done by the author in the mid-70's, suggesting that ships and small boats can be classified based on their RCS radar frequency spectral properties. Results from a pilot experiment are displayed, demonstrating multi-frequency operation using 32 radar frequencies over the HF band. [C520]

"The statistical analysis of SAR target based on the correlation algorithm"

Utilizing MSTAR measured target data, we analyze statistical trend in the entire measurement training set every 1 deg in azimuth based on correlation algorithm. After segmentation and normalization, each test image was correlated with all the training images to generate correlation and classification statistics and correlation plots. The correlation plots varied approximately sinusoidally with aspect, and all the training sets show that a target was highly correlated at both the correct aspect angle and the correct angle rotated 180 deg, and this two correlation scores corresponded to the two local amplitudes of the correlation plot. [C521]

"Polarimetric time-frequency distributions and applications to radar imaging"

We introduce the polarimetric time-frequency distribution (PTFD) and consider its applications to radar imaging applications for polarimetric Doppler signature estimation and source discrimination. The PTFD integrates polarization with time-frequency analysis, specifically bilinear transformations. It exploits the time-varying nature of both polarization and frequency for improved target identification, classification, and characterization. [C522]

"Direction angle estimation of moving targets by applying MUSIC to the outputs of quadrature mirror Doppler filter bank"

In radar signal processing, it is important to separate multiple targets that are covered in same radar antenna beam and in same range bin. It is also important to measure the position of each target. This paper proposes a new angular measurement system by applying MUSIC (multiple signal classification) to the outputs of Doppler filter bank consisting quadrature mirror filters. Some numerical experiments show that the proposed method can

estimate the angles of moving targets at high speed, even for coherent targets and under low signal-to-noise ratios. [C523]

"Targets classification of semi-arid region using polarimetric SAR data $an example in Xinjiang, China"

This paper develops a classification way using polarimetric synthetic aperture radar (SAR) data. Polarization of radar electromagnetic wave is a very important factor of backscattering theory and geosciences applications. However, polarimetric SAR images are still difficult to interpret and therefore there is a need to improve the classifier that can make use of the polarimetric information. Under the certain circumstance the present paper attempts to classify remotely sensed scenes by all the complete polarization response parameters, which are presented as data dimensions for classification arithmetic. The test site is located in Hetian of Xinjiang, China. SIR-C data were acquired in the test site in 1994. Fully polarimetric SAR data can be processed as multi-dimensions images. But the polarimetric information is related greatly with variable targets. Firstly, we decompose the backscattering matrix and get polarimetric ratios, polarimetric degree, and polarimetric entropy. These polarimetric parameters are considered as data dimensions in which elements change in terms of probability functions with variable targets. Training samples were then generated from the outputs of the unsupervised classification of K-means, to be used in subsequent supervised classifications of two frequencies (C- and L-band for SIR-C data) and various polarization combinations. The estimation of the classifier tallies with the local municipal statistics. The result shows that classification precision can be improved finely with the polarimetric technique. [C524]

"Improved polarimetric SAR classification by application of terrain azimuth slope corrections"

In polarimetric SAR imagery, along-track or azimuth slopes cause a shift in the polarization orientation angles. By estimating the orientation angle shift, Schuler et al. have been able to generate topographic models in good agreement with DEMs produced by other means. An improved method for estimating the orientation angle was developed by Lee et al. along with a unified analysis of available techniques. Another way to view this work is as a means of correcting the polarimetric SAR imagery for the terrain-induced slope effects in order to improve the accuracy of geophysical parameters derived from the SAR imagery. In this paper the techniques of Lee et al. are used to correct C and L-band polarimetric AIRSAR imagery taken in 1996 over the flanks of Mt Tongariro, New Zealand. We then use the corrected and uncorrected data in classification schemes and compare the results to demonstrate the effects of the azimuth slope corrections. The volcanic Mt Tongariro provides a rich variety of surface slopes, and a variety of vegetation is present including exotic forest, native forest, scrub, grasses and bare ground. Class statistics extracted from fore- and back-slopes (in the azimuth direction) are observed to cluster more tightly than for uncorrected data. This effect is more pronounced for L-band than for C-band. The largest effects were seen in targets of low polarisation entropy such as exotic forest. These corrections result in a modest improvement in the overall classification accuracies. [C525]

"Scattering signatures analysis using genetic algorithm"

A real-valued genetic algorithm is proposed as a means of extracting one-dimensional scattering centers. In terms of the extraction of scattering signatures from noise-corrupted data, the genetic algorithm has been compared to the state space approach, and the results show that this method has higher-noise immunity. [C526]

"Improving the radar target classification results by decision fusion"

The need for decision fusion appears when the classification results obtained using only one target signature are poor and have to be improved. Our idea was to use four target signatures corresponding to various polarization combinations in order to make the final decision more robust and more effective. The fusion method is based on the Sugeno's fuzzy integral and has some important advantages over the traditional methods like the vote technique. The method is validated on both synthetic and real data obtained in the anechoic chamber of ENSIETA from Brest, using four scale reduced target models. Some perspectives are finally presented for integrating also the radar imagery results into the fusion process in order to better assist the human operator to make the most appropriate decision. The main application of our research work is related to the enhancement of the airborne traffic surveillance by avoiding any confusion and increasing the flight safety. [C527]

"A Doppler-based target classifier using linear discriminants and principal components"

This paper describes the design of the automatic target classifier which has been introduced into the AMSTAR battlefield surveillance radar. It discusses the requirements which have driven the design of the classifier, the data which is used to make the classification, the choice of linear discriminant analysis as the classification technique and the use of principal components analysis to simplify the training of the discriminator. It also

discusses the testing of the classifier and the performance achieved. [C528]

"Experimental results on marine targets classification with surveillance HRR by means of non coherent techniques based on hot spots accurate location"

In this article, the experimental results are presented of applying a new non coherent and non statistic technique that allows us to endow the coastal surveillance high resolution radars (HRR) with a significant capacity for target classification and identification; making possible the estimation of their size, and also obtaining information about their structure by analyzing the intensity and position of their hot spots. The HRR used to obtain the experimental results is the ARIES, a surface marine radar able to transmit signals of almost 500 MHz of instantaneous bandwidth. [C529]

"Integrated maritime surveillance: protecting national sovereignty"

Protection of national sovereignty requires the ongoing, systematic collection of data from a range of sensors and other sources and the assembly and maintenance of a picture of the position, classification, identification and movement of cooperative and non-cooperative ships, aircraft and hazards in the exclusive economic zone. Integrated maritime surveillance maintains a continuous and affordable real-time picture of ship and aircraft tracks to beyond the 200 nautical mile limit of the EEZ using land based HF and microwave radar systems. The system associates ancillary data from other sources to provide a knowledge-based "recognized maritime picture" and the most effective surveillance of all significant targets within the EEZ. Overlays of GIS referenced data such as sea-state, currents, ice, water temperature, phytoplankton, etc., can be included to support the deployment of air and surface assets and maximize their effectiveness in dealing with fisheries protection, drug interdiction, illegal immigration, terrorist threats, search and rescue and other aspects of national sovereignty. [C530]

"Superresolution ISAR imaging of maneuvering targets via subspace tracking"

For the problem of ISAR imaging of maneuvering targets, the Doppler frequency shifts are time-varying and range migration may still happen even after the motion compensation due to the complex motion of targets. Sliding window MUSIC algorithm based on a computationally efficient subspace updating method which takes advantage of the URV decomposition is applied to solve this problem. The effectiveness of this algorithm is shown by presenting and discussing some simulation results. [C531]

"Automatic target recognition of ISAR object images based on neural network"

In this paper an integrate approach of automatic target recognition is proposed with a three-feedforward neural network. It includes images pre-processing, feature extraction and automatic target recognition and classification of ISAR object images. Using the log-spiral transform after moving the centroid of ISAR images to the original point makes the target recognition invariant on translation, rotation and scale. The approach improves the ratio of accurate recognition and reduces the amount of calculation. The results of experiments with field data show that the approach is effective. [C532]

"Performance evaluation for modern radars"

Modern radar systems are procured with tight specifications on a large number of different parameters. It is in the interests both of the customer and of the supplier that the procedures used evaluate radar performance are mathematically rigorous, precise and as cost-effective as possible. This paper describes some methods of evaluating the performance of different modes of modern radar system and discusses the accuracy of which they are capable. The important place of modeling within these methods is emphasized. [C533]

"Characterization of symmetric scattering using polarimetric SARs"

Cameron's coherent target decomposition (CTD) and classification are discussed in the context of SAR, and the limitations of Cameron's classification are examined. It is shown that these methods may lead to a coarse and misleading scattering segmentation because of the large radiometric dispersion tolerated in each of the elemental scatterer classes, as well as the implicit assumption on the coherence nature of target scattering. A new method, named the symmetric scattering characterization method (SSCM), is introduced to better exploit the information provided by the largest target symmetric scattering component, under coherent conditions. The SSCM, which expressed the symmetric scattering in term of the Poincare sphere angles, permits a better characterization of target symmetric scattering and the generation of coherent scattering segmentation of much higher resolution, in comparison with Cameron's segmentation. [C534]

"Tradeoffs between quality of results and resource consumption in a recognition system"

The implementation of computational systems to perform challenging operations often involves balancing the performance specification, system throughput, and available system resources. For problems of automatic target recognition (ATR), these three quantities of interest are the probability of classification error, the rate at which regions of interest are processed, and the capabilities of the underlying hardware (which is a function of the available computational resources and available power). An understanding of the inter-relationships between these factors can be an aid in making informed choices while exploring competing design possibilities. Combining characterizations of ATR performance, which yield probability of classification error as a function of target model complexity, with analytical models of computational performance, which yield throughput as a function of target model complexity and available resources, we can form a set of parametric curves which relate the quality of the results to the resources consumed. [C535]

"Data fusion of multiple polarimetric SAR images using discrete wavelet transform (DWT)"

Data fusion is a very effective technique which can be applied to many remote sensing areas such as classification, monitoring of environmental surveillance and man-made target tracking. In this paper, we tested fusion of multiple frequency (C-, and L-band), multiple polarization (HH, HV and VV) and multiresolution data sets. One can obtain a polarimetric SAR data after enhancing spatial resolution through the image fusion process. In order to fuse multiple SAR data and high spatial resolution data, they have to be geometrically co-registered over the same target area and have the same pixel size (spatial registrations). At this stage, we used the nearest neighbor resampling to avoid spectral distortion by interpolation. Multiresolution polarimetric SAR image fusion was performed using the multiscale image fusion technique-discrete wavelet transform after spatial registrations. To evaluate the spectral fidelity of fused polarimetric SAR data, spectral dissimilarity was calculated at each wavelet decomposition level. The resulting classification map based on polarimetric feature vectors shows better class separation after application of fusion processing than without fusion. The polarimetric SAR data over the Gong-ju areas, tested in this research, were acquired during NASA/JPL AIRSAR PACRIM-II experiment in 2000. [C536]

"Improving neural classifiers for ATR using a kernel method for generating synthetic training sets"

An important problem with the use of neural networks in HRR radar target classification is the difficulty in obtaining training data. Training sets are small because of this, making generalization to new data difficult. In order to improve generalization capability, synthetic radar targets are obtained using a novel kernel method for estimating the probability density function of each class of radar targets. Multivariate Gaussians whose parameters are a function of position and data distribution are used as kernels. In order to assess the accuracy of the estimate, the maximum a posteriori criterion has been used in radar target classification, and compared with the k-nearest-neighbour classifier. The proposed method performs better than the k-nearest-neighbour classifier, demonstrating the accuracy of the estimate. After that, the estimated probability density functions are used to classify the synthetic data in order to use a supervised training algorithm for neural networks. The obtained results show that neural networks perform better if this strategy is used to increase the number of training data. Furthermore, computational complexity is dramatically reduced compared with that of the k-nearest neighbour classifier. [C537]

"Segmentation and classification of multitemporal data: methodology and results of a modified Gaussian Markov random field model classification system"

Constructive and destructive interference have long been a significant problem for the classification of radar imagery. Several authors have noted the ability of segmentation to work around the problem by incorporation of spatially adaptive filters and fuzzy logic. We present the methodology and results of such a study using multitemporal datasets in the place of multispectral data. For the study 27 standard and ScanSAR images were collected over the region from 1996 to 2001. The majority of the images were S4 ascending, with ScanSAR narrow collected simultaneously. The ScanSAR images allowed us to assess the methodology over a wider swath, yielding results on a regional rather than local scale. Northern Australia exhibits an extremely seasonal climate. The monsoonal nature of this climate means a huge variation in the amount of available water to plant life both on and surrounding the flood plains of the major river systems. Within this area is Kakadu National Park, a heritage listed and Ramsar identified wetland of international significance. Kakadu has a long history of scientific study, and is an ideal site on which to conduct studies such as this. The seasonal nature of this area presents a unique opportunity, that of a worst case scenario for classification schemes, whereby each location on the flood plain undergoes significant change over the seasonal cycle, similar in many respects to the change between bands of a multi-spectral dataset. A modified Gaussian Markov random field model segmentation routine was used to cluster areas exhibiting similar radar response (both numerical and textural) at each successive date in the time series. For each date cluster statistics were then generated. This allowed the

construction of temporal curves due to the fact that as the target material dries the material's dielectric constant decreases. As dielectric constant is significantly dependent on water content, these temporal curves act as a proxy measure for water availability, and hence aid in the discrimination of wetland from non-wetland areas and any change in size and location of these areas throughout the season. The output of the segmentation routine is a series of three bands. The first and second bands are the statistics (mean and standard deviation) of t- he original image and the third a vector file of the edge locations. By outputting statistical information instead of arbitrary segment number standard classification routines may be used successfully on radar imagery. Classification of the results of the segmentation may be either supervised or unsupervised, however analysis indicated that the Isodata algorithm adequately addressed classification needs. As a combined system the segmentation and classification system used in this paper has shown some excellent results when applied to multi-date radar imagery of Kakadu National Park in Northern Australia. Results for a segmentation of multitemporal radar dataset are presented alongside the results of the subsequent classification. By creating a system that requires minimal user input a wide variety of applications may be addressed. Indeed, the registration of the imagery becomes the most user intensive portion of the process. Automated routines such as this allow for analysis of large areas on a regular basis, an exceptional result for monitoring change and establishing baselines for later comparison. [C538]

"Velocity estimates from fully polarimetric SAR"

Fully polarimetric SAR data provides sufficient information so that some level of feature attribute classification, is usually possible for signatures found in these images. In particular, polarimetric analysis can provide structural information from SAR image signatures for some target types Additionally, although not commonly recognized, there is evidence that polarimetric SAR data collected from systems similar to the C/X SAR (and the future RADARSAT 2) can also provide velocity information. This velocity information is not an attribute of the polarimetric ellipse information, but rather a consequence of the system's data acquisition method and the provision that the reciprocity relationship is assumed. Here, an example is presented which indicates that this velocity information is likely available in polarimetric data. This capability has great potential for classification purposes, since both velocity and structural properties of an imaged feature may be deduced from the same data acquisition. While the velocity estimates may have some limitations compared to Along-Track InSAR systems, this information is readily available from fully polarimetric SAR systems, such as the future RADARSAT 2. [C539]

"Nonlinear synthetic wideband waveforms"

Radars commonly use wide bandwidth pulses to attain high range resolution. However, when such wideband pulses are unavailable (or otherwise undesirable), high range resolution can still be achieved by coherently combining a sequence of narrowband pulses spanning the desired bandwidth. Collectively, such narrowband pulse sequences are said to compose a "synthetic wideband waveform" (specific variants are also known by the names "stepped frequency waveform", "frequency jump burst" and "frequency jump train"). Prior publications and reports have examined synthetic wideband waveforms that distribute energy uniformly over the frequency band. Such waveforms require heavy spectral weighting, highly overlapped pulses and/or nonperiodic pulses to control the range sidelobes and grating lobes; unfortunately, undesirable attributes are associated with each of these. We formulate synthetic waveforms that distribute energy nonuniformly over the desired frequency band. These new waveforms are shown to offer improved performance (i.e., lower range sidelobes, higher gain, higher range resolution and/or reduced grating lobes) when compared with traditional approaches. [C540]

"Direction/time of arrivals (D/TOA) estimation characteristics of the MUSIC algorithm for the actual extended targets of the chirp pulse tracking radar"

This paper proposes the time space MUSIC technique using the chirp pulse signal of a tracking radar. Direction/time of arrival (D/TOA) estimation characteristics are evaluated for the simulated point sources, simulated extended air targets, and the actual extended air targets. It is shown that the proposed technique is enable to highly resolve and precisely estimate D/TOA of the actual targets covered by one radar beam width. [C541]

"An optimal integrated tracking (ITS) for passive DOA tracking using unscented Kalman filter"

In this paper, a new algorithm is presented to adaptively estimate the direction of arrivals (DOAs) of multiple moving targets when linear equispaced sensor array is used for making the measurements. This algorithm is based on an extension of differential MUSIC method. It can also discriminate sources and their multi-paths. The results obtained by this algorithm are then applied as input to a nonlinear state linear measurements unscented Kalman filter. The unscented Kalman filter is also adapted to maneuver the target tracking. This algorithm gives 50 percent reduction in the computation and memory requirements over an unscented filter based tracker. [C542]

"A super-resolution locationing algorithm for ultra-wideband phased-array radars"

Super-resolution direction finding algorithms such as MUSIC or ESPRIT methods inherently assume narrow-band signals, which are not applicable to ultra-wideband radars such as GPR (ground penetration radar). We developed a time-domain algorithm to determine the time and direction of arrival pulses with an order higher resolutions than the nominal resolution determined by the aperture size. The received signal waveform at each array element is first analyzed by the recursive nonorthogonal decomposition using a dictionary of basic waveforms. After the delay time of the echoes in each element of the receiving array is determined, the number of targets and their locations are determined by analyzing variation of the delay time over the array with the aid of a Hough transform. The robustness of the proposed algorithm is confirmed by numerical simulations. [C543]

"Feature analysis using millimeter-wave real beam and Doppler beam sharpening techniques"

A challenging problem in digital signal and image processing is that of automatic target recognition (ATR) and object classification. In defense operations in particular, rapid object discrimination is critical. While this problem has been studied extensively, it remains a challenge, due to the complex and time-intensive methods of typical approaches. This study involved constructing features from the range profile signal returns, identifying the "best" set of features and performing ATR. Confusion matrices are presented for the targets of interest for simulation. Although the selection techniques for the features were not optimized, the results for ATR are promising [C544]

"Application of polarimetric synthetic aperture radar interferometry for land cover classification"

The development of radar polarimetry and radar interferometry is advancing rapidly. The textural fine structure, target orientation, system metrics and material constituents can be recovered with radar polarimetry; while with radar interferometry, the elevation structure of a target can be explored. Polarimetric synthetic aperture radar interferometric (Pol-InSAR) is interferometry between all possible polarization channels at each end of the baseline. Using polarimetric interferometry, the combination of the final structure properties and the spatial information of targets can be implemented. In this paper, we investigate the application of these three approaches to Earth terrain classification with results from the evaluation of fully polarimetric interferometric SIR-C/X-SAR data. The potential of Pol-InSAR for land cover classification has been demonstrated. [C545]

"A particle filtering approach to FM-band passive radar tracking and automatic target recognition"

We present two stochastic filters for an FM-band passive air surveillance radar. The first system uses an extended Kalman filter and delay-Doppler measurements to track targets. The second system uses a particle filter to simultaneously track and classify targets. Automatic target recognition is made possible by the inclusion of radar cross section (RCS) in the measurement vector. The extended Kalman filter cannot take advantage of radar cross section measurements because there is no closed-form relationship between the state elements which determine target aspect and the resulting RCS measurement. We believe that this is the first work to propose the use of RCS for the purpose of target recognition within a passive radar system. We also present many simulation results for a challenging 2-target 3-sensor task involving trajectories which nearly coincide for a portion of their track length. [C546]

"Improvement of high frequency ocean surveillance radar using subspace methods based on sea clutter suppression"

We present a new direction finding scheme for slow targets embedded in sea clutter that combines subspace methods (MUSIC and Root-MUSIC) and time domain sea clutter and noise suppression. The ocean surface behaves as a distributed source in contrast to ships that are point sources. By mapping data to eigenspaces, the sea clutter level decreases due to its non-deterministic behavior while point targets' levels remain unchanged while enhancing estimation performance. Since subspace methods have a higher threshold and are degraded heavily by the correlated sea clutter, clutter and noise suppression is introduced to enhance algorithm performance. Both simulated and real ship targets are used to show the lower threshold and higher estimation performance of the proposed algorithm. [C547]

"Bottom mounted active sonar for detection, localization, and tracking"

A bottom-mounted, wideband active sonar system designed to detect unfriendly vessels entering a closed area is described. We present signal processing algorithms for target detection, classification, localization, and tracking, and present performance predictions based on simulations. These algorithms are shown to be effective with state of the art, realizable sonar systems. The signals are binary phase shift keyed (BPSK) with a range resolution of approximately 0.01 m and Doppler resolution of 0.5m/s. Received signals from multiple directional

receive beams are basebanded and Hilbert transformed to obtain complex representation. These signals are correlated with replicas of the transmitted signal time compressed or dilated to represent a number of different hypothetical target Dopplers, giving a processed signal with three dimensions: time, channel, and target Doppler. Background interference is estimated using a block-transversal filter. The processed signal is divided by the estimated background to obtain signal-to-interference ratio (SIR) and SIR threshold crossings are detected and contiguous detections are clustered. Range is estimated using arrival time. Bearing is estimated using amplitude comparison for adjacent receive beams. Elevation is estimated using split beam phase between signals from elements separated vertically. Finally, the crossings are clustered by location and Doppler. Clusters are classified based on amplitude and estimated physical extent and shape. Clusters with sufficiently high classification are passed to a tracking algorithm that computes a Kalman filter track using clusters derived from sequential transmissions. This filter operates using linked line of sight (LOS) coordinates, a technique long used in radar. The LOS coordinates used in this application are range, range rate, bearing, and elevation. Use of such coordinates is advantageous in this application because the errors in the coordinates are nearly independent of one another. Performance of this algorithm was investigated using active acoustic signals synthesized by the Sonar Simulation Toolset (SST), a digital program written by Robert Goddard at the Applied Physics Laboratory. This program generates a complex baseband representation of the acoustic signal in each chan- nel. This signal is processed by the detection, classification, and tracking algorithms. SST simulates effects of acoustic propagation including refraction and scattering and reflection from a target. Several simulated encounters with different target geometries are presented to illustrate detection, localization, and tracking performance. [C548]

"Radar targets identification based on perfect parametric modeling using artificial neural networks"

In this paper, we have developed a new target recognition procedure. In order to efficiently obtain feature vectors for target discrimination, the closed-form expression of geometrical wave front have been derived to provide efficient and accurate computation. The resulting small dimensional feature vectors based on the developed extractor are identified using the well-known ANN classifier. The results show that the presented scheme gives successful correct automatic target recognition (ATR) in the low SNR with low computational costs. Although this work concentrates mainly on parametric modeling of electromagnetic target, further work should study more efficient ANN architecture when the number of candidates is dramatically increased in the practice. [C549]

"Joint optimal Tx-Rx design for multiple target identification problem"

A design methodology for jointly optimizing the transmit waveform and receiver filter for multiple target identification is presented. The methodology is applied and illustrated for various multi- 'target' ID problems. The resulting probability of correct classification is significantly better than that achieved by a conventional chirp or any other waveform. Unlike the classical radar case, the choice of transmit pulse shape can be critically important for the identification of extended targets in presence of additive channel noise. [C550]

"Neuro-fuzzy pattern classification model with rule extraction based on supervised learning"

The main objective of this paper is to design a new method for generating fuzzy rules for pattern classification. To start with, separation hyperplanes for classes are extracted from a trained neural network. The convex existence regions in the input space for each class is approximated by shifting these hyperplanes in parallel using the training data set for the classes. Using the fuzzy rules the numerical input data is classified directly without the need of neural networks. The proposed method is verified for target recognition using radar cross section signals. [C551]

"Environmental representation for fused millimetre wave radar and nightvision data"

This paper presents a method for the fusion of millimetre wave radar and nightvision sensors to generate an information-rich representation of the environment. The data from each of the sensors is divided into unstructured spatial objects according to the data available to that sensor. A hyperdimensional representation then constructed from these objects, with the observable characteristics providing the axes. This representation can then be provided to target extraction, classification and tracking algorithms to achieve advanced machine sensing and perception tasks. This differs significantly from the traditional approaches to this problem in which target identification is completed for each individual sensor and these estimates are then combined. The results of initial field trials are used to demonstrate the feasibility of this approach. [C552]

"Theory of search for moving objects"

The objectives of the paper are a development of a system of rules called "theory of search for moving objects", and a development of a new class of search problems for moving objects within the frames of this system, rather than a selection, classification or enumeration of all published articles, manuals, monographs, tasks statements

and other in the theory of search area. The following issues are considered in the paper: (1) analysis and classification of search problems; (2) an axiomatic basis of the research approach; (3) axioms of the theory of search; (4) common theorem of additivity; (5) theorems of multiplicity; and (6) computer prototype for the theory of search. The case of a complex observation system integrated within one carrier is a core of the proposed approach. A case of two different observation systems is considered, when an observation zone for the second system (contact detector like a laser) is approximated as a line or a rectangle. It is possible to determine a probability area of target localization when one or both observation systems detected the target (theorem of multiplicity). A computer prototype of the theory of search for moving objects has been designed based on the object-oriented approach. It appeared to be a useful tool for any theoretical research and a flexible media for the further development of the theory of search for moving objects. It is also shown that it can be implemented for an adequate computer interpretation of search problems. [C553]

"Underwater target identification using GVF snake and zernike moments"

This paper is focused on the development of robust object segmentation and shape-dependent feature extraction methods for automatic water target classification and identification using electro-optical imagery data. The sensor used for acquiring the data is the Streak Tube Imaging Lidar (STIL) that offers both range and contrast images with high resolution. In this paper, the gradient vector flow (GVF) snake is employed to segment the detected objects. The snake converges to the actual object boundary and provides a closed contour of the object even when some of the edges are missing. To reduce the distortion as a result of missing edges, the union of the binary silhouettes for contrast and the range images is obtained. Zernike moments are then computed for the combined silhouette of the segmented object. These moments provide shape-dependent features with high discriminatory ability, which are invariant to object rotation, translation and size scaling in the image. This set of features is then used for target identification from the STIL imagery data. To aid discrimination of different objects with potentially similar shape dependent features, mean and variance of the contrast and range images are also computed within the closed contour and then used as additional features for classification. Then the extracted features are applied to a multi-layer back-propagation neural network (BPNN) that performs target classification/identification. Different neural network structures are tried to determine the optimum classifier. The effectiveness of the developed algorithms is demonstrated on several data sets and the corresponding confusion matrices are also developed. [C554]

"Bayes-optimality based feature transform for high resolution range profile identification"

Many feature transform methods have been used for radar target identification. But most of them are based on scatter matrices or other statistics of the data, which do not directly correlate to classification accuracy. In this paper, a Bayes-optimality based adaptive feature transform method is proposed for radar target identification using high resolution range profile results show that this method is effective on radar target identification. [C555]

"A robust Doppler classification technique based on hidden Markov models"

A classification algorithm is presented that uses hidden Markov models (HMM) to carry out recognition between three classes of targets: personnel, tracked vehicles and wheeled vehicles. It exploits the time varying nature of radar Doppler data in a manner similar to techniques used in speech recognition, albeit with a modified topology, to distinguish targets with different Doppler characteristics. The algorithm was trained and tested on real radar signatures of multiple examples of moving targets from each class and the performance was shown to be invariant to target speed and orientation and was able to generalise with respect to variants within a class. [C556]

"The stability of polarimetric features for target classification from SAR imagery"

This study investigates the information content of polarimetric SAR imagery for use within automatic target detection and classification algorithms. Key questions such as the stability of polarimetric information and its relationship with image resolution are addressed. Using relatively simple polarimetric features, such as the percentage of pure odd and even bounce scattering events, we show how it is possible to identify the differences between two classes of military vehicle. The use of the radial power spectral density is proposed as a measure of the spatial distribution of these odd and even bounce scattering events, again enabling the two classes to be distinguished. [C557]

"Fractal dimension estimation using modified differential box-counting and its application to mstar target classification"

First Page of the Article [C558]

"Bistatic synthetic aperture radar"

Synthetic aperture radar (SAR) is becoming increasingly important in many military ground surveillance and targeting roles because of its ability to operate in all weather, day and night, and to detect, classify and geolocate objects at long stand-off ranges. Bistatic SAR, where the transmitter and receiver are on separate platforms, is seen as a potential means of countering vulnerability. This paper provides an overview of QinetiQ's on-going research into the processing techniques for bistatic SAR, the fundamental problems it introduces, and ways to overcome them. [C559]

"Target recognition and classification using neural networks"

Intelligent systems such as neural networks and fuzzy logic or a combination thereof have been successfully applied to solving problems in the area of pattern recognition. Neural networks are modeled off the biological neurons in the body and their triggered responses to stimuli; while, fuzzy logic uses human linguistic and expert knowledge to make decisions. In many situations, there are multiple sensors making measurements of the environment. The objective is to combine the measurements (data fusion) in a way that provides an output that describes the environment. The development of a mathematical formulation for solving a problem like this is often very difficult. On the other hand, intelligent systems such as neural networks and fuzzy logic have provide good solutions in complex scenarios like this, where it is difficult to develop closed form mathematical solutions to multi-input/multi-output problems. Therefore, in this paper a neural network approach is used to recognize and classify airborne targets. The target recognition and classification problem was broken into two parts. The first part consists of using a neural network to recognize the existence of a target. Then, given the existence of a target, the next step consists of classifying the target type. Two case studies are presented showing the efficacy of using neural networks for target recognition and classification. [C560]

"SAR image feature extraction and classification with fractal-based description"

In the field of synthetic aperture radar (SAR) image analysis, an effective feature extraction method based on a fractal Brownian increment random field (FBRIR) is introduced, and an effective classification method with a neuron network based on adaptive resonance theory (ART) is designed accordingly. At last the validity of this systematic approach is tested and compared using real data of Ku band SAR images. [C561]

"Radar target recognition based on peak location of HRR profile and HMMs classifiers"

The location information of prominent points backscattering, extracted from the high resolution radar echoes by the Relax algorithm, is used as the feature for radar target recognition. The sensitivity of high range resolution (HRR) profiles to the LOS of radar yields an idea that the multiaspect radar echoes can be modeled by a hidden Markov model (HMM); it gives the spatial-temporal information of a target. Several HMMs are cascaded in a chain to model the pose of a flying objective and is used for automatic target recognition in a class-attributed and aspect-attributed manner. Computer simulations with radar data show that for a close-set recognition, an averaged recognition rate of 96.77% for aspect-recognition and 99.80% for class-recognition is achieved, respectively; that for a open-set recognition, the averaged class-recognition rate reaches 81.25% under a maneuver condition. [C562]

"A Doppler-based automatic target classifier for a battlefield surveillance radar"

This paper describes the automatic target classifier which has been introduced into the Man Portable Surveillance and Tracking Radar (MSTAR) battlefield surveillance as part of its mid-life improvement. It discusses the background to the use of Doppler classifiers for radars of this type, based on the already-prevalent use of audio as a classification aid. It then discusses the principles of the classifier used in the MSTAR radar. This uses the Doppler spectrum to form a feature vector and uses a hierarchical Fisher linear discriminant to resolve the different classes. The training and testing of the classifier are discussed, together with the performance achieved. [C563]

"Pole patterns of radar-target scattering model based on ultra-wideband Gaussian pulses"

Time domain and frequency domain analysis of a radar-target scattering model based on ultra-wideband Gaussian pulses are presented. The scattering model is a useful tool for computing the range profile, or image, of a complex target that is illuminated by electromagnetic impulses. Computer plots of range profiles and pole patterns are obtained for a complex target that is composed of a finite number of scattering centers. The range profiles and the pole patterns are valuable information for radar-target classification and identification [C564]

"An efficient method of radar target classification"

An efficient method of choosing the mother wavelet for classification is proposed, and an efficient classifier based on genetic wavelet neural network is designed and applied to classify two types of radar targets. The classification experiment results are encouraging, which shows the method proposed is superior [C565]

"Segmentation and recognition of bridges in high resolution SAR images"

Based on analyzing the features of SAR images, this paper presents a novel algorithm for automatic segmentation and recognition of bridges in high-resolution SAR images according to the idea of detecting the targets along the edges of the image. At the same time, wavelet analysis is successfully used in prefiltering and denoising; good recognition results are thus obtained [C566]

"Extraction of characteristics of a target"

The similarity parameter between two scattering matrices is introduced. This parameter is not only independent of the spans of the scattering matrices, but also independent of the target orientation angles. From the definition of this parameter, we derive the parameters of similarities to the scattering matrices of a plate (sphere), a diplane, a wire and two helixes, which are very convenient for analyzing the characteristics of a radar target [C567]

"Aircraft HRRP classification based on RBFNN"

We present a classification scheme based on a new kind of RBFNN (radial basis function neural network) whose structure is similar to that of AWNN (adaptive wavelet neural network). To be more suitable for HRRP (high resolution range profile) classification, this kind of RBFNN substitutes wavelet basis functions in AWNN with Gaussian basis functions. In addition, we also devise an RBFNN initialization method of clear physical significance, and propose a decision rule based on average output vectors of RBFNNs. The new scheme is applied to HRRP classification of six aircraft at different SNR levels, and the results are compared with that obtained by MCCM (maximum correlation coefficient method). It is indicated that the RBFNN-based classification method has the potential in complex target classification and is promising to develop more practical HRRP classifiers [C568]

"Efficient implementation of comb filters using block processing"

First Page of the Article [C569]

"Application of local discriminant bases to HRR-based ATR"

Wavelet-based signal classification and compression techniques have gained substantial popularity due to their low computational costs, excellent localization properties, and the ability to choose from a large number of bases for signal representation. A difficulty with applying wavelet-based techniques is determining the best wavelet type and basis. For compression, the best-basis algorithm has been proposed to find the wavelet-packet basis with maximum energy compaction. The local discriminant basis (LDB) was previously introduced in the context of signal classification to find the best wavelet-packet basis with maximum class discrimination. In this paper, we apply the LDB to the problem of automatic target recognition. We describe the mechanics of the LDB as applied to one- and two-dimensional signals, and introduce a novel classification scheme that is tolerant to image scaling and moderate image translations and dilations [C570]

"Evolutionary design of neural network classifiers for radar target recognition"

An automatic method of designing classifiers for radar target recognition by the range profiles is proposed. The classifiers are made of feedforward neural networks whose topology and weight distributions are evolved by a hybrid evolutionary algorithm [C571]

"Multidimensional real aperture radar imaging"

One drawback of real aperture radar imaging is that closely placed scatterers that can not be separated in range will not be drawn apart in-cross range. An algorithm based on super-resolution spectral estimation and total least squares is proposed in order to solve this problem. The MUSIC algorithm is used to estimate the range position of closely located scatterers with high accuracy and total least squares is used to estimate the cross-range position of scatterers. Theoretical analysis and simulation show this method is capable of resolving closely placed scatterers and is robust to range position estimation error so that a more accurate multidimensional image of the target can be generated [C572]

"Efficient radar target classification using modular neural networks"

A radar target classifier based on modular neural networks is presented and its performance compared with that of a classifier based on non-modular neural networks. In this classifier, the response from an unknown target is sent to several waveform predictors that are BP neural networks trained by responses from known targets. The predictor errors are then sent to a classifier using the rule of maximum a posteriori or the rule of modified minimum squared errors. The simulation shows that the new classifier has a good performance on radar target recognition. The method also has other advantages such as easy realization, clear structure and easy expansion [C573]

"Polarimetric classification of trees"

Since scattering matrix acquisition capability will be equipped with space-borne radar systems such as ALOS PALSAR to be launched in 2003, radar polarimetry is now an indispensable tool for monitoring the Earth's cover. The advantage of using the vector nature of electromagnetic waves is the information on the amplitude, phase and their relations pertaining to target. In this paper, we retrieve a useful index for classifying broad leaf trees and conifer (needle like leaf) trees based on the scattering characteristics of tree canopies. The index used is the polarimetric correlation coefficient derived by the elements of the Sinclair scattering matrix. It is shown that correlation coefficient defined in the circular polarization basis serves to distinguish conifer tree and broadleaf tree [C574]

"Time-frequency analysis as a tool for improving neural detectors for low probability of false alarm"

This paper deals with the application of time-frequency analysis for transforming the received radar echoes in order to facilitate a neural network classification task. So as to compress the time-frequency representations maintaining most of the information, a feature extractor is designed. The proposed detector is compared with a single Multilayer Perceptron (MLP). The results show that time-frequency decompositions improve the performance of neural networks for slow fluctuating radar targets detection, specially for low values of Probability of False Alarm. The performance of the new detector is nearly independent on the Training-Signal-to-Noise-Ratio (TSNR) and the training initial conditions [C575]

"Advances in subspace eigenanalysis based algorithms: from 1D toward 3D superresolution techniques"

An overview of two superresolution methods, MUSIC and ESPRIT, for the ID case is firstly given. Afterwards, an extension of these algorithms to the three-dimensional case is proposed. New formulations for the signal model, data resampling, spatial smoothing method and estimate expression are provided. Although many applications can be considered in the areas of radar and wireless communications, only one of them is detailed: high-resolution radar target imaging. The concluding remarks drawn in the final part of the paper are supported by simulation results performed on synthetic signals and by comparing the proposed methods to the scattering center extraction technique using the Fourier transform [C576]

"Multistatic passive radar imaging using the smoothed pseudo Wigner-Ville distribution"

We investigate passive radar imaging of aircraft using reflected TV signals. We apply a smoothed pseudo Wigner-Ville distribution (SPWVD) based SAR imaging algorithm to two different scenarios. In the first simulation, a multistatic VHF-band dataset generated by fast Illinois solver code (FISC) is used. In the second simulation, a more realistic simulated passive radar dataset is used. A set of instantaneous images is produced by our algorithm. They have higher resolution and show more detail and features of the aircraft than can be obtained by direct Fourier reconstruction (DFR). The set of images provides more visual information about the target and helps to estimate its shape and features. This study suggests that the SPWVD-based imaging might be useful in passive radar imaging and target classification [C577]

"A generalized regression neural network (GRNN) scheme for robust estimation of target orientation using back-scattered data"

The ill-conditioned nature of electromagnetic inverse scattering problems calls for newer approaches to the old problem. The problem of estimating the orientation of a conducting target is successfully handled by a generalized regression neural network (GRNN). The training data set consists of backscattered RCS data measured when the target is exposed to an incident single frequency TM plane wave. Noisy data sets are then provided to increase system robustness. The network response proves to be highly robust to problem setup non-idealities such as target scaling, sensor misplacements, sensor noise and template deformations. Further

investigations show that even reducing the total number of sensors does not affect the general capabilities of the network much but slightly reduces the robustness, especially when the target is deformed. Also, confining the sensors to one half plane still maintains the generalization capability of the network but reduces its robustness. Time domain schemes, such as range profiling techniques, can utilize of this method to overcome their difficulties in estimating the orientation of the target [C578]

"Time-domain reconstruction of moderately rough dielectric interfaces via quasi-ray Gaussian beams"

The problem of determining the properties of rough surfaces from electromagnetic scattered field data arises in many importance subsurface sensing problems such as underground imaging using data from a ground penetrating radar (GPR). In GPR systems, arrays of above-ground transmitters and receivers illuminate areas of interest and receive backscattered signals from shallowly buried objects from surface reflections. The shape of the air-ground interface is unknown, and it is a principal corruptor of the backscattered signal from subsurface targets of interest. In order to enhance subsequent detection, classification and inverse scattering processing, it is important to compensate for the distortion introduced by the air-ground interface. As a first step toward this goal, we previously addressed the problem of estimating the profile of one-dimensional (1D) moderately rough dielectric interfaces from a limited number of multifrequency measurements under time-harmonic excitation. In this paper, we extend the approach to the case of time-dependent (short pulse) excitation. The proposed extension is based on a developed Gabor-based narrrow-waisted pulsed-beam representation of short-pulse scattering by moderately rough surfaces [C579]

"Netted radar sensing"

We consider how networks of radar sensors can offer a counter to stealth technology whilst simultaneously providing more detailed information for improved target classification. Specifically, it is shown how multiple independent sensors can provide an energetically more efficient collector of radar scatter. Further, the relative merits of non-coherent and coherent dependent networks are discussed particularly emphasising the balance between increased performance and increased complexity and cost [C580]

"High range resolution radar signal classification a partitioned rough set approach"

In automatic target recognition (ATR) systems there are advantages to developing classifiers based on a portion of the signal. A partitioning technique is introduced in this paper that allows rough set theory to be applied to real-world size problems. Rough set theory (RST) is an emerging concept for determining features and then classifiers from a training data set. RST guarantees that once the data has been labeled all possible classifiers (based on that labeling) can be generated. There are multiple classifiers for each signal partition and multiple partitions for each signal. Classifiers based on a single reduct (classifier) or one partition do not perform well enough to be useful. We fuse all the reducts from all the partitions into one classifier. This fusion of partitioned reducts yields a synergistic result that produces a classifier with a high probability of declaration and good probability of correct classification [C581]

"Buried object detection using ground penetrating radar"

A wide variety of sensors could be considered to aid this situation, and generally each will have a particular niche role but the sensor that is of most universal value is ground penetrating radar, or ground probing radar. Its main advantage is that it allows all types of objects to be detected irrespective of their material, operates over a sufficient bandwidth to allow target classification procedures to be implemented and makes use of modern digital electronics allowing wide areas to be searched rapidly. Other sensors provide complementary information that can be fused with radar data to provide a more complete view of the underground environment. [C582]

"UAV cooperative control"

This paper addresses the development of cooperative rendezvous and cooperative target classification agents in a hierarchical distributed control system for unmanned aerospace vehicles. For cooperative rendezvous, a Voronoi based polygonal path is generated to minimize exposure to radar. The rendezvous agent minimizes team exposure from Individual coordination functions while satisfying stringent timing constraints. For cooperative target classification, templates are developed, optimal trajectories are followed, and adjacent vehicles are assigned to view at complementary aspect angles. Views axe statistically combined to maximize the probability of correct target classification over various aspect angles [C583]

"Markov modeling of transient scattering and its application in multi-aspect target classification"

Transient scattered fields from a general target are composed of wavefronts, resonances and time delays, with these constituents linked to the target geometry. A classifier applied to transient scattering data requires a statistical model for such fundamental constituents. A Markov model is employed to characterize the transient scattered fields-for a set of target-sensor orientation over which the transient scattering is stationary-utilizing a wavefront, resonance, time-delay "alphabet". The Markov model is utilized in a classifier developed for multi-aspect transient scattering data, with a hidden Markov model (HMM) employed to address the generally non-stationary nature of the multi-aspect waveforms. Each state of the HMM is characteristic of a set of target-sensor orientations for which the scattering statistics are stationary, the statistics of which are characterized via the Markov model. The wavefront, resonance and time-delay features are extracted via a modified matching-pursuits algorithm [C584]

"Fractal and multifractal analysis of sea SAR clutter data"

The goal of this work is to investigate on the fractality of the sea clutter collected by SAR systems like the existing ERS1-2 SAR. The analysis of data generated by simulation is performed by using two kind of techniques: 1) Multiscale fractal analysis; 2) Multifractal analysis. The results show that sea clutter retains a few fractal features of the sea. This study is very interesting for applications in the field of sea remote sensing like classification and target recognition [C585]

"IGARSS 2001. Scanning the Present and Resolving the Future. Proceedings. IEEE 2001 International Geoscience and Remote Sensing Symposium (Cat. No.01CH37217)"

The following topics were dealt with: soil moisture remote sensing; archaeology; global clouds and aerosols; remote sensing; data compression and coding; SAR; floods and disasters; Antarctica; Arctic; classification, labelling and inference; visualization; advanced sensors and measurement techniques; missions and programs; skin sea surface temperature; agriculture, coastal lakes and rivers; hyperspectral environment; geoscience; Global Change Observation Mission; environmental degradation and Earth systems; student prize paper competition; processing and analysis methods; interferometry; Africa; Radarsat 1; sensor calibration; oceans; Australian applications; aquatic and submerged ecosystems; hyperspectral and multispectral mineral exploration; advanced lidar systems; Tropical Rainfall Mapping Mission; clouds and precipitation data fusion; thermal remote sensing; biophysical modelling; Shuttle Radar Topography Mission; forestry; fires; passive remote sensing; state communities; active remote sensing; snow; local communities; geospatial data fusion; multisource vision; knowledge based systems and unmixing; tropospheric refractivity estimation; radar polarimetry; ocean color; sea ice, snow and glaciers; short wind waves; topography, DTM and cartography; arid zone; rangelands; lidar technology; ozone; clouds and precipitation; inverse problems; spaceborne scatterometers; differential SAR interferometry; antipersonnel landmine detection and classification; landcover change; air-sea interaction; knowledge based systems and unmixing; Bayesian techniques; data formats, archiving and retrieval; EOS-Terra mission; ocean waves; agriculture; salinity; urban studies; hydrology; soils; geoscience; atmosphere; climate; large scale thematic products; emission and scattering; image processing and enhancement; GPS reflection; electromagnetics; AIRSAR and PACRIM; synthetic aperture techniques; processing systems; policy, education and societal issues; GPR; ocean winds; disaster assessment; target detection; environmental degradation; coastal landscapes and fisheries; biophysical modelling; neural networks, expert system systems; inverse problems [C586]

"SAR Interferometry coherence analysis for snow mapping"

For climatological and hydrological investigations, the areas covered by snow and their spatial variability are important parameters, particularly in alpine regions. A interferometric SAR technique not only can produce a high-resolution digital elevation models but also can detect the changes in the surface. By comparing four ERS-1/2 repeat pass SAR image in the Tibet Plateau test area, we find that the coherence measurements from the bare soil, bare rock and the short vegetation are significantly high, and lake and snow cover have very low coherence. On other way, the entire target may show very low coherence if there are great decorrelations due to other parameters, such as spatial baseline, rotation and temporal. We will demonstrate the method and result for snow mapping by using both backscattering and coherence measurements with repeat passes ERS-1 image data at the Kunlunshan Mountain, the Tibetan plateau (36°03'N, 91°00'E). An accuracy of better than 82% can be achieved if we consider the classification result from TM imagery as the ground truth. The results showed that the coherence measurements provide an effective way to map snow-covered area [C587]

"Netted radar sensing"

In this paper we consider a number of aspects illustrating how networks of radar sensor systems (rather than a single monostatic radar) can offer a counter to stealth technology whilst simultaneously providing more detailed

information for improved target detection, classification and location. The netted radar equation is developed, coverage, detection and location performance are quantified, and the potential utility of additional information offered by a network together with countermeasure capability are discussed [C588]

"Radar HRRP classification with support vector machines"

The SVM (support vector machine) has good generalization property and is proven to be a powerful classification method to a wide variety of applications. In this paper, the SVM classification method is applies to the HRRP (high resolution range profile) classification problem. Furthermore, we propose a preprocessing method and present a new SVM model selection method, the combined leave-one-out cross-validation scheme with VC bound method. Accordingly, the SVM classifiers for five aircraft are designed. Their anti-noise performance and tolerance to aspect variation are compared with that of MCM (maximum correlation method). The experimental results indicate that the preprocessing procedure and model selection method are effective and the SVM method has potential in radar complex target classification [C589]

"Direction of arrival estimation using super-resolution algorithm"

The angular resolution of conventional antenna is limited by the antenna mainlobe beamwidth. To reduce the antenna mainlobe beamwidth by conventional approach requires either using larger antenna or operating at a higher frequency. Both approaches may be undesirable for the application of airborne radar systems. This report suggests using a sensor array to perform space-time processing to enhance the angular resolution of antenna. By using the eigenanalysis method, the time sequence of sensor array outputs are decomposed into the signal and noise subspace and noise only subspace. The two subspaces are orthogonal to each other. Using the generalized MUltiple SIgnal Classification (MUSIC) method, closed spaced targets within the antenna mainlobe may be resolved. The theoretical background is discussed in this report. Computer simulation results are presented to verify the super resolution capability of this signal processing algorithm [C590]

"Bi-mode time-space multiplexing antenna array for multi-targets detection in automotive application"

A novel antenna array scheme BTSM is proposed where time-space multiplexing technology is used and advantages of panorama and detail modes are combined. Compared with conventional MAA, this array has high capability for multi-target detection, smaller size, lower cost and smaller computation. BTSM FMCW radar systems will allow lane prediction and the classification of objects, thus making possible the intelligent interpretation of traffic scenes [C591]

"Detection of the number of signals in super-resolution ocean surface current algorithm for OSMAR2000"

Super-resolution ocean surface current algorithm based on MUltiple SIgnal Classification (MUSIC) is used for current mapping of Wuhan University's ocean state measuring and analyzing radar (OSMAR2000), in which MUSIC is applied to estimate the bearings of the first-order sea echo signals. The premise of MUSIC processing is that the number of signals is known in advance. In fact, the number of signals is unknown, and needs to be estimated from received data. In the case of discrete targets, the problem can be perfectly solved using information theoretic criteria such as the Akaike Information Criterion (AIC) or the Minimum Description Length (MDL) criterion. However, these criteria are proved unsuccessful for sea echo signals both in simulation and in actual application, since sea surface is essentially a continuum. Therefore, an ad hoc method of detection of number of signals, a bit different from the existent methods, is developed for the current algorithm of OSMAR2000. The underlying idea is to determine the number of signals based on the variance of MUSIC spectra structure under different candidate number of signals [C592]

"Segmentation and labeling of polarimetric SAR data: can wavelets help?"

In this paper we report about a novel approach to segmentation and thematic labeling of SAR polarimetric data. A pre-processing phase based on a wavelet frame that works as a differential operator generates piece-wise smooth approximations of the covariance matrix power term images. This step matches the signal characteristics with the requirements of well proven and computationally robust clustering algorithms of the Bayesian MAP, hard or soft labeling, and contextual type. Segments defined in this first phase are then used to estimate polarimetric quantities such as the Cloude's and Pottier's target decomposition parameters. The advantage over methods that use local statistics in a moving window is that the variance of the estimators decreases with the segment size, good accuracy can be obtained without sacrificing spatial resolution, and errors due to the signal discontinuities are avoided. The passage is then made from pixel based clustering to segment wise thematic classification. To

the purpose reference feature vectors based on ground truth are needed, and segments are reassigned to the thematic labels. The per-segment feature vectors, including averages of polarimetric, radiometric quantities, or texture measures, can also be exploited to derive biophysical parameters and qualify additionally the classification categories. The proposed approach seems to be appealing because it can tackle under a unified framework resting on solid mathematical foundations-such as Bayesian inference and wavelet theory-different data sources (microwave and optical) and different thematic contexts [C593]

"Electro-optical systems for image recognition"

Detection and classification of targets by means of electro-optical sensors has been of interest for both defense and civilian applications for a number of years. In this presentation we emphasize two areas: extraction of more information from the sensors by polarimetric and frequency diversity, and reducing the processing and storage requirements by exploiting invariant attributes for detection and classification [C594]

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