Государственное образовательное учреждение
высшего профессионального образования
**«Томский государственный университет
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ТЕМАТИЧЕСКИЙ РЕФЕРАТИВНЫЙ СБОРНИК № 1-1

“Wavelet Radar Processing”
(«Вейвлет-обработка в радиолокации»)

Журнальные публикации

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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Журнальные публикации

"Multitemporal Image Change Detection Using Undecimated Discrete Wavelet Transform and Active Contours"

In this paper, an unsupervised change detection method for satellite images is proposed. Owing to its robustness against noise, the undecimated discrete wavelet transform is exploited to obtain a multiresolution representation of the difference image, which is obtained from two satellite images acquired from the same geographical area but at different time instances. A region-based active contour model is then applied to the multiresolution representation of the difference image for segmenting the difference image into the "changed" and "unchanged" regions. The proposed change detection method has been conducted on two types of image data sets, i.e., the synthetic aperture radar images and the optical images. The change detection results are compared with several state-of-the-art techniques. The extensive simulation results clearly show that the proposed change detection method consistently yields superior performance. [J1]

"Edge Enhancement Algorithm Based on the Wavelet Transform for Automatic Edge Detection in SAR Images"

This paper presents a novel technique for automatic edge enhancement and detection in synthetic aperture radar (SAR) images. The characteristics of SAR images justify the importance of an edge enhancement step prior to edge detection. Therefore, this paper presents a robust and unsupervised edge enhancement algorithm based on a combination of wavelet coefficients at different scales. The performance of the method is first tested on simulated images. Then, in order to complete the automatic detection chain, among the different options for the decision stage, the use of geodesic active contour is proposed. The second part of this paper suggests the extraction of the coastline in SAR images as a particular case of edge detection. Hence, after highlighting its practical interest, the technique that is theoretically presented in the first part of this paper is applied to real scenarios. Finally, the chances of its operational capability are assessed. [J2]

"Low-Power Technique for SRAM-Based On-Chip Arbitrary-Waveform Generator"

A low-power technique for a static random-access memory (SRAM)-based on-chip arbitrary-waveform generator (AWG) is proposed for two types of analog-signal-processing applications: multiresolution spectrum sensing and matched filter. The SRAM has an embedded address generator to limit the operation in a sequential-access mode of the AWG. Then, the power consumption of the AWG is analyzed according to the operation modes in multiresolution and multiwaveform spectrum-sensing functions. The low-power technique reduces power by 18% of the SRAM and the address generator and by about 2.2% of the entire AWG at a 1.8-V supply voltage. The AWG is fabricated in a 0.18-μm CMOS technology and demonstrates a chirp signal and a Daubechies wavelet with a 45-dBc spurious-free dynamic range and a cross-correlation factor of 0.96-0.988 with ideal signals. [J3]

"Tropical Cyclone Intensity Estimated From Wide-Swath SAR Images"

Due to the relatively small amount of in situdata available for the open oceans, remote sensing techniques take an important role in the retrieval of geophysical information, particularly during extreme events. The work presented here aims at the improvement of prediction of cyclone intensity using synthetic aperture radar (SAR) images. A new method to measure the hurricane intensity using SAR images, in combination with a parametric Holland-type model of wind speed, is presented. The algorithm is based on a least square minimization of the difference between the parametric model results and the SAR measurement. The radius of the maximum wind speed, required as input for the minimization procedure, is estimated from the SAR image using wavelet analysis. Information on wind direction is extracted from the SAR image through analysis of image features caused by boundary layer rolls. The root-mean-square error of the suggested method has been validated to be equal to 3.9 m/s. The study is based on a data set of wide-swath SAR images of about 400 km ?? 400 km coverage, acquired by the European Envisat satellite, over tropical cyclones. As a case study, hurricane Katrina is investigated in detail. A total of five tropical cyclone images will be used to validate the results of the new

algorithm. [J4]

"SAR and Multispectral Image Fusion Using Generalized IHS Transform Based on a Trous Wavelet and EMD Decompositions"

In the intensity hue saturation (IHS) based image fusion, the enhancement of the spatial information often leads to the distortion of the information in the spectral domain. In this paper, a spectral preserve fusion method is developed by introducing aГ‚Вї trous wavelet transform (AWT) and empirical mode decomposition (EMD) into one generalized IHS transform, which extends panchromatic sharpening of low-resolution multispectral images (LRMIs) through detail injection to the fusion of LRMIs and synthetic aperture radar imagery (SARI). The original LRMIs are first transformed into one low-resolution intensity component (LRIC) and the details from the SARI are abstracted using AWT. The LRIC and the approximation image of the SARI are fused through an intrinsic mode functions based model. Subsequently, high RIC produced through an inverse AWT is then substituted for the old one. High RMIs are obtained through an inverse IHS transform. Experiments reveal that this approach performs better than the AWT and IHS-AWT-based methods in preserving the spectral information of the LRMIs. The performance of the image fusion is examined both visually and quantitatively. [J5]

"Topographic Mapping of the German Tidal Flats Analyzing SAR Images With the Waterline Method"

The waterline method is used to derive the topography of the tidal flats along the German coast by evaluation of synthetic aperture radar (SAR) images. A series of about 70 European Remote Sensing Satellites SAR images of the German Bight taken at different water levels within four years is analyzed to detect the borderline between tidal flats and adjacent water areas using a wavelet-based edge-detection algorithm. After geocoding, the waterlines are combined with the corresponding water levels to represent the topography on an irregularly spaced grid. The water levels are taken from a numerical tide model and corrected with the measured gauge data. Interpolation of these data into a regular grid yields a topographic map of the intertidal zone. While the general practicability of this method has been demonstrated in previous studies for smaller test areas, this paper is the first attempt to generate maps of a large area on a yearly basis. [J6]

"Despeckling of TerraSAR-X Data Using Second-Generation Wavelets"

This letter presents the despeckling of synthetic aperture radar (SAR) images within the bandelet and contourlet domains. A model-based approach is presented for the despeckling of SAR images. The speckle-reduced estimate is found using the first-order Bayesian inference, and the best model's parameters are estimated using the second-order Bayesian inference. Synthetic and real images are used for evaluating the qualities of the despeckling methods. The experimental results showed that the combination of Bayesian inference and bandelet transform outperforms the contourlet-based despeckling algorithm using synthetic data and objective measurements. [J7]

"Gibbs Random Field Models for Model-Based Despeckling of SAR Images"

Synthetic aperture radar (SAR) images are affected by multiplicative noise called speckle. This noise makes automatic image classification and image interpretation difficult. Thus, many methods have been developed to remove speckle from SAR images while preserving the useful information of the scene such as texture and geometry. In this letter, a comparison between three different despeckling methods based on a Bayesian approach and Gibbs random fields is made. The used methods are Gauss-Markov random field (GMRF) and autobinomial modeling, which operate in the image domain, and the GMRF approach, which operates in the wavelet domain. Our methods are evaluated with synthetic and real SAR data (TerraSAR-X images). The experimental results show that, with these three methods, the speckle is well removed while structures are preserved; quantitative measures show that the autobinomial method provides the best smoothness and sharpness criteria in real SAR data, while the wavelet-based method generates the smallest bias. [J8]

"Dual-Tree Complex Wavelet Transform Based SAR Despeckling Using Interscale Dependence"

In this paper, a dual-tree complex wavelet transform (DTCWT) based despeckling algorithm is proposed for synthetic aperture radar (SAR) images, considering the significant dependences of the wavelet coefficients across different scales. The DTCWT has the advantage of improved directional selectivity, approximate shift invariance, and perfect reconstruction over the discrete wavelet transform. The wavelet coefficients in each subband are modeled with a bivariate Cauchy probability density function (PDF) which takes into account the statistical dependence among the wavelet coefficients. Mellin transform of two dependent random variables is utilized to estimate the dispersion parameter of the bivariate Cauchy PDF from the noisy observations. This

method is faster and effective when compared to that of the earlier techniques on numerical integration. Within this framework, we propose a new method for despeckling SAR images employing a maximum a posteriori estimator. Experimental results show that the proposed method based on bivariate Cauchy prior achieves better performance in terms of equivalent number of looks, peak signal-to-noise ratio, and Pratt's figure of merit. [J9]

"Micro-Doppler analysis of a rotating target in synthetic aperture radar"

Rotating targets cause phase modulation of the azimuthal phase history of a synthetic aperture radar (SAR) system. The phase modulation may be seen as a time-dependent micro-Doppler (m-D) frequency. This study presents two approaches for extracting m-D features from SAR images. In order to extract m-D features from SAR images, the time domain radar return is decomposed in two separate ways. One is based on wavelet decomposition in which the returned signal is decomposed into a set of components that are represented at different wavelet scales. The components are then reconstructed by applying the inverse wavelet transform. This wavelet approach has been used in previous m-D analysis work for an inverse SAR (ISAR) system, and it is presented here in the extraction of m-D features for a SAR system. The second approach is based on adaptive chirplet decomposition combined with time-frequency analysis. This new approach is introduced as an alternative to the wavelet approach of decomposing the SAR radar return. The results from the wavelet and adaptive chirplet decomposition proxcedures are compared, and the chirplet-based approach establishes itself as a viable alternative. The chirplet-based method of m-D extraction has been successfully applied to SAR data scene collected by the US Navy APY-6 radar. [J10]

"Fast computation of radar cross-section by fast multipole method in conjunction with lifting wavelet-like transform"

The fast multipole method (FMM) in conjunction with the lifting wavelet-like transform scheme is proposed for the scattering analysis of differently shaped three-dimensional perfectly electrical conducting objects. As a flexible and efficient matrix compression technique, the proposed method can sparsify the aggregation matrix and disaggregation matrix in real time with compression ratio about 30%. The computational complexity and choice of proper wavelet are also discussed. Numerical simulation and complexity analysis have shown that the proposed method can speed up the aggregation and disaggregation steps of the FMM with lower memory requirements. [J11]

"Two Novel Bayesian Multiscale Approaches for Speckle Suppression in SAR Images"

Speckle suppression is a prerequisite for many synthetic aperture radar (SAR) image-processing tasks. Previously, we introduced a Bayesian-based speckle-suppression method that employed the 2-D generalized autoregressive conditional heteroscedasticity (2D-GARCH) model for wavelet coefficients of log-transformed SAR images. Based on this method, we propose two new Bayesian speckle-suppression approaches in this paper. In the first approach, we introduce a new heteroscedastic model, i.e., the 2D-GARCH Mixture (2D-GARCH-M) model, as an extension of the 2D-GARCH model. This new model can capture the characteristics of wavelet coefficients. Also, the 2D-GARCH-M model introduces additional flexibility in the model formulation in comparison with the 2D-GARCH model, which results in better characterization of SAR image subbands and improved restoration in noisy environments. Then, we design a Bayesian estimator for estimating the clean-image wavelet coefficients based on 2D-GARCH-M modeling. In the second approach, the logarithm of an image is analyzed by means of the curvelet transform instead of wavelet transform. Then, we study the statistical properties of curvelet coefficients, and we demonstrate that the 2D-GARCH model can capture the characteristics of curvelet coefficients, such as heavy tailed marginal distribution, and the dependences among them. Consequently, under the 2D-GARCH model, we design a Bayesian estimator for estimating the clean-image curvelet coefficients. Finally, we compare these methods with other denoising methods applied on artificially speckled and actual SAR images, and we verify the performance improvement in utilizing the new strategies. [J12]

"Multiplicative Noise Removal Using Variable Splitting and Constrained Optimization"

Multiplicative noise (also known as speckle noise) models are central to the study of coherent imaging systems, such as synthetic aperture radar and sonar, and ultrasound and laser imaging. These models introduce two additional layers of difficulties with respect to the standard Gaussian additive noise scenario: (1) the noise is multiplied by (rather than added to) the original image; (2) the noise is not Gaussian, with Rayleigh and Gamma being commonly used densities. These two features of multiplicative noise models preclude the direct application of most state-of-the-art algorithms, which are designed for solving unconstrained optimization problems where the objective has two terms: a quadratic data term (log-likelihood), reflecting the additive and Gaussian nature of the noise, plus a convex (possibly nonsmooth) regularizer (e.g., a total variation or wavelet-based

regularizer/prior). In this paper, we address these difficulties by: (1) converting the multiplicative model into an additive one by taking logarithms, as proposed by some other authors; (2) using variable splitting to obtain an equivalent constrained problem; and (3) dealing with this optimization problem using the augmented Lagrangian framework. A set of experiments shows that the proposed method, which we name MIDAL (multiplicative image denoising by augmented Lagrangian), yields state-of-the-art results both in terms of speed and denoising performance. [J13]

"A CMOS Integrated Analog Pulse Compressor for MIMO Radar Applications"

Conventional radar pulse compressors use either surface acoustic wave devices or fast convolution processing, but both solutions have significant drawbacks. To overcome these drawbacks, an integrated analog pulse compressor for a multiple-input multiple-output (MIMO) radar has been developed with an 0.18-??m CMOS process using an arbitrary waveform generator, analog correlators, and analog-to-digital converters. The proposed scheme not only has advantages over conventional methods but also adds additional flexibility to the MIMO system. The die area is 5.67 mm2, and the power consumption is 62.6 mW from the 1.8-V supply. Arbitrary waveforms such as the wavelet and the chirp signal have been demonstrated, and the average signal-to-noise ratio for the pulse compression is 18.09 dB. The identification of overlapping multiple chirp signals is successfully demonstrated. [J14]

"Cloud and Rain Effects on AltiKa/SARAL Ka-Band Radar Altimeter-Part II: Definition of a Rain/Cloud Flag"

The main instrument of the French-Indian AltiKa/SARAL mission scheduled for launch in 2010 is the Ka-band AltiKa altimeter. The high attenuation due to atmospheric water (liquid or vapor) at this frequency band is the major drawback of the use of Ka-band. In part I of this paper, the impact of rain/clouds on Ka-band data and on the accuracy of the estimates of the geophysical parameters has been analyzed and quantified using an analytical model of waveform. Waveform distortion and errors on the geophysical parameters can be significant particularly for small dense clouds and rain cells. It is thus necessary to flag the data potentially affected by rain and clouds. The use of a single channel for AltiKa prevents the use of the classical dual-frequency rain flag used for Topex or Jason altimeters, and requires the definition of a new flag based on the altimeter signal alone. Past studies showed that clouds and rain are characterized by sharp coherent along-track fluctuations of the off-nadir angle estimates. The new flagging algorithm is based on the analysis of the variations of this parameter by the Matching Pursuit (MP) algorithm. MP allows the decomposition of a signal into a few salient features or atoms chosen from a dictionary of elementary functions. The dictionary is here defined by the wavelet decomposition of the signal. The method has been tested on an ensemble of AltiKa passes simulated for cloudy, rainy, and cloud/rain-free situations. The false alarm rate is almost nil while the detection performances are better than 90% at a range error of 5 cm and significant wave height error of 20 cm. The flag can easily be adapted to other altimeters' data and has been used to flag several Jason-1 passes. The comparison to the operational dual-frequency flag shows that the MP flag performs better in detecting range errors and waveforms distortion, while its performances are inferior in detecting samples attenuated by rain. [J15]

"Ionospheric clutter mitigation using one-dimensional or two-dimensional wavelet processing"

Ionospheric clutter mitigation is an important issue for high-frequency surface wave radar (HFSWR) signal processing. Clutter results from a sky wave propagation mode, which is backscattered by ionospheric ionisation irregularities. The random behaviour and the high strength of clutter signals can strongly limit the HFSWR detection capabilities. Here, an ionospheric clutter mitigation processing using wavelets is described. This new approach is founded on the ability of wavelets to separate signals having different variation scales or different directions of variations. The results obtained on real clutter signals with simulated targets are reported. Using the proposed method, one can expect, at mid-latitude, an improvement of the target-to-clutter ratio of 20-30-dB. [J16]

"Speckle Suppression in SAR Images Using the 2-D GARCH Model"

A novel Bayesian-based speckle suppression method for Synthetic Aperture Radar (SAR) images is presented that preserves the structural features and textural information of the scene. First, the logarithmic transform of the original image is analyzed into the multiscale wavelet domain. We show that the wavelet coefficients of SAR images have significantly non-Gaussian statistics that are best described by the 2-D GARCH model. By using the 2-D GARCH model on the wavelet coefficients, we are capable of taking into account important characteristics of wavelet coefficients, such as heavy tailed marginal distribution and the dependencies between the coefficients. Furthermore, we use a maximum a posteriori (MAP) estimator for estimating the clean image wavelet coefficients. Finally, we compare our proposed method with various speckle suppression methods

applied on synthetic and actual SAR images and we verify the performance improvement in utilizing the new strategy. [J17]

"Analysis by Wavelet Frames of Spatial Statistics in SAR Data for Characterizing Structural Properties of Forests"

Spatial statistics (texture) in SAR backscatter data of forested areas bears information on structural and geometric properties that could be useful in mapping forest extent, species type, and stages of regeneration or degradation. Based on a previously published theoretical approach in deriving texture measures from SAR data using wavelet frames, experiments are reported that aim to characterize, from a purely observational point of view, wavelet texture measures' sensitivity with respect to target structural properties and SAR configurations. Suitable analytical tools are introduced to represent dependences in the combined space-scale-polarization domain through signatures that condense information in graphical form. Moreover, class separability, afforded by wavelet texture measures in a supervised classification setting and based on the Fischer linear discriminant analysis, is considered. This paper focuses on two structurally different forest types (tropical rain forest in the Central Africa Congo Floodplain and mixed-species wooded savanna in Queensland, Australia) and uses data from orbital radars, particularly from the Japanese Advanced Land Observing Satellite Phased Arrayed L-band Synthetic Aperture Radar. The analysis indicated that textural information from spatial statistics can provide, in some cases, better class separability in forest mapping with respect to one-point statistics, although spatial resolution in texture products is reduced. However, dependences of texture measures on the polarization state are detected, particularly in forests where a greater diversity of scattering mechanisms occurs. [J18]

"An Analysis of Texture Measures in PCA-Based Unsupervised Classification of SAR Images"

In single-band single-polarized SAR images, intensity and texture are the information source available for unsupervised land cover classification. Every textural feature measure identifies texture patterns by different approaches. For efficient land cover classification, textural measures have to be chosen suitably. Therefore, in this letter, the role of various intensity and textural measures is analyzed for their discriminative ability for unsupervised SAR image classification into various land cover types like water, urban, and vegetation areas. To make the algorithm adaptable, these textural features are fused using principal component analysis (PCA), and principal components are used for classification purposes. To highlight the effectiveness of PCA, the difference between PCA- and non-PCA-based classifications is also analyzed. Analysis of the role of texture measures for unsupervised classification of real-world SAR data with application of PCA is presented in this letter. The analysis of how every individual feature measure contributes for classification process is presented, and then, textural measures for a feature set are chosen according to their role in improving classification accuracy. By analysis, it is observed that the feature set comprising mean, variance, wavelet components, semivariogram, lacunarity, and weighted rank fill ratio provides good classification accuracy of up to 90.4% than by using individual textural measures, and this increased accuracy justifies the complexity involved in the process. [J19]

"Detecting and Downscaling Wet Areas on Boreal Landscapes"

This letter presents an approach to classify wet areas from European Remote Sensing 2 (ERS-2) synthetic aperture radar (SAR)-, Landsat Thematic Mapper (TM)-, and Light Detection and Ranging (LiDAR)-derived terrain data and downscale the result from the coarse resolution of satellite images to finer resolutions needed for land managers. Using discrete wavelet transform (DWT) and support vector machines (SVM), the algorithm finds multiple relationships between the radar, optical, and terrain data and wet areas at different spatial scales. Decomposing and reconstructing processes are performed using a 2-D DWT (2D-DWT) and inverse 2D-DWT respectively. The underlying relationships between radar, optical, and terrain data and wet areas are learned by training an SVM at the coarse resolution of the wet-area map. The SVM is then applied on the predictors at a finer resolution to produce wet-area detailing images, which are needed to reconstruct a finer resolution wet-area map. The algorithm is applied to a boreal landscape in northern Alberta, Canada, characterized by many wet-area features including ephemeral and permanent streams and wetlands. [J20]

"Windowed Fourier Transform for Noise Reduction of SAR Interferograms"

In this letter, since these methods are able to process signals locally, two spatial frequency analyses including windowed Fourier transform and wavelet transform are used to reduce synthetic aperture radar interferometric phase noise. [J21]

"Multiscale Change Detection in Multitemporal Satellite Images"

In this letter, we propose a novel technique for unsupervised change detection in multitemporal satellite images. The difference image which is computed from multitemporal images acquired on the same geographical area at

two different time instances is decomposed using S-levels undecimated discrete wavelet transform (UDWT). For each pixel in the difference image, a multiscale feature vector is extracted using the subbands of the UDWT decomposition and the difference image itself. The final change detection map is achieved by clustering the multiscale feature vectors using k-means algorithm into two disjoint classes: changed and unchanged. Experimental results confirm the efficacy of the proposed approach on both optical and synthetic aperture radar images. [J22]

"MST Radar Signal Processing Using Wavelet-Based Denoising"

Atmospheric signal processing is of interest to many scientists, where there is scope for the development of new and efficient tools for cleaning the spectrum, detection, and estimation of parameters like zonal (U), meridional (V), wind speed (W), etc. This letter deals with a signal processing technique for the estimation of the aforementioned parameters, based on the wavelets, by analyzing the mesosphere-stratosphere-troposphere radar data that are backscattered from the atmosphere at high altitudes and severe weather conditions with low signal-to-noise ratio. The proposed algorithm is self-consistent in detecting wind speeds up to a height of 18 km, in contrast to the existing method which estimates the Doppler manually and fails at higher altitudes. The results have been validated using the Global Positioning System sonde data. [J23]

"A Generalized Approach to Multiresolution Complex SAR Signal Processing"

Multiresolution synthetic aperture radar (SAR) image formation has been proven to be beneficial in a variety of applications such as improved imaging and target detection as well as speckle reduction. SAR signal processing traditionally carried out in the Fourier domain has inherent limitations in the context of image formation at hierarchical scales. We present a generalized approach to the formation of multiresolution SAR images using biorthogonal shift-invariant discrete wavelet transform (SIDWT) in both range and azimuth directions. Particularly in azimuth, the inherent subband decomposition property of wavelet packet transform is introduced to produce multiscale complex matched filtering without involving any approximations. This generalized approach also includes the formulation of multilook processing within the discrete wavelet transform (DWT) paradigm. The efficiency of the algorithm in parallel form of execution to generate hierarchical scale SAR images is shown. Analytical results and sample imagery of diffuse backscatter are presented to validate the method. [J24]

"Lake Level Variations Monitored With Satellite Altimetry Waveform Retracking"

Over lake shores, altimetric waveforms are generally contaminated by lands, rough lake surfaces, and lag effects of the altimeter's automatic gain control. To improve altimeter ranging accuracy and in turn to get better surface height measurement, contaminated waveforms should be retracked against geophysical corrections. In this paper, an improved threshold retracker (ITR) is developed to retrack waveforms over lakes. ITR considers not only the physical characteristics of the reflecting surface, but also the stochastic feature of waveform, and two new retrackers, the N-Beta function model, and the N-5-Beta function model, are also put forward to develop the waveform retracking program of this study. TOPEX/POSEIDON waveforms over Hulun Lake in the North China are retracked to monitor the temporal lake level variations. A comparison with the in situhydrological data indicates ITR is very efficient to monitor the lake level variations with the retracked altimetric data. The result of our study shows accurate seasonal level variations and the descending trend of Hulun Lake. [J25]

"Wavelet-Based SAR Image Despeckling and Information Extraction, Using Particle Filter"

This paper proposes a new-wavelet-based synthetic aperture radar (SAR) image despeckling algorithm using the sequential Monte Carlo method. A model-based Bayesian approach is proposed. This paper presents two methods for SAR image despeckling. The first method, called WGGPF, models a prior with Generalized Gaussian (GG) probability density function (pdf) and the second method, called WGMPF, models prior with a Generalized Gaussian Markov random field (GGMRF). The likelihood pdf is modeled using a Gaussian pdf. The GGMRF model is used because it enables texture parameter estimation. The prior is modeled using GG pdf, when texture parameters are not needed. A particle filter is used for drawing particles from the prior for different shape parameters of GG pdf. When the GGMRF prior is used, the particles are drawn from prior in order to estimate noise-free wavelet coefficients and for those coefficients the texture parameter is changed in order to obtain the best textural parameters. The texture parameters are changed for a predefined set of shape parameters of GGMRF. The particles with the highest weights represents the final noise-free estimate with corresponding textural parameters. The despeckling algorithms are compared with the state-of-the-art methods using synthetic and real SAR data. The experimental results show that the proposed despeckling algorithms efficiently remove noise and proposed methods are comparable with the state-of-the-art methods regarding objective measurements. The proposed WGMPF preserves textures of the real, high-resolution SAR images well. [J26]

"Wavelet-Based Compression With ROI Coding Support for Mobile Access to DICOM Images Over Heterogeneous Radio Networks"

Most of the commercial medical image viewers do not provide scalability in image compression and/or region of interest (ROI) encoding/decoding. Furthermore, these viewers do not take into consideration the special requirements and needs of a heterogeneous radio setting that is constituted by different access technologies [e.g., general packet radio services (GPRS)/ universal mobile telecommunications system (UMTS), wireless local area network (WLAN), and digital video broadcasting (DVB-H)]. This paper discusses a medical application that contains a viewer for digital imaging and communications in medicine (DICOM) images as a core module. The proposed application enables scalable wavelet-based compression, retrieval, and decompression of DICOM medical images and also supports ROI coding/decoding. Furthermore, the presented application is appropriate for use by mobile devices activating in heterogeneous radio settings. In this context, performance issues regarding the usage of the proposed application in the case of a prototype heterogeneous system setup are also discussed. [J27]

"UWB in Millimeter Wave Band With Pulsed ILO"

A simple but efficient transmitter for ultra-wide-band impulse radio wavelet generator in millimeter-wave band is presented. It is suitable for RADAR, gigabit wireless personal area network, and localization applications. This front-end involves a subharmonic injection-locked oscillator driven by a pulse generator (PG) with fast transition time (<25 ps). Its frequency oscillation is locked on one of the numerous harmonic components generated by the PG around 30 GHz. This allows to obtain a stable pulse-to-pulse phase condition and a very low phase noise (<-110 dBc/Hz@100 kHz). Two monolithic microwave integrated circuits have been designed using a commercial pseudomorphic high-electron mobility transistor foundry process (ft = 100 GHz). The first one is a PG with position and width modulation capabilities, and the second one is an oscillator with a 30-GHz free-running output frequency. The start of the oscillations is studied, using the external quality factor as main factor. [J28]

"Noise Reduction in Interferograms Using the Wavelet Packet Transform and Wiener Filtering"

A novel noise reduction scheme for synthetic aperture radar (SAR) interferograms based on the wavelet packet transform (WPT) and the Wiener filter is introduced in this letter. First, by employing the WPT in the spatial frequency domain, the real and imaginary parts of the complex noisy interferogram are decomposed, respectively, and the wavelet coefficients are obtained. Then, for these coefficients, Wiener filtering is adopted to remove noise. This scheme can filter noise adaptively according to the local noise level, without requiring any a priori information. By using a simulated noisy interferogram and two ENVISAT advanced synthetic aperture radar C-band interferograms, the performance of this scheme, in terms of noise reduction and fringes preservation, is reported and compared with other filter algorithms. The experimental results demonstrate the effectiveness of the proposed scheme. [J29]

"Sweep signal time-delay estimation with time-frequency cross-correlation algorithm"

Sweep signal is usually employed as a source signal in active detection such as radar and sonar. Since the frequency spectrum of the sweep signal varies against time, a novel algorithm, namely a time-frequency cross-correlation (TFCC) algorithm based on wavelet packet transform (WPT), is proposed to estimate the time delay of sweep signal. In this algorithm, the source sweep and the received signals are decomposed with WPT to obtain their time-frequency representations and the TFCC between the source sweep and the received signals is performed. Each reflected sweep in the received signal is converted into a time-frequency correlation peak whose position can indicate its time delay. The TFCC algorithm can suppress ambient noise effectively and improve the performance of sweep extraction and can match more precisely the source and the reflected sweeps to their known time-frequency characters. Numerical experiments were performed to compare the performance of the TFCC algorithm with that of the conventional cross- correlation and phase-data algorithms. The results proved that the TFCC algorithm can extract the reflected sweeps effectively and its performance is better than that of the conventional algorithms. [J30]

"A Stationary Wavelet-Domain Wiener Filter for Correlated Speckle"

In this paper, we develop a Wiener-type speckle filter that operates in the stationary wavelet domain. We denote it as the stationarywavelet-domainWiener(SWW) speckle filter. We assume that both the speckle-free image and the speckle contribution have spatial correlations and utilize well-established models for the power density spectrum of the radar cross section to estimate the autospectra that define the filter. It turns out that the filter is independent of the wavelet-domain scale level, i.e., the filter is the same at all scale levels. The SWW filter works on nonoverlapping blocks in the wavelet domain, which are obtained by a quadtree algorithm. Due to the

dyadic support of the wavelet coefficients, a natural smoothing is carried out on the boundaries between neighboring blocks, and no visual boundary effects can be observed. The SWW filter is unbiased and shows good performance in despeckling synthetic aperture radar (SAR) images. It smooths homogeneous areas while preserving textured areas and point scatterers. In contrast to most other speckle filters, the SWW filter requires the SAR data to be given in single-look complex form. [J31]

"Processing of Envisat Alternating Polarization Data for Vessel Detection"

The alternating polarization (AP)-mode data from Envisat/Advanced Synthetic Aperture Radar (ASAR) can simultaneously generate two well-georegistered images in different polarizations, including VV/HH, HH/HV, and VV/VH combinations. This additional polarimetric information between channels is helpful for enhancing the accuracy of vessel detection. In this letter, different processing methods of AP single-look complex (APS) and precision (APP) data for vessel detection are investigated. For APS data, we propose a dual-polarization whitening fusion filter to combine dual-channel data and present its superiority to other traditional detectors. For APP data, based on the distinct polarimetric properties of each polarization, we utilize different fusion methods for different polarization combinations, including a wavelets-based method for VV/HH and a simple product fusion method for the other two pairs including the cross-polarization channel (HV or VH). Finally, in the experiments, we use real Envisat AP data sets to verify the method, and the results of our proposed processing strategy indicate that it cannot only suppress the speckle and the sea clutter but also improve the vessel detection performance. [J32]

"Spectral Clustering Ensemble Applied to SAR Image Segmentation"

Spectral clustering (SC) has been used with success in the field of computer vision for data clustering. In this paper, a new algorithm named SC ensemble (SCE) is proposed for the segmentation of synthetic aperture radar (SAR) images. The gray-level cooccurrence matrix-based statistic features and the energy features from the undecimated wavelet decomposition extracted for each pixel being the input, our algorithm performs segmentation by combining multiple SC results as opposed to using outcomes of a single clustering process in the existing literature. The random subspace, random scaling parameter, and Nystrom approximation for component SC are applied to construct the SCE. This technique provides necessary diversity as well as high quality of component learners for an efficient ensemble. It also overcomes the shortcomings faced by the SC, such as the selection of scaling parameter, and the instability resulted from the Nystrom approximation method in image segmentation. Experimental results show that the proposed method is effective for SAR image segmentation and insensitive to the scaling parameter. [J33]

"A Recursive Filter for Despeckling SAR Images"

This correspondence proposes a recursive algorithm for noise reduction in synthetic aperture radar imagery. Excellent despeckling in conjunction with feature preservation is achieved by incorporating a discontinuity-adaptive Markov random field prior within the unscented Kalman filter framework through importance sampling. The performance of this method is demonstrated on both synthetic and real examples. [J34]

"A Wavelet-Based Technique for Sea Wind Extraction from SAR Images"

We present the follow-up of our previously published work, where we described a wavelet-based method to characterize the sea surface backscatter structures in Synthetic Aperture Radar (SAR) images. The method relies on the ability of the 2-D continuous wavelet technique to detect the spatial structure of the Marine Atmospheric Boundary Layer (MABL) and to isolate wind-related cells and features. The analysis of the cells' geometry, molded by the radiometric characteristics of the sea surface, permits the identification of the wind direction inside the cells, due to the along-wind asymmetry of backscatter structures, and thus the computation of the wind speed through standard algorithms. Twenty-one SAR images (ERS-2 and Envisat ASAR Wide Swath) over the Mediterranean Sea have been analyzed, and the results are compared with satellite wind fields. The images cover a range of meteorological conditions from low to moderate winds. Comparison of the SAR-derived wind fields with those provided by satellite scatterometers indicates a good score of success (roughly 70%-80%). The developed methodology, once tested over an adequate number of images to derive statistically reliable results, could be routinely used to enrich SAR images with the wind field as well as to characterize the MABL in terms of size, distribution, and shape of the backscatter cells. [J35]

"Compression of multi-polarimetric SAR intensity images based on 3D-matrix transform"

The algorithms for multi-polarimetric synthetic aperture radar (SAR) intensity image compression are investigated. First, the multi-polarimetric SAR intensity images (HH, HV and VV) are considered as a 3D-matrix unit, and then a 3D-matrix transform is adopted to remove the redundancies, which includes ID discrete cosine

transform (DCT) in the polarimetric channels and 2D discrete wavelet transform (DWT) in each polarimetric SAR image plane. After the 3D-matrix transform, two methods are proposed to encode the 3D mixed coefficients. One is a bit allocation encoding based on differential entropy and the other is a 3D set partitioning in hierarchical trees (SPIHT) encoding which is an improvement of the conventional SPIHT. The two methods can remove not only the redundancies of the image inside but also the redundancies among the polarimetric channels, because they do not process every channel image separately. Both the theory and experimental results show that the proposed methods are efficient. [J36]

"Wavelet Contribution to Remote Sensing of the Sea and Target Detection for a High-Frequency Surface Wave Radar"

High-frequency waves (3-30 MHz) interact with the sea surface. Thus, a high-frequency surface wave radar (HFSWR) is well suited to perform remote sensing of the sea. The HFSWR coverage range is not limited by the radio horizon: it is possible to keep watch over the sea up to a few hundred kilometers from the coastline. Oceanographic parameters (i.e., wave height, surface current velocity, wind direction, and wind velocity) are derived from the so-called sea spectrum. Moreover, the HFSWR can be used for maritime surveillance of the Exclusive Economic Zone. In that case, the sea spectrum is an unwanted signal because it can mask targets. Sea spectrum extraction is an important issue for HFSWR signal processing since it is a key point for the remote sensing accuracy and the target detection features. In this letter, we show how wavelets may be applied to improve the remote sensing of oceanographic parameters and the target detection using wavelet-based sea clutter extraction. The results obtained using real data with opportune targets validate our approach. [J37]

"Segmentation-Based MAP Despeckling of SAR Images in the Undecimated Wavelet Domain"

In this paper, a novel despeckling algorithm based on undecimated wavelet decomposition and maximum aposterioriestimation is proposed. Such a method represents an improvement with respect to the filter presented by the authors, and it is based on the same conjecture that the probability density functions (pdfs) of the wavelet coefficients follow a generalized Gaussian (GG) distribution. However, the approach introduced here presents two major novelties: 1) theoretically exact expressions for the estimation of the GG parameters are derived: such expressions do not require further assumptions other than the multiplicative model with uncorrelated speckle, and hold also in the case of a strongly correlated reflectivity; 2) a model for the classification of the wavelet coefficients according to their texture energy is introduced. This model allows us to classify the wavelet coefficients into classes having different degrees of heterogeneity, so that adhocestimation approaches can be devised for the different sets of coefficients. Three different implementations, characterized by different approaches for incorporating into the filtering procedure the information deriving from the segmentation of the wavelet coefficients, are proposed. Experimental results, carried out on both artificially speckled images and true synthetic aperture radar images, demonstrate that the proposed filtering approach outperforms the previous filters, irrespective of the features of the underlying reflectivity. [J38]

"Analysis of radar micro-Doppler signatures from experimental helicopter and human data"

This paper highlights the extraction of micro-Doppler (m-D) features from radar signal returns of helicopter and human targets using the wavelet transform method incorporated with time-frequency analysis. In order for the extraction of m-D features to be realised, the time domain radar signal is decomposed into a set of components that are represented at different wavelet scales. The components are then reconstructed by applying the inverse wavelet transform. After the separation of m-D features from the target's original radar return, time-frequency analysis is then used to estimate the target's motion parameters. The autocorrelation of the time sequence data is also used to measure motion parameters such as the vibration/rotation rate. The findings show that the results have higher precision after the m-D extraction rather than before it, since only the vibrational/rotational components are employed. This proposed method of m-D extraction has been successfully applied to helicopter and human data. [J39]

"Wavelet Based Deconvolution Algorithm for Time-Domain Near-Field ISAR Imaging"

Based on correlation receiver in communication theory, the measured backscattering waveform of a calibration conducting sphere is adopted as the system impulse response. This antenna-target system response is then approximated by the derivatives of a Gaussian function (DGF) as well as the Coiflets to restore the impulse response of the target and to reconstruct the ISAR images. Both the DGF and Coiflets are applied to the deconvolution and their results are compared. The Gaussian and Coiflet function parameters are derived by a best-fit to the measured time-domain system response. Employing the parametric fits, a lowpass filter has been automatically embedded which performs regularization of the conjugate gradient (CG) optimization and speeds up the CG convergence. Numerical results show that the image quality from the Coiflet system is similar to or

better than from the DGF system. Owing to the continuity, smoothness, orthogonality and compact support of the Coiflets, the size of the system matrix has been reduced from 1024 times 1024 for DGF to 261 times 261, and the deconvolution process is accelerated more than 22 fold without sacrificing image characters. [J40]

"Spatially Adaptive Wavelet-Based Method Using the Cauchy Prior for Denoising the SAR Images"

The speckle noise complicates the human and automatic interpretation of synthetic aperture radar (SAR) images. Thus, the reduction of speckle is critical in various SAR image processing tasks. In this paper, we introduce a new spatially adaptive wavelet-based Bayesian method for despeckling the SAR images. The wavelet coefficients of the logarithmically transformed reflectance and speckle noise are modeled using the zero-location Cauchy and zero-mean Gaussian distributions, respectively. These prior distributions are then exploited to develop a Bayesian minimum mean absolute error estimator as well as a maximum a posteriori estimator. A new context-based technique with a reduced complexity is proposed for incorporating the spatial dependency of the wavelet coefficients with the Bayesian estimation processes. Experiments are carried out using typical noise-free images corrupted with simulated speckle noise as well as real SAR images, and the results show that the proposed method performs favorably in comparison to some of the existing methods in terms of the peak signal-to-noise ratio, speckle statistics and structural similarity index, and in its ability to suppress the speckle in the homogeneous regions [J41]

"Contourlet-based image denoising algorithm using directional windows"

Contourlet is a new effective signal representation tool in many image applications. Proposed is a contourlet-based image denoising algorithm using directional windows which takes advantage of the captured directional information of the images. Experiments show that the proposed algorithm achieves better performance than other contourlet-based image denoising algorithms [J42]

"Discriminating real objects in radar imaging by exploiting the squared modulus of the continuous wavelet transform"

New technique based on continuous wavelet transform (CWT) for classifying objects in synthetic aperture radar (SAR) imaging is presented. The CWT allows to analyse two-dimensional SAR images to highlight the frequency and angular behaviour of the scatterers. This technique allows to build a SAR hyperimage, that is, a four-dimensional data cube which represents for each spatial location (x, y) of the scatterer in the image, its frequency and angular energy behaviour. When analysing different targets, objects or areas in SAR images, it has been recently observed that some scatterers belonging to a same class of objects could have similar frequency and angular energy responses. The previous observations have motivated the determination to exploit these energy responses to discriminate these objects. This discrimination is performed by frequency and angular correlations between the response of a particular scatterer (measured) and those of all the scatterers in the SAR image. Some examples of discrimination from real SAR data are presented and show an interest of the method for target classification and recognition for SAR imaging [J43]

"Wavelet-Based Despeckling of SAR Images Using Gauss-Markov Random Fields"

In this paper, a wavelet-based speckle-removing algorithm is represented and tested on synthetic aperture radar (SAR) images. The SAR image is first transformed using a dyadic wavelet transform. The noise in the wavelet-transformed image is modeled as an additive signal-dependent noise with Gaussian distribution. The distribution of a noise-free image in a wavelet domain is modeled as a generalized Gauss-Markov random field (GGMRF). An unsupervised stochastic model-based approach to image denoising is represented. If the observed area is homogeneous, the parameters of the Gaussian distribution and GGMRFs are estimated from incomplete data using mixtures of wavelet coefficients. An expectation-maximization algorithm is used to estimate the parameters of both noisy and noise-free images. The unknown parameters are estimated using image and noise models that are defined in the wavelet domain for heterogeneous areas. Different inter-and intrascale dependences of wavelet coefficients were used to estimate the unknown parameters. The represented wavelet-based method efficiently removes noise from SAR images. [J44]

"Novel Airborne Real-Time Survey System"

Although satellite imaging is widely used today, an airborne survey system is still more efficient and effective under certain circumstances. Airborne survey can successfully detect and transmit target information in real time that is useful and critical for related agencies, such as environmental management, natural-disaster monitor and control, etc. Using a real-time synthetic-aperture-radar image processing approach based on a distribution system, image data are synchronized with a global positioning system; a satellite-communication system of data transmission is designed and implemented; and a novel image-compression method, which is wavelet-based, is

developed. The main idea of the proposed system is based on a function-distribution personal computer (PC) system: Data preprocessing, post processing, and extraction of images, data processing, image display, and image printing, are performed by different PCs. The method of image transmission proposed here is based on the satellite communication system. The proposed system has the advantage of low cost (both hardware prototype and maintenance) and rapid processing speed (only in several seconds; the disaster images from the air are processed and transmitted to the Disaster Reduction Center and to other users by the satellite communication system). The system has been applied to a real-time disaster monitor (such as a forest fire, a flood, etc.), real-time target tracking, large-scale topographic mapping, environmental survey, etc. [J45]

"Target Detection and Texture Segmentation in Polarimetric SAR Images Using a Wavelet Frame: Theoretical Aspects"

Theoretical aspects of a technique for target detection and texture segmentation in synthetic aperture radar (SAR) imagery using a wavelet frame are presented. Texture measures consist of multiscale local estimates of the following: 1) normalized second moment of the backscattered intensity and 2) variance of the wavelet-frame coefficients. This work is an extension of a method proposed in the image-processing literature. Novel issues, which are considered in the passage to radar imagery, are the influence of speckle on texture measures afforded by the wavelet frame and their dependence on polarization states (polarimetric texture). Regarding speckle, estimators that decouple the influence of speckle over texture are introduced and characterized by their expected value and variance. The response of the wavelet frame to discontinuities, which is an important issue in target detection problems, is addressed in terms of signal-to-speckle-noise ratio. The notion of polarimetric texture is revisited, providing a theoretical model that explains the dependences of texture measures on the polarization states. For one-point statistics, such model calls for a mixture of diverse polarimetric scattering mechanisms within the texture estimator support. For two-point statistics, the difference in spatial correlation properties among the polarimetric channels is called into play. To analyze these effects in polarimetric SAR data, a novel tool is introduced that is called the Wavelet Polarimetric Signature. The tool encapsulates, in graphical form, the dependence on scale and polarization state of the texture measure afforded by the wavelet frame. The theory exposed here underpins a method that has been proven successful and computationally attractive in a selected number of SAR thematic applications. It also sets the stage for the exploitation of novel target detection and textural segmentation capabilities based on polarimetric diversity. [J46]

"A Discrete Wavelet Transform Approach to Multiresolution Complex SAR Image Generation"

We present a signal processing approach using discrete wavelet transform (DWT) for the generation of complex synthetic aperture radar (SAR) images at an arbitrary number of dyadic scales of resolution. The method is computationally efficient and is free from significant system-imposed limitations present in traditional subaperture-based multiresolution image formation. Problems due to aliasing associated with biorthogonal decomposition of the complex signals are addressed. The lifting scheme of DWT is adapted to handle complex signal approximations and employed to further enhance the computational efficiency. Multiresolution SAR images formed by the proposed method are presented. [J47]

"A Novel Clutter Suppression Algorithm for Landmine Detection With GPR"

In this paper, we propose a new algorithm for the enhancement of plastic-cased antipersonnel mine detection using a video-impulse ground-penetrating radar (GPR). The algorithm is implemented as a nonlinear signal processor, which searches for the presence of a reference waveform in a 1D GPR echo return. The reference waveform represents a class of targets within a certain environment. The processor marks the presence of all responses similar to the reference waveform with a sharp mono-cycle. Simultaneously, responses with different waveforms, which presumably correspond to clutter, are suppressed. The reference waveform and other algorithm parameters are determined from training data sets acquired in a controlled environment. After training, the algorithm can be successfully applied at sites where soil, targets, and measurement scenarios are similar but not identical to those of the training site. The processor is integrated into an automated data processing and mine detection scheme as an additional clutter suppression step. The scheme consists of clutter suppression, synthetic aperture radar focusing, construction of a confidence map, and automated detection in it. The suggested algorithm is tested on experimental data, and its performance is compared against schemes where clutter suppression is organized by means of background removal and the cross correlation with a reference wavelet. The performance comparison is done in terms of receiver operating characteristic curves. It has been found that the suggested algorithm reduces the false alarm rate in about two and a half times in comparison to the cross-correlation-based clutter suppression. [J48]

"Partially Supervised Oil-Slick Detection by SAR Imagery Using Kernel Expansion"

Spaceborne synthetic aperture radar (SAR) is well adapted to detect ocean pollution independently from daily or weather conditions. In fact, oil slicks have a specific impact on ocean wave spectra. Initial wave spectra may be characterized by three kinds of waves, namely big, medium, and small, which correspond physically to gravity and gravity-capillary waves. The increase of viscosity, due to the presence of oil damps gravity-capillary waves. This induces not only a damping of the backscattering to the sensor but also a damping of the energy of the wave spectra. Thus, local segmentation of wave spectra may be achieved by the segmentation of a multiscale decomposition of the original SAR image. In this paper, a semisupervised oil-slick detection is proposed by using a kernel-based abnormal detection into the wavelet decomposition of a SAR image. It performs accurate detection with no consideration to signal stationarity nor to the presence of strong backscatters (such as a ship). The algorithm has been applied on ENVISAT Advanced SAR images. It yields accurate segmentation results even for small slicks, with a very limited number of false alarms [J49]

"Gauss–Markov Model for Wavelet-Based SAR Image Despeckling"

This letter presents synthetic aperture radar (SAR) image despeckling using dyadic wavelet transform. Maximum a posteriori (MAP) estimation is used to despeckle a SAR image in the wavelet domain. A wavelet transformed speckle-free image is approximated with a Gauss–Markov random field, and a Gaussian model is chosen to approximate speckle in the wavelet domain. A speckle-free wavelet coefficient is estimated with Bayesian inference using image and noise model parameters, which produce the highest evidence. The experimental results showed that the despeckling algorithm removes speckle noise in the homogeneous areas better than the state-of-the-art methods, which operate in the wavelet and image domain. The proposed method is very simple and computationally not demanding. [J50]

"Lossless Information Fusion for Active Ranging and Detection Systems"

The authors develop a centralized information fusion architecture from basic principles of information theory and Bayesian statistics. It is well known that any clustering, quantizing, or thresholding of data causes loss of information unless a sufficient statistic is computed in the processing. For the case of wideband active ranging systems, the coherent output of an optimum beamformer and a matched filter is a sufficient statistic that can be transmitted to the fusion center. For unknown target velocity, range, and bearing, the wideband space-time matched filter output can be interpreted as a multidimensional wavelet transform or a delay-scale-bearing map. In this paper, a Bayesian, joint estimation-detection approach is used for computation of sufficient statistics and multisensor information fusion. An approach borrowed from sequential Bayesian processing is used to compute prior densities for joint Bayesian estimation-detection. In this approach, a posteriori densities become priors after a coordinate transformation that transforms the outputs of each sensor to a common reference frame for all sensors. Reproducing prior densities are used to simplify Bayesian computation [J51]

"Automated delineation of dry and melt snow zones in Antarctica using active and passive microwave observations from space"

This paper presents the algorithms and analysis results for delineating snow zones using active and passive microwave satellite remote sensing data. With a high-resolution Radarsat synthetic aperture radar (SAR) image mosaic, dry snow zones, percolation zones, wet snow zones, and blue ice patches for the Antarctic continent have been successfully delineated. A competing region growing and merging algorithm is used to initially segment the SAR images into a series of homogeneous regions. Based on the backscatter characteristics and texture property, these image regions are classified into different snow zones. The higher level of knowledge about the areal size of and adjacency relationship between snow zones is incorporated into the algorithms to correct classification errors caused by the SAR image noise and relief-induced radiometric distortions. Mathematical morphology operations and a line-tracing algorithm are designed to extract a vector line representation of snow-zone boundaries. With the daily passive microwave Special Sensor Microwave/Imager (SSM/I) data, dry and melt snow zones were derived using a multiscale wavelet-transform-based method. The analysis results respectively derived from Radarsat SAR and SSM/I data were compared and correlated. The complementary nature and comparative advantages of frequently repeated passive microwave data and spatially detailed radar imagery for detecting and characterizing snow zones were demonstrated [J52]

"A unified framework for the Sussman, Moyal, and Janssen formulas"

This paper derives three fundamental identities in the radar and sonar literature, namely, Sussman' identity for ambiguity functions, Moyal's formula which establishes the value of the inner product between two scattering functions, and Janseen's formula which establishes identities for mixed inner products between waveforms and Gabor wavelets. Starting from the fundamental convolution identity, we derive Sussman's identity. Following from an initial value theorem of Fourier analysis, we obtained Moyal's formula. Following from Poisson's sum formula

and an initial value theorem, we also obtained Janssen's equality. The relationship between these three identities is as follows: Janssen's formula is a sampled-data version of Moyal's formula, and both follow from Sussman's identity. In turn, Sussman's identity is a consequence of the fundamental convolution identity. [J53]

"Multiresolution MAP Despeckling of SAR Images Based on Locally Adaptive Generalized Gaussian pdf Modeling"

In this paper, a new despeckling method based on undecimated wavelet decomposition and maximum a posteriori (MAP) estimation is proposed. Such a method relies on the assumption that the probability density function (pdf) of each wavelet coefficient is generalized Gaussian (GG). The major novelty of the proposed approach is that the parameters of the GG pdf are taken to be space-varying within each wavelet frame. Thus, they may be adjusted to spatial image context, not only to scale and orientation. Since the MAP equation to be solved is a function of the parameters of the assumed pdf model, the variance and shape factor of the GG function are derived from the theoretical moments, which depend on the moments and joint moments of the observed noisy signal and on the statistics of speckle. The solution of the MAP equation yields the MAP estimate of the wavelet coefficients of the noise-free image. The restored SAR image is synthesized from such coefficients. Experimental results, carried out on both synthetic speckled images and true SAR images, demonstrate that MAP filtering can be successfully applied to SAR images represented in the shift-invariant wavelet domain, without resorting to a logarithmic transformation [J54]

"Varying complexity in tree-structured image distribution models"

Probabilistic models of image statistics underlie many approaches in image analysis and processing. An important class of such models have variables whose dependency graph is a tree. If the hidden variables take values on a finite set, most computations with the model can be performed exactly, including the likelihood calculation, training with the EM algorithm, etc. Crouse et al. developed one such model, the hidden Markov tree (HMT). They took particular care to limit the complexity of their model. We argue that it is beneficial to allow more complex tree-structured models, describe the use of information theoretic penalties to choose the model complexity, and present experimental results to support these proposals. For these experiments, we use what we call the hierarchical image probability (HIP) model. The differences between the HIP and the HMT models include the use of multivariate Gaussians to model the distributions of local vectors of wavelet coefficients and the use of different numbers of hidden states at each resolution. We demonstrate the broad utility of image distributions by applying the HIP model to classification, synthesis, and compression, across a variety of image types, namely, electrooptical, synthetic aperture radar, and mammograms (digitized X-rays). In all cases, we compare with the HMT. [J55]

"Efficient Texture Analysis of SAR Imagery"

We address the problem of efficiency in texture analysis for synthetic aperture radar (SAR) imagery. Motivated by the statistical occupancy model, we introduce the notion of patch reoccurrences. Using the reoccurrences, we propose the use of approximate textural features in analysis of SAR images. We describe how the proposed approximate features can be extracted for two popular texture analysis methods—the gray-level cooccurrence matrix and Gabor wavelets. Results on image texture classification show that the proposed method can provide an improved efficiency in the analysis of SAR imagery, without introducing any significant degradation in the classification results. [J56]

"A novel approach to complex target recognition using RCS wavelet decomposition"

A novel approach to complex target recognition using wavelet decomposition of the radar cross section is introduced. The analysis technique is presented, and it shown how it can be implemented using MATLAB software. Applications in the radar field are then investigated, both for simple and complex targets. The results obtained show that this technique is very promising and yields recognition levels difficult to achieve with any other available technique. [J57]

"Practical landmine detector using forward-looking ground penetrating radar"

A practical landmine detector using forward-looking ground penetrating radar is presented. The detector uses a wavelet packet transform and the sequential feature selection algorithm to extract the most discriminant information distributed in the joint time-frequency domain for detecting landmines. A cascade training method that allows the detector to continue learning from errors made on unseen environments to improve its detection performance is also proposed. The testing results based on a recently conducted blind test are presented. [J58]

"A wavelet-based algorithm to estimate ocean wave group parameters from radar images"

In recent years, new remote sensing techniques have been developed to measure two-dimensional (2-D) sea surface elevation fields. The availability of these data has led to the necessity to extend the classical analysis methods for one-dimensional (1-D) buoy time series to two dimensions. This paper is concerned with the derivation of group parameters from 2-D sea surface elevation fields using a wavelet-based technique. Wave grouping is known to be an important factor in ship and offshore safety, as it plays a role in dangerous resonance phenomenons and the generation of extreme waves. Synthetic aperture radar (SAR) data are used for the analysis. The wavelet technique is introduced using synthetic ocean surfaces and simulated SAR data. It is shown that the group structure of the ocean wave field can be recovered from the SAR image if the nonlinear imaging effects are moderate. The method is applied to a global dataset of European Remote Sensing satellite (ERS-2) wave mode data. Different group parameters including the area covered by the largest group and the number of groups in a given area are calculated for over 33 000 SAR images. Global maps of the parameters are presented. For comparison, classical 1-D grouping parameters are calculated from colocated wave model data showing good overall agreement with the wavelet-derived parameters. ERS-2 image mode data are used to study wave fields in coastal areas. Waves approaching the island of Sylt in the North Sea are investigated, showing the potential of the wavelet technique to analyze the spatial wave dynamics associated with the bottom topography. Observations concerning changes of wavelength and group parameters are compared to linear wave theory. [J59]

"Closed-form correlation functions of generalized Hermite wavelets"

A closed-form expression is given for the correlation functions of generalized Hermite wavelets, constructed from an also-generalized definition of Hermite polynomials. Due to their Gaussianity, these wavelets can be used as a tool in the analysis or design of systems involving nonsinusoidal wavelets as well as to model impulsive waveforms found in real-world applications and signal processing problems. As such, the formula is potentially applicable to various areas of science. [J60]

"A novel algorithm for ship detection in SAR imagery based on the wavelet transform"

Carrying out an effective control of fishing activities is essential to guarantee a sustainable exploitation of sea resources. Nevertheless, as the regulated areas are extended, they are difficult and time consuming to monitor by means of traditional reconnaissance methods such as planes and patrol vessels. On the contrary, satellite-based synthetic aperture radar (SAR) provides a powerful surveillance capability allowing the observation of broad expanses, independently from weather effects and from the day and night cycle. Unfortunately, the automatic interpretation of SAR images is often complicated, even though undetected targets are sometimes visible by eye. Attending to these particular circumstances, a novel approach for ship detection is proposed based on the analysis of SAR images by means of the discrete wavelet transform. The exposed method takes advantage of the difference of statistical behavior among the ships and the surrounding sea, interpreting the information through the wavelet coefficients in order to provide a more reliable detection. The analysis of the detection performance over both simulated and real images confirms the robustness of the proposed algorithm. [J61]

"Image denoising algorithm via doubly local Wiener filtering with directional windows in wavelet domain"

Local Wiener filtering in the wavelet domain is an effective image denoising method of low complexity. In this letter, we propose a doubly local Wiener filtering algorithm, where the elliptic directional windows are used for different oriented subbands in order to estimate the signal variances of noisy wavelet coefficients, and the two procedures of local Wiener filtering are performed on the noisy image. The experimental results show that the proposed algorithm improves the denoising performance significantly. [J62]

"A wavelet packet transform-based approach for interference measurement in spread spectrum wireless communication systems"

This paper mainly concerns interference measurement in spread spectrum, wireless communication systems. A new digital signal-processing method is proposed, which proves to be nonintrusive and independent of the specific system considered. Thanks to the properties of the wavelet packet transform, the method is capable of extracting the interference that occurred from the spread spectrum signal, thus ensuring accurate interference magnitude and frequency estimates also in critical conditions: interference level much smaller than that characterizing the spread spectrum signal, and interference spectral content very close to the carrier frequency of the considered system. [J63]

"A detail-preserving scale-driven approach to change detection in multitemporal SAR images"

This paper presents a novel approach to change detection in multitemporal synthetic aperture radar (SAR) images. The proposed approach exploits a wavelet-based multiscale decomposition of the log-ratio image (obtained by a comparison of the original multitemporal data) aimed at achieving different scales (levels) of representation of the change signal. Each scale is characterized by a different tradeoff between speckle reduction and preservation of geometrical details. For each pixel, a subset of reliable scales is identified on the basis of a local statistic measure applied to scale-dependent log-ratio images. The final change-detection result is obtained according to an adaptive scale-driven fusion algorithm. Experimental results obtained on multitemporal SAR images acquired by the ERS-1 satellite confirm the effectiveness of the proposed approach. [J64]

"Wavelet transform-based interferometric SAR coherence estimator"

A novel method to estimate interferometric coherence in synthetic aperture radar interferometry is proposed. It is demonstrated that this approach is not affected by the terrain topography, contrary to multilook techniques. In addition, since the method is based on the two-dimensional discrete wavelet packet transform, it allows recovering coherence information with a high spatial resolution. Results derived from simulated and experimental ESAR-DLR X- and L-band interferograms corroborate the performance of the proposed technique. [J65]

"Multiple scale correlation of signals by shift-invariant discrete wavelet transform"

Correlation of signals at multiple scales of observation is useful for multiresolution interpretation of image, data and target signature analysis. Multiresolution analysis is inherent in the discrete wavelet transform (DWT), but shift-variance of the coefficients of the transform in dyadic orthogonal and biorthogonal basis spaces is the problem associated with it. Shift-variance of the transform and absence of a direct transform domain relationship make correlation of signals by the DWT inconvenient at multiple scales. The circulant shift property of the DWT coefficients is used in a novel way to produce correlation of signals at multiple scales with the critically sampled DWT only. The algorithm is derived in both discrete time and z-domain for signal vectors of finite duration. The algorithm is independent of signal waveform and wavelet kernel and is applied particularly for multiple scale correlation of radar signals, namely linear frequency modulated (LFM) chirp signals. [J66]

"Adaptive learning approach to landmine detection"

We consider landmine detection using forward-looking ground penetrating radar (FLGPR). The two main challenging tasks include extracting intricate structures of target signals and adapting a classifier to the surrounding environment through learning. Through the time-frequency (TF) analysis, we find that the most discriminant information is TF localized. This observation motivates us to use the over-complete wavelet packet transform (WPT) to sparsely represent signals with the discriminant information encoded into several bases. Then the sequential floating forward selection method is used to extract these components and thereby a neural network (NNW) classifier is designed. To further improve the classification performance and deal with the problem of detecting mines in an unconstraint environment, the AdaBoost algorithm is used. We integrate the feature selection process into the original AdaBoost algorithm. In each iteration, AdaBoost identifies the hard-to-learn examples and a new set of features which provide the specific discriminant information for these hard samples is extracted adaptively and a new classifier is trained. Experimental results based on measured data are presented, showing that a significant improvement on the classification performance can be achieved. [J67]

"CardioSmart: Cardiological Monitoring Intelligent system using GPRS"

This paper presents a Medicine/Engineering multidisciplinary research project, in which a European Telecardiology system has been developed for the continuing monitoring of patients using GPRS/GSM. The system consists in a portable terminal and a call center that provide 24h-duty medical supervision and assistance. The system includes advanced signal processing for the recognition of cardiac pathologies using neural networks, compression with wavelets, encryption and GPS to locate the patient in case of fading. The main requirements for this project have been its technical and economical viability and the user's acceptance of the system. The results obtained validate the system, showing its transnational supervision and remote attendance capability. The main achievements generate ambient intelligence and can be easily applied to other telemedical fields. This research project has been partially funded by the European Union under the VFP Information Society Technologies programme (IST-2001-35073) [J68]

"Application of the biorthogonal multiresolution time-domain method to the analysis of elastic-wave interactions with buried targets"

The biorthogonal multiresolution time-domain (Bi-MRTD) method is introduced for the analysis of elastic-wave interaction with buried targets. We provide a detailed discussion on implementation of the perfectly matched layer and on treatment of the interface between two different materials. The algorithm has also been parallelized by the use of the message-passing interface. The numerical results show that numerical dispersion can be significantly improved by using biorthogonal wavelets as bases, as compared to the conventional pulse expansion employed in the finite-difference time-domain (FDTD) method. We demonstrate that with comparison to the second-order FDTD, the Bi-MRTD yields significant CPU time and memory savings for large problems, for a fixed level of accuracy. [J69]

"Bayesian wavelet shrinkage with edge detection for SAR image despeckling"

In this paper, we present a wavelet-based despeckling method for synthetic aperture radar images and derive a Bayesian wavelet shrinkage factor to estimate noise-free wavelet coefficients. To preserve edges during despeckling, we apply a modified ratio edge detector to the original image and use the obtained edge information in our despeckling framework. Experimental results demonstrate that our method compares favorably to several other despeckling methods on test images. [J70]

"M-band biorthogonal interpolating wavelets via lifting scheme"

Recently, the lifting scheme was generalized to the multidimensional and multiband cases and was used to design M-band interpolating scaling filters and their duals. Based on this idea, we develop a new lifting pattern, namely, the progressive lifting pattern. This pattern allows us to pairwise generate M-band interpolating filterbanks and wavelets by the order from lowpass to highpass filters. A complete lifting procedure is divided into M-1 simple steps, in each step, a pair of filters (the l'th filter and its dual) are generated. In this way, an M -band biorthogonal interpolating filterbank/wavelet is determined by M(M-1) lifting filters. The first 2(M 1) lifting filters completely characterize the two scaling filters as well as the vanishing moments of bandpass and highpass filters; the residual (M-1) (M-2) lifting filters are used to pairwise optimize the bandpass and highpass filters in terms of the criterion of stopband energy minimization. The obtained M-band biorthogonal interpolating filterbanks and wavelets provide excellent frequency characteristics, in particular, low stopband sidelobes. Furthermore, the pattern is also utilized to design signal-adapted interpolating filterbanks and their rational coefficient counterparts in terms of subband coding gain. The obtained filterbanks achieve large subband coding gains. The rational coefficient filterbanks preserve the biorthogonality and allow wavelet transforms from integers to integers and a unifying lossy/lossless coding framework at the cost of a slight degradation in subband coding gain. [J71]

"Reconstruction of Radar reflectivity densities in a narrowband regime"

This paper is concerned with reconstruction problems arising in the context of radar signal analysis. The goal in radar is to obtain information about objects by emitting certain signals and analyzing the reflected echoes. In this paper, we shall focus on the narrowband model for radar echoes and on the case of continuously distributed objects D (reflectivity density). Following the approach of Naparst and Rebolla-Neira et al., we suggest to treat this problem by transmitting not just one signal but a family of signals. Indeed, a reconstruction formula can be derived, provided that the set of outgoing signals forms a frame. [J72]

"Wavelet support vector machine"

An admissible support vector (SV) kernel (the wavelet kernel), by which we can construct a wavelet support vector machine (SVM), is presented. The wavelet kernel is a kind of multidimensional wavelet function that can approximate arbitrary nonlinear functions. The existence of wavelet kernels is proven by results of theoretic analysis. Computer simulations show the feasibility and validity of wavelet support vector machines (WSVMs) in regression and pattern recognition. [J73]

"Homomorphic wavelet-based statistical despeckling of SAR images"

In this paper, we introduce the homomorphic Γ-WMAP (wavelet maximum a posteriori) filter, a wavelet-based statistical speckle filter equivalent to the well known Γ-MAP filter. We perform a logarithmic transformation in order to make the speckle contribution additive and statistically independent of the radar cross section. Further, we propose to use the normal inverse Gaussian (NIG) distribution as a statistical model for the wavelet coefficients of both the reflectance image and the noise image. We show that the NIG distribution is an excellent statistical model for the wavelet coefficients of synthetic aperture radar images, and we present a method for estimating the parameters. We compare the homomorphic Γ-WMAP filter with the Γ-MAP filter and and the recently introduced Γ-WMAP filter, which are both based on the same statistical assumptions. The homomorphic Γ-WMAP filter is shown to have better performance with regard to smoothing homogeneous regions. It may in some cases introduce a small bias, but in our studies it is always less than that introduced by the Γ-MAP filter.

Further, the speckle removed by the homomorphic Γ-WMAP filter has statistics closer to the theoretical model than the speckle contribution removed with the other filters. [J74]

"Fuzzy-coded space-frequency quantization for SAR data compression"

In this letter, we propose a new image coding technique, which is a combination of space frequency quantization and a context-based modeling using fuzzy logic. The compression results showed that the proposed coder outperforms the state-of-the-art coders in the rate-distortion sense for compression of processed synthetic aperture radar amplitude data. [J75]

"A novel approach to the classification of regional-scale Radar mosaics for tropical vegetation mapping"

The Global Rain Forest Mapping (GRFM) radar mosaics, generated from L-band Japanese Earth Resources Satellite 1 imagery downsampled to 100-m pixel size, provide a two-season spatially continuous coverage of the humid tropical ecosystems of the world. This paper presents a novel classification approach suitable for regional-scale vegetation mapping using the GRFM datasets. The mapping system consists of: 1) an application-dependent wavelet-based edge-preserving smoothing algorithm and 2) a two-stage per-pixel hybrid learning nearest multiple-prototype (NMP) classifier, whose unsupervised first stage is a per-pixel near-optimal vector quantizer, called enhanced Linde-Buzo-Gray (ELBG), recently proposed in pattern recognition literature. Identified as ENMP (NMP with ELBG), this novel classification approach is compared against two alternative systems in the classification of forest cover disturbances located across an area in the Amazon Basin. Surface classes of interest are primary forest, degraded forest, nonforest, and water bodies. Reference maps, derived from 30-m resolution Landsat Thematic Mapper imagery, are provided by the National Aeronautics and Space Administration and the Food and Agriculture Organization of the United Nations. Abundant quantitative and qualitative evidence shows that: 1) in a forest/nonforest data-mapping task, ENMP provides a testing accuracy of 87%, in line with training accuracies, i.e., the proposed method seems capable of generalizing well over the GRFM South America dataset and 2) among three competing approaches, ENMP provides the best compromise between ease of use, mapping accuracy, and computational time. Starting from these results, ENMP is employed to generate a swamp forest map of the whole Amazon Basin from the two-season GRFM radar mosaic of South America, in the context of the Global Land Cover project (GLC 2000). [J76]

"Automatic seabed classification by the analysis of sidescan sonar and bathymetric imagery"

The authors present a technique for making use of both sidescan amplitude and bathymetric data provided from sidescan bathymetric sonars for the classification of underwater seabeds. Sidescan amplitude is corrected for physical factors and used to plot 'processed' sidescan images. Both amplitude and textural features are derived from these images. Textural features are obtained using 2-D discrete wavelet transforms. Bathymetric images are used to derive features indicating seafloor variability. These features are combined together and the most relevant ones are selected by feature selection algorithms. If grab samples are available, the areas around them are used as training data in a supervised approach. The backpropagation elimination algorithm is used on the training dataset to select relevant features. If training data are not available, an unsupervised approach can be used. The dimensions of the whole dataset are reduced using principal component analysis in this case, and the principal components are used as features. In both cases, clustering techniques are used to cluster the data into sediment classes. The classified points are then plotted against their GIS position in the survey. Classification results correlate with grab sample types from the areas considered (in the supervised case) and with expert observation of sidescan images, where training data is not available. [J77]

"Landsat ETM+ and SAR image fusion based on generalized intensity Modulation"

This work presents a novel multisensor image fusion algorithm, which extends panchrmomatic sharpening of multispectral (MS) data through intensity modulation to the integration of MS and synthetic aperture radar (SAR) imagery. The method relies on SAR texture, extracted by ratioing the despeckled SAR image to its low-pass approximation. SAR texture is used to modulate the generalized intensity (GI) of the MS image, which is given by a linear transform extending intensity-hue-saturation transform to an arbitrary number of bands. Before modulation, the GI is enhanced by injection of high-pass details extracted from the available panchrmomatic image by means of the "a`-trous" wavelet decomposition. The texture-modulated panchrmomatic-sharpened GI replaces the GI calculated from the resampled original MS data. Then, the inverse transform is applied to obtain the fusion product. Experimental results are presented on Landsat-7 Enhanced Thematic Mapper Plus and European Remote Sensing 2 satellite images of an urban area. The results demonstrate accurate spectral preservation on vegetated regions, bare soil, and also on textured areas (buildings and road network) where SAR texture information enhances the fusion product, which can be usefully applied for both

visual analysis and classification purposes. [J78]

"SAR image data compression using wavelet packet transform and universal-trellis coded quantization"

A wavelet packet image coding algorithm for synthetic aperture radar (SAR) image data compression is proposed in this paper. High rate-distortion (R-D) performance of this algorithm [wavelet packet quantization universal trellis-coded quantization (WPQUTCQ)] is achieved by incorporating the wavelet packet transform for representing the rich texture information of SAR image data, the quadtree technique for classifying the wavelet packet coefficients, and the universal trellis-coded quantization (UTCQ). For a typical SAR image, WPQUTCQ outperforms set partitioning in hiearchical trees and JPEG2000 by about 1.21 and 0.81 dB in peak signal-to-noise ratio (PSNR) at 2 bpp, respectively. The effect of best basis selection on the R-D performance of coding algorithm for SAR image data compression is also evaluated through comparing the effects of different cost functions (e.g., entropy, the texture energy, which is designed for SAR image data compression particularly, and the cost function, based on the actual coding strategy proposed by us) on the R-D performance of WPQUTCQ. The experimental results show the suitability of the cost function based on the actual coding strategy for SAR image data compression when compared with other cost functions. For a typical SAR image, the coding results by WPQUTCQ corresponding to the cost function based on the actual coding strategy achieve gains 0.59 and 0.49 dB on average in PSNR when compared with the coding results corresponding to entropy and the texture energy, respectively. [J79]

"Precipitation type determination from spaceborne radar observations"

The Tropical Rainfall Measuring Mission (TRMM) program is dedicated to observing and understanding the impact of tropical rainfall. Two important products of the TRMM precipitation radar include the classification of precipitation into convective and stratiform type as well as determination of the height of the brightband. Currently, TRMM uses an algorithm to arrive at these products based on a characterization of horizontal and vertical variability of reflectivity. This paper presents a new algorithm for classifying precipitation type into convective or stratiform as well as detect the height of brightband developed using wavelet analysis. The results obtained from wavelet analysis are compared against simultaneous ground validation products from the TRMM program. The results show that the wavelet-based algorithms provide fairly accurate results for both convective/stratiform classification as well as brightband determination. [J80]

"A fast intensity-hue-saturation fusion technique with spectral adjustment for IKONOS imagery"

Among various image fusion methods, intensity-hue-saturation (IHS) technique is capable of quickly merging the massive volumes of data. For IKONOS imagery, IHS can yield satisfactory "spatial" enhancement but may introduce "spectral" distortion, appearing as a change in colors between compositions of resampled and fused multispectral bands. To solve this problem, a fast IHS fusion technique with spectral adjustment is presented. The experimental results demonstrate that the proposed approach can provide better performance than the original IHS method, both in processing speed and image quality. [J81]

"Multisensor fusion in the frame of evidence theory for landmines detection"

In the frame of humanitarian antipersonnel mines detection, a multisensor fusion method using the Dempster-Shafer evidence theory is presented. The multisensor system consists of two sensors-a ground penetrating radar (GPR) and a metal detector (MD). For each sensor, a new features extraction method is presented. The method for the GPR is mainly based on wavelets and contours extraction. First simulations on a limited set of data show that an improvement in detection and false alarms rejection, for the GPR as a standalone sensor, could be obtained. The MD features extraction method is mainly based on contours extraction. All of these features are then fused with the GPR ones in some specific cases in order to determine a new feature. From these results, belief functions, as defined in the evidence theory, are then determined and combined thanks to the orthogonal sum. First results in terms of detection and false alarm rates are presented for a limited set of real data and a comparison is made between the two cases: with or without multisensor fusion. [J82]

"Contribution of the fractal dimension to multiscale adaptive filtering of SAR imagery"

Radar images can show great variability from pixel to pixel, which is an obstacle to effective processing. This variability, due to speckle created by the radar wave coherence, necessitates the use of more adapted filters. Previous studies have shown that multiresolution wavelet analysis yields better results but produces artefacts due to multiscale decomposition. This paper proposes a method that reduces these effects by introducing the fractal dimension. The resultant filter combines wavelet decomposition and variance change model based on the level of variance estimated by studying the fractal dimension of the image. [J83]

"The application of wavelets correlator for ship wake detection in SAR images"

The detection of the wake can provide substantial information about a ship, such as its size, direction, and speed of movement. In general though, ship-generated wakes in synthetic aperture radar images are associated with high sea clutter, which will cause some deterioration in the detection performance. Therefore, a wavelet correlator, based on an orthogonal basis function, is adopted. Three highpass images-horizontal, vertical, and diagonal direction-are generated for each resolution scale, followed by a process to correlate among the moduli of different scale modulus images formed from the three highpass images. The output of the correlation process is highly representative at the ship's wake edges. Comparisons with other methods indicate the superior performance of the present approach, in that not only can the wakes be detected, but their V-shaped pattern is well preserved. The second stage involves the application of the Radon transform technique to an estimation of the V-opening angle from the detected ship wakes. Ship-generated wake edges are found to be the local maxima in the wavelet transform method of several adjacent scales, and hence, the wake edge will be enhanced in the reconstructed data. The background noise is also greatly reduced. In particular, the process of spatial correlation is found to be critical. Compared to a direct Radon transform, the proposed scheme is demonstrated to be much more effective in terms of efficiency, as well as reliability, for ship wake detection in noisy backgrounds. [J84]

"Texture analysis and classification of ERS SAR images for map updating of urban areas in The Netherlands"

In single-band and single-polarized synthetic aperture radar (SAR) image classification, texture holds useful information. In a study to assess the map-updating capabilities of such sensors in urban areas, some modern texture measures were investigated. Among them were histogram measures, wavelet energy, fractal dimension, lacunarity, and semivariograms. The latter were chosen as an alternative for the well-known gray-level cooccurrence family of features. The area that was studied using a European Remote Sensing Satellite 1 (ERS-1) SAR image was the conurbation around Rotterdam and The Hague in The Netherlands. The area can be characterized as a well-planned dispersed urban area with residential areas, industry, greenhouses, pasture, arable land, and some forest. The digital map to be updated was a 1:250000 Vector Map (VMap1). The study was done on the basis of nonparametric separability measures and classification techniques because most texture distributions were not normal. The conclusion is that texture improves the classification accuracy. The measures that performed best were mean intensity (actually no texture), variance, weighted-rank fill ratio, and semivariogram, but the accuracies vary for different classes. Despite the improvement, the overall classification accuracy indicates that the land-cover information content of ERS-1 leaves something to be desired. [J85]

"SAR image denoising via Bayesian wavelet shrinkage based on heavy-tailed modeling"

Synthetic aperture radar (SAR) images are inherently affected by multiplicative speckle noise, which is due to the coherent nature of the scattering phenomenon. This paper proposes a novel Bayesian-based algorithm within the framework of wavelet analysis, which reduces speckle in SAR images while preserving the structural features and textural information of the scene. First, we show that the subband decompositions of logarithmically transformed SAR images are accurately modeled by alpha-stable distributions, a family of heavy-tailed densities. Consequently, we exploit this a priori information by designing a maximum a posteriori (MAP) estimator. We use the alpha-stable model to develop a blind speckle-suppression processor that performs a nonlinear operation on the data and we relate this nonlinearity to the degree of non-Gaussianity of the data. Finally, we compare our proposed method to current state-of-the-art soft thresholding techniques applied on real SAR imagery and we quantify the achieved performance improvement. [J86]

"Reflectivity estimation for SAR image compression"

Synthetic aperture radar (SAR) images suffer from speckle noise that degrades image quality. Also, speckle removal is needed for lossy image compression as such noise increases image entropy. Nevertheless, most lossy compression schemes act as lowpass filters that might not suit multiplicative noise reduction. In order to build a compression scheme that takes into consideration statistics of SAR images, a well-known reflectivity estimator is integrated into an JPEG 2000-like image compression strategy, so that image compression artifacts may be viewed as an adaptive despeckle filter instead of a simple lowpass filter. It yields a compression algorithm that acts in a similar way to the Lee (or Kuan) filter. [J87]

"Three-band biorthogonal interpolating complex wavelets with stopband suppression via lifting scheme"

Wavelet research has primarily focused on real-valued wavelet bases. However, the complex filterbanks provide much convenience for complex signal processing. For example, in radar and sonar signal processing, the complex signals from the I/Q receiver can be efficiently processed with complex filterbanks rather than real filterbanks. Specifically, the positive and negative Doppler frequencies imply different physical content in the moving target detector (MTD) and moving target identification (MTI); therefore, it is significant to design complex multiband filterbanks that can partition positive and negative frequencies into different subbands. We design two novel families of three-band biorthogonal interpolating complex filterbanks and wavelets by using the three-band lifting scheme. Unlike the traditional three-band filterbanks, the novel complex filterbank is composed of three channels, including the lowpass channel, the positive highpass channel whose passband distributes in the positive frequency region, and the negative highpass channel in the negative frequency region. Such a filterbank/wavelet naturally provides the ability to extract positive frequency components and negative frequency components from complex signals. Moreover, a novel set of design constraints are introduced to manipulate the stopband characteristic of highpass filters and are referred to as stopband suppression, which strengthens the traditional constraints of vanishing moments. Finally, a numerical method is given to further lower stopband sidelobes. [J88]

"SAR raw data compression by subband coding"

A technique for compressing synthetic aperture radar raw data using multiresolution representations and subband coding is considered. In particular, we present the performance of a transform coding compression method using wavelet basis, coupled with a threshold quantizer optimized for Gaussian statistics, as well as a proper subband bit allocation strategy. The performances achieved in terms of bit rate reduction and certain quality parameters computed on the images obtained by compressed data have been evaluated. These show an increased performance in the compression method with respect to conventional methods, albeit with a slightly increased complexity in the algorithm implementation. [J89]

"Iterated wavelet transformation and signal discrimination for HRR radar target recognition"

This paper explores the use of wavelets to improve the selection of discriminant features in the target recognition problem using high range resolution (HRR) radar signals in an air to air scenario. We show that there is statistically no difference among four different wavelet families in extracting discriminatory features. Since similar results can be obtained from any of the four wavelet families and wavelets within the families, the simplest wavelet (Haar) should be used. We use the box classifier to select the 128 most salient pseudo range bins and then apply the wavelet transform to this reduced set of bins. We show that by iteratively applying this approach, the classifier performance is improved. We call this the iterated wavelet transform . The number of times the feature reduction and transformation can be performed while producing improved classifier performance is small and the transformed features are shown to quickly cause the performance to approach an asymptote. [J90]

"A time-frequency application with the Stokes-Woodward technique"

Elfouhaily et al. (2003) generalized Woodward's theorem and applied it to the case of random signals jointly modulated in amplitude and frequency. This generalization yields a new spectral technique to estimate the amount of energy due to mode coupling without calling for higher order statistics. Two power spectra are detected; the first is related to the independent modes, and the second contains extra energy caused by mode coupling. This detection is now extended from frequency to time-frequency domain. A comparison between a wavelet transform and our time-frequency technique shows good agreement along with new insight into the time occurrence of the nonlinearities or mode coupling. An application to water surface waves is given as an example. [J91]

"Effect of nonuniform target motion on radar backscattered waveforms"

The effect of nonuniform motion on radar waveforms is discussed. By considering the physical model of a perfectly reflecting mirror with an arbitrary law of motion r(t), it is possible to determine the functional form of the scattered wave at the receiver for any waveform in general. The particular example of an interrupted continuous wave waveform is used to analyse the effect of nonuniform motion on the return spectrum. These models provide a theoretical foundation for the observations of micro-Doppler that have been discussed by a number of authors. Finally, some of the implications, both physical and mathematical, of nonuniform motion for time-frequency methods are addressed [J92]

"Segmentation of remotely sensed images using wavelet features and their evaluation in soft computing framework"

The present paper describes a feature extraction method based on M-band wavelet packet frames for

segmenting remotely sensed images. These wavelet features are then evaluated and selected using an efficient neurofuzzy algorithm. Both the feature extraction and neurofuzzy feature evaluation methods are unsupervised, and they do not require the knowledge of the number and distribution of classes corresponding to various land covers in remotely sensed images. The effectiveness of the methodology is demonstrated on two four-band Indian Remote Sensing 1A satellite (IRS-1A) images containing five to six overlapping classes and a three-band SPOT image containing seven overlapping classes. [J93]

"A Bayesian transformation model for wavelet shrinkage"

Wavelet shrinkage estimators, in general, make the additive normal noise assumption and disregard the nonlinear nature of contamination. We develop Bayesian wavelet shrinkage estimators (based on the power transformations in the linear model) to accommodate a broad class of noise models in image processing applications. We intend to admit, under one roof, the widespread additive model, the product models common in imaging (such as in synthetic aperture radar (SAR) imagery), as well as noise that may exist amid these two extremes. Tactful prior elicitation in this model, such as the simultaneous assignment of mixture priors for wavelet coefficients and the transformation, imparts flexibility and ample insight into the underlying structure. The model permits estimation with unknown noise structure for reasonably unimodal and well-behaved (on the tails) distributions, wherein it can outperform common shrinkage estimators. Extensions with multiple transformations and Markov random field priors are also considered for adaptation to local variations in contamination. Modern Markov chain Monte Carlo (MCMC) Bayesian computation has been used for simulations and several examples are reported. [J94]

"Automated removal of ghost noise from SAR images using wavelet packet transform"

Due to interference caused by ground transmitters, so-called ghost noise occurs on images obtained from synthetic aperture radar (SAR). This letter proposes a scheme based on the wavelet packet transform to remove this ghost noise from the SAR image. The wavelet packet transform is employed to decompose the SAR image with the ghost noise both in the spatial and in the spatial frequency domain. To automatically detect and remove the ghost noise, an energy detection method is developed in this letter. The performance of the proposed scheme is demonstrated by some experimental results on real SAR images. In addition, we point out that the proposed scheme is also useful for other applications of image processing and analysis. [J95]

"Almost translation invariant wavelet transformations for speckle reduction of SAR images"

Two wavelet transformations are used for speckle reduction and enhancement of synthetic aperture radar (SAR) images. First, a discrete wavelet transformation (DWT) based on oversampled filter banks is used. The oversampled DWT is called a double-density DWT (DD-DWT) and is based on a single-scaling function (low pass) and two distinct wavelet functions (high pass). Second, a discrete wavelet transformation based on two dual real wavelet trees is applied. Each tree produces a set of real DWTs, which together form the complex wavelet transformation (CWT), i.e., a transformation with both real and imaginary parts. Both of these DWTs are almost translation invariant and are useful for speckle reduction through their subband images, and the speckle reduction is obtained by thresholding the subband image coefficients of the digitized SAR images. A thresholding method based on the use of nonlinear functions, which are adapted for each selected subband, is used. The nonlinear functions are based on sigmoid functions. The denoising method presented shows great promise for speckle removal and, hence, can provide good detection performance for SAR-based recognition. [J96]

"Analysis of SAR images by multidimensional wavelet transform"

The description and development are described of a multidimensional continuous wavelet transform for synthetic aperture radar (SAR) image analysis, especially for the analysis of 'dispersive' reflectors located on a ground illuminated by a SAR. The usual imaging process makes the assumption that the reflectors are isotropic (i.e. that they behave the same way regardless of the angle from which they are viewed) and white (they have the same properties within the emitted frequency bandwidth). New imaging capacities (offering large bandwidth, low band and large angular excursions of analysis, for example) make these assumptions obsolete. The goal is to present methods based on the multidimensional continuous wavelet transform which highlight these effects for target recognition or identification. Some examples of this analysis are given by processing real data collected in X-band by the RAMSES airborne SAR facilities at ONERA [J97]

"ISAR motion compensation using evolutionary adaptive wavelet transform"

Many time-frequency analysis techniques have been used for ISAR motion compensation. One of them, the adaptive wavelet transform (AWT), is cross-term free and has high resolution, but its accuracy is limited because it uses a bisection search method and fast Fourier transform (FFT) for parameter extraction. A novel time-

frequency (T-F) analysis, called the evolutionary adaptive wavelet transform (EAWT), is used for ISAR motion compensation. The EAWT is more accurate than the conventional AWT. Using artificially created data from three time-frequency centres and simulated MIG-25 ISAR data, this algorithm is compared with the conventional AWT for accuracy. From the constructed ISAR image using AWT and EAWT, it is demonstrated that the EAWT algorithm can obtain a more clear motion-compensated ISAR image than the conventional AWT [J98]

"Validation of sea ice motion from QuikSCAT with those from SSM/I and buoy"

Arctic sea ice motion for the period from October 1999 to March 2000 derived from QuikSCAT and ocean buoy observations.Special Sensor Microwave/Imager (SSM/I) data using the wavelet analysis method agrees well with ocean buoy observations. Results from QuikSCAT and SSM/I are compatible when compared with buoy observations and complement each other. Sea ice drift merged from daily results from QuikSCAT, SSM/I, and buoy data gives more complete coverage of sea ice motion. Based on observations of six months of sea ice motion maps, the sea ice motion maps in the Arctic derived from QuikSCAT data appear to have smoother (less noisy) patterns than those from NSCAT, especially in boundary areas, possibly due to constant radar scanning incidence angle. For late summer, QuikSCAT data can provide good sea ice motion information in the Arctic as early as the beginning of September. For early summer, QuikSCAT can provide at least partial sea ice motion information until mid-June. In the Antarctic, a case study shows that sea ice motion derived from QuikSCAT data is consistent with pressure field contours. [J99]

"Wavelet detection scheme for small targets in sea clutter"

A radar detection scheme based on wavelet determination of scatterer lifetime within the Doppler spectra of non-Gaussian sea clutter is reported. The method is shown to be complementary to simple intensity thresholding when applied to a low-observable time varying target [J100]

"SAR interferometric phase statistics in wavelet domain"

Synthetic aperture radar (SAR) interferometry is employed to obtain topographic information. Owing to noise, interferometric information has to be filtered. The wavelet transform can be employed to filter the interferometric phase, maintaining the spatial resolution, but new signal models have to be studied in this domain for further processing [J101]

"A study of two-channel complex-valued filterbanks and wavelets with orthogonality and symmetry properties"

We investigate two-channel complex-valued filterbanks and wavelets that simultaneously have orthogonality and symmetry properties. First, the conditions for the filterbank to be orthogonal, symmetric, and regular (for generating smooth wavelets) are presented. Then, a complete and minimal lattice structure is developed, which enables a general design approach for filterbanks and wavelets with arbitrary length and arbitrary order of regularity. Finally, two integer implementation methods that preserve the perfect reconstruction property of the filterbank are proposed. Their performances are evaluated via experimental results [J102]

"Progressive space frequency quantization for SAR data compression"

The authors propose a new wavelet image coding technique for synthetic aperture radar (SAR) data compression called a progressive space-frequency quantization (PSFQ). PSFQ performs spatial quantization via rate distortion-optimized zerotree pruning of wavelet coefficients that are coded using a progressive subband coding technique. They compared the performances of zerotree-based methods: EZW, SPIHT, SFQ, and PSFQ with the classical wavelet-based method (CWM), which uses uniform scalar quantization of subbands followed by recency rank coding. The performances of the methods based on zerotree quantization were better than the CWM in the rate distortion sense. The embedded coding techniques perform better SNR results than the methods using scalar quantization. However, the probability density function (PDF) of the reconstructed amplitude SAR data compressed using CWM, better corresponded to the PDF of the original data than the PDF of the reconstructed data compressed using the zerotree based methods. The amplitude PDF of the reconstructed data obtained using PSFQ compression algorithm better corresponded to the original PDF than the amplitude PDF of the data obtained using the multilook method [J103]

"Two-dimensional phase unwrapping using wavelet transform"

A method for solving the least squares two-dimensional phase unwrapping problem is presented. This technique is based on the multiresolution representation of a linear system using the discrete wavelet transform. By applying the wavelet transform to the original system, a better convergence condition of an equivalent new

system can be achieved [J104]

"Modeling and reduction of SAR interferometric phase noise in the wavelet domain"

This paper addresses the problem of interferometric phase noise reduction in synthetic aperture radar interferometry. A new phase noise model in the complex domain is introduced and validated by using both simulated and real interferograms. This noise model is also derived in the complex wavelet domain, where a novel noise reduction algorithm, which is not based on a windowing process and without the necessity of phase unwrapping, is addressed. The use of the wavelet transform allows to maintain the spatial resolution in the filtered phase image and prevents to filter low coherence areas. By using both, simulated as well as real interferometric phase images, the performance of this algorithm, in terms of noise reduction, spatial resolution maintenance, and computational efficiency, is reported and compared with other conventional filtering approaches. [J105]

"A wavelet transform coder supporting browsing and transmission of sea ice SAR imagery"

A wavelet-transform-based algorithm for sea ice synthetic aperture radar (SAR) image data compression is presented. Compression of the relatively low resolution (100 m) SAR data is necessary to enable the transmission of such images from the Finnish Ice Service to users in the Baltic Sea. On board the ships, the SAR images are used for navigation purposes. Hence, in the visual appearance of the compressed image, special attention must be paid to the sharpness of small details. Several target-dependent features are incorporated in the compression scheme developed. The addition of these features was motivated by an examination of the wavelet coefficient statistics for the SAR data. In the quantization phase, the sensitivity characteristics of the human visual system were taken into account. As a result, the proposed algorithm deviates in several respects from the standard procedures used in wavelet-based compression. The algorithm requires the setting up of multiple user-defined parameters to satisfy the requirements of the users and data. This requires supervision of an expert, but also makes it flexible for many kinds of data and user requirements. The algorithm presented gives satisfactory results with a compression ratio of 20:1. Since only the location of ice-covered areas is of significance for ship traffic, the algorithm introduced contains an option to mask off open sea areas with the aid of an automatic open-water detection procedure. We also report the results of a user evaluation, in which the proposed algorithm is compared to the algorithm currently used by the Finnish Ice Service, as well as to the JPEG standard. The results of the evaluation favor the use of the proposed algorithm. [J106]

"Speckle removal from SAR images in the undecimated wavelet domain"

Speckle reduction is approached as a minimum mean-square error (MMSE) filtering performed in the undecimated wavelet domain by means of an adaptive rescaling of the detail coefficients, whose amplitude is divided by the variance ratio of the noisy coefficient to the noise-free one. All the above quantities are analytically calculated from the speckled image, the variance and autocorrelation of the fading variable, and the wavelet filters only, without resorting to any model to describe the underlying backscatter. On the test image Lena corrupted by synthetic speckle, the proposed method outperforms Kuan's local linear MMSE filtering by almost 3-dB signal-to-noise ratio. When true synthetic aperture radar (SAR) images are concerned, empirical criteria based on distributions of multiscale local coefficient of variation, calculated in the undecimated wavelet domain, are introduced to mitigate the rescaling of coefficients in highly heterogeneous areas where the speckle does not obey a fully developed model, to avoid blurring strong textures and point targets. Experiments carried out on widespread test SAR images and on a speckled mosaic image, comprising synthetic shapes, textures, and details from optical images, demonstrate that the visual quality of the results is excellent in terms of both background smoothing and preservation of edge sharpness, textures, and point targets. The absence of decimation in the wavelet decomposition avoids typical impairments often introduced by critically subsampled wavelet-based denoising. [J107]

"A measurement method based on a modified version of the chirplet transform for instantaneous frequency estimation"

A measurement method for instantaneous frequency estimation is presented in this paper. The method is based on the use of the chirplet transform, a linear time-frequency representation (TFR) allowing additional modifications of each cell on the time-frequency plane with respect to other TFRs. In particular, a modified version of this transform is proposed here; a bending effect can be further imposed on the cells. Thanks both to this feature and a suitable measurement procedure, properly set up by the authors, the method assures a satisfying accuracy in reconstructing the instantaneous frequency trajectory of monocomponent signals as well as a good resolving capability in the analysis of multicomponent signals whose instantaneous frequency

trajectories are strongly nonlinear and very close to one another. Theoretical details concerning the chirplet transform and its modified version are first given. Then, the proposed measurement procedure for choosing the optimal values of the parameters of the transform according to the local features of the analyzed signal is described. At the end, the results of several experimental tests conducted both on monocomponent and multicomponent signals are presented; advantages over other solutions are also highlighted. [J108]

"SAR speckle reduction using wavelet denoising and Markov random field modeling"

The granular appearance of speckle noise in synthetic aperture radar (SAR) imagery makes it very difficult to visually and automatically interpret SAR data. Therefore, speckle reduction is a prerequisite for many SAR image processing tasks. In this paper, we develop a speckle reduction algorithm by fusing the wavelet Bayesian denoising technique with Markov-random-field-based image regularization. Wavelet coefficients are modeled independently and identically by a two-state Gaussian mixture model, while their spatial dependence is characterized by a Markov random field imposed on the hidden state of Gaussian mixtures. The Expectation-Maximization algorithm is used to estimate hyperparameters and specify the mixture model, and the iterated-conditional-modes method is implemented to optimize the state configuration. The noise-free wavelet coefficients are finally estimated by a shrinkage function based on local weighted averaging of the Bayesian estimator. Experimental results show that the proposed method outperforms standard wavelet denoising techniques in terms of the signal-to-noise ratio and the equivalent-number-of-looks measures in most cases. It also achieves better performance than the refined Lee filter. [J109]

"On shape, orientation, and structure of atmospheric cells inside wind rolls in two SAR images"

Synthetic aperture radar (SAR) images of the sea surface often show roll-vortex structures and other features which, in general, are spread out over several length scales and may present spatial periodicity as well as intermittence. Standard techniques, such as two-dimensional (2-D) Fourier analysis, are unsuitable both when it is of interest to detect intermittent phenomena and to analyze the spatial disposition of the backscatter structures inside the SAR images. For the above reasons, the 2-D continuous wavelet transform analysis has been applied to two European Remote Sensing mission SAR images over the Mediterranean Sea, showing wind rolls and atmospheric gravity waves. Through the evaluation of the wavelet variance map, which ideally corresponds to the 2-D Fourier spectrum, it has been possible to assess the presence of two main energy areas at large (from 7-28 km) and small (from 0.5-2 km) spatial scales. While the large-scale fluctuations may be ascribed to atmospheric gravity waves and other features induced by the surroundings, the small-scale fluctuations reveal the inner structure of the atmospheric wind rolls. The SAR-like maps, obtained by adding the wavelet coefficient maps pertaining to the small scales, have permitted us to highlight the high- and low-intensity backscatter cells associated with the wind rolls. These cells have been statistically characterized by means of the frequency distributions of the size of the cells maximum and minimum axes, of the orientation of the maximum axis, and of their area. The results indicate that high- and low-intensity backscatter cells have similar characteristics in both cases studied: they appear of elliptic shape, with the major axis along the wind roll direction; the average axes ratio is 2.5:1. The frequency distributions of the cell area indicate a continuous distribution of sizes, without significant gaps. [J110]

"Multiwavelet neural network and its approximation properties"

A model of multiwavelet-based neural networks is proposed. Its universal and L2approximation properties, together with its consistency are proved, and the convergence rates associated with these properties are estimated. The structure of this network is similar to that of the wavelet network, except that the orthonormal scaling functions are replaced by orthonormal multiscaling functions. The theoretical analyses show that the multiwavelet network converges more rapidly than the wavelet network, especially for smooth functions. To make a comparison between both networks, experiments are carried out with the Lemarie-Meyer wavelet network, the Daubechies2 wavelet network and the GHM multiwavelet network, and the results support the theoretical analysis well. In addition, the results also illustrate that at the jump discontinuities, the approximation performance of the two networks are about the same [J111]

"Electromagnetic imaging in science and medicine with wavelet applications [JBook Review]"

First Page of the Article [J112]

"Wavelet preprocessing for high range resolution radar classification"

We develop a wavelet denoising scheme to aid an automatic target recognition (ATR) system in recognizing aircraft from high range resolution radar (HRR) signatures. A template matching classification technique is used with templates formed from synthetically generated signatures. The goal of the classification system is to achieve

classification accuracy equivalent to that obtained with measured HRR signatures. Results suggest that a large portion of HRR signature content is nondiscriminatory. The wavelet denoising process removes the nondiscriminatory information, thereby leading to remarkable increases in classification accuracy. Results are shown for HRR signatures from six aircraft [J113]

"Subsurface inverse scattering problems: quantifying, qualifying, and achieving the available information"

In inverse scattering problems, only a limited amount of independent data is actually available whenever the finite accuracy of the measurement set up is taken into account. The authors deal with the problem of quantifying such an amount in the subsurface sensing case. In particular, an alternative formulation of the problem is given which also allows one to understand how to dimensionate the measurement setup in an optimal fashion. Analytical results are reported for the case of a lossless soil, while a numerical study is carried out in the general case. By relying on the same formulation and tools, the authors also discuss the kind of unknown profiles that can actually be retrieved. In particular, it is shown that the class of retrievable functions exhibits intrinsic multiresolution features. This suggests that adoption of wavelet expansions to represent the unknown function may enhance the reconstruction capabilities. Numerical examples support this conclusion [J114]

"On-board selection of relevant images: an application to linear feature recognition"

We propose an on-board selection scheme for aerial and space images, based on linear feature detection in a feature hyperspace. The detection task is performed by means of the Radon transform (RT) and the wavelet transform; a fast algorithm for the RT computation is described, and counteractions against the discretization errors are proposed. A new, wavelet-based algorithm is introduced, which performs a fine analysis of the waveforms of the RT peaks, yielding a possibly error-free detection in images corrupted by a high level of noise. A technique, based on the feature hyperspace, is proposed, able to significantly exploit all the available pieces of information on these peaks. Results of the tests on synthetic and real images are reported, which show that this method achieves satisfactory results, making the detection task highly reliable in the presence of both noise and clutter [J115]

"SAR image data compression using a tree-structured wavelet transform"

SAR image compression is very important in reducing the costs of data storage and transmission in relatively slow channels. The authors propose a compression scheme driven by texture analysis, homogeneity mapping and speckle noise reduction within the wavelet framework. The image compressibility and interpretability are improved by incorporating speckle reduction into the compression scheme. The authors begin with the classical set partitioning in hierarchical trees (SPIHT) wavelet compression scheme, and modify it to control the amount of speckle reduction, applying different encoding schemes to homogeneous and nonhomogeneous areas of the scene. The results compare favorably with the conventional SPIHT wavelet and the JPEG compression methods [J116]

"Multiscale MAP filtering of SAR images"

Synthetic aperture radar (SAR) images are disturbed by a multiplicative noise depending on the signal (the ground reflectivity) due to the radar wave coherence. Images have a strong variability from one pixel to another reducing essentially the efficiency of the algorithms of detection and classification. We propose to filter this noise with a multiresolution analysis of the image. The wavelet coefficient of the reflectivity is estimated with a Bayesian model, maximizing the a posteriori probability density function. The different probability density function are modeled with the Pearson system of distributions. The resulting filter combines the classical adaptive approach with wavelet decomposition where the local variance of high-frequency images is used in order to segment and filter wavelet coefficients [J117]

"Wavelet-based simulations of electromagnetic scattering from large-scale two-dimensional perfectly conducting random rough surfaces"

Simulations of electromagnetic waves scattering from two-dimensional perfectly conducting random rough surfaces are performed using the method of moment (MoM) and the electric field integral equation (EFIE). Using wavelets as basis and testing functions, the resulting moment matrix is generally sparse after applying a threshold truncation. This property makes wavelets particularly useful in simulating large-scale problems, in which reducing memory storage requirement and CPU time are crucial. In this paper, scattering from Gaussian conducting rough surfaces of a few hundred square wavelengths are studied numerically using Haar wavelets. A matrix sparsity less than 10% is achieved for a range of root mean square (RMS) height at eight sampling points

per linear wavelength. Parallelization of the code is also performed. Simulation results of the bistatic scattering coefficients are presented for different surface RMS heights up to 1 wavelength. Comparisons with sparse-matrix/canonical-grid approach (SM/CG) and triangular discretized (RWG basis) results are made as well. Depolarization effects are examined for both TE and TM incident waves. The relative merits of the SM/CG method and the present method are discussed [J118]

"M-band compactly supported orthogonal symmetric interpolating scaling functions"

In many applications, wavelets are usually expected to have the following properties: compact support, orthogonality, linear-phase, regularity, and interpolation. To construct such wavelets, it is crucial designing scaling functions with the above properties. In two- and three-band cases, except for the Haar functions, there exists no scaling function with the above five properties. In M-band case (M⩾4), more free degrees available in design enable us to construct such scaling functions. A novel approach to designing such scaling functions is proposed. First, we extend the two-band Dubuc (1986) filters to the M-band case. Next, the M-band FIR regular symmetric interpolating scaling filters are parameterized, and then, M-band FIR regular orthogonal symmetric interpolating scaling filters (OSISFs) are designed via optimal selection of parameters. Finally, two family of four-band and five-band OSISFs and scaling functions are developed, and their smoothness are estimated [J119]

"SAR interferometric phase noise reduction using wavelet transform"

The problem of synthetic aperture radar interferometric phase noise reduction is addressed. A new technique based on discrete wavelet transforms is presented. This technique guarantees high resolution phase estimation without using phase image segmentation. Areas containing only noise are hardly processed. Tests with synthetic and real interferograms are reported [J120]

"Toward edge sharpening: a SAR speckle filtering algorithm"

This paper makes two contributions. It first introduces an algorithm for synthetic aperture radar (SAR) speckle reduction and edge sharpening. Existing speckle filtering algorithms can effectively reduce the speckle effect but unfortunately also, to some degree, smear edges and blur images. Even for unfiltered images, there is still a need for edge sharpening; since SAR sensors have limited bandwidths, leading to slow responses to sudden changes (smearing sharp edges). The proposed algorithm functions as an adaptive-mean filter. Edge crossing points are detected by using the second-order derivative of the Gaussian function as a wavelet transform function. A proper dilation scale factor enables the wavelet transform function to detect only edge crossings and ignore the local oscillations. Then in a moving window the mean filter is applied if there is no edge crossing point. Otherwise, averaging is only applied to the part of the window separated by edge crossing points. Consequently, the algorithm smooths uniform areas while it sharpens and enhances edges. Edges of the filtered images are generally sharper than the original. Similarities between the proposed filter and other popular speckle filters, such as the Lee, Kuan, and Frost filters, designated for SAR multiplicative noise, are analyzed. Another contribution of the paper is the evaluation of popular filters from the viewpoint of texture preservation. The evaluation is carried out using the first and second-order histograms. Possible distortions caused by filters are explained [J121]

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с использованием специализированного программного модуля (ПИО ТУСУР)