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Automatic Target Recognition for Synthetic Aperture Radar Imagery Data Using Hausdorff Distance Transform
The Airborne Radar Systems and Techniques group at MIT Lincoln Laboratory trained neural networks to classify different targets at sea based on inverse synthetic aperture radar (ISAR) data. Simulated data was used to train these neural network based automatic target recognition (ATR) systems. The technical challenge of this project was to find a way to evaluate the quality and adequacy of a limited set of training data. Using simulated ISAR images to train neural networks, the project determined the minimum amount of variation in terms of parameters such as aspect angle to adequately train a neural network. Establishing a correspondence between training data variation and the resulting feature space of the data informed the minimum spanning-set of training data required for future data collects.

Adaptive Waveforms for Automatic Target Recognition and Range-Doppler Ambiguity Mitigation in Cognitive Sensor

Traditional synthetic aperture radar (SAR) systems tend to discard phase information of formed complex radar imagery prior to automatic target recognition (ATR). This practice has historically been driven by available hardware storage, processing capabilities, and data link capacity. Recent advances in high performance computing (HPC) have enabled extremely dense storage and processing solutions. Therefore, previous motives for discarding radar phase information in ATR applications have been mitigated. First, we characterize the value of phase in one-dimensional (1-D) radar range profiles and two dimensional (2-D) SAR imagery with respect to the ability to correctly estimate target features, which are currently employed in ATR algorithms for target discrimination. These features correspond to physical characteristics of a target through radio frequency (RF) scattering phenomenology. Physics-based electromagnetic scattering models developed from the geometrical theory of diffraction are utilized for the
information analysis presented here. Information is quantified by the error of target parameter estimates from noisy radar signals when phase is either retained or discarded. Operating conditions (OCs) of signal-to-noise ratio, bandwidth, and aperture extent are considered. Second, we investigate the value of phase in 1-D radar returns with respect to the ability to correctly classify canonical targets. Classification performance is evaluated via three techniques, namely, naïve Bayes, logistic regression and a bound on Bayes error rate (BER). These classification techniques maintain varying assumptions on the observed data set, with the BER bound making no assumptions. In each case, phase information is demonstrated to improve radar target classification rates.

Teorija na poznanieto, kritika na idealizma, istorija na naukata

Radar Signal Processing and Its Applications brings together in one place important contributions and up-to-date research results in this fast-moving area. In twelve selected chapters, it describes the latest advances in architectures, design methods, and applications of radar signal processing. The contributors to this work were selected from the leading researchers and practitioners in the field. This work, originally published as Volume 14, Numbers 1-3 of the journal, Multidimensional Systems and Signal Processing, will be valuable to anyone working or researching in the field of radar signal processing. It serves as an excellent reference, providing insight into some of the most challenging issues being examined today.

Automatic Target Recognition

"Feature Extraction using Attributed Scattering Center Models for Model-Based
Automatic Target Recognition. The primary research goal of the program was to develop fundamental understanding and advanced signal processing techniques for feature extraction to support feature-based automatic target recognition (ATR) systems employing synthetic aperture radar. This report summarizes the major technical accomplishments that were realized. We developed a set of attributed scattering center models for SAR ATR whose model primitives that balance between modeling fidelity and estimation accuracy. We developed computationally-efficient algorithms for automatic feature extraction of attributed scattering center features from complex SAR image-domain data. We analyzed feature uncertainty and derived analytical uncertainty bounds. We implemented stand-alone match scoring methods to evaluate target discriminability and feature estimation tradeoffs. We developed STAP/SFAP-Based Adaptive Antennas. We developed techniques for understanding rough surface scattering. We developed ultrawide bandwidth antennas, and slot array antennas with wide scan angles. Finally, we increased the U.S. technology base by training of graduate students and by disseminating research through technical publications and presentations.

Progress in Pattern Recognition, Image Analysis, Computer Vision, and Applications

This dissertation shows the performance of adaptive waveforms when applied to two radar applications. One application is automatic target recognition (ATR) and the other application is range-Doppler ambiguity mitigation. The adaptive waveforms are implemented via a feedback loop from receiver to transmitter, such that previous radar measurements affect how the adaptive waveforms proceed. For the ATR application, adaptive transmitter can change the waveform's temporal structure to improve target
recognition performance. For range-Doppler ambiguity mitigation application, adaptive transmitter can change the pulse repetition frequency (PRF) to mitigate range and Doppler ambiguity. In the ATR application, commercial electromagnetic software is used to create high-fidelity aircraft target signatures. Realistic waveform constraints are applied to show radar performance. The radar equation is incorporated into the waveform design technique and template-based classification is performed. Translation invariant feature is used for inaccurately known range scenario. The performance of adaptive waveforms is evaluated with not only a monostatic radar, but also widely separated MIMO radar. In MIMO radar, multiple transmit waveforms are used, but spectral leakage caused by constant-modulus constraint shows minimal interference effect. In the range-Doppler ambiguity mitigation application, particle-filter-based track-before-detect for a single target is extended to track and detect multiple low signal-to-noise ratio (SNR) targets, simultaneously. To mitigate ambiguity, multiple PRFs are used and improved PRF selection technique is implemented via predicted entropy computation when both blind and clutter zones are considered.

**Synthetic Aperture Radar (SAR) Automatic Target Recognition (ATR) Parametric Study**

Mechanical vibrations or rotations (micro-motion dynamics) of structures on a target may introduce frequency modulation on the radar return from the target's body. The modulation due to this vibration or rotation is referred to as the micro-Doppler (m-D) phenomenon. In this report, the m-D effect is introduced and the mathematics of micro-Doppler signatures, induced by simple sinusoidal vibrations or rotations, is developed. Simulated results confirm that the mathematical analysis is valid. The m-D features derived from a target's vibrational/rotational motion are extracted by utilizing discrete
wavelet transforms. During this process, the time domain radar signal is decomposed into a set of components that are represented by different wavelet scales. The m-D features are extracted by sorting the components that are associated with the vibrational/rotational motions of a target and is achieved by applying the inverse wavelet transform. After the extraction of m-D features, time-frequency analysis is employed to analyze the oscillation and to estimate the motion parameters. The vibration/rotation rate is estimated by taking the autocorrelation of the time sequence data. The findings show that these results have higher precision after the m-D extraction since only vibrational/rotational components are employed. The proposed method of the m-D extraction has been successfully applied to both simulated data and experimental helicopter and human data. The preliminary results clearly demonstrate that the m-D signatures can be observed by radar and suggest that applications of m-D should be investigated and exploited for target detection, classification and recognition. It is recommended that the exploitation of micro-Doppler, as a new identification/recognition tool, be undertaken as it could impact all aspects of radar sensing and may enhance the effectiveness of Automatic Target Recognition (ATR) and Automatic Gait Recognition (AGR) techniques. We recommend that.

**Deep Learning for Radar and Communications Automatic Target Recognition**

**Recueil factice d'articles de presse sur le bal Mabille. 1840-1940**

The ability to detect and locate targets by day or night, over wide areas, regardless of weather conditions has long made radar a key sensor in many military and civil
applications. However, the ability to automatically and reliably distinguish different targets represents a difficult challenge. Radar Automatic Target Recognition (ATR) and Non-Cooperative Target Recognition (NCTR) captures material presented in the NATO SET-172 lecture series to provide an overview of the state-of-the-art and continuing challenges of radar target recognition. Topics covered include the problem as applied to the ground, air and maritime domains; the impact of image quality on the overall target recognition performance; the performance of different approaches to the classifier algorithm; the improvement in performance to be gained when a target can be viewed from more than one perspective; the impact of compressive sensing; advances in change detection; and challenges and directions for future research. Radar Automatic Target Recognition (ATR) and Non-Cooperative Target Recognition (NCTR) explores both the fundamentals of classification techniques applied to data from a variety of radar modes and selected advanced techniques at the forefront of research, and is essential reading for academic, industrial and military radar researchers, students and engineers worldwide.

**Classification of Radar Targets Using Invariant Features**

We present the design, development, and test of three novel, distinct automatic target recognition (ATR) systems for the recognition of airplanes and, more specifically, non-cooperative airplanes, i.e. airplanes that do not provide information when interrogated, in the framework of passive bistatic radar systems. Passive bistatic radar systems use one or more illuminators of opportunity (already present in the field), with frequencies up to 1 GHz for the transmitter part of the systems considered here, and one or more receivers, deployed by the persons managing the system, and not co-located with the transmitters. The sole source of information are the signal scattered on the airplane and
the direct-path signal that are collected by the receiver, some basic knowledge about the transmitter, and the geometrical bistatic radar configuration. The three distinct ATR systems that we built respectively use the radar images, the bistatic complex radar cross-section (BS-RCS), and the bistatic radar cross-section (BS-RCS) of the targets. We use data acquired either on scale models of airplanes placed in an anechoic, electromagnetic chamber or on real-size airplanes using a bistatic testbed consisting of a VOR transmitter and a software-defined radio (SDR) receiver, located near Orly airport, France. We describe the radar phenomenology pertinent for the problem at hand, as well as the mathematical underpinnings of the derivation of the bistatic RCS values and of the construction of the radar images. For the classification of the observed targets into pre-defined classes, we use either extremely randomized trees or subspace methods. A key feature of our approach is that we break the recognition problem into a set of sub-problems by decomposing the parameter space, which consists of the frequency, the polarization, the aspect angle, and the bistatic angle, into regions. We build one recognizer for each region. We first validate the extra-trees method on the radar images of the MSTAR dataset, featuring ground vehicles. We then test the method on the images of the airplanes constructed from data acquired in the anechoic chamber, achieving a probability of correct recognition up to 0.99. We test the subspace methods on the BS-CRCS and on the BS-RCS of the airplanes extracted from the data acquired in the anechoic chamber, achieving a probability of correct recognition up to 0.98, with variations according to the frequency band, the polarization, the sector of aspect angle, the sector of bistatic angle, and the number of (Tx,Rx) pairs used. The ATR system deployed in the field gives a probability of correct recognition of $0.82$, with variations according to the sector of aspect angle and the sector of bistatic angle.
An Automatic Target Recognition (ATR) system is a sensor which is usually able to recognize targets or objects based on gathered data. The application of automatic target recognition technology is a critical element of robotic warfare. ATR systems are used in unmanned aerial vehicles and cruise missiles. There are many systems which are able to collect data (e.g. radar sensor, electro-optic sensor, infra-red devices) which are commonly used to collect information and detect, recognise and classify potential targets. Despite significant effort during the last decades, some problems in ATR systems have not been solved yet. This Ph. D. tried to understand the variation of the information content into an ATR system and how to measure as well as how to preserve information when it passes through the processing chain because they have not been investigated properly yet. Moreover the investigation focused also on the definition of class-separability in ATR system and on the definition of the degree of separability. As a consequence, experiments have been performed for understanding how to assess the degree of class-separability and how the choice of the parameters of an ATR system can affect the final classifier performance (i.e. selecting the most reliable as well as the most information preserving ones). As results of the investigations of this thesis, some important results have been obtained: Definition of the class-separability and of the degree of class-separability (i.e. the requirements that a metric for class-separability has to satisfy); definition of a new metric for assessing the degree of class-separability; definition of the most important parameters which affect the classifier performance or reduce/increase the degree of class-separability (i.e. Signal to Clutter Ratio, Clutter models, effects of despeckling processing). Particularly the definition of metrics for assessing the presence of artefacts introduced by denoising algorithms, the ability of denoising algorithms in preserving geometrical features of potential targets, the suitability of current mathematical models at each stage of processing chain (especially for clutter models in radar systems) and the measurement of variation of information.
content through the processing chain are some of them most important issues which have been investigated.

**Radar Signal Processing and Its Applications**

The goal of the research is to develop a multiple model extended Kalman filter to perform simultaneous target identification and tracking using high range resolution (HRR) radar measurements. The idea is to use a multiple model estimator (MME) with multiple Kalman filters (one for each target type) to process HRR measurements. The resulting algorithm will provide estimates of the target kinematics (e.g. position, velocity, and possibly acceleration) and predict model probabilities, which correspond to the target probability. Hence, the approach proposed here is named the automatic target recognition (ATR) and tracking filter.

**A Unified Multiresolution Framework for Automatic Target Recognition (ATR)**

Automatic Target Recognition (ATR) is a pattern recognition technique used to detect targets in a defined area of interest. The objective of the research was to discover the potential of applying ATR to Synthetic Aperture Radar (SAR) images and to explore the opportunities of employing Hausdorff Distance Transform (HDT) on multiple feature sets.

**Characterization of Deep Neural Network Feature Space for Inverse Synthetic Aperture Radar Automatic Target Recognition**
A new algorithm is presented for Automatic Target Recognition (ATR) using High Range Resolution (HRR) profiles as opposed to traditional Synthetic Aperture Radar (SAR) images. ATR performance using SAR images degrades considerably in case of moving targets due to blurring caused in the cross-range domain. ATR based on HRR profiles, which are formed without Fourier transform in the cross-range, is expected to have superior performance for moving targets with the proposed method. One of the major contributions of this project so far has been the utilization of Eigen-templates as ATR features that are obtained via Singular Value Decomposition (SVD) of HRR profiles. SVD analysis of a large class of HRR data revealed that the Range-space eigenvectors corresponding to the largest singular value accounted for more than 90% of target energy. Hence, it has been proposed that the Range-space Eigen-vectors be used as templates for classification. The effectiveness of data normalization and Gaussianization of profile data in improving classification performance is also studied. With extensive simulation studies it is shown that the proposed Eigen-template based ATR approach provides consistent superior performance with recognition rate reaching 99.5% for the four class XPATCH database. This research project is being conducted in direct collaboration with the Sensors Directorate's ATR Assessment Branch, Wright Laboratories, Wright-Patt AFB, Dayton, Ohio, where it is being monitored by Dr. Rob Williams. A primary objective of this collaborative effort is to complement and augment various other ongoing research activities being conducted or supported by the Wright Labs ATR research team.

Bispectrum- and Bicoherence-Based Discriminative Features Used for Classification of Radar Targets and Atmospheric Formations

This chapter is dedicated to bispectrum-based signal processing in the surveillance
radar applications. Detection, recognition, and classification of the targets by surveillance radars have various applications including security, military intelligence, battlefield purposes, boundary protection, as well as weather forecast. One of the particular and effective discriminative features commonly exploited in modern radar automatic target recognition (ATR) systems is the micro-Doppler (m-D) contributions extracted from joint time-frequency (TF) distribution. However, a common drawback of the energy-based strategy lies in the impossibility to retrieve additional particular information related to frequency-coupling and phase-coupling contributions containing in the radar backscattering. Phase coupling contains additional discriminative features related to individual target properties. Bispectrum-based strategy allows retrieving a phase-coupled data containing unique discriminative features related to individual target properties. Bispectrum tends to zero for a stationary zero-mean additive white Gaussian noise (AWGN), providing smoothing of AWGN in TF distributions. Hence, bispectrum-based approach allows improving extraction of robust discriminative features for ATR radar systems.

**Automatic Target Recognition Using Passive Bistatic Radar Signals**

Template based automatic target recognition (ATR) algorithms such as the Synthetic Aperture Radar Target Location and Recognition System (STARLOS) algorithm typically use separate templates to represent target signatures for ranges of articulations, aspect, depression, and squint angles. There is a performance tradeoff between ATR accuracy and the number of templates used. We use a hybrid model/template with target models to augment a small set of target templates. The basic idea will be to determine the transformation or perturbations required to modify a given template so that it accurately represents the signature of a neighboring sensor geometry or target
articulation. By incorporating a model for these perturbations into the ATR algorithm, we can reduce the total number of templates required and provide robustness to new collection geometries, obscuration, and articulation.

**Automatic Target Recognition Display Format Study**

A project to develop an automatic target recognition (ATR) algorithm for synthetic aperture radar (SAR) imagery data, matching an unknown target to one of the known reference targets based on a maximum likelihood estimation procedure. Central to the algorithm is the CLEAN method, which tries to strengthen peak feature image classification importance. The effectiveness of the CLEAN algorithm will be assessed by comparing target recognition accuracy of CLEANed images to those that have not undergone the CLEAN method.

**Radar Automatic Target Recognition (ATR) and Non-Cooperative Target Recognition (NCTR)**

Micro-Doppler Characteristics of Radar Targets is a monograph on radar target’s micro-Doppler effect theory and micro-Doppler feature extraction techniques. The micro-Doppler effect is presented from two aspects, including micro-Doppler effect analysis and micro-Doppler feature extraction, with micro-Doppler effects induced by different micro-motional targets in different radar systems analyzed and several methods of micro-Doppler feature extraction and three-dimensional micro-motion feature reconstruction presented. The main contents of this book include micro-Doppler effect in narrowband radar, micro-Doppler effect in wideband radar, micro-Doppler effect in bistatic radar, micro-Doppler feature analysis and extraction, and three-dimensional
micro-motion feature reconstruction, etc. This book can be used as a reference for scientific and technical personnel engaged in radar signal processing and automatic target recognition, etc. It is especially suitable for beginners who are interested in research on micro-Doppler effect in radar. Presents new views on micro-Doppler effects, analyzing and discussing micro-Doppler effect in wideband radar rather than focusing on narrowband Provides several new methods for micro-Doppler feature extraction which are very helpful and practical for readers Includes practical cases that align with main MATLAB codes in each chapter, with detailed program annotations

**Analysis of Performance of Automatic Target Recognition Systems**

**Optimization of Automatic Target Recognition with a Reject Option Using Fusion and Correlated Sensor Data**

This authoritative resource presents a comprehensive illustration of modern Artificial Intelligence / Machine Learning (AI/ML) technology for radio frequency (RF) data exploitation. It identifies technical challenges, benefits, and directions of deep learning (DL) based object classification using radar data, including synthetic aperture radar (SAR) and high range resolution (HRR) radar. The performance of AI/ML algorithms is provided from an overview of machine learning (ML) theory that includes history, background primer, and examples. Radar data issues of collection, application, and examples for SAR/HRR data and communication signals analysis are discussed. In addition, this book presents practical considerations of deploying such techniques, including performance evaluation, energy-efficient computing, and the future unresolved issues.
Hybrid Template- and Model-Based ATR Formulation

Comparison of Different Feature-based and Intensity Signature-based Matching Algorithms for Automatic Target Recognition in Synthetic Aperture Radar

This book examines the roles of sensors, physics-based attributes, classification methods, and performance evaluation in automatic target recognition. It details target classification from small mine-like objects to large tactical vehicles. Also explored in the book are invariants of sensor and transmission transformations, which are crucial in the development of low latency and computationally manageable automatic target recognition systems.

Statistical Pattern Recognition for Synthetic Aperture Radar (SAR)/Automatic Target Recognition (ATR)

Micro-Doppler Radar Signatures for Intelligent Target Recognition

Adaptive Processing of SAR Data for ATR.

State-of-the-art research on spectral estimation, feature extraction, and pattern recognition algorithms are presented for radar signal processing and automatic target
Advanced space-time spectral estimation algorithms are presented for multiple moving target feature extraction as well as clutter and jamming suppression for airborne high range resolution (HRR) phased-array radar. A nonparametric adaptive filtering-based approach, referred to as the Gapped-data Amplitude and Phase EStimation (GAPES) algorithm, is proposed for the spectral analysis of gapped data sequences as well as synthetic aperture radar (SAR) imaging with angle diversity data fusion. A QUasi-parametric ALgorithm for target feature Extraction (QUALE) algorithm is also investigated for angle diversity data fusion. Support Vector Machines (SVMs) as compared with other advanced classifiers in the MSTAR Public Domain Release and HRR data are found to outperform neural networks and matched filters. A new concept to create negative examples from the known target class is presented and shown to tremendously improve the rejection of confusers. Finally, Information Theoretic Learning (ITL) is proposed as a new algorithm to demix HRR signatures of closely parked targets.

**Micro-Doppler Characteristics of Radar Targets**

**Vorarlberger Flurnamenbuch**

The application of Automatic Target Recognition (ATR) on High Range Resolution (HRR) radar data in a scenario that contains unknown targets is of great interest for military and civilian applications. HRR radar data provides greater resolution of a target as well as the ability to perform ATR on a moving target, which gives it an advantage over other imaging systems. With the added resolution of HRR comes the disadvantage that a change in the aspect angle or orientation results in greater changes in the collected
data, making classical ATR more difficult. Closed set ATR on HRR radar data is defined when all potential targets are assumed to be part of the training target data base. Closed set ATR has been able to achieve higher rates of correct classification by the selection of proper feature extraction algorithms, however, only a few methods for performing open set ATR have been developed. Open set ATR is the ability to identify and discard when a target is not one of the trained targets. By identifying these untrained targets, the number of misclassified targets is reduced, thereby, increasing the probability of a correct classification in a realistic setting. While the open set ATR produces a more realistic approach, the classical closed-set ATR is the standard method of ATR. One of the more popular classification algorithms currently used today is the Support Vector Machine (SVM). The SVM by nature only works on a binary closed-set problem. However, by extracting probabilities from an SVM as proposed by Platt [1], this classification algorithm can be applied to open set. In this thesis, the feature extraction methods established in closed-set ATR are modified to facilitate the application of the Probabilistic Open Set Support Vector Machine (POS-SVM). Utilizing the Eigen Template (ET) and Mean Template (MT) feature extraction methods developed for closed-set ATR, in combination with centroid alignment, an open set ATR Probability of correct classification (PCC) rate of 80% has been achieved. Utilizing POS-SVM, it is possible to successfully perform open set ATR on HRR data with a high PCC.

**A Human Factors Evaluation of ESAR/ATR Integration for the Theater Missile Defense (TMD) Automatic Target Recognition (ATR) Rapid Response Targeting Against Mobile Ground Targets (RTM) Program**
Automatic Target Recognition Using High-Range Resolution Data

This report focuses on the development of an automatic target recognition (ATR) system using high resolution synthetic aperture radar (SAR) imagery. The system achieves 95 to 100 percent recognition rates when applied to a set of MSTAR images. Typically, the system takes less than one minute to match an input image to a candidate vehicle class with Matlab programs running on a Pentium II 300 MHz machine. Experiments based on conventional recognition techniques were conducted for comparisons. Study of persistent scattering confirms the feasibility of implementing a SAR ATR system using physical image features. A new generic vehicle model, parameterized by the length, width, and orientation of a target is used in a two-phase recognition process with hypothesis generation and verification aimed at addressing the combinatorial target recognition problem. In the hypothesis generation stage, a few likely candidate target classes are identified from a target database with positive evidence. The candidates are assessed using both positive and negative evidence in the hypothesis verification stage. Leading surface estimation, image alignment, Delaunay walk, and recognition metrics are introduced to improve performance of the SAR ATR system.

New Feature Extraction and Matching Algorithms for Automatic Target Recognition in Synthetic Aperture Radar

This report describes a human factors evaluation of the target prosecution benefits of integrated enhanced synthetic aperture radar (ESAR) and automatic target recognition (ATR) technologies. Workstation operators aboard E-8C Joint Surveillance Target Attack Radar System (JSTARS) aircraft field-tested integrated ATR information and ESAR imagery during performance of mobile missile launcher targeting tasks on a series of
demonstration flights. Two methods of data collection were used: post-flight questionnaires collected subjective operator assessments, and a human factors engineer conducted in-flight observation. The evaluative goal was to assess operator acceptance and to establish guidelines for the integration of ATR and ESAR capabilities on the JSTARS. Results included significantly positive ratings for increase in situation awareness, somewhat decreased or unchanged ratings for workload, and no reports of increase in visual fatigue. Three of four operators recommended the incorporation of an integrated ATR/ESAR imagery capability into the JSTARS graphic display. Operators also requested inclusion of ATR numeric confidence ratings and that display of ATR information be optional. Human factors design recommendations cited existing military standards and human factors industry guidelines for improved displays and display interfaces.

ATR Performance Modeling and Estimation

Automatic target recognition (ATR) using radar commonly relies on modeling a target as a collection of point scattering centers. Features extracted from these scattering centers for input to a target classifier may be constructed that are invariant to translation and rotation, i.e., they are independent of the position and aspect angle of the target in the radar scene. Here an iterative approach for building effective scattering center models is developed, and the shape space of these models is investigated. Experimental results are obtained for three-dimensional scattering centers compressed to nineteen-dimensional feature sets, each consisting of the singular values of the matrix of scattering center locations augmented with the singular values of its second and third order monomial expansions. These feature sets are invariant to translation and rotation and permit the comparison of targets modeled by different
numbers of scattering centers. A metric distance metric is used that effectively identifies targets under “real world” conditions that include noise and obscurations.

Diffusion Maps and Geometric Harmonics for Automatic Target Recognition (ATR). Volume 2. Appendices

The object of Automatic Target Recognition (ATR) for Synthetic Aperture Radar (SAR) involves comparing extracted target signatures (features) to the statistics of features of all potential targets. Central to this processing paradigm is the search algorithm, which helps assess and optimize the favorable effects of multiple image features on recognition accuracy. The ATR algorithms discussed fall into two categories: feature and intensity-based. The feature-based algorithms create binary images of the edges, corners, gradient and ceiling peaks of the tank. The intensity-based signatures are created using algorithms that extract the tank image, block out the background, normalize the MSTAR (Moving and Stationary Target Acquisition and Recognition) data within the tank region and can be exploited to minimize false classifications. Several scenarios will be explored to determine the effectiveness of using the CLEAN method on the ceiling peak feature extraction method and the validity of using the intensity signatures of the MSTAR tank image.

Automatic Target Recognition and Tracking Filter

This report describes the development of multiscale, multiresolution methods for automatic target recognition (ATR). The methods are applied to and developed specifically for synthetic aperture radar data. Applications include high level reasoning over learned target models, information theoretic approaches for pose estimation, and
read book radar automatic target recognition atr and non cooperative target recognition nctr iet radar sonar and navigation

model development from multiple views.

**Analysis of High Resolution Polarimetry Data of Static Targets in Automatic Target Recognition Context**

The purpose of this document is to assess the state of the art of performance modeling and estimation for synthetic aperture radar (SAR) automatic target recognition (ATR) algorithms. The study underlying this report is part of the Lincoln Laboratory effort under the OSD ATR Program. The intent is not to produce an exhaustive, detailed, voluminous report describing all ongoing efforts, but rather to capture in a succinct yet essentially complete way the approaches currently in use for modeling the performance of SAR ATR algorithms. To provide context for this document's assessment and recommendations, a brief discussion of the breadth of ATR problems and some of the resulting technical challenges will be conducted. This discussion will generally be couched in terms of the SAR ground surveillance problem of detecting and recognizing various military vehicles, though many of the statements are easily extended to other sensors and other applications. Basic performance metrics will be defined, and a discussion will ensue of the kinds of questions it would be useful to have addressed by a performance model. The principal approaches to modeling the performance of SAR ATR algorithms and estimating performance characteristics under a variety of conditions will then be outlined and assessed. The document concludes by recommending certain actions to encourage progress in the development of SAR ATR performance modeling and evaluation tools and methodologies.

**Context and Quasi-Invariants in Automatic Target Recognition (ATR) with...**
This work explores automatic target recognition (ATR). It is divided into sections which look at topics such as: advanced systems for ATR, including airborne video surveillance; multisensor ATR; and adaptive and learning techniques for ATR.

Geometric harmonics provides a framework for taking data in high-dimensional measurement spaces and embedding them in low dimensional Euclidean space according to a similarity measure. Euclidean coordinates then characterize the "manifold" on (or near) which the data live. Our goal in this project is to develop this manifold as a mechanism for integrating data from different sensors to facilitate automatic recognition. During the tenure of this research grant, we were able to formulate and complete the first series of experiments on embedded fusion. The resulting experiment on integrating voice and audio streams was extremely successful. This definitely revealed the potential for this approach and set the stage for further experiments. The problem formulation has been completed and confirmed with an
experiment on the integration of audio and video streams. Researchers at AFRL, Wright-Patterson Air Force Base, have received a first version of the software, and are attempting to apply it to radar signal interpretation.

**Probabilistic SVM for Open Set Automatic Target Recognition on High Range Resolution Radar Data**

SAR ATR is a very complex problem that still has not been mastered. SAR ATR is difficult largely due to the fact that SAR imagery exhibits large variability. SAR imagery is a function of many variables called operating conditions (OCs) that can be subdivided into three large groups. The three main OCs are target, environment, and sensor. Sensor operating conditions deal with the properties of the sensor that have some of the largest effects on the formation of SAR images, including depression angle, squint angle, frequency, PRF, polarization, single/multi-look, sensor abnormalities, noise level, strip versus spot, and resolution. In the development and testing of SAR ATR algorithms to date the effects of sensor OCs have been given very little thought. The ultimate objective of this study is to develop a road map for studying various effects of varying sensor OCs on the performance of SAR ATR algorithms. For achieving this goal, we conducted literature searches to see how much had been done in sensor OC study. We also studied alternative data sources and the ways to generate SAR data related to the variation of sensor OCs to support SAR parametric study. In addition, we allocated and implemented a number of baseline ATR algorithms for the evaluation of their performance under the variation of sensor OCs. Our research has established an experimental paradigm for SAR parametric study.
This book constitutes the refereed proceedings of the 16th Iberoamerican Congress on Pattern Recognition, CIARP 2011, held in Pucón, Chile, in November 2011. The 81 revised full papers presented together with 3 keynotes were carefully reviewed and selected from numerous submissions. Topics of interest covered are image processing, restoration and segmentation; computer vision; clustering and artificial intelligence; pattern recognition and classification; applications of pattern recognition; and Chilean Workshop on Pattern Recognition.

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