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Adaptive Filtering Applications in Radar Signal Processing: A Litrature Review

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***Abstract*— A system for detecting the presence, direction, distance and speed of aircraft, ships, and other objects, by sending out pulses of radio waves which are reflected from the object back to the source is radar system. Radar images enhancement is wide field of research This paper is critical review of all the reference paper in which all the advantages and drawbacks of the techniques used in all the papers which is based on radar system are compared. And seeking the technology to overcome all the problems and can give the best result for the signal enhancement of the Radar system.**

***Index Terms*— radar system, adaptive filter, signal tracking, enhancement**

I. INTRODUCTION

An adaptive filter is a system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. Because of the complexity of the optimization algorithms, almost all adaptive filters are digital filters. Using the reference signal, cancellation algorithms can be designed to eliminate unwanted echoes affecting the signal collecting at the surveillance antenna. Adaptive cancellation filters have been used in the PBR literature. Examples of such filters are the NLMS and RLS which both use an iterative approach for a progressive cancellation of direct path and multipath interferences. Owing to their high performance and excellent coverage, PBRs have been of a growing interest in the radar field. This technology uses existing eliminator of broadcasting communications, and navigation systems to detect objects. The most important feature of a PBR is that the receiver is completely passive. It makes radar undetectable more over there is no need to assign any frequency from the electromagnetic spectrum to emit a signal [1]. A real-time image processing algorithm, using a GPU with NVDIA's CUDA technology, for 3-D through-clothes detection radar in the THz band has been developed [2]. A new tracking algorithm based on Mean shift (MS) algorithm with Unscented Kalman filter (UKF) is proposed to track the detected objects in the image plane, in which UKF is used to predict the initial position of iteration for MS algorithm Inverse Synthetic Aperture Radar (ISAR) is generally used for classification of ship targets after detection and tracking by the radar [4]. Multi-circular synthetic aperture radar (MCSAR) has the full 360^{o} 3-D imaging ability by using multiple circular tracks at different elevation angles. Compressive sensing (CS) based imaging method provide a solution for MCSAR elevation reconstruction when the circular tracks distribute sparsely and no uniformly [5]. The aim of radar systems is to collect information about their surroundings in many scenarios besides static targets there are numerous moving objects with very different characteristics, such as extent, movement behavior of micro-Doppler spread [6].

Signal model

The signal of echo channel contains the direct path and multi path interferences, noise and target echo signal.

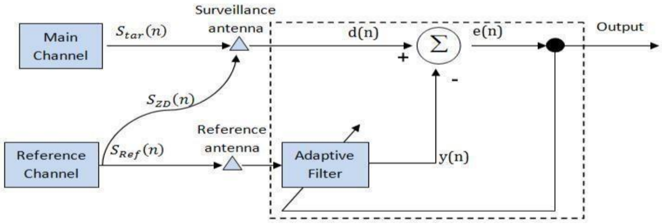

Fig 1: Interference cancellation algorithm [1]

II. CONCEPT OF ADAPTIVE FILTER

The idea behind a closed loop adaptive filter is that a variable filter is adjusted until the error (the difference between the filter output and the desired signal) is minimized. The Least Mean Squares (LMS) filter and the Recursive Least Squares (RLS) filter are types of adaptive filter. There are two input signals to the adaptive filter: d_k and x_k which are sometimes called the primary input and the reference input respectively. Adaptive filters are actually based on an approach which is somewhere in between these two extremes. When a priori knowledge of a dynamic process and its statistics is limited then the use of adaptive filters can offer performance improvements over the more conventional parametrically based filter designs. Filtering in the most general terms is a process of noise removal from a measured process in order to reveal or enhance information about some quantity of interest. Filtering problem can be identified and characterized more specifically by the terms filtering, smoothing, prediction and deconvolution.

A. Linear Adaptive Filters

A linear adaptive filter system filters a sequence of input data by controlling its adjustable parameters via an adaptive process. The choice of filter structure is a very important part of the system.

There are three main types of structures commonly used.

1. Transversal structure (tapped delay line) - similar to the

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2. Lattice predictor - a modular structure with a lattice appearance.
3. Systolic array - a parallel computing network ideally suited for mapping important linear algebra computations such as matrix multiplication, riangulation, and back substitution.

B. Nonlinear Adaptive Filters

The linear adaptive filters discussed above are all based on the minimum mean square error criterion, which results in the Wiener solution for wide sense stationary statistics. This means that these filters can only relate to the second order statistics of the input data and are strictly only optimum for Gaussian, or at least symmetrical, statistics.

III. PERFORMANCE ANALYSIS

A. Adaptive Filters for Direct Path and Multipath Interference Cancellation: Application to FM-RTL-SDR based Passive Bistatic Radar

The signal of the echo channel contains the direct path and multipath interferences, noise and target echo signal. Therefore, the signal at the surveillance channel can be written as:

$$S_{Surv}(t) = \beta_0 d(t) + \sum_{i=1} \beta_i d(t-\tau_i) + \sum_{j=1} \gamma_j d(t - \tau_j)' exp\left(i2\pi f_{d_j} t\right) + \eta_{Surv}(t) \quad (1)$$

Where $S_{Surv}(t)$ is the surveillance signal, d(t) the complex envelope of the direct signal, τi and τj the propagation delays

LMS Algorithms

The structure of a transversal LMS filter is shown in Figure 2. As stipulated earlier, the reference signal is the adaptive filter's input and the surveillance signal, the desired signal. The error signal of the filter represents the estimated target signal. The LMS algorithm minimizes the least-square of the error signal so that the direct path and the multipath signals are suppressed in the error signal.

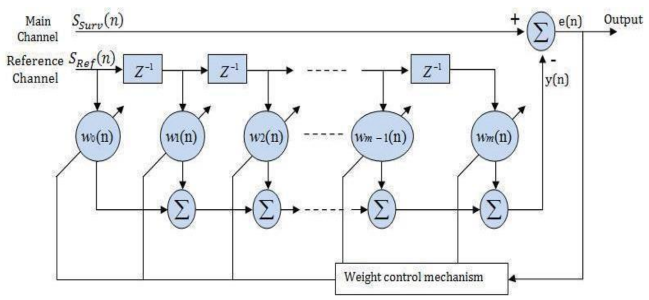

Fig 2: Structure of a transversal filter [1]

B. Real-time GPU-based image processing for 3-D THz radar

A real-time image processing algorithm, using a GPU with NVIDIA's CUDA technology, for a 3-D through clothes detection radar in the THz band has been developed. Traditional CPU-based architectures lack the computing power and parallelization needed to meet the image refresh rates imposed by the radar's scanning. This solution presents a low-cost and flexible alternative that allows image refresh at a rate of more than 8 fps for images linear FIR filters structure. composed of 6000 pixels, corresponding to a scanned area of 50x90 cm^2. The performance of this code has been profiled, with comparison against a previous CPU-executed version, and some optimizations that would enable even faster refresh have been analyzed. The below diagram describe the following image processing.

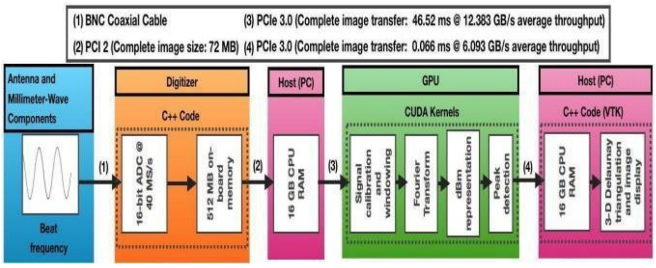

Fig 3: Sequence of events and transfers, from the reception of the beat frequency until the display of its image. The legend details the connections in each stage, and the colour code separates hardware platforms [2]

Table1. GPU Specification [3]

Parameter	NVIDIA GTX 970
CUDA Architecture	Maxwell
CUDA Compute Capability	5.2
Clock Speed (MHz)	1178
Global Memory (GB)	4
Memory Bandwidth (Gbps)	1792
Streaming Multiprocessors (SMs)	13
CUDA Cores	1664
Shared Memory (KB)	96
Warp Schedulers	4
ALU Units	128
Special Function Units	32

Per Streaming Multiprocessor.

C. Advanced Obstacles Detection and Tracking by Fusing Millimetre Wave Radar and Image Sensor Data

Reliable object detection and recognition for Adaptive Cruise Control (ACC) by multi-sensor and multi-algorithm have attracted much attention recently. Aiming at the calibration complexity problem, a novel calibration method is proposed to calibrate the millimetre wave radar data and the CCD camera data using a homography. The proposed method does not require estimation of rotation and translation between them or intrinsic parameters of the camera. And the calibration can be done without any manual manipulation. Tracking of the detected object by radar is done in image plane as the radar is insensitive to object size and has a low object recognition rate as well. A new tracking algorithm based on Mean Shift(MS) algorithm with Unscented Kalman filter (UKF)is proposed to track the detected objects in the image plane, in which UKF is used to predict the initial position of iteration for MS algorithm. Then MS is applied to find out the accurate position of the object and positions of objects are mapped to radar plane to judge it is a new object or old one. We demonstrated the validity of the proposed methods through experiments.

Tracking result

Radar is used for detect the obstacle, while tracking phase carried out in image plane for image has higher object recognition ability. Fig 5 shows the white car tracking result by the MS tracking with black rectangle and the proposed tracking strategy with white rectangle. We can see that the proposed method can well locate the car. The traditional MS column thresholding. In both cases σ is chosen 3.

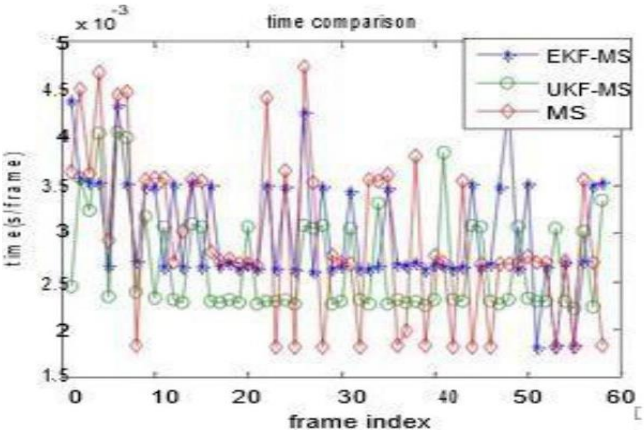

Fig 4: Time Complex [3]

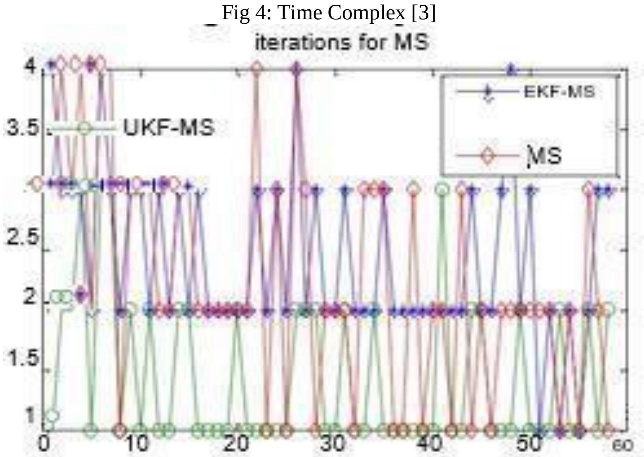

Fig 5: MS iteration times comparison [3]

D. Post Processing Techniques for Inverse Synthetic Aperture Radar Imaging

Inverse Synthetic Aperture Radar (ISAR) is generally used for classification of ship targets after detection and tracking by the Radar. There are various methods for high resolution 2D imaging of maritime targets in ISAR mode like Range Doppler Algorithm and Polar Format Algorithm. After the raw image is formed, it has to pass through the post processing algorithm suite before an acceptable image can be displayed to observer. This paper presents an efficient algorithm suite for the post process.

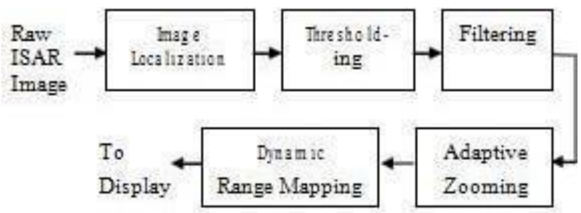

Fig 6: ISAR Image Post Processing Algorithm Suite [4]

IV. Results and Discussion

The techniques mentioned here are applied on multiple ISAR image data obtained from a Maritime Patrol Airborne Radar developed by LRDE having resolution capabilities up to 1m. The results of one of the images obtained in recent trials of the Radar are shown in figures below.

it can be observed that after global thresholding, there still remains the vertical streaks which are removed after column thresholding. In both cases σ is chosen 3.

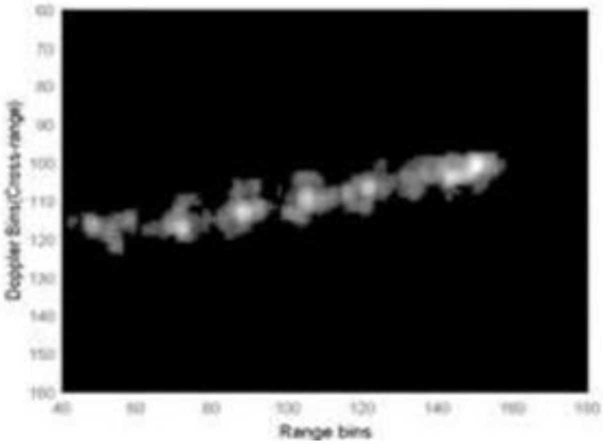

Fig 7: Image after average filtering [4]

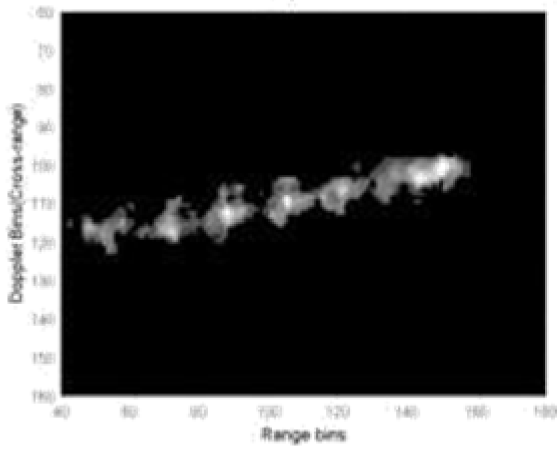

Fig 8: Image after median filtering [4]

This paper presents an efficient algorithm suite for the post processing of ISAR image with low computation requirements. These techniques are essential before displaying a formed ISAR image to an observer for proper interpretation and target classification. Improvement in these techniques are ongoing research area.

E. Multi-circular synthetic aperture radar imaging processing procedure based on compressive sensing

Multi-circular synthetic aperture radar (MCSAR) has the full 360° 3-D imaging ability by using multiple circular tracks at different elevation angles. Compressive sensing (CS) based imaging methods provide a solution for MCSAR elevation reconstruction when the circular tracks distribute sparsely and non-uniformly. When processing the MCSAR real data, the issues of off-grid effect and the spurious estimate should be taken into consideration. In this paper, we present the CS-based imaging processing procedure for MCSAR real data and show the first 3-D imaging results of the MCSAR data collected by the Institute of Electronics, Chinese Academy of Sciences.

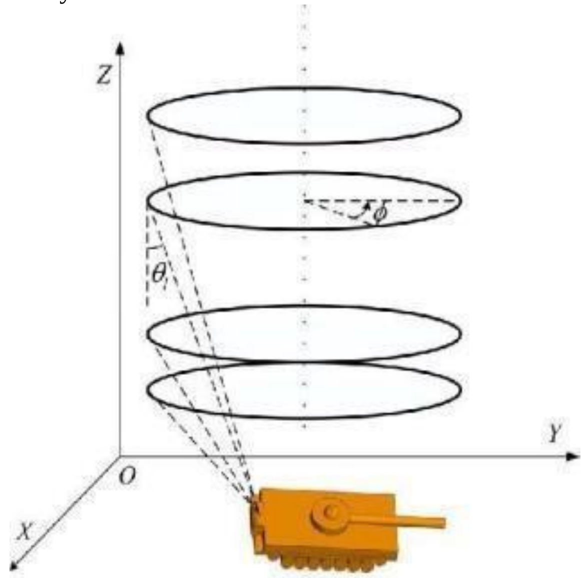

Fig 9: Imaging geometry of MCSAR [5]

This paper presents a compressive sensing based imaging processing procedure for multi-circular synthetic aperture radar, which can obtain the true 3-D image by using multiple circular tracks at different elevation angles. The processing procedure considers the problems of off-grid effect and spurious estimates. The image results of the MCSAR real data verify the proposed processing procedure. The grid refinement scheme is used to remedy the offgrid effect in this paper, however, we find that if the grids are chosen too dense, the reconstruction performance may worsen. Thus, we will test and compare some gridless sparse recovery methods for the MCSAR imaging in our further study.

F. Radar Signal Processing for Jointly Estimating Tracks and Micro-Doppler Signatures

The aim of radar systems is to collect information about their surroundings. In many scenarios besides static targets there are numerous moving objects with very different characteristics, such as extent, movement behaviour or micro Doppler spread. It would be most desirable to have algorithms that extract all information on static and moving object automatically, without a system operator. In this work, we present measurements conducted with a commercially available higher resolution multi-channel linear frequency-modulated continuous wave radar and algorithms that do not only produce radar images but a description of the scenario on a higher level. After conventional spectrum estimation and thresholding, we present a clustering stage that combines individual detections and generates representations of each targets individually. This stage is followed by a Kalman filter based multi-target tracking block. The tracker allows us to follow each target and collect its properties over time. With this method of jointly estimating tracks and characteristics of each individual target in a scenario, inputs for classifiers can be generated. Which, in turn, will be able to generate information that could be used for driver assistance or alarm trigger systems.

In this paper, we have shown a method for jointly estimating micro-Doppler signatures and tracks of multiple targets present simultaneously in a scenario. Features suitable for classification of the individual targets could be extracted. A CFAR algorithm is not needed

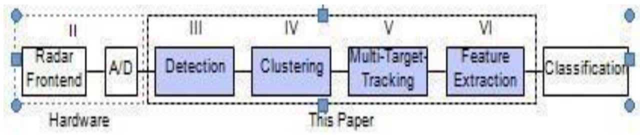

Fig 10: Block diagram from sampling the IF data to classification [6]

Applications

1. One application area is automotive safety. Demands in automotive scenarios, especially towards protection of vulnerable road users like pedestrians and bicyclist, have significantly increased in the last few years.
2. Another field of application for radar sensors is making road-side infrastructure intelligent. Some countries.
3. Comparable demands are expected for property surveillance. Due to their low price, many existing surveillance systems rely on infrared based motion sensors.

V. COMPARISION OF EXISTING LGORITHM FOR RADAR IMAGES

Sr.No.	Title	Algorithm/Technique Used	Measurement Efficiency Check	Applications	Limitations
1	Adaptive Filters for Direct Path and Multipath Interference Cancellation: Application to FM-RTL-SDR Based Passive Bistatic Radar [1]	Adaptive cancellation NLMS & RLS Algorithm	Ambiguity Function by NLMS Algorithm- Delay=.223 ms Doppler=-100Hz Range=66.8Km RLS Algorithm- Delay=.168ms Doppler=-90Hz Range=55.7Km Velocity=83m/s	Direct path and Multipath Interference cancellation	RLS algorithm involves complex mathematics and requires more processing time.

2	Real-time GPU based image processing for a 3-D THz radar [2]	NVIDIA'S CUDA Technology CUDA- Computer unified device Architecture	Detection 3D surface complete image transfer =46.52ms. CPU image Transfer data Tscan = 0.55s TGPUn=.075s Tdisplay=.55s Trefresh=0.55s	Real-time GPU based image processing for a 3-D THz radar.	The mechanical scanning speed can limit to 2 fps the image refresh.
3	Detection and Tracking by Fusing Millimetre Wave Advanced Obstacles Radar and Image Sensor Data [3]	Unscented kalman filter algorithm Mean shift algorithm	Average means and errors in Mean shift algorithm MS=5.8 pixels/frame UKF-MS=2.4 KFMS=2.4 Average location time (SEC/FRAME)- MS=.0061 Sec/frame UKF-MS=.0058 KF-MS=.0060	Advanced obstacles detection and tracking	MS- Iteration time is more location error is also more.
4	Post Processing Techniques for Inverse Synthetic Aperture Radar Imaging [4]	Range Doppler Algorithm(RDA). & Polar format Algorithm(PFA).	Range Doppler Algorithm(RDA). & Polar format Algorithm(PFA).	Used for classification of ship targets after detecting and tracking by the radar.	Average filter cannot give more sharp images
5	Multi-circular synthetic aperture radar imaging processing procedure based on compressive sensing.[5]	MCSAR processing based on compressive sensing.	Ex- fc=15Hz For Signal BW =6GHz Range resolution =0.025m Elevation angle=78.2 to 82degree Total circular Tracks=20	Obtain 3Dimaging by multiple circular tracks at different elevation angle	The grid refinement scheme is used to remedy the off-grid effect. If grids are chosen too dense the reconstruction performance may worsen.
6	Radar signal processing for jointly estimating tracks and micro Doppler signatures [6]	.Kalman Filter Algorithm	In pedestrian area At time=20s, Range rate=1m/s Micro Doppler=-4m/s At time=15s Range rate=-3m/s Micro Doppler=-4m/s	Algorithm that extracts all information on static and moving objects and produces radar images when multiple targets are there.	In this PDAF approaches have a slightly higher chance to wrongfully add a cluster to a track.

VI. CONCLUSION

An adaptive filter is a system with a linear filter that has a transfer function controlled by variable parameters and a means to adjust those parameters according to an optimization algorithm. Because of the complexity of the optimization algorithms, almost all adaptive filters are digital filters.

An experimental passive radar system based on FM broadcast transmitter is introduced in this paper. Real data have been acquired by the RTL-SDR. The simulations result of the ambiguity function showed that both NLMS and RLS cancellation techniques can suppress DPI and MPI contribution. The square module of filters output shows, however, that the RLS algorithm converges faster than the NLMS algorithm. Yet, the RLS algorithm involves complex mathematics and requires more processing time. Therefore, due to their reasonable computational complexity, the NLMS algorithms are suited for radar applications. A real time GPU image processing in radar image has done by CUDA Technology and Advanced Obstacles Detection and Tracking by Fusing Millimeter Wave Radar and Image by

Unscented Kalman filter algorithm Mean shift algorithm has compared in this paper. Finally, to enhance the cancellation quality and processing time as well, we ambition to use other kinds of illuminators of opportunity and other types of noise cancellation algorithms.

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