A Model-based Track-Before-Detect Strategy

M. Lops *1, M. Mancino #2, D. Orlando *3, G. Ricci #4, L. Venturino *5

*DAEIMI, Università degli Studi di Cassino
Via G. Di Biasio 43, I-03043 Cassino (Fr), Italy
[1]lops@unicas.it
[3]danilo.orlando@unisalento.it
[5]l.venturino@unicas.it

#Dipartimento di Ingegneria dell'Innovazione, Università del Salento
Via Monteroni, 73100 Lecce (Le), Italy
[2]michele.mancino@gmail.com
[4]giuseppe.ricci@unisalento.it

***Abstract*— This paper addresses adaptive detection and tracking of a point-like target in thermal noise plus clutter which is assumed to be heterogeneous from one range cell to another. To this end, a track-before-detect scheme is derived and assessed; its design relies on autoregressive modeling of noise returns. A preliminary performance assessment, based upon Monte Carlo simulation, shows that it can outperform previously proposed TBD strategies.**

I. Introduction

Traditional tracking algorithms are designed assuming that the sensor provides a set of point measurements at each scan. In a radar system such measurements are obtained by thresholding the output of a matched filter fed by a baseband version of collected data. Then, the tracking algorithm links measurements across time and estimates the parameters of interest. The threshold value must be low enough to guarantee a sufficiently high probability of target detection. However, a low threshold gives rise to a high rate of false alarms. It follows that to avoid false tracks it is necessary to effectively solve the data association problem [1]. A reliable means of validating the track estimate as a target-originated one is also required.

Since the detector threshold must be set in order to ensure a high detection probability, for low signal-to-noise ratio (SNR) targets solving the data association problem may become a formidable challenge. An alternative approach, referred to as track-before-detect (TBD), consists of feeding the processor with unthresholded data. TBD-based procedures jointly process several consecutive scans (or frames) and, relying on a target kinematics or, simply, exploiting the physically admissible target transitions, jointly declare the presence of a target and, eventually, its track. A TBD algorithm can improve track accuracy and follow low SNR targets.

The main problem with TBD techniques is that the measurements depend on the target kinematics in a highly nonlinear way. A possible means to solve the nonlinear estimation problem is to resort to particle filtering [2]. An alternative is to discretize the target state space. In fact, when the state is discrete the linearity is irrelevant [3], [4], [5], [6], [7]. However, a discrete-state space is typically more demanding in terms of computational and memory resources. We refer the readers to [8] for a comparison of several different TBD strategies to detect low amplitude targets.

Most of TBD algorithms have been proposed to detect and track small moving objects in optical images corrupted by high cluttered noise. Their use in connection with radar systems has received less attention: for a description of the existing results see [9], [10], [11], [12], [13]. In particular, a family of low-complexity power-efficient TBD procedures has been presented in [11]. Therein, the continuous-time continuous-amplitude signal collected by a pulse Doppler radar is discretized to reflect the sectorization of the coverage area and the range gating operation, and the generalized likelihood ratio test (GLRT) is solved resorting to a Viterbi-like tracking algorithm. The proposed algorithm has a complexity linear in the number of integrated scans and in the time on target (TOT). A reduced-complexity algorithm is also derived assuming, at the design stage, that the target motion during the TOT in each scan is negligible. This algorithm has a complexity only linear in the number of integrated scans, but suffers from energy losses for large relative target velocities. The emphasis is on detection performance more than tracking: in fact, the GLRT does not rely on the target kinematics; it simply takes into account a maximum target velocity in order to define the admissible target transitions in range and azimuth (the Doppler is dealt with as a nuisance quantity due to the considered system and target parameters). However, a rough estimate of the target parameters is obtained as a by-product of the construction of the target statistic.

The extension of [11] in the context of space-time adaptive processing (STAP) is given in [13]. The system, equipped with a linear array of N_a sensors, illuminates the surveillance area by transmitting M coherent pulse trains, each consisting of N_p pulses, before deciding whether or not a target is present over L range cells. GLRT-based and ad hoc procedures are adopted to derive detectors assuming either a *scan-to-scan varying* scenario (where the unknown clutter covariance matrix can possibly change from scan to scan) or a *stationary* scenario (where the unknown clutter covariance matrix remains constant from scan to scan). In this paper we attack TBD for