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Optimal local sensor decision rule for target detection with channel fading statistics in multi-sensor networks

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Abstract

In this paper, we investigate the optimal local sensor decision rule based on non-ideal transmission channels between local sensors and the fusion center for distributed target detection system. The optimality of a likelihood-ratio test (LRT)-based local decision rule at local sensor, which requires only the knowledge of *channel statistics* instead of instantaneous channel state information (CSI), is established. The coupled local decision rule at each sensor is derived in a closed-form for coherent BPSK and OOK and non-coherent OOK. The iterative person-by-person optimization (PBPO) algorithm is employed to solve the coupled local thresholds. Simulation analysis reveals that the derived thresholds according to the local decision rule are consistent to the exhaustive searching. Furthermore, the detection performance of the system with the proposed optimal local decision rule for different reception modes and modulations is analyzed and compared.
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1. Introduction

Multi-sensor networks (MSNs) have been extensively used in varieties of application including civilian monitoring and military surveillance. The rapid deployment, wide range of

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surveillance, reliable performance and low-cost sensors make MSNs to be a pervasive tool to implement widespread monitoring task, such as disaster forecasting [1], biomedical applications [2], target detection, localization and tracking in battlefield [3–5] and intrusion detection [6]. We are particularly interested in the distributed target detection for MSNs, which has been attracting researchers' significant attention due to the development of wireless sensor networks (WSNs). The distributed target detection can be dated back to the 1980s for detecting airplanes with distributed radars, where the costly data transmission among radars makes data compression a reality [7]. An MSN consists of geographically dispersed sensors and a fusion center, where local sensors obtain observations of the region of interest, make preliminary decisions according to the decision rules of local sensors and then transmit the corresponding results to the fusion center over cable or wireless channel. The fusion center combines all the data and makes a final decision about the state of targets according to the fusion rule. In this paper, we focus on the distributed target detection based on MSNs, more specifically, the process of optimal decision fusions of local sensors is investigated to give the further results in the presence of fading and noisy transmission channels with fading statistics.

In a distributed detection system with MSNs, many researchers concentrate on the optimal local decision rules at sensors as well as the optimal fusion rule at the fusion center under Neyman-Pearson or Bayesian detection criteria. Under the assumption of conditionally independent observations given H_0 (target absence) and H_1 (target presence) hypotheses, the optimality of likelihood ratio tests (LRTs) both at the fusion center and local sensors was established for binary local sensor outputs [8,9]. This result is also compatible when the assumption is relaxed to multilevel quantization outputs of local sensors. Also, the optimality holds regardless of the ideal or non-ideal channel between local sensors and the fusion center [10,11]. The optimality of LRT was summarized in [12]. This study dramatically reduces the search space for the optimal rules at the fusion center as well as the local sensors.

The optimal detection rule is an LRT, nevertheless, different models, assumptions and the knowledge of transmission channels result in different formulations. The optimization of the detection performance can be achieved by considering the following three different levels: (1) the fusion rule at the fusion center is optimized while the local sensor decision rules at local sensors are fixed; (2) both the fusion rule and the local sensor decision rules are optimized; (3) the sensor decision rules are optimized while the fusion rule is fixed.

Previous study mainly concentrated on the level 1), i.e., the optimization of the fusion rule at the fusion center for fixed local sensor decision rules [13–20]. In [13], the optimal Chair-Varshney fusion rule was proposed based on the assumption that the fusion center obtains the local detection performance indices, i.e., the detection probabilities and the false alarm probabilities. However, the prior information is not available at the fusion center. To solve this problem, a Bayesian approach by averaging probability density under H_1 hypothesis over the prior distribution of the targets location was developed in [14]. Also, a generalized LRT was described in [15], where the target location is estimated by the maximum likelihood (ML). The Bayesian approach and the generalized LRT are computationally expensive for resource-constrained detection systems with MSNs. An intuitive heuristic counting fusion rule that uses the total number of "1"s of the local decisions was proposed in [16,17]. In addition to these fusion rules, an alternative fusion rule that is insensitive to the probability distributions of sensors' observations was presented based on multi-times and multilevel quantization of local sensors outputs in [18]. Traditionally, the above fusion rules are based on the assumption that the transmission channels between local sensors and the fusion center are error-free. However, the transmission channels are always subject to channel fading, environmental noise and

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