Journal of Network and Computer Applications 34 (2011) 1894–1902

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

A novel Parzen probabilistic neural network based noncoherent detection algorithm for distributed ultra-wideband sensors

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ARTICLE INFO

Article history:
Received 30 July 2010
Received in revised form
1 November 2010
Accepted 11 December 2010
Available online 31 December 2010

Keywords:
Ultra-wideband
Distributed sensor networks
Noncoherent detection
Characteristic spectrum
Parzen window
Probabilistic neural networks
Bayesian optimality

ABSTRACT

Ultra-wideband (UWB) has been widely recommended for significant commercial and military applications. However, the well-derived coherent structures for UWB signal detection are either computationally complex or hardware impractical in the presence of the intensive multipath propagations. In this article, based on the nonparametric Parzen window estimator and the probabilistic neural networks, we suggest a low-complexity and noncoherent UWB detector in the context of distributed wireless sensor networks (WSNs). A novel characteristic spectrum is firstly developed through a sequence of blind signal transforms. Then, from a pattern recognition perspective, four features are extracted from it to fully exploit the inherent property of UWB multipath signals. The established feature space is further mapped into a two-dimensional plane by feature combination in order to simplify algorithm complexity. Consequently, UWB signal detection is formulated to recognize the received patterns in this formed 2-D feature plane. With the excellent capability of fast convergence and parallel implementation, the Parzen Probabilistic Neural Network (PPNN) is introduced to estimate a posteriori probability of the developed patterns. Based on the underlying Bayesian rule of PPNN, the asymptotical optimal decision bound is finally determined in the feature plane. Numerical simulations also validate the advantages of our proposed algorithm.

1. Introduction

Being capable of potentially providing extremely high-data-rates surpassing 1 Gbps, ultra-wideband has long been considered as a promising alternative for wireless broadband accessing in short-range applications (Yang and Giannakis, 2004; Roy et al., 2004). Currently, UWB serves as an appealing candidate to the emerging wireless personal area networks (WPAN; Siep et al., 2000). Moreover, the precise ranging and material penetration capability of UWB is of great significance for specific military applications, such as the high-precision radar (Kolenchery et al., 1998) and the through-wall target detection (Yarovoy et al., 2006). Additionally, UWB technique is also attractive to the distributed sensor networks, as the transmission strategies can be optimized according to the estimated geographical/range information (Shen et al., 2005). Nowadays, UWB sensor networks have been widely suggested to environmental pollution sensing and remote medical monitoring (Zasowski and Wittneben, 2009).

UWB impulse radio (UWB-IR) is one of the physical proposals considered for UWB communications, in which the emitted information bit is directly coded into baseband short duration pulses (Win and Scholtz, 1998, 2000). Owing to the enormous emission bandwidth, which always approaches several gigahertzes (GHz), the intensive multipath propagations have posed great challenges to low-complexity receivers designing, and hence, signal processing is generally vital to UWB receivers. Under the traditional coherent frameworks, a UWB receiver is supposed to capture dozens of resolvable multipath trajectories. Channel estimation algorithms for such a case may tend to be computationally unaffordable (Yang and Giannakis, 2004; Durisi and Benedetto, 2005; Lottici et al., 2002; Witrisal et al., 2009). Meanwhile, RAKE receiver also requires a population of correlators, which could bring considerable difficulties to hardware implementations (Rajeswaran et al., 2003; Cassioli et al., 2007). Consequently, these well-developed receiving architectures, originally for the narrow-band systems, may become inapplicable to UWB sensors especially for large-scale wireless sensor networks, which pay close attention to simple realizations. To overcome these challenges, the transmitted-reference (T-R) structure is introduced in Hoctor and Tomlinson (2002) and Franz and Mitra (2006). However, the transmission efficiency inevitably experiences an obvious degradation due to the dedicated reference pulse which carries no information. Additionally, the analog delay line in TR structure is difficult to realize with high accuracy, resulting in a deteriorated performance. As another appealing transmission strategy, on the other hand, multi-band orthogonal

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doi:10.1016/j.jnca.2010.12.015