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Robust Stochastic Integration Filtering for Nonlinear Systems Under Multivariate t-Distributed Uncertainties

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Abstract

Bayesian filtering solutions that are developed under the assumption of heavy-tailed uncertainties are more robust to outliers than the standard Gaussian ones. In this work, we consider robust nonlinear Bayesian filtering in the presence of multivariate t-distributed process and measurement noise. We develop a robust stochastic integration filter (RSIF) based on the stochastic spherical-radial integration rule that achieves asymptotically exact evaluations of multivariate t-weighted integrals of nonlinear functions that arise in nonlinear Bayesian filtering framework. The superiority of the proposed scheme is demonstrated by comparing its performance against the cubature Kalman filter (CKF), a robust CKF, and the standard SIF in a representative example concerning bearings-only target tracking.

Keywords: Nonlinear filtering, robust filtering, stochastic integration, heavy-tailed noise, Student t-distribution.

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1. Introduction

Bayesian filtering provides a theoretical framework for recursive estimation of unknown dynamic state vectors in linear/nonlinear filtering applications. In Bayesian paradigm, the posterior probability of the state vector given the noisy observations is recursively updated, at each instant, using a process and a measurement model. However, in general, the evaluation of the posterior probability is analytically intractable, and hence only approximate solutions are available [1]. A widely used approximation utilizes the assumption that the required posterior distribution is Gaussian and the corresponding filters maybe termed as the Gaussian assumption (GA) filters [2]. In Table 1, we list a number of important GA filters available in literature. The Gaussian assumption, however, is frequently violated in practice. For instance, occurrence of outliers is a type of non-Gaussian phenomenon found in many applications of practical interest [3]. Consequently, filters based on the Gaussian assumption perform poorly in the presence of outliers.

A filter can be made robust to outliers by incorporating heavy-tailed uncertainties in the process and measurement models. A popular choice in literature is the use of multivariate

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