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基于GPR模型的自适应平方根容积卡尔曼滤波算法

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Adaptive Square-root Cubature Kalman Filter Algorithm Based on Gaussian Process Regression Models

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摘要

与传统算法一样,动态系统的参数化模型(含噪声统计特性)未知或不够准确易导致容积卡尔曼滤波(CKF)效果严重下降,甚至滤波结果发散。为此,利用高斯过程回归(GPR)方法对训练数据进行学习,得到动态系统的状态转移GPR模型和量测GPR模型以及噪声统计特性,用以替代或增强原有动态系统模型,并将其融入到平方根容积卡尔曼滤波(SRCKF)中,分别提出了无模型高斯过程SRCKF(MFGP-SRCKF)和模型增强高斯过程SRCKF(MEGP-SRCKF)两种算法。仿真结果表明:这两种新的自适应滤波算法提高了动态系统模型精度,且实时自适应调整噪声的协方差,克服了传统算法滤波性能易受系统模型限制的问题;与MFGP-SRCKF相比,在给定一个不够准确的参数化模型,且有限的训练数据未能遍布估计状态空间的情况下,MEGP-SRCKF具备更高的滤波精度。

关键词： 非线性滤波 平方根容积卡尔曼滤波 高斯过程回归 状态估计 状态转移模型 量测模型 模型增强

Abstract:

In many applications, the parametric models of dynamical systems (including the process and measurement of noise statistics) are difficult to obtain or are insufficiently accurate, which results in the serious deterioration or even divergence of the filtering of cubature Kalman filter (CKF). In this paper, the Gaussian process regression (GPR) method is used to learn the training data to obtain the transition and measurement GPR models and their noise statistics of dynamical systems. These GPR models are used to replace or enhance the primary system models and integrate them into the square-root CKF (SRCKF), which yields a model-free Gaussian process SRCKF (MFGP-SRCKF) algorithm and a model-enhanced Gaussian process SRCKF (MEGP-SRCKF) algorithm. Simulation results show that, by improving the accuracy of the models of dynamical systems and adjusting adaptively the noise covariance real-time, the two new adaptive filters alleviate the problem of unknown or insufficiently accurate system models in the classical filters. Meanwhile, in the case that an insufficiently accurate parametric model is given and the limited training data do not fill all over the estimated state space, MEGP-SRCKF can yield higher filtering accuracy than MFGP-SRCKF.

Keywords: nonlinear filtering square-root cubature Kalman filter Gaussian process regression state estimation state transition model measurement model model enhancement

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