胡宇,杨月诚,张世英,孙振生,朱杰堂.基于改进平方根无迹卡尔曼滤波方法的涡扇发动机气路状态监控[J].航空动力学报,2014,29(2):441~450

基于改进平方根无迹卡尔曼滤波方法的涡扇发动机气路状态监控

Turbofan engine gas path performance monitoring based on improved square root unscented Kalman filter

投稿时间： 2013-10-10

DOI：10.13224/j.cnki.jasp.2014.02.025

中文关键词： 涡扇发动机 高斯过程回归 无迹卡尔曼滤波 超球体单形采样 健康参数

英文关键词:turbofan engine Gaussian process regression (GPR) unscented Kalman filter (UKF) spherical simplex sampling health parameter

基金项目:

作者	单位
胡宇	第二炮兵工程大学 动力工程系，西安 710025
杨月诚	第二炮兵工程大学 动力工程系，西安 710025
张世英	第二炮兵工程大学 动力工程系，西安 710025
孙振生	第二炮兵工程大学 动力工程系，西安 710025
朱杰堂	第二炮兵工程大学 动力工程系，西安 710025

中文摘要:

针对涡扇发动机气路状态监控存在模型未知或不准确导致滤波效果下降甚至发散的问题，研究了一种融入高斯过程回归（GPR）的改进平方根无迹卡尔曼滤波（UKF）方法.该方法利用GPR对训练数据进行学习，建立发动机气路部件状态监控的GPR模型，替代UKF方法中的非线性系统模型；采用超球体单形采样和平方根滤波方法来提高滤波的计算效率和数值稳定性.仿真结果表明：训练的GPR模型解决了UKF方法对发动机原系统模型和噪声协方差矩阵依赖性的问题；与扩展卡尔曼滤波（EKF）和平方根UKF方法相比较，改进平方根UKF方法精度更高，对健康参数的估计精度达到99.9%，实现了对涡扇发动机单个和多个气路部件健系参数的有效跟踪.

英文摘要:

An improved spherical simplex square root unscented Kalman filter (ISRUKF) algorithm based on Gaussian process regression (GPR) was investigated to specifically address unknown or inaccurate models problems, resulting in bad or even divergent filtering results in turbofan engine performance monitoring. The transition and measurement GPR models of turbofan engine dynamic systems were established, and used as a substitute for nonlinear model in unscented Kalman filter (UKF). Meantime, the spherical simplex sampling was exploited to decrease the computational complexity, while square root of measurement residuals covariance matrixes was used instead of variance matrixes during recursive arithmetic process to improve the calculation efficiency and numerical stability in ISRUKF algorithm. Using the GPR, the models were firstly trained and verified, thus overcoming dependency on the previous engine models with the abilities of adaptive noise adjustment and high precision. The gradual and rapid deterioration process of different turbofan engine gas path components were then testified and compared by the extended Kalman filter (EKF), SRUKF and ISRUKF. The results show that the precision of ISRUKF has reached 99.9%, demonstrating the effectiveness of the ISRUKF for health parameters monitoring of turbofan engine gas path.