Filtering and fault detection for nonlinear systems with polynomial approximation.

Summary: This paper is concerned with polynomial filtering and fault detection problems for a class of nonlinear systems subject to additive noises and faults. The nonlinear functions are approximated with polynomials of a chosen degree. Different from the traditional methods, the approximation errors are not discarded but formulated as low-order polynomial terms with norm-bounded coefficients. The aim of the filtering problem is to design a least squares filter for the formulated nonlinear system with uncertain polynomials, and an upper bound of the filtering error covariance is found and subsequently minimized at each time step. The desired filter gain is obtained by recursively solving a set of Riccati-like matrix equations, and the filter design algorithm is therefore applicable for online computation. Based on the established filter design scheme, the fault detection problem is further investigated where the main focus is on the determination of the threshold on the residual. Due to the nonlinear and time-varying nature of the system under consideration, a novel threshold is determined that accounts for the noise intensity and the approximation errors, and sufficient conditions are established to guarantee the fault detectability for the proposed fault detection scheme. Comparative simulations are exploited to illustrate that the proposed filtering strategy achieves better estimation accuracy than the conventional polynomial extended Kalman filtering approach. The effectiveness of the associated fault detection scheme is also demonstrated.

Keywords: polynomial filtering; nonlinear systems; polynomial approximation; fault detection; adaptive threshold; recursive algorithm; Kronecker power

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