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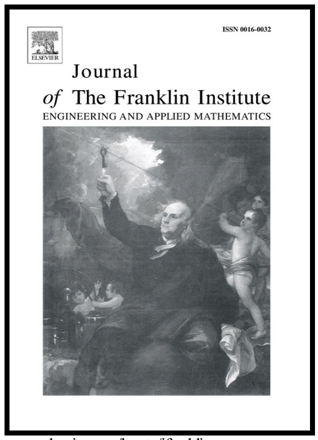

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Incremental locally linear embedding-based fault detection for satellite attitude control systems

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Abstract: This paper presents a novel fault detection method based on incremental locally linear embedding (I-LLE) to improve the accuracy of fault detection for a satellite with high-dimensional telemetry data. Firstly, the I-LLE algorithm is introduced, followed by an application on Satellite "TX-1" telemetry to extract the low-dimensional features, which can be used to perform fault detection with statistical indexes. A rapid semi-physical platform for satellite attitude control systems based on PC104 and AD7011-EVA is designed to perform fault simulation, because limited telemetry contains fewer fault patterns, which renders fault simulation for in-orbit satellites difficult. The I-LLE-based fault detection scheme is then employed to detect anomalies in simulation data. Simulation results presented in this paper validate the fault detection scheme.

Keywords: Incremental locally linear embedding, rapid platform, fault detection, telemetry data

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1. Introduction

Satellites in orbit transmit huge volume of telemetry data back to earth which indicates their running status as well as the implementation of tasks. In order to fulfill task requirements, there is a need to understand the complex behavior of satellites. This greatly increases the demands of reliability for satellites[1-4]. However, with the advancement of space technology, telemetry data of satellites become more complex and the application of conventional fault diagnosis(FD) methods is ineffective[5]. In order to overcome this shortcoming, a novel manifold learning-based fault detection scheme for satellite attitude control systems(SACs) is presented in consideration of the high-dimensional telemetry data.

Considerable efforts have been made in recent decades to optimize the use of high-dimensional data. Quite a number of fault diagnosis approaches were proposed based on the feature extracted from high-dimensional data. For instance, Sue et al.[6] used principal component analysis (PCA) to detect anomalies for SACs combining with multivariate statistical knowledge. While Gao et al.[7] utilized a fault detection and diagnosis scheme by combining the PCA and support vector machine(SVR). These classical dimensionality reduction methods, such as PCA, partial least squares (PLS)[8] and multidimensional scaling (MDS)[9], all tried to reduce the dimensionality of original data without decreasing the accuracy of fault diagnosis. However, feature extraction based on these methods is restricted to linear structures and cannot be effectively applied to nonlinear structures. To cope with these problems, Chang and Ma[10] and Li et al.[11] introduced the kernel PCA and kernel PLS methods, respectively, which were successfully applied in chemical industry. To deal with the nonlinear

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