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Iterated Robust kernel Fuzzy Principal Component Analysis and Application to Fault Detection

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Abstract

In this paper, we propose an iterated Robust kernel Fuzzy Principal Component Analysis (IRkFPCA), which is the method that attempts to combine the advantages of the state of art methods and use a more accurate multi-objective function for jointly reducing the modeling errors, optimizing the robustness to outliers and improving the time complexity since it does not require the storage and inversion of the covariance matrix to obtain a memory-efficient approximation of kernel PCA. This proposed technique computes iteratively the principal components, which are used for modeling and fault detection. The detection stage is related to the evaluation of residuals, also known as detection indices, which are signals that reveal the fault presence. Those indices are obtained from the analysis of the difference between the process measurements and their estimations using the IRkFPCA technique. The performance of the proposed method is illustrated and compared to iterated kernel Principal Component Analysis (IkPCA) and iterated Principal Component Analysis (IPCA) methods through two simulated examples, one using synthetic data and the other using simulated continuously stirred tank reactor (CSTR) data. The results of the comparative studies reveal that the developed IRkFPCA method provides a better performance in terms of modeling and fault detection accuracies than the iterated Robust Fuzzy Principal Component Analysis (IRFPCA) and iterated kernel Principal Component Analysis (IkPCA) methods; while both methods provide improved accuracy over the iterated Principal Component Analysis (IPCA) method.

Keywords: Iterated robust fuzzy, kernel principal component analysis, fault detection, modeling.

1. Introduction

Due to consistent product quality demand and higher requirements in safety, the process monitoring performance has become a key factor in improving productivity and safety. Process systems are using large amount of data from many variables that are monitored and recorded continuously every day. For these reasons, the problem of fault detection that responses effectively to faults that mislead the process and harm the system reliability represents a key process in such operation of these systems. The fault detection problem is an important process in process monitoring. Abnormal faults management mainly depends on diagnosis of the process faults and accurate fault detection. State