Support Vector Machine based Fault Classification in Batch Reactor Process

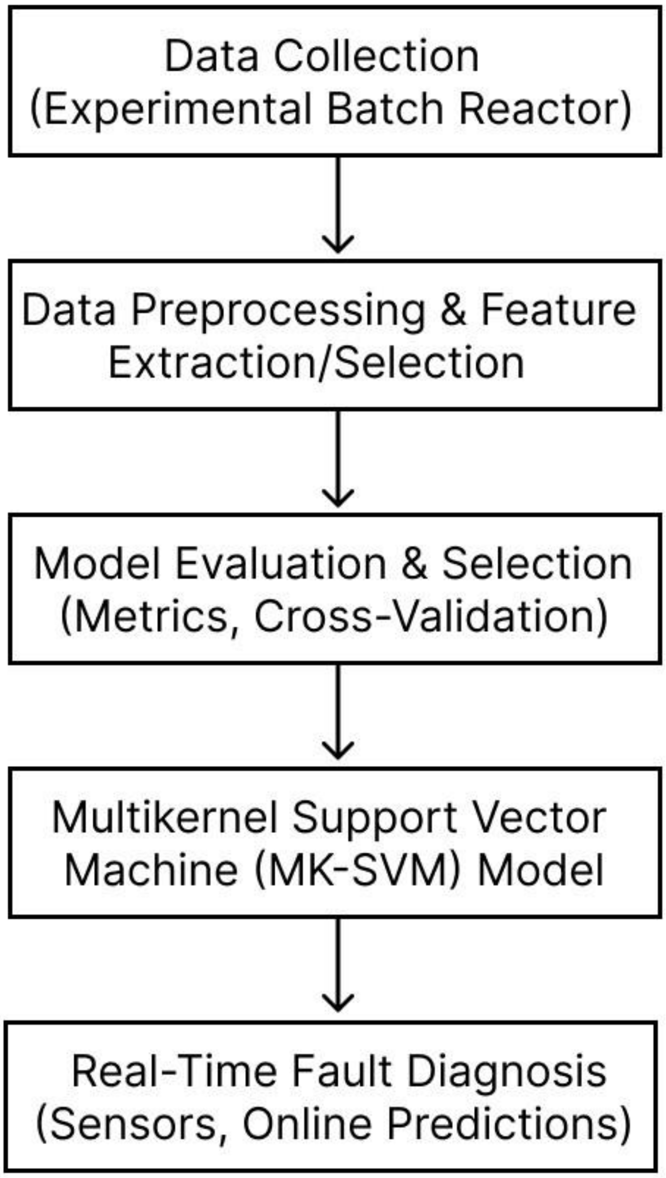
Abstract

Fault detection and diagnosis (FDD) in process industries is an important task for efficient process monitoring and plant safety. It is also essential for improving product quality and reducing production cost by reducing process downtime. Real-time multi scale classification of faults plays a vital role in process monitoring. However, some major issues such as high correlation, complexity, and non linearity of data are yet to be addressed. In this paper, a fault diagnosis approach based on multi-kernel support vector machines is proposed to classify the internal and external faults such as Reactor Temperature, Coolant In Temperature and Jacket Temperature in batch reactor experimental works. The data set is generated collected from experimental works. The classification has been done by various methods such as decision tree, K-nearest neighbors, linear discriminant analysis, artificial neural network, subspace discriminant, and multi kernel support vector machine.

Introduction

Batch reactor processes are widely used in chemical and pharmaceutical industries for the production of various chemicals, pharmaceuticals, and specialty products. However, these processes are susceptible to various faults and anomalies that can lead to undesirable outcomes, such as decreased yield, product quality deviations, or even hazardous conditions. Early detection and classification of these faults are essential for timely intervention and effective process control. Support Vector Machines (SVMs) have emerged as powerful tools for fault classification in complex industrial processes. They are particularly effective in dealing with high-dimensional data, noisy data, and situations where the data might not be linearly separable. Traditional SVMs are designed to work with linearly separable data, but they can struggle with complex, nonlinear relationships. To address this limitation, researchers have developed the concept of using multiple kernels in SVMs, known as Multiple Kernel Support Vector Machine (MK-SVM). This approach's ability to handle non-linearity can lead to enhanced process understanding, early fault detection, and improved process control, ultimately contributing to safer and more efficient industrial operations.

Block Diagram



Block Diagram of Fault Diagnosis in Batch Reactor Process using SVM

Literature Survey

1. Fault Diagnosis of Batch Reactor Using Machine Learning Methods

[Sujatha Subramanian,Fathima Ghouse,Pappa Natarajan]

Abstract:

In this paper, support vector machine (SVM) is used to estimate the heat release of the batch reactor both normal and faulty conditions. The signature of the residual, which is obtained from the difference between nominal and estimated faulty values, characterizes the different natures of faults occurring in the batch reactor. In this paper, SVM model is used to generate the residual images. Fault classification has been done from the extracted image features.

Methodology:

Model based fault detection method is developed based on the assumption that the developed model is replica of the real plant dynamics. The input-output data are obtained by simulating the batch reactor with nominal operating conditions. The different faults have been introduced in the reactor through simulation by using MATLAB software. From the simulated input and output data, SVM estimator model is developed using LIBSVM toolbox. The heat release of the reactor which is not a measurable parameter is estimated through the SVM model.

Outcome:

In this paper, SVM model is used to generate the residual images. Fault classification has been done from the extracted image features. This paper is mainly focused on identifying fault classification of batch reactor from the residual features using artificial intelligent classifiers such as multilayer perceptron (MLP), radial basis function (RBF), and Bayes net.

2. Multiple Fault Diagnosis in Distillation Column Using Multikernel Support Vector Machine

[Syed A. Taqvi, Lemma Dendena Tufa,Haslinda Zabiri,Abdulhalim Shah Maulud and Fahim Uddin]

Abstract:

In this paper, a fault diagnosis approach based on multikernel support vector machines is proposed to classify the internal and external faults such as reflux failure, change in reboiler duty, column tray upsets, and change in feed composition, flow, and temperature in a distillation column. The data set is generated using Aspen plus dynamics simulation at normal and faulty states. The classification has been done by various methods such as decision tree, K-nearest neighbors, linear discriminant analysis, artificial neural network, subspace discriminant, and multikernel support vector machine.

Methodology:

This paper proposes the fault classification method to determine the various types of fault is distillation column. The main contribution of this work is as follows:

1. A fault diagnosis method for the distillation column is proposed on the basis of machine learning techniques.
2. A multiple kernel support vector machine (MK-SVM) is constructed for the recognition of normal and fault classes to classify the novel faults in the distillation column.

Outcome:

This paper proposed a diagnostic system based on multikernel support vector machines. In this work, the application of SVM is presented for fault diagnosis in the distillation column. For the specific type of faults SVM has better classification accuracy.

3. Big data approach to batch process monitoring: Simultaneous fault detection and diagnosis using nonlinear support vector machine-based feature selection

[Melis Onel,Chris A. Kieslichd,Yannis A. Guzmanc,Christodoulos A. Floudas,Efstratios N. Pistikopoulos]

Abstract:

This paper presents a novel data-driven framework for process monitoring in batch processes. This paper have proposed to exploit high dimensional process data with nonlinear Support Vector Machine-based feature selection algorithm, where the aim is to retrieve the most informative process measurements for accurate and simultaneous fault detection and diagnosis. The proposed framework is applied to an extensive benchmark data set which includes process data describing 22,200 batches with 15 faults.

Methodology:

The proposed paper consists of two phases: (i) Offline phase includes the formulation of the fault and time-specific models for fault detection and diagnosis via historical signal process data where the novel optimization-backed feature selection algorithm is used. (ii) Online phase monitors ongoing batches in realtime by using the fault and time-specific models. Prior to both phases, data needs to be re-organized and/or processed.

Outcome:

The implementation of the end-models as an online decision support tool as proposed in this paper can enable early intervention to the process to reverse the detected fault, significantly reduce the number of sensor measurements to diagnose the detected fault, and possibly guide for the optimal sensor placement The paper have focused on training 2-class models where one can access historical and/or simulation-based process data.

4. Using SVM Based Method for Equipment Fault Detection in a Thermal Power Plant

[Kai-Ying Chen, Long-Sheng Chen, Mu-Chen Chen, Chia-Lung Lee]

Abstract:

This work proposes a support vector machines (SVM) based model which integrates a dimension reduction scheme to analyze the failures of turbines in thermal power facilities. Finally, a real case from a thermal power plant is provided to evaluate the effectiveness of the proposed SVM based model.

Methodology:

As modern power plants have been computerized, a huge amount of data could be automatically collected and stored.Here first step of model is to identify the monitoring parameters which are related to turbine failure detection. The condition attributes (inputs) and the decision attribute (output) could be confirmed in step 1. Step 2 is data preparing phase. In this step, collected data should be prepared for implementing feature selection and constructing classifiers. In step 3, two feature selection techniques including correlation analysis and decision tree have been utilized to reduce dimension of input data.Next, the major task in step 4 is to build a SVM classifier including selecting kernel function, finding optimal parameter settings and training SVM. Finally here, they have used a testing data to validate the effectiveness of the built SVM classifier.

Outcome:

In this proposed work a real-world data from a thermal power company has been employed to evaluate the effectiveness of model. By comparing various ML algorithms, experimental results indicated the performance of the classifier of SVM model as being superior to those of BPN and LDA. The SVM based model can successfully detect the types of turbine faults with a high degree of accuracy (greater than 90%).

5. Wiener-Neural-Network-Based Modeling and Validation of Generalized Predictive Control on a Laboratory-Scale Batch Reactor

[Prajwal J, Jatin Kumbhare, Eadala Yadav, and Thirunavukkarasu Indiran]

Abstract:

The first part is modeling the WNN-based batch reactor using the provided input−output data set. The input is feed given to the reactor, and the reactor temperature needs to be maintained in line with the optimal profile. The objective in this part is to train the neural network to efficiently track the nonlinear temperature profile that is provided from the data set. The second part is designing a generalized predictive controller (GPC) using the data obtained from modeling the reactor to successfully track any arbitrary temperature profile.

Methodology:

The aim is to initially find the weights for the Wiener neural network that successfully track the temperature profile provided from the existing data set. Secondly, the weights obtained from the modeling are incorporated in the generalized predictive controller (GPC) to track the arbitrary set point profile. The results section is divided into two parts. First Part consists of the results obtained during the modeling of the batch reactor to satisfactorily track the data set temperature profile. Second Part, consists of the results obtained during the design of the generalized predictive controller. The tracking performance of the controller with respect to various set point profiles can be examined.

Outcome:

In this paper advanced Back propagation algorithm. Using WNN prediction based controllers, one can be able to maintain the temperature of the reactor in a controlled manner to avoid any thermal runaway.Support Vector Machine can be used to increase the productive outcome.

Objectives

- Collection of dataset from Batch Reactor process, which includes major attributes like actuator data, temperature of the coolant, temperature of the reactor and temperature jacket (outcome).
- Fault diagnosis model is built using MK-SVM algorithm.
- Model has to predict the fault (temperature attributes) introduced in the Batch Reactor process.
- Upon detecting these faults, the model will generate visual plots that clearly depict the temperature variations and anomalies, allowing for easy identification and analysis.