White paper

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ANN Based Machine Fault Classification

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ABSTRACT

Predictive maintenance ensures plant economics and safety. In this paper, a deep learning based Artificial Neural Network model is built to classify the fault in the machinery. Initially the feature extraction technique is applied over a faulty triplex reciprocating pump's data. The time domain features and the spectral features such as mean, standard deviation, RMS, kurtosis, skewness, peak value, modal coefficients and band power are extracted from the signal using Diagnostic Feature Designer app. The extracted features are pre-processed to ensure that the raw data does not degrade the quality of the result. Dimensionality reduction technique - Principal Component Analysis is applied to the pre-processed data, comprising 95% of information about the data. Various machine learning classifier models - Decision tree, Random forest, Multinomial logistic regression, and k-nearest neighbors were applied to compare for the highest accuracy. On comparing the different accuracies obtained, it was evident that the deep learning Artificial Neural Network model is found to be more accurate in classifying the Triplex pump fault than the other Machine learning models.

Keywords - Artificial neural network, diagnostic feature designer, dimension reduction, machine fault classification, principal component analysis.

INTRODUCTION

Every machine that is manufactured is bound to fail one day. Preventing the minor shutdowns or analyzing and acting to replace the depleting machines enhances the plant's economy. Predictive maintenance is designed to aid the decision maker in this particular area. Predictive maintenance techniques plays a major role in industries nowadays. They help to determine the condition of an equipment in order to estimate when maintenance is required. This approach reduces cost over the regular preventive maintenance. Fault classification or fault diagnosis is one of the key method in predictive maintenance which determines where the fault has occurred. For classifying the faults in a machine, a machine learning or a deep learning model is required. The goal of this paper is to create an advanced classifier for fault classification by doing a comparative study on the machine learning and deep learning - Artificial Neural Network models. This paper is structured as follows. The second section explains the previous work on fault classification. The third section describes the proposed method. Evaluation and analysis discussion of the proposed method is described in section four and the last section gives the conclusion of this paper.

REVIEW OF LITERATURE

Any industrial machine should be monitored to examine the presence of fault in regular intervals. Since industrial machines are expensive and to avoid wastage of productivity time, Predictive maintenance is followed to detect the fault in the machine in advance. These detected faults are currently classified using the Machine Learning models. But due to the lack of accuracy in predicting the fault classification, the proposing system explains about the Deep learning model using Artificial Neural Network.

PROPOSED METHOD

Machine Learning / Deep Learning models with more number of redundant features, results in less accuracy. Hence to reduce the number of features selected, the process of Feature selection is followed. Feature selection is also known as attribute selection. This is achieved by the process of Principal Component Analysis (PCA). In this technique, the primary features are transferred into a new space with fewer dimensions. No new features are made. Our proposed method of Fault classification has two main steps. The first step is to reduce the dimension of the features, however comprising 95% information about the data using Principal Component Analysis. And, the second step is classifying the Fault using Deep Learning - Artificial Neural Network.

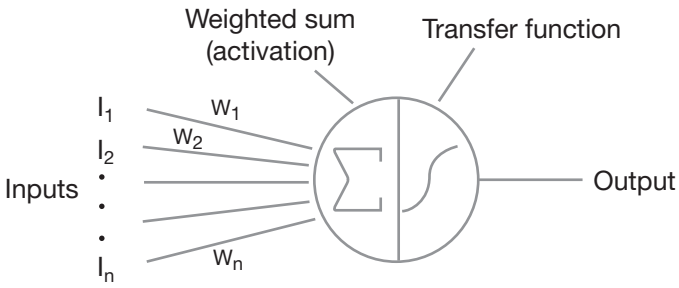
A. Dimensional Reduction

Reducing the dimension of the feature space is called “dimensionality reduction.” Principal component analysis is a technique for feature extraction - it combines our input variables in a specific way, then we can drop the “least important” variables while still retaining the most valuable parts of all of the variables.

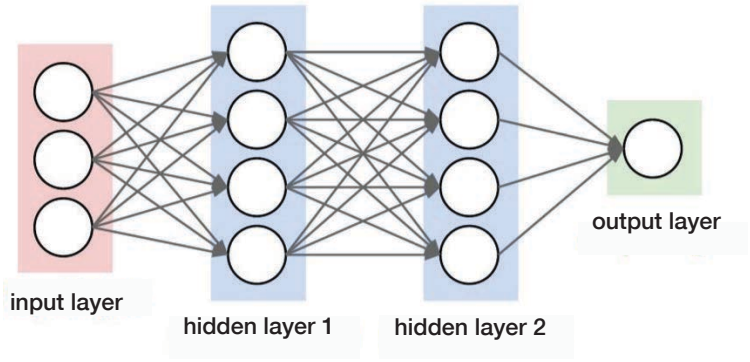
More important = more variance/more spread out data

B. Fault Classification

To achieve more accuracy in predicting the Fault Classification, we choose to build the model using Artificial Neural Network Model. In simple terms, a Neural network algorithm will try to create a function to map your input to your desired output. This structure is called a neuron.



Activation functions ‘relu’ and ‘softmax’ are used in building the model. The model consists of two hidden layers and an output layer. The function can be anything: a linear function or a sigmoid or a softmax function. Of course, a single neuron has no advantage over a traditional machine learning algorithm. In this proposed model, relu activation function is used in the first two hidden layers and softmax activation function in the output layer. 200 epoch’s are used in our ANN model. An epoch is a measure of the number of times all of the training vectors are used once to update the weights. For batch training, all of the training samples pass through the learning algorithm simultaneously in one epoch before weights are updated. Therefore, a neural network combines multiples neurons. Think of neurons as the building blocks of a neural network. By stacking them, we can build a neural network as shown below.



EXPERIMENTAL RESULTS

This section explains about the evaluations of the proposed method on datasets and discusses the comparison results of accuracy obtained between the Machine Learning models and the Deep Learning – Artificial Neural Network model.

A. Datasets

Triplex pump fault data is taken into consideration. The pump data contains 240 flow and pressure measurements for different fault conditions. There are three fault types (leaking pump cylinder, blocked pump inlet, and increased pump bearing friction). The measurements cover conditions where none, one, or multiple faults are present. The data is collected in a table where each row is a different measurement. The time domain features and the spectral features such as mean, standard deviation, root mean square (RMS), kurtosis, skewness, peak value, modal coefficients, and band power are extracted from the signal (both flow and pressure data) using time domain features and power spectrum. Thus these features are used as the dataset to train the models.

B. Classifiers

Dimensionality reduction of extracted features is done through Principal Component Analysis, comprising 95% of information about the data. Machine learning models namely Decision tree, Random forest, multinomial logistic regression, and KNN has been built using the dimensionally reduced data to compare for the highest test accuracy. Deep learning models have also been built to enhance the accuracy obtained.

RESULTS AND DISCUSSION

We did several simulations and experiments using various classifiers to evaluate the performance of the proposed method. 80% of the data is considered as the training data and the remaining 20% is considered to be the test set. Stratified sampling of the training dataset is fed to the model after seeding. The test accuracy of the classification was used as the criteria to compare the performance of different methods.

CLASSIFICATION RESULTS

ML Model	DL Model	Accuracy
Random Forest		75%
Decision Tree		75%
Logistics Regression		77%
K-nearest neighbor		
	Artificial Neural Network	83%

As the results show, in almost all classifiers, the proposed method has better outcomes. For example, in Decision tree, Random forest, multinomial logistic regression, and KNN models the output test accuracy is less than the proposed model. Moreover, the accuracy results show that ANN model Classifier achieved higher accuracy compared to the other Machine Learning Model Classifier.

CONCLUSION

In this paper we applied several machine learning models and deep neural networks (Artificial neural networks (ANN)) to the problem of fault classification. We compared the results of the aforementioned models and showed how deep neural network is more accurate. We also showed the importance of feature extraction, the process of extracting necessary information from the data which enhances the performance of the classifier.

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