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A Project Report

on

ENGINE FAULT DETECTION USING NEURAL NETWORKS

Submitted in partial fulfillment of the requirement for the award of the degree of

Bachelor Of Engineering

in

Computer Science and Engineering

Submitted By

KEERTHI VAIDYANANTH HR	**1DT18CS123**
PARIKSHITH H	**1DT18CS074**
R N SAI MADHAV	**1DT18CS087**
SNEHA M	**1DT18C100**

Under the Guidance of

SHIVA SUMANTH REDDY
Professor, Department of CSE

DAYANANDA SAGAR ACADEMY OF TECHNOLOGY AND MANAGEMENT
Udayapura, Kanakapura Road, Bangalore-560082
Department of Computer Science and Engineering

Academic Year : 2021-22

DAYANANDA SAGAR ACADEMY OF TECHNOLOGY AND MANAGEMENT
Udayapura, Kanakapura Road, Bangalore-560082
Department of Computer Science and Engineering

CERTIFICATE

Certified that the Project Entitled **"Engine Fault Detection Using Neural Networks"** carried out by **Keerthi Vaidyanath HR**, bearing **USN 1DT18CS123**, **Parikshith H** ,bearing **USN 1DT18CS074, R N Sai Madhav**, bearing **USN 1DT18CS087, Sneha M,** bearing **USN 1DT18CS100,** bonafide students of Dayananda Sagar Academy 0f Technology and Management, is in partial fulfillment for the award of the **BACHELOR OF ENGINEERING** in **Computer Science and Engineering** from Visvesvaraya Technological University, Belagavi during the year 2021-2022. It is certified that all the corrections/suggestions indicated for Internal Assessment have been incorporated in the report submitted to the department. The Project report has been approved as it satisfies the academic requirements in respect of the Project-Work Phase-1 prescribed for the said Degree.

Dr. Kavita C. Professor Department of CSE DSATM, Bengaluru.	Dr. Nandini C Vice Principal, Professor & HOD Department of CSE DSATM, Bengaluru.	Dr. M. Ravishankar Principal DSATM, Bengaluru.

DAYANANDA SAGAR ACADEMY OF TECHNOLOGY AND MANAGEMENT
Udayapura, Kanakapura Road, Bangalore-560082
Department of Computer Science and Engineering

DECLARATION

We, **Keerthi Vaidyanath HR**, bearing **USN 1DT18CS123**, **Parikshith H**, bearing **USN 1DT18CS074, R N Sai Madhav**, bearing **USN 1DT18CS087, Sneha M**, bearing **USN 1DT18CS100,** students of Seventh Semester B.E, Department of Computer Science and Engineering, Dayananda Sagar Academy 0f Technology and Management, Bengaluru, declare that the Project Work Phase 1 entitled "**Engine Fault Detection Using Artificial Neural Networks**" has been carried out by us and submitted in partial fulfilment of the course requirements for the award of degree in **Bachelor of Engineering** in **Computer Science and Engineering** from **Visvesvaraya Technological University, Belagavi** during the academic year **2020-2021**.

KEERTHI VAIDYANATH HR	1DT18CS123
PARIKSHITH H	1DT18CS074
R N SAI MADHAV	1DT18CS087
SNEHA M	1DT18CS100

Place: Bengaluru
Date:04/02/2022

ABSTRACT

Fault detection and isolation (FDI) in dynamic data from an automotive engine air path using artificial neural networks is investigated. A generic SI mean value engine model is used for experimentation. Several faults are considered, including leakage, EGR valve and sensor faults, with different fault intensities. RBF neural networks are trained to detect and diagnose the faults, and also to indicate fault size, by recognising the different fault patterns occurring in the dynamic data.

A number of fault detection systems for vehicle maintenance, repair have been developed in recent years. These systems are used for diagnosing variety of faults in the vehicle and are available at service level. A wavelet neural networks model is constructed based on wavelet frame theory and neural networks technology. The model is validated through the testing that simulates the faults of engine. RBF neural networks are trained to detect and diagnose the faults, and also to indicate fault size, by recognising the different fault patterns occurring in the dynamic data.

A dynamic neural network is developed to detect soft failures of sensors and actuators in automobile engines. The network, currently implemented off- line in software, can process multi-dimensional input data in real time. The network is trained to predict one of the variables using others. It learns to use redundant information in the variables such as higher order statistics and temporal relations. The difference between the prediction and the measurement is used to distinguish a normal engine from a faulty one. Using the network, we are able to detect errors using sensors with a high degree of accuracy.

ACKNOWLEDGEMENT

The satisfaction and the euphoria that accompany the successful completion of any task would be incomplete without the mention of the people who made it possible. The constant guidance of these people and encouragement provided, crowned us with success and glory. We take this opportunity to express our gratitude to one and all.

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Keerthi Vaidyanath HR	1DT18CS123
Parikshith H	1DT18CS074
R N Sai Madhav	1DT18CS087
Sneha M	1DT18CS100

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ABBREVIATIONS

ANN	Artificial Neural Network
SNN	Simulated Neural Network
PNN	Probabilistic Neural Network
SVSF	Smooth Variable Structure Filter
CNN	Convolution Neural Network
DCNN	Deep Convolutional Neural Network

Chapter 1

Introduction

1.1 Background:

- Neural networks, also known as artificial neural networks (ANNs) or simulated neural networks (SNNs), are a subset of machine learning and are at the heart of deep learning algorithms. Their name and structure are inspired by the human brain, mimicking the way that biological neurons signal to one another.
- Artificial neural networks (ANNs) are comprised of a node layers, containing an input layer, one or more hidden layers, and an output layer. Each node, or artificial neuron, connects to another and has an associated weight and threshold. If the output of any individual node is above the specified threshold value, that node is activated, sending data to the next layer of the network. Otherwise, no data is passed along to the next layer of the network.

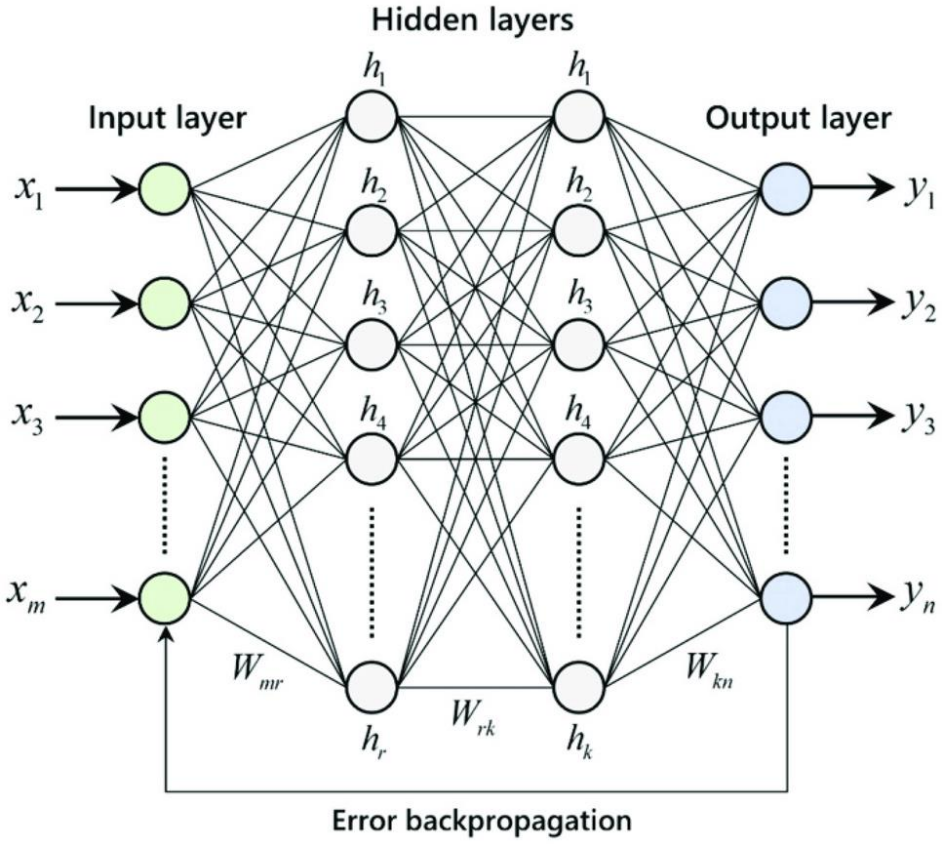

Fig.1: Neural Network Architecture

ENGINE FAULT DETECTION:

- Wavelengths and amplitudes are properties of sound that can be objectively identified. Automobiles can produce more complex sounds. Automobiles are complex machines with components that work together, producing diverse sounds, many of them concurrently.
- Consider the choral humming from the powertrain as a combination of parts. Faults in even minor components are bound to cause dissonance. It is not possible even for skilled individual to listen to the sound and diagnose what component is at fault.
- It is a difficult challenge for even the most skilled mechanics. The sounds we hear from the engine room or powertrain are significantly more varied and complex.
- This problem can be overcomed using neural networks where the machines are trained using the previous data available.
- Fault detection based on the vibration signal of an engine is an effective non-disassembly method for engine diagnosis because a vibration signal includes a lot of information about the condition of the engine.
- The vibration signal from an engine body includes a lot of information about the engine operating process, and this signal is used as the fault detection tool.
- The fault table contains information about various engine problems using which the component at fault can be found and diagnosed.

1.2 Brief project outline:

The automobile's working will be directly influenced by the running states of the engine. To clear the fault's which occur in the engine will cost much, and will have to spend a lot of time on it in order to rectify those faults. A variety of diagnosis methods have been proposed under the umbrella of model-based techniques. The feature of all these techniques is that some form of mathematical knowledge of the process of interest along with inputs and outputs are used to generate more information about that process. This redundant information is then used in a diagnostic process to arrive at decisions regarding fault or no fault conditions. Occurrence of a fault influences various system parameters which deviate from their normal values. A typical fault table indicates relation between various vehicle parameters. The amount by which the parameter value is deviated depends upon the type of fault.

Chapter 2

Literature Review

2.1 System Study:

- S. Zhu, M. K. Tan, R. K. Y. Chin, B. L. Chua, X. Hao and K. T. K. Teo proposed "Engine Fault Diagnosis using Probabilistic Neural Networks". Engine failure is one of the major factors caused vehicle breakdown. In the current practice, the engine faults are diagnosed manually by mechanics and the accuracy is highly relied on their experience. Therefore, this study would like to explore the feasibility of implementing auto fault diagnosis using Probabilistic Neural Network (PNN). The proposed PNN is trained using the collected engine fault data from experiment and the probability density of PNN is determined based on the Parzen window estimation method. Bayes decision rule is implemented for classifying the types of the engine faults.
- R. Ahmed, M. El Sayed, S. A. Gadsden, J. Tjong and S. Habibi, "Automotive Internal-Combustion-Engine Fault Detection and Classification Using Artificial Neural Network Techniques". In this paper, an engine fault detection and classification technique using vibration data in the crank angle domain is presented. These data are used in conjunction with artificial neural networks (ANNs), which are applied to detect faults in a four-stroke gasoline engine built for experimentation. A comparative study is provided between the popular backpropagation (BP) method, the Levenberg-Marquardt (LM) method, the quasi-Newton (QN) method, the extended Kalman filter (EKF), and the smooth variable structure filter (SVSF). The SVSF is a relatively new estimation strategy, based on the sliding mode concept. It has been formulated to efficiently train ANNs and is consequently referred to as the SVSF-ANN.
- Mingyong Li, Qingmin Wei, Hongya Wang & Xuekang Zhang (2019) Research on fault diagnosis of time-domain vibration signal based on convolutional neural networks. In order to maintain the safe operation of various types of equipment, the health status of main components should be monitored in real-time, and the demand for intelligent fault diagnosis algorithm has increased sharply. However, the traditional intelligent diagnosis algorithm is based on the manual method for signal feature extraction, which has high requirements for expert experience and poor generality. A convolutional neural network, with big data as its engine, is the most

effective pattern classification algorithm at present. In this paper, the convolutional neural network is applied to time-domain vibration signal fault diagnosis, taking the bearing as an example, and an intelligent diagnosis method of bearing based on convolution neural network is proposed. The proposed method does not need manual feature extraction, and can automatically complete feature extraction and automatic fault recognition. The convolutional neural network has three convolutional layers. We use data enhancement techniques for the input raw signal and convert the one-dimensional original time-domain vibration signal into a two-dimensional signal. The model shows good results on CWRU dataset and the recognition accuracy of the algorithm in the CWRU bearing database is more than 96%.

- Ryan M. Ahmed; Mohammed A. El Sayed; S. Andrew Gadsden; Saeid R. Habibi proposed Fault detection of a engine using a Neural Network trained by the smooth variable structure filter. A multilayered neural network is a multi-input, multi-output (MIMO) nonlinear system in which training can be regarded as a nonlinear parameter estimation problem by estimating the network weights. In this paper, the relatively new smooth variable structure filter (SVSF) is used for the training of a nonlinear multilayered feed forward network. The SVSF is a recursive sliding mode parameter and state estimator that has a predictor-corrector form. Using a switching gain, a corrective term is calculated to force the network weights to converge to within a neighbourhood of the optimal weight values. SVSF-based trained neural networks are used to classify engine faults on the basis of vibration data. Two faults are induced in a four-stroke, eight-cylinder engine. Furthermore, a comparative study between the popular back propagation method, the extended Kalman filter (EKF), and the SVSF is presented. Experimental results indicate that the SVSF is comparable with the EKF, and both methods outperform back propagation.

- Wang Weijie; Kang Yuanfu; Zhao Xuezheng; Huang Wentao proposed study of Automotive Engine Fault Diagnonsis based on Wavelet Neural Network. The engine vibration signals characters are extracted using wavelet packet technology. A model of wavelet neural networks is constructed based on wavelet frame theory and neural networks technology. Then multiresolution analysis is used to choose and optimize the wavelet neuron. The model is validated through the testing that simulates the faults of engine valve clearance. The experimental results show that

the proposed automobile engine fault diagnostic model based on wavelet neural networks can diagnose the engine fault effectively.

2.2 Proposed Work:

- The RBF neural network receives five inputs signals, the first three inputs signals are manifold pressure, temperature and crankshaft speed which containing fault information, and the second two inputs signals are the throttle angle and the fuel mass flow and has three outputs with each indicating one of the investigated states in Amplitude.
- This neural network will use at the beginning only the first three rows of the MVEM output matrix which consists of signals values of manifold pressure, manifold temperature and crankshaft speed, all these three inputs contain sensor, component and actuator faults, after that the output of the neural network will be used as a target matrix, that means this neural network is an independent model.
- The hidden nodes which are chosen by k-means method are 12, this is because the test result is very good and the size of neural network will be small, consequently the train and test time will be small. Width and weights are trained using ρ - nearest neighbours algorithms and the same data of μ, w(0), P(0) which were used to train neural network engine model are used here. The trained network is then tested for all faults occurring.

2.3 Scope of the project

- Aimed at the fault diagnosis and prediction of automobile engine, firstly designed a framework structure of automobile engine fault diagnosis and prediction system, and built a hardware platform.
- Secondly adopted the genetic algorithm neural network to fault prediction and diagnosis reasoning; Finally after analyzing automobile exhaust components, engine vibration, engine abnormal sound parameters, inferred the appeared and impending fault of automobile then made the tips for users on the screen.
- The results show that the performance of system is well, the accuracy of diagnosis and prediction is 95% in different conditions of experiment and debugging.

- A dynamic neural network is developed to detect soft failures of sensors and actuators in automobile engines. The network, currently implemented offline in software, can process multi-dimensional input data in real time.
- The network is trained to predict one of the variables using others. It learns to use redundant information in the variables such as higher order statistics and temporal relations. The difference between the prediction and the measurement is used to distinguish a normal engine from a faulty one.

Chapter 3

System Requirement Specification

3.1 Functional Requirements:

- EGR sensor: - An external device Sensors pass meticulous quality control to assure accurate voltage output.
- Temperature sensor : - A temperature sensor is a device used to measure temperature. This can be air temperature, liquid temperature or the temperature of solid matter. These features have to be extracted to find the specifications of each
- unique characteristic.
- Pressure sensor : - A pressure sensor is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area.
- Creation of database and connect it to requirements dataset to retrieve data.
- Data extraction: - Data is extracted through fault table through various sensors or using microphone to record noise.
- Noise coversion using Librosa :- using this library the noise is converted to heatmaps which is used to train Neural network.
- CNN : - convolutional neural network (CNN, or ConvNet) is a class of artificial neural network, most commonly applied to analyze visual imagery.

3.2 Non functional requirements:

- Usability: The system Should be user-friendly
- Reliability: The system should be Reliable
- Performance: The system Should not take excess time in detectingthe fingerprint
- Supportability: The system should be easily updatable forfuture enhancement
- Collection of dataset:- Database should contain one copy of each person one being fake and the other being a real fingerprint

3.3 Hardware and software requirements:

Hardware Requirements

The Hardware requirements are very minimal and the program can be run on most of the machines.

- **Processor:** Intel Core i3-7020U CPU @ 2.30GHz or above.
- **RAM:** 4.00 GB or more.
- **System type:** 32-bit or 64-bit operating system.
- **Storage:** 2GB or more.
- Active Internet Connection.

Software Requirements:

a) **Operating System:** Windows, MacOS or Linux.
b) **Web Browser:** Google Chrome, Internet Explorer, Mozilla Firefox
c) Language used: Python
d) **Framework :** Flask

Chapter 4

System Design

This document is intended to describe the design of the system model at an abstract level. The purpose of this design document is to identify different modules involved and how they interact with each other to achieve the system goals. The document also contains details on the system architecture, user interface and system performance. The system specifications are detailed in a non-technical way so that it can be easily understood by end users.

4.1 Design Overview

General Constraints:

- Regulatory policies
- The availability of database for testing
- Hardware limitations like processor speed

Dependencies:

- The system depends on Apache server uptime.

The system requires the browser to support the application implementation.

Operating Environment

- Hardware platform: Desktop/Laptop systems with internet connectivity
- Operating system: Windows 7 and above
- Software components: XAMPP Server

PHP as a scripting language

- Python as a programming language
- HTML, CSS for frontend development
- SQL for database operations

Communication Interfaces :

- Web Browser: Chrome 28, Firefox 18 or higher version.

a. Local intranet and internet protocols like TCP/IP

b. Supports all HTTP and HTTPS services.

c. Apache XAMPP uses default port 80

4.2 System Architecture

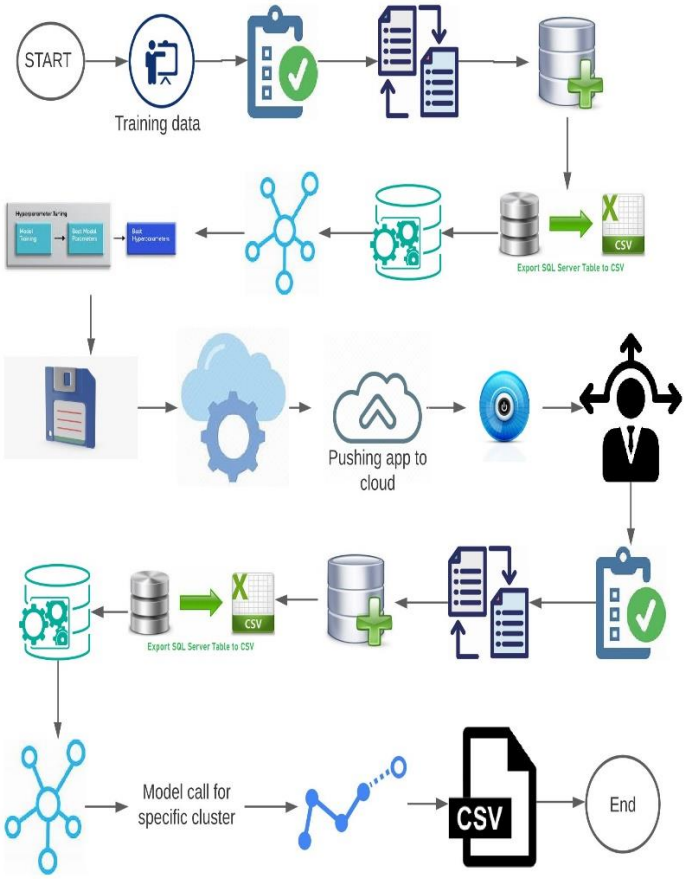

FIG 2:System Architecture

Block Diagram :

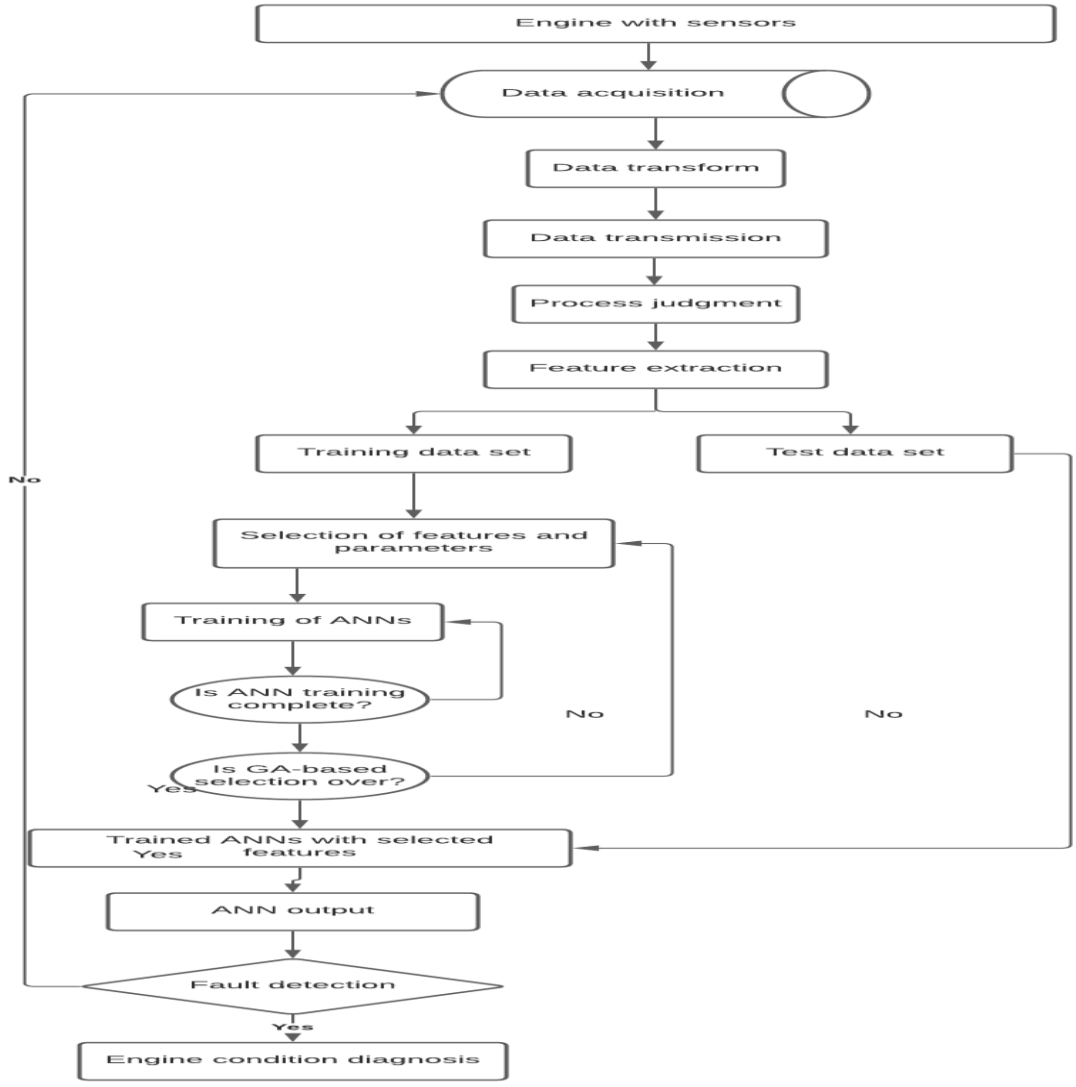

FIG 3:Block Diagram

4.3 Modules :

- Data acquisition is done through two ways.
    - The fault table containing various information about the engine condition is collected. Few elements that are used are temperature, pressure, humidity etc.
    - We have also collected noise sample of various engines which is used to train the model.
- Data preprocessing of fault data starts with handling of missing values, removing duplicate values in the data and feature scaling techniques.

  - Steps involved in data preprocessing are Data Cleaning, Data Transformation, Data Reduction.

- Data Cleaning of noise data is done by splitting into 3 categories. Good, bad and other. We have used Librosa a python library to work on noise data.
  - Noisy data is a meaning less data that is generated due to faulty data collection, data entry errors etc. It is handled by techniques such as Binnig method, regression, and clustering.
  - Clustering: This approach group similar data into clusters. The outliers fall outside the cluster.
- Folder structure has been created to define the flow of application.

Chapter 5
Software/tools/special libraries/Framework

1.Mongo db :

MongoDB is a cross-platform and open-source document-oriented database,
a kind of NoSQL database. As a NoSQL database, MongoDB shuns the relational database's table-based structure to adapt JSON-like documents that have dynamic schemas which it calls BSON.This makes data integration for certain types of applications faster and easier. MongoDB is built for scalability, high availability and performance from a single server deployment to large and complex multi-site infrastructures.

Features:

*Indexing - any field in the BSON document can be indexed.

*Replication - provides high availability via replica sets which consists of two or
more copies of the original data

Advantages:

*Due to the structuring (BSON format - key value pair)
way of the data in MongoDB, no complex joins are needed.

*Very easy to scale.

2-Django :

Django is a high-level Python web framework that encourages rapid development and clean, pragmatic design. Built by experienced developers, it takes care of much of the hassle of web development,
so you can focus on writing your app without needing to reinvent the wheel. It's free and open source

Features:

*Django is a framework that takes less time to build web applications. While working with Django, you don't have to start from scratch. You only need the basic knowledge of the backend because most of the work Django handles itself.

*SEO Optimized - You might be thinking, what is SEO? SEO stands for "search engine optimization". It is about making small modifications to the parts of the website and adding it to the search engine such that it appears to be at the top.

Advantages -

*Security

*Python Web-framework

3-Tensorflow:

TensorFlow is an end-to-end open source platform for machine learning. It has a comprehensive, flexible ecosystem of tools, libraries, and community resources that lets researchers push the state-of-the-art in ML, and gives developers the ability to easily build and deploy ML-powered applications.

Features:

*It is an open-source library that allows rapid and easier calculations in machine learning.
It eases the switching of algorithms from one tool to another TensorFlow tool.
*It allows you to reflect each node, i.e., operation individually concerning its evaluation.
Tensor Board works with the graph to visualize its working using its dashboard.
It provides computational graphing methods that support an easy to execute paradigm.
Advantages:
*TensorFlow provides a better way of visualizing data with its graphical approach.
It also allows easy debugging of nodes with the help of TensorBoard. This reduces the effort of visiting the whole code and effectively resolves the neural network.
*It is compatible with many languages such as C++, JavaScript, Python, C#, Ruby, and Swift. This allows a user to work in an environment they are comfortable in.

4- Librosa:

Librosa is a python package for music and audio analysis. It provides the building blocks necessary to create music information retrieval systems. At a high level, librosa providesimplementations of a variety of common functions used throughout the field of music information retrieval.
Advantages:
*ease of implementation,
*ease of use,
*ease of interoperability with other libraries, and.
*syntactic similarity to previous MATLAB-based implementations, as well as theoretical

5 – Numpy:

NumPy is a library for the Python programming language, adding support for large, multi-dimensional arrays and matrices, along with a large collection of high-level mathematical functions to operate on these arrays.

Features

*It contains a multidimensional container for generic data

*Additional linear algebra, Fourier transform, and random number capabilities

*It consists of broadcasting functions

Advantges

*consumes less memory.

*fast as compared to the python List.

*convenient to use.

6-Pandas:

pandas is a software library written for the Python programming language for data manipulation and analysis. In particular, it offers data structures and operations for manipulating numerical tables and time series. pandas is a fast, powerful, flexible and easy to use open source data analysis and manipulation tool,built on top of the Python programming language.

Features:

*Fast and efficient DataFrame object with default and customized indexing.

*Tools for loading data into in-memory data objects from different file formats.

*Data alignment and integrated handling of missing data.

*Reshaping and pivoting of date sets.

Advantages:

*Pandas provide extremely streamlined forms of data representation.

This helps to analyze and understand data better

*Less writing and more work done

*Pandas provide a huge feature set to apply on the data you have so that you can customize, edit and pivot it according to your own will

and desire. This helps to bring the most out of your data.

Chapter 6

Conclusion

This provides and overview of how AI and ML models are used to detect soft failures of sensors and actuators in automobile engines. In this analysis we have taken two distinct methods to consideration that is Radial Basis function networks, wavelet neural networks. The workflow is also applicable to other engines as well, not only the truck engine. With the help of data integration platform, we can easiy acquire patient data which can be used in different models designed for multiple tasks. In this study a complete statistical framework for constructing and using WNs in various applications was presented. Although a vast literature about WNs exists, to our knowledge this is the first study that presents a step by step guide for model identification for WNs. More precisely, the following subjects were examined: the structure of a WN, training methods, initialization algorithms, model selection methods, variable significance and variable selection methods and finally methods to construct confidence and prediction intervals. Finally the partial derivatives with respect to the weights of the network, to the dilation and translation parameters as well as the derivative with respect to each input variable are presented. The MVEM developed by Hendricks and et al (2000) is used for simulations during the research period after small modification. Expansion work has been done to the existing MVEM simulation by including air fuel ratio sensor time delay, temperature sensor dynamics etc. Three sensor faults (intake manifold pressure, temperature and speed), one component fault (leakage in the intake manifold) and one actuator fault (injected fuel mass flow) have been simulated when the simulation model is subjected to disturbances and noise. An independent RBF neural network model was used to model engine dynamics and the training algorithms are reviewed and derived. By using ρ – Nearest Neighbours method and K-means algorithm the width in hidden layer nodes of the RBF neural network σ and the centres c are calculated for RBFNN. The recursive least square algorithm was applied for training the weights w of the RBFNN. Fault detection for engine studied in this paper is using neural network modelling method, this method can detect dynamic faults, and this is because the modelling is for dynamic system, so can detect the faults in dynamic condition and for other simulated three types of fault (sensor, actuator and component). From The simulation results it can be seen that the independent RBF neural networks were able to detect sensor, actuator and component faults clearly

Chapter 7

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