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Machine Learning Based Vehicle Health Monitoring System

N.Hemavathi[1] M.Meenalochani[2],R.Janani[3], Sunkavalli Sai Chandana[3], Amrita sona P.R[3]

[1]Assistant Professor, School of Electrical and Electronics Engineering, SASTRA Deemed to be University, Thanjavur, Tamilnadu, India
[2)] Assistant Professor, Department of Electrical and Electronics Engineering, Kings College of Engineering, Pudukkottai, Tamilnadu, India
[3]UG Student, School of Electrical and Electronics Engineering, SASTRA Deemed to be University, Thanjavur, Tamilnadu, India

nuhemasen@gmail.com

Abstract. This paper presents the design and implementation of a machine learning based prediction system for monitoring and maintenance of vehicle's health. The proposal aims to examine the normal operation of the vehicle and if any abnormal condition or variation from regular routine is observed, the user will be informed. These predictions can reduce the rate of road accidents that occur due to defects in the parts of the vehicle. Such deviation can be predicted by implementing Machine learning using software like Matlab, Python etc. Machine learning algorithms such as Fine tree, linear regression and linear SVM are chosen and the prediction is carried out using these algorithms. Results obtained using these algorithms are compared. It is found that Linear SVM is capable of obtaining better results due to its precise prediction within less training time.
Keywords: Vehicle health, Prediction, Machine learning.

INTRODUCTION

Now-a-days, one of the issues that need to be focused is road accidents due to poor vehicle maintenance. A computing system to predict vehicle maintenance needs can be designed. The system may be internal or external (mobile device) to the vehicle. Prediction is done using machine learning model which is implemented in the computing system. Maintenance can be of three types which include corrective, preventive and predictive maintenance [1]. Corrective maintenance is carried out when a fault is detected. It is suggested for faults that occur rarely and also the repair cost is high. Preventive maintenance is used commonly in the automotive industry, in which the vehicle components are replaced periodically.

On the other hand, predictive maintenance aims to predict the condition of the vehicle and indicates which part will probable to fail and when it will occur [2].Sensor data may be noise data from different parts within the vehicle, data from maintenance records etc. and/or other suitable vehicle data. Machine Learning is used in order to predict these changes beforehand. The data set developed from the changes in parts like steering, tyres

and headlights. This is given as input to different algorithms.The outputs and the graphs obtained are recorded. These graphs are compared to find the best method. The algorithm that gives optimal output is used for prediction in the proposed work. The algorithm is later used to produce graph between durability of the vehicle versus time. This is used in predicting the durability of the vehicle. The prediction can be made even more accurate by training the algorithm with the data set that contains the data of the repaired vehicles.

Machine Learning for predicting vehicle maintenance can be extended by using internet. The cloud database can be connected and used for identifying nearest repair shops and estimated cost for the work to be done. This comes handy in case of sudden breakdowns and can also be used in sending alert texts to the owner during unexpected breakdowns. Also to notify the next traffic signals and toll plazas. The load spectrum data along with workshop data is used in training the *random forest* algorithm in predicting the RUL in lead-acid batteries used in heavy duty trucks. The algorithms *random forest* and *k-Nearest Neighbours* are used in predicting the compressor faults in trucks. The rule learning methods can be used by engineers to identify the stress patterns that are dangerous for certain parts of the automobiles.

RELATED WORK

A vehicular pollution monitoring system using Internet of Things (IoT) was proposed. The system was able to identify the pollution caused by the vehicles and can assess the proportion of pollutants in the atmosphere. Status of the atmospheric quality can be indicated through internet using IoT to the concerned department if required [3]. Fault prediction of fuel system, ignition system, exhaust system, and cooling system in a vehicle is presented [4]. Data from the sensors are collected under normal conditions as well as when there is a failure. The data is then forwarded to the central system which performs prediction based on Decision Tree, Support Vector Machine, Nearest Neighbor, and Random Forest. Comparison of the classifiers in terms of efficiency is performed.

Consensus self-organized models for fault detection (COSMO) in vehicles was presented [5].Sensor data from heavy trucks and city bus were used in experiments .The technique was proposed for general purpose fault detection and diagnostics which further improves the lifetime of the vehicle. An on-board vehicle diagnostic system based on android phone application which monitors the vehicle’s health was proposed [6].Further, the driver was signaled when there is any fault occurrence. A technique for prediction of vehicle’s compressor fault was suggested [7]. Here, the logged on-board data was utilized for prediction of fault. An Approach predicting the repair in air compressor in buses and trucks was proposed [8]. Random Forest was applied for fault prediction and which was demonstrated on Volvo trucks.

A model-based fault diagnosis and prognosis method for a vehicle steering system was presented [9].Different faults such as abrupt fault, incipient fault, and intermittent fault, are detected based on the Augmented Global Analytical Redundancy Relations (AGARRs) idea. fault detection is carried out through a novel adaptive hybrid differential evolution (AHDE) algorithm. Smart Wireless Internal Combustion Engine for utilizing as a mini-vehicle computer system (Mini-VCS) was presented [10]. The system comprises hardware components, software with interface components designed for the Army. The main purpose of SWICE is to improve Condition-Based Maintenance Plus (CBM+) for

improving the security with diagnostics, logging of data, prognostics with integration of sensors.

Signal processing techniques required to facilitate an automated and distributed road-surface condition- monitoring system was suggested [11]. Data from sensors such as accelerometers mounted on vehicles are obtained monitoring the condition of roads. A novel vehicle detection method utilizing an AND–OR graph (AOG) for providing solution to the occlusion trouble in case of traffic congestion was proposed [12]. The approach is based on three steps i.e. framing of AOG which indicates vehicle, object training of different parameters in the AOG and lastly detection of vehicles based on bottom-up inference.

Detection of anomalies and faults using real-time diagnosis for autonomous spacecraft was discussed [13]. In order to satisfy the necessity of the fault diagnosis of an autonomous spacecraft, a novel technique which is based on transition system model is proposed. The technique comprises an off-line stage where majority of the computational mechanisms are performed and the on-line stage where the fault candidate sets are generated with the minimum matching space. Classification of faults occurring in a micro-grid precisely based on Deep Neural Network (NN) and Convolution Neural Network (CNN) was suggested [14]. The technique learns from data by extracting the characteristics through identification of anomalies in the output voltage of converter and inverter, DC-link capacitor voltage, amplitude, phase angle and harmonic components. Fault classification by above technique portraits improved performance over fault classification methods which are based on conventional artificial intelligence.

A data-driven diagnostics technique to detect faults in automotives based on deep neural networks was proposed [15]. The approach consists of two steps. Initially, a novel diagnostics method for learning the data-driven algorithms was presented. Next, a novel fault detection model was proposed which combines convolutional and long short-term memory neural networks. Machine Learning for predicting vehicle maintenance can be extended by using internet. The cloud database can be connected and used for identifying nearest repair shops and estimated cost for the work to be done. This comes handy in case of sudden breakdowns. It can also be used in sending alert texts to the owner during unexpected breakdowns. Also, the next traffic signals and toll plazas can be notified. The load spectrum data along with workshop data is used in training the *random forest* algorithm in predicting the RUL in lead-acid batteries used in heavy duty trucks. The algorithms *random forest* and *k-Nearest Neighbours* are used in predicting the compressor faults in trucks. The rule learning methods can be used by engineers to the identify the stress patterns that are dangerous for certain parts of the Automobiles.

PROPOSED SYSTEM

A novel vehicle health monitoring system based on machine learning is proposed. If any vehicle part is found to behave abnormally, indication is provided. Prediction of vehicle health is carried out using machine learning techniques. Machine learning algorithms such as Fine Tree, Linear Regression, and Linear SVM are used for predicting the health of vehicle. Machine learning is a branch of artificial intelligence. It is a study to build algorithms that keep on improving through experience automatically. These algorithms build a mathematical model based on sample data to make predictions

automatically without external programming. The sample data is called training data. The behaviour is stored and many such algorithms are built. Later when a data is fed it compares to the existing ones and trains the given data through an appropriate algorithm. Machine learning is mostly related to computational statistics which does prediction with the help of computers. There are three main approaches in it based on the signal or feedback given to it. They are *supervised learning, unsupervised learning* and *reinforcement learning.* The first kind is used when input with examples is given to produce desired output. The second kind is implemented when no prior examples or pattern is fed along with input and left to itself. The last type is performed in cases when computer interacts with dynamic environment.

Tool Utilized - Matlab

There are many tools for implementing machine learning. The tool used here is Matlab. Matlab is relatively easy and it can be used in understanding the theory and math involved. The point-and-click apps present train and compare the models. In optimizing the performance of a model feature selection and hyper parameter tuning comes handy. For embedded and high performance applications C, C++ codes can be generated automatically. Algorithms such as *classification, regression, clustering* is available for supervised and unsupervised learning. It has faster execution too. All the algorithms used here fall under supervised learning. Matlab code to alert when the threshold values are crossed has also been developed and is shown in Figure 1. The data sheet required to train the algorithms has been generated and shown in Figure 2.

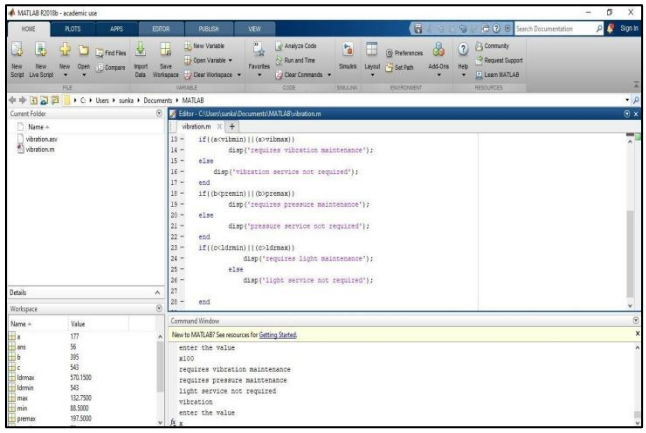

FIGURE. 1. Matlab code.

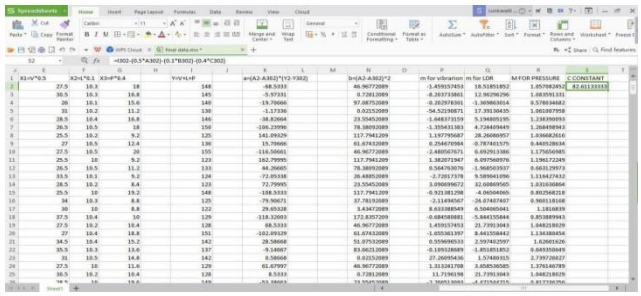

FIGURE. 2. Data sheet generated for training.

Algorithms

There are various methods for prediction in Matlab. They are *fine tree, linear regression* and *linear SVM.* A data set consisting of vehicle parameters is generated. The same set of data is given to the all three methods. The outputs obtained in graph and standard terms are compared amid each other. The method that provides the output with the optimized output is chosen to implement in prediction for the proposed work.

Fine Tree Algorithm

This method covers the major part of machine learning as it is used in both classification and regression. As the name implies it has tree like structure but inverted. The main condition is written on the top and the possibilities are split up. These possibilities are again split up and continued till the proper outcome is encountered. *Pruning* can be introduced to increase the efficiency. This is used to eliminate the nodes with least possibility.

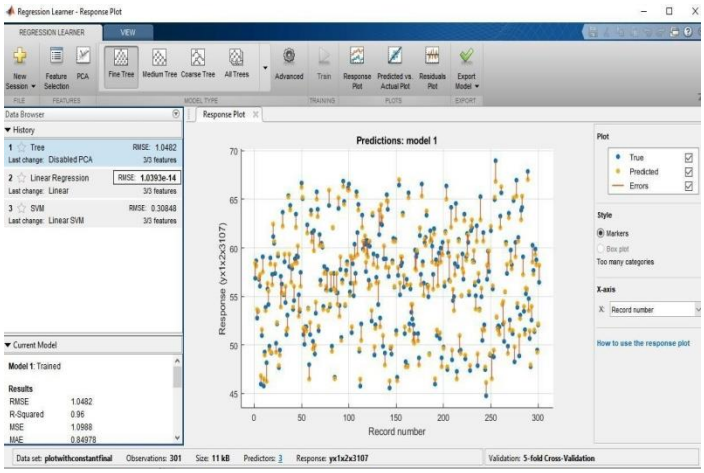

FIGURE. 3. Graph obtained from fine tree.

Linear Regression Algorithm

This algorithm relates the dependent and the independent variables through a linear equation. The simplest form of a linear regression is given below.

$$y = (a*x) + b \quad (1)$$

The algorithm predicts the value of dependent variable y basing upon the value of independent variable x. Multiple linear regressions can be used when two or more independent variables are present. In case of multiple linear regression the relationship is fitted as follows.

$$y = (a1*x1 + a2*x2 + a3*x3) + b \quad (2)$$

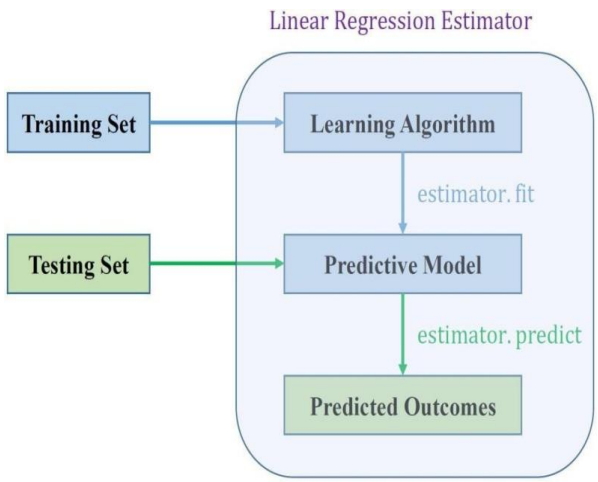

FIGURE. 4.Process involved in linear regression.

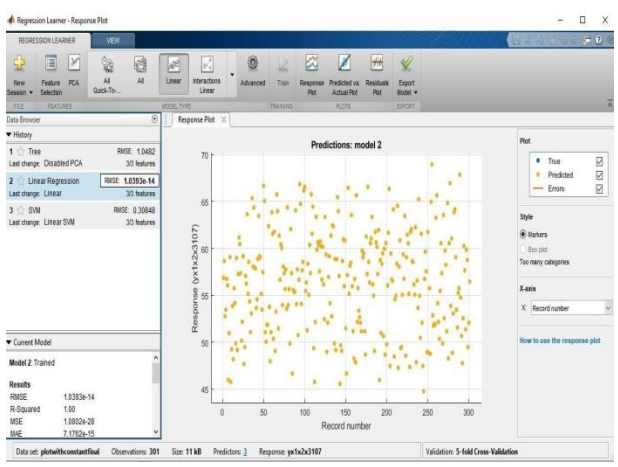

FIGURE. 5. Graph obtained from linear regression.

Linear SVM Algorithm

Linear Support Vector Machine comes under supervised learning. It is used for predicting both linear and non-linear problems. This algorithm plots every data in n dimensional space (n - number of features). These are separated using hyper-planes. The plane which has highest margin and involves miscalculation is the best for prediction. In

case of non- linear classifications *kernel trick* can be used to transform data as per requirement.

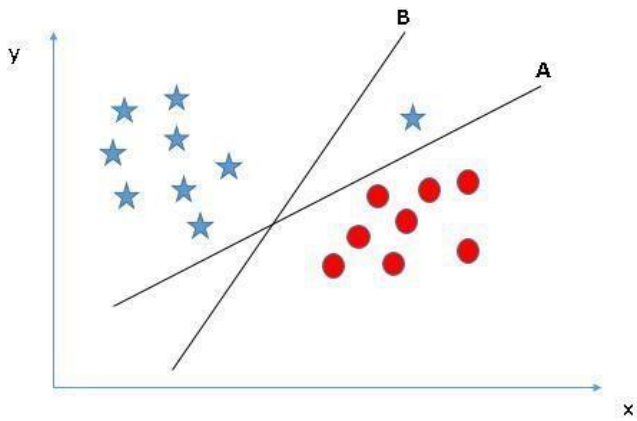

FIGURE. 6. Example for linear SVM.

In the above figure, hyper-lane A is selected even though B has high margin because A includes all the items of a class. The data on given to this algorithm has predicted as shown in the figure.

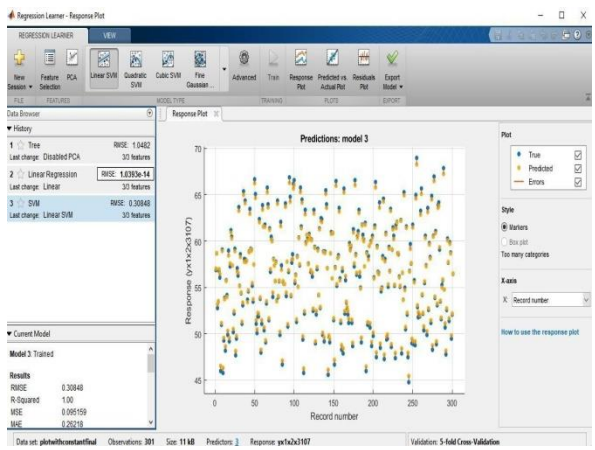

FIGURE. 7. Graph obtained from linear SVM.

Algorithm Selection

Each algorithm has its own advantages and disadvantages. In this advancing world, time is the most precious of all. So the algorithm with least training speed is preferred. The outputs obtained from the above algorithms are compared.

Table 1. Comparison of the outputs

Type	Fine Tree	Linear Regression	Linear SVM
Prediction Speed	-6400 obs/sec	-6300 obs/sec	~11000 obs/sec
Training Time	5.877 sec	3.8064 sec	1.555 sec

From the above table it can be seen that linear SVM has the least training speed and also highest prediction speed. Hence Linear SVM is chosen as the optimal algorithm for the proposed work. The interdependence of the subsystems is calculated and the data set is fed into the various classifiers in the machine learning technique. The prediction done using various classifiers includes fine tree, linear regression and linear SVM. Among the classifiers linear SVM is considered as the best method for the prediction since it has good prediction time and very less training time. By using linear SVM prediction a graph is plotted for durability of the vehicle. From the graph the health of the vehicle in a particular time period can be calculated and the vehicle can be taken care according to the data in it.

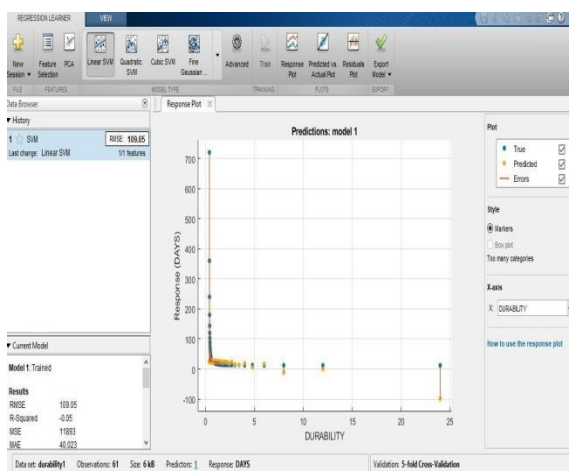

FIGURE. 8. Durability plot of the vehicle using linear SVM.

CONCLUSION

One of the significant factors that influence road accidents is poor maintenance of vehicles. The data of the vehicle subsystems are taken and is processed through the machine learning classifiers which gives the durability of the vehicle. The data set from steering, vibration and headlight are given to different classifiers in machine learning. Among them Linear Support Vector Machine (SVM) is considered as the best algorithm. This is chosen, as it exhibited faster prediction with most accuracy. The algorithm is then used to produce the graph for durability of the vehicle versus time. The result obtained is used in calculating the durability, then in predicting the time at which the vehicle requires maintenance. Thus it helps in reaching the objective set for the proposed work.

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