RESEARCH SURVEY ON MACHINE LEARNING USED IN VEHICLE PROGNOSTICS

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ABSTRACT

Due to increasing safety needs, automotive industry introduces a number of safety vehicle components in the vehicle like Antilock brake system, Airbag. But vehicle diagnostic has limitation because it only diagnoses after vehicle components get damaged. To handle the large data generation from the complex vehicle electronics system, the need for secured operations are on high priority. This can be now achievable with different machine learning algorithms and advanced data handling capability with the concepts like big data. In Automobile area vehicle prognostic is an important term and in high demand. Machine learning is an emerging field and rapidly popular in engineering applications. This review is mainly focused on the different machine learning applications for vehicle prognostic used in the automobile sector. This review referred papers from 2004 to 2019. Vehicle prognostic is not effectively used earlier but in recent years due to evolving machine learning area it becomes popular in many engineering applications. Different types of application are covered like Early fault detection, Predictive maintenance, Car Damage classification, RUL. The review can also describe how the current application uses machine learning algorithms with available dataset generated from vehicle components. This paper reviewed different machine learning techniques used in vehicle prognostic system.

Keywords-- Artificial Intelligence (AI), Deep Learning, Fault detection, Machine learning, Vehicle prognostics

I. INTRODUCTION

Increasing Complexity of electronics in the vehicle diagnostics is getting important day by day. Due to high demand of safety needs, automotive industry introduces a number of safety vehicle components in the vehicle like Antilock brake system, Airbag. But vehicle diagnostic has limitation because it only diagnoses after vehicle components get damaged. Vehicle safety is the top most priority for the automobile world. Due to a large number of accidents and failures in vehicles causes severe damage to human beings.

World Health Organization(WHO) declares that 80% of cars which are sold in the world are not compliant with safety standards. Every 8 minutes, 1.5 times more likely than vehicle occupants loses life in an automobile crashes in the United States. To strengthen the vehicle safety automobile industry introduces various safety standards ISO WHO.[45]

Additional with the help of advanced mechatronics system, vehicles designs are introduced with safety vehicle components like Airbags, Anti break system, CTIS (Central Tier Inflation System), ESC (Electronic Stability Control), seat belts, Day time running Lamp. Many organizations are now focused on vehicle safety. To address this vehicle prognostic serves a bigger role and need to be addressed effectively. Different traditional techniques are used earlier to achieve vehicle prognostic like expert system, Rule-based system, Case-based system, Model-based reasoning in the research area but found not effective as the complexity of vehicle components is increased day by day. In recent years the machine learning field offers great flexibility in dealing with large data generated from vehicle sensors. In association with machine learning, big data and IOT also helps in achieving the different task for engineering applications.

The purpose of this paper is to review various engineering applications in which various machine learning algorithms are used mainly in predictive maintenance, Remaining useful life, fault detection, etc. This review covers papers published from 2004 to 2019 where vehicle prognostics and machine learning are the centralized part. The search keywords used for this review is “deep learning/machine learning for vehicle diagnostics and prognostics”. To more focused the search is centralized for different machine learning and deep
learning algorithms used in the prognostic applications. This paper is focused on how different areas of application in which machine learning and deep learning techniques are used effectively. Based on the review these area is divided into below parts
- RUL Methodology
- PHM (Predictive health management)
- Fault Diagnosis and fault prediction
- Predictive analysis
- Monitoring and Detection Systems

II. REMAINING USEFUL LIFE
Remaining useful life is an important part of the prognostic system by which one can estimate the remaining system life and predict earlier diagnosis. There are various applications and techniques are involved in RUL prediction. Advancements in the RUL techniques with the help of machine learning is more prominent and accurate than other RUL techniques. RUL is very important for safety, stability and a long life time of electric vehicles. RUL of lithium-ion battery based on data-driven techniques is proposed by Lifelong. In this paper[2], RUL prediction methods Data-driven methodologies for lithium-ion batteries were reviewed. RUL prognostics methodologies based on data-driven are divided into AI, filtering and stochastic process. The comparison of these three is detailed out in this paper[2]. In the AI part (also refer Machine learning) Methods such as the AutoRegressive (AR) model, neural network, support vector machine (SVM), and relevance vector machine (RVM) are used.[2]. In paper [3] authors investigated a computational approach for RUL predictions for IGBT modules. data-driven prognostics approaches based on Neural Network (NN) and Adaptive Neuro-Fuzzy Inference System (ANFIS) models are developed and used to predict the degradation of an IGBT Device[3]. In paper [4] authors investigate deep-learning-enabled battery RUL prediction. an LSTM recurrent neural network has been used to construct a data-driven battery RUL predictor. A fusion RUL prediction approach based on Deep Belief Network (DBN) and Relevance Vector Machine (RVM) is proposed in Paper [5]. DBN is responsible for extracting features from the capacity degradation of lithium-ion batteries, and RVM takes the extracted features as input to provide RUL prediction. In this authors contributed fusion concepts to gain more accuracy with two different machine learning techniques. also, they state about future improvements in the accuracy also with further deep learning techniques. In paper [6] authors proposed a method where the system can process inaccurate fault signals with different kinds of noise in the actual working environment, and it can be conducted in the long term. This study only utilizes the information of the fault signal, proposed RUL prognostics method has good generalization. Paper [1] describes the RUL of battery in different flight conditions is tackled using machine learning techniques. Thus with the help of different machine learning techniques, RUL is estimated with the above applications.

III. PHM (PREDICTIVE HEALTH MANAGEMENT)
A Predictive diagnosis is also called prognosis were as health management is the capability to make appropriate decisions about maintenance based on the diagnostic and prognostic information.[7]. This concept is in the industry from a long time and this review referred the paper published in the year 2004[7] in which all details of diagnostic, prognostic and health management describes along with air craft health management. From this, the reader can sense that the concepts are presents and evolve from a long time but recently the need for this is on high demand. Reason for this is to big data handling capability and algorithms which can process this big data with the help of machine learning, deep learning techniques.
Michael G. Pecht explains details and deep understanding of the PHM system in which he describes start from prognostic basics to PHM sensors and their structure. It also describes methods, data-driven approaches for PHM, Economics of PHM.[8]. Sreerupa Das, Richard Hall, Stefan Herzog, Gregory Harrison, Michael Bodkin explains the essential steps involved in building an effective PHM system. Paper describes time and frequency domain features that can be extracted from raw sensor data. These features or condition indicators can help summarize the information in raw data and extract critical clues that reflect the health of the machinery[9]
With reference to Figure 1. The first step in the PHM system is to collect sensor Data, the next step is Data characterization. After this feature extraction from raw Data needs to perform, a further step is towards to building the model. And the final step to run the PHM system.

Paper [10] introduces the concepts of PHM and discusses the opportunities provided by the IOT.

Figure 2 explains, PHM system has four main concepts and functional parts as Sensing, diagnostics, and predictive diagnostic also referred to as prognostics and last is management to manage the maintenance of the system.

This paper[10] explains the detailed technology map for PHM management through advance concepts like IOT, Cloud. This paper also explains the PHM in details from basics to advanced implementation information. This paper presented many examples of companies successfully implementing IOT-based PHM, a major impediment is still the human capital to develop, validate, and maintain the models necessary for prognostics. The key conclusion from this paper is IoT-based PHM is expected to have a significant influence on the implementation of reliability assessment, prediction, and risk mitigation, and create new business opportunities. In Paper [11] explains the overall on-board preventive maintenance system. A schematic has been developed for malfunction prediction and root cause analysis by utilizing both machine learning and deep learning methods. Since on-board data is usually collected real-time, it contains much more information on the time scale. Because of this, the authors developed a model by combining Gaussian Mixture Models and k Nearest Neighbors (kNN). Convolutional Neural Network has been used for processing time-series data.

In paper [12] explains Probabilistic Prognostics and Health Management and details out the probability management system. Nam-Ho Kim • Dawn An • Joo-Ho-Choi is written a thorough article [13] on PHM for engineering. They also describe application based on Matlab tool. It also explains about Neural network and their effective techniques. Also discusses issues in data-driven prognostics. This article briefs about few prognostic applications such as situ monitoring and prediction of joint wear.

Paper [14] Explains an approach is presented for fault prediction of four main subsystems of vehicle, fuel system, ignition system, exhaust system, and cooling system. The sensor data is collected when a vehicle is on the move, both in faulty condition (when any failure in a specific system has occurred) and in normal condition. The data is transmitted to the server which analyzes the data. Interesting patterns are learned using four classifiers, Decision Tree, Support Vector Machine, Nearest Neighbor, and Random Forest. Paper [16] explains proposed Bayesian deep-learning-based health prognostics with uncertainty quantification. the Bayesian multi-scale CNN based method and the Bayesian bi-directional LSTM based method were developed

IV. PREDICTIVE ANALYSIS

Prediction of system or signal is an important parameter in the vehicle prognostics. Different signals /parameters can be predicted based on a
different methodology. Machine learning and deep learning plays an important role to achieve this purpose, they mainly help in contributing to handle large data and extract the feature which helps to predict the specific occurrence. Many machine learning techniques are being used to perform this analysis. This paper reviewed nine papers which deals mainly with predictive analysis. Jingjing Xie presents a deep neural network is proposed for accurately forecasting PM2.5 pollution concentration based on manifold learning. deep neural network based on manifold learning (M-DNN) is built for the PM2.5 concentration forecasting.[25]

Many existing approaches fail at providing favorable results due to shallow architecture in a prediction model that can not learn multiparameter’s features insufficiently. To address this issue paper [24] proposed a deep neural network (DNN), consisting of a deep belief network (DBN) in the bottom and a regression layer on the top. a deep neural network is introduced to predict the manufacturing quality.

Phattara Khumprom and Nita Yodo present paper [23] the preliminary development of the data-driven prognostic, using a Deep Neural Networks (DNN) approach to predict the SoH and the RUL of the lithium-ion battery [23]. Chunsheng Yanga, Weiming Shenb, Qiangqiang Chenb, Burak Gunayc explains about practical approach for HVAC prognostics in paper [26].

In Paper [21] Chen-Yang Cheng develops two models to predict freeway travel time through big data analysis of data collected from the TaiwanHighway Electronic TollCollection Systems (ETC). This paper implements a random forests algorithm on Apache Hadoop for travel time prediction and prognosis from Taiwan electronic toll collection (ETC) data. Paper [20] proposed to develop machine learning based models for TTF estimation by using the techniques from machine learning and data mining .MAITANE BERECIBAR written article on Accurate predictions of lithium-ion battery life. In Paper [18] authors design a multi-class classification algorithm based on deep learning method the general process of satellite fault diagnosis; the main features of the original data extraction by using the principal component analysis. And the deep learning technology is used for spacecraft pattern recognition Somnath Pradhan, Joydeb Roychaudhury explains SOC or State-of-Charge estimation is one of the well-known methods to predict the runtime of a battery [17]

V. FAULT DIAGNOSIS AND PREDICTION

The Vehicle fault generation is an important key element which can lead to defining vehicle health. The vehicle can generate different faults based on the components. These faults can help in vehicle prognostics. Vehicle faults consider different parameters of signals. Monitoring of these parameters or study of history data of parameters can help to implement prognostics for the system. There are various papers published which describes how using machine learning techniques fault prediction can be possible. This paper refers to the two most recently paper on this topic.

Yushan Sun proposes a new method for the fault diagnosis of AUV's thruster, based on Deep Neural Network(DNN) and Denoising Autoencoder(DAE). a fault diagnosis method for intelligent underwater robot propeller based on DNN deep neural network is proposed. The method can intelligently extract the characteristics of the thrust level of the thruster from the residual signal of the theoretical state and the measured state of the AUV, and perform a higher precision distinction [29]. Cheng Zhang, Liqing Xu, Xingwang Li, Huiyun Wang explains deep neural network can be modeled for fault classification[36]

VI. MONITORING AND DETECTION SYSTEMS

In this section, continuous monitoring for the prognostic system is applied though different machine learning techniques. Any detection through continuous monitoring data is possible through machine learning algorithms. This monitoring helps to analyze the prediction and alarm system for any future malfunction of the system. This kind of systems helps in prognostics and widely used in the industry for many engineering applications which required safety and stability in a complex system. There are many applications and papers published based on this section. This paper referred to the recent two published paper. In Paper [38] authors proposed system can ensure safe driving by real-time monitoring of driving pattern. Prominent ML classifier algorithms like LR, SVM, MLP, and RF, to formulate a trained model for drowsiness detection are analyzed and compared. In Paper [37]
Bhaskar Saha, Kai Goebel proposes the combined Bayesian regression-estimation approach implemented as an RVM-PF framework has significant advantages over conventional methods of RUL estimation like Autoregressive Integrated Moving Average (ARIMA) and Extended Kalman Filter.

VII. CONCLUSION

This Paper reviews different papers published on vehicle prognostics using different machine learning techniques such as traditional machine learning techniques and deep learning techniques. Vehicle diagnostics, prognostics and its management have a crucial role in vehicle safety and stability. This paper reviewed different aspects of prognostics systems in which various authors contributed to their work. This paper also reviewed different machine learning techniques used for the various proposed applications. This paper reviews general insight for vehicle prognostics and its literature. This information helps to understand the current utilization of machine learning techniques in vehicle prognostics. This Paper mainly categorizes the prognostic implementation of different parts like PHM, fault detection, RUL, monitoring and detection, and predictive analysis. Future research may require a deep dive with more accurate machine learning based solutions.

REFERENCES


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[19] H jeep m. (n.d.). lithium-ion battery life.