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Predictive Diagnostic Approach for Vehicle Transmission Clutch Using Fuzzy Logic and Bayesian Algorithm

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Abstract

A clutch is an important part of the vehicle transmission system. It can be affected by the various reasons for vehicle operations such as heavy load, frequent use of clutch in traffic and abnormal gear selection. Due to this clutch failure can happen and lead to affect vehicle transmission operations. Thus, it is important to predict the clutch behavior and health status to intimate the vehicle user. Vehicle diagnostics can help to identify faults after the damage of the vehicle part but cannot predict in advance the failure mode is approaching. Vehicle prognostics can be the answer to this problem.

In our system, we used a machine-learning algorithm to predict clutch health. Here two approaches are used Bayesian and Fuzzy logic, which are easily used to achieve this prediction. In the Bayesian approach, we considered two parameters one is vehicle speed and the second is environment condition. We have trained the historic data and test it. The output is in the form of YES or NO. Further, in the fuzzy logic system, we considered transmission oil temperature which can give clutch life status.

Keywords – *Vehicle Prognostic, Machine Learning, Fuzzy logic*.

I. Introduction

Today the automotive world is full of electronic intelligence which makes it possible to aware of the vehicle condition through various sensors fitted in the vehicle. These sensors can act as the gateway to introduce vehicle data to the outer world through different vehicle interface. The various manufacturer has already built the vehicle diagnostics based on the data fetched from the vehicle. Onboard and off-board diagnostics are already used widely and are in high demand as one of the important parts of vehicle repairing and maintenance. In addition to diagnosis, prognostics become more popular these days. Prognostics are nothing but predictive diagnostics. Prediction can be done based on various classical techniques. Rule-based is one of the examples[ref].

We can use machine learning for the prognostics of the vehicle components. A clutch is an important part of the vehicle which is responsible to operate

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the transmission in a smoother way. A clutch is a direct interface to human operations into a vehicle. If the clutch gets faulty, the vehicle is no more in operating condition hence it is very important to know the clutch health to the human cooperates. There are certain components in the vehicle which need to take care and monitor from the start of its life. Clutch life is one of them for which we need to monitor and predict its health. This can be possible by monitoring certain parameters with a machine learning algorithm and predict the result.

This Paper Is Followed With a Literature Review, System Design, System Methodology, Result Analysis And Conclusion in the next part of the paper.

II. Literature Review

Ikram remadeet.al.[1] presents the utility of deep learning in prognostics and also gives differences between different Deep learning techniques. R.Krishan et.al.[2] review use cases and applications for deploying Hadoop in the automotive industry. The relevance of Deep Neural Network (DNN) is studied in big data scenarios, especially for the prognostic application. In Guangquan Zhaoet.al. [3], explains deep learning methods which are used in fault diagnostics and prognostics. MominulAhsan et.al.[4] representsPrognostics and Health Monitoring (PHM) concept, current PHM approaches PHM applications. While AlexandruPrisacaru[5] summarizes recent studies in system-level PHM of an electronic system.

Hatem M. Elattar et.al.[6] gives the concept of prognostic and can be considered as the starting point for studying prognostic and health management. Paper [7] gives the study of layered architecture and the model of the Internet of Vehicles. This also Discuss the evolution from an intelligent vehicle grid to autonomous, internet-connected vehicles and vehicular clouds. Paper[9] says about The use of machine learning algorithms in systems while paper [10] gives information for Fault diagnosis of Heavy Duty machines for Automatic Transmission Clutches.

Similarly, Paper [8] introduces concepts of PHM and discusses opportunities provided by the IoT for vehicular network and vehicular clouds. Paper [14] presents a generic approach to fault diagnosis of heavy-duty machines that combines signal processing, statistics, machine learning, and case-based reasoning for on-board and o_-board analysis of clutch. Paper [11] gives Confidence interval prognostic results that are provided to predict the RUL of the clutch throughout its limited life in near-real-time. Paper [12] says about Machine learning methods for vehicle predictive maintenance using off-board and on-board data. Paper [13]says about Machine Learning Algorithm for Predicting Truck Compressor Failures Using Logged Vehicle Data.

III. System Design

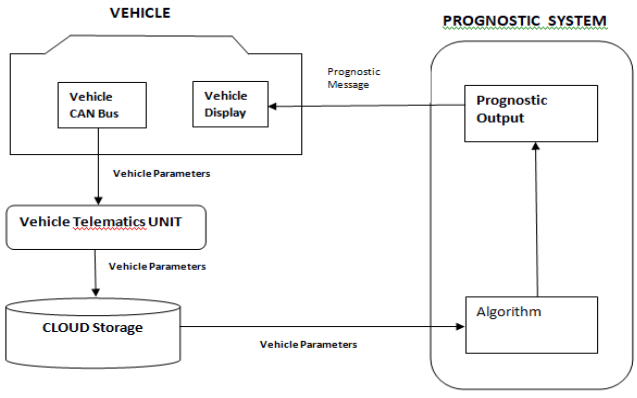

Fig1.Block diagram of the System

Figure 1. shows a block diagram of the proposed system. It has mainly three parts. First is cloud-based diagnostic data storage through the Vehicle Telematics Unit, the second is a smart process of data through the Bayesian Deep Learning Method and the third is Prognosis Display information Module.

Design a component to extract the vehicle telematics data and store this data on cloud storage. From various ECU locations, data can be collected

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into the cloud-based storage. This data can form big data. To identify, classify and validate big data, deep learning techniques are required.

IV. System Methodology Using Bayesian Algorithm and Fuzzy Logic

Vehicle speed and environmental temperature can cause to change the transmission oil temp. These two signals we can get from the vehicle to compare it to the past data. This comparison can give the prediction of effect on the clutch with yes or no. Through this users can get guidance for operating the vehicle with respect to surrounding temperature and vehicle speed range to maintain clutch life. This can be achieved with the Bayesian algorithm. The Bayesian algorithm is applied to the base parameters which causes heat. The main parameter is the transmission oil temperature. If clutch oil rises to high or critical temperature then end-users immediately need to replace oil. So indirectly clutch oil predicts the life of the clutch. So, from the research point of view clutch oil is a major parameter.

Table 1. refer sample data set of the two parameters one vehicle speed and other is environmental temperature. Based on the historical data of these two we can have the output result that is whether it affects clutch or not. This trained data can be used for the training of the Bayesian algorithm. From this, we can get new output results for any new data.

TABLE I. VEHICLE SPEED AND ENVIRONMENTAL TEMPERATURE

Environmental Temperature	**Vehicle Speed**	**Clutch life affect**
45	80	Y
50	80	Y
35	80	N
30	80	N
25	80	N
40	80	Y
32	80	N
22	80	N
20	80	N
50	80	Y

Further transmission oil temperature can be applied as input to the fuzzy logic system which gives different status outputs saying clutch life is on high risk, critical and so on.

Hence the output of Bayesian can combine with the output fuzzy logic system. And from this, we can derive the status of the clutch.

Clutch life is based on clutch oil temperature. If Clutch oil temperature is between -50 to 60 degree then it is low temperature. If the clutch oil temperature is between 60 to 120 degree then it is medium temperature or normal temperature. If the clutch oil temperature is between 120 to 135 then it is high temperature. And at last, if the clutch oil temperature is between 135 to 150 then it is critical temperature.

TABLE II. CLUTCH OIL TEMPERATURE VARIATION

Clutch Oil Temperature ^{o}C	**Vehicle Temperature Status**
-50 – 60	Low
60 – 120	Medium
120- 135	High
135- 150	Critical

Fuzzy Logic provides a more efficient and resourceful way to solve Control Systems in vehicle diagnostic. Some Examples are Temperature Controller and Anti – Lock Brake System (ABS). It is able to be applied to control systems and other applications in order to improve the efficiency and simplicity of the design process. Three main steps are used in vehicle diagnostics when fuzzy logic is applied on first is Fuzzification, second is Rule and the third one is Defuzzification. This is given in the figure below.

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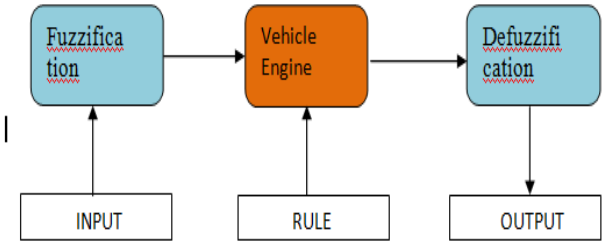

Fig 2: Fuzzy Logic System on Vehicle Engine

In figure 2, INPUT is provided to Fuzzification, it generates a fuzzifier result. This further applied with the rule on the vehicle Engine to check the clutch oil temperature, finally, after Defuzzification, OUTPUT message is generated to intimate or to predict clutch life.

Fuzzy logic Pseudocode is used for the analysis of the clutch oil temperature written below.

```
if ((speed >= -50)&&(speed < 60))
{
        // Vehicle Temperature Is Low And Clutch Life Is On Low Risk.
}
else if ((speed >= 60)&&(speed < 120))
{
        // Vehicle Temperature Is Medium And Clutch Life Is On Medium Risk

}
else if ((speed >= 120)&&(speed < 135))
{
        // Vehicle Temperature Is High And Clutch Life Is On High Risk
}
else // if ((speed >= 135 && (speed < 150))
{
        // Vehicle Temperature Is Very High And Clutch Life Is Critical
    }
```

Here in the above code, it says about. If Clutch oil temperature is between -50 to 60 then Vehicle temperature is low and clutch life is at low risk. If Clutch oil temperature is between 60 to 120 then Vehicle temperature is medium and clutch life is on medium risk or normal. If Clutch oil temperature is between 120 to 135 then Vehicle temperature is high and clutch life is at high risk. And at last, if the clutch oil temperature is between 135 to 150 then Vehicle temperature is very high and clutch life is critical.

In system implementation, dataset can be prepared based on the vehicle sensor data. This data can be divided into two parts, trained Data set and Test Data set. 80% of available data is used for trained data set and the remaining 20% is used for test Dataset. Before system implementation, a pseudocode and design flow of the algorithm is created. We used Python for system implementation.

V. Result Analysis

For result analysis in the given system implementation, many parameters are considered in the given dataset as TimeStamp; EngSpeed (rpm); TurSpeed (rpm); SUMPTEMP (ohm); From these all, major parameters are Engine speed(Eng Speed), Turbo Speed (TurSpeed) and Temperature(SUMTEMP). The following table shows the sample dataset used for system implementation.

TABLE III. SAMPLE DATASET

Sr. No	TimeStamp	EngSpeed (rpm)	TurSpeed (rpm)	SUMPTEMP (ohm)
1.	21:43.6	897	906	320
2.	21:43.7	897	907	320
3.	21:43.8	897	906	320
4.	21:43.9	897	906	320
5.	21:44.0	1015	907	320
6.	21:44.1	1015	907	320
7.	21:44.2	1279	906	320
8.	21:44.3	1384	907	320
9.	21:44.4	1385	906	320
10.	21:44.5	1385	906	320
11.	21:44.6	1704	906	320
12.	21:44.7	1750	906	320
13.	21:44.8	1750	907	320

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14.	21:44.9	1750	907	320
15.	21:45.0	1750	906	320
16.	21:45.1	1750	1232	320
17.	21:45.2	1750	1232	320
18.	21:45.3	1750	1445	320
19.	21:45.4	1750	1446	320
20.	21:45.5	1750	1448	320

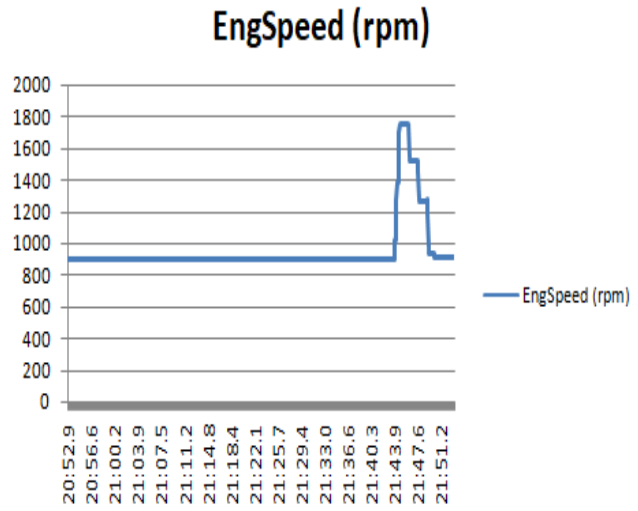

Fig 3. The graph on Engine Speed Variation with a timestamp

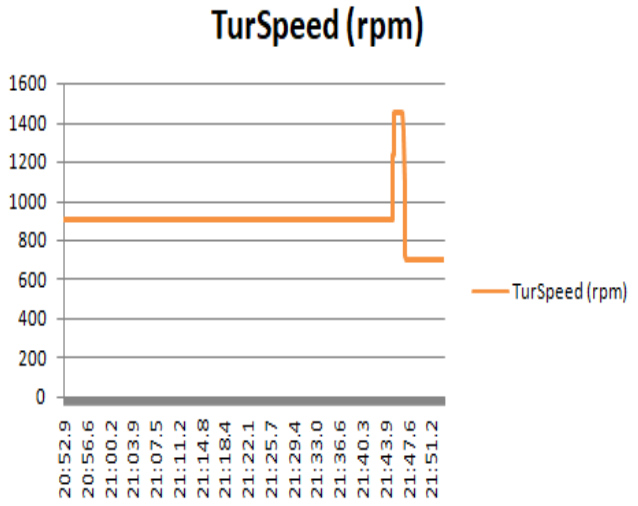

Fig 4. The graph on Engine Turbo speed variation with a timestamp

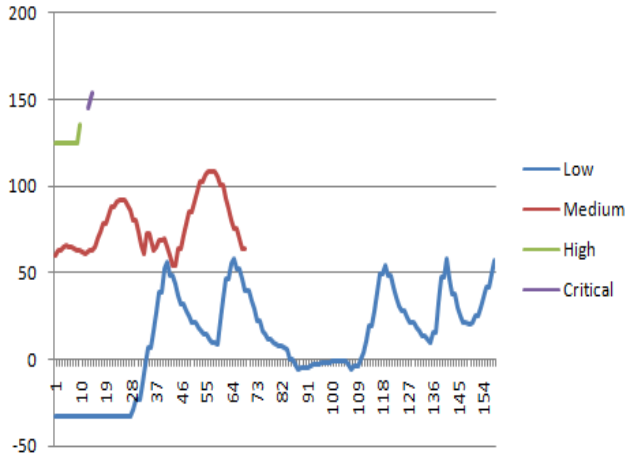

Fig 5. Graph On Sump Oil Temperature Variation with different bands

Figure 3 shows the resultant graph on Engine Speed Variation with time stamp and Figure 4 shows resultant graph Engine Turbo speed variation with a timestamp. Figure 5 shows the Graph on Sump Oil Temperature Variation with different bands.

Here, in the Bayesian approach, vehicle speed and environment conditions as temperature are considered as two parameters. We have trained the historic data and tested it. the output is in the form of YES or NO. Further, the fuzzy logic system considers transmission oil temperature value which can give clutch life status.

VI. Conclusion

A vehicle clutch is an important part that needs to monitor to prevent sudden failures. This can be achieved through the vehicle prognostics concept. This concept has different aspects of machine learning and can play an important role in the real world vehicle analysis system. This paper uses the Bayesian algorithm and fuzzy logic by which we can predict vehicle clutch health and communicate it to the user. Bayesian can predict whether the current condition of vehicle speed and environmental temperature affect the clutch which is based on historical data. This data can predict the output in the form of YES or NO. Then further consider a fuzzy logic system that is based on transmission oil temperature to predict the clutch health result status.

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Algorithm logic works with a two-layer of the component parameter. first is the immediate and direct impact parameter on the vehicle clutch health and second is the parameters who can affect the first layer parameters. Thus the use of two algorithms increases the chances of prediction accuracy. There is a scope of increasing layers with this approach to get more and more accurate results.

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