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Predictive Models for ABS and TPMS based on Gaussian Naïve Bays

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Abstract: - The car industry is currently preoccupied with the issue of safety. The increasing number of accidents occurring around the world as a result of automobile problems is a major contributing factor to these incidents. The amount of complicated electronics that is used in vehicles is becoming more prevalent every day. A great effort has been made in evaluating vehicle features in relation to vehicle components. Through such systems, a smart architecture and complex function designs are involved. During all of this vehicle transformation and evolution, the automotive industry recognises a high demand for vehicle safety. While designing and manufacturing this system, automotive experts understand a need for a strict monitoring and feedback system for complex vehicle architecture, which can notify the end user if there is any indication of a failure ahead of time.

In order to effectively participate in vehicle design activities, it is critical to grasp the significance of safety features. Tire system failures and braking system failures have played a large role in several recent traffic accidents. The failures of the tyre system and the braking system in the vehicle are addressed in this study. While investigating this system, it is discovered that it is supported by complex electrical systems, which include an ECU (electronic controller unit), sensors, and a wire system.

Through the use of these technologies, censored data can be processed in a timely manner and made available for diagnostic purposes. Nevertheless, car diagnostics is needed after any vehicle failure but that does not serve the aim of maintaining vehicle safety. As a result, predictive analysis or predictive diagnostics may be a viable option for informing the driver about the health of a particular vehicle component in advance. In this study, the author discusses the concepts of vehicle prognostics for the tyre pressure monitor system and the antilock braking system, which are accomplished using a statistical method of machine learning. In today's world, machine learning is expanding in breadth, and the world is becoming more aware of its enormous potential in the field of data analytics. It is the purpose of this study to introduce methodologies by which machine learning can assist vehicle predictive analytics to attain the intended goal of vehicle safety.The author of this article discusses how Bayesian statistics may be used to produce predictions in the form of probability estimation. The prediction's outcome is thoroughly analysed.

Keywords — Gaussian Naïve Bays, ABS, TPMS.

I. INTRODUCTION

Every automotive manufacturer in the modern vehicle era is extensively involved in the development of strategic components for automobiles. Using a strong and clever electronics architecture, these car components make it easier and more flexible to operate the vehicle. Sensors, actuators, wiring systems, and intelligent systems based on microcontrollers all play a vital role in this operation improvement. Vehicle data acquisition systems are an integral component of the complicated vehicle electronics architecture, and they play a vital role in this. While a manufacturer is developing complicated vehicle features, it is also necessary to effectively monitor these systems at the same time. Predictive maintenance may be the best solution for future vehicle maintenance when the primary purpose is to keep the vehicle safe on the road. A disciplinary approach to dealing with the vehicle's electronic systems is required due to the increased complexity of these systems. The author of this study conducts tests with data generated by smart systems that have been developed for tyre pressure monitoring and antilock brake systems. Losses resulting from vehicle failures and accidents could not be prevented with vehicle diagnostic examination. Because of the availability of created data, timely analysis may be performed. The data can be retrieved in real time through a remote system and saved. This information can be used for predictive analytics purposes in the future. Several efficient statistical approaches are now being investigated by researchers, and more are expected in the future.

The author experimented with the data supplied by the ABS and TPMS systems using a Baysian model that was constructed using Baysian statistical methodologies. Based on this probability estimation of an important parameter, it is possible to calculate the health of the targeted system and to predict its future health as well. An effective machine learning technique is given in this paper, which may be used to develop a predictive solution for various car components. Because ABS and TPMS

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are critical components of a vehicle and play a significant part in its overall safety, it is crucial to understand how they work. The author is primarily concerned in developing a predictive model for this component. These models have the potential to play a key role in analysing data from on-board systems and assisting in the assessment of predictive maintenance. The author tries with this fusion strategy in order to obtain the most analysis possible using a trained statistical model. These days, service protocol standards such as UDS, J1939, and KWP, as well as communication protocols such as CAN, Flex Ray, and IP, are widely used to connect vehicle data with off-board systems such as Navigation system. These protocols contribute to the development of a reliable data gathering system.

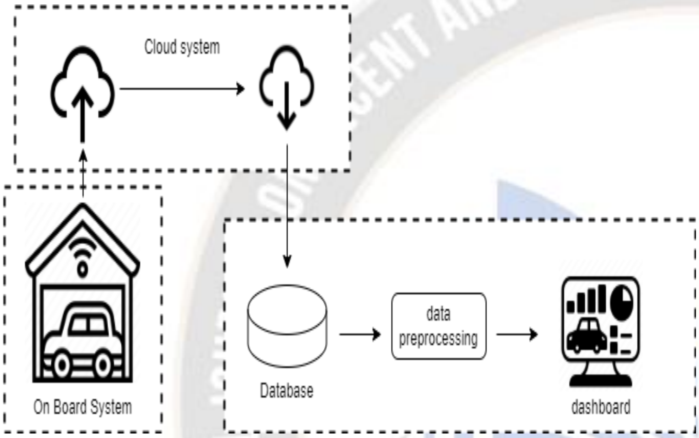

Figure1:- Off Board Vehicle data processing

The on-board system includes a vehicle function unit with smart controller support, which is a component of the vehicle. This system communicates with off-board systems, such as personal computers and mobile-based applications. Through the use of these apps, one can develop intelligent engineering solutions that will assist in the maintenance and operation of vehicles. In this live communication configuration, the author collects data from the vehicle and stores it on a remote server, which is accessible over the internet.

II. LITERATURE SURVEY

Performing real-time analysis may be time consuming and incompatible with other vehicle designs. Yang, Feng, Ma, and Sun propose the use of a virtual environment for the simulation and design of an anti-lock braking system (ABS). This is a generic solution for all types of vehicles, both in terms of real design and production.(Bi, Kapoor, and Bhatia 2016)

Wang, Atat, Lee, and Xi have developed an artificial intelligence model to estimate the confidence value for the degradation of a vehicle sensor's performance. As sensors are an integral part of the vehicle system, any degradation in the sensor's performance may have an impact on the overall operation of the vehicle.(Institute of Electrical and Electronics Engineers. Madras Section., Product Safety Engineering Society., and Institute of Electrical and Electronics Engineers, n.d.)

According to Modi, Padia, and Patel, the fuzzy logic method, when used in conjunction with a microcontroller, is critical for estimating speed values and operating the ABS. This study suggests that, in the future, it may be possible to construct a strong functional model with the assistance of techniques such as fuzzy logic and artificial intelligence.(Egaji, Chakhar, and Brown 2019)

Itung explains how real-time pressure and temperature monitoring systems for vehicle tyres work in more detail. Pressure sensor and microcontroller integration with the TPMS system will be eliminated as a result of this change.(Yue et al. 2021)

Namjo and Golbakshi conducted experiments on the deformation of the tyre as a result of the motion of the vehicle. The author experimented with numerical stimulation in relation to the maximum temperature that could be created and the critical level temperature.(Jain, n.d.)

A literature survey was conducted to understand the effect of air pressure in a tyre on driving comfort, fuel efficiency, and road safety. CABAN, Drozozeal, Barta, and LISCAR explain pressure control systems used in automotive vehicles based on the results of the survey.(Yang et al. 2004)

To estimate the tyre pressure of the vehicle, Reina, Gentile, and Messina proposed an indirect tyre pressure monitoring system that used existing features and extracted information using model-based approach to estimate the tyre pressure of the vehicle. The onboard system can receive feedback from the estimation of this model.(IEEE Reliability Society and Institute of Electrical and Electronics Engineers, n.d.)

A mobile device's GPS and accelerometer data are used in an experiment by J-Siegal, Rahul, and Bsesaram in order to calculate predicted and true wheel rotational frequencies. These are utilised in the calculation of tyre circumference and related pressure through the use of a tree-based classification system.(Svensson et al. 2017)

To calculate tyre pressure in the vehicle using existing sensors, Svnsson and colleagues (thelin, bytther, and fan) present a supervised machine learning model that they developed.(Vanjire and Patil, n.d.)

To demonstrate a decision rule-based approach for tyre monitoring, Egaji, Chakhar, and Brown created a video. The authors concentrate on temperature pressure complexity, in which they fix on a parameter and generate rule bases for the other parameters to be used.("Finite Element Analysis for Estimating the Effect of Various Working Conditions on the Temperature Gradients Created Inside a Rolling Tire" 2014)

They used the decision fusion method to discuss a prognostic approach for fuel cell hybrid electric vehicles, which Yue,

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Masery, Jemei, and Zerhouri presented.(Patil and Shinde 2021) During their conversation, Patil and Shinde discussed the possibility of a wireless system that would allow tyre pressure to be controlled remotely through an electronic system. The Internet of Things (IoT) technique allows the system to measure tyre pressure and temperature.(Huang 2013)

In their survey paper, Vanjire and Patil discussed the use of expert systems, machine learning, and deep learning techniques for vehicle prognostics, as well as the limitations of these techniques.(Modi, Padia, and Patel 2012)

Mnif talked about tyre pressure and temperature monitoring using remote sensing technology.("Real Time Tire Pressure Monitoring System in Automobiles Using SPLUNK Enterprise 407," n.d.)

It was discussed by Meissner, Meyer, and Raddatz how the prognostics performance of the tyre pressure system could be improved by using Monte Carlo simulation.(Caban et al. 2014)

Sharmila and Vinod talked about a real-time tyre pressure system that uses ABS sensors to calculate pressure differences between tyres in real time.(Reina, Gentile, and Messina 2015)

Yogashri, Jayanthya, and Rathi talked about Splunk Enterprise, which is a software programme that is designed to monitor changes in tyre pressure and temperature.(Lee et al. 2008). Studies in IoT machine learning have been presented by S. L. Bangare et al. [15-16]. Researchers J. Surve et al. [17] focused on utilising IoT to improve medical care. In the field of human-computer interaction, J. Alanya-Beltran et al. [18] have made contributions. Xu Wu and coworkers [19] were involved in the field of network security. K. Gulati et al. [20] reviewed IOT methods. S. Pande et al., have presented the latest variant of CNN termed as capsule network based approach which is the best architecture that maintains the relationships among the learned features throughout the network and KNN based approach for medicinal leaf retrieval [21] [22].

III. PROPOSED WORK

As shown in diagram 1 , TPMS and ABS system are having on board system which consist of functional unit attached with different sensors and actuator of the functional unit. TPMS (tire pressure monitor system) consist of pressure and temperature sensor and ABS (Antilock breaking system) consist of wheel speed sensor and vehicle speed sensor. These sensors are controller based intelligence system that is called ECU (electronic controller unit).This centralised intelligence system is closely connected and get the respective input from the different sensors. Also it is connected to the actuators to actuate respective functional activities. Thus sensors and actuators plays important role in the functional operation of the respective vehicle component.

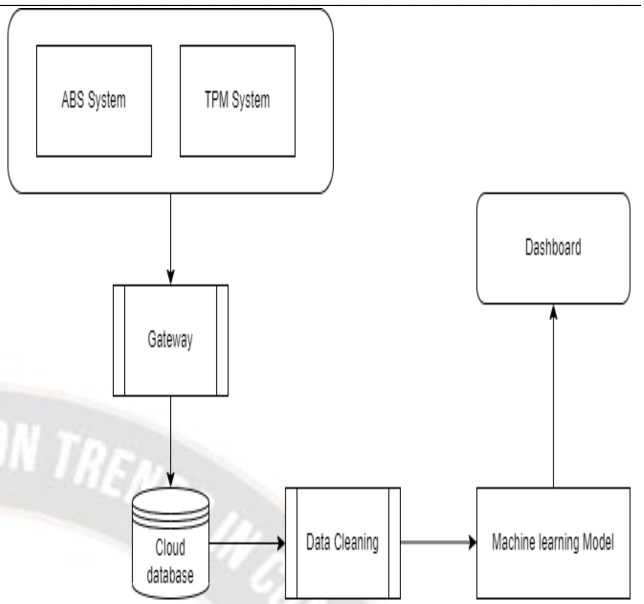

Figure 1: Block diagram of System Design

Thus TPMS and ABS system consist of sensors, actuators, wiring and intelligence system. Intelligence system or ECU performs different logical operations for the functional component. Its main goal is to sense the data and based on requirement design logic performs the operations for example based on the sensors value it will generate fault codes for failure or faults with in component .It will help help for continuous monitoring of the different sensor parameters. Thus ECU stores all this information. This overall system is called on-board system. This on-board system has provision to connect with the outer world through communication gateways. Through this gateway vehicle data which is stored in the ECU can be processed and transferred to the targeted off board system. Generally transfer or communication of this data can be handled by telematics units, wireless systems with these systems data can be transfer to the centralised server. This server can store this data for further usage. Thus this stored data can be utilised for the further off board operations. Predictive analytics or prognostics is one of the application area which can be designed to support early predictions for the vehicle operations .With the help of machine learning methods this stored data can be processed .The output of this ML models could be predictive analysis in the form of state of health (SOH) or remaining useful life (RUL) .Thus well designed dashboard system presents the output results of the ML model.

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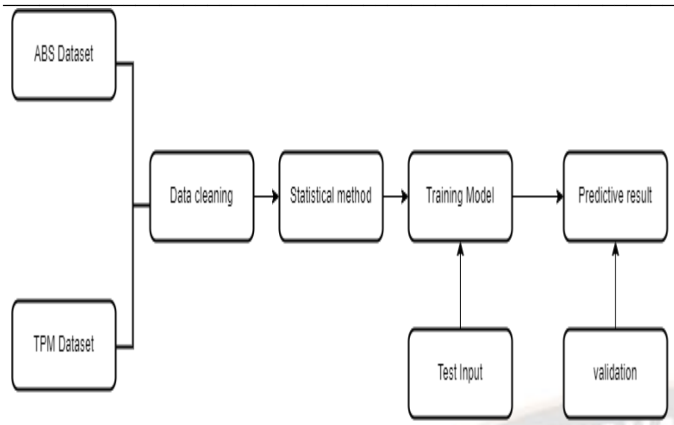

Figure 2. Data processing and prediction system.

Referring to the diagram 2 ABS and TPMS dataset are in the form of rawdata collected from the vehicle.Before proceeding or giving input to the training model it is require to clean the data .The data treatment operation may include handlingof duplicate data,data labelling with numeric form.

As machine learning model only processes numeric data type it is important to feed numeric data.In the preprocessing it is essential process that converts any text data in to numeric form.Once data is preprocessed then it is feed to machine learning model.The data can be split in to 80 to 20 ratio so 80 present data can be used for training the model and 20 percent data can be used for testing the model .After training the model the data can be tested where accuracy estimation and validation operations takes place .thus the data in the form of raw processed to get the prediction results.

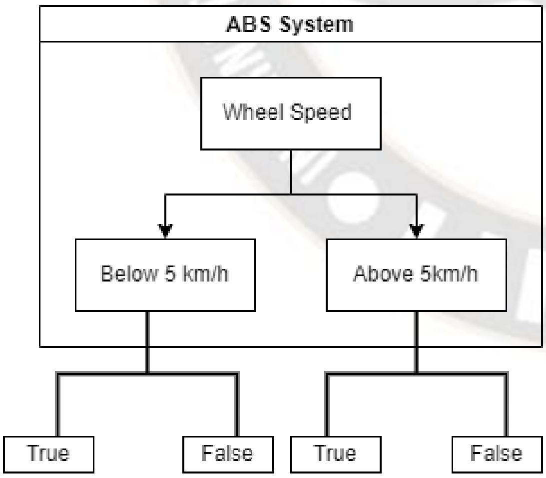

Figure 3. ABS Work flow model

Refers how baysian algorithm could be used for the faulty sensor probability .The wheel speed sensor output can be checked.If the output speed is greater than 5 then the model output sould be true .if the speed is less than 5 then model output should false .If any of this statement give wrong status then model can predict as sensor is faulty.

Dataset design :

In the experimentation for ABS and TPMS author collects the sensor data.For ABS author collects wheel speed sensor data as input and for TPMS author collects pressure sensor and temperature sensor data as input.With data preprocessing for ABS labelling is done as below where wheel speed sensor condition is checked with greater than or less than 5 in TRUE and FALSE form.This TRUE and FALSE in text this preprocessed with 1 and 0 respectivelly.

Table : ABS Ouput Label

Health Out Put	Numeric label
True	1
False	0

Table- ABS Resultant Data

Vehicle Speed(km/H) - I/P	Vehicle Wheel speed status
0	FALSE
0.11	FALSE
1.76	FALSE
3.85	FALSE
3.77	FALSE
43.73	TRUE
65.24	TRUE
63.95	TRUE
41.73	TRUE
32.11	TRUE

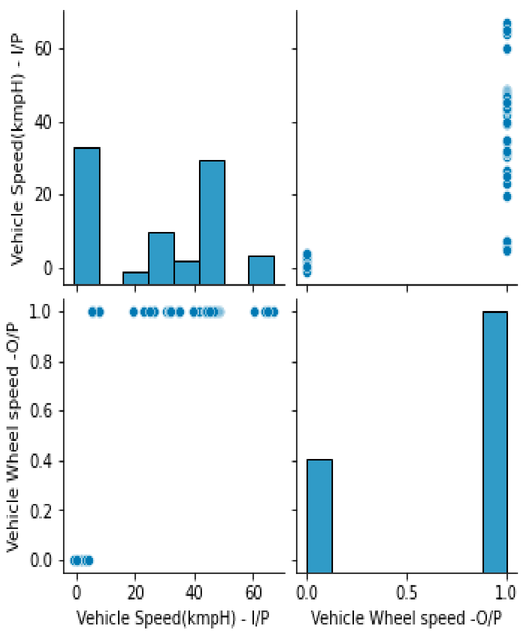

Figure :- ABS Resultant Graph

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Similarly for TPMS output label is in the low, mid,high status of health which interprets with 0,1,2 in the numerical form after pre-processing.

Table : TPMS Output Label

Health	label
Low	0
Medium	1
High	2

Table-TPMS Resultant Data

Temperature	Pressure	Health
30	100	1
30	103	1
30	118	1
30	121	1
30	124	0
30	127	0
30	130	0
30	133	2
9	118	0
9	121	0
30	169	2
9	112	1
9	115	0
9	118	0
9	121	0
9	124	2

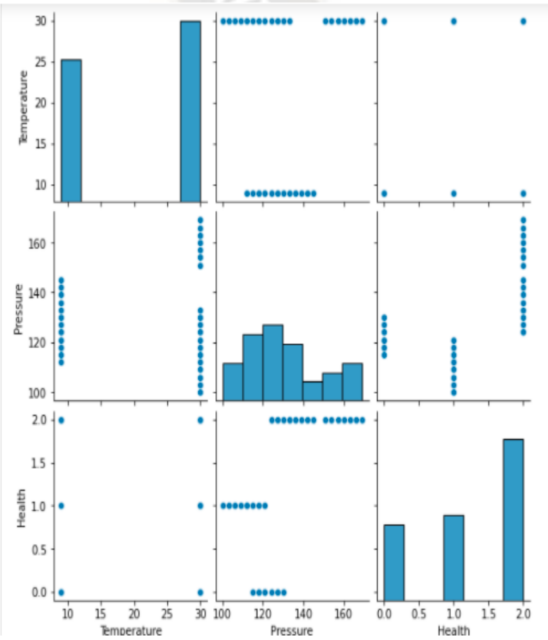

Figure :- TPMS Resultant Graph

Sample dataset – Large dataset of 1000 samples were collected and processed for training and testing operation below is the sample data set for ABS and TPMS.

IV. TEMPERATURE PRESSURE SENSOR

Above shows Temperature Pressure sensor used for the experiment purpose. Below table shows the
Technical specification of the sensor.

Table:- Technical Specification

Specification	**Approx Value**
Max Pressure	3000 psi
Accuracy	< ±100% FS
Max Operating Temperature	105℃
Zero pressure offset	0.50v
Burst Pressure	15000PSI
Temperature error	< ±1% FS

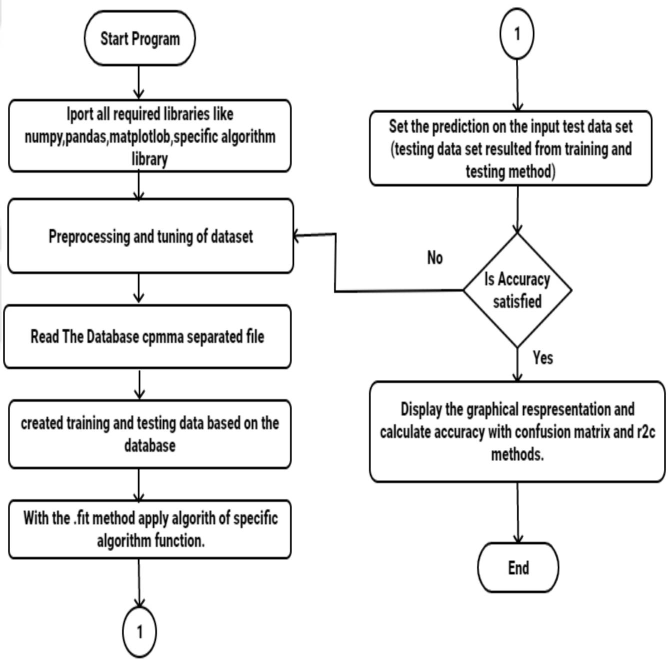

Figure 6: System flow chart

The flow chart shown in figure 6 explains the different steps

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covers to achieve machine learning operations for the predictions.

V. GUASSIAN NB

The Bayes theorem is a mathematical formula that calculates the conditional probability of an event A occurring given the occurrence of another event B previously. Its mathematical formula is as follows:

$$P(\frac{T}{H}) = \frac{\mathrm{P}\left(\frac{\mathrm{H}}{\mathrm{T}}\right) * \mathrm{P(T)}}{\mathrm{P(H)}}$$

Where,

- T and H are two events
- P(T|H) is the probability of event T given event H has already occurred.
- P(H|T) is the probability of event H given event T has already occurred.
- P(T) is the independent probability of T
- P(H) is the independent probability of H

In order to develop a classification model, the following Bayes theorem can be reconfigured:

Gaussian Naïve Bayes is a naive Bayes approximation. The Gaussian or normal distribution is the simplest function to construct since it requires only the mean and standard deviation of the training data, whereas other functions estimate the distribution of the data.To this point, we've seen that the T's are classified, but what about when T is a continuous variable? How do we compute probabilities in this case? Suppose that T follows a particular distribution, and you want to compute the probability of likelihoods, you can use the probability density function of that distribution.

Suppose T's follow a Gaussian or normal distribution. In this case, we must substitute the probability density of the normal distribution, which we will refer to as Gaussian Nave Bayes, for the probability density of the normal distribution. You'll need the mean and variance of T in order to compute this calculation.

$$P(\frac{T}{H} = F) = \frac{1}{\sqrt{2\pi\sigma^2 F}} e^{-(x-\mu f)^2 / 2\sigma^2 F}$$

The variance and mean of the continuous variable T determined for a given class F of H are represented by the sigma and mu in the formulas above. The Gaussian Nave Bayes classifier is a fast and simple classifier algorithm that performs admirably well with little effort and a high degree of accuracy.

VI. RESULTS ANALYSIS

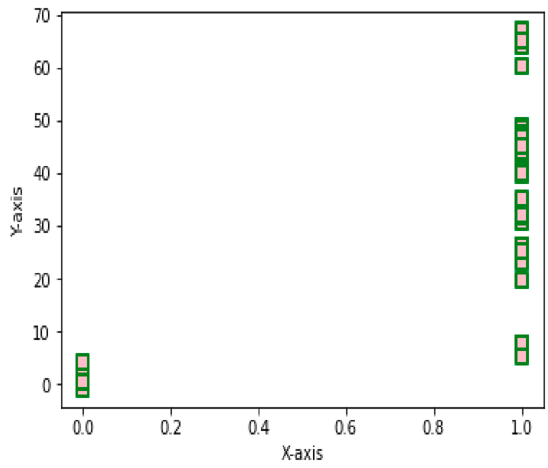

Figure:- graph result for bays algorithm

The Graph shows the result of Bays algorithm. Two possibilities are plotted with x axis and Temperature is plotted on Y axis.

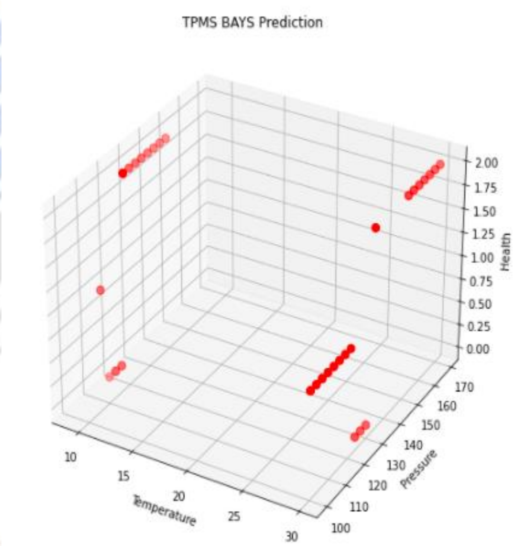

Figure:- 3D Graph for TPMS Bays Prediction

The diagram shows the three dimensional graph for the Health verses temperature and pressure parameters.Bays theorem helps us to calculate successfully the predictive values.

VII. CONCLUSION

For the prediction of ABS and TPMS health, the Gaussian Bayesian model is taken into consideration. It is necessary to extract the recorded dataset from car sensors, pre-process the data, and establish dependent and independent parameters for the model to work. This collection of data is utilised as an input dataset for the machine learning model.. The classifier has an accuracy of 82.34 percent, which is considered to be excellent. It has been noticed that increasing the number of data sets used to make a forecast improves the quality of the prediction. These predictions are a tough process, and the starkness of manual observation demonstrates the necessity of certifying the system. The suggested system in this paper makes a significant contribution to the atomization domain of vehicle maintenance through its high performance in this domain. There is still room for experimentation with alternative machine learning models in order to achieve higher accuracy levels, and more sensors can be considered in order to get greater precision.

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