ENGINE CONTROL UNIT MONITOR

A MINI PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

The electronic engine control unit (ECU) is the central controller and heart of the engine management system. It controls the fuel supply, air management, fuel injection and ignition. Due to the scalability of its performance, the control unit is also able to control the exhaust system as well as to integrate transmission and vehicle functions . If any kind of fault occurs in the ECU the vehicle would be inoperable, Since there is no existing system which predicts the malfunction and informs the user. Without such a system the vehicle's operation is abruptly disturbed which includes the inability to start the vehicle and unable to operate electronic systems in the vehicle.

Nowadays in most of the vehicles the user would not be able to open the doors without the proper functioning of ECU. Engine control unit (ECU) is an electronic control unit that ensures the optimal work of an internal combustion engine. It controls fuel supply and injection, fuel-to-air ratio, ignition, idle speed, and the timing of valve opening and closing. Modern ECUs also include cruise control, anti-skid brake control, and other features.A modern car can't function without an ECU. Because of this, it is important to keep an eye out for problems that might be related to the ECU .

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INTRODUCTION

1.1 ENGINE CONTROL UNIT

Engine control unit (ECU) is an electronic control unit that ensures the optimal work of an internal combustion engine. It controls fuel supply and injection, fuel-to-air ratio, ignition, idle speed, and the timing of valve opening and closing.The ECU controls everything in the engine, including the wheel speed, braking power, ignition timing, idle speed and the air/fuel mixture.

Figure 1.1 ECU

Whether you're taking the car to the shops or to a track day, your ECU is working in the background to ensure your car's engine is working as efficiently and is as environmentally friendly as possible. Modern ECUs also include cruise control, anti-skid brake control, and other features.An ECU is essentially a small computer that manages the actuators on your car's engine to ensure it performs flawlessly All of this is important to ensure that the engine is working efficiently and the amount of emissions is as low as possible. To do this, the ECU receives input from several sensors that help it determine the right way of action. These sensors usually include temperature and pressure sensors, accelerator pedal position sensor, anti-lock braking system module and other modules within the vehicle.

The Engine Control Unit (ECU) is a critical component in modern automotive systems that controls and manages the various functions of an internal combustion engine. It receives information from a variety of sensors placed around the engine and other systems within the vehicle to make decisions on how to manage fuel injection, air-to-fuel ratio, ignition timing, and other parameters. The ECU is like a small computer that continuously monitors and adjusts the engine to optimize performance, reduce emissions and maximize fuel efficiency. Additionally, modern ECUs can also control other features such as anti-lock braking system, traction control, and cruise control to enhance the overall driving experience.

Modern ECUs are highly advanced, with advanced microprocessors and software that can handle complex calculations and decision-making processes in real-time. They can control a wide range of functions, from managing fuel and air mixture ratios to controlling transmission shift points, managing cruise control, and even regulating advanced safety features like anti-lock brakes.

The goal of the ECU is to optimize engine performance while minimizing emissions and ensuring safe and reliable operation. As such, it's an essential component of modern vehicles, and its proper functioning is critical to ensure that the engine operates efficiently and safely.

1.1.1 HOW DOES AN ECU WORK?

As your engine is running, sensors feedback information to the ECU on how the engine is running. The ECU takes data from several sensors in your car's engine, coolant system, exhaust and fuel injection system. It makes millions of calculations every second, comparing the information it gathers to performance maps inside it. If it spots a problem, it makes the necessary adjustments to ensure the smooth and efficient running of the engine.As well as ensuring the optimal performance of your engine, an ECU can increase its energy efficiency too.

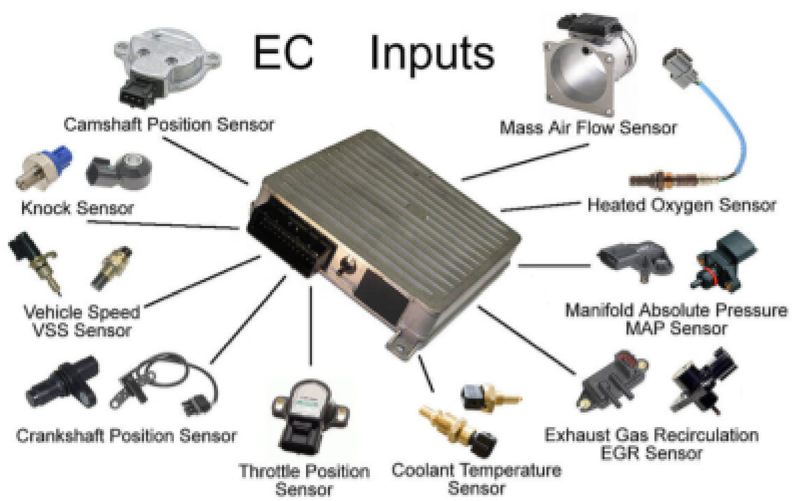

Figure 1.2 ECU inputs

As your car is driving, the ECU can detect whether your car's engine is running too rich (having too much fuel) or too lean (not receiving enough fuel). In a split second, it can accurately adjust the balance, improving performance and energy efficiency while reducing emissions.The ECU map inside your car's ECU is designed to adhere to all emissions regulations and to perform in all conditions, temperatures and altitudes. The ECU fitted to your car’s engine provides the best all-round performance for your car’s engine, not the optimum speed or torque.

The ECU receives information from various sensors installed in the engine, such as the oxygen sensor, throttle position sensor, and engine speed sensor. These sensors provide data about the engine's current state, such as the amount of oxygen in the exhaust gas, the position of the throttle, and the engine's rotational speed. The ECU processes this information and sends commands to various actuators to control the engine's performance .

1.1.2 APPLICATIONS OF ENGINE CONTROL UNIT :

- **Automotive**: The ECU is most commonly used in automobiles, where it is responsible for managing the engine's performance. It monitors various engine parameters, such as the air-fuel ratio, exhaust gas temperature, and engine speed, and uses this information to make adjustments to the fuel injection, ignition timing, and other critical components. This helps to ensure that the engine is running efficiently and meeting emissions standards.
- **Marine**: The ECU is also commonly used in marine engines, where it is responsible for controlling and regulating various engine functions. In marine applications, the ECU is often responsible for monitoring the engine's temperature, oil pressure, and fuel consumption, and it uses this information to adjust the engine's performance accordingly.
- **Aviation**: The ECU is also used in aviation applications, where it is responsible for controlling and regulating various aspects of the engine's performance. In aviation applications, the ECU is often responsible for

monitoring the engine's temperature, fuel consumption, and other critical parameters, and it uses this information to make adjustments to the engine's performance to ensure safe and efficient operation.

- **Industrial**: The ECU is also used in various industrial applications, such as in power generation equipment and heavy machinery. In these applications, the ECU is responsible for controlling and regulating the engine's performance, ensuring that it is running efficiently and meeting emissions standards.

1.1.3 WHAT HAPPENS IF MY ECU BECOMES FAULTY?

The ECU is a sophisticated computer onboard your car and, like all components, can break down or fail. A faulty ECU can lead to several faults occurring, some of which can be serious.If your ECU is failing, the first thing you’re likely to notice is the orange engine management light appearing on your dash. This can make your heart skip a beat as you imagine thousands of pounds draining from your account, but that’s not always the case.While all cars are different, the warning signs are usually the same. A solid amber light means that there’s an issue with the emissions system. If the EML flashes, it’s indicating that your engine has a misfire that needs attention. If it’s a solid red color, then there’s a serious fault that needs to be looked at immediately.

Even if the engine warning light isn’t on, some other signs of a faulty ECU include a lumpy or misfiring engine, poor engine performance, lower fuel economy (lower miles-per-gallon) and a car that won’t start.A fault with your ECU can lead to some serious issues, such as your engine overheating or even freezing. If your ECU isn’t working correctly, your engine will be inefficient, leaking harmful emissions into the environment – so you'll need to get it fixed. It goes without saying (but we will anyway) that a faulty ECU will lead to an MOT failure. An ECU repair or replacement will need to be diagnosed by a professional. They can assess the cause of your engine problems and recommend a solution**.**

1.2 PROBLEM STATEMENT

- The Engine Control unit is the heart of the automobile world.
- If the engine control unit fails to operate due to abnormal conditions the vehicle cannot be operated, it stops abruptly.
- There is no system to indicate any kind of malfunction occurs in the Engine control unit.

1.3 OBJECTIVES

- To sense the Voltage and Temperature data from the Engine Control Unit (ECU).
- To detect the malfunctioning of the ECU.
- To prematurely inform the user about the malfunction.
- To provide proper indication to the user .

1.4 PARAMETERS

1.4.1 Voltage

The Voltage level of the ECU under normal operating conditions is 12.6V[1]. Under normal conditions the voltage variations can cause malfunctioning of the ECU. This voltage level can be monitored to predict the malfunctioning of the ECU. The below image depicts the various voltage levels of the ECU under different operating conditions.

For our purpose only the nominal voltage level was considered for modeling our system.

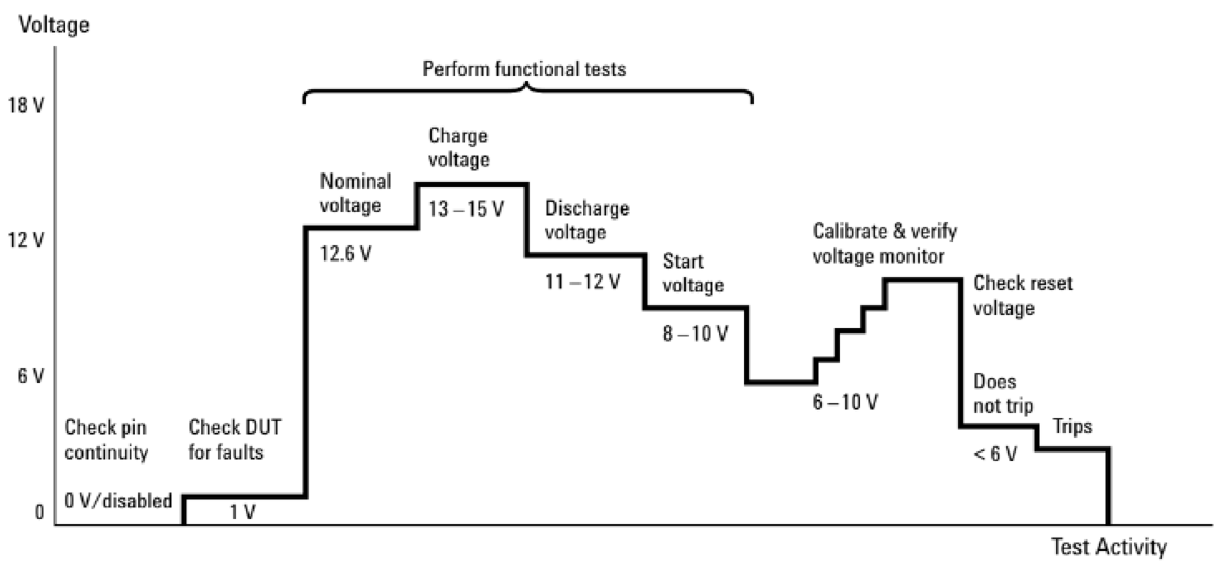

Figure 1.3 Voltage Values Of ECU

1.4.2 Temperature

The ECU has a threshold limit to its inner air Temperature $E_{i,ECU}$ [2]. The temperature limit varies from -40^{o}C to $125^{o}C$. If the ECU operates near these threshold levels the life time of the ECU is reduced. Above or below these thresholds the ECU might experience damage. We have designed our system in the consideration that if the ECU operates at more or less than the rated temperature then the ECU might fail soon.

The below table represents the ECU load typical temperature-load distribution [2].

$T_{i,ECU}$ = ECU inner air temperature	**Typ.Load (Passenger Car)**	
	Vehicle body, bulkhead,extension close to the engine	
-40°C…10℃	6.0 %	480 h
10°C…45℃	20.0 %	1600 h
45°C…60℃	33.0 %	2640 h
60°C…70℃	18.0 %	1440 h
70°C…80℃	9.0 %	720 h
…85℃	3.0 %	240 h
…90℃	2.0 %	160 h
…95℃	1.7 %	136 h
…100℃	1.5 %	120 h
…105℃	1.4 %	112 h
…110℃	1.3 %	104 h
…115℃	1.2 %	96 h
…120℃	1.0 %	80 h
…125℃	0.9 %	72 h
Total	100 %	8000 h

Table 1.1 Various Temperature Values of ECU

CHAPTER -2
PROJECT MANAGEMENT

2.1 NEED ANALYSIS

- To sense the Voltage and Temperature data from the Engine Control Unit (ECU).
- To detect the malfunctioning of the ECU.
- To prematurely inform the user about the malfunction.
- To provide proper indication to the user .

2.1.1 BULL DIAGRAM

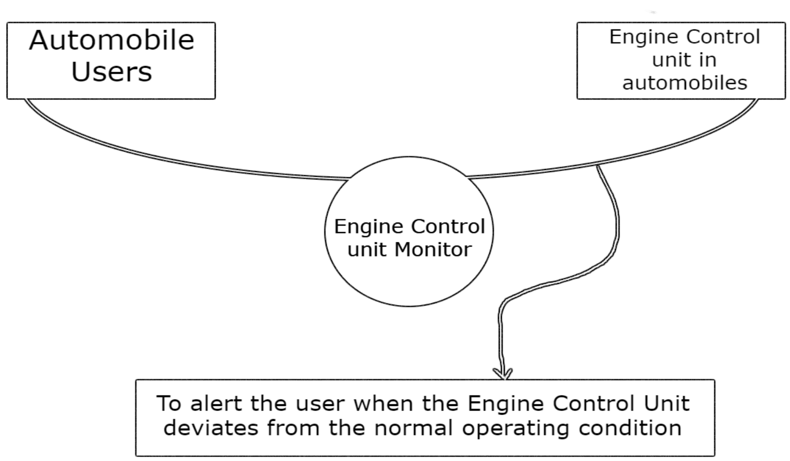

Figure 2.1 Bull Diagram

a) In the product we designed, the face of the bull is the title of our product which is an Engine Control Unit Monitor.
b) The left horn is the end users , in our case it is the Automobile Users.

c) In the right horn we have specified the Engine Control Unit in automobiles

d) The main purpose of our project is to alert the user when the Engine Control unit deviates from the normal operating condition .

2.2 FUNCTION ANALYSIS

2.2.1 OCTOPUS DIAGRAM

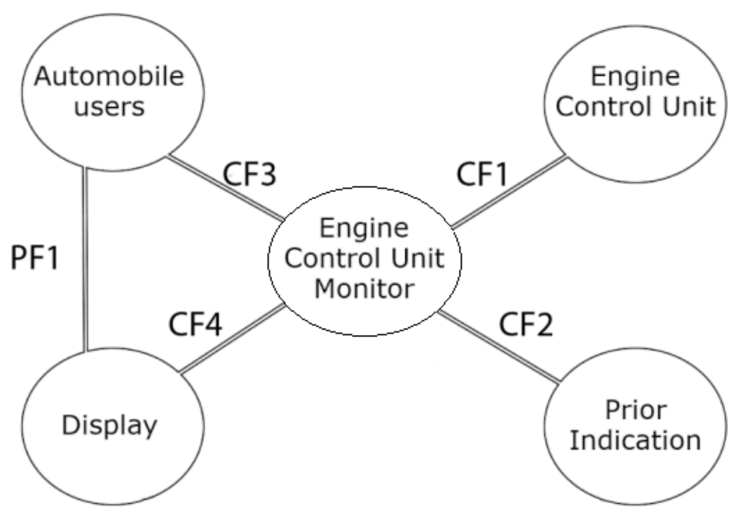

Figure 2.2 Octopus Diagram

Principle Functions	
PF1	To alert the user of any malfunction prematurely

Constraint Functions	
CF1	To obtain data from Engine Control Unit
CF2	To predict the malfunction of Engine control unit before failure
CF3	alerted before the failure of Engine Control Unit
CF4	Provide accurate prediction

Table 2.1 Principle and Constraint functions

- The ECU monitor that we are designing consists of a single principle function which is mainly to alert or indicate to the user that a fault is going to occur.
- There are also several Constraint functions(CF), the CF1 is to obtain the data directly from the Engine Control Unit, the CF2 is used to predict the malfunctions in data that we just obtained before any failures occurs, the CF3 which is the communication between the automobile users and the ECU that mainly focuses on alerting the user before any failures, the CF4 which is the ECU connected to the display will display the data that helps to accurately predict the fault and the ECU monitor only requires less power to operate is the CF5.

2.2.2 RISK ANALYSIS

Risk	Assessment of the risk - Likelihood Criteria					Assessment of the risk - Consequences Criteria					Global Assessment
	Student 1	Student 2	Student 3	Student 4	Student 5	Student 1	Student 2	Student 3	Student 4	Student 5	
Simulation complexity	3	2	3	2	2	2	3	2	3	2	144
Technical issues	2	1	2	3	2	3	2	1	2	2	100
Inadequate data	3	4	3	3	4	3	4	3	3	3	272
False positive output	1	2	2	1	2	2	2	2	2	1	72

Table 2.2 Risk Analysis

- Initially, there are simulation complexities like selecting the exact toolbox and understanding the usage and internal specifications of it as we implement our ideas in the MATLAB and then we sorted out the issue by selecting classification learner from predictive maintenance toolbox and random source block from DSP System Toolbox library.
- The technical issues we faced were the generation of data and the error in codes, later on we sorted it out by debugging one by one.
- For the data generation we did not get any real time data for the fault prediction and later on we created synthetic data for the comparison of this data with the data from the ECU.
- At the very beginning of completing the coding for the fault prediction we faced inaccuracies in the prediction and later on we sorted it out by refining our code.

2.3 GANTT CHART

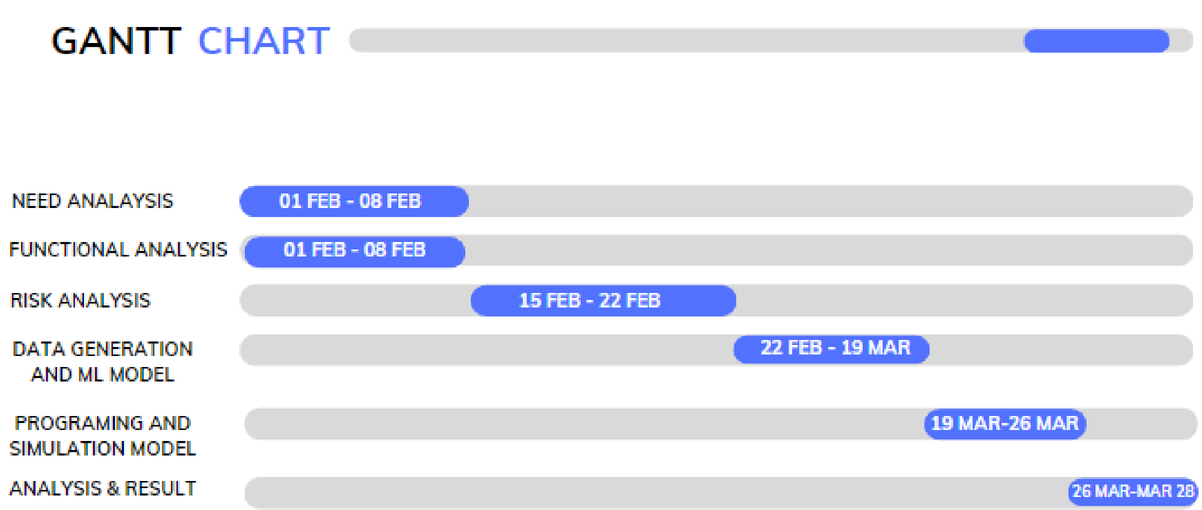

Figure 2.3 Gantt Chart

- We have represented the amount of work done or simulation completed in certain periods of time in relation to the amount planned for those periods using the Gantt chart.
- We planned and completed our need analysis and functional analysis within February 01- February 08.
- We planned and collected data from our respective team members and analyzed the risks using risk analysis and completed it within February 15- February 22.
- The main task for us was to create the datasets , As it wasn't readily available .So we decided to create our own data set using a random source block from DSP System Toolbox library and Machine Learning from Classification learner app in MATLAB and we planned to create our dataset within February 15 - March 19.
- We needed to create a code and simulation model to replicate the fault and good data and analyze and detect the fault . We planned to complete our block within March 19 - March 26.
- We planned to analyze and produce our required output within March 26 - March 28 .

2.4 FUNCTIONAL SPECIFICATIONS

2.4.1 FAST DIAGRAM

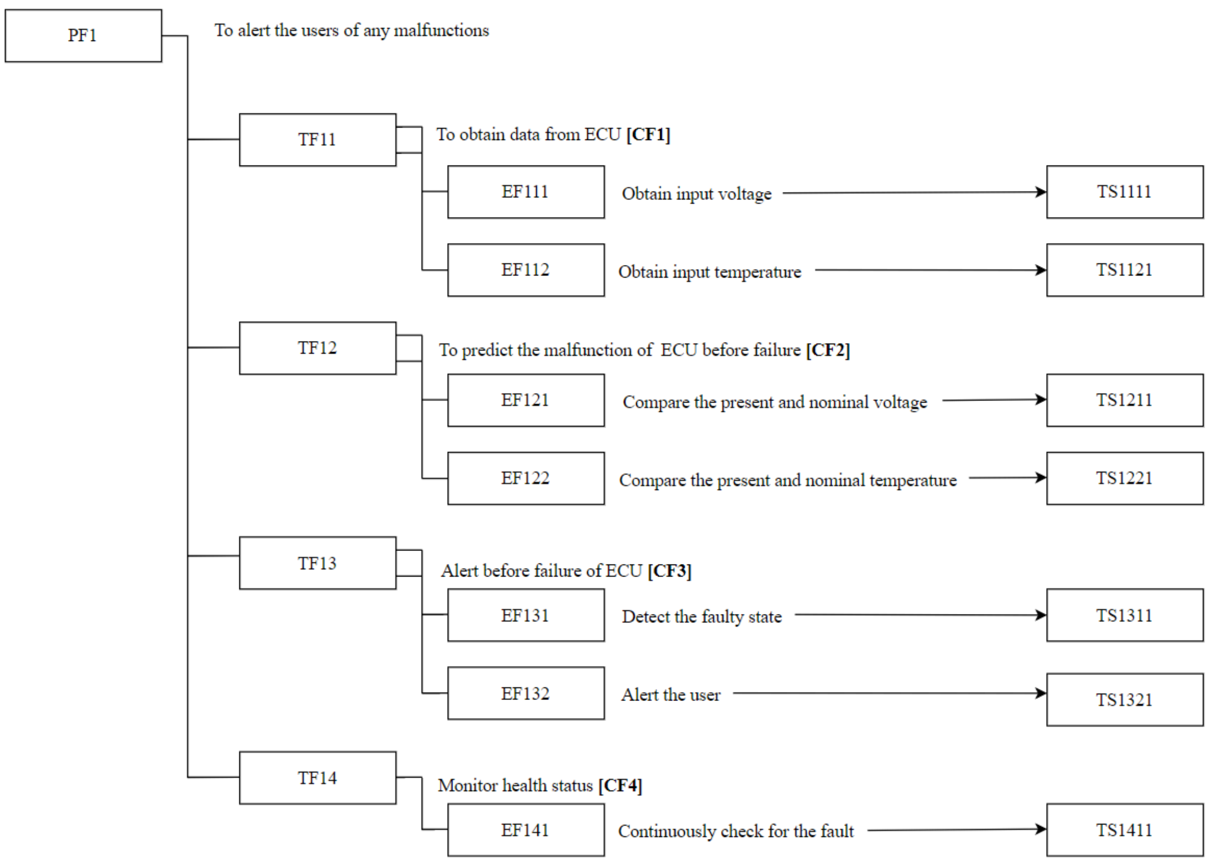

Figure 2.4 Fast Diagram

We used a FAST diagram to represent the complex technology behind the project in a simple chart and to identify the interaction between the different functions .

- The Primary Function of our project is to alert the user of any kind of malfunction in the ECU.
- Our first technical function is to obtain data from the ECU and it has two elementary functions to obtain input voltage and temperature.

- Our second technical function we have is to predict the malfunction of ECU before failure and it has two elementary functions to compare the present and nominal values of voltage and temperature.
- Our third technical function we have is to alert the user about the malfunction of ECU before failure and it has two elementary functions to detect the faulty state and to alert the user.
- Our fourth technical function we have is to monitor the health status of ECU and its elementary function is to continuously check for fault .

CHAPTER 3

PROPOSED SYSTEM

3.1 PROPOSED SYSTEM

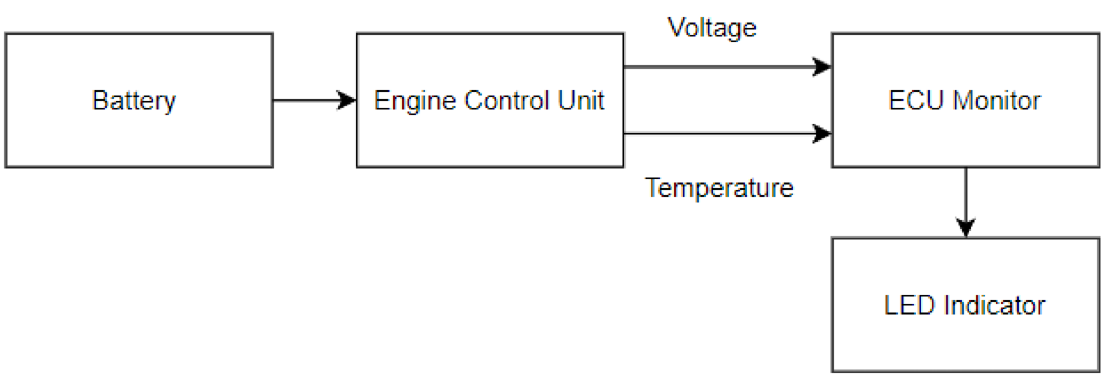

Figure 3.1 Block diagram of ECU monitor

We propose a system that monitors the Voltage and Temperature of the ECU to predict faults using Machine Learning. The system obtains live Voltage and Temperature data from the ECU and the signals are evaluated by a Classification model which provides an output signal indicating the status of the Engine Control Unit. The output signal is visualized by an LED which provides an indication to the user regarding the status of the Engine Control Unit. The Voltage and Temperatures are logged on to a table which is then passed on to the trained Classification model which classifies the data as “Healthy” or “Faulty”. The Classification model was trained using synthetic data obtained from specifying the threshold values as mentioned in 2.4.1 and 2.4.2 in the Random Source Block under the DSP System Toolbox library in MATLAB. The system uses the Classification ‘fine tree’ algorithm to predict the occurrence of faults .

3.2 MACHINE LEARNING

Machine Learning algorithms are the programs that can learn the hidden patterns from the data, predict the output, and improve the performance from experiences on their own. Different algorithms can be used in machine learning for different tasks, such as simple linear regression that can be used for prediction problems like stock market prediction, ECU monitoring and the KNN algorithm can be used for classification problems.

Types of machine learning

Machine Learning Algorithm can be broadly classified into three types:

1. Supervised Learning Algorithms
2. Unsupervised Learning Algorithms
3. Reinforcement Learning algorithm

1) Supervised Learning Algorithm

Supervised learning is a type of Machine learning in which the machine needs external supervision to learn. The supervised learning models are trained using the labeled dataset. Once the training and processing are done, the model is tested by providing sample test data to check whether it predicts the correct output.

The goal of supervised learning is to map input data with the output data. Supervised learning is based on supervision, and it is the same as when a student learns things under the teacher's supervision. The example of supervised learning is spam filtering.

Supervised learning can be divided further into two categories of problem :

- Classification
- Regression

Examples of some popular supervised learning algorithms are Simple Linear regression, Decision Tree, Logistic Regression, KNN algorithm, etc.

2) Unsupervised Learning Algorithm

It is a type of machine learning in which the machine does not need any external supervision to learn from the data, hence called unsupervised learning. The unsupervised models can be trained using the unlabelled dataset that is not classified, nor categorized, and the algorithm needs to act on that data without any supervision. In unsupervised learning, the model doesn't have a predefined output, and it tries to find useful insights from the huge amount of data. These are used to solve the Association and Clustering problems. Hence further, it can be classified into two types:

- Clustering
- Association

Examples of some Unsupervised learning algorithms are K-means Clustering, Apriori Algorithm, Eclat, etc.

3) Reinforcement Learning

In Reinforcement learning, an agent interacts with its environment by producing actions, and learns with the help of feedback. The feedback is given to the agent in the form of rewards, such as for each good action, he gets a positive reward, and for each bad action, he gets a negative reward. There is no supervision provided to the agent. The Q-Learning algorithm is used in reinforcement learning.

These are the machine learning types which are present .The machine learning model we used for our project is Classification which comes under Supervised Learning . For using the classification app in MATLAB we should have any one of the machine learning algorithms . We use decision trees for classification.

3.3 DECISION TREE

Decision trees are a popular machine learning algorithm that can be used for both regression and classification tasks. They are easy to understand, interpret, and implement, making them an ideal choice for beginners in the field of machine learning[7]. In this comprehensive guide, we will cover all aspects of the decision tree algorithm, including the working principles, different types of decision trees, the process of building decision trees, and how to evaluate and optimize decision trees.

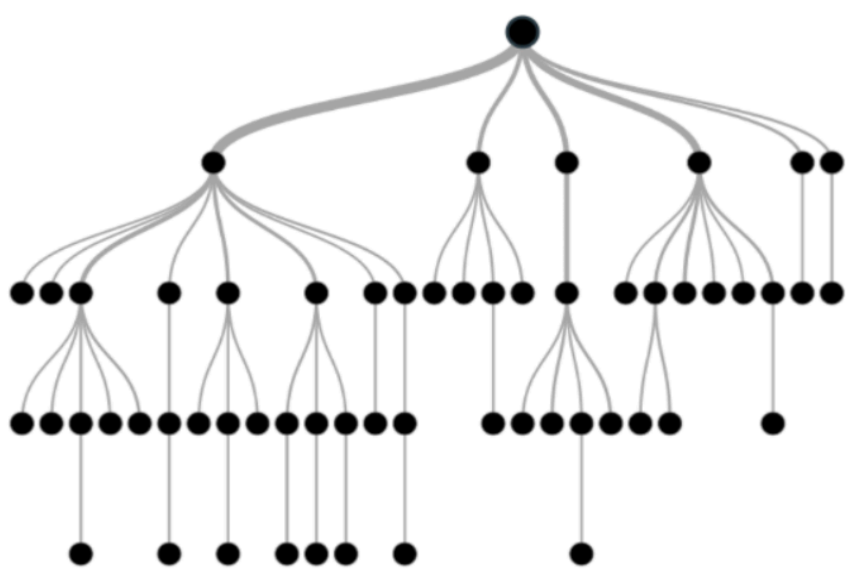

Figure 3.2 Decision tree

It is a tool that has applications spanning several different areas. Decision trees can be used for classification as well as regression problems. The name itself suggests that it uses a flowchart like a tree structure to show the predictions that result from a series of feature-based splits. It starts with a root node and ends with a decision made by leaves. Some of the basic terminologies used in Decision trees are

- Root Nodes – It is the node present at the beginning of a decision tree from this node the population starts dividing according to various features.
- Decision Nodes – the nodes we get after splitting the root nodes are called Decision Node
- Leaf Nodes – the nodes where further splitting is not possible are called leaf nodes or terminal nodes
- Sub-tree – just like a small portion of a graph is called sub-graph similarly a subsection of this decision tree is called sub-tree.
- Pruning – is nothing but cutting down some nodes to stop overfitting.

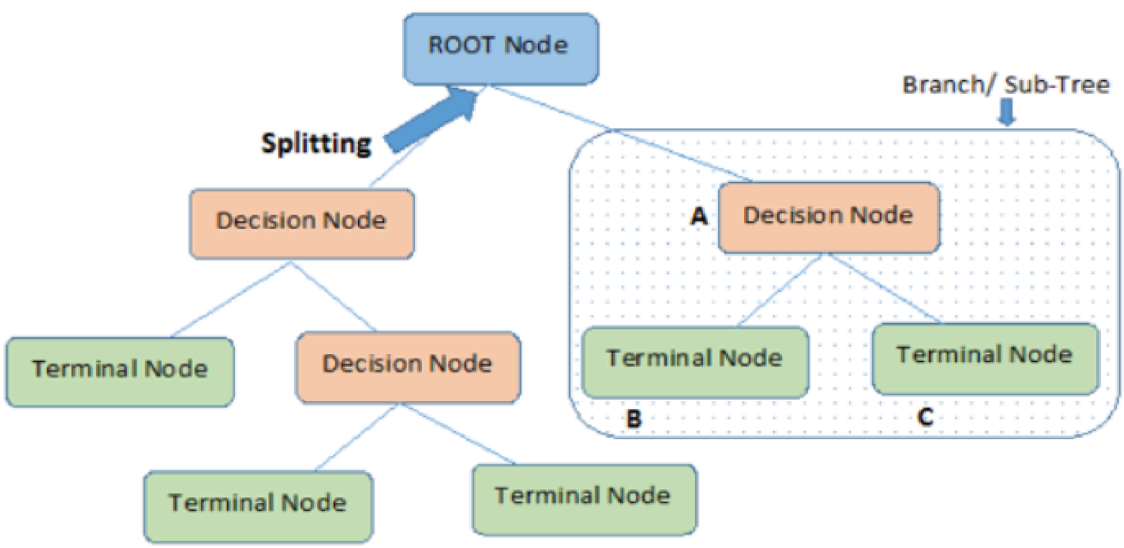

Figure 3.3 Terminologies of Decision tree

We used a fine tree model in a classification learner app to train a machine learning model and obtain an accuracy and confusion matrix.

3.4 FINE TREE ALGORITHM

The Fine tree model can be performed using the Classification Toolbox in the MATLAB environment. In this environment, decision trees are given as three separate structures. The first building is the most complex 'Fine' decision trees among the three[8]. The second is ‘Medium’ and the third is the ‘Coarse’ decision tree structure. In this study, these three DT structures were designed to estimate wind speed. The Gini index was selected for all three decision trees. The data set was obtained and arranged before the decision tree models were created.

The Fine-Tree algorithm is a classification machine learning algorithm that is designed to handle imbalanced datasets, where the number of examples in each class is not equal. It is a modification of the popular decision tree algorithm, and it works by building multiple decision trees on different subsets of the data and then combining them into a single model.

The Fine-Tree algorithm begins by randomly selecting a subset of the majority class and all of the minority class examples. It then builds a decision tree on this subset of data. This process is repeated multiple times with different subsets of data, and each time a new decision tree is built.

The output of the Fine-Tree algorithm is a combination of all the decision trees that were built during the process. To classify a new example, the algorithm uses each of the decision trees to predict the class of the example. The final prediction is determined by a voting mechanism, where each decision tree casts a vote for the class it predicted. The class with the most votes is then selected as the final prediction.

The Fine-Tree algorithm has several advantages over traditional decision tree algorithms, particularly when dealing with imbalanced datasets. By building multiple decision trees on different subsets of the data, the Fine-Tree algorithm is able to capture more of the minority class examples, which can improve the overall accuracy of the model. Additionally, the voting mechanism used to combine the decision trees can help to reduce the impact of noisy or irrelevant features in the data.

However, the Fine-Tree algorithm does have some limitations. Building multiple decision trees can be computationally expensive, particularly for large datasets. Additionally, the algorithm can be sensitive to the specific subsets of data that are chosen for each decision tree, which can lead to variability in the performance of the model.

3.5 CLASSIFICATION LEARNER APP

The Classification Learner app trains models to classify data. Using this app, you can explore supervised machine learning using various classifiers. You can explore your data, select features, specify validation schemes, train models, and assess results. You can perform automated training to search for the best classification model type, including decision trees, discriminant analysis, support vector machines, logistic regression, nearest neighbors, naive Bayes, kernel approximation, ensemble, and neural network classification.

You can perform supervised machine learning by supplying a known set of input data (observations or examples) and known responses to the data (labels or classes). You use the data to train a model that generates predictions for the response to new data. To use the model with new data, or to learn about programmatic classification, you can export the model to the workspace or generate MATLAB code to recreate the trained model.

CHAPTER 4
SIGNAL GENERATION

4.1 DATA FOR TRAINING ML MODEL

The data required for training the classification model was obtained from the random source block under DSP System Toolbox in MATLAB. Due to unavailability of data sets regarding Voltage and Temperature of ECUs so synthetic data was obtained from threshold values [1][2]. For the sake of training the classification model a table was created with randomly generated values along with its fault labels indicating if the particular data the point lies inside or outside the threshold limit of Temperature and Voltage. The data that was generated was with a ±6% limit to the specified threshold.

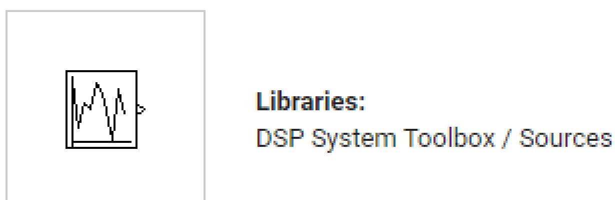

Figure 4.1 Random block

4.2 LIVE HEALTHY DATA

Since the classification models was designed to predict faults above ±6% limit to the specified threshold the random source block was configured to produce signals within those limits to simulate a healthy ECU.

For obtaining healthy voltage levels the ‘Random source’ block was configured such that the minimum threshold is 11.844 V and the maximum threshold is 13.356 V allowing a $\pm$6% leeway to the specified nominal voltage.

For obtaining healthy temperature levels the ‘Random source’ block was configured such that the minimum threshold is 0 and the maximum threshold is 132.5.

4.3 LIVE FAULTY DATA

For generating faulty data which represents a malfunctioning ECU the random source block was configured in such a way that the output is allowed to vary beyond the imposed limit of healthy data.

For obtaining faulty voltage levels the ‘Random source’ block was configured such that the minimum threshold is 11.2 V and the maximum threshold is 13.8 V allowing a $\pm$6% leeway to the specified nominal voltage.

For obtaining faulty temperature levels the ‘Random source’ block was configured such that the minimum threshold is -40 and the maximum threshold is 137.

CHAPTER 5
MACHINE LEARNING MODEL

For our application we are considering two parameters for detection of fault: Voltage and Temperature. Hence we created two classification models for each with the synthetic data obtained. For the creation of ML models the Classification Learner app from MATLAB was utilized.

5.1 FEATURE ENGINEERING

The data obtained from the simulated ECU was obtained as a time series data. This time series data was converted into a table and the obtained 100,000 rows was split into 10 signals with 10,000 rows for each signal by adding a column "Unit" which ranges from 1 to 10 specifying each signal.

Then for the training the classification algorithm another column was introduced to indicate if the specific datapoint was above or below the threshold values defined for Voltage and Temperature.

5.2 CONFUSION MATRIX

A confusion matrix is a matrix that summarizes the performance of a machine learning model on a set of test data. It is often used to measure the performance of classification models, which aim to predict a categorical label for each input instance. The matrix displays the number of true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN) produced by the model on the test data.

For binary classification, the matrix will be of a 2X2 table, For multi-class classification, the matrix shape will be equal to the number of classes i.e for n classes it will be nXn.

A 2X2 Confusion matrix is shown below for the image recognition having a Dog image or Not Dog image.

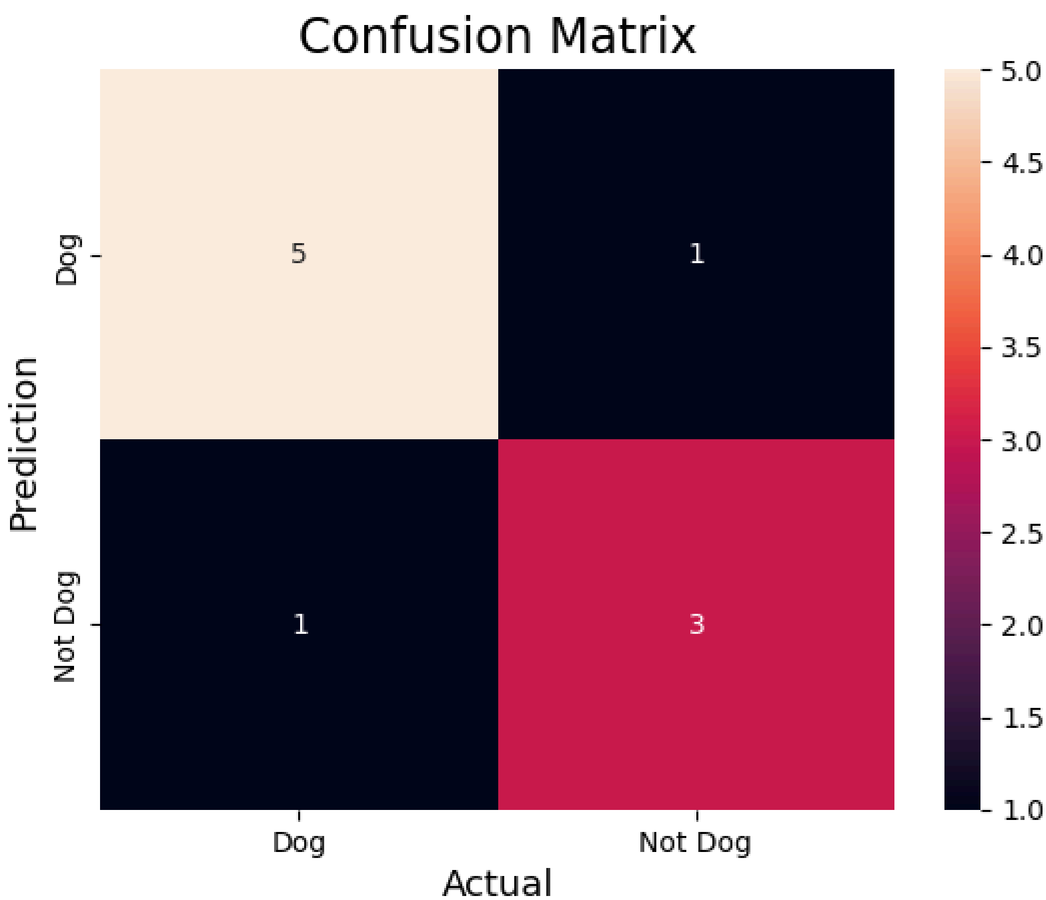

Figure 5.1 Confusion Matrix

5.3 VOLTAGE MODEL

The training data was obtained from the random source block using the ‘To Workshop’ block in Simulink. The data was then visualized using a table. 10 signals for Voltage were obtained with each containing 10,000 data points with a total of 100,000 data points.

Then the data set was provided to the Classification Learner App where the predictors and response variables were set as “Random Source:1” (name of the column for Voltage readings in the voltage dataset) and “FaultCode” respectively. For the classification Cross Validation Scheme was utilized. The model produced an accuracy of 100% when run with the tree selected as ‘fine tree’.The corresponding Confusion matrix was:

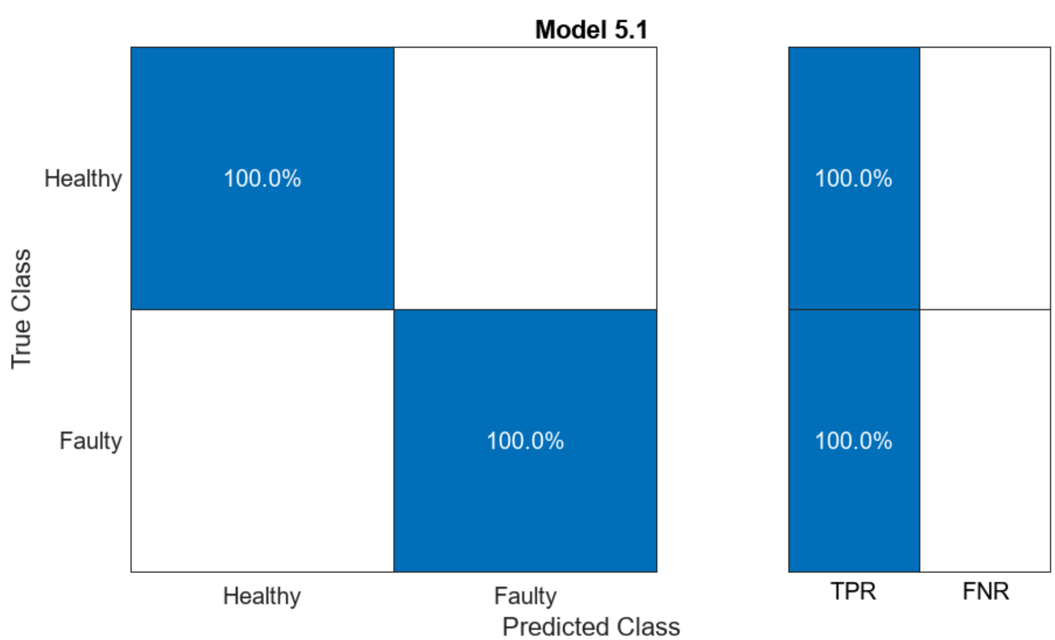

Figure 5.2 Machine Learning Trained Model for Voltage

5.2 TEMPERATURE MODEL

The training data was obtained from the random source block using the 'To Workshop' block in Simulink. The data was then visualized using a table. 10 signals for Temperature were obtained with each containing 10,000 data points with a total of 100,000 data points as done for the Voltage model.

Then the data set was provided to the Classification Learner App where the predictors and response variables were set as "Random Source:2" (name of the column for Temperature readings in the voltage dataset) and "FaultCode" respectively. For the classification Cross Validation Scheme was utilized. The model produced an accuracy of 100% when run with the tree selected as 'fine tree'.

The corresponding Confusion matrix was:

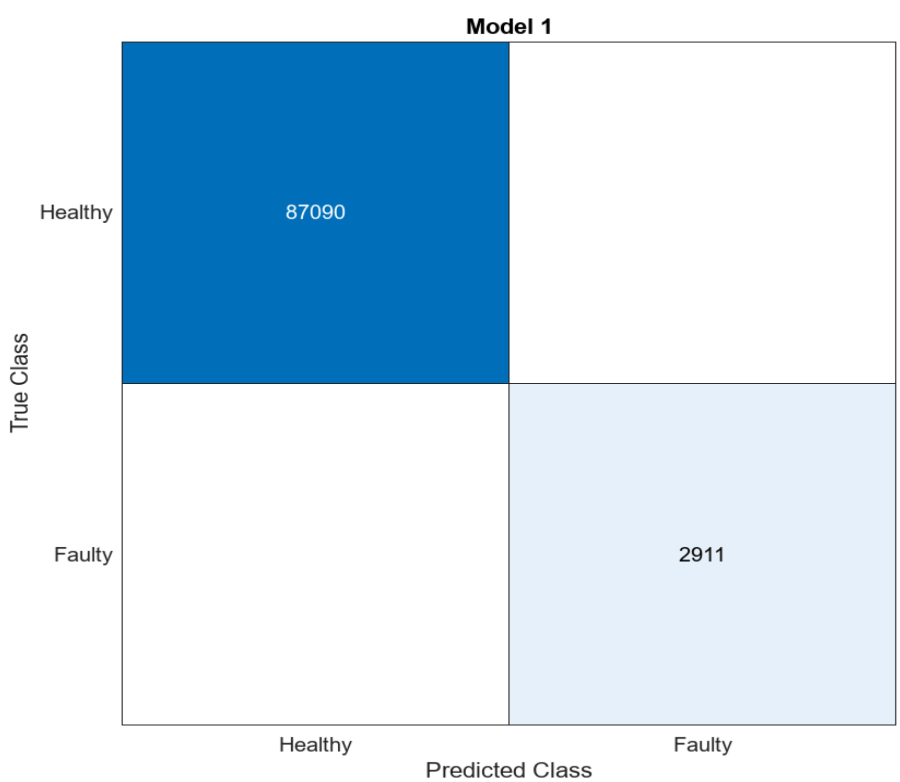

Figure 5.3 Machine Learning Trained Model for Temperature

5.3 MODEL EXTRACTION

After the training and testing the models with the training data sets the model was extracted to the workshop as variables “trained model” and “trainedmodelTemp” for Voltage model and Temperature model respectively. For utilizing the model for predictions of actual data from the ECU the predictFcn() function was used and the table containing the data from the ECU was passed as an argument. The model completes the prediction and outputs an array containing output which specifies the status of the signal. This array was used to provide an indication signal .

CHAPTER 6

PROGRAM AND FINAL MODEL

6.1 PROGRAM

To integrate the machine learning models with the Simulink simulation a matlab script has been created which does the following functions: log data, tabular data, and predict faults.

The below flowchart depicts the flow of the matlab script.

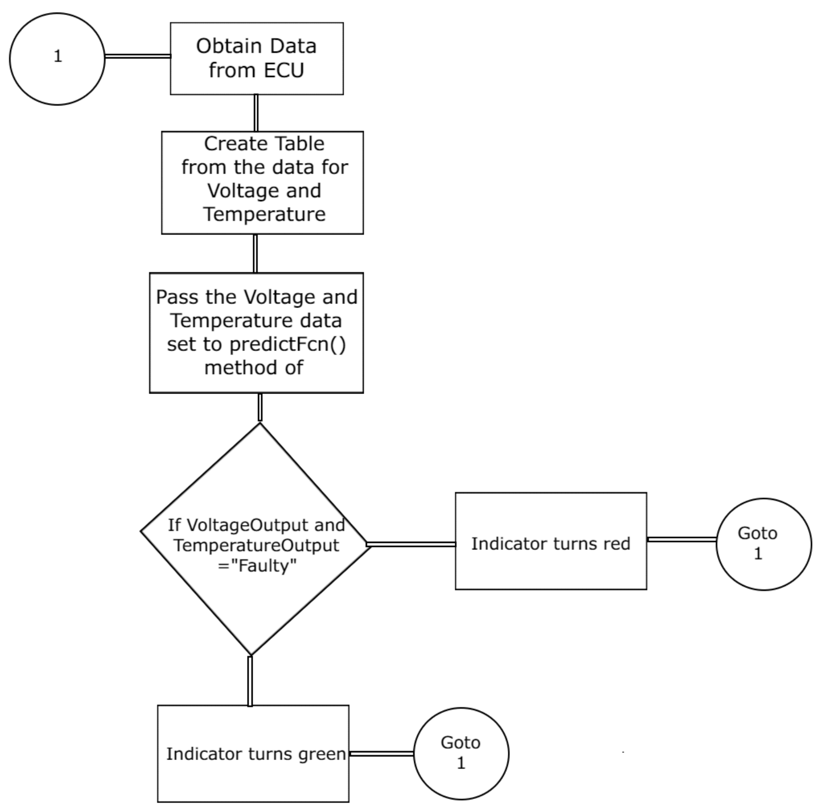

Figure 6.1 Matlab Script flow

The script first runs the simulink model to log data from the ECU. The logged data is sent to the workshop as time series data using the ‘To Workshop’. This time series data is converted to a tabular format for Voltage and Temperature data. Then the data is then converted into a format that can be passed onto the classification models. These Voltage and Temperature Tables are then passed onto the predictFcn() method of the corresponding Classification models as an argument. These Classification models output an array containing the predicted response which is either “Healthy” or “Faulty”. This array is produced by both the Voltage and Temperature models. The responses present in the arrays are used for producing an output signal for the indicator to produce respective indications to the user.

6.2 SIMULATION MODEL

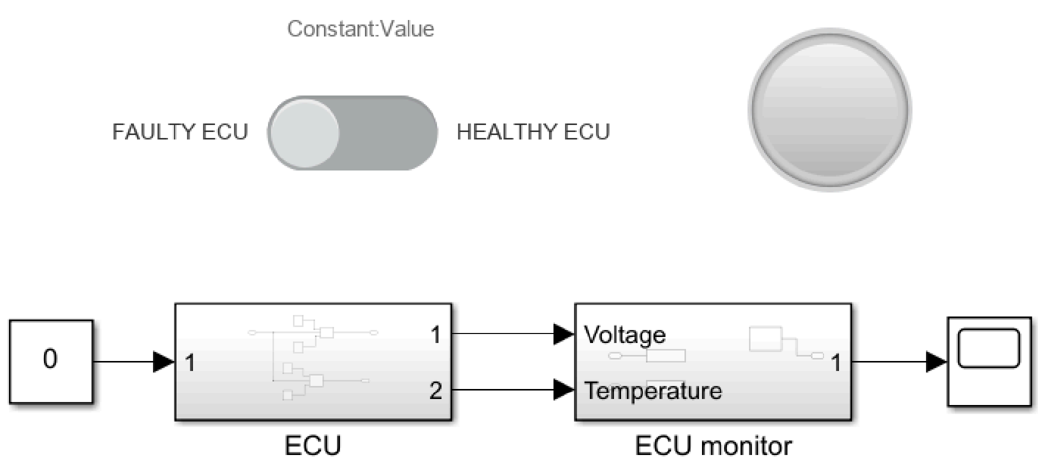

Figure 6.2 Simulation model

We have implemented our idea in the above simulation model. The simulation model consists of a constant block, ECU, ECU monitor and scope. The constant block is integrated with the slider switch dashboard icon which is present in the simulink dashboard library and is used to control whether the ECU must output the nominal voltage and temperature or faulty voltage and temperature. The switch simply switches the value of the constant block either one(healthy) or zero(faulty). When the switch is in the Healthy ECU side the ECU output voltage and temperature will be nominal. When the switch is in Faulty side the ECU output voltage and temperature will be faulty.

6.2.1 ECU

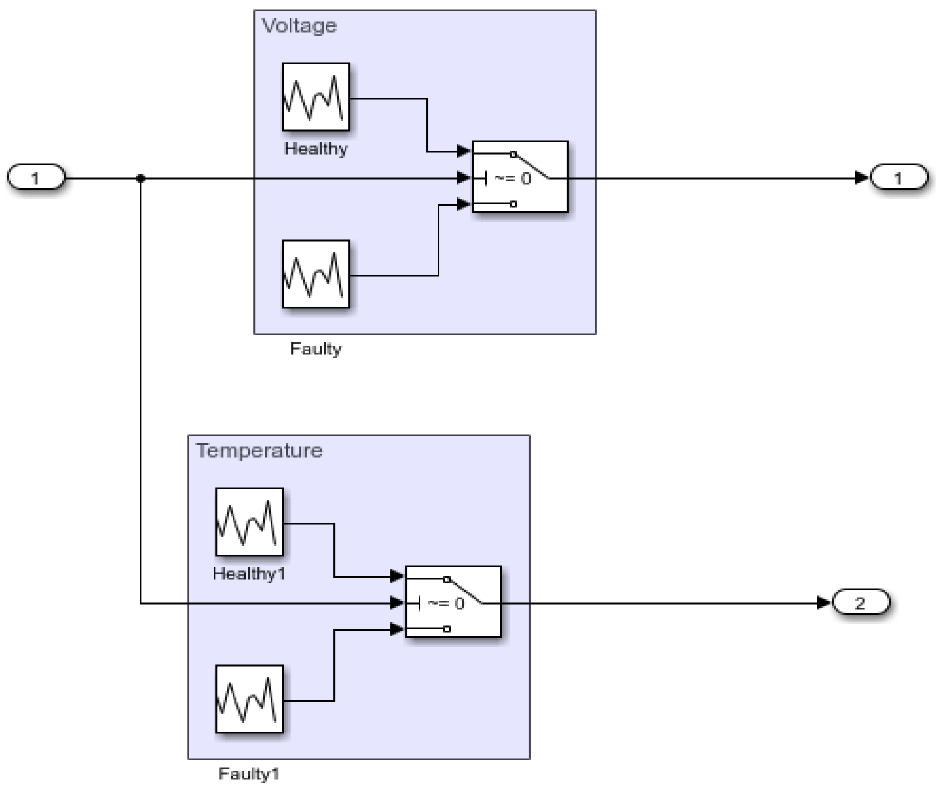

Figure 6.3 ECU Block in MATLAB

The above subsystem is the ECU block, this is not actually an ECU since a full fledged ECU model is not available in MATLAB we have used two sets of random source blocks to replicate the output data of voltage and temperature synthetically which will be obtained during the healthy and faulty conditions. Based on the value of the switch it will give either healthy or faulty output which will be further sent to the ECU monitor block for fault prediction.

6.2.2 ECU MONITOR

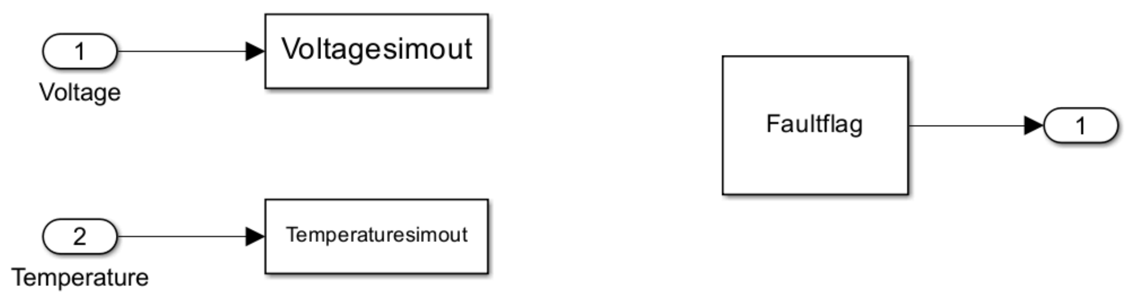

Figure 6.4 ECU Monitor Block in MATLAB

This subsystem represents the ECU monitor block. This block contains three main components. There are two which go to the workspace block and one from the workspace block. Using the go to workspace block the synthetic voltage and temperature data obtained from the ECU replica is sent to the workspace as time series data. From the workspace the voltage and temperature data is given to the matlab script. The matlab script processes the voltage and temperature data and sets the Fault flag if fault is predicted or resets the Fault flag if it is healthy. This Fault flag data will be present in the workspace. In order to do this the form workspace block is used. If the Fault flag is set then the led will glow red in color to indicate it has predicted fault in the ECU. If the Fault flag is reset the led will glow green in color to indicate the ECU is in healthy condition. Based on the color of the indication the end user is able to find whether the ECU is in healthy condition or not.

6.2.3 WORKING

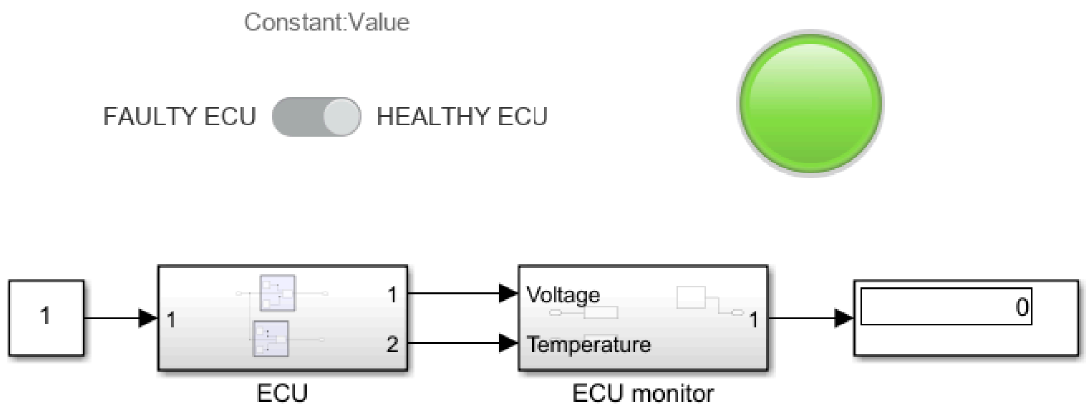

Figure 6.5 Healthy ECU Indication

In this simulation the switch is towards the Healthy ECU side making the value of the constant block to be one. This will make the ECU output the nominal voltage and temperature data. Based on the prediction done by the trained model the fault flag is reset. As a result the led glows green in color indicating healthy ECU.

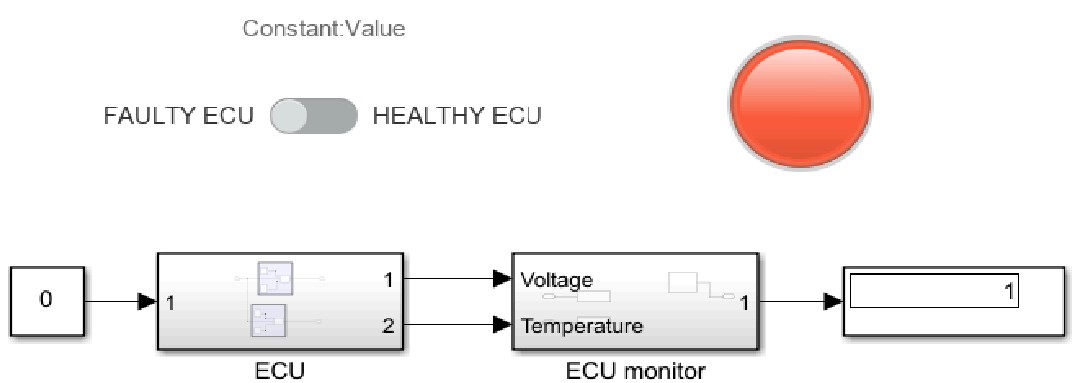

Figure 6.6 Faulty ECU Indication

In this simulation the switch is towards the Faulty ECU side making the value of the constant block to be zero. This will make the ECU output the faulty voltage and temperature data. Based on the prediction done by the trained model the fault flag is set. As a result the led glows green in color indicating healthy ECU.

CHAPTER 7
CONCLUSION

In this project, we have tried to present a comprehensive research work in the field of Automobile for Analyzing the predefined values of Engine Control Unit with the current values and predicting the failure of Engine Control unit before malfunctioning. We have implemented a comprehensive Engine Control Unit monitoring using a supervised machine learning approach. The aim of our comprehensive Engine Control unit monitor is to meet all the research objectives that we have mentioned in Introduction. We studied compressively the strength of various state-of-the-art classifiers (SVM, NB, DTC) on several syntactic and semantic features and various machine learning algorithms. In order to enhance the performance of our Engine control unit monitor we used an finite tree approach algorithm . We created our own synthetic data using random source block from DSP system toolbox .Then the data set was provided to the Classification Learner App where the predictors and response variables were set as “Random Source:1” (name of the column for Voltage readings in the voltage dataset) and “FaultCode” respectively. For the classification Cross Validation Scheme was utilized. The model produced an accuracy of 100% when run with the tree selected as ‘fine tree’ and using which we predicted the current state of the engine control unit and will check whether the engine control is working fine or if any error will occur and display it to the user using light indications .

7.1 PROJECT OUTCOME

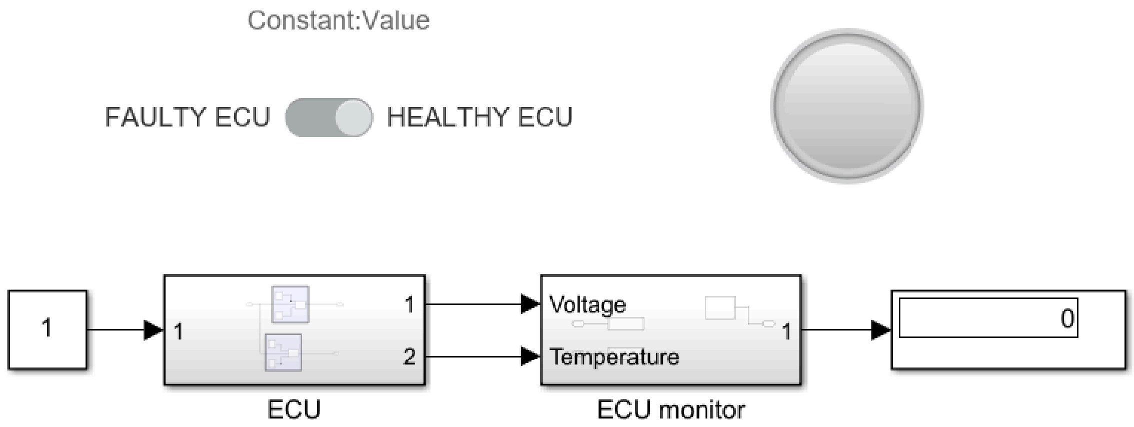

Figure 7.1 Simulink Model

Hence an attempt is made to design a simulation which predicts the malfunction of Engine Control Unit(ECU) and display it to the user .We have succeeded in designing a simulink model in MATLAB which compares the faulty data and the predefined value and predicts the malfunction . Hence a design model which is used to indicate any kind of malfunction occurs in the Engine control unit.

7.2 FUTURE SCOPE :

The future scope of Electronic Control Unit (ECU) monitoring systems is quite broad, as the technology is becoming increasingly important in modern vehicles. Here are some potential areas where ECU monitoring systems may play a significant role in the future .

- Autonomous vehicles: As the development of self-driving cars continues to progress, ECU monitoring systems will be essential for ensuring the safe and reliable operation of these vehicles. These systems can monitor the status of various sensors, processors, and other components to detect any potential issues that could affect the vehicle's performance or safety.

- Predictive maintenance: ECU monitoring systems can also be used for predictive maintenance, allowing vehicles to detect and address issues before they become serious problems. This could potentially save vehicle owners a lot of money in repair costs, as well as prevent accidents caused by faulty components.
- Real-time data analysis: ECU monitoring systems can provide real-time data about a vehicle's performance, including information about fuel efficiency, engine output, and other key metrics. This data can be used to optimize vehicle performance, reduce emissions, and improve overall efficiency.
- Improved cybersecurity: ECU monitoring systems can also play a key role in improving vehicle cybersecurity. By monitoring the status of various systems and detecting any potential breaches or attacks, these systems can help prevent cybercriminals from gaining access to sensitive data or taking control of the vehicle.

Overall, the future of ECU monitoring systems is likely to be focused on improving the safety, reliability, and efficiency of vehicles, while also enhancing cybersecurity and providing valuable data insights.

7.3 EXPECTED IMPROVEMENTS:

Although the main objective of this project is achieved, we want to enhance this project as an Add-on device to all kinds of Automobiles. We want to expand the connection of the module to various devices so that the Engine Control Unit can be monitored and we can detect any kind of malfunction in an automobile before it occurs. More accurate measurements and fast response is also considered as a major improvement . There are several expected improvements in the ECU monitoring system that could enhance its capabilities and make it more effective. Here are some of the key areas where we like to improve:

- More advanced sensor technology: As sensor technology continues to advance, we can expect to see more sophisticated sensors that can provide more detailed data about the vehicle's performance. This data can be used to monitor the status of various components and detect any potential issues before they become serious problems.
- Machine learning and AI: With the advent of machine learning and artificial intelligence, ECU monitoring systems can become smarter and more capable of detecting potential issues. These systems can use data from various sensors to learn about the vehicle's normal operating patterns and quickly identify any deviations from those patterns that could indicate a problem.
- Increased connectivity: As vehicles become more connected, ECU monitoring systems can become more effective at monitoring the vehicle's performance in real-time. This connectivity can allow the ECU monitoring

system to communicate with other systems in the vehicle and make adjustments to optimize performance and efficiency.

- Improved cybersecurity: With the increasing threat of cyber attacks, ECU monitoring systems will need to become more robust and secure to prevent breaches. This could involve implementing more sophisticated encryption methods, as well as developing new techniques for detecting and responding to cyber attacks.

Overall, we can expect to see significant improvements in the ECU monitoring system in the coming years, as technology continues to advance and new challenges arise. These improvements will help to enhance the safety, reliability, and efficiency of vehicles, while also improving cybersecurity and providing valuable data insights.

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