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THOMSON REUTERS

[Agrawal* *et al.*,7(7): July, 2018]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ARCHITECTURE FOR MOTO MONITORING SYSTEM FOR VEHICLE

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DOI: 10.5281/zenodo.1312728

ABSTRACT

"Would you not prefer to ride a vehicle with the smart inbuilt system which scans all the component of your vehicle and predict any fault or failure in real time and give you a smooth driving experience?"
Despite some serious advancement in vehicle system including an intelligent infrastructure and many different interactive driver assistance system, there are still some major drawbacks which needs to be resolved efficiently and effectual. Generally, drivers expect a smooth ride but during any component failure the whole vehicle system is affected which in turn affects the riding experience of driver. Every machinery regardless of how good manufacturing is done, eventually gets affected directly or indirectly by the surrounding and leads to complications in the system. The main problem domain in the existing vehicle system is inapt detection of fault and prediction of adverse actions caused by these faults. The improper functioning of vehicle system can only be detected if the driver experiences it explicitly. To find these problems user needs to visit a vehicle service centre for identifying the issue. This process is not user friendly because of the inordinate time and extravagant human effort.
Another problem discerned by us was that immediate help is not provided to resulting in decreased chances of faster recovery. The problem with the existing system is the need to communicate with emergency call center explicitly. "Now, envisage a smart system which monitors various car systems, predicts the system's behaviour and failure. A system is capable of detecting scale of damage done during accident and also capable of providing immediate help to victim without any human interaction?"
For such a smart system, detection of fault and prediction of action caused by these faults is very crucial. Thus, by the use of Internet of Things(Iot) and Machine Learning(ML) a digital twin of existing system can be devised which could be integrated in any vehicle.
For making a strong communication with user, the concept of "Digital Twin" is introduced in this solution which is better than any 3D model. Digital Twin of automobile will be created simulated by sensors data and real time decisions for better system monitoring experience and ease in understanding the component of system which is affected. After our machine learning algorithm identifies the defect in any component/system of vehicle, respective simulations will be sent to digital twin which will then be reflected on LCD (User Interface).

Keywords: Vehicle, sensors, Internet of Thing, Cloud, Cloud services.

I. INTRODUCTION

Automobile is one of the very important machinery which we use in our everyday life. But one can't afford to spend time in regularly checking their vehicles for any problem detection. Moreover, if a vehicle system fails then it directly or indirectly affects one's daily activities. In order to solve this glitch, we are proposing a solution which includes an additional system which is an integration of hardware and software.

Engine monitoring system includes a sound recorder used to record sound of engine whenever user need to monitor engine. The sound recorder will be capable of recording engine's sound and saving the files to a local memory of microcontroller. This will be sent to cloud with the help of a WiFi module. Certain other sensor's data including temperature sensor, smoke sensor, engine oil level sensor and rpm sensor will be saved on cloud. In cloud (for our proposed system we are preferring AWS cloud platform) the sound file will be analyzed using spectrograph analysis and other frequency curves. The collective data from sound analysis and other sensors' data will be fitted in machine learning algorithms; linear regression for monitoring different components and logistic regression for predicting engine system failure in percentage in near future.

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Fuel monitoring system will be capable of predicting the current mileage of the automobile, distance which can be covered with amount of fuel left and check for any oil leakages. Firstly, data from fuel tank will be collected and by using a weight sensor combined with fuel tank's base register and used as level sensor. Simultaneously reading from odometer/rpm sensor and speedometer will be collected and sent to cloud. Relational database will aid with data analytics and machine learning algorithm will be applied to predict real time mileage of vehicle and thereby predicting the total distance which can be covered with remaining fuel.

Battery is a very vital component in car as it will power all the electrical components in vehicle. Battery can be checked by using a voltage value sensor which will allow user to know battery status and also physical condition of battery with help of hydrometer sensor.

Tyre monitoring system allows to monitor tyre pressure and will also be able to detect puncture as soon as it takes place. Wheel alignment will be checked by using accelerometer and gyroscope sensors which will be connected to each rim of your vehicle.

Brake monitoring system will be monitoring the drum bakes used in vehicle. This system will predict the fault in physical components of brakes. Friction sensor will be used to find the friction coefficient, it will also use sound analyzer module which will determine any irrelevant brake drag.

The last system which will be included in our module is about accident detection which will detect accident of a vehicle and will also predict scale of damage done during accident. Based on this prediction, appropriate help will be provided to victim as soon as possible. Certain sensors including accelerometer, relays, gyroscope, air bag sensor and vibration will be used to detect accident and data from vehicle monitoring will be used to predict scale of damage done to the vehicle.

Data from all the above systems will be used for simulating digital twin which will be displayed on a LCD screen provided to user. Digital Twin of vehicle will reflect current monitoring status of each subsystem included in our vehicle monitoring system and will help users to better understand their vehicle's condition and will also predict any system failure which can occur in near future.

II. PHYSICAL ARCHITECTURE

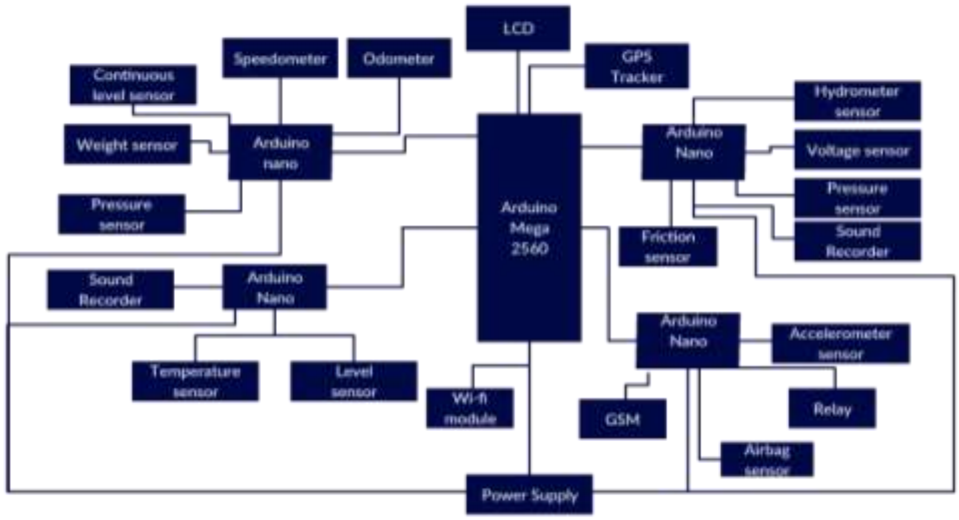

Figure 5: Physical Architecture

Sensors to generate data set

1. Devices:

In this section we are including all the devices which will be used for developing our physical working system . These sensors collect information about different components of the vehicle. The data is collected and sent to the microcontroller for processing.

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Microcontroller: The electrical signals from all the sensors are collected by the microcontroller. The microcontroller locally processes the data and converts them to JSON Object to be sent over the internet. This JSON object contains Id of the vehicle, Id of the sensor, an array of data with a timestamp.

JSON object is sent to cloud platform over MQTT (Message Queuing Telemetry Transport) Protocol. The microcontroller is configured as an MQTT publisher.

ESP8266 Wi-Fi Module: This is connected to the microcontroller which acts as an internetgateway to send data to the cloud.

- Oil temperature and level: This has two sensors that collect the temperature and level of oil which helps in analyzing the health of the vehicle.
- Engine temperature: This sensor will be used for identifying engine temperature.
- Engine Sound: The sound of the engine is collected using a high precision microphone. The sound samples are run against many possible fault sound recordings. This helps to predict the chance of failure and the part that may fail.
- rpm sensor-This sensor is included in almost all the vehicles which will be used by us to monitor our engine.
- Microphone-For recording sample of engine's sound.
- Speedometer-for detecting speed of vehicle continuously.
- Fuel capacity prediction system-This will give quantity of fuel in litres which is
- present in vehicle’s fuel tank.
- Odometer-This will give us distance covered by vehicle .
- Voltage sensor-this will give output voltage of battery.
- Hydrometer-This will be used for determining battery life of each cell.
- Pressure sensor-For determining pressure of each tyre.
- Friction sensor-For determining friction coefficient .
- Friction sensor-For determining friction coefficient .
- Microphone-For recording sample of brake drag sound.
- relays-For determining external damage in vehicle.
- accelerometer gyroscope sensor-This will be used for determining axis in which vehicle is aligned.
- Air bag sensor-For detecting strong impact .
- GSM module-For sending text to emergency contact.
- GPS tracker-For getting exact latitude and longitude of vehicle.

III. ML ALGORITHM USED IN ENGINE, FUEL, BRAKE AND TYRE SYSTEM

Algorithm for sound analysis used in Engine , Tyre and Brake System

Step 1: Load audio files
Step 2: Extract features from audio
Step 3: Convert the data to pass it in our deep learning model
Step 4: Run a deep learning model and get results

- Now let us load this audio in our notebook as a numpy array. For this, we will use librosa library in python. To install librosa, just type this in command linepip install librosa
- to extract features from this audio representations

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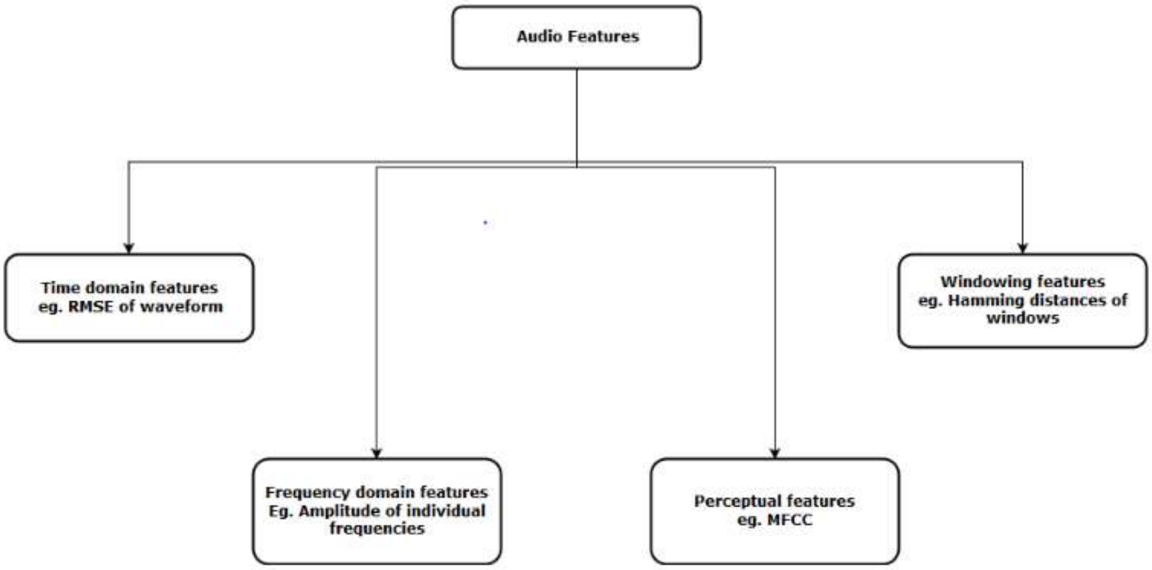


- for this purpose sampling is done
- choose and apply any classification model or deep learning onto that sampled data.

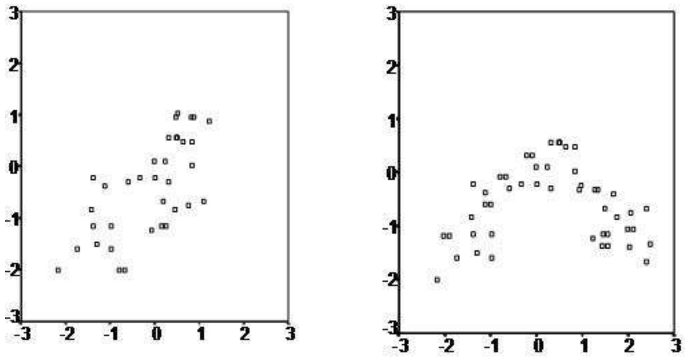
Algorithm for fuel system

Linear Regression Analysis consists of more than just fitting a linear line through a cloud of data points. It consists of 3 stages –

(1) analyzing the correlation and directionality of the data, (2) estimating the model, i.e., fitting the line, and (3) evaluating the validity and usefulness of the model.

Firstly, a scatter plot should be used to analyze the data and check for directionality and correlation of data. The first scatter plot indicates a positive relationship between the two variables. The data is fit to run a regression analysis.

The second scatter plot seems to have an inverse U-shape this indicates that a regression line might not be the



best way to explain the data, even if a correlation analysis establishes a positive link between the two variables. However, most often data contains quite a large amount of variability in these cases it is up for decision how to best proceed with the data.

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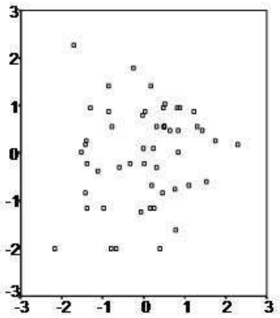
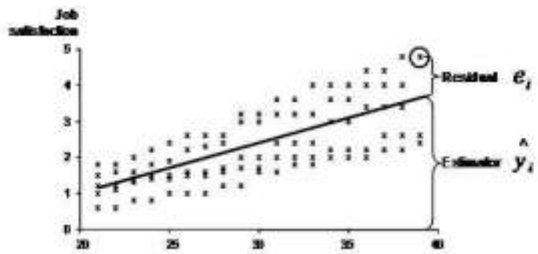


The first step enables the researcher to formulate the model, i.e. that variable X has a causal influence on variable Y and that their relationship is linear.

The second step of regression analysis is to fit the regression line. Mathematically least square estimation is used to minimize the unexplained residual. The basic idea behind this concept is illustrated in the following graph. In our example we want to model the relationship between age and job satisfaction. The research team has gathered several observations of self-reported job satisfaction and the age of the participant.



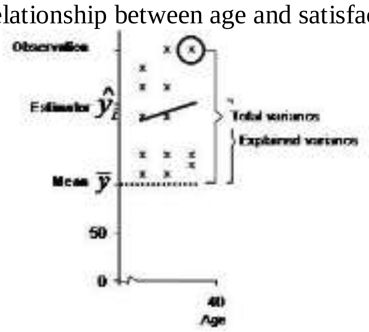
When we fit a line through the scatter plot, the regression line represents the estimated job satisfaction for a given age. However the real observation might not fall exactly on the regression line. We try to explain the scatter plot with a linear equation of y = b0 + b1x. The distance between the regression line and the data point represents the unexplained variation, which is also called the residual ei.

The method of least squares is used to minimize the residual.

$$\sum e_i^2 = \sum (y_i - \hat{y}_i)^2 = \sum (y_i - b_0 - b_1 x_i)^2 \rightarrow \min \quad \Rightarrow \hat{y}_i = b_0 + b_1 x_i$$

The result of this equation would for instance be yi = 1 + 0.1 * xi. This means that for every year of age we would expect an increase of 0.1 in job satisfaction.

Now that we got our equation we evaluate the validity and usefulness of the equation. The key measure to the validity of the estimated linear line is R^2. R^2 = total variance / explained variance. The following graph illustrates the key concepts to calculate R^2. In our example the R^2 is approximately 0.6, this means that 60% of the total variance is explained with the relationship between age and satisfaction.



As you can easily see the number of observations and of course the number of independent variables increases the R^2. However over-fitting occurs when the model is not efficient anymore. To identify whether the model is fitted efficiently a corrected R^2 is calculated, which is defined:

$$R^2_c = R^2 - \frac{J(1-R^2)}{N-J-1}$$

*J is the number of independent variables and N the sample size.

As you can see the larger the sample size the smaller the effect of an additional independent variable in the model. In our example $R^2c = 0.6 – 1(1-0.6)/95-1-1 = 0.5957$. Thus the model is quite well fitted with only one independent variable in the analysis.

The last step for the linear regression analysis is the test of significance. Linear regression uses two tests to test whether the found model and the estimated coefficients can be found in the general population the sample was drawn from. Firstly, the F-test tests the overall model. The null hypothesis is that the independent variables have no influence on the dependent variable. In other words the F-tests of the linear regression tests whether the $R^2=0$. Secondly, multiple t-tests analyze the significance of each coefficient and the intercept. The t-test has the null hypothesis that the coefficient/intercept is zero.

IV. TOOLS & ENVIRONMENT

Modeling

A model is three-dimensional representation of the thing. The physical system is an IoT enabled vehicle with many sensors. The 3D modeling of the vehicle is done using a suite of CREO and ANSYS software platforms. The model shows a schematic of the vehicle with all the sensors that are labeled and represented in the model. All the sensors are updated every few seconds to show the current value and status. The model is also using different color schemes to represent errors and health in the schematic virtual model of the vehicle. An example of this is engine temperature in degree celsius and green color representing the normal temperature of the engine. The model will receive data from the cloud and update it every few seconds depending on user preferences.

Simulation

Simulation is the imitation of the operation of a real-world process or system. To simulate a digital twin we first need its model. Simulation is used to test behavior and functions of the physical system on the virtual model. Simulation tools such as PTC CREO Software platform is used to simulate the model that was made earlier. The sample data set is generated using custom scripts for each sensor. This sample data set is then used to simulate the model in Creo software.

Cloud

- Amazon Web Services (AWS) is the platform that will be used for the facilitating data flow between physical devices and the digital twin. AWS provides many scalable, highly available, managed and fully managed services at minimum cost. In our system, we are using 5 managed services that are AWS IoT, AWS Kinesis, AWS DynamoDB, AWS Lambda and AWS API Gateway. All the services are fully compatible with each other.
- AWS IoT is used as an MQTT Broker for the collection of messages from all the edge devices.
- AWS Kinesis Streaming is used for ingestion of data and AWS Kinesis Analytics is used to perform near real-time analytics and machine learning.
- AWS DynamoDB fully managed highly scalable and cost-effective NoSQL database. It will be used for long-term storage of output from Kinesis Analytics.
- The Digital Twin displays the reports and device state. The user interface will refresh every few seconds based on the user preferences. Digital Twin device request AWS API Gateway for data.
- AWS API gateway receives API calls from many digital twin devices and responds them with the requested data in the required format. To get the data API Gateway can directly invoke an AWS Lambda function.

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- AWS Lambda is a serverless compute service. In simple word, we can run code without deploying a server. Lambda receives a request for data from API gateway and then run the code. The code queried to DynamoDB for the requested result which is processed and sent to the digital twin

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Saxena, C. (2018). ARCHITECTURE FOR MOTO MONITORING SYSTEM FOR VEHICLE. *INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY, 7*(7), 123-129.