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# Advanced Data Monitoring and Predictive Maintenance of Valves using IOT and Data Analytics

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**Abstract -** *This research paper will cover the monitoring of data through use of advanced technology and also the predictive maintenance of a mechanical equipment along with prediction model using data analytics with which the mechanical equipment can be continuously monitored and also predictions can be made based on the data available thus enabling us to predict the failures and thus avoid any breakdown. This research paper is mainly divided into parts which are IOT and Data Analytics. Efforts have been to put forth the entire work in terms of literature and thus will help the reader to have a clear and effective understanding of the concept and thus contribute to the knowledge of the reader*.

***Key Words***: **IOT, Valves, Fluid Machinery, Predictive Maintenance, Data Analytics, Mechatronics, Mechanical Device, Control Engineering, Instrumentation Engineering, Electronics Engineering.**

## 1.INTRODUCTION

In this research paper exhibits the application of IOT and Data Analytics onto a mechanical device which helps to control, monitor the behavior and the working conditions of a mechanical control device and also with data available a prediction model is been setup in order to predict the failure and thus avoid any breakdowns or accidents. This research paper will give an idea on use of these technologies on conventional mechanical control equipment with help of electronic sensors, programming of various parts has been done in order to facilitate wireless technology and thus achieving an interface which monitors, controls, predicts the actual working of the control equipment. In conclusion this research paper will showcase the application of wireless technology that can be implemented on mechanical device and also data analysis of the data that can be extracted through IOT.

## 2. Data Analytics

What is data analytics? Data analytics is process of analyzing the available dataset to find the insights of data and historical trends for solving problem and data driven decision making. It involves use of math, statistic, and computer techniques for converting raw data into actionable insights. It helps in getting the relationship between the independent and dependent variables which gives a clear linear representation about the dataset

How data analytics can be implemented on control equipment**:** Implementing data analytics on any control device helps in continuously monitoring and evaluating the data which helps to analyze the current condition and predict the future scenario of device. It helps in remotely monitor the data allowing to get the performance of device and take the preventive action on it. Data analytics has helped for analyzing the data and converting the raw dataset in multiple ways.

Manipulating data:

Data analytics helped selecting the true row and column removing the duplicate data reordering the data and also adding new data statistical summering the data

Regression analysis:

Finding the residuals in the data which allows us knowing errors in the raw dataset and also fitting the linear equation to observed data evaluating the model

Failure prediction:

With the use of linear regression and applying algorithms such as random forest on the datasets. Data analytics helped us in the predicting the further scenario of valve on which corrective action would be implemented.

The equation used for linear regression model

$Y=A+BX+E$

Where,

Y - Dependent variable

A - Intercept

B - Slope that change in dependent variable for unit change in independent variable

X- Independent variable

E - Error.

### 2.1 Methodology used for build prediction model

**1. Data collection:**

The data collected was of 3-way ball which involved two key variables the valve opening (Percentage) and the corresponding flow rate (liters per second)

**2. Manipulating and Filtration of data:**

The data collected was filtered by removing the unwanted and Garbage data and relevant data which would make a impact on the result was taken into consideration

**3. Model building by the actionable data:**

Based on the data available a model was built.

**4. Splitting the data:**

The data was split into two things that is test and train data where 80 percent of the data was allocated to train the model and 20 percent to test the model.

**5. Fitting the model:**

A linear regression line was generated by the model based on which the error in the model and data was Anomaly.

**6. Model prediction:**

The build model will predict the Subsequent values of the flow rate corresponding to the opening.

**7. Model evaluation:**

Evaluating the model involve checking the residual the mean, median standard error and r(square and finally plotting the results comparing it with observed and predicted value.

| Sl.no | Percentage Valve opening(%) | Flow Rate (Q) in mt^3/hr. |
|---|---|---|
| 1. | 0 | 0 |
| 2. | 10 | 18.073 |
| 3. | 20 | 28.200 |
| 4. | 30 | 41.350 |
| 5. | 40 | 58.890 |
| 6. | 50 | 76.450 |
| 7. | 60 | 104.668 |
| 8. | 70 | 128.812 |
| 9. | 80 | 150.696 |
| 10. | 90 | 173.563 |
| 11 | 100 | 187.596 |

**Fig-2.2:** Dataset used for analyzing

The about table represents the datasets of 3-way ball valve on which the analyses were being done. It consists of two variables (percentage opening and flow rate) here the percentage is independent variable and flow rate is dependent variable.

The opening is incremented by 10 unit each and corresponding flow rate is measured.

### 2.2 Logic for Code

Initially a package called "**Tidyverse**" was installed in which sub package are Designed

As the data set was obtained from the sensor was covered into Excel file this file was attached and was assigned to variable called "data"

For data visualization plots were created **qplo**t which is from **ggplot2** packages and this package is sub package designed inside the **Tidyverse** package

A linear regression was built by using lm() function with flow rate as dependent and opening as independent variable

Using the function predict () the model predicted certain values of flow rate for given values of opening.

Finally, a tabular column was created in which the comparison was shown between actual flow rate and predicted flow rate.

### 2.3 Data Visualization

Presenting of raw data in graphical form is called as data visualization various tools in data analytics are used such as scatter plot, box plot histogram, to get a graphical view of the datasets to understand and filtration of data into actionable data.

Using the various plots to visualize datasets made easier to understand and analyses the data quickly to known flow rate corresponding to opening is taking place and also looking at the trends rather than the numerical values facilitated to take the decision and explain the data more clearly.

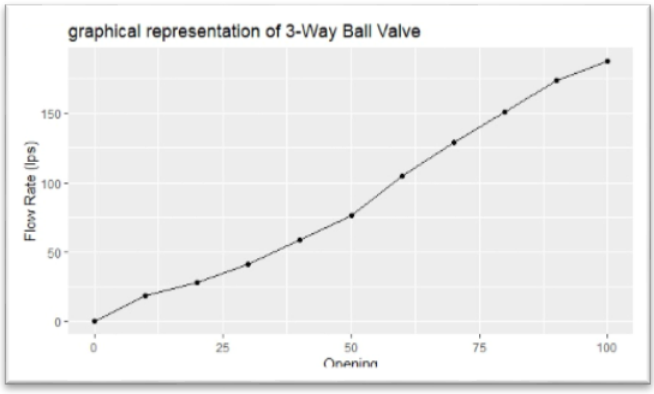


**Fig-2.3.1:** Line Graph For Data Visualization.

The figure 2.3.1 is depicting the line graph for 3-way ball valve having variables (flow rate and opening) the data point at bottom left corner indicates lowest flow rate corresponding to opening and the data point at top right indicates the highest flow rate corresponding to opening

As we can examine from the graph initially there is a gradual surge in the flow rate for certain range of opening yet opening range at 85 to 100 percent the change in flow rate is gradually reduced reason for this likely would be the turbulence which is resisting the flow rate of valve or another reason would be design constraint while manufacturing of the ball valve.

## 2.4 Linear Regression

In data analytics regression is a technique of predicting the depended variable based on the know or the related data.

It consists analyzing a linear equation the equation is combination of various independent variables which help to predict the dependent variable.

Linear regression helped me to understand and predict the data more accurately and it gave me an indication of what will be the flow rate for values of opening or vice versa also it is a super power in data analytics to reduce the errors in the data sets by plotting a straight line also called as best fit line.[1]

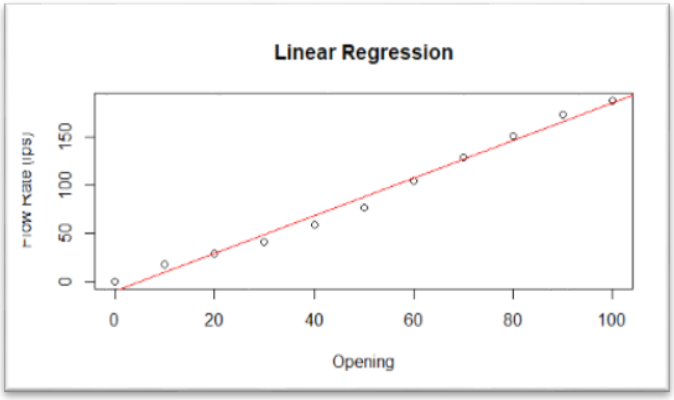


**Fig-2.4.1:** Graph using Linear Regression.

The figure 2.4.1 depicts linear regression applied on the dataset of 3-way ball valve where the x axis is displaying percentage opening and y axis is displaying flow rate at liters per sec.

Here the linear model is trying to plot a best fit line for the dataset of 3-way ball valve that is it trying to predict the dependent variable which in our case is Flow rate by using the data points of independent variable which in our case is percentage opening.

For each unit change in percentage opening the change in flow rate in 3way ball valve taking place.

## 2.5 Prediction Model

A Prediction model is used to predict or determine the values which may be required by the user. Here the model analyses the data available already and then predicts a value that is based on the dataset that was fed to the model.

| | Opening | `Flow rate lps` | predicted |
|---|---|---|---|
| | <dbl> | <dbl> | <dbl> |
| 1 | 0 | 0 | -9.62 |
| 2 | 10 | 18.1 | 9.91 |
| 3 | 20 | 28.2 | 29.4 |
| 4 | 30 | 41.4 | 49.0 |
| 5 | 40 | 58.9 | 68.5 |
| 6 | 50 | 76.4 | 88.0 |
| 7 | 60 | 105. | 108. |
| 8 | 70 | 129. | 127. |
| 9 | 80 | 151. | 147. |
| 10 | 90 | 174. | 166. |
| 11 | 100 | 188. | 186. |

**Fig-2.5.1:** Tabular column of Percentage Opening, actual flow rate and predicted values for flow rate.

The above table depicts the comparison between the actual flow rate and the predicted flow rate made by the model. The model predicted the flow rate corresponding to the opening.

From the table we can observe that at certain range of opening the model has predicted the approximate value for flow rate and this we can relate from the linear regression as the data points are close to the linear line the model has predicted the approximate values for the flow rate.

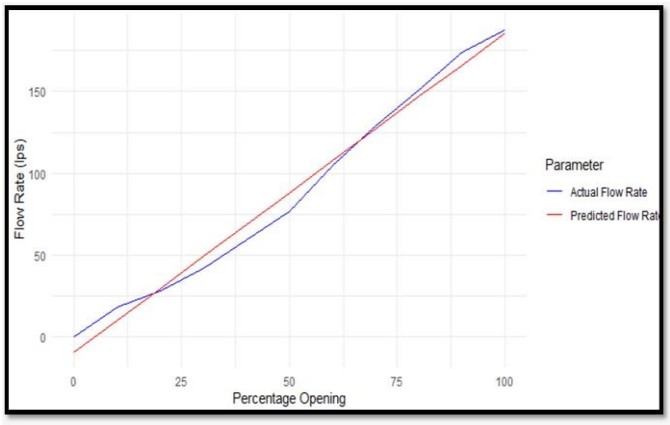


**Fig-2.5.2:** Graph representing Comparison between actual flow rate and predicted flow rate.

```
predict(model,data.frame(Opening=c(23,32,37,42,56,75,80,85)))
```

**Fig-2.5.3:** Input provided for model.

```
       1        2        3        4        5        6        7        8
35.30026 52.87587 62.64010 72.40433 99.74416 136.84823 146.61245 156.37668
```

**Fig-2.5.4:** Output based on input provided.

## 3. IOT

IOT stands for Internet of things it is an approach of achieving wireless connection through the use of software and electronics It helps in achieving a overall optimization of the systems, In the case of mechanical devices IOT helps in wireless monitoring through multiple devices by using WIFI and Bluetooth. It enables us in improving the systems which require continuous monitoring and devices which need to be controlled remotely. With the use of IOT such modifications and optimization of the systems is possible.[2][3][4]

### 3.1 CRUX of IOT

In the following we use an ESP 32 with a sensor for vibration i.e. MPU 6050, using the follow Values using the following Sensor for the following values are then send through the web server for Live Monitoring and data Collection.

### 3.2 Component/Module Selection

MPU 6050 was selected for its 3-axis gyroscope and a 3-axis accelerometer on the same silicon die, together with an onboard Digital Motion Processor™ (DMP™)

ESP 32 is a great Development Board for IOT and Bluetooth based application, Being Open Source and having many connection for GPIO pins we have selected the following Pins.
Arduino IDE was used for its simplicity with its default modules and open Source Contribution , the MPU 6050 libraries available directly on the Library Managers are a plus Point for using the following IDE although ESP 32 provides the native support for the following IDE

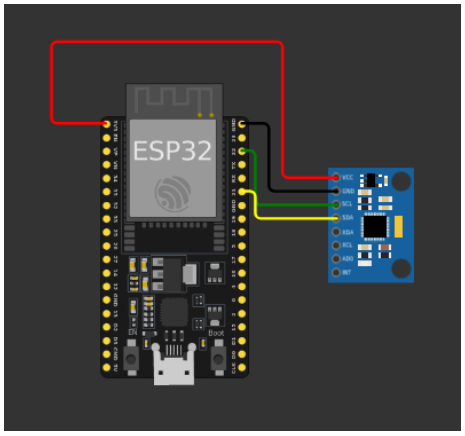


**Fig 3.2.1: Circuit Simulation**

The connection for the following Setup was simulated on wokowi as shown in the given figure3.2.1 this was done to test out the primary Circuit for the following Setup and its Capability.

### 3.3 Library Selection:

For the code the following libraries were used,

ESPAsync webserver - to create the webserver for the following application, AsyncTCP to handle Tcp communication in a non-blocking manner, Ardunio _JSON library for interchange and exchange of the the JSON format, adafruit MPU 6050.h, Adafruit Sensor.h for the interface with the MPU 6050 and the esp 32 throught the IDE, Aduino.h for Arduino functions and wifi.h for the connection through the WIFI sensor for the following sensor.

SPIFFS.h- provides access to the SPIFFS (SPI Flash File System) filesystem on the ESP 32.

Hence using the following libraries we send the Sensor values for the ESP 32 and file systems associated with it although we get the following systems values The MPU 6050 has the Capability to measure the rotation and acceleration and the Temperature in this we only use the Acceleration values for the Measurement of the following Sensor values because we are focusing on Acceleration And on valves there is no rotation or not so have ignored the following system for the no rotation of the following system.

### 3.4 Data Collection for IOT:

Data is collected using PuTTy SSH Client for Data Logging the Serial Monitor the Data is Stored in ODT format which is then structured in CSV or Excel file for Data Analysis followed by Prepossessing.

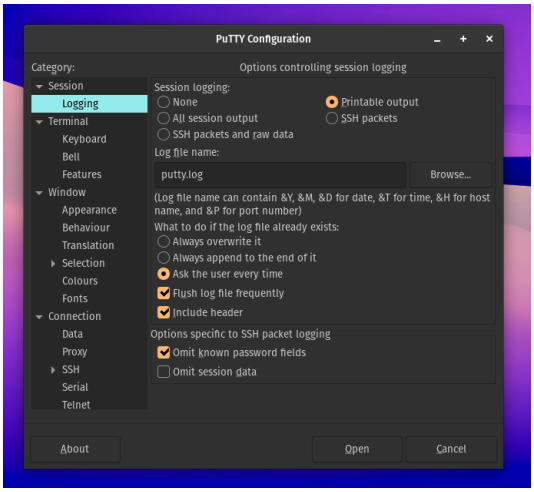


**Fig -3.4.1**: Data Collection Method

**Multi Devices Setup:**

The Esp 32 would be used for the following for better communications for the following values can be connected to multiple Device for better communications and multi-device along with secure Protection of Data

**Network Security** – The Esp 32 and the Host used the WPA2- PSK security protocol, so it provides the most security for the following protocol and WIFI Use given in the following systems.

Also the following values can be shared with the rest of the network or the Internet using secure network protocol for the following.

The following front-end webpage was Built using HTML, CSS and JavaScript taking reference from Random Nerd Tutorial.

## 3.5 Methodology for IOT

1. Primary Circuit Design and Simulation on Wokwi.

2. Physical Design of the Circuit.

3. Installation of Libraries and Dependencies on the Host Flashing Setup.

4. Testing and quality checking the sensor and Calibration

5. Code testing and debugging on the IDE

6. Testing the Whole Setup

7. Multi Device Testing and Development

**ESP 32 MPU 6050 Web sever**

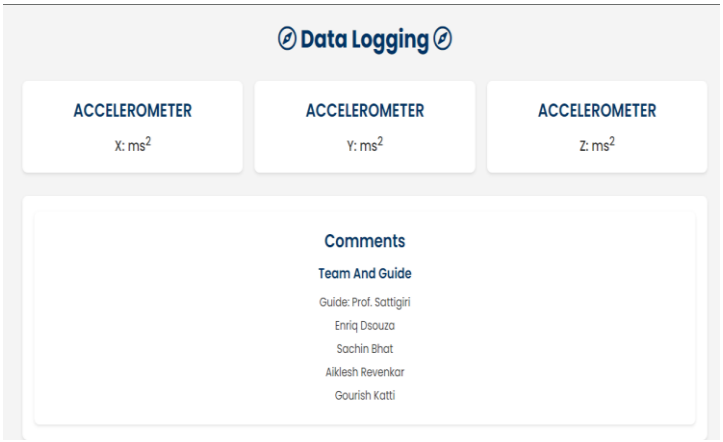


**Fig -3.5.1:** Webpage Setup

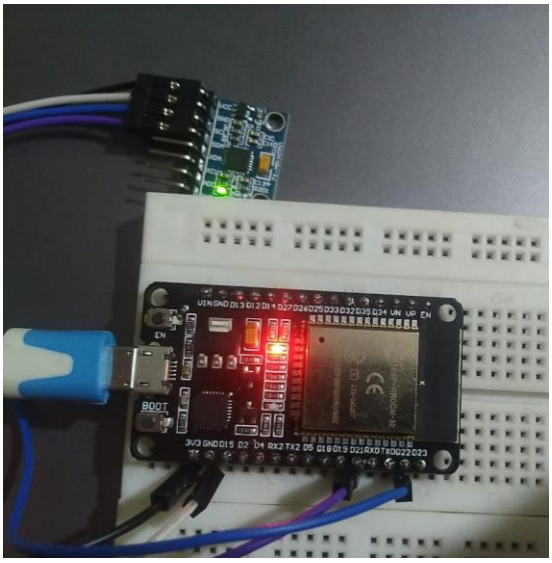

**Fig- 3.5.2:** Final Physical Circuit

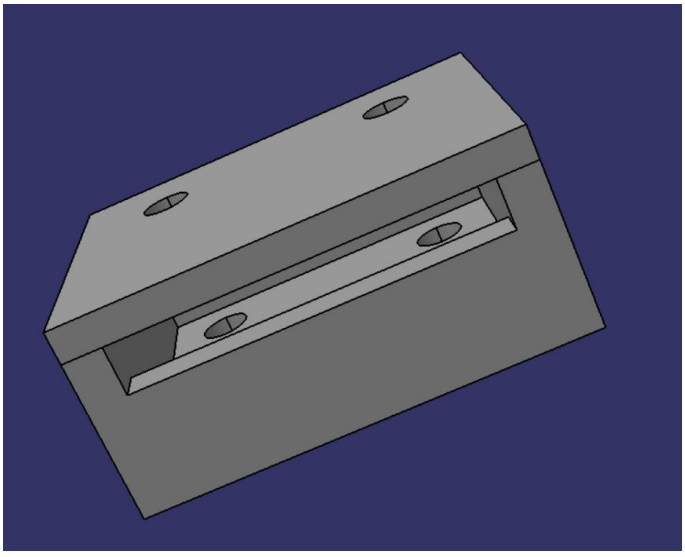

**Fig-3.5.3:** Design for Protective Case for MPU 6050

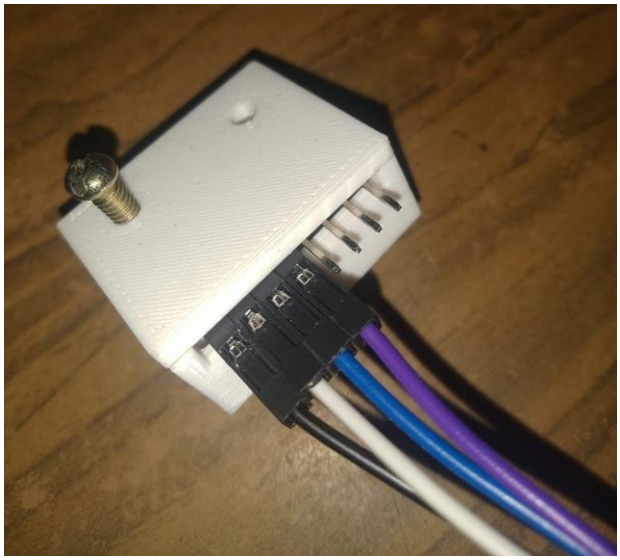

**Fig-3.5.4:** 3D Printed case with attachment


**Fig-3.5.5:** Testing of the sensor

## 4. CONCLUSIONS

From the above entire work, we have built an IOT model which can be implemented on to mechanical devices by the use of which we are enabled to obtain monitoring of the device and also can be used for predictive maintenance. Also, with the help of data analytics and the use of linear regression and prediction model we can explore the data interpret the trends and analyze the behavior of the flow of fluid through the valve prediction model helps us to predict the values for a given value of input. In general, these techniques can help improvise the performance and overall user experience of mechanical devices and also enable us for better monitoring and advanced control through the use of wireless technology.

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## BIOGRAPHIES

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