Machine Learning-Based Predictive Analytics for Aircraft Engine

PROJECT REPORT

Submitted by

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In partial fulfillment for the award of the degree of

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CHAPTER-I

INTRODUCTION

1.1 Project Overview:

- You'll be able to understand the problem to classify if it is a regression or a classification kind of problem.
- You will be able to know how to pre-process/clean the data using different data pre-processing techniques.
- Apply different algorithms according to the dataset
- You will be able to know how to find the accuracy of a model.
- You will be able to build web applications using the Flask framework.

1.2 Project Flow:

You will go through all the steps mentioned below to complete the project.

- Download the dataset.
- Preprocess or clean the data.
- Analyze the pre-processed data.
- Train the machine with pre-processed data using an appropriate machine learning algorithm.
- Save the model and its dependencies.
- Build a Web application using a flask that integrates with the model built.

CHAPTER-2

LITERATURE SURVEY

2.1 Introduction :

The aviation industry is capital intensive, and is subject to stringent environmental and safety regulations. To minimize risk, technological improvements of aircraft engines are generally made incrementally, drawing heavily from experiences and lessons learned. Engine companies have generated and collected large amounts of data over the years. These big data, from various sources such as the database of currently manufactured engines, current development projects, previously completed development projects, and the designs that were not manufactured, are valuable resources of intelligence that can support new engine development. With increasing computational power and employing machine learning, data can be mined to provide valuable insights that could bring high levels of efficiency to engine conceptual design.

2.2 literature Review:

SURVEY 1: Machine Learning- Based Predictive Analytics for Aircraft Engine Conceptual Design (Author - Michale T.Tong).

Big data and artificial intelligence/machine learning are transforming the global business environment. Data is now the most valuable asset for enterprises in every industry. With that, the adoption of machine learning-based data analytics is rapidly taking hold across various industries, producing autonomous systems that support human decision-making. This work explored the application of machine learning to aircraft engine conceptual design. Supervised machinelearning algorithms for regression and classification were employed to study patterns in an existing, open-

source database of production and research turbofan engines, and resulting in predictive analytics for use in predicting performance of new turbofan designs.

SURVEY 2: ***Approach And Landing Aircraft on-board Parameters Estimation with LSTM Networks (Author – Gabriel Jarry).***

This paper addresses the problem of estimating aircraft on-board parameters using ground surveillance available parameters. The proposed methodology consists in training supervised Neural Networks with Flight Data Records to estimate target parameters. This paper investigates the learning process upon three case study parameters: the fuel flow rate, the flap configuration, and the landing gear position. Particular attention is directed to the generalization to different aircraft types and airport approaches. From the Air Traffic Management point of view, these additional parameters enable a better understanding and awareness of aircraft behaviors. These estimations can be used to evaluate and enhance the air traffic management system performance in terms of safety and efficiency

SURVEY 3: **Monitoring Of Aircraft Operation Using Statistics and Machine Learning (Author – Fazel Famili and Sylvain Letourneau**

This paper describes the use of statistics and machine learning techniques to monitor the performance of commercial aircraft operation. The purpose of this research is to develop methods that can be used to generate reliable and timely alerts so that engineers and fleet specialists become aware of abnormal situations in large fleet of commercial aircraft that they manage. We introduce three approaches that we have used for monitoring engines and generating alerts. We also explain how additional information can be generated from machine learning experiments so that the parameters influencing the particular abnormal situation and their ranges are also identified and reported. Various benefits of fleet monitoring are explained in the paper.

SURVEY 4 :Aircraft Engine Reliability Analysis Using Machine Learning Algorithms(Author –

Deepnkar Singh)

In the aviation industry, the reliability analysis of aircraft engines is essential for ensuring the smooth functioning of each component of an aircraft engine. The reliability analysis is also important to predict their scheduled maintenance event and the Remaining Useful Life (RUL) of engine parts. Existing approaches for engine reliability are based on numerical methods, which do not predict RUL accurately. Hence, a more accurate model is required for predicting maintenance events. The reliability of an aircraft engine can be measured using readings of different sensors. In this work, the performances of different machine learning algorithms are studied, and finally, a better algorithm is suggested for predicting RUL. Additionally, a classification approach is proposed to classify the health state of an engine. The experimental results show that the XGBoost gives the best prediction accuracy in terms of root mean square error. The proposed LightGBM-based classifier further enhances the maintenance prediction based on the health state of the aircraft engine. Thus, the proposed analysis shows that XGBoost and LightGBM is a better choice for predicting the RUL, and for classifying the health state of the aircraft engine.

SURVEY 5: **Predictive Maintenance and Performance Optimisation in Aircrafts using Data Analytics.**

Airline industry has provided a significantly conventional, faster and reliable mode of transportation for passengers and freight over the decades in which the industry has been in service despite the pressure being applied especially in maintaining operational affordability. The study critically reviews the techniques and tools, infrastructure and general application architecture for discussing the applicability of data analytics based on both batch processing and real time stream data in general aviation for health monitoring and predictive analysis in order to predict maintenance and optimize the performance of aircrafts. In this respect, the study further evaluates the significant capability in addressing contemporary problems which are uniquely addressed by data analytics system.

SURVEY 6: **Application of Machine Learning Techniques to Web_Based Intelligent Learning**

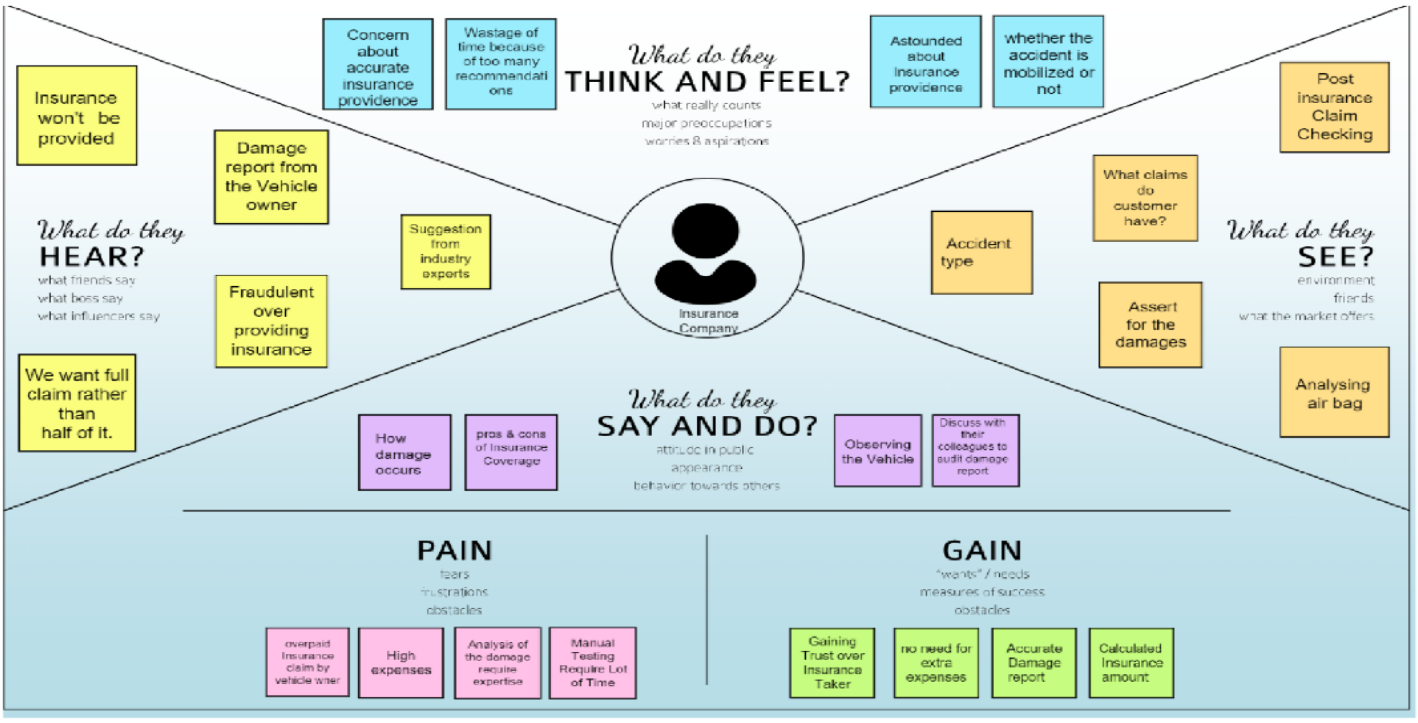
Diagnosis System.(Author – Chenn- Jung Huang).

T his work proposes an intelligent learning diagnosis system that supports a Web-based t hematic learning model, which aims to cultivate learners' ability of knowledge integration by g iving the learners the opportunities to select the learning topics that they are interested, and g ain knowledge on the specific topics by surfing on the Internet to search related learning c ourseware and discussing what they have learned with their colleagues. Based on the log files t hat record the learners' past online learning behavior, an intelligent diagnosis system is used to g ive appropriate learning guidance to assist the learners in improving their study behaviours and g rade online class participation for the instructor. The achievement of the learners' final reports c an also be predicted by the diagnosis system accurately. Our experimental results reveal that t he proposed learning diagnosis system can efficiently help learners to expand their knowledge w hile surfing in cyberspace Web-based "theme-based learning" model.

CHAPTER-3

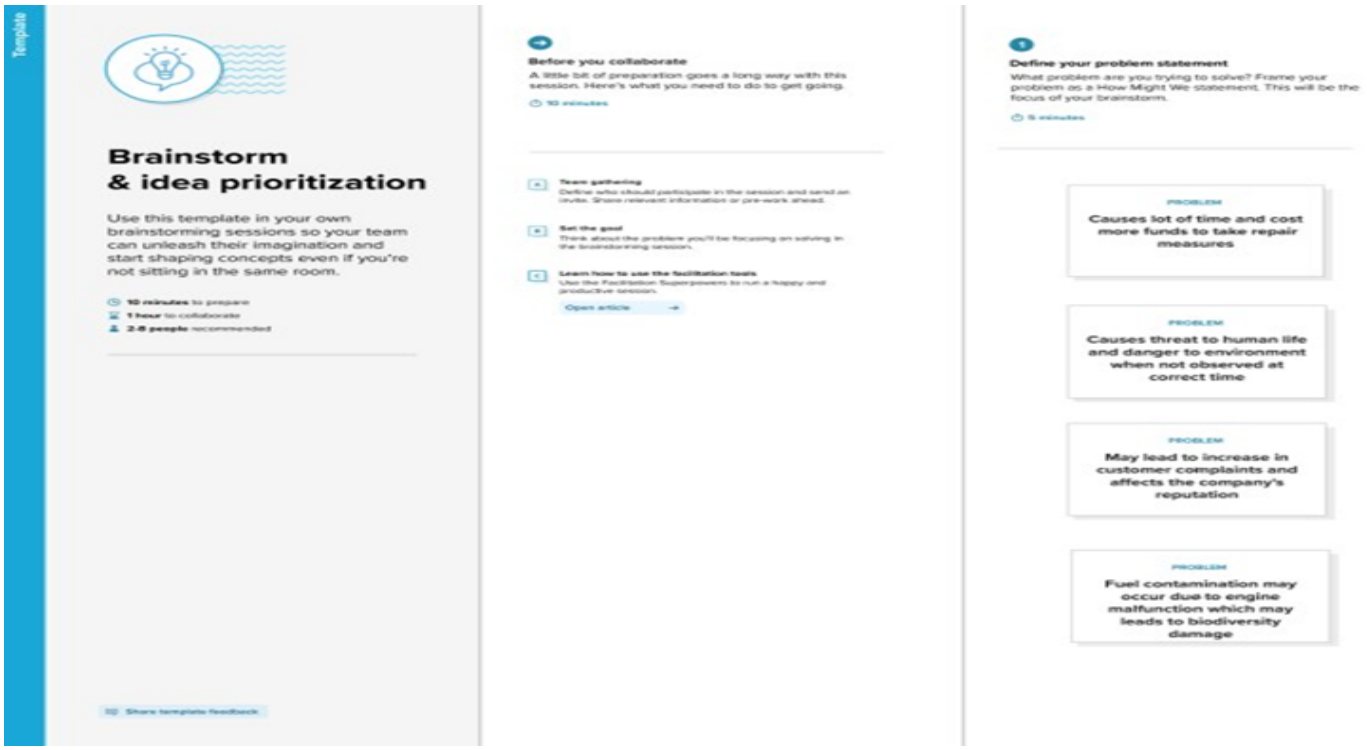
IDEATION & PROPOSED SOLUTION

3.1 Empathy Map Canvas:

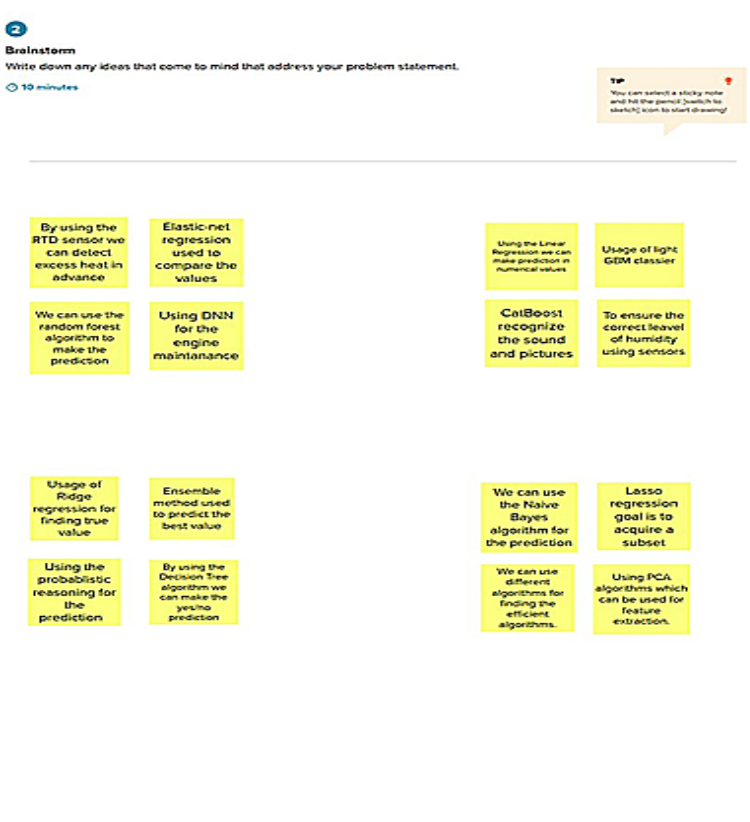


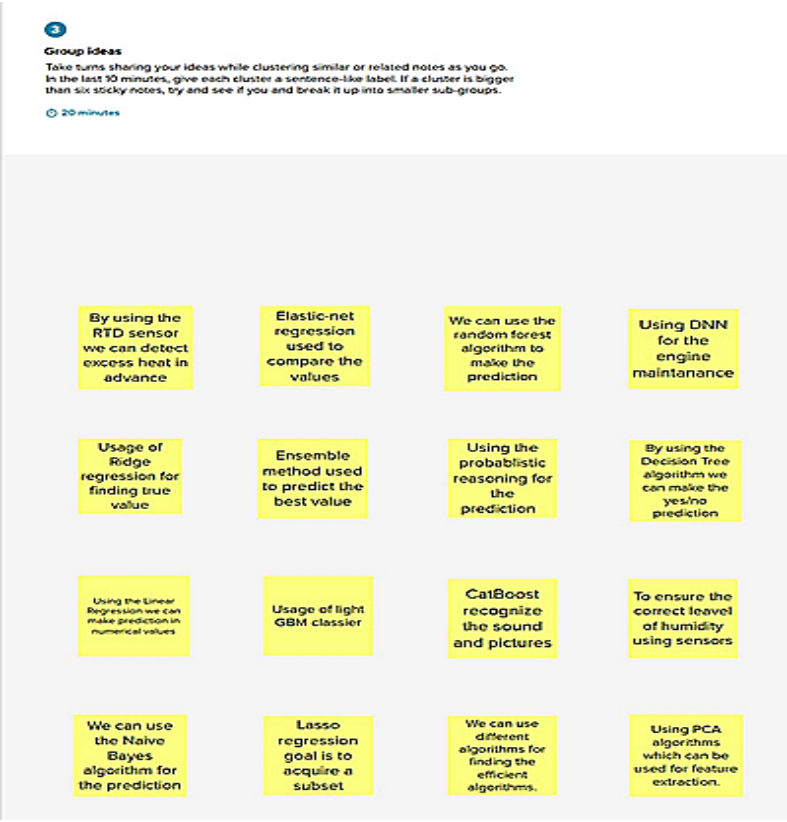
3.2 Ideation & Brainstorming:

Step-1: Team Gathering, Collaboration and Select the Problem Statement

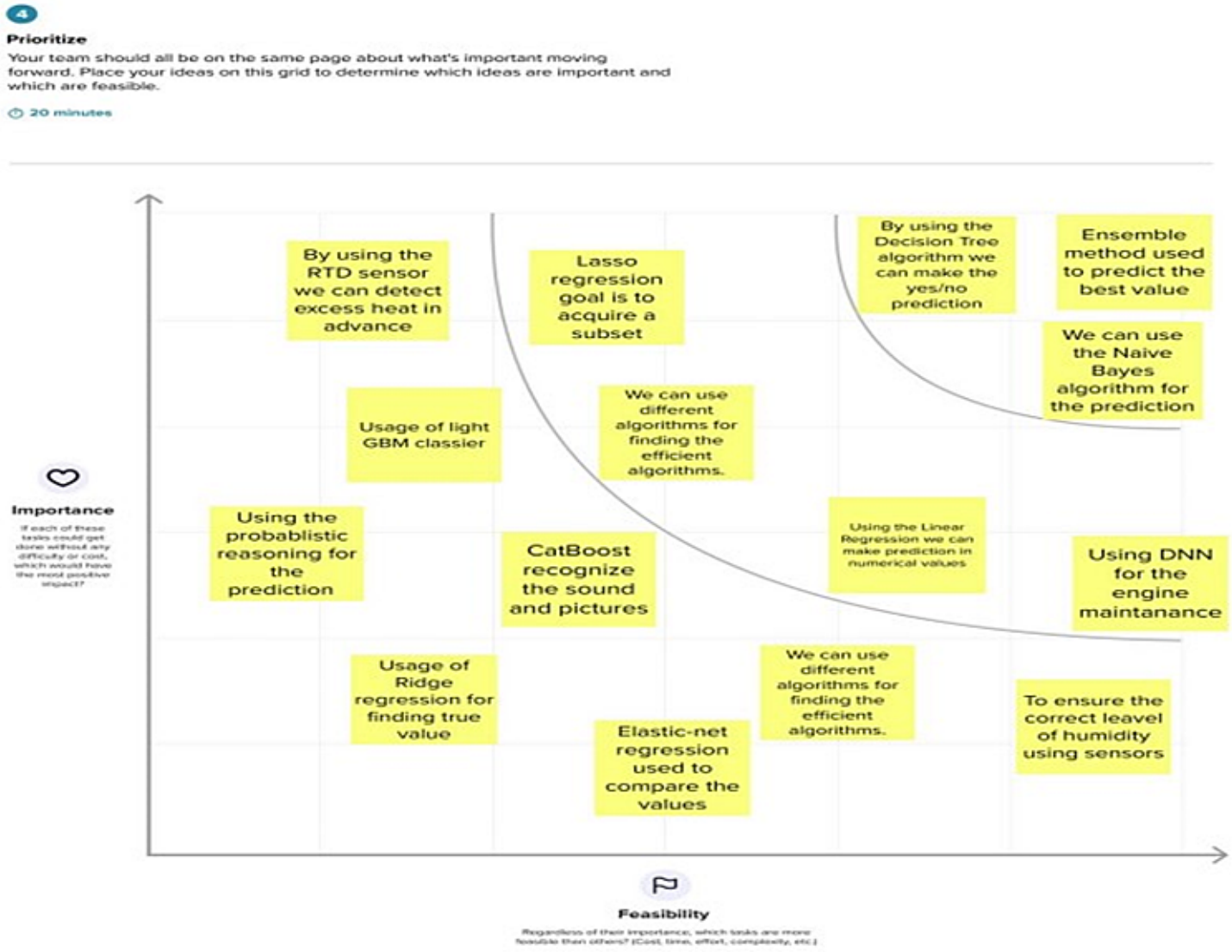


Step-2: Brainstorm, Idea Listing and Grouping :





Step-3: Idea Prioritization:



3.3 Problem Statement:

Extracting and modeling the engine symmetry characteristics is significant in improving remaining useful life (RUL) predictions for aircraft components, and it is critical for an effective and reliable maintenance strategy. Such predictions can improve the maximum operating availability and reduce maintenance costs. Due to the high nonlinearity and complexity of mechanical systems, conventional methods are unable to satisfy the needs of medium- and long-term prediction problems and frequently overlook the effect of temporal information on prediction performance. To address this issue, this study presents a new attention-based deep convolutional neural network (DCNN) architecture to predict the RUL of turbofan engines. The prognosability metric was used for feature ranking and selection,

whereas a time window method was employed for sample preparation to take advantage of multivariate temporal information for better feature extraction by means of an attention-based DCNN model.

Statement (PS)	**I am (Customer)**	**I'm trying to**	***But***	***Because***	***Which makes me feel***
Problem statement-1	Passenger	Focus on safety and security	I can't focus on huge passenger at the time	Hard to instruct at the same time	Afraid to tr avel
Problem statement-1	pilot	Get the situation under the control	Due to some technical issues	Improper monitoring	rustrated
Problem statement-1	Civilians	Trying to see the safety and	Due to some technical issues	Engine beyond the control	Anxiety to travel

CHAPTER-4

REQUIREMENT ANALYSIS

4.1 Functional requirement:

1. Python
2. NLP
3. IBM Cloud
4. IBM Watson Assistant
5. Deep Learning
6. Python-Flask

4.2 Non Functional requirement:

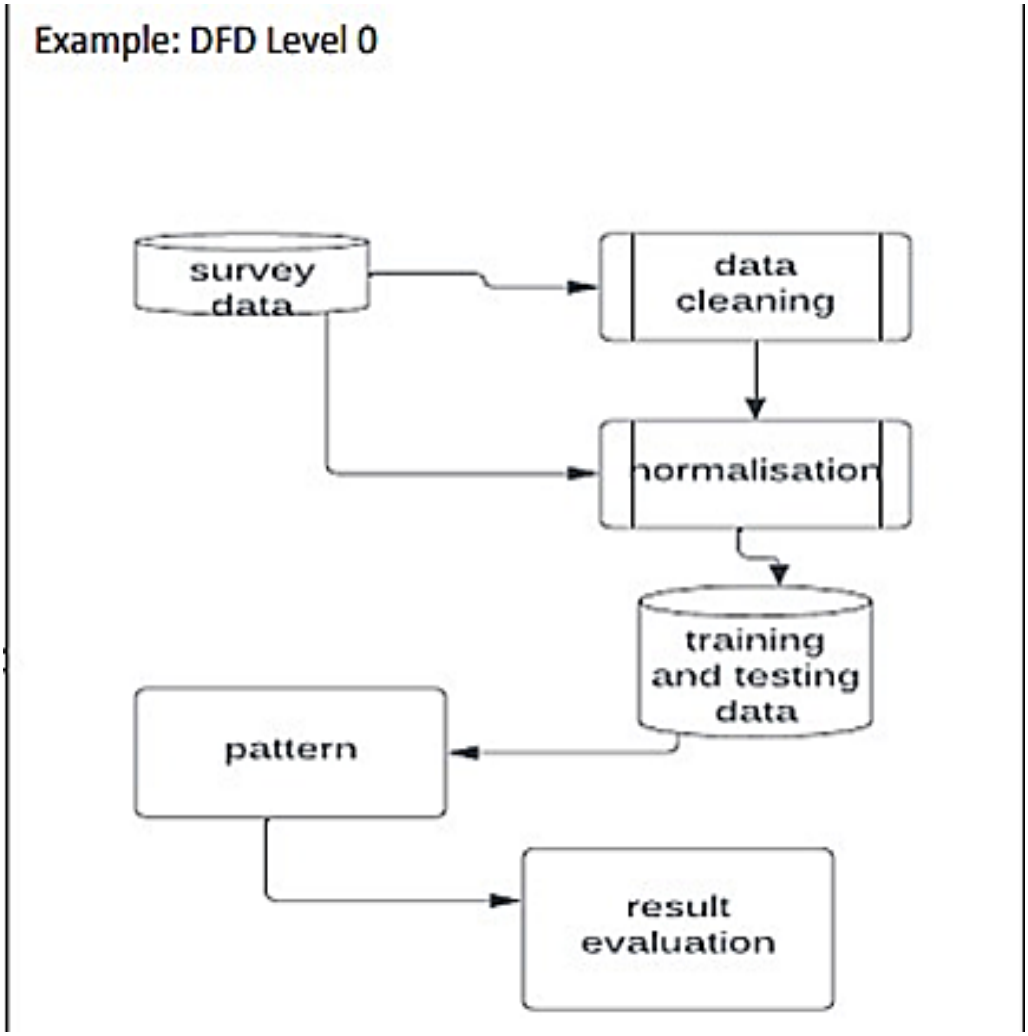
a. Security,
b. Performance,
c. Usability, And
d. Availability

CHAPTER-5

PROJECT DESIGN

5.1 Data Flow Diagrams

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It shows how data enters and leaves the system, what changes the information, and where data is stored.

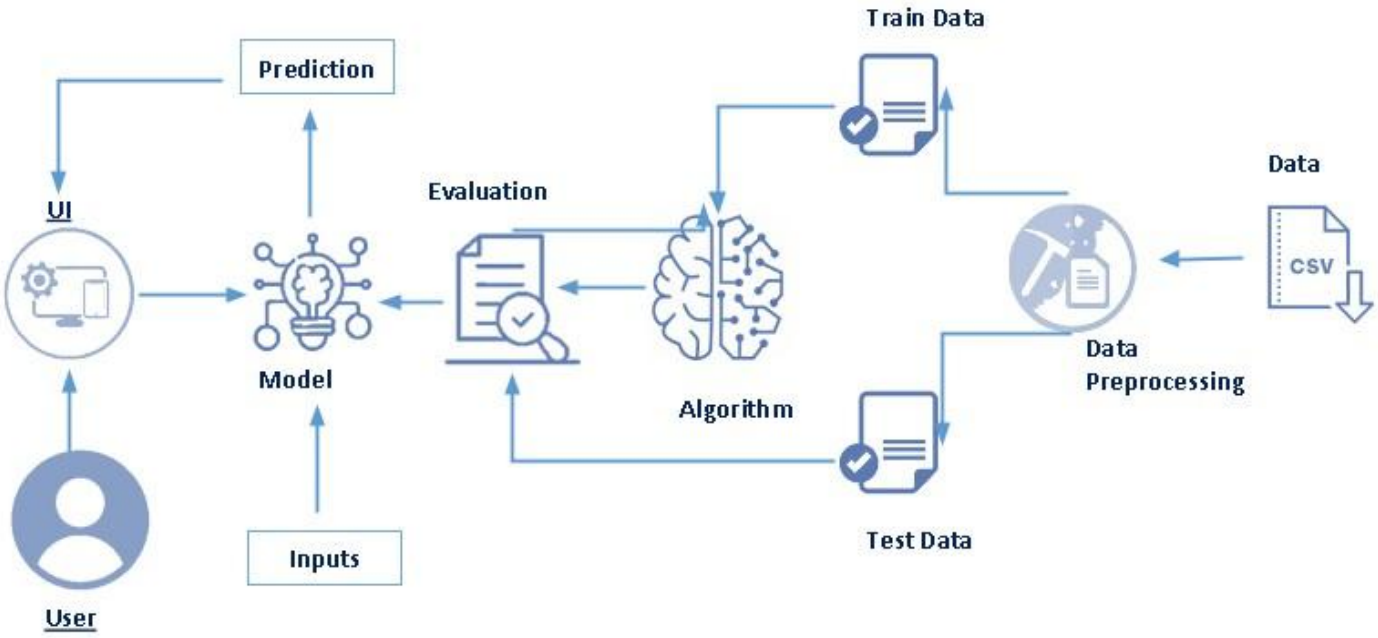


5.2 Solution & Technical Architecture

Engine failure is highly risky and needs a lot of time for repair. Unexpected failure leads to loss of money and time. Predicting the failure prior will save time, effort, money and sometimes even lives. The failure can be detected by installing the sensors and keeping a track of the values. The failure detection and predictive maintenance can be for any device, out of which we will be dealing with the engine failure for a threshold number of days.

The project aims to predict the failure of an engine by using Machine Learning to save loss of time & money thus improving productivity.

Technical Architecture:



CHAPTER-6

PROJECT PLANNING & SCHEDULING

6.1 **milestone and activity：**

TITLE	DESCRIPTION	DATE
Literature Survey & Information Gathering	*Literature survey on the selected project & gathering information by referring the technical papers, research publications etc*	01 OCTOBER 2022
Prepare Empathy Map	*Prepare Empathy Map Canvas to capture the user Pains & Gains, Prepare list of problem statements*	01 OCTOBER 2022
Ideation	*List the by organizing the brainstorming session and prioritize the top 3 ideas based on the feasibility & importance.*	03 OCTOBER 2022

Proposed Solution	*Prepare the proposed solution document, which includes the novelty, feasibility of idea, business model, social impact, scalability of solution,*	02 OCTOBER 2022
Problem Solution Fit	*Prepare problem - solution fit document*	03 OCTOBER 2022
Solution Architecture	*Prepare solution architecture document.*	08 OCTOBER 2022
Customer Journey	*Prepare the customer journey maps to understand the user interactions & experiences with the application.*	02 NOVEMBER 2022
Solution Requirements	*Prepare solution requirement document for functional and nonfunctional requirements.*	02 NOVEMBER 2022
Data Flow Diagrams	*Draw the data flow diagrams and submit for review.*	02 NOVEMBER 2022

Technology Architecture	*Prepare the technology architecture diagram.*	02 NOVEMBER 2022
Prepare Milestone & Activity List	*Prepare the milestones & activity list of the project.*	05 NOVEMBER 2022
Project Development - Delivery of Sprint-1, 2, 3 & 4	*Develop & submit the developed code by testing it.*	*IN PROGRESS...* **....**

6.2 Sprint Planning & Estimation:

Use the below template to create product backlog and sprint schedule

Sprint	Functional Requirement (Epic)	User Story Number	User Story / Task	Story Points	Priority	Team Members
Sprint-1	Registration	USN-1	As a user, I can register for the application by entering my email, password, and confirming my password.	5	High	4
Sprint-1	Facebook Registration	USN-2	As a user, I can register for thapplicationt hrough Facebook	4	Medium	4
Sprint-1	Gmail registration	USN-3	As a user, I can register for the applicationthr ough Gmail	3	Low	4
Sprint-2	login	USN-4	As a user, I can log into the application by entering email & password	5	High	4

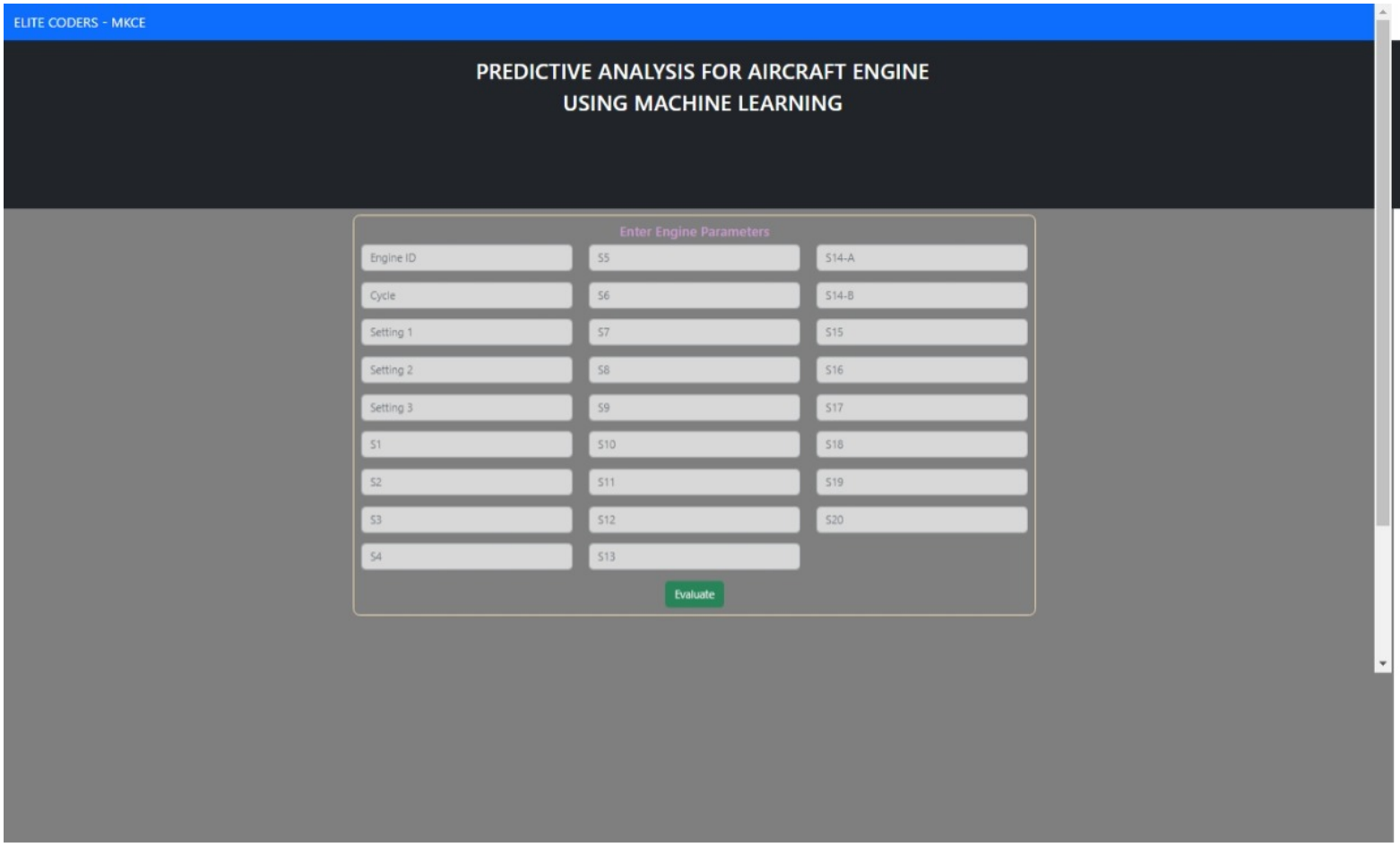
Sprint-2	Facebook	USN-5	As a user, I can log in into this application through Facebook	4	Medium	4
Sprint-2	Email	USN-6	As a user, I can log in into this application by entering my Google Account	3	Low	4
Sprint-3	Analyzing / Detecting Problems	USN-7	As a user, I can able analyze the defects in Aircraft Engine	5	High	4
Sprint-3	Analyzing / Detecting Problems	USN-8	As a user, I can able to view the repeated problems occurs in Aircraft Engine	4	Medium	4
Sprint-3	Analyzing / Detecting Problems	USN-9	As a user, I can able to find the defects occurs in Aircraft	4	Low	4
			Engine			
Sprint-4	Solution	USN-10	As a user, I can view the solution for minor problems of the Aircraft Engine	3	Medium	4

Sprint-4	Solution	USN-11	As a user, I can view the solution for major problems of the Aircraft Engine	5	High	4
Sprint-4	Solution	USN-12	As a user, I can find the solution and suggestion to maintain for regular services	4	Low	4

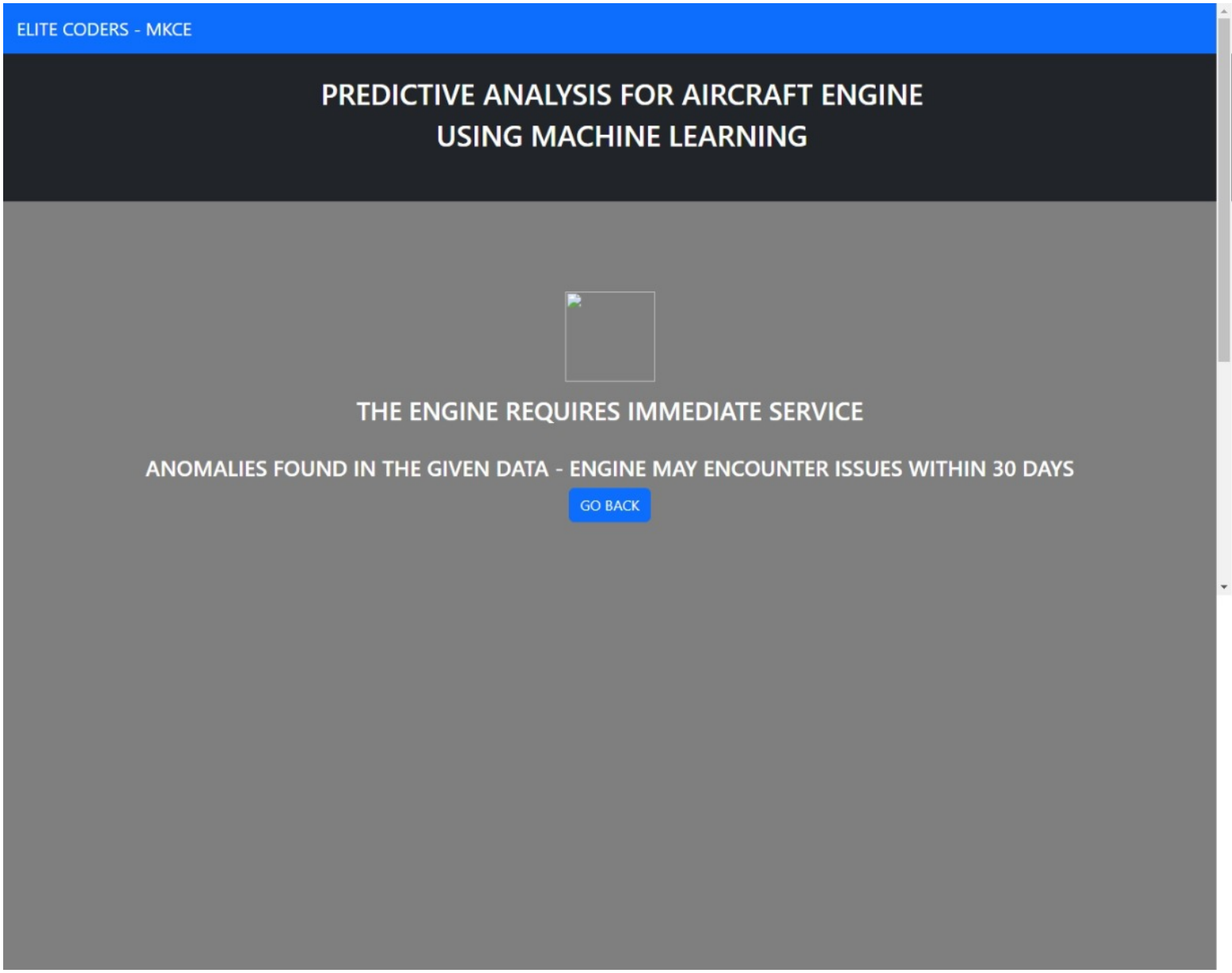
CHAPTER-7
TESTING

7.1 TEST CASE:

The final predictive analytics, built with the parameters determined during the preliminary training and with all 137 training data (i.e., no cross validation), were then used to predict the engine TSFC and core sizes in the testing dataset (the 46 engines unseen by the analytics



CHAPTER-8
RESULT



CHAPTER-9
ADVANTAGES & DISADVANTAGES

ADVANTAGES:

- High power to weight ratio.
- Very high speed therefore save time.

DISADVANTAGES:

- High fuel consumption.
- Require labor
- Cost increasing

CHAPTER-10
CONCLUSION

conclution:

The author developed two machine-learning predictive analytics for turbofan TSFC and core-size predictions, respectively. The development used the database of 183 manufactured engines and engines that were studied previously in NASA aeronautics projects. The TSFC predictive analytics has an average accuracy of 98.3 percent, with 3.5 percent uncertainty. The engine core-size predictive analytics has an overall accuracy of 100 percent, with 4.3 percent uncertainty. Overall, both predictive analytics show remarkable prediction accuracy. To further improve the accuracy (and reduce the uncertainty) of TSFC prediction, the database needs to be expanded. However, the limitation of publicly available engine data is a challenge to overcome.

References:

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2. Daly, M., “Jane’s Aero-Engine,” 2017-2018.

3. Meier, N., “Civil turbojet/turbofan specifications.” http://www.jet-engine.net/civtfspec.html. Accessed August, 2018

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9. Guynn, M.D., Berton, J.J., Fisher, K.L., Haller, W.J., Tong, M., Thurman, D.R., “Engine Conceptual Study for an Advanced Single-Aisle Transport,” NASA/TM—2009-215784, August 2009.

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CHAPTER-11
FUTURE SCOPE

- The current engine-weight prediction results, together with those for the TSFC (thrust specific fuel consumption) and core-size predictions that were studied previously by the author, show that machine learning-based predictive analytics can be an **effective, time-saving tool for assessing aircraft engine system performance (TSFC, weight, and core size)** during the conceptual design stage.

- The studies for this case were all performed on conventional aircraft configurations.

- Looking to see if these methods work for unconcentional aircraft configurations like Blended wing bodies etc. will be an interesting next step.

- For those configurations, the interactions between the different disciplines are extremely complex and modelling them using regression methods might not work out as well as they did for this case.

CHAPTER-12
APPENDIX

12.1 source code:

Python code:

```
import numpy as np
 from flask import Flask, request, jsonify, render_template
import joblib
import random
```

In [14]:

```
app = Flask(__name__)
```

In [15]:

```
@app.route('/') def index():
    return render_template('/content/index.html')
```

In [16]:

```
@app.route('/result', methods=['POST']) def result():
try:         if request.method == 'POST':
            l=[]
            l.append(float(request.form['id']))
            l.append(float(request.form['cycle']))
            l.append(float(request.form['set1']))
            l.append(float(request.form['set2']))
            l.append(float(request.form['set3']))
            l.append(float(request.form['s1']))
            l.append(float(request.form['s2']))
            l.append(float(request.form['s3']))
            l.append(float(request.form['s4']))
            l.append(float(request.form['s5']))
            l.append(float(request.form['s6']))
```

```
            l.append(float(request.form['s7']))
            l.append(float(request.form['s8']))
            l.append(float(request.form['s9']))
            l.append(float(request.form['s10']))
            l.append(float(request.form['s11']))
            l.append(float(request.form['s12']))
            l.append(float(request.form['s13']))
            l.append(float(request.form['s14']))
            l.append(float(request.form['s15']))
            l.append(float(request.form['s16']))
            l.append(float(request.form['s17']))
            l.append(float(request.form['s18']))
            l.append(float(request.form['s19']))
            l.append(float(request.form['s20']))
            l.append(float(request.form['s21']))             print(l)
  if predict(l):                  return
  render_template('/content/result.html',data="problem")             else:
                return render_template('/content/result.html',data="normal")
  except:
          return render_template('/content/result.html',data="error")
```

In [17]:

```
runfile
```

Out[17]:

html code:

```
<!DOCTYPE html>
<html lang="en">
<head>
    <meta charset="UTF-8">
    <meta http-equiv="X-UA-Compatible" content="IE=edge">
    <meta name="viewport" content="width=device-width, initial-scale=1.0">
    <title>Engine - Test</title>
    <!-- CSS only
    col_name =
['id','cycle','set1','set2','set3','s1','s2','s3','s4','s5','s6','s7','s8']+['s9','s10','s11','s12','s13','s14','s14','s15','s16','s17','s18','
s19','s20']

    -->
<link href="https://cdn.jsdelivr.net/npm/bootstrap@5.2.0/dist/css/bootstrap.min.css" rel="stylesheet"
integrity="sha384-gH2yIJqKdNHPEq0n4Mqa/HGKIhSkIHeL5AyhkYV8i59U5AR6csBvApHHNl/vI1Bx"
crossorigin="anonymous">
<style>
```

```
        #hero{
            width: 102%;
            height: 25vh;
            color: white;
            text-align: center;
            padding-top: 25px;
        }
        .formd{
            width: 102%;
            height: 95vh;
            background: linear-gradient( rgba(0, 0, 0, 0.5), rgba(0, 0, 0, 0.5) ), url('../static/full_img.jpg');
        background-position:center top;
        }
        .formd form{
            margin-top: 10px;
            width: 100%;
            border: 1px solid wheat;
            border-radius: 10px;
            padding: 10px;
        }
        .form-control{
            opacity: 0.7;
        }
    </style>
    </head>
    <body style="overflow-x: hidden;">
        <nav class="navbar bg-primary navbar-dark">
            <a class="navbar-brand" style="margin-left: 15px;">ELITE CODERS - MKCE</a>
        </nav>
        <div id="hero" class="bg-dark">
            <div>
                <h2>PREDICTIVE ANALYSIS FOR AIRCRAFT ENGINE</h2>
                <h2>USING MACHINE LEARNING</h2>
            </div>
        </div>
        <div class="formd row">
            <div class="col-md-3"></div>
            <div class="col-md-6" style="text-align: center;">
                <form action="result" method="post">
                    <span style="color: rgb(201, 157, 207);"><h5>Enter Engine Parameters</h5></span>
                    <div class="row text-center">
                        <div class="col-md-4">
                            <div class="mb-3" style="color: white;">
                                <input name="id" step="any" type="number" class="form-control" id="id"
placeholder="Engine ID">
```

```
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="cycle" step="any" type="number" class="form-control" id="cycle"
placeholder="Cycle">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="set1" step="any" type="number" class="form-control" id="set1"
placeholder="Setting 1">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="set2" step="any"  type="number" class="form-control" id="set2"
placeholder="Setting 2">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="set3" step="any" type="number" class="form-control" id="set3"
placeholder="Setting 3">
                        </div>
                        <div class="mb-3" style="color: white;">
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placeholder="S1">
                        </div>
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                        </div>
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placeholder="S3">
                        </div>
                        <div class="mb-3" style="color: white;">
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placeholder="S4">
                        </div>
                    </div>
                    <div class="col-md-4">
                        <div class="mb-3" style="color: white;">
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                        </div>
                        <div class="mb-3" style="color: white;">
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placeholder="S6">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s7" step="any" type="number" class="form-control" id="s7"
```

```
placeholder="S7">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s8" step="any" type="number" class="form-control" id="s8"
placeholder="S8">
                        </div>
                        <div class="mb-3" style="color: white;">
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placeholder="S9">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s10" step="any" type="number" class="form-control" id="s10"
placeholder="S10">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s11" step="any" type="number" class="form-control" id="s11"
placeholder="S11">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s12" step="any" type="number" class="form-control" id="s12"
placeholder="S12">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s13" step="any" type="number" class="form-control" id="s13"
placeholder="S13">
                        </div>
                    </div>
                    <div class="col-md-4">
                        <div class="mb-3" style="color: white;">
                          <input name="s14" step="any" type="number" class="form-control" id="s14-A"
placeholder="S14-A">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s15" step="any" type="number" class="form-control" id="s14-B"
placeholder="S14-B">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s16" step="any" type="number" class="form-control" id="s15"
placeholder="S15">
                        </div>
                        <div class="mb-3" style="color: white;">
                          <input name="s17" step="any" type="number" class="form-control" id="s16"
placeholder="S16">
                        </div>
                        <div class="mb-3" style="color: white;">
```

```
                        <input name="s18" step="any" type="number" class="form-control" id="s17"
placeholder="S17">
                    </div>
                    <div class="mb-3" style="color: white;">
                        <input name="s19" step="any" type="number" class="form-control" id="s18"
placeholder="S18">
                    </div>
                    <div class="mb-3" style="color: white;">
                        <input name="s20" step="any" type="number" class="form-control" id="s19"
placeholder="S19">
                    </div>
                    <div class="mb-3" style="color: white;">
                        <input name="s21" step="any" type="number" class="form-control" id="s20"
placeholder="S20">
                    </div>
                </div>
            </div>
            <center> <input style="opacity: 0.85;" type="submit" class="btn btn-success"
value="Evaluate"/></center>
        </form>
    </div>
    <div class="col-md-3"></div>
</div>
</body>
<script>

    function test_pass(){
        document.getElementById("id").value = 1;
        document.getElementById("cycle").value = 7;
        document.getElementById("set1").value = 0;
        document.getElementById("set2").value = 0.0002;
        document.getElementById("set3").value = 100.0;
        document.getElementById("s1").value = 518.67;
        document.getElementById("s2").value = 642.11;
        document.getElementById("s3").value = 1583.34;
        document.getElementById("s4").value = 1404.84;
        document.getElementById("s5").value = 14.62;
        document.getElementById("s6").value = 21.61;
        document.getElementById("s7").value = 553.89;
        document.getElementById("s8").value = 2388.05;
        document.getElementById("s9").value = 9051.39;
        document.getElementById("s10").value = 1.30;
        document.getElementById("s11").value = 47.31;
        document.getElementById("s12").value = 522.01;
        document.getElementById("s13").value = 2388.06;
```

```
  document.getElementById("s14-A").value = 8134.97;
  document.getElementById("s14-B").value = 8.3914;
  document.getElementById("s15").value = 0.03;
  document.getElementById("s16").value = 391;
  document.getElementById("s17").value = 2388;
  document.getElementById("s18").value = 100.00;
  document.getElementById("s19").value = 38.85;
  document.getElementById("s20").value = 23.3952;
 }
 function test_fail(){
  document.getElementById("id").value = 6;
  document.getElementById("cycle").value = 88;
  document.getElementById("set1").value = 0.0011;
  document.getElementById("set2").value = -0.0005;
  document.getElementById("set3").value = 100.0;
  document.getElementById("s1").value = 518.67;
  document.getElementById("s2").value = 642.39;
  document.getElementById("s3").value = 1592.67;
  document.getElementById("s4").value = 1415.76;
  document.getElementById("s5").value = 14.62;
  document.getElementById("s6").value = 21.61;
  document.getElementById("s7").value = 553.89;
  document.getElementById("s8").value = 2388.12;
  document.getElementById("s9").value = 9059.83;
  document.getElementById("s10").value = 1.30;
  document.getElementById("s11").value = 47.56;
  document.getElementById("s12").value = 521.30;
  document.getElementById("s13").value = 2388.07;
  document.getElementById("s14-A").value = 8131.43;
  document.getElementById("s14-B").value = 8.4262;
  document.getElementById("s15").value = 0.03;
  document.getElementById("s16").value = 393;
  document.getElementById("s17").value = 2388;
  document.getElementById("s18").value = 100.00;
  document.getElementById("s19").value = 39.01;
  document.getElementById("s20").value = 23.3342;
 }
</script>
</html>
```

12.2 GitHub & Project Demo Link:

github:

TEAM ID : PNT2022TMID45543

GitHub Project Link : https://github.com/IBM-EPBL/IBM-Project-54339-1661851835

Project demo vedio Link : https://user-images.githubusercontent.com/113543704/202865909-0fd0f7ee-4870-4429-9bb2-f9290b8291e0.mp4