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BANGALORE

Internship Report

On

"Performance Monitoring and Analytics for Aero-Gas Turbine Engines"

At

GTRE (DRDO)

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ABSTRACT

This project focuses on building a visualization and analytics tool that directly processes data from a structured database, removing the need for manual extraction or intermediate files. Users will interact with a GUI-based system to select parameters for visualizing trends and patterns. In the next phase, a Generative AI model**,** will compare visualizations with predefined insights and generate conclusions based on detected trends. The system will also support natural language queries, allowing users to request specific graphs/queries, compare performance trends, identify similar performance patterns, and extract relevant data insights. By automating visualization and analysis, this tool aims to improve efficiency and decision-making in performance monitoring

LITERATURE REVIEW

1. Predicting Aircraft Engine Failures using Artificial Intelligence

(Bentaleb, Toumlal and Abouchabaka 2024)

This paper explores the use of AI for **early fault detection in aircraft engines**, analyzing **real-time sensor data** such as **temperature, pressure, and vibration**. The study highlights **pattern recognition techniques** to identify **anomalies and potential failures**, helping to optimize maintenance schedules and prevent unexpected breakdowns. It demonstrates the effectiveness of **machine learning models** in improving **operational efficiency and safety**. However, the approach lacks **interactive visualization tools** that allow users to define analysis parameters, an aspect that my project addresses by enabling **GUI-based data selection and generative AI for insights**.

Relevance to My Work:

- Uses **sensor-driven AI analysis**, similar to my project.
- Focuses on **predictive maintenance and trend detection** for reliability.

Research Gaps:

- No **interactive visualization or user-driven graph generation**.
- Lacks **generative AI for new insights**, limiting automation.

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2. A Machine-Learning Approach to Assess Aircraft Engine System Performance

(Tong 2020)

This paper investigates **aircraft engine performance assessment using ML models**, focusing on **data-driven anomaly detection and predictive maintenance strategies**. The study emphasizes the role of **sensor-based diagnostics** in optimizing maintenance schedules and improving efficiency. It provides a structured approach to **data collection, preprocessing, and modelling**, ensuring accurate **fault detection and performance tracking**. While effective in engine health monitoring, it does not include **interactive analysis** where users can select parameters dynamically or generate insights through **AI-driven automated interpretation**, both of which are core components of my project.

Relevance to My Work:

- Uses **ML for performance monitoring**.
- Aligns with my project's focus on **sensor-based trend analysis**.

Research Gaps:

- Lacks **GUI-based visualization** for user-defined analysis.
- Does not support **natural language queries for retrieving insights**.

3. Enhancing Predictive Maintenance in the Industrial Sector: A Comparative Analysis of ML Models

(Levin 2024)

This study evaluates **multiple machine learning models** for predictive maintenance across different industries, analyzing their effectiveness in **fault detection, reducing downtime, and optimizing efficiency**. By comparing various ML approaches, it identifies the most **reliable models** for maintenance forecasting. The paper provides **valuable insights into model performance**, but it does not explore **aerospace-specific applications**.

Relevance to My Work:

- Helps in selecting **effective ML models** for predictive maintenance.
- Provides insight into **performance evaluation of different AI techniques**.

Research Gaps:

- Doesn't explore **aerospace-specific applications**.
- Lacks **AI-driven adaptive insights for automated conclusions**.

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4. Predicting Machine Failures from Multivariate Time Series: An Industrial Case Study

(Vago, et al. 2024)

This paper focuses on **time-series-based failure prediction**, analyzing **sensor data across multiple time points** to detect **patterns and anomalies**. The study demonstrates how ML techniques can **improve failure prediction accuracy** and optimize **maintenance planning**. It presents a strong foundation for **trend analysis and forecasting**, but does not incorporate **interactive querying** or allow **user-defined parameters for visualization**. My project builds on this by enabling users to **dynamically select data for analysis** and by incorporating **AI-driven responses to user queries**, improving overall system usability.

Relevance to My Work:

- Uses **time-series data analysis** to predict failures.
- Aligns with my project's **focus on performance monitoring**.

Research Gaps:

- No **interactive query-based result retrieval**.
- Lacks **generative AI-based insights** for deeper automation.

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5. Advanced ML for Predictive Maintenance: A Case Study on Remaining Useful Life Prediction

(Meddaoui, Hachmoud and Hain 2024)

This research applies **ML models to estimate the remaining useful life (RUL) of machines**, helping in **scheduling proactive maintenance**. The study highlights **deep learning techniques** that improve **predictive accuracy**, ensuring **early failure detection**. However, the research focuses **only on model efficiency**, lacking **interactive visualization, flexible querying, and AI-driven insight generation**. My project enhances this by **providing a user-friendly interface** where users can define visualization parameters and interact with the AI model using **natural language queries**, allowing for more adaptive and user-controlled analysis.

Relevance to My Work:

- Focuses on **predictive maintenance and lifespan estimation**.
- Similar approach to **analyzing machine performance trends**.

Research Gaps:

- No **interactive visualization or user-defined analysis**.
- Does not use **generative AI for automated conclusions**.

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6. Machine Learning-Based Fault-Oriented Predictive Maintenance in Industry 4.0

(Justus and Kanagachidambaresan 2024)

This study presents an **ML-based fault classification framework** for **Industry 4.0 applications**, focusing on **automated fault detection and system optimization**. It demonstrates how **fault-oriented models** can improve predictive maintenance but lacks **aerospace-specific applications** and does not explore **flexible user-driven analysis**. My project builds on this by enabling **interactive analysis, dynamic visualizations, and NLP-driven querying**, allowing users to **extract meaningful insights** beyond automated fault classification.

Relevance to My Work:

- Uses **ML for fault detection and predictive maintenance**.
- Aligns with my project's **performance monitoring goals**.

Research Gaps:

- No **interactive visualization or user input** support.
- Lacks **natural language-based querying** for deeper insights.

OBJECTIVES

1. Data Collection, Preparation, Cleaning, and Preprocessing

- Sensor data is retrieved directly from the database.
- Raw data undergoes cleaning and preprocessing
- Time-series processing techniques before it is fed into the AI model.

2. UI and API Design

- A Graphical User Interface (GUI) to select the X and Y axes dynamically, for custom visualizations.
- Natural language queries, to request specific visualizations or retrieve insights without manually analysis.

3. AI Model Design

- Detect performance anomalies, compare trends, and generate insights based on predefined patterns.
- Incorporation of Generative AI to analyse data and generate insights.
- Optimization to process large amounts of sensor data and provide accurate conclusions.

4. Scaling and Optimization of Performance Monitoring

- Handle large volumes of sensor data.
- Usage of various Optimization techniques to enhance speed and accuracy.
- Model's continuous learning from new data, improving its performance.

PROBLEM IDENTIFICATION, AND FORMULATION OF PROBLEM STATEMENT

Problem Identification

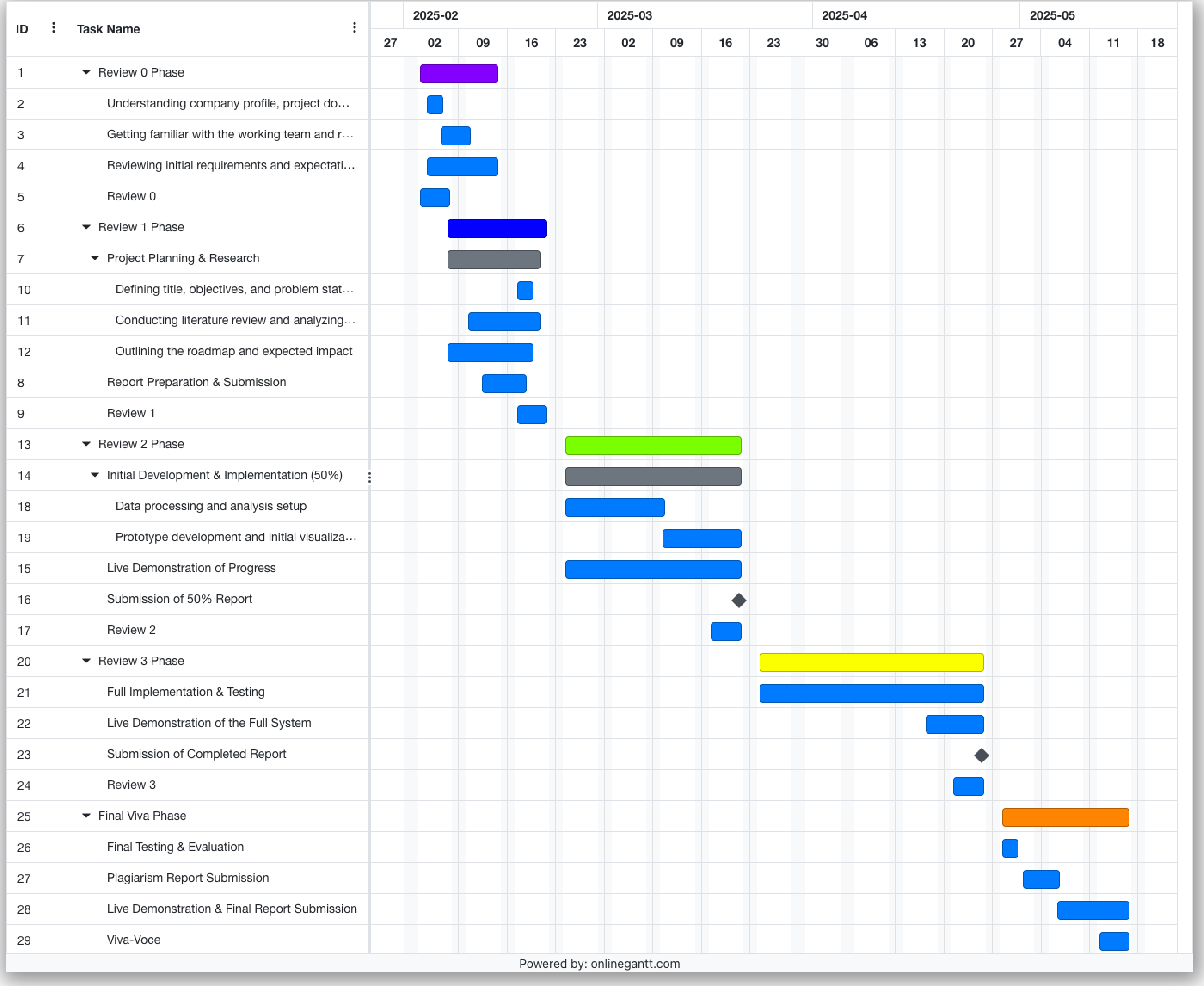
Performance monitoring of aero-gas turbine engines involves multiple steps, often requiring data to be extracted, processed, and analyzed across different tools before insights can be derived. This leads to **longer processing times** and **multiple handovers**, making the process more complex than necessary.

A system that **integrates data retrieval, visualization, and analysis in one place** can make the entire process **faster and more efficient**. By allowing users to directly select **what they want to visualize** through a **customizable GUI**, unnecessary data movement is reduced, and results are obtained efficiently. Instead of relying on separate tools for **data extraction, plotting, and analysis**, a **single AI-driven system** can streamline everything, ensuring **faster decision-making** with minimal manual intervention.

Problem Statement

Develop an AI-driven system that streamlines aero-gas turbine engine performance monitoring by integrating custom visualizations, automated analysis, and interactive insights, reducing data movement and improving the speed and efficiency of result generation.

ROAD MAP (GANTT CHART)



GITHUB LINK

https://github.com/saipriya-dipika/AI-ML-Internship

ALGORITHM DETAILS (UI)

Objective: Engine Data Visualization using Flask (using Grafana and MatplotLib)

1. **Initialize Flask application.**
2. **Connect to MySQL database.**
3. **Render index.html.**

4. **Define function generate_modules():**

a. Fetch necessary tables

b. For each table:

i. Retrieve columns.

ii. Filter out unwanted columns.

iii. Map module names to columns.

5. Define route '/get_modules' (GET):

a. Retrieve run_id from request.

b. Call generate_modules().

c. Check tables for run_id and return relevant modules.

6. Define route '/generate_plot' (POST):

a. Retrieve run_id, selected_module, and table_name from request.

b. create a plot using Matplotlib.

c. Encode plot as base64 and return in JSON response.

7. **Run Flask application**

SYSTEM REQUIREMENTS

Hardware Requirements:

- High-performance workstation with GPU support

Software Requirements:

- DBMS for structured data storage
- Python with AI/ML and other Libraries for data analysis and UI-Backend Integration
- Visualization tools/Libraries (Matplotlib, Seaborn, etc)

ADVANTAGES OF PROPOSED WORK

- **Performance Monitoring:** Faster detection of performance anomalies
- **Predictive Maintenance:** Prevents failures and reduces downtime
- **Automated Insights:** AI-driven trend analysis & recommendations
- **User-Driven Visualizations:** Dynamic selection of parameters for customized performance analysis.
- **Scalability & Efficiency:** Work with large datasets for accurate performance tracking

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