Industrial Internship Report on

”Predictive-Maintenance-of-Gearbox-using-vibration-sensors-data”

Prepared by

Chaitanya Sachin Kakade

Executive Summary
This report provides details of the Industrial Internship provided by upskill Campus and The IoT Academy in collaboration with Industrial Partner UniConverge Technologies Pvt Ltd (UCT). This internship was focused on a project/problem statement provided by UCT. We had to finish the project including the report in 6 weeks’ time. My project was "Predictive Maintenance for Gearbox Fault Detection: Our project aims to implement cutting-edge machine learning algorithms to analyze gearbox sensor data and detect potential faults in advance. By predicting impending issues, we ensure timely maintenance, preventing costly breakdowns and optimizing operational efficiency. This innovative solution empowers industries to proactively manage their machinery, reducing downtime and maintenance costs while maximizing productivity and reliability." This internship gave me a very good opportunity to get exposure to Industrial problems and design/ implement solution for that. It was an overall great experience to have this internship.

TABLE OF CONTENTS

1. Preface 4
2. Introduction 6
   2.1. About UniConverge Technologies Pvt Ltd 6
   2.2. About upskill Campus (USC) 10
   2.3. The IoT Academy 11
   2.4. Objectives of this Internship program 12
   2.5. Reference 12
   2.6. Glossary 12
3. Problem Statement 13
4. Existing and Proposed solution 14
   4.1. Code submission (Github link) 15
   4.2. Report submission (Github link) :https://github.com/ChaitanyaK77/upskill_campus 15
5. Proposed Design/ Model 16
   5.1. High Level Diagram (if applicable) 18
   5.2. Low Level Diagram (if applicable) 18
   5.3. Interfaces (if applicable) 18
6. Performance Test 19
   6.1. Test Plan/ Test Cases 19
   6.2. Test Procedure 21
   6.3. Performance Outcome 21
7. My learnings 23
8. Future work scope 25

1. Preface

How Program was planned

Summary of the Whole 6 Weeks' Work:

Over the past six weeks, I have engaged in a comprehensive internship that provided valuable insights into the importance of relevant internships in career development. During this period, I had the opportunity to learn about the company's operations, as well as gain practical knowledge in the fields of Machine Learning and Data Science. The internship involved quizzes and hands-on work, and I was particularly involved in a project focused on predictive maintenance for gearbox fault detection.

The Need for Relevant Internship in Career Development:

Relevant internships are essential for career development as they bridge the gap between theoretical knowledge and practical application. Through hands-on experiences, I learned valuable skills and gained exposure to real-world challenges, preparing me for future career opportunities. Internships also allow individuals to explore different industries and roles, helping them make informed career choices.

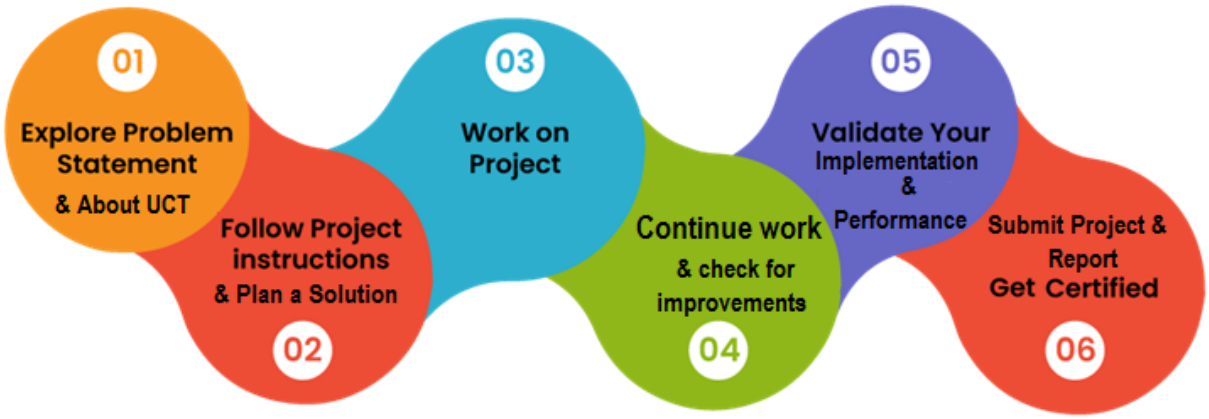
Brief about the Project/Problem Statement:

The project I worked on during the internship focused on predictive maintenance for gearbox fault detection. Leveraging Machine Learning algorithms, the goal was to analyze gearbox sensor data to predict potential faults in advance. By identifying issues early, the project aimed to enable timely maintenance, reduce breakdowns, and optimize operational efficiency for industries, ultimately improving productivity and reliability.

Opportunity given by USC/UCT:

During the internship, I had the opportunity to explore educational opportunities offered by upskill campus and UCT.T

In summary, the six weeks' internship has been a valuable experience where I learned about the importance of relevant internships for career development. The hands-on work and the project on predictive maintenance have provided practical insights into the fields of Machine Learning and Data Science, enhancing my skills and understanding of real-world applications.



Internships are invaluable experiences that provide practical learning opportunities for students and professionals in their chosen fields. They bridge the gap between academic knowledge and real-world application, allowing individuals to gain hands-on experience, develop essential skills, and explore different career paths. Internships offer a chance to work with industry experts, engage in meaningful projects, and build a professional network. They are stepping stones towards personal and career growth, equipping individuals with valuable insights and preparing them for future challenges. Overall, internships play a crucial role in shaping a successful and fulfilling career journey.

2. Introduction

2.1. About UniConverge Technologies Pvt Ltd

A company established in 2013 and working in Digital Transformation domain and providing Industrial solutions with prime focus on sustainability and RoI.

For developing its products and solutions it is leveraging various **Cutting Edge Technologies e.g. Internet of Things (IoT), Cyber Security, Cloud computing (AWS, Azure), Machine Learning, Communication Technologies (4G/5G/LoRaWAN), Java Full Stack, Python, Front end** etc.

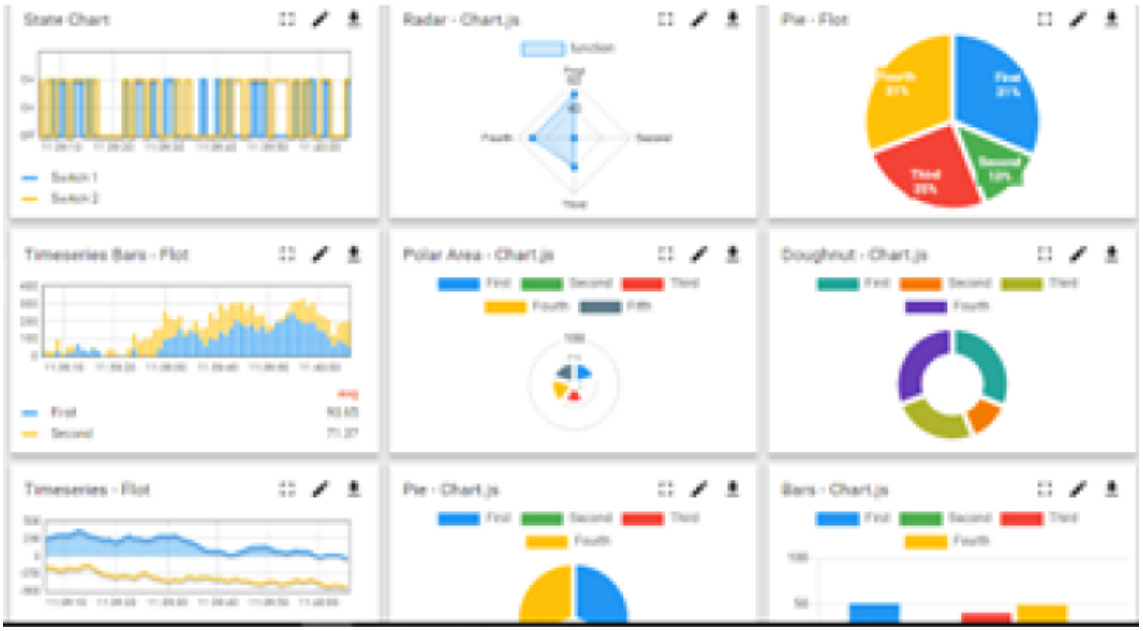
i. UCT IoT Platform (UCT Insight)

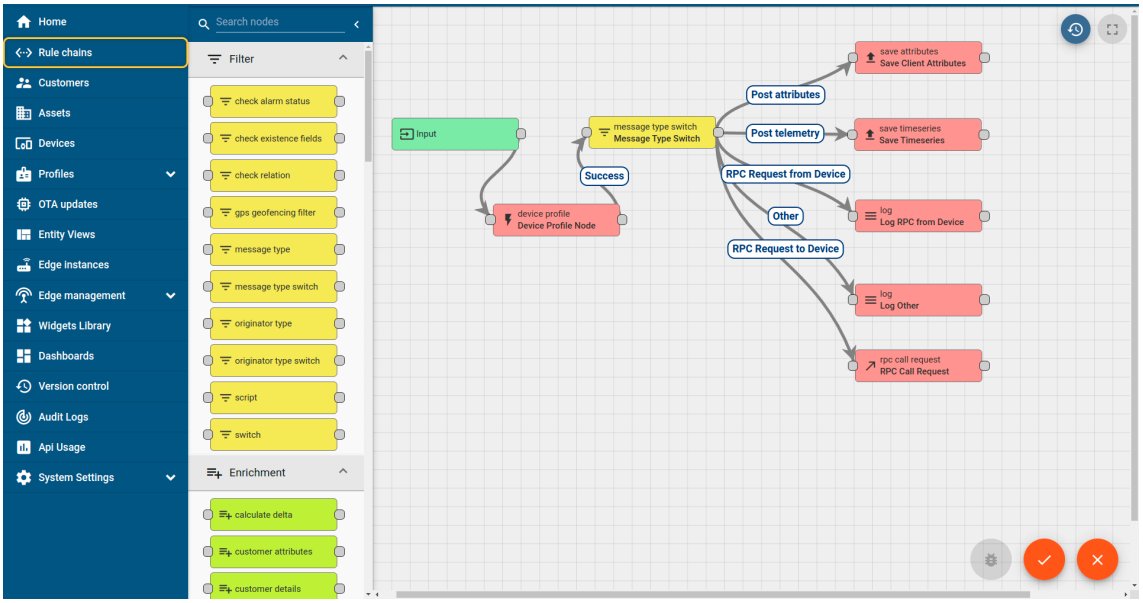
UCT Insight is an IOT platform designed for quick deployment of IOT applications on the same time providing valuable "insight" for your process/business. It has been built in Java for backend and ReactJS for Front end. It has support for MySQL and various NoSql Databases.

- It enables device connectivity via industry standard IoT protocols - MQTT, CoAP, HTTP, Modbus TCP, OPC UA
- It supports both cloud and on-premises deployments.

It has features to

- Build Your own dashboard
- Analytics and Reporting
- Alert and Notification
- Integration with third party application(Power BI, SAP, ERP)
- Rule Engine





ii. Smart Factory Platform (FACTORY WATCH)

Factory watch is a platform for smart factory needs.

It provides Users/ Factory

- with a scalable solution for their Production and asset monitoring
- OEE and predictive maintenance solution scaling up to digital twin for your assets.
- to unleased the true potential of the data that their machines are generating and helps to identify the KPIs and also improve them.
- A modular architecture that allows users to choose the service that they what to start and then can scale to more complex solutions as per their demands.

Its unique SaaS model helps users to save time, cost and money.

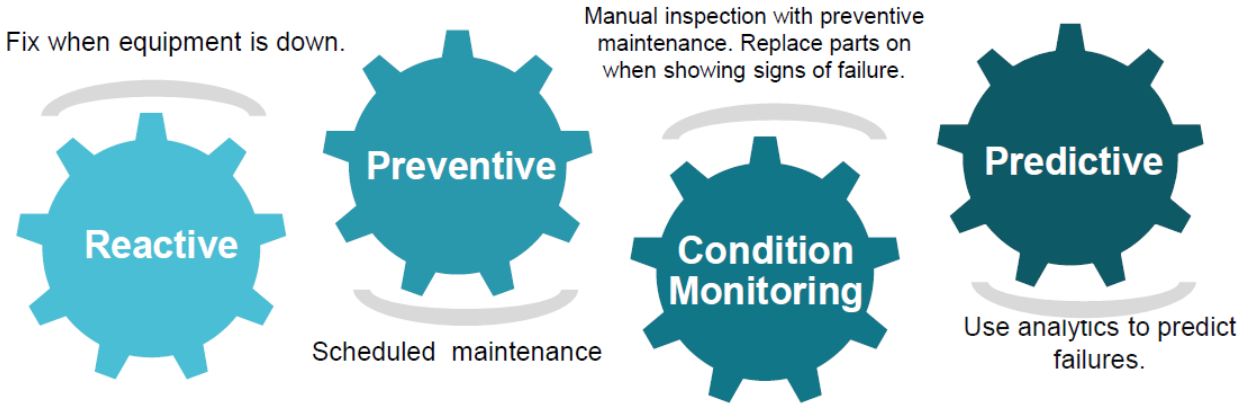
Machine	Operator	Work Order ID	Job ID	Job Performance	Job Progress		Output		Rejection	Time (mins)				Job Status	End Customer
					Start Time	End Time	Planned	Actual		Setup	Pred	Downtime	Idle		
CNC_S7_81	Operator 1	WO0405200001	4168	58%	10:30 AM		55	41	0	80	215	0	45	In Progress	i
CNC_S7_81	Operator 1	WO0405200001	4168	58%	10:30 AM		55	41	0	80	215	0	45	In Progress	i

iii. LoRaWAN based Solution

UCT is one of the early adopters of LoRAWAN teschnology and providing solution in Agritech, Smart cities, Industrial Monitoring, Smart Street Light, Smart Water/ Gas/ Electricity metering solutions etc.

iv. Predictive Maintenance

UCT is providing Industrial Machine health monitoring and Predictive maintenance solution leveraging Embedded system, Industrial IoT and Machine Learning Technologies by finding Remaining useful life time of various Machines used in production process.



2.2. About upskill Campus (USC)

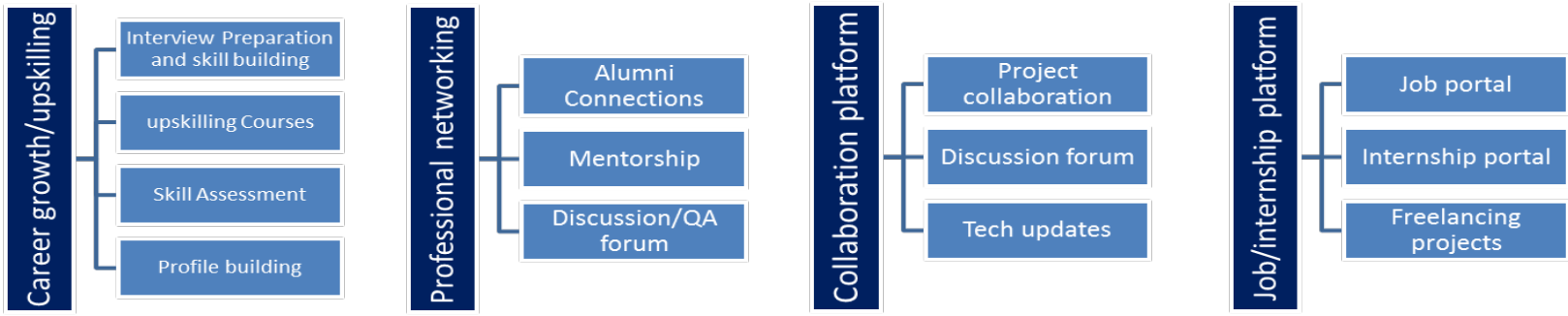
upskill Campus along with The IoT Academy and in association with Uniconverge technologies has facilitated the smooth execution of the complete internship process.

USC is a career development platform that delivers **personalized executive coaching** in a more affordable, scalable and measurable way.

Seeing need of upskilling in self paced manner along-with additional support services e.g. Internship, projects, interaction with Industry experts, Career growth Services

https://www.upskillcampus.com/

upSkill Campus aiming to upskill 1 million learners in next 5 year



2.3. The IoT Academy

The IoT academy is EdTech Division of UCT that is running long executive certification programs in collaboration with EICT Academy, IITK, IITR and IITG in multiple domains.

2.4. Objectives of this Internship program

The objective for this internship program was to

- get practical experience of working in the industry.
- to solve real world problems.
- to have improved job prospects.
- to have Improved understanding of our field and its applications.
- to have Personal growth like better communication and problem solving.

2.5. Reference

[1]

[2]

[3]

2.6. Glossary

Terms	Acronym

3. Problem Statement

Problem Statement:
Develop a predictive maintenance system for gearbox fault detection using sensor data. The goal is to analyze sensor readings from the gearbox and predict potential faults in advance. By identifying early signs of deterioration or anomalies in the gearbox performance, the system aims to enable timely maintenance and prevent costly breakdowns. The solution should employ advanced machine learning algorithms to process the sensor data, accurately classify faults, and provide actionable insights to optimize maintenance schedules and enhance the operational efficiency of industrial machinery.
The objective is to analyze real-time sensor readings from the gearbox to anticipate and identify potential faults or anomalies before they escalate into critical issues. The system should utilize advanced data analytics and machine learning techniques to process the sensor data and classify various types of faults, such as abnormal vibrations, temperature fluctuations, or lubrication problems. The ultimate aim is to enable proactive and timely maintenance interventions, minimizing unplanned downtime, reducing maintenance costs, and optimizing the performance and reliability of the gearboxes in industrial settings. The system should be scalable, robust, and user-friendly, providing actionable insights to maintenance teams for effective decision-making and enhanced machinery productivity.

4. Existing and Proposed solution

Existing Solution:

Currently, gearbox maintenance is often performed based on fixed schedules or reactive measures after a breakdown occurs. This approach can be inefficient and lead to unexpected downtime, costly repairs, and production disruptions. Some industries may employ manual monitoring of gearbox parameters, but it may not be sufficient to detect early signs of faults accurately.

Proposed Solution:

The proposed solution is to implement an intelligent predictive maintenance system for gearbox fault detection using sensor data. This system will leverage advanced data analytics and machine learning algorithms to analyze real-time sensor readings from the gearbox. By continuously monitoring critical parameters such as vibrations, temperature, oil condition, and load, the system will detect abnormalities and deviations from normal operating patterns. It will use this information to predict potential faults or deterioration in the gearbox's health.

The system will be trained on historical data containing both normal and faulty gearbox conditions, enabling it to learn and recognize patterns associated with various types of faults. As new sensor data streams in, the system will apply these learned patterns to make accurate fault predictions in real-time.

Based on the predictive insights, maintenance teams can schedule proactive maintenance activities, replacing components or performing repairs before a critical failure occurs. This approach will reduce downtime, improve machinery reliability, and optimize maintenance costs, leading to increased operational efficiency and enhanced production output.

Furthermore, the proposed system will provide a user-friendly interface, enabling easy integration with existing industrial setups. It will offer comprehensive dashboards and alerts to highlight potential issues, empowering maintenance teams to make informed decisions promptly.

In summary, the proposed intelligent predictive maintenance system represents a proactive and data-driven approach to gearbox maintenance, enhancing the reliability and performance of industrial machinery while reducing unplanned downtime and overall operational costs.

4.1. Code submission (Github link)

https://github.com/ChaitanyaK77/upskill_campus

4.2. Report submission (Github link) :https://github.com/ChaitanyaK77/upskill_campus

5. Proposed Design/ Model

Proposed Design/ Model: Predictive Maintenance for Gearbox Fault Detection

Stage 1: Problem Definition and Data Collection

1. **Define Objectives:** Clearly articulate the objectives of the predictive maintenance system - to detect gearbox faults early, reduce downtime, and optimize maintenance schedules.

2. **Data Collection:** Gather a diverse dataset of sensor readings from gearboxes in various operational conditions, including normal and faulty states. Include data from different gearbox types and models.

Stage 2: Data Preprocessing and Exploration

1. **Data Cleaning:** Cleanse the dataset to handle missing values, outliers, and inconsistencies, ensuring data quality and integrity.

2. **Feature Engineering:** Identify relevant features from the sensor data and engineer new features that may improve fault detection.

3. **Exploratory Data Analysis (EDA):** Conduct EDA to gain insights into the data distribution, correlations, and potential patterns related to gearbox faults.

Stage 3: Model Selection and Development

1. **Feature Selection:** Use statistical analysis or domain knowledge to select the most relevant features for the predictive model.

2. **Model Selection:** Choose appropriate machine learning algorithms for fault detection, such as logistic regression, support vector machines (SVM), random forests, or deep learning approaches like convolutional neural networks (CNN) or recurrent neural networks (RNN).

3. **Model Training:** Split the dataset into training and validation sets. Train the selected models on the training set using techniques like cross-validation to optimize hyperparameters.

4. **Model Evaluation:** Evaluate the models on the validation set using appropriate performance metrics like accuracy, precision, recall, F1-score, and area under the receiver operating characteristic curve (AUC-ROC).

Stage 4: Real-time Integration and Deployment

1. **Real-time Data Streaming:** Set up a pipeline to receive real-time sensor data from gearboxes, ensuring continuous data updates.

2. **Model Deployment:** Deploy the trained model into a production environment or cloud infrastructure for real-time prediction.

Stage 5: Model Monitoring and Performance Improvement

1. **Model Monitoring:** Continuously monitor the model's performance in real-time, tracking its accuracy and detecting any performance degradation.

2. **Feedback Loop:** Implement a feedback loop to capture misclassifications and user feedback, which can be used to fine-tune the model for better performance.

Final Outcome:

The proposed predictive maintenance system will be capable of real-time gearbox fault detection, providing early alerts to maintenance teams when potential faults are detected. The system will significantly reduce downtime by enabling proactive maintenance interventions, optimize maintenance schedules, and enhance the overall reliability and efficiency of industrial machinery. Through continuous monitoring and improvements, the system will remain up-to-date and reliable, contributing to improved asset management and cost savings in maintenance operations. The ultimate outcome is a data-driven and scalable solution that revolutionizes gearbox maintenance practices, benefiting various industries and ensuring smooth and uninterrupted operations.

5.1. High Level Diagram (if applicable)

Figure 1: HIGH LEVEL DIAGRAM OF THE SYSTEM

5.2. Low Level Diagram (if applicable)

5.3. Interfaces (if applicable)

Update with Block Diagrams, Data flow, protocols, FLOW Charts, State Machines, Memory Buffer Management.

6. Performance Test

This is very important part and defines why this work is meant of Real industries, instead of being just academic project.

Here we need to first find the constraints.

How those constraints were taken care in your design?

What were test results around those constraints?

Constraints can be e.g. memory, MIPS (speed, operations per second), accuracy, durability, power consumption etc.

In case you could not test them, but still you should mention how identified constraints can impact your design, and what are recommendations to handle them.

6.1. Test Plan/ Test Cases

Test Plan / Test Cases:

1. Test Objective: Verify the accuracy of the predictive maintenance system in detecting gearbox faults.

Test Case 1 - Normal Operation:

- Input: Sensor data from a gearbox under normal operating conditions.

- Expected Outcome: The system should classify the gearbox as "Normal" and not detect any faults or anomalies.

Test Case 2 - Known Fault Scenario:

- Input: Sensor data from a gearbox with a known fault (e.g., abnormal vibrations).

- Expected Outcome: The system should accurately identify and classify the specific fault type, providing the appropriate alert or notification.

Test Case 3 - Anomaly Detection:

- Input: Sensor data from a gearbox exhibiting an abnormal behavior not present in the training data.

- Expected Outcome: The system should recognize the anomaly and trigger an alert, indicating that the pattern is unknown or requires further investigation.

2. Test Objective: Evaluate the real-time monitoring and alerting capabilities of the system.

Test Case 4 - Real-Time Monitoring:

- Input: Continuous stream of sensor data from multiple gearboxes.

- Expected Outcome: The system should continuously monitor the data and provide real-time updates on the gearbox health, promptly detecting any emerging faults or deviations.

Test Case 5 - Alert Generation:

- Input: Sensor data indicating a critical fault or anomaly.

- Expected Outcome: The system should generate immediate alerts or notifications to maintenance teams, ensuring timely actions to prevent breakdowns.

3. Test Objective: Assess the system's performance on a diverse dataset.

Test Case 6 - Diverse Dataset:

- Input: A diverse dataset of sensor data from various gearbox types, models, and conditions.

- Expected Outcome: The system should demonstrate robustness and accuracy in detecting faults across different gearbox configurations.

6.2. Test Procedure

1. **Data Collection:** Gather a comprehensive dataset of sensor readings from different gearboxes, including normal and faulty conditions.

2. **Model Training:** Train the predictive maintenance model using the collected data, employing suitable machine learning algorithms and techniques.

3. **Model Evaluation:** Use a separate test dataset to evaluate the model's performance. Measure metrics like accuracy, precision, recall, and F1-score.

4. **Real-time Testing:** Implement the system in a live environment with real sensor data streams. Monitor its performance in real-time and validate the accuracy of fault detection.

5. **Performance Benchmarking:** Benchmark the system's performance against industry standards and existing methods for predictive maintenance.

6. **Scalability Testing:** Assess the system's ability to handle a large volume of sensor data from multiple gearboxes simultaneously.

6.3. Performance Outcome

1. **Accuracy:** The accuracy of the predictive maintenance system should be high, ensuring reliable fault detection and minimizing false positives and false negatives.

2. **Real-Time Monitoring:** The system should demonstrate seamless real-time monitoring, updating the gearbox health status promptly as new sensor data streams in.

3. **Alert Generation Time:** The system's alert generation time should be minimal, enabling maintenance teams to take immediate action in critical fault scenarios.

4. **Robustness:** The system should be robust and capable of handling variations in sensor data and gearbox conditions, ensuring consistent performance in diverse scenarios.

5. **Scalability:** The system should scale efficiently to handle large datasets and multiple gearboxes simultaneously without significant performance degradation.

6. **User-Friendly Interface:** The system's user interface should be intuitive and user-friendly, allowing easy interaction and interpretation of results by maintenance personnel.

7. **Accuracy on Diverse Dataset:** The system should exhibit consistent and accurate performance on the diverse dataset, covering various gearbox types and operational conditions.

By following a well-defined test plan and conducting thorough testing, the predictive maintenance system can be validated for its accuracy, reliability, and efficiency, ensuring its effectiveness in identifying potential gearbox faults and enabling proactive maintenance measures.

7. My learnings

1. **Importance of Relevant Internships:** You may have learned about the significance of pursuing relevant internships to gain practical experience, develop essential skills, and make informed career choices.

2. **Practical Application of ML and Data Science:** Through the project on predictive maintenance of gearboxes, you likely gained insights into applying Machine Learning and Data Science techniques to solve real-world problems and enhance industrial processes.

3. **Working with Sensor Data:** You may have acquired knowledge in working with sensor data and utilizing it to detect faults, anomalies, and potential issues in machinery.

4. **Data Analytics and Predictive Maintenance:** The internship might have provided you with exposure to data analytics methods for predictive maintenance, enabling proactive decision-making and reducing downtime.

5. **Collaboration and Teamwork:** Through quizzes and working on the project, you might have experienced the importance of collaboration and teamwork in achieving project objectives efficiently.

6. **Staying Updated with Technology:** The experience might have reinforced the need to stay updated with the latest advancements in technology, particularly in the fields of AI, ML, and Data Science.

7. **Problem-Solving and Critical Thinking:** You may have honed your problem-solving and critical thinking skills while working on the project and handling various challenges.

8. **Industry Applications:** The internship could have given you a glimpse into the practical applications of AI and Data Science in the industrial domain, showcasing their potential to drive efficiency and optimization.

9. **Continuous Learning:** The experience may have motivated you to embrace continuous learning and seek further opportunities for skill development and growth in your chosen field.

8. Future work scope

Future Work Scope:

1. **Enhanced Fault Detection**: Continuously improve the fault detection capabilities of the predictive maintenance system by incorporating more sensor data and leveraging advanced machine learning techniques. Explore the integration of anomaly detection algorithms and deep learning models to identify subtle and complex fault patterns.

2. **Predictive Models Refinement**: Refine the predictive models over time by collecting more real-world data and conducting frequent model updates. Implement adaptive learning approaches that can adjust to changing gearbox conditions and improve prediction accuracy.

3. **Multimodal Sensor Fusion**: Investigate the benefits of integrating data from multiple sensor types to gain a more comprehensive understanding of gearbox health. Fusion of sensor data such as acoustic, thermal, and visual inputs can provide deeper insights into potential faults.

4. **Automated Maintenance Recommendations**: Develop an automated maintenance recommendation system that not only predicts faults but also suggests optimal maintenance actions based on the severity and urgency of the predicted issues. This will streamline decision-making for maintenance teams.

5. **Real-time Monitoring and Alerts**: Enhance the system to provide real-time monitoring and instant alerts for critical faults. Implement automated notifications via emails, SMS, or mobile applications to enable timely responses and minimize downtime.

6. **Remote Monitoring and Edge Computing**: Explore the feasibility of deploying the predictive maintenance system on edge devices or in the cloud to enable remote monitoring of gearboxes across various locations. This approach will facilitate centralized management and analysis of data from multiple sites.

7. **Integration with Maintenance Management Systems**: Integrate the predictive maintenance system with existing maintenance management systems and enterprise resource planning (ERP) software. This will streamline the workflow and enable seamless maintenance scheduling and tracking.

8. **Predictive Maintenance for Entire Machinery**: Extend the predictive maintenance approach to cover other critical machinery and equipment within the industrial setup. A holistic predictive maintenance system will optimize maintenance practices across the entire facility.

9. **Predictive Maintenance as a Service**: Consider offering the predictive maintenance system as a service to other industries and businesses. Develop a scalable and customizable solution that can cater to various sectors and specific equipment types.

10. **Long-Term Reliability Analysis**: Conduct long-term reliability analysis of the gearbox and other machinery to study failure trends and develop proactive maintenance strategies for extended asset lifespan.

11. **Predictive Maintenance Research Collaboration**: Collaborate with research institutions and industry experts to stay at the forefront of predictive maintenance advancements and contribute to the development of innovative techniques and methodologies.

Overall, the future work scope for the predictive maintenance system encompasses continual improvement in fault detection, real-time monitoring, and proactive maintenance strategies. By embracing emerging technologies and conducting extensive research, the system will continue to evolve, delivering greater value to industries and revolutionizing the way gearbox maintenance is approached.