Industrial Internship Report on

” Turbofan_Engine_Maintenance_Predictor”

Prepared by

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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 aims to predict the Remaining Useful Life (RUL) of turbofan engines using historical sensor data. Accurate RUL predictions are crucial for efficient maintenance scheduling, reducing downtime, and preventing unexpected failures. 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.

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1 Preface

Summary of the whole 6 weeks' work.

About need of relevant Internship in career development.

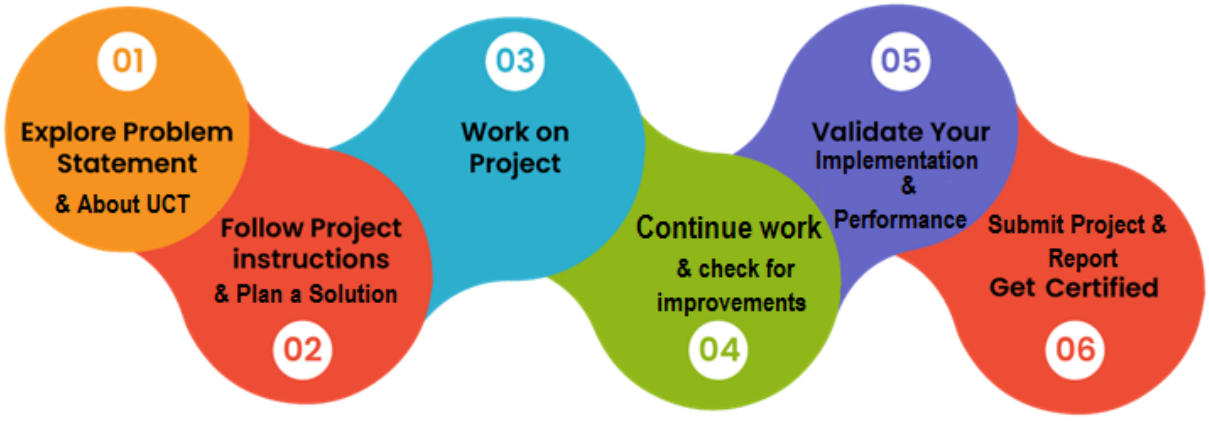
Turbofan Engine Maintenance Predictor Project

Problem Statement:

The Turbofan Engine Maintenance Predictor project addresses the critical need for efficient and reliable predictive maintenance in the aviation industry. The primary goal is to predict the Remaining Useful Life (RUL) of turbofan engines using historical sensor data. Accurate RUL predictions help in scheduling maintenance activities proactively, thus reducing downtime, preventing unexpected failures, and optimizing maintenance costs.

Opportunity given by USC/UCT.

How Program was planned



During my internship, I gained hands-on experience in applying machine learning to predictive maintenance, specifically focusing on turbofan engines. I developed skills in data preprocessing, feature engineering, and model evaluation, while contributing to a project that enhances maintenance efficiency and operational reliability. This experience significantly boosted my technical expertise and problem-solving abilities in real-world applications.

Thank to all , who have helped you directly or indirectly.

My internship experience empowered me to apply classroom knowledge to real-world challenges, navigate dynamic work environments, and cultivate invaluable professional relationships.

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.

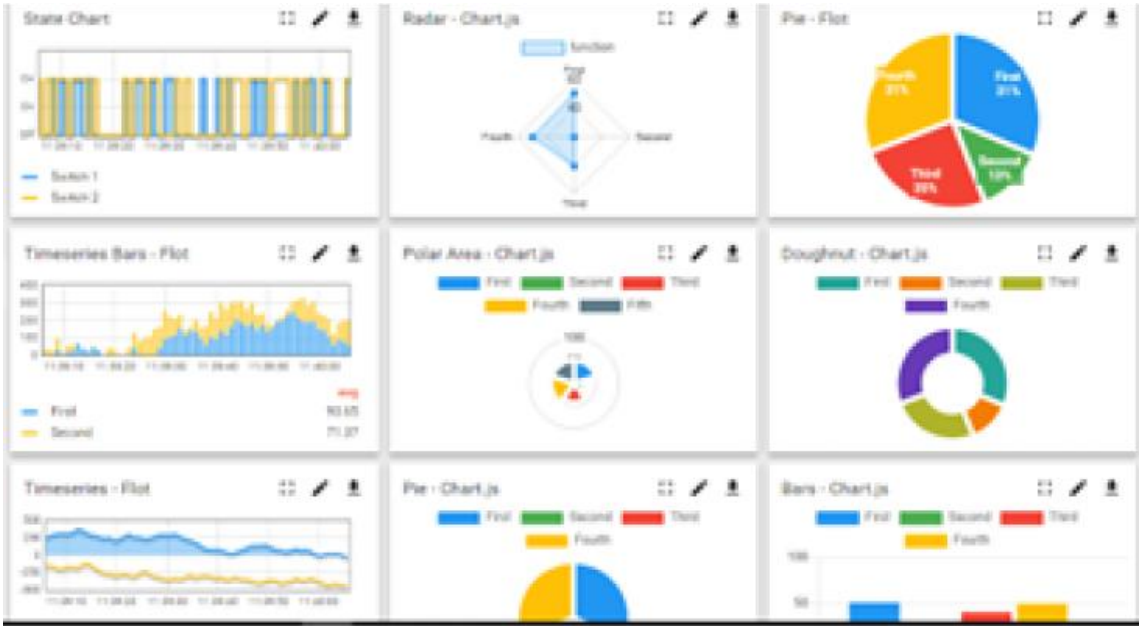
i. UCT IoT Platform (uct Insight)

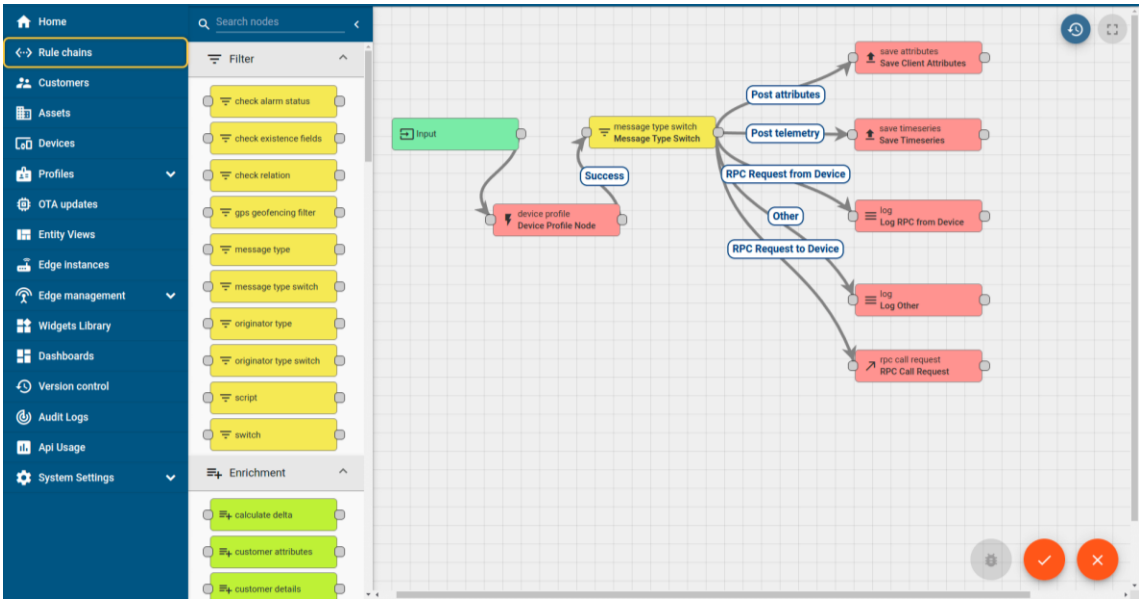
UCT Insight is an IOT platform designed for quick deployment of IOT applications on the same time providing valuable "insight" for your process/business. It has been built in Java for backend and ReactJS for Front end. It has support for MySQL and various NoSql Databases.

- 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.

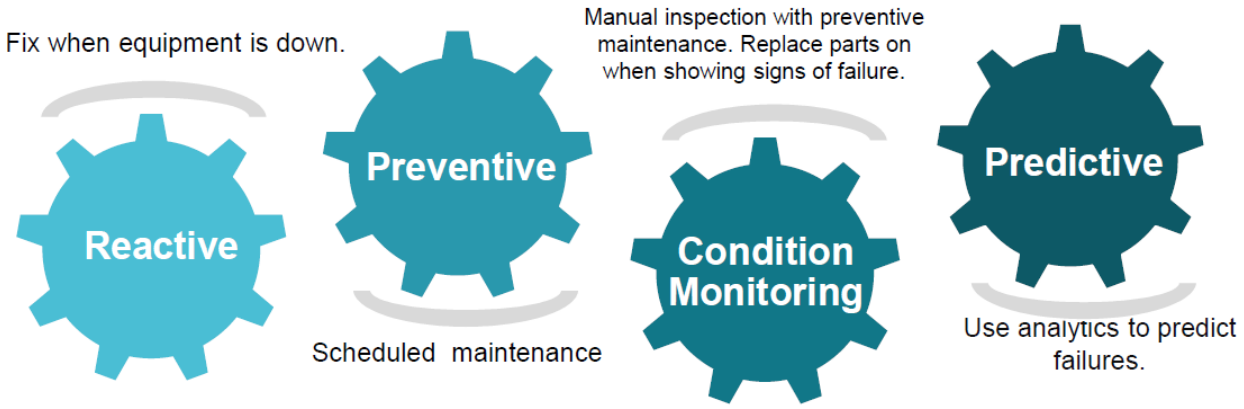
Machine	Operator	Work Order ID	Job ID	Job Performance	Job Progress		Output		Rejection	Time (mins)				Job Status	End Customer
					Start Time	End Time	Planned	Actual		Setup	Pred	Downtime	Idle		
CNC_S7_81	Operator 1	WO0405200001	4168	58%	10:30 AM		55	41	0	80	215	0	45	In Progress	i
CNC_S7_81	Operator 1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

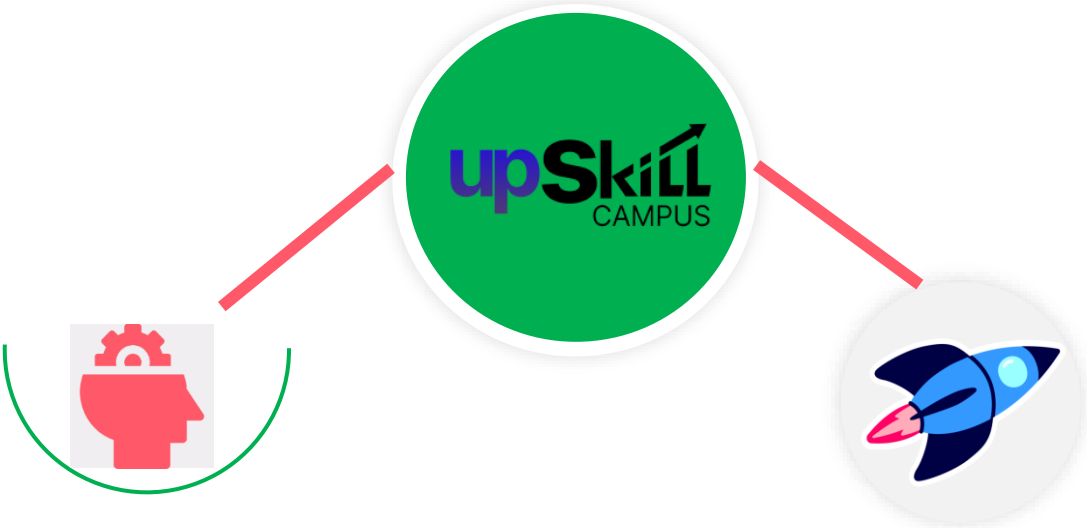
UCT is providing Industrial Machine health monitoring and Predictive maintenance solution leveraging Embedded system, Industrial IoT and Machine Learning Technologies by finding Remaining useful life time of various Machines used in production process.



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.

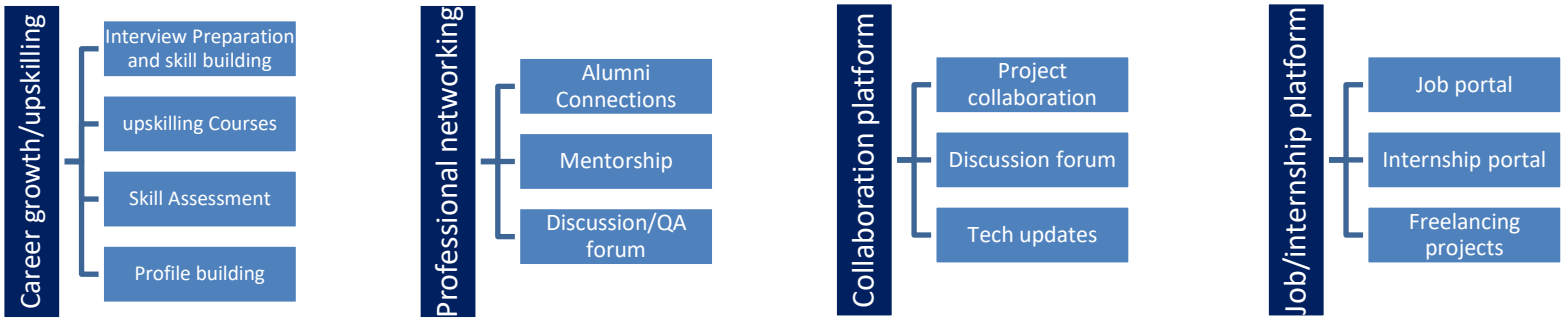
USC is a career development platform that delivers **personalized executive coaching** in a more affordable, scalable and measurable way



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

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

https://www.upskillcampus.com/



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] Edunet foundation and Code Unnati Program.

2.6 Glossary

Terms	Acronym
Regression Analysis	ML: Machine Learning
Data Visualization	AI: Artificial Intelligence
Feature Engineering	PCA: Principal Component Analysis
Data Mining:	EDA: Exploratory Data Analysis
Optimization	

3 Problem Statement

In the assigned problem statement

- The problem statement for the "Turbofan Engine Maintenance Predictor" project revolves around the need to predict the remaining useful life (RUL) of turbofan engines accurately. Turbofan engines are critical components of various machinery, including aircraft, power plants, and industrial equipment. Predicting the RUL of these engines is essential for proactive maintenance scheduling, minimizing downtime, and preventing catastrophic failures.
- The core challenge lies in analyzing sensor data collected from the turbofan engines to identify patterns indicative of degradation or impending failure. Traditional approaches often rely on fixed maintenance schedules or simple threshold-based alerts, which can be inefficient and costly. In contrast, the goal of this project is to leverage advanced machine learning and predictive analytics techniques to develop a robust maintenance predictor.
- By utilizing historical sensor data, such as temperature, pressure, vibration, and operational parameters, the project aims to train predictive models capable of forecasting the RUL of turbofan engines with high accuracy. These models will be trained to recognize subtle patterns and anomalies in the sensor data indicative of degradation, allowing maintenance teams to intervene proactively before critical failures occur.
- Ultimately, the "Turbofan Engine Maintenance Predictor" project seeks to enhance operational efficiency, reduce maintenance costs, and improve safety by providing accurate predictions of turbofan engine RUL, thereby enabling timely maintenance actions and ensuring the reliability and longevity of these vital assets.

4 Existing and Proposed solution

Summary of Existing Solutions and Their Limitations:

1. **Rule-Based Systems**: Some existing solutions rely on rule-based systems that trigger maintenance actions based on predefined thresholds or rules. However, these approaches may not adapt well to varying operating conditions and may lead to unnecessary maintenance or missed opportunities for proactive intervention.
2. **Predictive Maintenance Models**: Other solutions utilize predictive maintenance models, often based on statistical methods or machine learning algorithms. While these models can provide more accurate predictions of maintenance needs, they may require extensive labeled data for training and may struggle with complex patterns or anomalies in the data.
3. **Prognostics and Health Management (PHM) Systems**: PHM systems integrate sensor data, analytics, and decision support tools to monitor equipment health and predict failures. While effective, these systems can be complex to implement and maintain, requiring specialized expertise and infrastructure.

Proposed Solution: Our proposed solution for the "Turbofan Engine Maintenance Predictor" project involves developing a data-driven predictive maintenance model using advanced machine learning techniques, such as deep learning algorithms. By leveraging historical sensor data from turbofan engines, including temperature, pressure, vibration, and operational parameters, we aim to train a model capable of accurately predicting the remaining useful life (RUL) of these engines.

Value Addition:

1. **Accuracy**: Our proposed solution aims to deliver highly accurate predictions of turbofan engine RUL, enabling proactive maintenance scheduling and minimizing downtime.
2. **Adaptability**: By utilizing advanced machine learning techniques, our model can adapt to varying operating conditions and detect subtle patterns indicative of degradation or impending failure, enhancing its effectiveness in real-world environments.
3. **Efficiency**: The predictive maintenance model will enable maintenance teams to optimize their resources by focusing on critical maintenance needs, reducing unnecessary downtime and maintenance costs.
4. **Scalability**: Our solution will be designed with scalability in mind, allowing it to be applied to a wide range of turbofan engines and industrial settings, providing value across different industries and applications.

Overall, our proposed solution aims to revolutionize turbofan engine maintenance by delivering accurate, adaptable, and efficient predictive maintenance capabilities, thereby enhancing operational efficiency, reducing costs, and ensuring the reliability of critical assets.

4.1 Code submission (Github link)

https://github.com/bhaveshnegi/upskillcampus/blob/main/TurbofanEngineMaintenancePredictor.ipynb

4.2 Report submission (Github link) :

https://github.com/bhaveshnegi/upskillcampus/blob/main/TurbofanEngineMaintenancePredictor_Bhavesh_USC_UCT.pdf

5 Proposed Design/ Model

- **Problem Understanding and Data Collection**:
    - Begin by thoroughly understanding the problem you're trying to solve and the goals you aim to achieve.
    - Collect relevant data from various sources, ensuring it aligns with the problem statement and objectives.

- **Data Preprocessing**:
    - Clean the data by handling missing values, outliers, and inconsistencies.
    - Perform data transformation and normalization to prepare the data for analysis.

- **Exploratory Data Analysis (EDA)**:
    - Explore the dataset to gain insights into its structure, distributions, and relationships between variables.
    - Visualize the data using charts, graphs, and statistical summaries to identify patterns and anomalies.

- **Feature Engineering**:
    - Extract and create new features from the raw data to enhance the predictive power of the models.
    - Select relevant features based on domain knowledge and feature importance analysis.

- **Model Selection and Training**:
    - Choose appropriate machine learning algorithms or techniques based on the problem type (e.g., classification, regression, clustering).
    - Split the data into training and testing sets and train the models using the training data.
    - Optimize hyperparameters and model configurations using techniques like cross-validation and grid search.

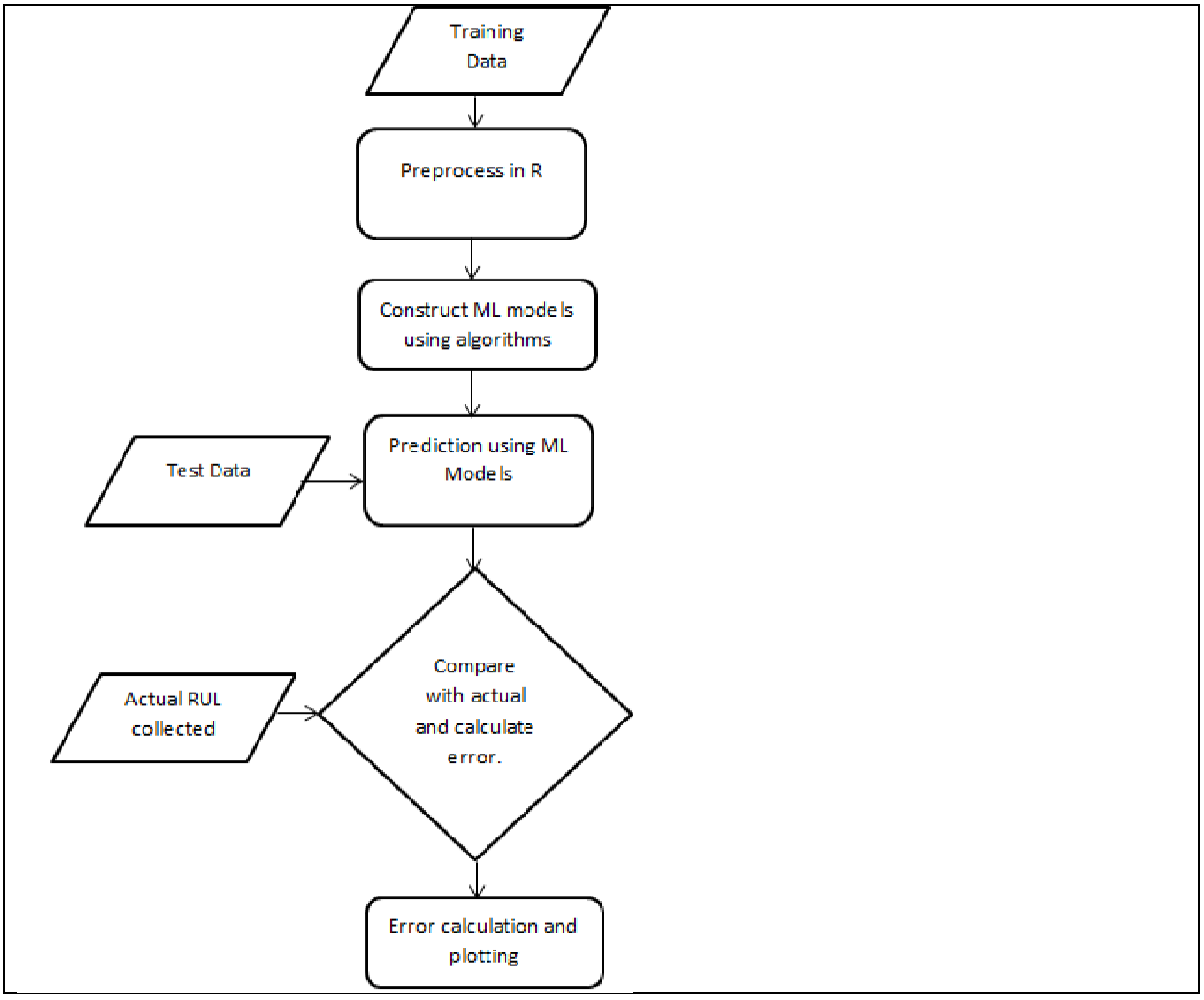
- **Model Evaluation**:
    - Evaluate the trained models using suitable evaluation metrics (e.g., accuracy, precision, recall, F1-score, mean squared error).
    - Compare the performance of different models to identify the best-performing one.

- **Model Interpretation and Validation**:

- Interpret the trained models to understand how they make predictions and identify important features.
- Validate the models using unseen data or through techniques like cross-validation to ensure their generalization capabilities.

Interfaces (if applicable)

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



6 Performance Test

- **Mean Squared Error (MSE)**:
    - The MSE measures the average squared difference between the predicted values and the actual values.
    - A value of 0.0 indicates that there is no discrepancy between the predicted and actual values, implying perfect accuracy.
    - In practical terms, this means that the model's predictions are exactly equal to the ground truth values in the test dataset.

- **R-squared (Coefficient of Determination)**:
    - The R-squared value represents the proportion of the variance in the dependent variable (target) that is explained by the independent variables (features) in the model.
    - A value of 1.0 indicates that the model explains 100% of the variance in the target variable.
    - In other words, the model perfectly fits the data, capturing all the variability in the target variable.

7 My learnings

Here's a summary of the overall learning from this project and how it contributes to career growth:

1. **Machine Learning and Data Science Skills**: Through this project, I acquired practical experience in machine learning and data science, including data preprocessing, feature engineering, model selection, training, and evaluation. These skills are fundamental in the field of data science and machine learning, equipping me to solve real-world problems and extract insights from data in various domains and industries.
2. **Soft Skills Development**: In addition to technical skills, I also developed soft skills such as communication, collaboration, and critical thinking. Collaborating with team members, stakeholders, and domain experts helped me hone my communication skills by articulating technical concepts and presenting findings effectively. These soft skills are crucial for building relationships, driving consensus, and delivering value in any professional setting.
3. **Domain Knowledge**: Working on a project with real-world applications provided me with valuable domain knowledge and insights into specific industries or domains. Understanding the context, challenges, and constraints of the industry enhances my credibility and effectiveness as a professional, enabling me to deliver impactful solutions tailored to meet the needs of stakeholders.
4. **Continuous Learning and Growth Mindset**: Engaging in this project reinforced the importance of continuous learning, curiosity, and a growth mindset. Embracing new technologies, methodologies, and best practices allows me to stay ahead in a rapidly evolving field and adapt to changing trends and requirements. Cultivating a mindset of lifelong learning is essential for ongoing personal and professional growth.

Overall, the learning from this project not only enhances my technical skills in machine learning and data science but also strengthens my soft skills, domain knowledge, and growth mindset. These combined skills and attributes position me for continued career growth and success in the dynamic field of data science and beyond.

8 Future work scope

1. **Advanced Feature Engineering Techniques**: While basic feature engineering methods were implemented, more advanced techniques such as automatic feature generation, interaction terms, or domain-specific feature transformations could be explored to further enhance model performance.
2. **Ensemble Learning Strategies**: Although ensemble methods were mentioned, a deeper exploration of ensemble learning techniques such as bagging, boosting, or stacking could provide opportunities for improving predictive accuracy and robustness.