FSM Online Internship Completion Report
on
[Remaining Usable Life Estimation]

In

[Machine Learning]

Submitted by

[Shadab Sheikh]
{GH Raisoni College of Engineering}

Under Mentorship of
[Devesh Tarasia]

IITD-AIA Foundation for Smart Manufacturing

[1-June-2021 to 31-July-2021]
[Remaining Usable Life Estimation (Bearing Dataset)]

Abstract

In this project, we aim to develop a Random Forest Regressor model for predicting the Remaining Useful Life (RUL) of bearings using sensor data from bearing tests. The model will be trained on historical data after undergoing data preprocessing to handle missing values and noise effectively. Feature engineering techniques will be applied to extract relevant information from the sensor readings, enhancing the model's accuracy in predicting RUL. Performance evaluation will be done using metrics like R-squared scores and Mean Squared Error (MSE).

The final deliverables include a trained model, Python code for data preprocessing and feature engineering, and evaluation metrics. By accurately predicting RUL, the proposed solution will enable industries to adopt proactive maintenance practices, reducing unplanned downtime and maintenance costs. The scalability of the implementation allows the extension to other critical industrial components, offering potential benefits in cost reduction, increased equipment lifespan, and improved production efficiency through data-driven decision-making, leveraging historical sensor data, including rotating speed, load force, temperature, and vibration patterns, along with operational conditions, the model estimates the remaining lifespan of bearings with high accuracy. The implementation involves Python3, PyTorch, Tensorflow, Scikit-Learn, Numpy, Pandas, and Flask.

Keywords: Predictive Maintenance, Remaining Usable Life(RUL), Random Forest Regressor, Rolling Bearings, Machine Learning, R-squared scores, Sensor Data Analysis, Proactive Maintenance.

Table of Content

1. Introduction-

As part of the FSM IITD-AIA Foundation for Smart Manufacturing Online Internship Program, the completion report outlines the project's objectives, methodologies, and outcomes. The project aimed to develop a machine-learning model for predicting the remaining usable life of rolling bearings using historical sensor data, vibration patterns, and operational conditions. The main goal was to enable proactive maintenance, minimize unexpected failures in rotating machinery, and optimize the performance of industrial equipment.

1.1. Project Background-

Predictive maintenance is a crucial aspect of industrial operations, especially in heavy machinery and equipment-intensive industries. Unplanned equipment failures can lead to costly downtime, production delays, and increased maintenance expenses. To address this challenge, companies have been leveraging sensor data and machine learning techniques to predict the Remaining Useful Life (RUL) of critical equipment accurately.

RUL prediction enables maintenance teams to schedule proactive maintenance actions, optimizing operational efficiency and reducing the risk of unexpected breakdowns. In this context, our project focuses on RUL prediction using sensor data from bearing tests. Bearings are vital components in various industrial systems, and their failure can have severe consequences on the overall machinery performance. By developing an accurate RUL prediction model, we aim to assist maintenance teams in planning and executing maintenance activities effectively, ultimately leading to increased productivity and reduced downtime.

1.2. Project Scope and Objectives-

The scope of the project involves the following key components:

- Data Collection: We will collect sensor data from bearing tests conducted over different time intervals.
- Data Preprocessing: The collected data may contain missing values and noise, which needs to be handled through preprocessing techniques.
- Model Development: We will implement a Random Forest Regressor model to predict the RUL of the bearings based on the sensor data.
- Model Evaluation: The performance of the developed model will be evaluated using appropriate metrics like R-squared scores and Mean Squared Error (MSE).
- Visualization: For better insights, we will create visualizations to present the model's predicted RUL against the true RUL values.

2. Problem Definition-

The main problem addressed in this project is the accurate prediction of the Remaining Useful Life (RUL) of bearings based on sensor data. The RUL prediction is essential for predictive maintenance as it allows maintenance teams to anticipate and address potential equipment failures proactively. The challenge lies in dealing with complex sensor data, handling missing values, and developing a reliable machine-learning model that can generalize well to unseen data.

3. Existing Solution-

Traditionally, maintenance strategies have been either reactive (fixing issues after failure) or time-based preventive maintenance (maintenance at fixed intervals). These approaches often lead to either costly downtime or unnecessary maintenance, respectively. Predictive maintenance has gained traction to overcome these limitations, where data-driven models are developed to predict the RUL of equipment.

Some existing solutions in predictive maintenance use statistical methods like moving averages, exponential smoothing, or regression techniques. However, these approaches may not capture the underlying patterns in the data accurately. Machine learning models, particularly Random Forest Regressors, have shown promising results in RUL prediction due to their ability to handle non-linearity and complex relationships in the data.

4. Proposed Development-

Our proposed development involves building a Random Forest Regressor model to predict the RUL of bearings based on sensor data. The data will be preprocessed to handle missing values and feature engineering techniques may be employed to extract relevant information from the sensor readings. The Random Forest model will be trained on historical data and tested on unseen data to assess its generalization capabilities.

To ensure robustness, hyperparameter tuning, and cross-validation will be performed. The model's performance will be evaluated using metrics such as R-squared scores and MSE, and visualizations will be created to illustrate the predicted RUL against the true RUL values.

5. Functional Implementation-

The implementation of the proposed solution involves the following steps:

- Data Collection: Obtain sensor data from bearing tests conducted at different time intervals.
- Data Preprocessing: Handle missing values and noise in the data using appropriate techniques like imputation and filtering.
- Feature Engineering: Extract relevant features from the sensor data to effectively represent the bearing's health condition.
- Model Development: Implement a Random Forest Regressor model to predict the RUL based on the engineered features.
- Model Training and Evaluation: Train the model on historical data, tune hyperparameters, and evaluate its performance on test data using R-squared scores and MSE.
- Visualization: Create scatter plots to visualize the model's predicted RUL against the true RUL values for better interpretability.

6. Final Deliverable-

The final deliverable of the project will include the following components:

- Python code for data preprocessing, feature engineering, and model training.
- Trained Random Forest Regressor model for RUL prediction.
- Evaluation metrics (R-squared scores, MSE) to assess the model's performance.
- Visualization of predicted RUL vs. true RUL values to gain insights into the model's accuracy.

7. Innovation in Implementation-

The proposed development utilizes a Random Forest Regressor, a machine-learning algorithm known for its robustness and ability to handle complex data relationships. Additionally, feature engineering techniques will be applied to extract relevant information from the sensor data, improving the model's predictive capabilities.

Moreover, the implementation focuses on data preprocessing to handle missing values effectively. The use of cross-validation and hyperparameter tuning ensures the model's generalization, making it more reliable in real-world scenarios.

8. Scalability to Solve Industrial Problems-

The developed RUL prediction model has the potential to provide significant benefits to industrial maintenance practices. By accurately predicting the RUL of bearings, companies can shift from reactive and time-based preventive maintenance strategies to predictive maintenance, leading to the following advantages are,

- Cost Reduction: Proactive maintenance minimizes unplanned downtime, reducing maintenance costs and avoiding expensive emergency repairs.
- Increased Equipment Lifespan: Timely maintenance extends the lifespan of critical equipment, optimizing asset utilization.
- Improved Production Efficiency: With fewer unexpected breakdowns, production processes can run more smoothly, improving overall efficiency.
- Data-Driven Decision-Making: Predictive maintenance facilitates data-driven decision-making, allowing for better resource allocation and planning.

The proposed solution's scalability lies in its ability to be applied to various types of industrial machinery and equipment beyond bearings. With the appropriate sensor data and domain-specific adjustments, the model can be extended to predict the RUL of other critical components, providing a comprehensive predictive maintenance framework for the entire industrial setup.

In conclusion, the project aims to develop a Random Forest Regressor model for RUL prediction based on bearing sensor data. By accurately predicting the RUL of bearings, this solution can enable industries to transition from traditional maintenance approaches to proactive and data-driven predictive maintenance strategies, resulting in enhanced operational efficiency, cost savings, and increased equipment lifespan. The implementation leverages machine learning and data preprocessing techniques to address the challenges in RUL prediction and demonstrates its potential to solve real-world industrial problems effectively.

Patrick Nectoux, Rafael Gouriveau, Kamal Medjaher, Emmanuel Ramasso, Brigitte Morello, Noureddine Zerhouni, Christophe Varnier. PRONOSTIA: An Experimental A platform for Bearings Accelerated Life Test. IEEE International Conference on Prognostics and Health Management, Denver, CO, USA, 2012.

9. References-

1. IEEE PHM 2012 Prognostic Challenge
   http://www.phmconf.org/
2. http://www.asme.org/about-asme/terms-of-use
3. https://creativecommons.org/licenses/by/4.0/