IE3100M Systems Design Project AY2018/19 | Department of Industrial Systems Engineering and Management (ISEM)

PREDICTIVE MAINTENANCE USING REMAINING USEFUL LIFE

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Introduction

With many companies in Singapore undergoing some form of Digital Transformation, Company X hopes to employ Predictive Maintenance to help improve efficiency and reduce costs. Currently, manual inspection and experience are used to determine if a machine is going to breakdown which leads to increased downtime.

This case study focuses on a machine that Company X currently employs and is done to help the company with the implementation of Predictive Maintenance. The case study includes a raw dataset with operational and sensor data.

Problem Description

Company X has a limited budget and therefore implementing all sensors would be too costly and out of budget. Analysis has to be done to find out which sensors should be implemented to ensure Company X stays within its budget without compromising on the accuracy of its Remaining Useful Life prediction.

Key Skillsets

Data Analysis
- Cleaning of data
- Interpretation of relevant data using Minitab

Modelling & Analytics
- Identifying models to understand RUL
- Train & Test models

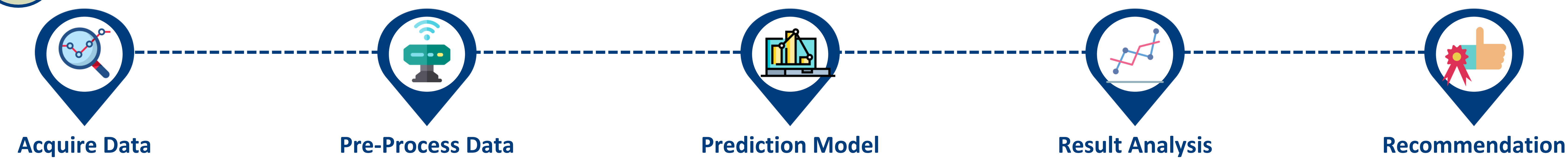
Cost Analysis
- Understanding long-term and short-term cost savings using NPV

Programming
- Matlab to obtain machines RUL
- R language for data processing

Objectives

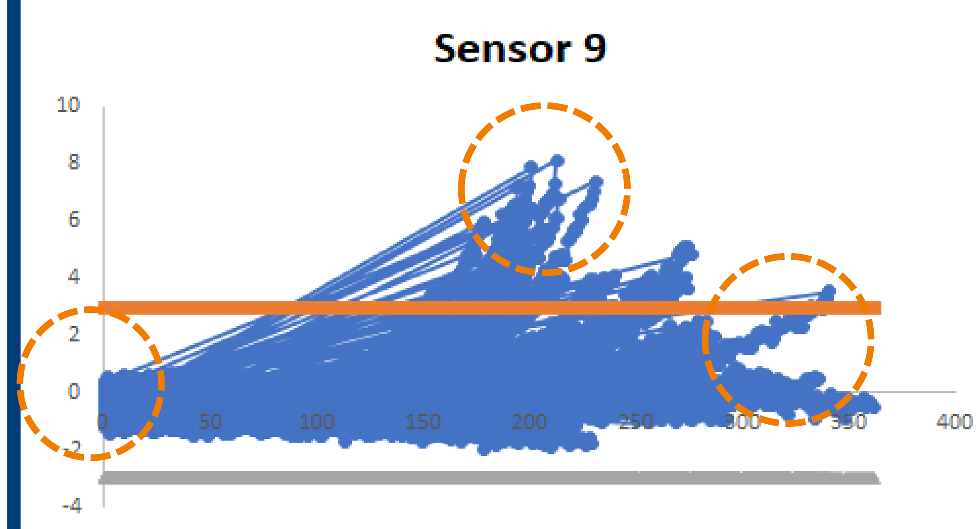
This project is aimed at evaluating prediction models and obtaining the best predictive maintenance model that is commercially viable.

Methodology



Pre-Process Data

Sensor Analysis
- Sieve out important sensors for predicting the RUL.

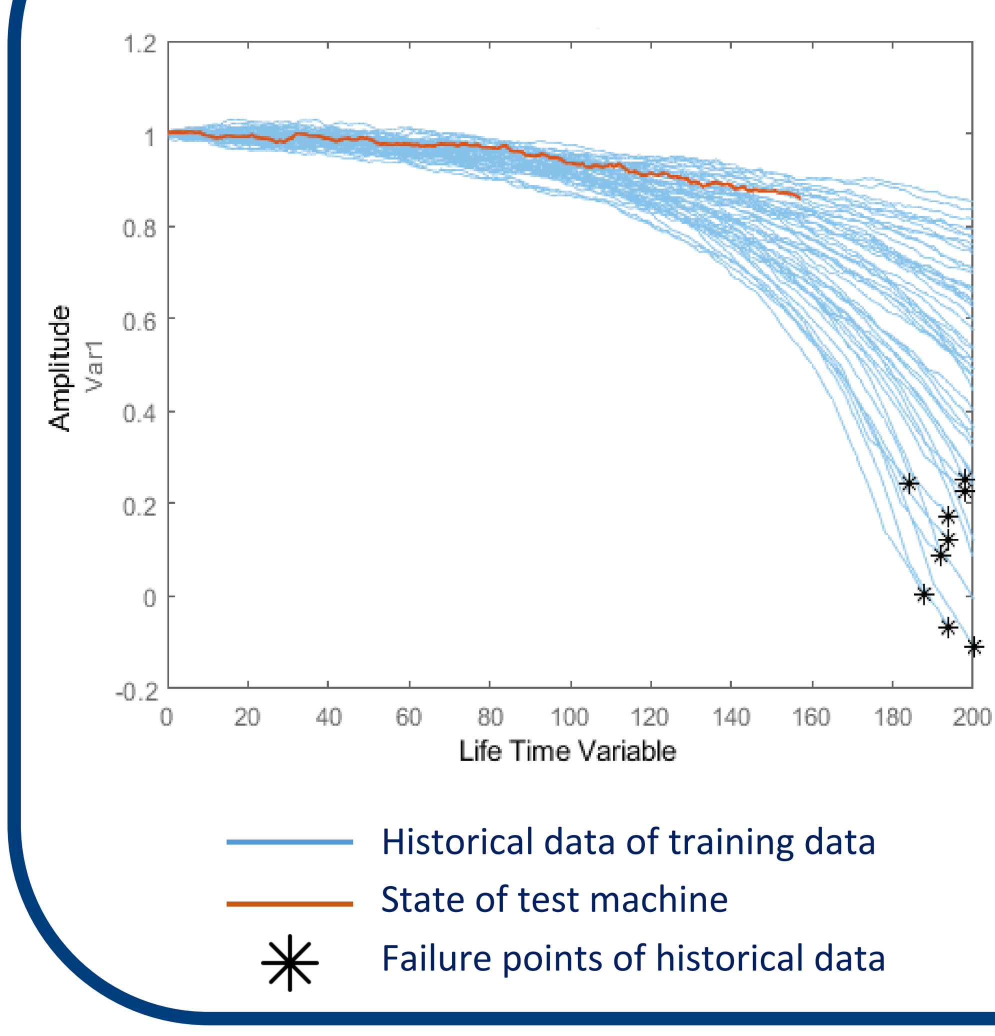


(1) Normalised with a Mean of 0 and Standard Deviation of 1 (2) Higher variance than the other sensors (3) Increasing Trend

Trendability Analysis
- Run each individual sensor in Minitab to test for changing trends
- Exclude sensors without trend from our predictive model
- Further analyse if selected sensors can be reduced through permutations, health conditions and trends

Normalisation
- Standardisation of data to allow comparison across different machines and sensors

Prediction Model

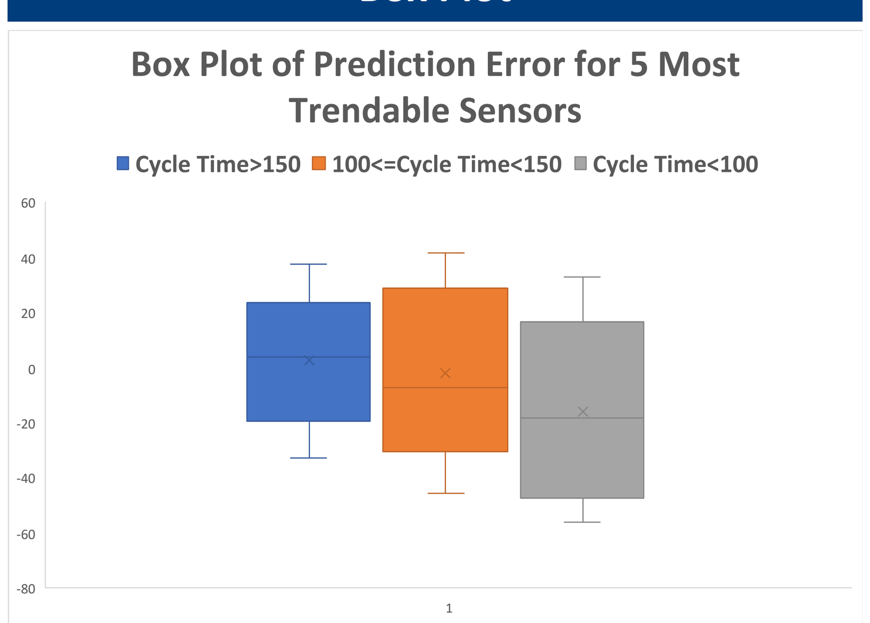


Similarity Comparison Model
- Processed data is ran on Matlab.
- Matlab identifies condition indicators and trains the model using all the input training data.
- Input test data into the model to estimate its RUL.
- The estimated RUL will be the median of the similar engine profiles.
- The more cycle time available for test machine, the more accurate the estimated RUL will be

Results Analysis

Based on sensor analysis, we analysed different models based on different sensor analysis. There are 5 sets of results namely, 21 sensors, 15 most trendable sensors, 5 most trendable sensors, 5 sensors with highest variance and 5 cheapest sensors. The results analysis will focus on the accuracy and the cost savings of the model.

Box Plot



- Box plot shows the prediction error of model. The estimated RUL is still closest if it has over 150 cycle time. A narrower Interquartile ranges represents higher accuracy.
- MSE reflects the accuracy of different model
- Cost analysis with the different scenarios. The model with 21 sensors and 5 most trendable sensors had the most cost savings.

MSE

Sensor Analysis	MSE Value
21 Sensors	478.24
Top 15 Trendable Sensors	481.79
Top 5 Trendable Sensors	543.01
Top 5 Selected Sensors with Highest Variance	652.14
Top 5 Cheapest Sensors	656.83

Cost Analysis

Scenario 0 (No Sensors)		Scenario 1 (All 21 Sensors)		Scenario 3 (Top 5 Trendable Sensors)	
Year	Cash Flow	Year	Cash Flow	Year	Cash Flow
0	-800000	0	-36500	0	-11000
1	-800000	1	-800000	1	-800000
2	-800000	2	-800000	2	-800000
3	-800000	3	370000	3	357500
4	-800000	4	370000	4	357500
5	-800000	5	370000	5	357500
NPV	-$3,813,231.73	NPV	-$593,278.70	NPV	-$596,224.72

Recommendation

Recommendations are made based on accuracy and cost of each model.
- Based on the current budget of Company X, the short term approach is to implement the top 5 most trendable sensors to maximise cost-effectiveness.
- However, in the long-term aspect, the goal will be to implement 21 sensors.

Benefits

- Reduction in downtimes of machinery resulting in increased machine availability.
- Avoids unnecessary equipment replacements.
- Increased workplace machine performance and efficiency.
- Ultimately, saves costs and increases revenue for company.

Future Directions

- Understanding of more modelling methods would improve prediction outcomes.
- Increase data integrity for commercial companies
- Integrate two aspects of maintenance, preventive maintenance together with predictive maintenance methodology.