Master Thesis: Vibration Data Forecasting For Industrial Ventilators

Sachin Shibu Dominic

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The aim of this thesis is to develop a system to forecast the time series data of an industrial ventilator based on the time series data for the past one year for the following parameters:

- Vibration (Frequency)
- Power/Energy
- Speed (rotation in rpm)
- Temperature

Based on the forecast data, the system would be extended to detect an anomaly in the vibration data and alert the operator to schedule a maintenance. The data for these parameters is coming from the industrial ventilators in the factory of Aurubis AG (azeti's parent company).

The traditional methods for time series modelling involved statistical methods such as Autoregressive (AR), Moving-Average (MA), and Autoregressive Integrated Moving-average (ARIMA). The problem with these traditional methods are that there have a lot of parameters which need to be configured correctly (especially if you are not an expert in time series) which accounts for seasonality and trends in the analyzed data. Failing to do so results in less than accurate results. Recently, a new algorithm Facebook Prophet (developed by Facebook's Data Science Team) has been gaining a lot of attention. Prophet also uses statistical methods for forecasting however it automatically accounts for seasonality and trends in data [1], this should help in generating better forecasts.

Additionally, it can be concluded that Support Vector Machines (SVM), a supervised machine learning algorithm used for classification and regression, gives a better result in forecasting machine vibrations compared to AR, MA and ARIMA [2]. The objective here is to compare the Facebook Prophet and SVM models for the data set provided from azeti. The data set will be split into training and validation data based on a suitable method (to be explored in the literature survey), and the forecast results will be compared to see which model performs better. Continuing from this point, the forecasted data will be compared to the real time measurement to see if there is an anomaly, in case of which and alert would be raised for the operator. An example of implementation of such a system can be found in [3].

This ultimately leads to the question: ***"How well does SVM and Facebook Prophet forecast vibration data for an industrial ventilation system based on time series data for the past one year. Can this be further extended to detect an anomaly and schedule a maintenance of the system?"***.

This system would help azeti's client to have forecast of the vibration data of their ventilator system and hence monitor it's condition. Additionally, the anomaly detector would help in doing predictive maintenance by scheduling a maintenance when required instead of doing a planned maintenance or having a machine stop working suddenly. This would in turn, reduce downtime and increase production efficiency, thereby reducing operating costs.

The success of this systems depends upon how accurately it is able to forecast the vibration data base on how close it is to the test data from the original data set. Additionally, it should be able to predict an anomaly with a high degree of reliability as otherwise, it would be generating a false alarm which significantly reduces the benefit of such a system.

Basically, there are four errors which are generated in such an anomaly detection system:

- True Positive (TP)
- False Positive (FP)
- True Negative (TN)
- False Negative (FN)

In order to evaluate the reliability of this system we would be making use of F-score, which is a measure of a test accuracy and evaluates the above mentioned errors. It is defined as the harmonic mean of precision and recall. Usually the F-score gives equal weights to precision and recall and is therefore called an F_1-score. However, in case of an anomaly detection system, we require the recall factor to be given more importance, hence we calculate the F_β-score. It's a modification of the F_1-score, which weighs the recall higher than precision by a factor of β. [4]. During the thesis, the optimal value of β for this application will be determined.

Timeline

- **April-May:** Conduct the literature survey for the topic. This includes but is not limited to:
  - Reading existing publications on the topic.
  - Finding a suitable approach (if possible) that can be applied with minimal adaptation.
  - Understanding the working of SVM and Facebook Prophet.
  - Understanding the methodology to evaluate the system.
  - Exploring possible preprocessing methods of data set, which would produce better forecast results. Additionally, also find out the most suitable way to split the data for training and validation.
  - **Result:** Reviewed 20-30 papers on the topic and would have 10-20 pages of research data. This would include information on evaluation methodology, functionality of the algorithm preprocessing of datasets and additional datasets.
- **June-July(First Half):**
  - Start experimenting with the data set, investigate the functioning of SVM and Facebook Prophet and obtain preliminary results.
  - Train the SVM and Facebook Prophet model on the given data set.
  - Evaluate the results from the forecast and find out which algorithm is better.
  - **Result:** Completed implementation of SVM and Prophet alogorithms and have a sample forecast ready with the given data set. Additionally, completed evaluation of both the algorithms with the chosen method and finalized which one would be better.
- **July(Second Half)-August(First Half):** Based on the forecasting model chosen, implement an anomaly detection algorithm based on the forecasted and the test data.
  - **Result:** Completed implementation of the anomaly detector and evaluated whether it would raise an alarm in case of abnormal data points.
- **August-September(First Half):** With the chosen forecasting and anomaly detection algorithm, implement and design a software system which can forecast the vibration data for the industrial ventilators and alert in case of an anomaly.
- **September(First Half)-October:** Complete the documentation of the thesis and finish up any other pending tasks.

Thesis Supervisors:

- Dr. Philipp M. Scholl, Chair of Computer Architecture, University of Freiburg.
- Carsten Fenneker, Senior Software Engineer, azeti GmbH.

References

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[2] Fan Jiang and Ming J Zuo. Forecasting machine vibration trends using support vector machines. *International Journal of Performability Engineering*, 4:pp. 169– 181, 2008.

[3] Arun Thomas. Predictive Maintenance - using FB prophet package. `https://arun-thomas.xyz/2019-06-18-BearingAnalytics/`, 2019. Last accessed 1st April 2022.

[4] Wikipedia. F-score. `https://en.wikipedia.org/wiki/F-score`, 2022. Last accessed 6th April 2022.