EE.ma – Condition Monitoring, Predictive Maintenance

Master Project – Topic I

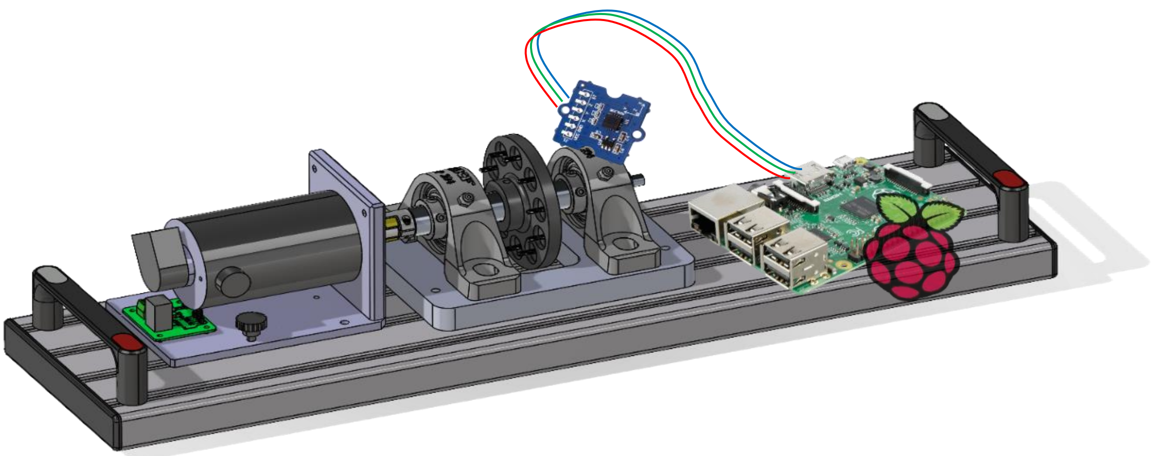
MATLAB Algorithms used for Feature Extractions and Classification Learning (Machine Learning)

Task of this master project is to analyse MATLAB algorithms used for machine learning process. In detail, algorithms used for feature extractions (Diagnostic Feature Designer) and algorithms used for training various ML-models (Classification Learner) should be treated. The focus is on assessing which models and algorithms are most suitable for a particular use case. The use case is a laboratory demonstrator consisting of a DC-motor, shaft, bearings and an unbalance disc. Test data in the form of vibration measurements are obtained from a low budget acceleration sensor applied on top of one bearing and recorded by a Raspberry Pi.

Master Project – Topic II

RUL-Model Development (Remaining Useful Life) of a Laboratory Demonstrator

Task of this master project is the development of a RUL-model of a laboratory demonstrator consisting of a DC-motor, shaft, bearings and an unbalance disc. The project is to be approached based on a grey box model. Theoretical and synthetically generated date should be combined and extended with real vibration data measured by an acceleration sensor applied on top of one bearing and recorded by a Raspberry Pi.



Lab demonstrator – e-drivetrain incl. shaft, bearings, unbalance disc, sensor and rasbpi

Start of project: October 2024, in a group of up to 8 students (topics can be splitted)

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If you are interested in applying **mathematics** and/or **statistics**, these master's projects can also be conducted in collaboration with DI Dr. Harald Hinterleitner, harald.hinterleitner@fh-wels.at offering the following opportunities:

Master Project – Topic I

1. Data Analysis and Preprocessing

- Statistical Descriptions: Use fundamental statistical measures (mean, median, variance, standard deviation) to describe the vibration test data.

- Data Distribution: Analyze the distribution of the vibration test data (histograms, box plots) to identify outliers and assess data quality.

- Data Cleaning: Techniques for removing noise and outliers (e.g., moving average, median filter).

2. Feature Extraction

- Time-Domain Features: Calculate statistical time-domain features such as RMS, peak value, kurtosis, and skewness.

- Frequency-Domain Features: Use Fourier Transform to analyze the frequency components of vibrations and extract relevant frequency features (principal frequencies, amplitudes).

- Time-Frequency Analysis: Apply Wavelet Transform for simultaneous analysis of time and frequency features.

- Correlation Analysis: Examine correlations between different sensor positions and directions to identify redundant or relevant features.

3. Feature Selection and Dimensionality Reduction

- Principal Component Analysis (PCA): Apply PCA for dimensionality reduction and identification of the most important features.

- Statistical Tests: Use t-tests, ANOVA, or chi-square tests to select significant features.

- Recursive Feature Elimination (RFE): Implement RFE to select the best subsets of features for classification.

4. Model Training and Validation

- Cross-Validation: Apply techniques such as k-fold cross-validation for robust evaluation of ML models.

- Confusion Matrix: Calculate and analyze the confusion matrix to assess classification accuracy.

- ROC Curves and AUC: Generate Receiver Operating Characteristic (ROC) curves and calculate the Area Under the Curve (AUC) to evaluate model performance.

5. Model Comparison and Selection

- Statistical Tests for Model Comparison: Use tests like paired t-tests or the Wilcoxon test to statistically evaluate performance differences between models.

- Hyperparameter Tuning: Apply grid search or random search for optimizing model hyperparameters.

- Bayesian Optimization: Utilize Bayesian optimization methods for efficient hyperparameter tuning.

6. Model Interpretability

- Shapley Values: Calculate Shapley values to explain individual feature contributions to model decisions.

- Partial Dependence Plots: Create partial dependence plots to visualize the relationship between features and predictions.

7. Time Series Analysis

- Autocorrelation and Cross-Correlation: Analyze the Autocorrelation Function (ACF) and Cross-Correlation Function (CCF) to identify temporal patterns in the vibration test data.

- ARIMA Modeling: Apply ARIMA models for forecasting future vibrations and anomaly detection.

Master Project – Topic II

1. Data Analysis and Preprocessing

- Statistical Descriptions: Use fundamental statistical measures (mean, median, variance, standard deviation) to describe the vibration data.

- Data Distribution: Analyze the distribution of the vibration data (histograms, box plots) to identify outliers and assess data quality.

- Data Cleaning: Techniques for removing noise and outliers (e.g., moving average, median filter).

2. Feature Extraction

- Time-Domain Features: Calculate statistical time-domain features such as RMS, peak value, kurtosis, and skewness from the vibration data.

- Frequency-Domain Features: Use Fourier Transform to analyze the frequency components of vibrations and extract relevant frequency features (principal frequencies, amplitudes).

- Time-Frequency Analysis: Apply Wavelet Transform for simultaneous analysis of time and frequency features.

- Correlation Analysis: Examine correlations between different sensor positions and directions to identify redundant or relevant features.

3. Model Development

- Grey Box Modeling: Combine theoretical models with empirical data to develop a grey box model that accurately represents the system's behavior.

- Parameter Estimation: Use statistical techniques for estimating model parameters based on the combined synthetic and real data.

- Model Calibration: Apply statistical methods to calibrate the grey box model using real vibration data.

4. RUL Prediction

- Regression Analysis: Implement regression techniques (linear, polynomial, or logistic regression) to predict the remaining useful life (RUL) of the system.

- Survival Analysis: Use survival analysis methods to estimate the probability of failure over time.

- Bayesian Methods: Apply Bayesian statistical methods for RUL prediction to incorporate prior knowledge and update predictions as new data becomes available.

5. Model Validation

- Cross-Validation: Apply techniques such as k-fold cross-validation for robust evaluation of the RUL model.

- Residual Analysis: Perform residual analysis to check the adequacy of the model and identify potential improvements.

- Goodness-of-Fit Tests: Use statistical tests to evaluate the fit of the model to the data (e.g., chi-square test, Kolmogorov-Smirnov test).

6. Uncertainty Quantification

- Monte Carlo Simulations: Use Monte Carlo simulations to quantify uncertainty in RUL predictions.

- Confidence Intervals: Calculate confidence intervals for the RUL estimates to provide a measure of uncertainty.

- Sensitivity Analysis: Perform sensitivity analysis to determine the impact of different parameters on the RUL predictions.

7. Model Interpretability

- Shapley Values: Calculate Shapley values to explain individual feature contributions to the RUL predictions.

- Partial Dependence Plots: Create partial dependence plots to visualize the relationship between features and RUL estimates.

8. Time Series Analysis

- Autocorrelation and Cross-Correlation: Analyze the Autocorrelation Function (ACF) and Cross-Correlation Function (CCF) to identify temporal patterns in the vibration data.

- ARIMA Modeling: Apply ARIMA models for forecasting future vibrations and estimating the RUL based on these forecasts.

Prerequisites: Mathematics 1 and 2 in the EE Bachelor's program, Statistics in the EE Master's program, and at least concurrent completion of the course during the project.