Predicting the wind condition of wind turbines using machine learning

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Overview

Motivation.

The demand for renewable energy has increased significantly in recent years, and wind energy is a promising alternative to traditional sources of power. Optimized control strategies are essential for the efficient operation of wind turbines, requiring numerous sensors to be installed on the system. These sensors capture a variety of data that aid in the prediction of wind speed and system features, like yaw error, pitch angle error, etc. which are important for efficient operation of the turbines.

Problem setting.

However, due to the delicate nature of these sensors and the intense air current at the height of the turbine, sensor location and temperature can significantly impact their readings. For example, the anemometer, which measures wind conditions at the hub segmentation behind the rotor blades, can be distorted by the blades' movement. This thesis will explore the impact of these factors on wind turbine sensors and propose solutions to improve their accuracy and reliability.

Approach.

We propose in this thesis to explore machine learning (ML) and deep learning (DL) algorithms to improve the accuracy and reliability of sensors and consequently how to improve the efficiency of wind turbines. Specially we will focus on predicting wind speed, and factors such as yaw error and turbulence, and use the predicted values to optimize wind turbine operation. The data is derived from simulation models that model sensors installed on wind turbines. It consists of a fine-grained time series of regularly spaced sensor readings with up to 33 samples per second. We will explore models based on interval-based preprocessing as well as models that use the raw data to predict more accurate sensor readings. For this, we aim to employ and compare various ML and DL algorithms.

Outlook.

We expect that outcomes will improve wind turbine performance, accurate wind prediction, and novel ML AND DL methodologies for wind turbine performance prediction. These outcomes have significant implications for the wind energy industry, as they can help optimize wind turbine operation and improve energy production.

Tasks

Data collection and preprocessing

- Loading and converting data into appropriate data formats for machine learning
- Data analysis (e.g., clustering)

Model development and training

Feature based models

- Feature engineering (existing and novel)
- Baseline models
- Deep learning models

Raw data-based model

Advanced modeling techniques

- Model reduction
- Model variants (e.g., transformers)
- Multitask modeling

Performance analysis and interpretation

- Model performance
- Model resources (runtime, memory consumption)
- Model analysis (e.g., feature interpretation)

Documentation

- Writing and composing thesis

Methodology

1. Data Collection and Preprocessing

1.1 Define the research question and specify the requirements for the data.

1.2 Identify potential data sources and acquire the necessary data.

1.3 Convert the data into appropriate formats for machine learning and perform initial data analysis

1.4 Conduct exploratory data analysis (EDA) to identify data quality issues, missing values, outliers, and perform data cleaning.

1.5 Apply data transformation techniques, such as normalization, feature scaling, and standardization.

1.6 Conduct data analysis, such as clustering, to understand the underlying patterns and relationships.

2. Model Development and Training

2.1 Define the modeling approach based on the research question and data analysis results.

2.2 Develop feature-based models, including feature engineering, baseline models, and deep learning models.

2.3 Develop raw data-based models if necessary.

2.4 Apply advanced modeling techniques, such as model reduction, model variants, and multitask modeling.

2.5 Train and test the models using appropriate evaluation metrics.

2.6 Fine-tune the models to improve their performance by adjusting hyperparameters.

3. Performance Analysis and Interpretation

3.1 Evaluate the performance of the models using appropriate metrics, such as accuracy, precision, recall, and F1 score.

3.2 Analyze the resources required by the models, such as runtime and memory consumption.

3.3 Interpret the model features and determine which features contribute most to the model's performance.

3.4 Compare the performance of different models and determine which one is the best fit for the research question and data.

4. Documentation

4.1 Write a thesis documenting the entire research process, including the research question, data collection, preprocessing, modeling approach, model training, and performance analysis.

4.2 Include a detailed description of the models used, including their architecture, hyperparameters, and performance metrics.

4.3 Discuss the limitations of the research and suggest future directions for improvement.

4.4 Provide references to the sources used in the research.

4.5 Format the thesis according to the guidelines provided by the academic institution.