Data Analysis in Parabolic Trough Fields

Determination of Mirror Cleanliness with Machine Learning

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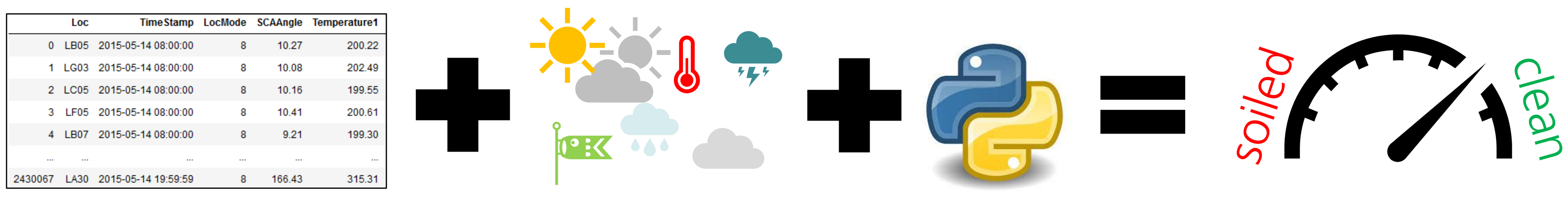
Motivation

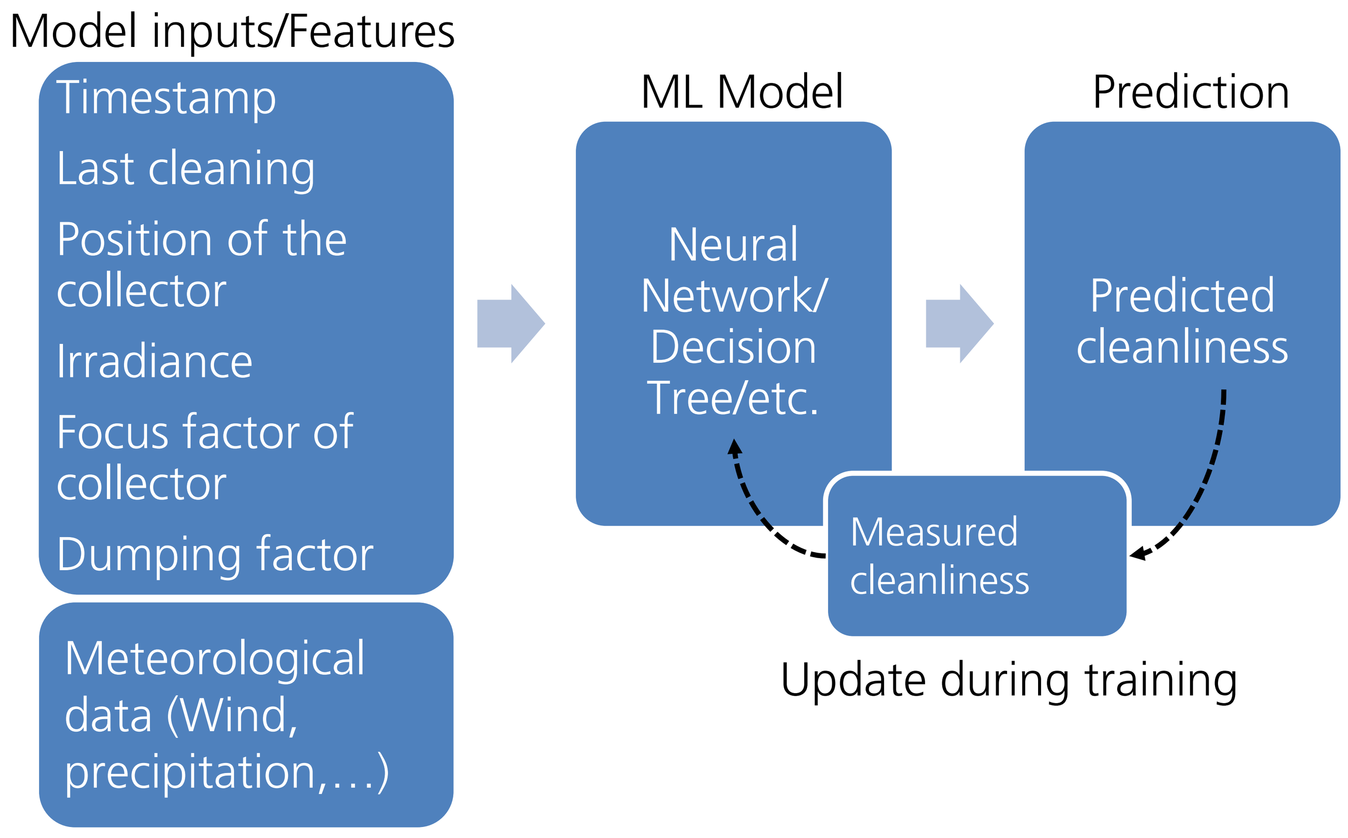
- Concentrated solar power (CSP) plants are located in arid regions with high dust loads
- Mirrors need to be cleaned frequently to maintain high reflectivity
- Knowledge about cleanliness of mirrors is crucial for cleaning decision
- Cleanliness usually measured with hand-held devices
  - Accurate but costly

Objectives

- Development of an alternative method to estimate the cleanliness of individual collectors
- Optimization of the cleaning schedule towards a demand oriented schedule based on model predictions
- Only operational data from the power plant and meteorological data available at the site are used
  - Easy and cheap implementation without additional hardware requirements
- Which model inputs have the biggest influence on the model prediction?



Approach & Methods



Models

- Machine Learning models: Neural Network (NN), Decision Tree (DT), Gaussian Processes (GP), Support Vector Regression (SVR), Linear Regression (LR)
- Models are trained with datasets of different sizes
  - Models should be adaptable to different CSP plants with changing data availability

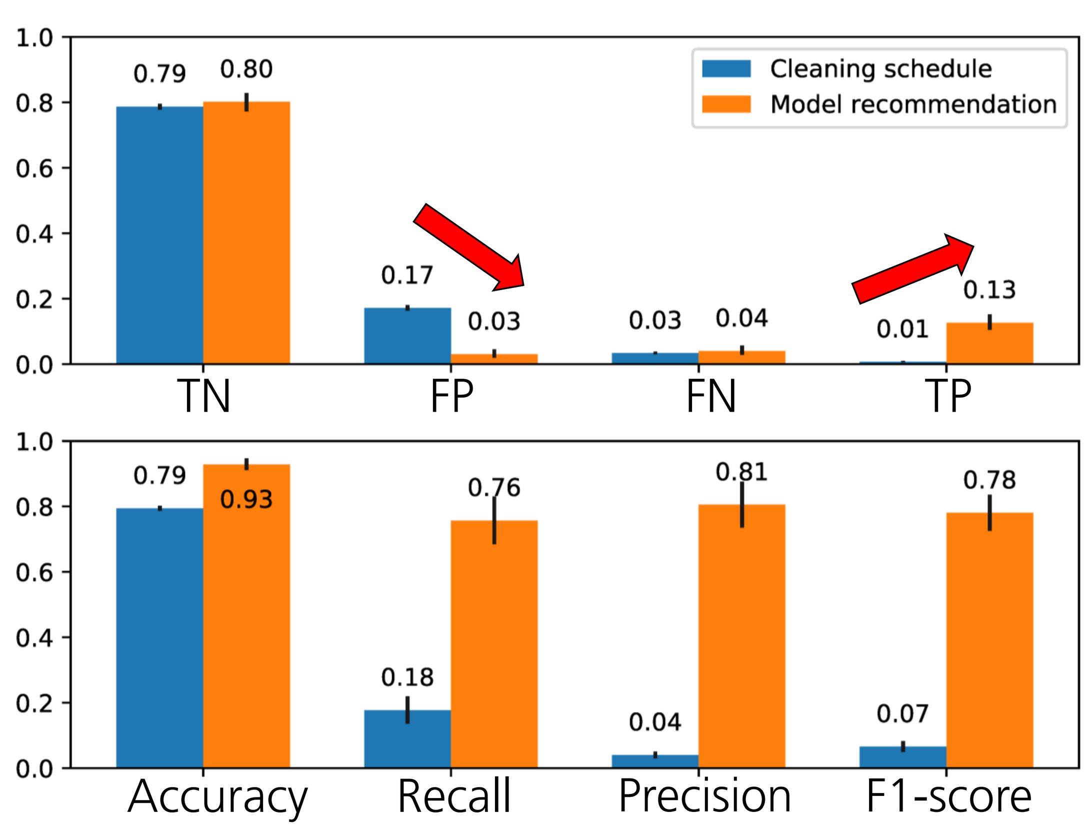
Metrics for model evaluation

- Comparison with reference cleanliness measurements (optimal outcome is a perfect fit of the reference measurements)
- Comparison with cleaning schedule (only a classification of mirror cleanliness between clean/soiled required)

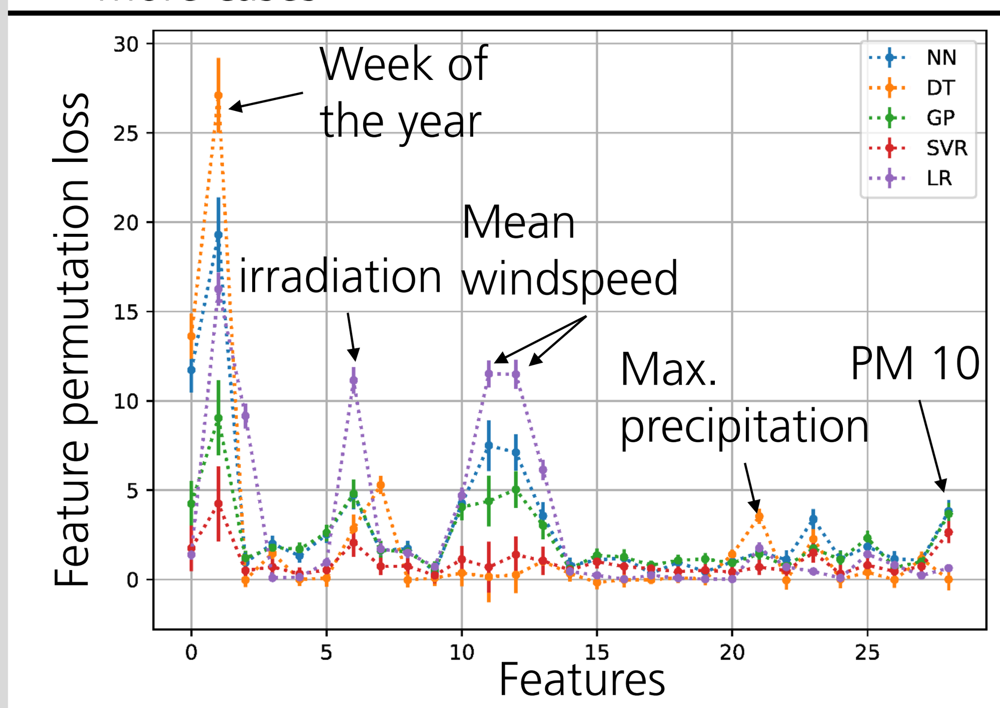
- Feature Permutation Loss used as method to estimate the influence of different model inputs
- Uncertainties of model predictions are taken into account via multiple model runs (systematic uncertainty) and confidence intervals (statistic uncertainty)

Results

Optimizing cleaning schedule

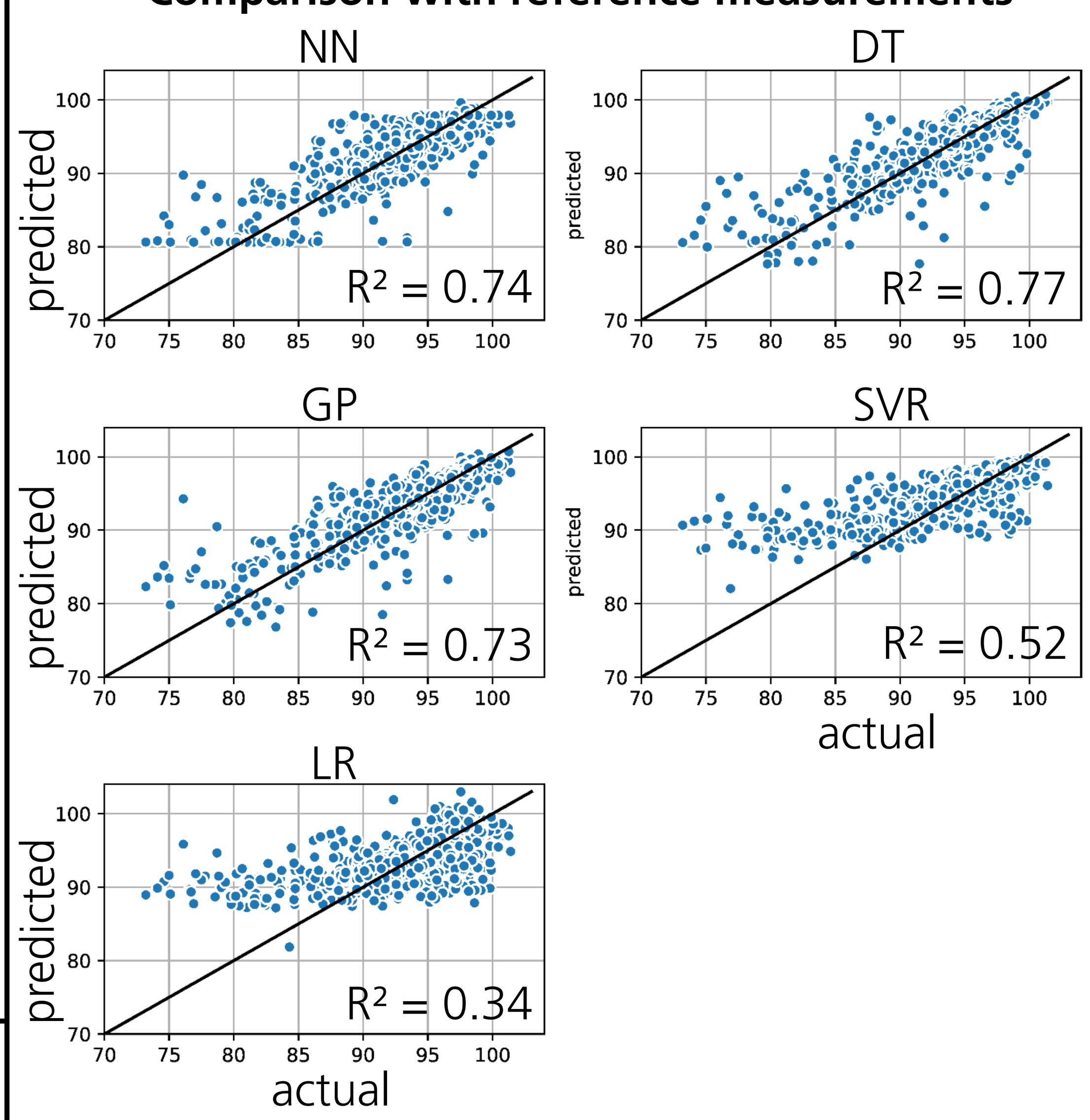


- Too early cleanings can be reduced by 14.3 %
- Necessary cleanings are detected in 12.2 % more cases



- High influence of temporal feature in accordance with high seasonality of soiling

Comparison with reference measurements



- Best results are achieved with Decision Tree model using the biggest dataset (operational and meteorological data)
  - 77 % of the data can be explained by the model
- Neural Network and Decision Tree both show good results with different dataset sizes
  - Beneficial for model integration in other power plants with different measurement setup

Summary & Outlook

Key results

- Operational data and meteorological data can be used to build a model for cleanliness determination
- Optimizing the cleaning schedule is easier task
- Best results for Decision Trees, followed by Neural Networks

Related work

- Similar approaches for photovoltaic are available, but they are not directly applicable (2)
- Physical models for CSP Systems are available, but they require meteorological data and they do not use operational data from solar field (3)

Ongoing and future work

Cleanliness determination:

- Predicting average values for entire subfield with Convolutional Neural Networks

Flow determination:

- Using "time-of-flight" measurements from temperature deviation in solar field to calculate flow

Anomaly detection:

- Using Autoencoders to detect and locate anomalies in parabolic trough fields

References

(1) Parabolic trough at Plataforma Solar de Almería (Owned by the Spanish research center CIEMAT), Source DLR
(2) W. Javed et al., Modeling of photovoltaic soiling loss as a function of environmental variables, Solar Energy 157 (2017) 397–407
(3) G. Picotti et al., Development and experimental validation of a physical model for the soiling of mirrors for csp industry applications, Solar Energy 173 (2018) 1287–1305

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