Condition Monitoring for Parabolic Trough Fields – Soiling determination

SFERA-III Doctoral Colloquium

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Condition Monitoring for Parabolic Trough Fields – Soiling determination

Agenda

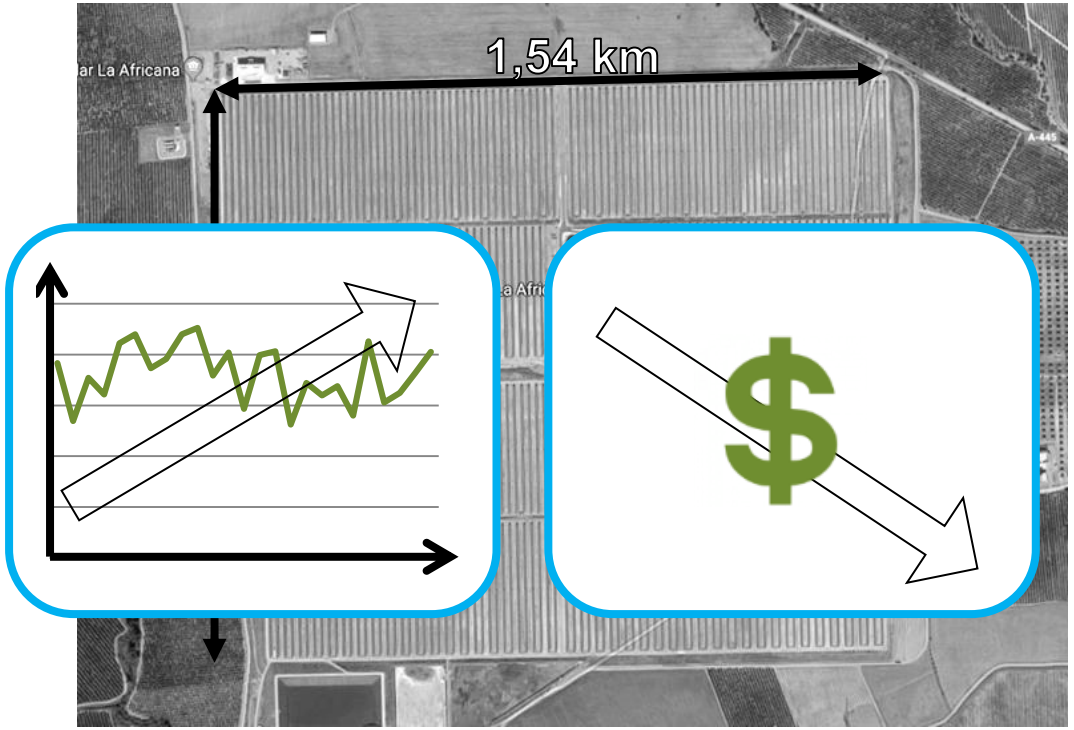
1. Introduction
   - Motivation: Why do we need condition monitoring?
   - Research question
2. State of the art
3. Methodology
   - Using operational data to quantify the solar field condition
   - Machine Learning to process big-data
4. Case study: Soiling determination
   - Approach
   - Correlations
   - Decision tree implementation
5. Conclusion: We can read much more out of our data!

1. Introduction
Motivation

- Condition Monitoring: Permanent monitoring of process/machinery conditions
- Condition Monitoring is used as a method to quantify the goodness of operation

- **Optimize power output** of the solar field with:
  - Early detection of degradations (Predictive Maintenance)
  - Reduction of down times
  - Optimize control parameters
- Reduction of **operation costs**:
  - Reduced personnel costs
  - Maintenance follows requirements not strict time interval
  - Increase in component lifetime

Satellite image of La Africana



Google. Google Maps. 2019 [cited 2019 18. September]; Available from: https://www.google.com/maps/@37.7544897,-5.0605687,2216m/data=!3m1!1e3.

1. Introduction
Research question

„How can we use the available data in a parabolic trough solar field to maximize the information about the solar field condition?“

2. State of the art
Condition Monitoring in parabolic trough fields

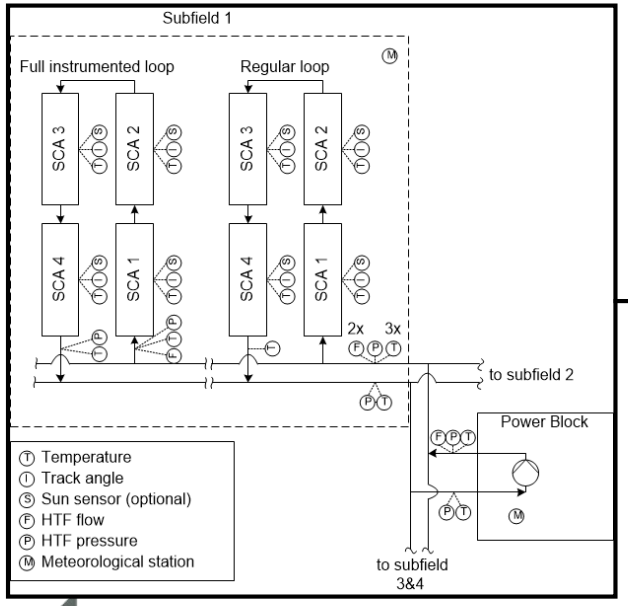
- Condition Monitoring in conventional power plants
  - Monitoring of heat and mass balance
  - Comparison of actual measured value with data-based model → Predictive Maintenance
  - ➢ No spatial distribution
  - ➢ No influence of environmental conditions (e.g. irradiance, soiling,…)
- Condition Monitoring in PV Plants
  - Thermographic assessment of PV Panels to evaluate performance
  - Inverter data to determine status of PV field
  - ➢ Not directly usable in CSP applications
- Anomaly Detection/ Failure Detection in parabolic trough systems, e.g. simulation study Muñoz et al. 2019
  - Data-based models of fault-free sub systems of solar plant (solar field, heat exchangers, pumps,…)
  - Comparison of regular simulation data (with operation faults) and data-based model (fault-free model)
  - ➢ But … fault-free conditions are hard to determine in real datasets
  - ➢ Every real fault is (slightly) different and occurs rarely, and can be overlaid with others

➢ In CSP applications still a lot of work to do: Start with soiling determination from operational and meteorological data

3. Methodology

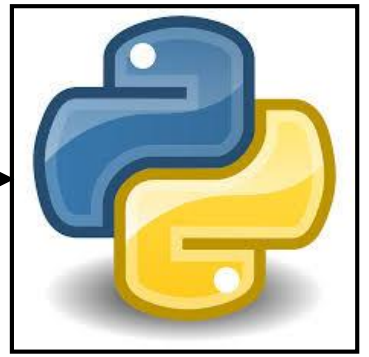
Operational data and Machine Learning

- Use of already measured data from the solar field
  - Keeps implementation hurdle and costs as low as possible
- What we have: temperature, inclinometer, flow, commands from control system, meteorological data,…
- ~1GB of operational data from solar field per day
- Machine Learning (ML) to process big-data



	Loc	TimeStamp	LocMode	SCAAngle	Temperature1	Temperature2	LoopInletTemp
0	RH08	13.5.2015 23:59:59	2	-0.11	229.38	0.00	238.00
1	RE08	13.5.2015 23:59:59	2	-0.02	230.67	0.00	238.00
2	RE10	13.5.2015 23:59:59	2	-0.13	231.58	0.00	237.97
3	RA10	13.5.2015 23:59:59	2	-0.05	230.72	0.00	238.08
4	LB02	13.5.2015 23:59:59	2	-0.04	267.82	264.01	239.99
...	...	...	...	...	...	...	...
5296129	RB19	14.5.2015 23:59:59	2	-0.07	197.00	185.66	272.33
5296130	RF19	14.5.2015 23:59:59	2	-0.14	216.77	223.61	270.36
5296131	RC21	14.5.2015 23:59:59	2	-0.08	166.34	162.69	272.23
5296132	RB21	14.5.2015 23:59:59	2	-0.06	194.81	185.77	272.23
5296133	RF21	14.5.2015 23:59:59	2	-0.05	218.21	220.91	270.52

5296134 rows × 7 columns



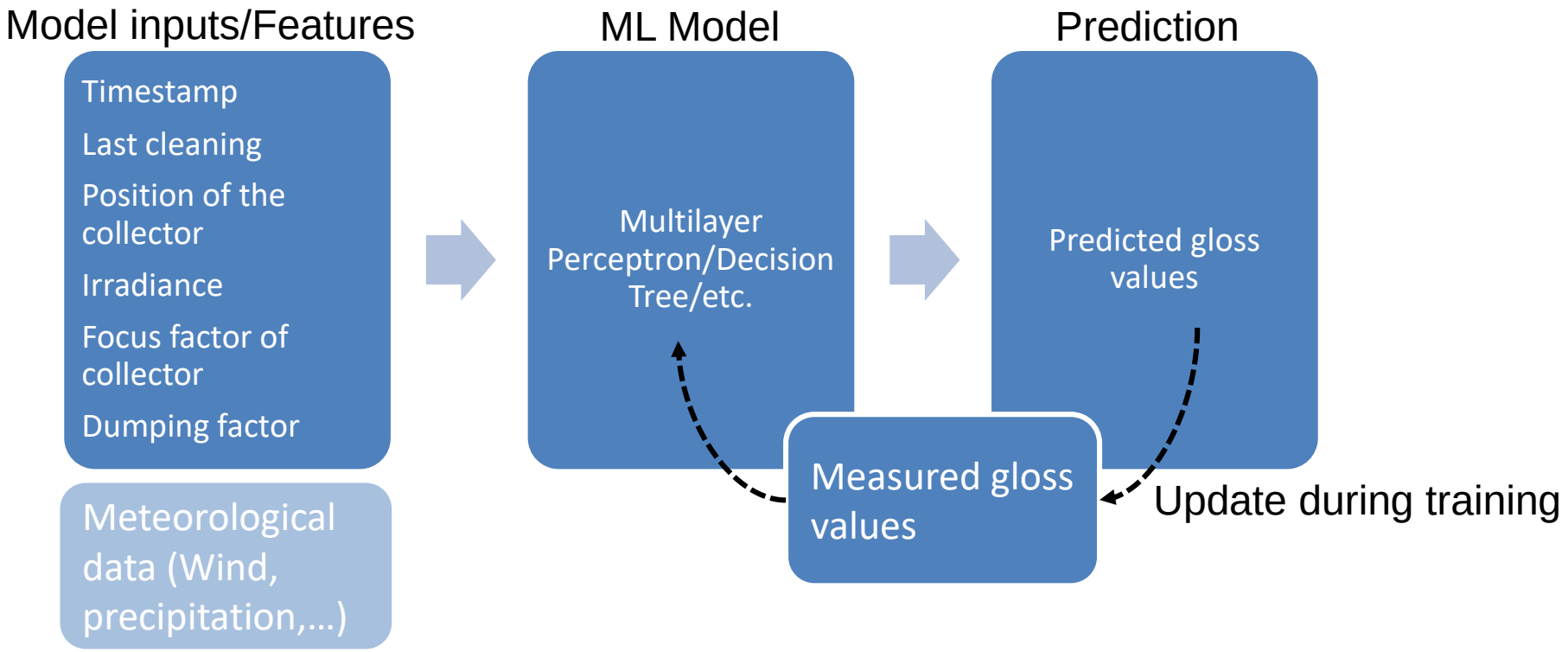
4. Case study: Soiling determination
Approach

- Soiling is always present in CSP plants
- Overlays other effects and faults in the field
- Continuous determination of cleanliness values for each collector is time consuming and expensive (with hand held devices)

1. Data collection:
   - Specific case: We use of gloss values instead of reflectivity measurements (not enough data available)
   - In our example plant operation team collects gloss measurements frequently
2. Model fitting:
   - Train ML model with gloss values as ground truth→ pre-trained model, adaptable to other plants and locations

4. Case study: Soiling determination
Approach

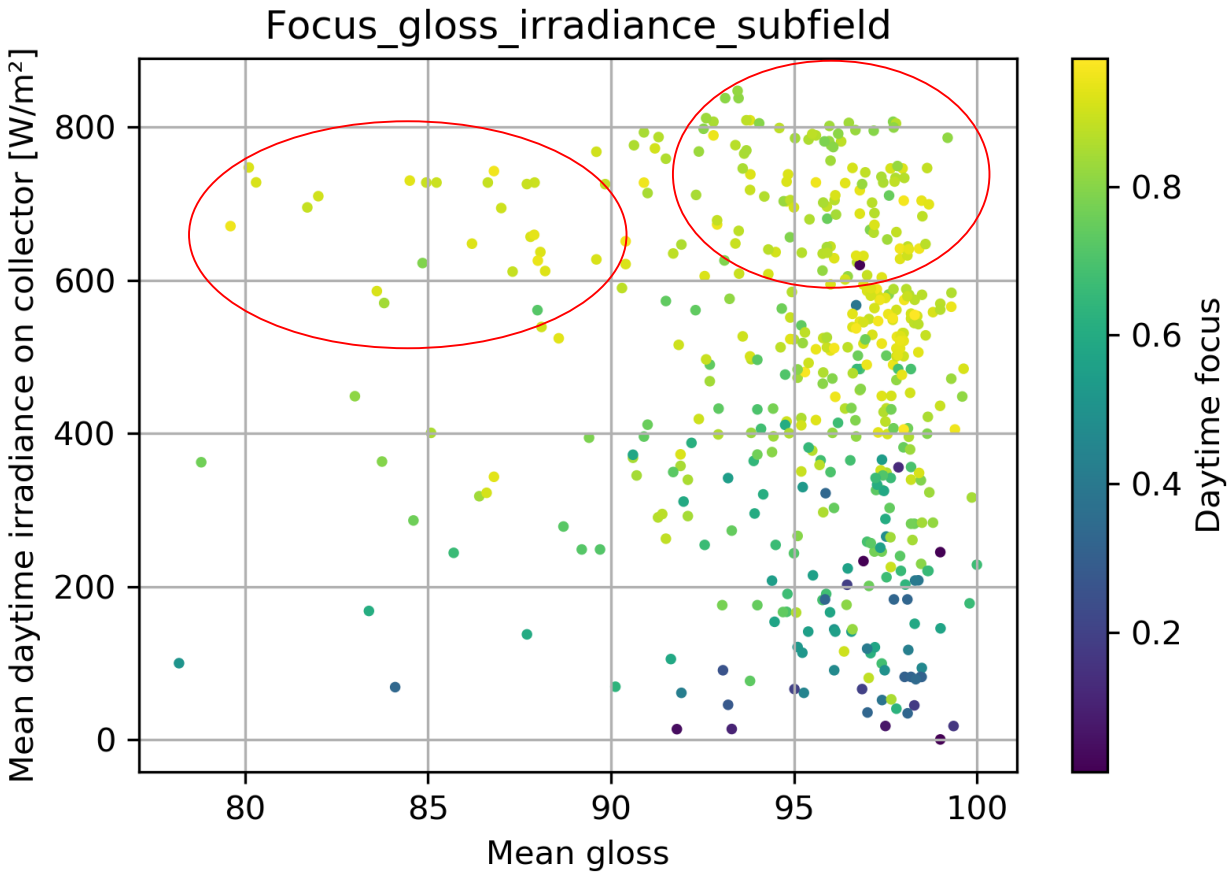
- Machine Learning Model (Decision Tree, Gaussian Process, Artificial Neural Network,…) learns to predict gloss value of collector



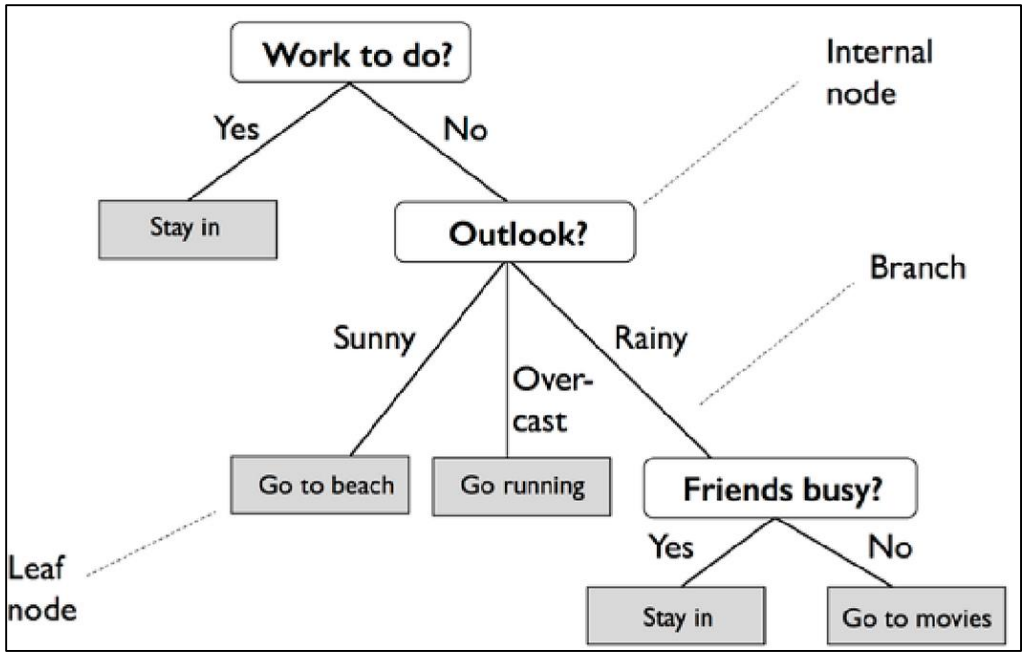
4. Case study: Soiling determination
Correlation

- Correlation checking: Collector focus
- Idea: Use collector focus factor as substitute value for gloss/soiling determination
  - For high gloss and high irradiance values → low focus
  - For low gloss and high irradiance values → high focus

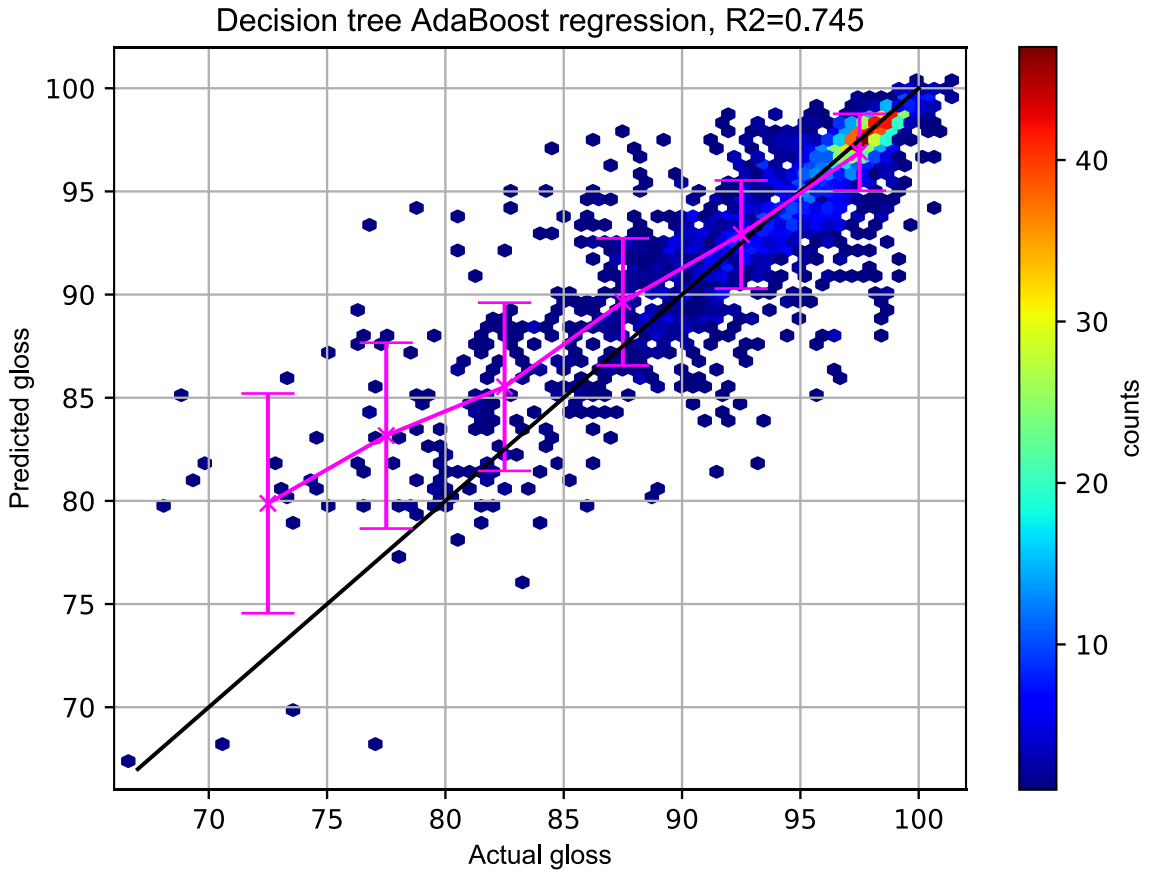
➢ Not an easy correlation → machine learning as possible way to go



4. Case study: Soiling determination
Decision Tree implementation



Raschka, S. and V. Mirjalili, Python Machine Learning : Machine Learning and Deep Learning with Python, Scikit-Learn, and TensorFlow 2, 3rd Edition. 2019, Birmingham, UNITED KINGDOM: Packt Publishing, Limited.



5. Conclusion

- Data from parabolic trough solar fields are mainly time-series data
  - ➢ Cannot be directly included into machine learning systems
  - ➢ Feature generation needed (either manual or automatic)
- If we consider valuable features we can read more from out measured data
  - ➢ Predictions of values which are hard to measure
  - ➢ Include features which cannot be directly used in a physical model
  - ➢ Predicted values have high uncertainties, but in some cases this is sufficient
- Case study: Soiling determination
  - ➢ Reduce needed gloss/reflectivity measurements
  - ➢ Use the continuous values from the model to optimize cleaning schedules

Thank you for your attention.
Questions?

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