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Predictive Maintenance of Photovoltaic Panels via Deep Learning

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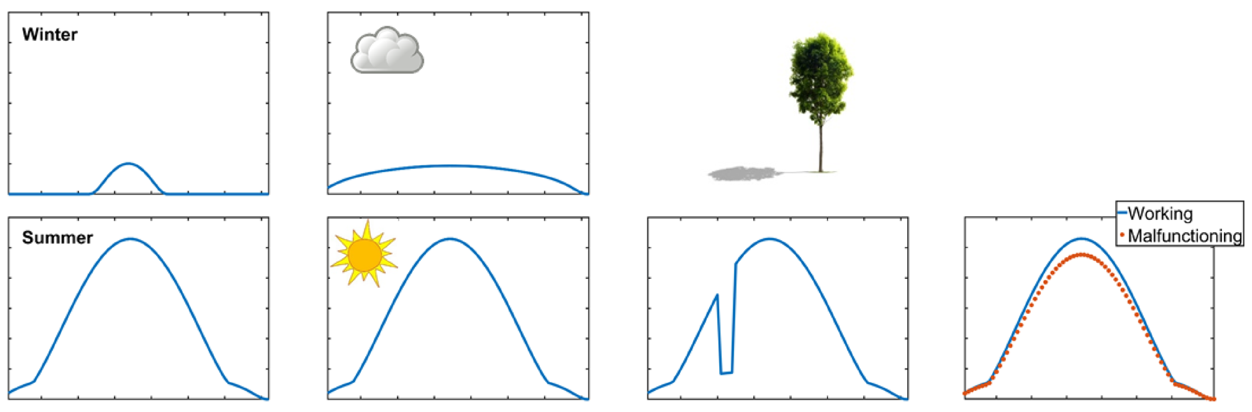
1. How to detect a malfunctioning photovoltaic (PV) panel?

- **Input data:** Electrical power curve of each PV panel,

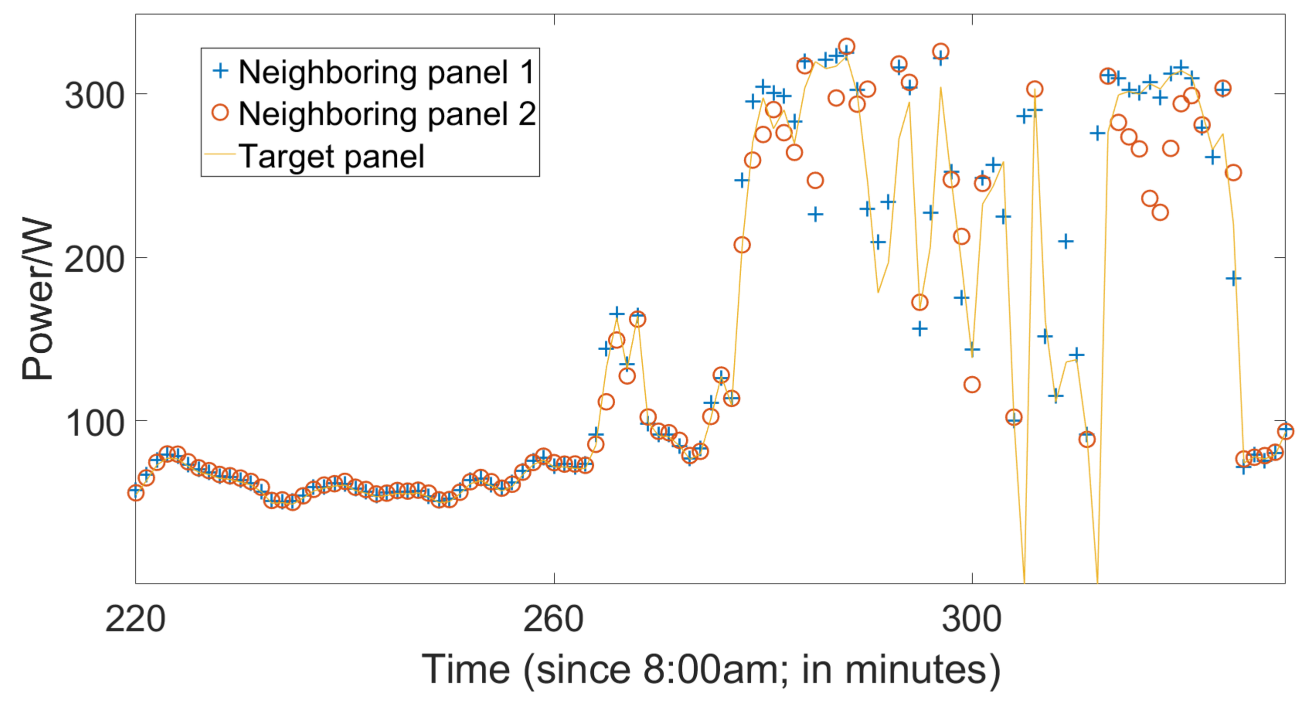
$$P(t, d, s)$$

where t = time of the day (in minutes), d = day of the year, s = spatial location of the panel

- **The challenge:** $P(t, d, s)$ depends on several time-dependent factors:



- Example of a measured PV panel power curve:



2. Machine learning problem setup

- No training data from malfunctioning panels available
- Find a **predictor** for the power curve using the training data from the panels in its spatial neighborhood, $\mathcal{V}$,

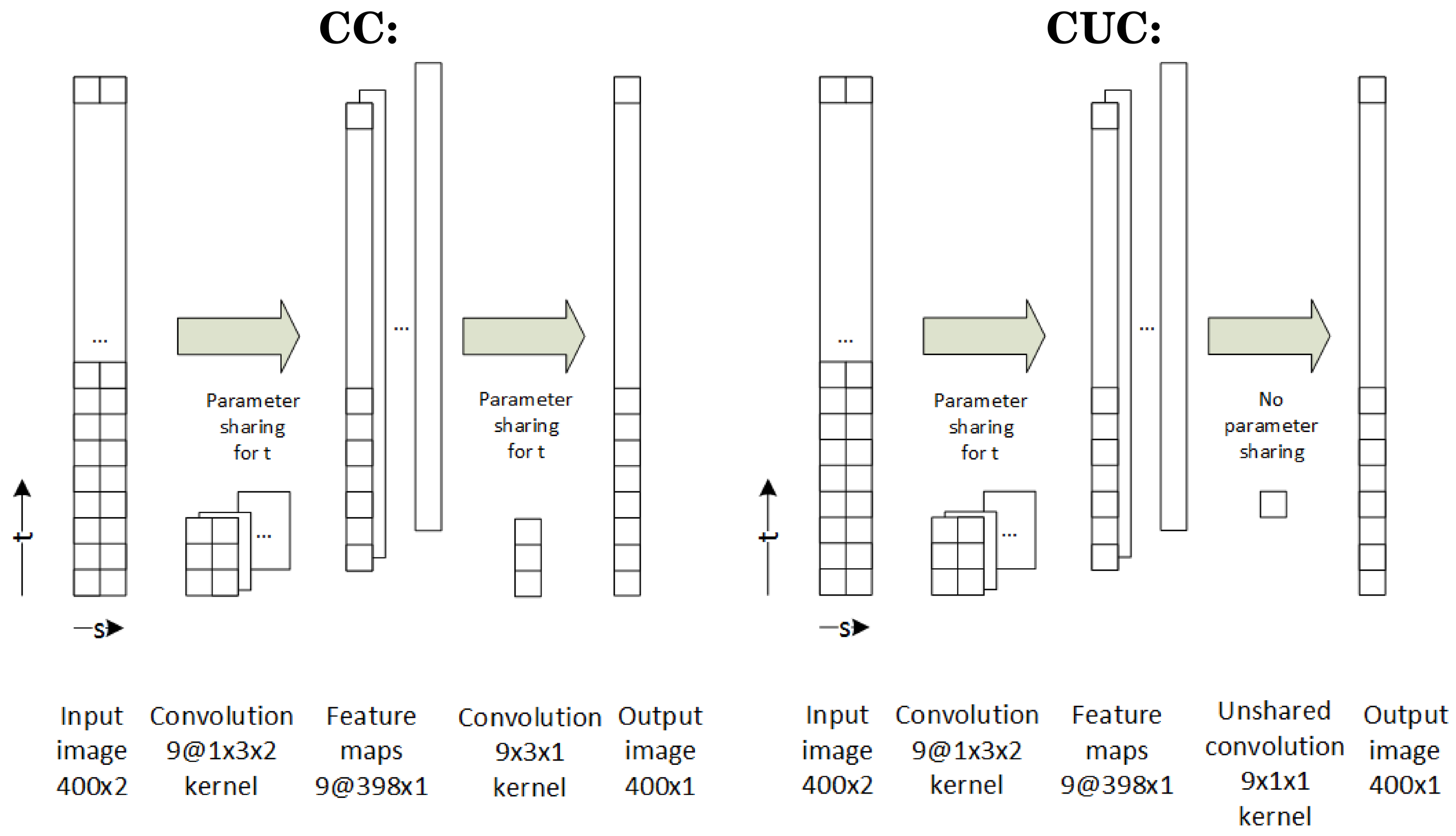
$$\hat{P}(t, d, s_{target}) = f(P(t, d, s)); s \in \mathcal{V}$$

- Compare the **predicted** ($\hat{P}(t, d, s_{target})$) and **actual** power curves ($P(t, d, s_{target})$) $\implies$ a large difference indicates a malfunctioning PV panel
- Benchmark for advanced predictors: average of the two adjacent panels, s_0 and s_1, (**AVE**),

$$\hat{P}(t, d, s_{target}) = \frac{P(t, d, s_0) + P(t, d, s_1)}{2}$$

3. CNN-based predictors

- Convolutional neural network (CNN) with two fully convolutional layers (**CC**)
- CNN with fully convolutional first layer, unshared convolution for the second layer (**CUC**)

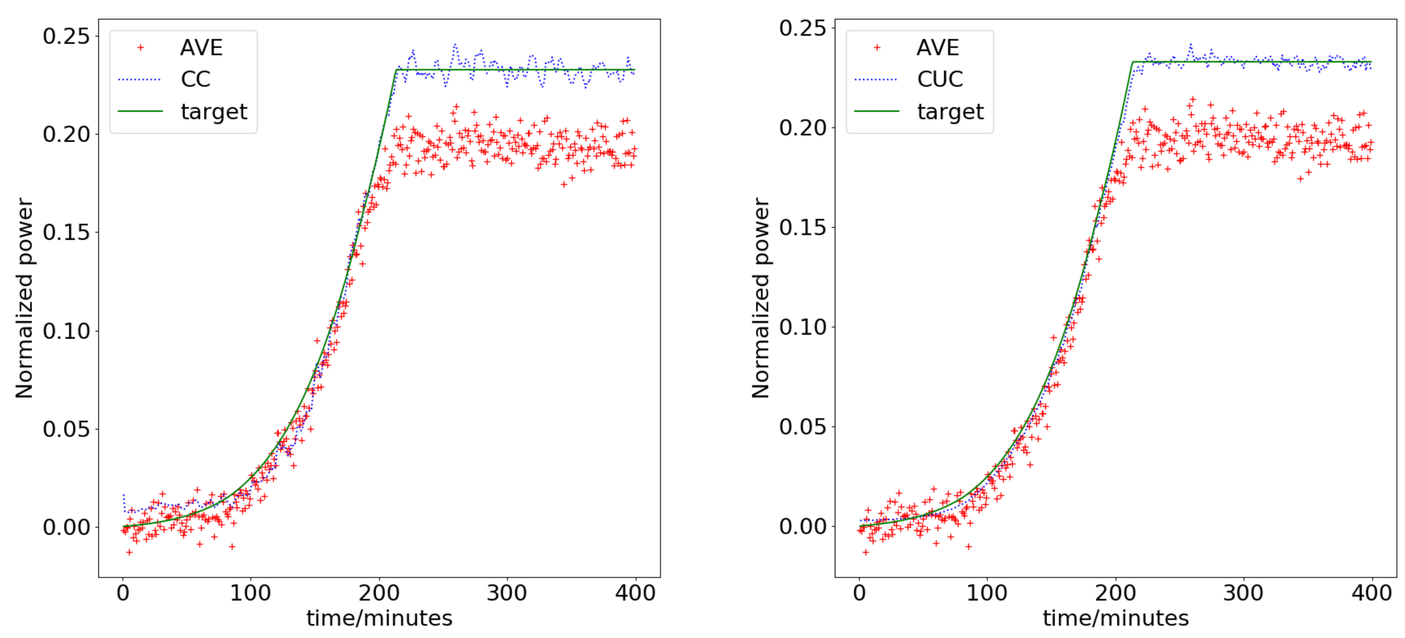


4. Results

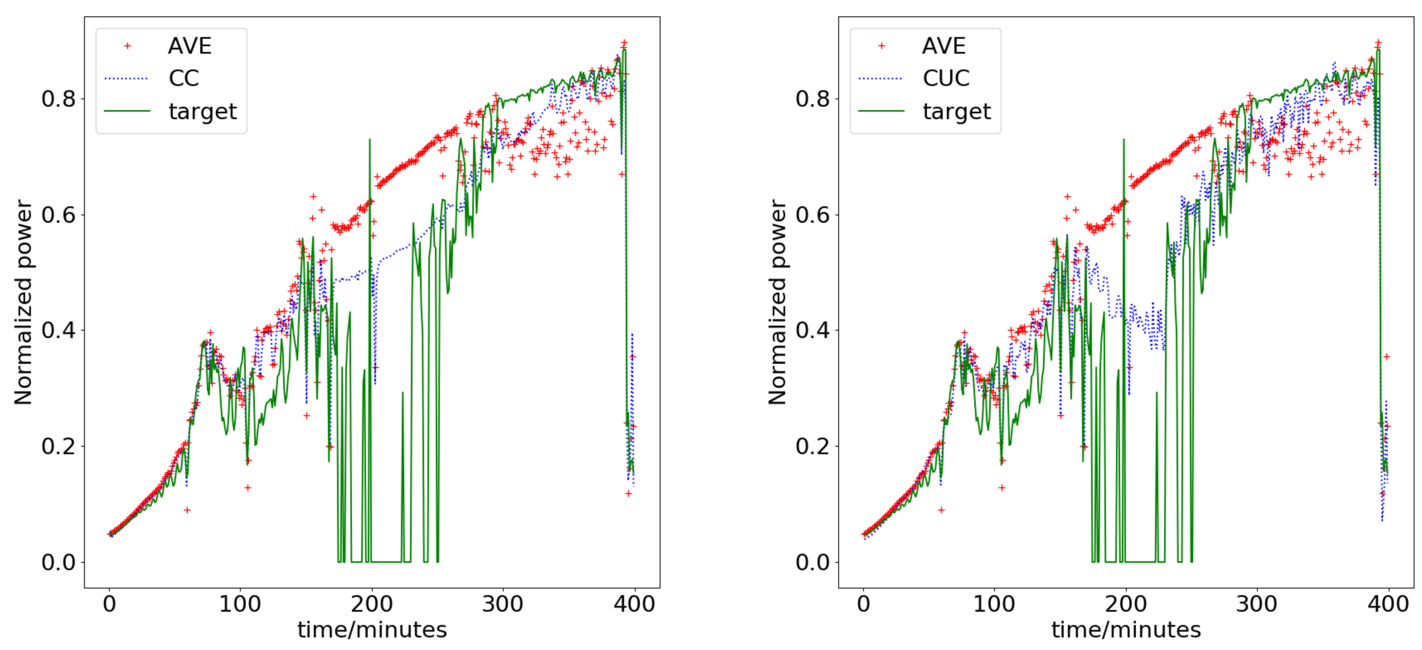
- Mean Square errors:

Method	Synthetic test set	Real test set
CC	0.000037	0.002589
CUC	**0.000010**	**0.002346**
AVE	0.000421	0.003561

- Samples of actual and estimated power curves - synthetic signal:



- Samples of actual and estimated power curves - real signal:



5. Conclusion

- CNN based methods have potential for predictive maintenance of PV systems
- Both CNN-based algorithms (CC and CUC) outperformed the benchmark
- CUC algorithm was able to track the impact of regular shadows better

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