Karlsruhe Institute of Technology

Physics-Informed Neural Networks for PV forecasts

Supervising groups: Schäfer (Institute for Automation and Applied Informatics), Debus (Scientific Computing Center), Cermak (Institute of Photogrammetry and Remote Sensing, Institute of Meteorology and Climate Research)

Problem / state of knowledge: Power generation and demand need to be balanced at all times. Hence, forecasts of Photovoltaics (PV) power generation are extremely important to have sufficient dispatchable generation available guaranteeing the balance. Pure data-based models have limits as they often require large amounts of training data and are poor in extrapolating.

Research questions:

1. Can we incorporate physical knowledge about PV systems and cloud movements into PV generation forecasts?
2. What are the climatological patterns of solar radiation (in space and time) in specific weather type situations?

Data and methods: satellite information from above the clouds, Physics-Informed Neural Networks (PINNs): Include constraints or potentially full equations into the neural net as an inductive bias.

- Thesis 1: High-resolution climatologies of morning cloud disappearance by linking geostationary satellites (high temporal resolution, low spatial resolution) and low-earth orbiting satellites (low temporal resolution, high spatial resolution)
- Thesis 2: Very-high resolution spatial patterns of radiation obtained by linking balcony PV output with satellite maps.

Relevant course programmes:

- M.Sc. Informatics
- (M.Sc. Meteorology and Climate Physics / Faculty of Physics?)
- M.Sc. Remote Sensing and Geoinformatics

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Spatial statistics to predict clear skies

Supervising groups: Schienle (Statistical Methods and Econometrics), Cermak (Institute of Photogrammetry and Remote Sensing, Institute of Meteorology and Climate Research)

Problem / state of knowledge: The dissipation of persistent fog in the Upper Rhine Valley is hard to predict, making it hard to plan the photovoltaics potential even a few hours ahead of time. Satellite data with a high temporal resolution are available for the analysis of such situations, but no technique exists to date for the short-term prediction of their development.

Research qestions:

1. Can GNNs be used to predict the clearance of persistent fog in the Upper Rhine Valley?
2. What distinct spatio-temporal patterns can be identified in fog dissipation?

Data and methods: Time series of satellite data of low cloud distribution in the upper Rhine valley, graph neural networks

Relevant course programmes:

- M.Sc. Wirtschaftsingenieurwesen
- M.Sc.Wi-Wirtschaftsinformatik
- M.Sc.Digital Economics
- M.Sc. Remote Sensing and Geoinformatics
- M.Sc. Meteorology and Climate Physics
- M.Sc. Geoökologie

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Quantifying radiation below clouds from satellite data

Supervising groups: Hagenmeyer (Institute for Au- tomation and Applied Informatics), Cermak (Institute of Photogrammetry and Remote Sensing, Institute of Meteorology and Climate Research)

Problem / state of knowledge: Cloudiness reduces the radiation available for PV. Short-term forecasting and long-term planning will benefit from knowledge regarding the amount of radiation transmitted by clouds. While satellite-based products on the optical thickness of clouds exist, there is large potential to improve this data basis by explicitly linking raw satellite-derived measurements with ground-based measurements of radiation at PV installations.

Research questions:

1. How are satellite-based measurements of cloudy areas related to radiation obtained at the ground?

Data and methods: PV and radiation data from Campus Nord will be statistically linked to Sentinel 2 LEO satellite observations in a machine-learning approach making use of the full spectral potential of the satellite sensor.

Relevant course programmes:

- M.Sc. Remote Sensing and Geoinformatics
- M.Sc. Meteorology and Climate Physics
- M.Sc. Geoökologie

Can also be scaled to a B.Sc. thesis.