Remote Sensing-Driven Machine Learning Methods in the Field of Energy System Analysis

Contribution to the KonKIS Conference 2024 - Conference of the German AI Service Centers on the Topic of Artificial Intelligence Applications in the Energy Sector

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The expansion of renewable energies is of crucial importance for the future of energy supply. There are numerous reasons for this change and highlight the need for a transition from fossil fuels to sustainable energy sources. Access to clean energy plays a central role in improving the quality of life and protecting our environment. A diverse data basis is essential for efficient implementation at the various levels.

In recent years, the number of satellites orbiting the earth has increased rapidly. They are used for a variety of applications. For example, satellite-based services include global communication via mobile telephony and internet connections, navigation using GPS, weather forecasts based on weather data, and the provision of up-to-date maps of the earth's surface for various mapping services. These are part of the daily habits of billions of people. Favorable drivers of advancing technologization and decreasing costs for satellite launches have led to an increasing number of different players such as countries and companies being able to operate satellites in Earth orbit. This results in large quantities of data collected by satellites, which is often made available at low cost or even free of charge. However, this is also accompanied by the great challenge of handling such enormous amounts of data.

Methods from the field of machine learning can provide a remedy for handling the enormous amounts of data that arise in the field of remote sensing. Machine learning methods offer a wide range of possible applications in data-driven domains such as the financial industry, the automotive industry, and also in the various areas of image-based processes. For example, recurring and conspicuous patterns can be identified in large data sets. Large amounts of data collected by satellites on land use, soil conditions, cover, and other geographical features can be processed automatically using machine learning methods to obtain information that would otherwise be difficult or impossible to obtain.

When the two areas of remote sensing and machine learning are combined, a wide range of possibilities arise for various aspects of the energy system. For example, machine learning methods can be combined with aerial and satel-

lite images to map the stock of renewable energy plants. Various studies have already dealt with the automated detection of PV, wind power, biogas, and hydropower plants. The methods and data used vary greatly. In the planned presentation, 3 different studies on remote sensing-based machine learning for energy system analysis will be presented. The resulting findings will then be used to identify paths for the energy system landscape.

- The first article shows the extent to which semi-automatic approaches can be used to create training patterns for object recognition in photovoltaic systems on roofs. Using a selection of 100,000 automatically generated patterns, a network with a RetinaNet-based architecture combining ResNet101, a feature pyramid network, a classification network and a regression network is trained, applied to a large area and post-filtered by overlapping with other automatically identified locations of existing rooftop PV systems. This shows that the time and effort required for manual identification can be greatly reduced if existing spatial information is automatically combined. At the same time, very good results could still be achieved in subsequent applications. The article has already been published (Kleebauer et al. 2021). The methodology can also be used in a similar way to improve the location accuracy of wind turbines (Kleebauer et al. 2024).

- In a further contribution, varying training data will be examined with regard to their suitability for the detection of renewable energy plants. Various modern deep learning-based approaches for recognition will be combined and compared with a wide variety of aerial images and satellite images. Our research presents a method for training a network using various image data from UAV, aerial and satellite sources that achieves very good performance. This model, which is based on the DeepLabV3 ResNet101 architecture, can be applied to a wide range of image data and is freely available for further applications even for users without programming knowledge due to its implementation in the open source environment QGIS using the plugin Deepness . (Kleebauer et al. 2023a, Kleebauer et al. 2023b, Aszkowski et al. 2023).

- In a third contribution, methods for image super-resolution by combining satellite and aerial images with various deep learning methods are tested. Various popular architectures such as Generative Adversarial Networks and different Transformer Networks can be used to artificially increase the resolution of the original imagery. To improve spatial resolution in remote sensing, interpolation filters or pan-sharpening techniques with higher resolution panchromatic images are commonly used. In the presented work, we implement and train a model based on the Enhanced Super-Resolution Generative Adversarial Network (Real-ESRGAN). For this purpose, we use image pairs from digital orthophotos (ground truth) and Sentinel-2 data (low resolution) to generate super-resolution Sentinel-2 outputs with a four-fold scaling factor. (Horst & Kleebauer 2022).

The results of the various contributions are then summarized and examined with regard to their future suitability, associated challenges and further potential in the area of the energy system landscape.

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