Deep Learning Utilizing Satellite Imagery Feature Detection to create a Wind Turbine Register

Project Goal

In consideration of the growing scarcity of fossil fuels, renewable energy sources are becoming increasingly important economically, socially and politically as an environment friendly and efficient way of generating electricity. As a pioneer in fighting global climate change, Germany is investing into renewable energies, especially wind energy. With around 300 new turbines from 2016 to 2017, North Rhine Westphalia is one of the leading federal states in building new wind turbines.

The aim of the project was to support the federal ministry in North Rhine-Westphalia in generating regional registers of the locations and types of wind turbines to guide national energy producers in the spatial planning process of new plants.

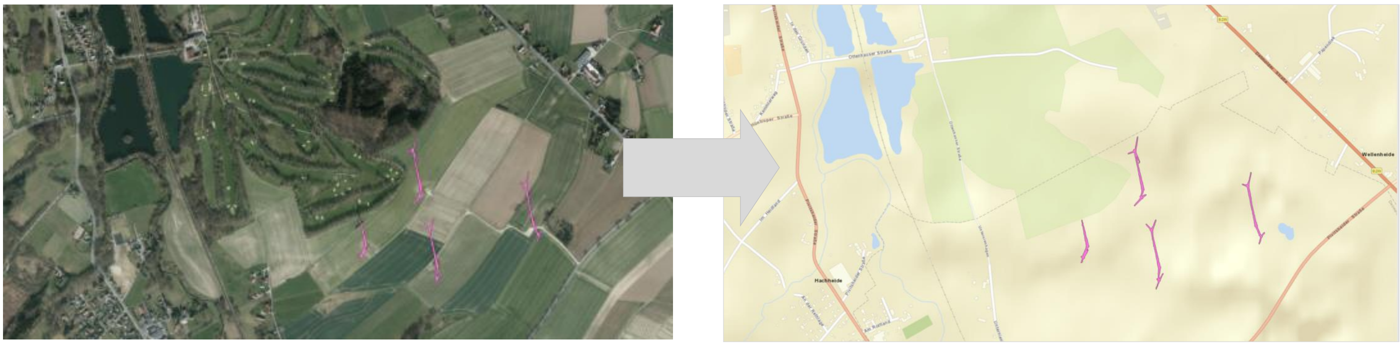
A Convolutional Neural Network (CNN) was trained to identify and segment wind turbines and on-shore wind parks based on satellite imagery. The output wind turbine polygons can then be fed into Geographic Information Systems (GIS) and enriched with current wind data to efficiently monitor the current wind power.

Provided Data

The satellite imagery used in this project contained 280,000 image tiles provided by Esri’s (the market leader in geoinformation systems) World Imagery. The images cover the bounding-box area of the federal state North Rhine Westphalia and have an area of 1 km² each. For each image tile, the corresponding geographic metadata was tracked. For the training data set 500 images and 200 for the validation data set were selected, including 200 wind turbines of different types and in different landcover situations. For both sets wind turbine polygons have been created.

Applied Methods

First, an image pre-processing was performed to normalize satellite images with differing brightness, saturation and contrast levels.



Then the training and validation data had to be generated by visually locating wind parks and turbines in ArcGIS Pro (Esri's Professional GIS-Tool). The located turbines were then marked and converted into georeferenced polygons. After matching the resulting polygons with the corresponding image tile, they were converted into image masks. The mask classifies, if an image pixel belongs to a wind turbine or not. This serves as the desired classification scheme for the developed artificial neural network. The Deep Learning framework used is based on a U-Net architecture, which has been proven to perform very well for segmentation tasks with a low amount of training data. The segmentation performance was tracked using the Jaccard-Index to depict the ratio of correctly classified pixels. The training was calibrated to achieve the maximum accuracy in the validation set in order to prevent model overfitting. The final layer of the neural net outputs an image mask with a pixelwise prediction of the likelihood of a pixel to belong to a wind turbine.

Challenges

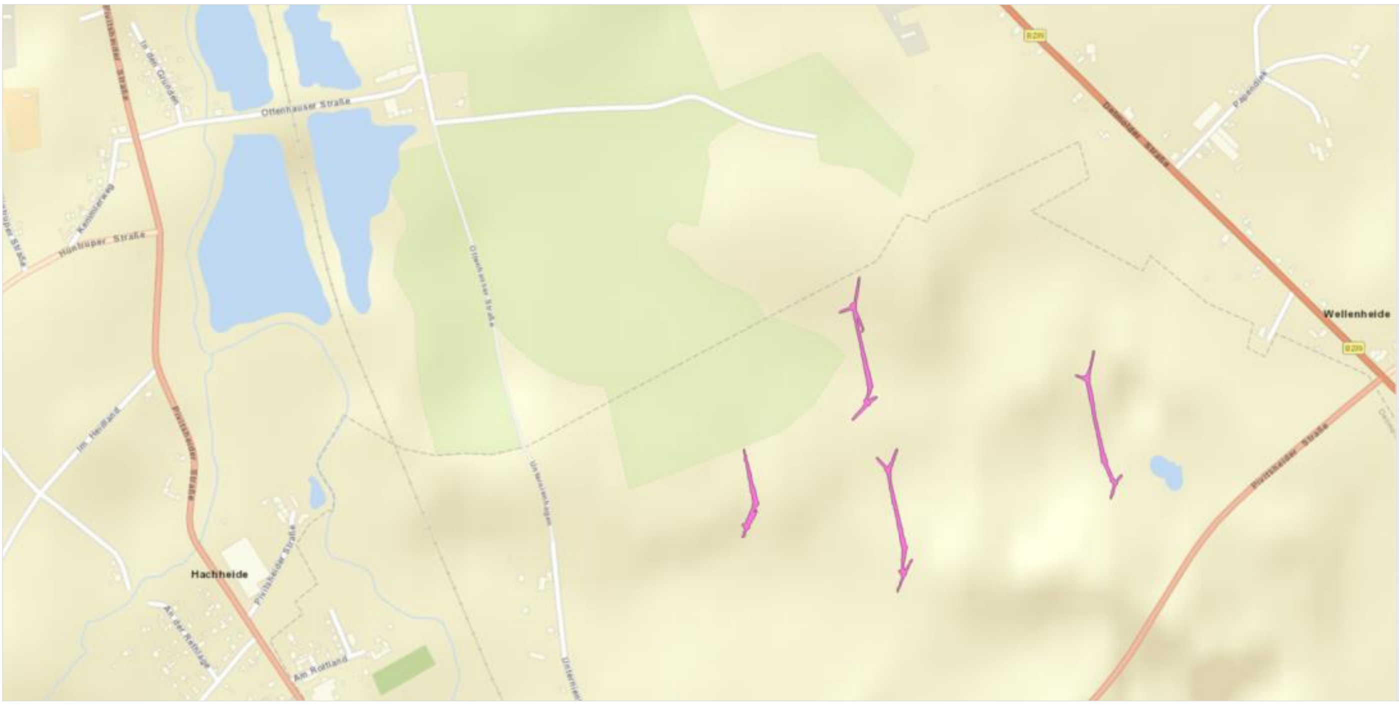
The first challenge was to create the training features and to generate polygons of the wind turbines in the 700 satellite images. The application of unsupervised clustering, namely a K-Means color clustering, helped with pattern recognition and extracting the polygon shape. Another time-consuming challenge was to detect the false positives of the network, i.e. recognized image segments that were falsely identified as wind turbines, like branching roads or aircrafts. Further training epochs were needed to train the neural net to differentiate between those similar looking objects.

Project Outcome

Using the developed Deep Learning Model, a regional register of wind turbines of North Rhine Westphalia was created. In total, about 3,300 wind turbines have been identified in the satellite images. This register was also captured as a layer in ArcGIS Pro and is now available as map material within the software, displaying the location of all identified wind turbines as polygons of their shapes. As a next step, the model can also be applied to other German states or even to create a worldwide wind turbine register. The wind turbine layer can be merged with current wind speed data to monitor the wind power generation and with average wind speed layers to support the spatial planning of new wind turbine sites.

Further applications

The developed Deep Learning Model has already been utilized in other projects within the field of satellite image segmentation. Based on provided satellite imagery, stylized map material has been created. The neural net has been trained to detect different objects and land cover types on satellite imagery, such as roads, trees, forests, vehicles, buildings, rivers and agricultural fields.



Layer in ArcGIS with highlighted wind turbines (pink)