Detection and Mapping of Photovoltaic Panels using ArcGIS and Deep Learning

Project Goal

Green energy sources like solar and wind energy are replacing the already existing non-renewable energy sources i.e. fossil fuel and nuclear power plants. With increased global energy demand, its essential to plan for the implementation of new renewable energy infrastructure. This planning is only possible, if there are no information gaps on the distribution of the available infrastructure.

To bridge this information gap, we integrated deep learning and GIS to detect and map photovoltaic (PV) panels in North Rhine-Westphalia through the use of remote sensing imagery. The PV panel detection pipeline can be fully integrated into the ArcGIS Pro environment. The primary objective of this project was to train a neural network that automatically detects and maps PV-panels. This neural network will be updatable in case of new infrastructure implementation, transferable to new locations and extendible to other features e.g. wind turbines and streetlights.

Provided Data

The drone imagery was obtained from the OpenGeoData portal of North Rhine-Westphalia as Digital Orthophotos. The imagery had 4-spectral band (red, green, blue and Infrared), with a spatial resolution of 0.1 meters and a spatial reference of EPSG 25832 (UTM Zone 32N). A total of 46,818 single images of 1km by 1km (10000 by 10000 pixel) each, were collectively obtained.

Challenges

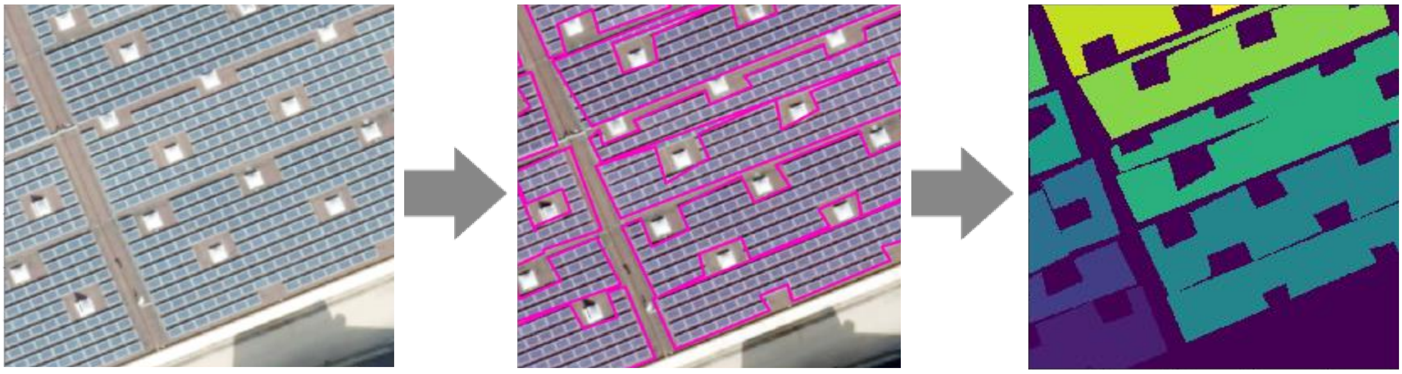
The undiscriminating color properties of the PV panels (shown below in figure 1), made the labeling process (i.e. creating of training data) tedious since all the color properties needed to be represent in the training sample. Secondly, the PV panels with smaller surface area generate no visual features to train therefore they were not taken into account. During digital mapping, there was optical deformation of the PV panels due to their orientation and differences in roofs' slants, hence appearing longer or shorter in a 2D visualization (Polygon).

1. Example imagery of PV-panels on the drone imagery

Applied Methods

Generating Training Data

The training data was extracted and validated from three regions of 20km² each, that were created by mosaicking 60 (RGB) orthophotos. These different areas provided distinct properties of the PV panels for generating training samples. As a process of labeling, shapes of the PV panels were digitized and then stored as feature polygons (image 2b). With the corresponding imagery, the feature polygons were exported from ArcGIS pro as RCNN image masks for training in TensorFlow. These masks of 500 by 500 pixels with a 50% overlap, classify if an image pixel belongs to a PV panel or not and acts as a segmentation scheme for the artificial neural networks. From this data a so called TensorFlow Record file is created, which serves as input for the training of the neural networks.



2a. Orthophoto   2b. Labelling   2c. RCNN Mask

Model Training and Analysis

3. Detected bounding box and masks

For the training of the Mask RCNN models the *TensorFlow Object Detection API* and pre-trained neural networks are fed with the generated training data of the PV-panels. The so trained models work with a Region Proposal Network feature extraction. This way PV-panels are detected with bounding boxes at first. Instance segmentation allows for fine-grained information about the extent of the photovoltaic panels within the bounding boxes (image 3).

The trained model is loaded into ArcGIS Pro and by using the software's deep learning tool of detecting objects, a digital map of all PV-panels is generated. (image 4) This way the detection can be applied on any remote sensing imagery loaded into ArcGIS Pro.

Project Outcome

4. Output layer with detection visualization in the area of cologne