Global Offshore Wind Energy Infrastructure Dynamics Derived from Sentinel-1 Imagery with CNNs based on Synthetic Training Data

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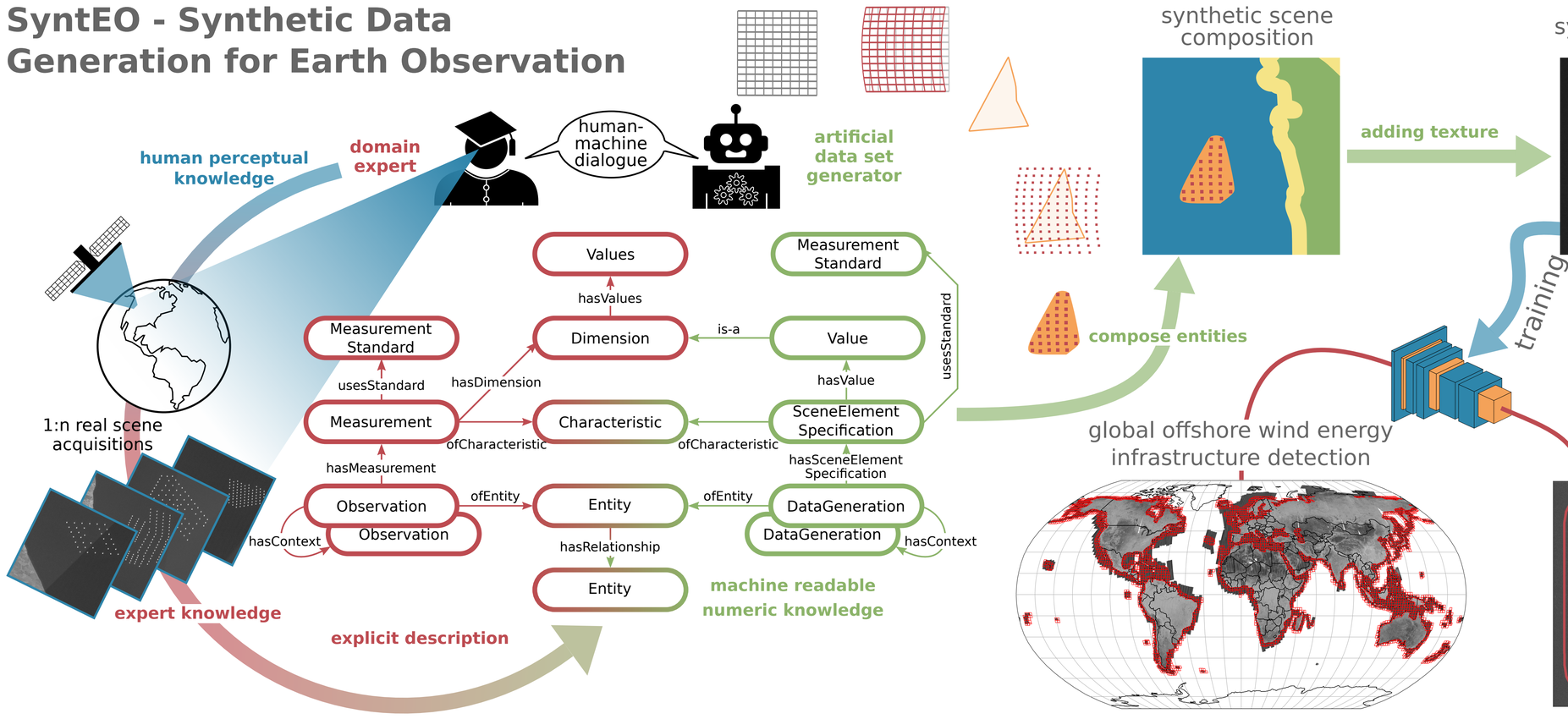
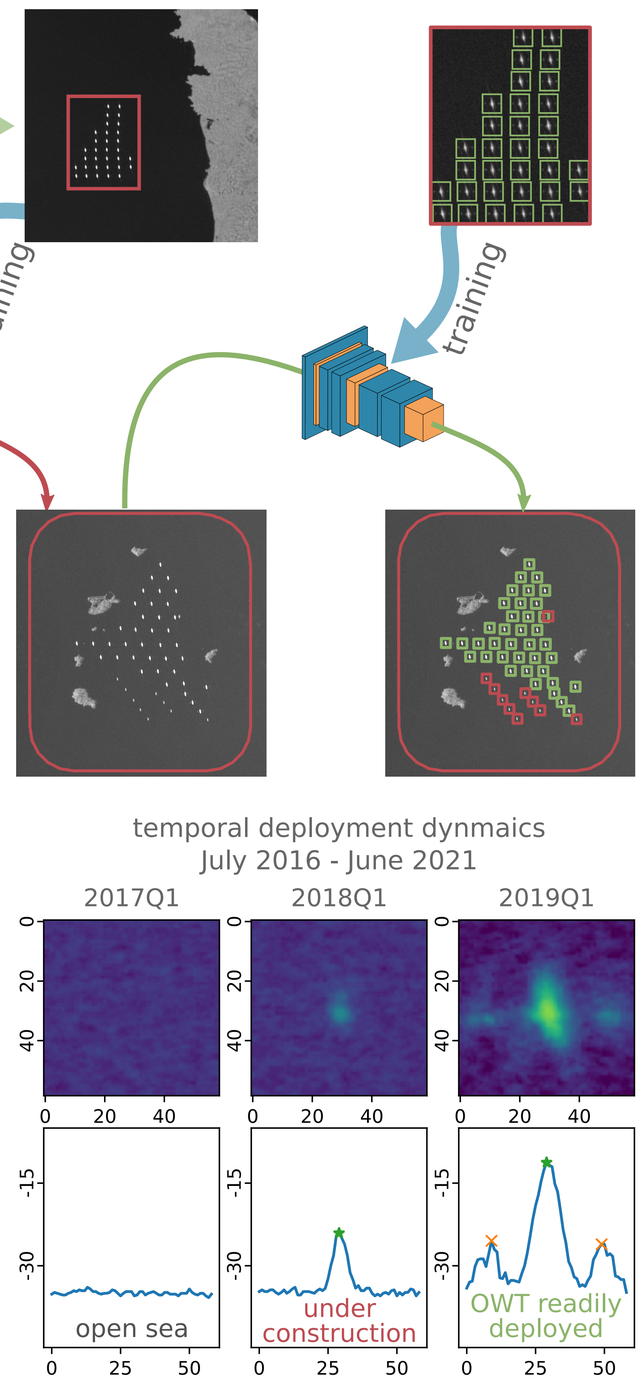
SyntEO - Synthetic Data Generation for Earth Observation

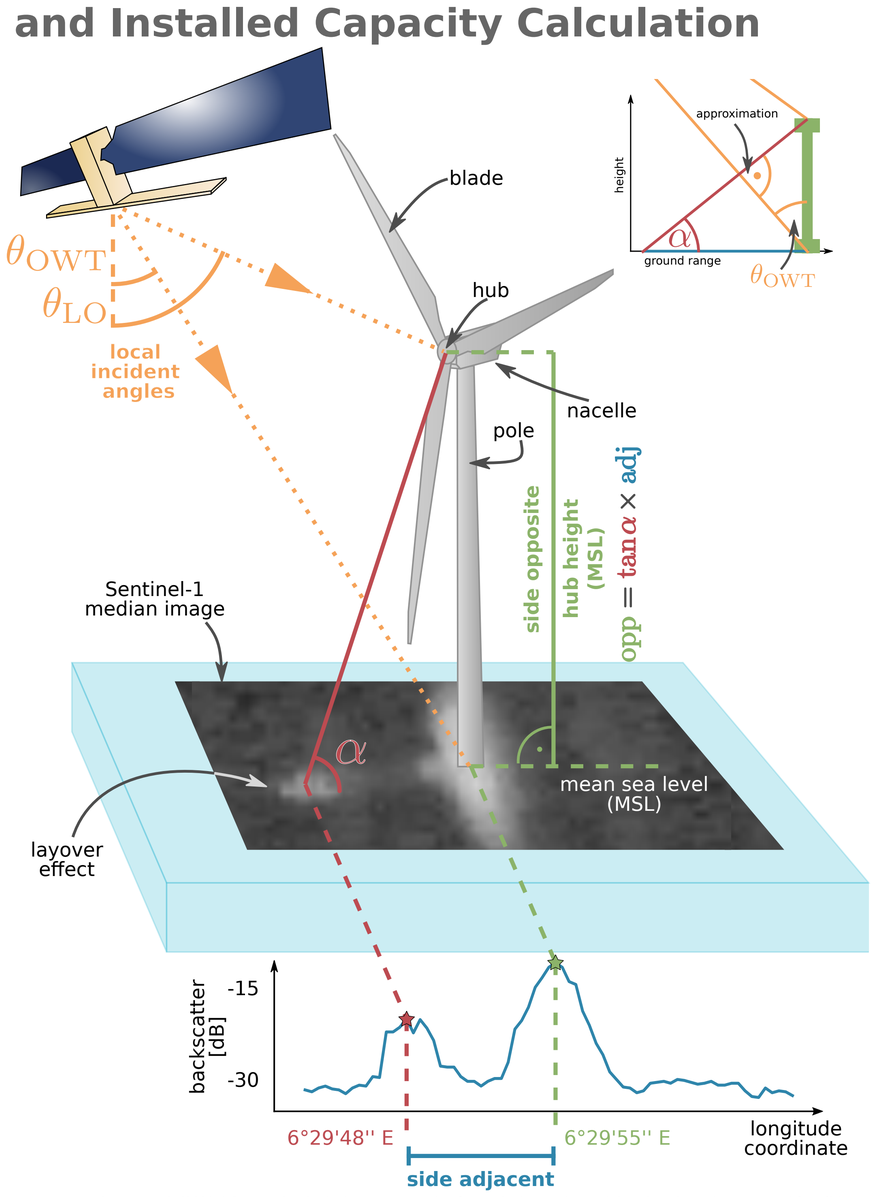


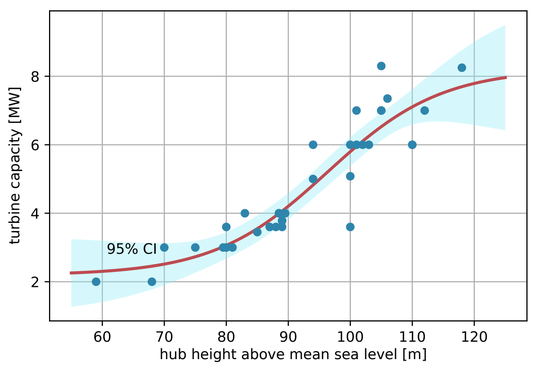
SyntEO is a synthetic data generation framework with a specific focus on the needs of Earth observation data. SyntEO uses an ontology to make human expert knowledge accessible to a machine which can use this structured knowledge representation to compose a synthetic remote sensing scene automatically. The entities (the so-called targets and non-targets) in such a synthetic scene composition have a meaningful spatial relationship. Thus the real-world context of complex remote sensing scenes is preserved. That way, SyntEO training data sets contain target information and non-target information to support a higher generalisation during model optimisation.

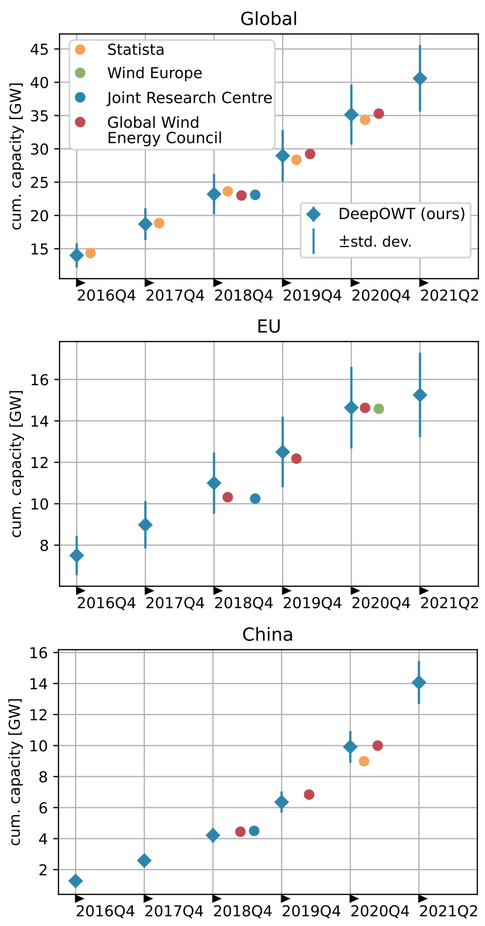
The approach was used to detect offshore wind energy infrastructure globally. Two synthetic training data sets are generated to train a two-stage cascade of ResNet-50 Faster R-CNN object detectors. The first stage detects potential offshore wind farms. The second stage detects wind turbines, transformer stations and platforms under construction. A subsequent temporal analysis of the changes in the Sentinel-1 radar signal in each detected location provides the deployment stages of each object in a quarterly frequency from July 2016 until June 2021.



Offshore Wind Turbine Hub Height and Installed Capacity Calculation







In a radargrammetric approach, the backscatter clusters of a wind turbine's foundation and the layover effect of the turbine's nacelle are used in combination with the local incident angle to calculate the hub height.

The hub height is used as an input variable in a sigmoid regression to estimate the installed capacity for each of the 8,885 globally detected turbines.

The spatiotemporal analysis emphasises the contribution of the EU, China and UK to the global offshore wind energy sector, with China being the major driver of the recent expansion within the last five years.

Hoeser, T., and Kuenzer, C. (2022a) Synteo: Synthetic dataset generation for earth observation and deep learning – demonstrated for offshore wind farm detection. ISPRS Journal of Photogrammetry and Remote Sensing 189, 163–184.

Hoeser, T., Feuerstein, S., and Kuenzer, C. (2022) DeepOWT: a global offshore wind turbine data set derived with deep learning from Sentinel-1 data. Earth System Science Data 14, 4251–4270.

Hoeser, T., and Kuenzer, C. (2022b) Global dynamics of the offshore wind energy sector monitored with sentinel-1: Turbine count, installed capacity and site specifications. International Journal of Applied Earth Observation and Geoinformation 112, 102957.