Predicting the Solar Potential of Rooftops using Image Segmentation and Structured Data

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Introduction

- Climate change **mitigation** and **adaptation** partly involves switching from carbon emitting energy sources to **renewables energy sources**.

- Dense environments such as cities
  Roofs are available space
  → photovoltaic energy on **rooftops**

Estimation of potential is time-consuming and difficult to achieve at a large scale

nam.R solaR

- nam.R is a data & deep-tech company building the 1st **geolocated data hub**. We're working on renewable energy transition projects.

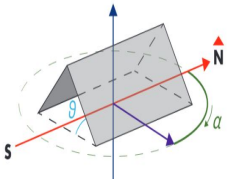
- With the solaR project, we accelerate the development of **photovoltaic energy** by estimating the production on each roof.

- Computer vision and classic ML models used to **predict missing information** and make a large **scale estimations** possible.

Workflow

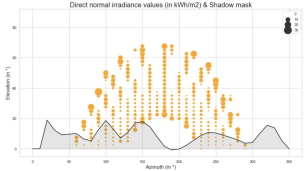
Aerial Image

Roof Section and Object Segmentation

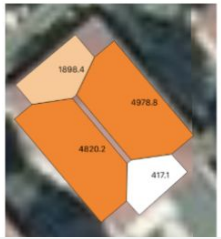


Pitch/Azimuth Prediction

Arrangement of Solar Panels



Shading Mask and Specific Photovoltaic Power



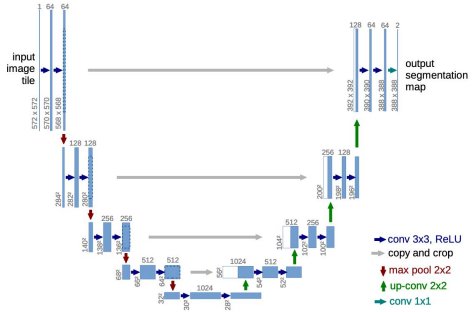
Solar Potential

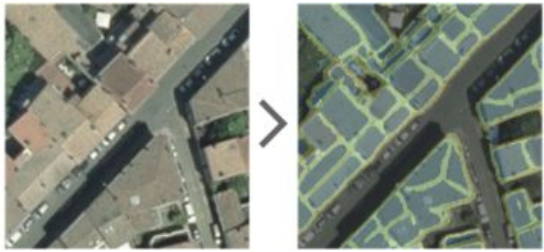
$$solar\ potential\ (kWh/year) = N_{panels} \times P_{max} \times PV_{out}$$

N_{Panels} : maximum number of solar modules on a roof slope
P_{max} : module nominal maximum power *(kW)*
PV_{OUT} : specific photovoltaic power output *(kWh/kW/year)*

Roof Sections and Objects Segmentation

- Segmentation with a pixel-wise classification + vectorization
- U-Net [1] with a ResNet-34 backbone

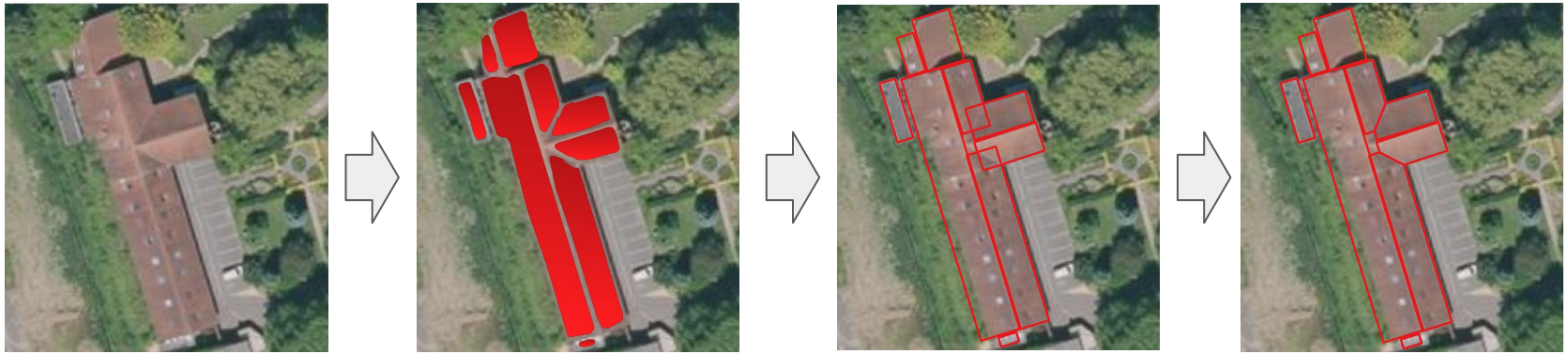




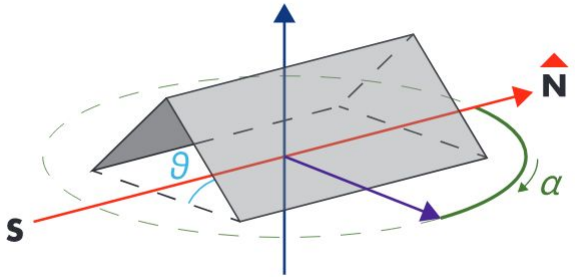
- Training set:
  - 30,000 images + rasterized **roof sections** geometries from 3D models
  - 400 images with manually labelled **objects**

[1] O. Renneberger, P. Fischer, T. Brox, "U-Net: Convolutional Networks for Biomedical Image Segmentation" (2015).

Roof Segmentation: Post-processing



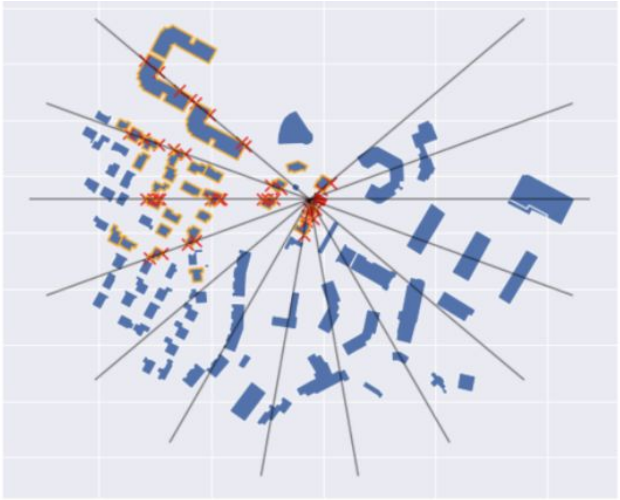
IGN Aerial Images | U-Net Segmentation | Bounding Boxes | Regularization



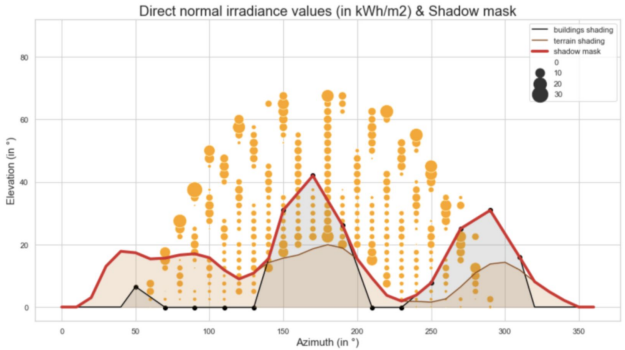
- Roof sections are enhanced by geometrical regularization
- Roof **azimuth** is computed through a **geometric algorithm** based on the building footprint and nearby roof sections
- Roof **pitch** is estimated using a **Random Forest regressor** with building structured features

Specific photovoltaic power and shading mask

- Specific photovoltaic power computed from multi-year hourly irradiance estimations, meteorological variables and roof features
- **Sky-View factor** methodology used to compute a mask of shadows on two different scales: neighboring buildings and surrounding topography
- **Shading** is applied separately to direct and diffuse solar irradiance



(top) Rays intersecting the surrounding buildings footprints in each of the sampled azimuth directions.



(left) Rays intersecting the surrounding buildings footprints in each of the sampled azimuth directions.

Results

- Method applied to a scope of more than **1.1 million buildings** in France
- Algorithms used in each step are validated separately
- Qualitative validation for shading mask
- The **two main steps** of our methodology, roof section segmentation and azimuth prediction, **show very good results**
- Limitations for roof object segmentation and pitch prediction

Task	Model	Score
Roof sections segmentation	ResNet-34-based UNet	Pixel accuracy = 77%
Roof objects segmentation	ResNet-34-based UNet	Pixel accuracy = 30%
Azimuth	Geometric	Accuracy = 79%
Mean pitch as a function of latitude	Linear Regression	$R^2 = 0.93$, MAE = 3.9°
Normalized pitch	Random Forest	$R^2 = 0.37$, MAE = 5.5°

(top) Neighborhood view of the resulting solar potential. (bottom) Aggregated view (sum) of the solar potential over French Hérault department.

Conclusion

- **AI for scaling up**
- Best benefits when combined with geometric computation and **expert rules**
- **More data** means more solar panels on **optimal** roof sections
  → climate change mitigation and adaptation

Thank you!

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