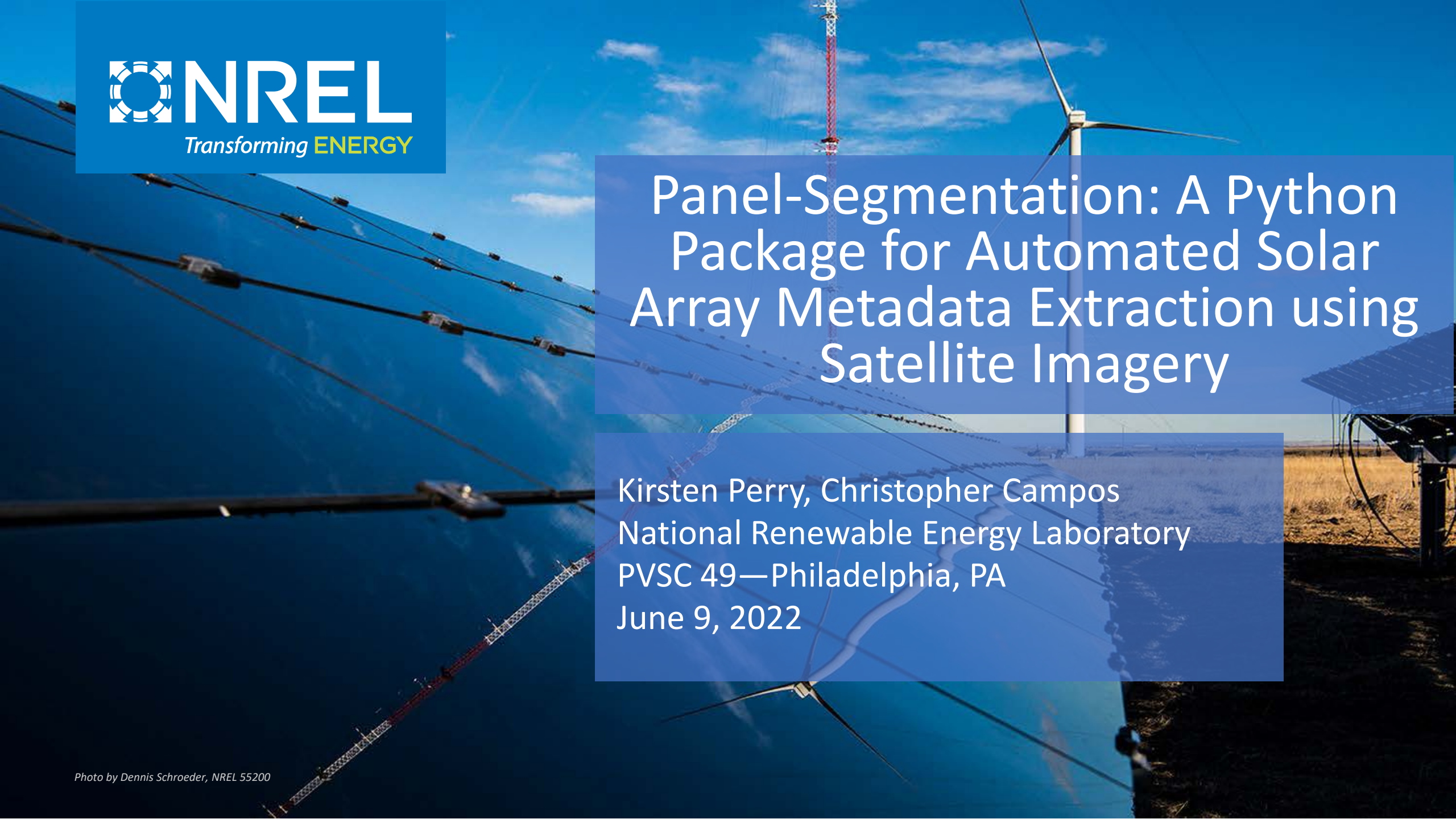

Panel-Segmentation: A Python Package for Automated Solar Array Metadata Extraction using Satellite Imagery

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PVSC 49—Philadelphia, PA
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Photo by Dennis Schroeder, NREL 55200

Background

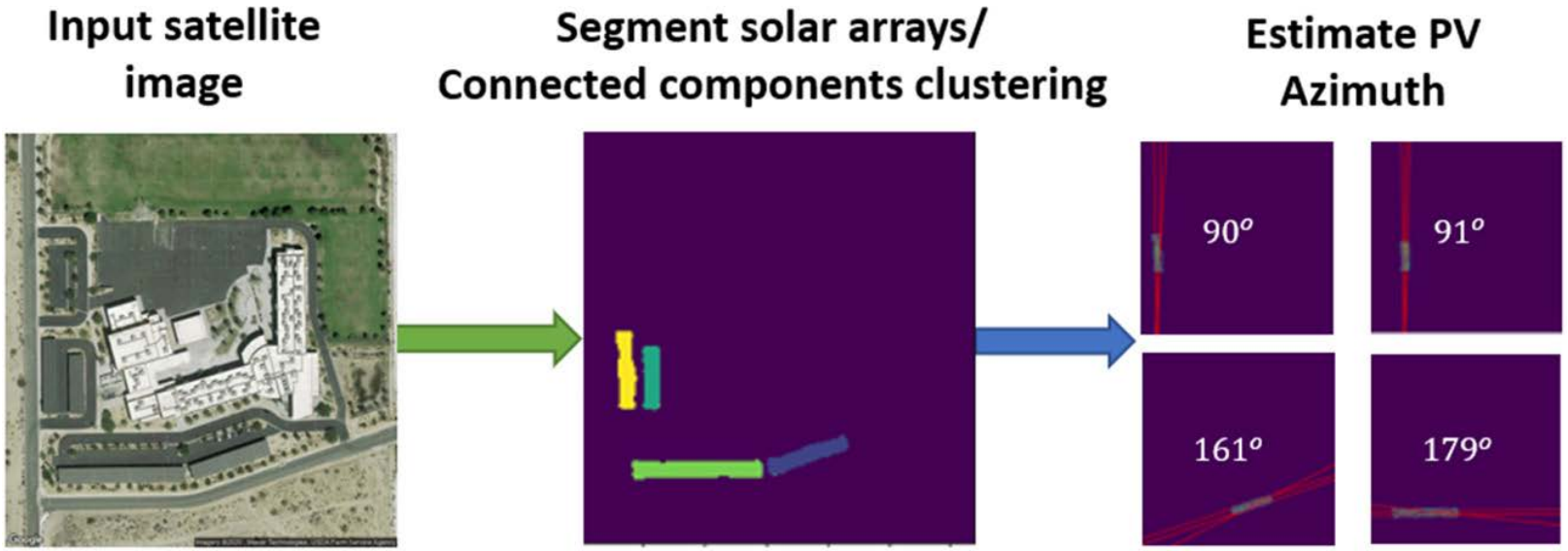
- Rise in solar investments → rise in solar acquisitions [1]
- Data lost during transference between owners
- Metadata: tilt, azimuth, module type, and mounting configuration
- Manual entry **OR** costly site inspections
- **Why is having accurate metadata important?**
  - Expected energy yield and degradation rates
  - Mounting configuration type affects system degradation rate [2]

[1] “Solar funding and MA: 2021 first half report,” Mercom Capital Group, Tech. Rep., 2021
[2] D. Jordan, et al., “PV degradation - mounting temperature.”

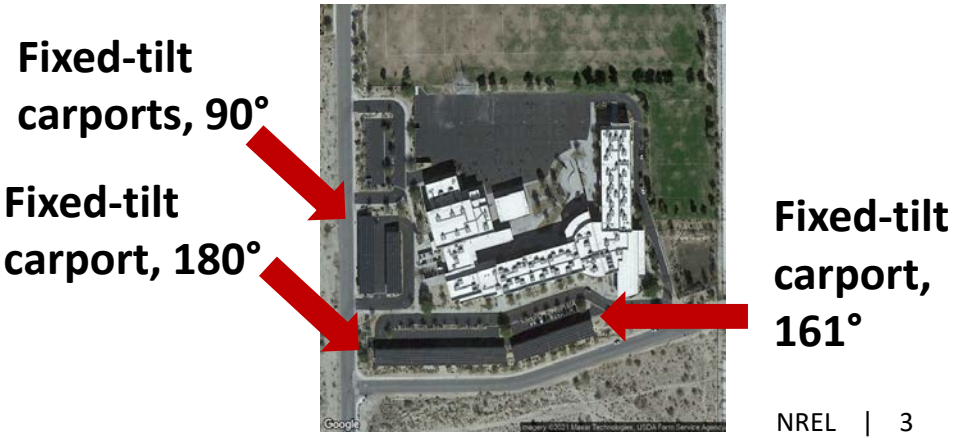
Approach

Panel-Segmentation v0.0.1 [1]

- NREL Panel-Segmentation package
  - Example model pipeline [3]
- **New Goal**: Identify mounting configuration
  - Fixed tilt or tracking
  - Carport, ground, or rooftop mount



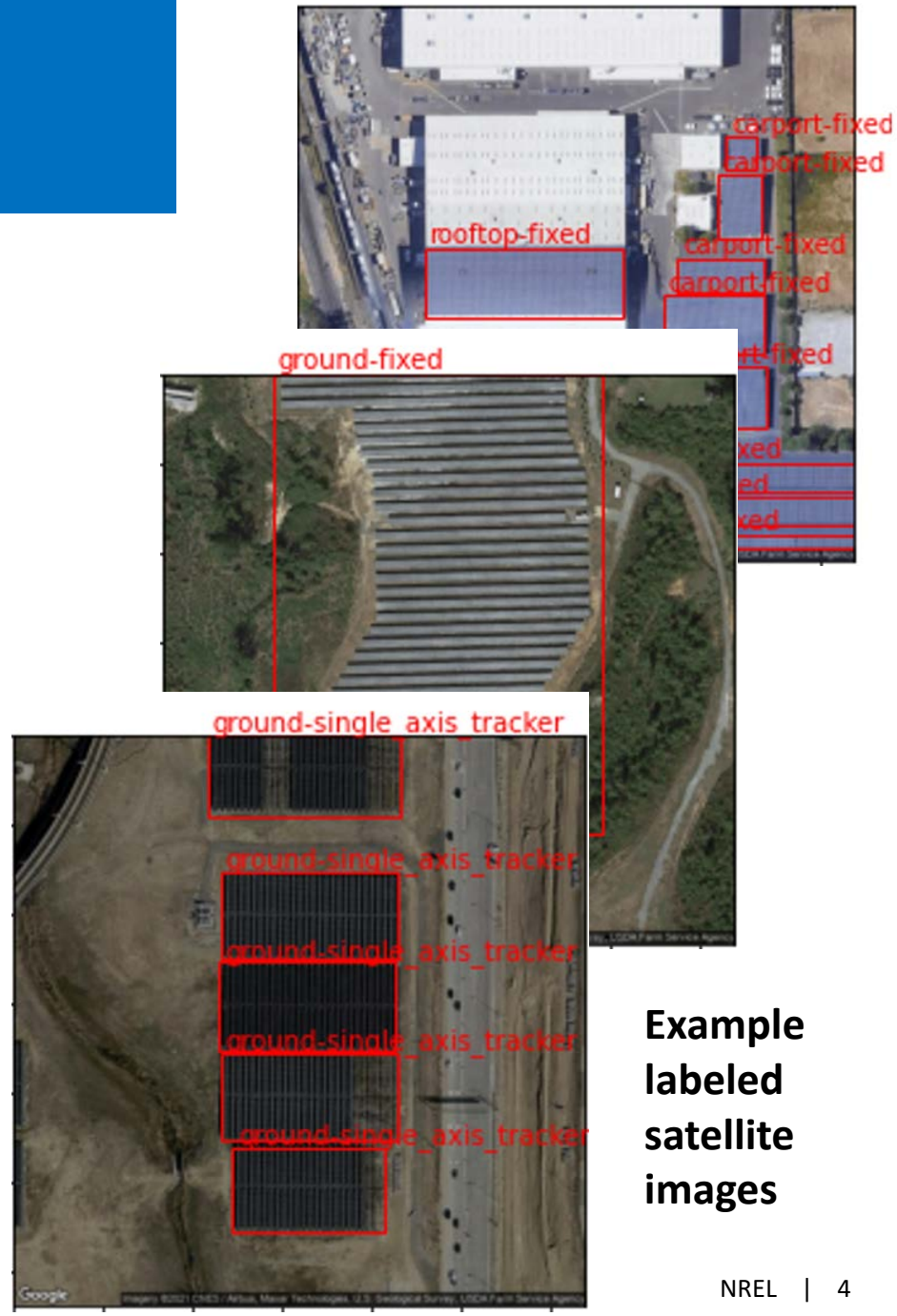
Goal for Panel-Segmentation v0.0.2



[3] A. S. Edun, K. Perry, et al., "Unsupervised azimuth estimation of solar arrays in low-resolution satellite imagery through semantic segmentation and hough transform," Applied Energy, 2021.

Methods

- Data Sets
  - 862 satellite images
  - Label mounting configuration:
    - Rooftop-fixed
    - Ground-fixed
    - Carport-fixed
    - Ground-single-axis-tracker
- Object Detection Model
  - Backbone: Faster-RCNN Resnet-50 FPN [6]
  - Model specifics available in our full paper



Example labeled satellite images

[4] Jordan, DC, Anderson, K, Perry, K, et al. “Photovoltaic fleet degradation insights.” Progress in Photovoltaics, 2022.
[5] NREL. (2021). Photovoltaic Data Acquisition (PVDAQ) Public Datasets.
[6] K. He, G. Gkioxari, P. Dollár, and R. Girshick, “Mask R-CNN,” in 2017. IEEE ICCV.

Measuring Object Detection Model Performance

- Average Precision (AP) score
- Mean Average Precision (mAP) score
- Intersection-over-Union (IoU)
  - Used to calculate precision and recall
  - Vary IoU score to build precision-recall curve
  - AP score: Area under the precision-recall curve
- mAP score: Average of all AP scores

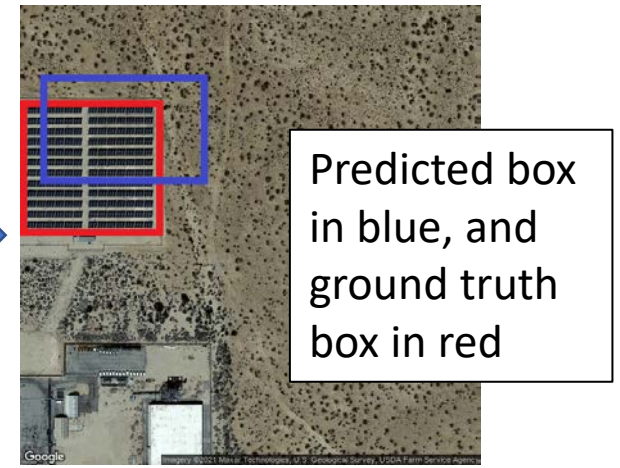
$$\text{Precision} = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

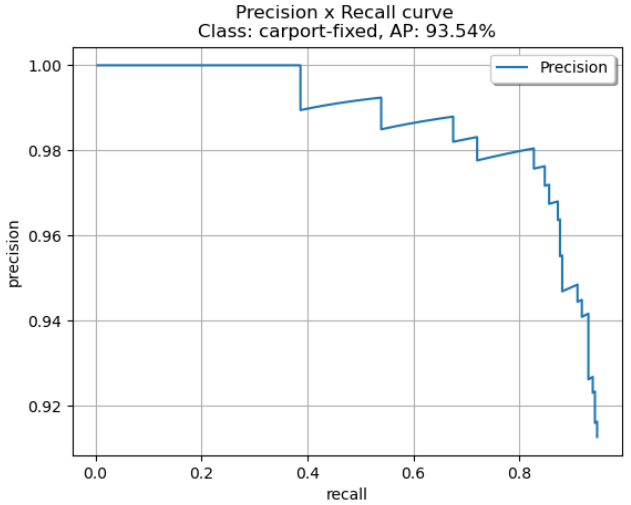
$$\text{Recall} = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

Precision and recall equations

Image courtesy of [7]

$$\text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$





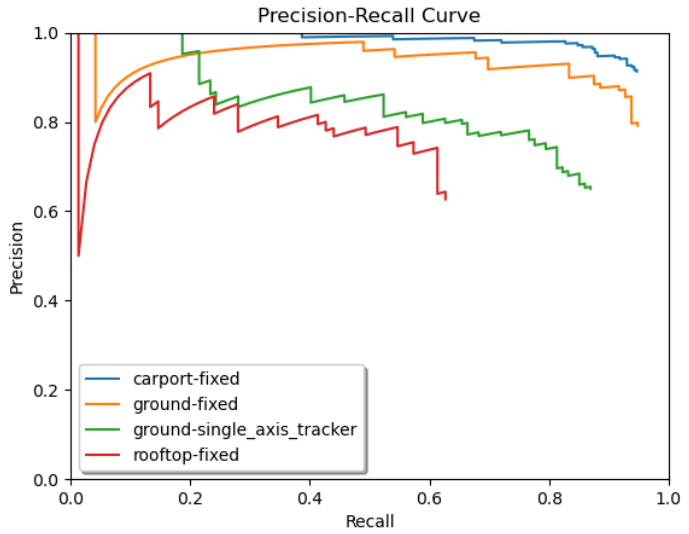
Example Precision-recall curve—carport-fixed class.

[7] https://pyimagesearch.com/2016/11/07/intersection-over-union-iou-for-object-detection/

Results

- Precision-recall curve and AP score by class
- Overall mAP score: 77.79%
- **How does this compare to the state-of-the-art?**
  - Direct comparison not available
  - Previous literature for detecting solar arrays ONLY: 95.66% mAP [8]
  - Easier object detection task (1 class vs. 4)

Class	AP Score (%)
Rooftop-fixed	51.99
Ground-fixed	90.62
Ground-single_axis_tracker	75.01
Carport-fixed	93.54



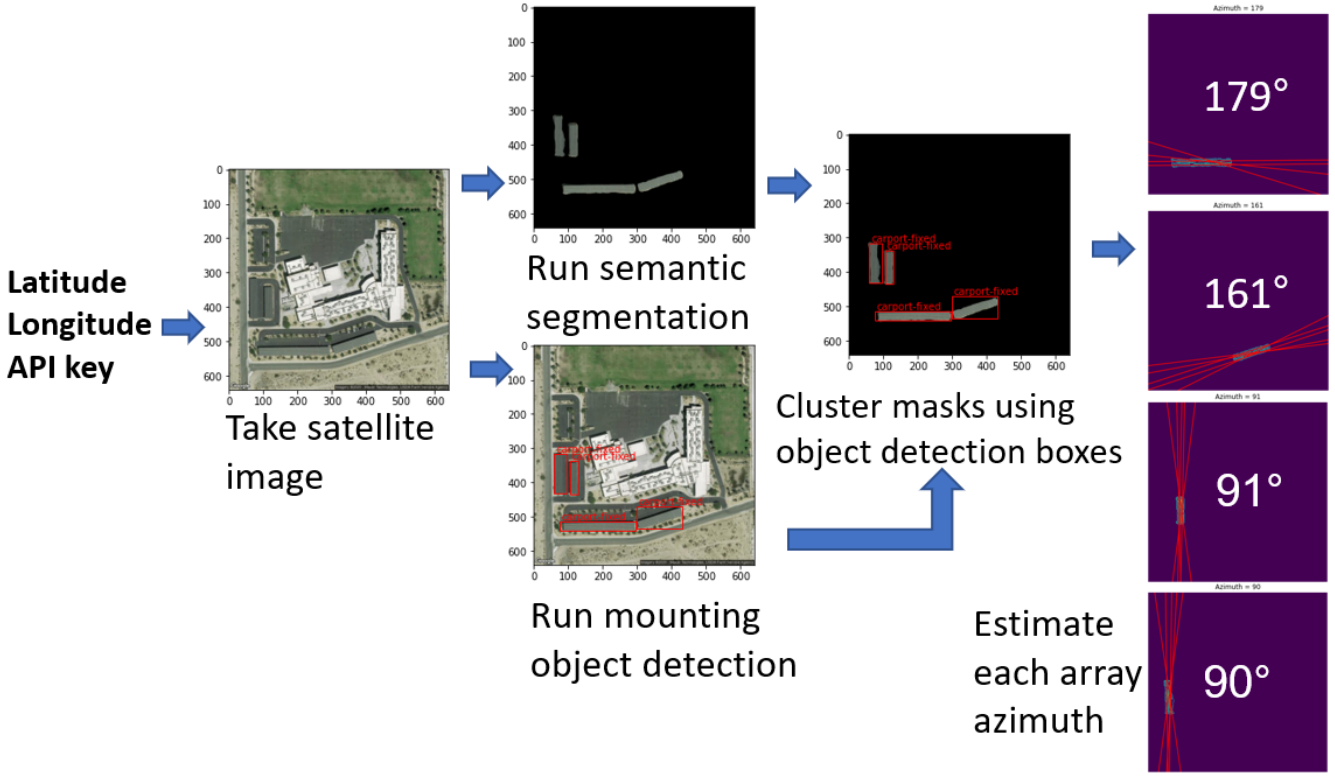
Precision-recall curve for each model class

[8] K. He and L. Zhang, "Automatic detection and mapping of solar photovoltaic arrays with deep convolutional neural networks in high resolution satellite images," 2020 IEEE EI2.

Panel-Segmentation Pipeline Integration

- Updated model pipeline
  - Input: Google Maps API Key, lat-long coordinates
  - Output: Azimuth and mounting configuration

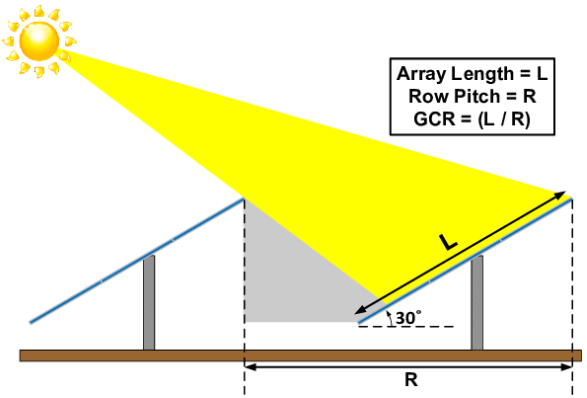
- Labeled data sets publicly available via the DOE DuraMAT DataHub
  - Only satellite images, no identifying info



Updated Panel-Segmentation pipeline (v0.0.2)

Continued Research

- Panel-Segmentation updates
  - Array size/energy output
  - Ground coverage ratio (GCR)
  - Tilt estimations
- **What is the actual cost of incorrect metadata?**
  - This research heavily leveraged by PV Fleets
  - Quantifying the financial cost of incorrect metadata



Tilt and GCR illustrated on a solar installation. Image courtesy of [9]

LiDAR is used to estimate rooftop solar potential via Google's Project Sunroof

[9] Deline, Chris, et al. (2014). Evaluation of Maxim module-Integrated electronics at the DOE Regional Test Centers. PVSC 2014.

Thank you!

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