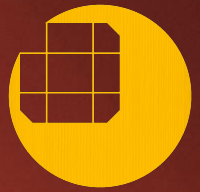


HyperionSolarNet

Solar Panel Detection from Aerial Images

Nathan Nusaputra | Poonam Parhar | Ryan Sawasaki | Felipe Vergara

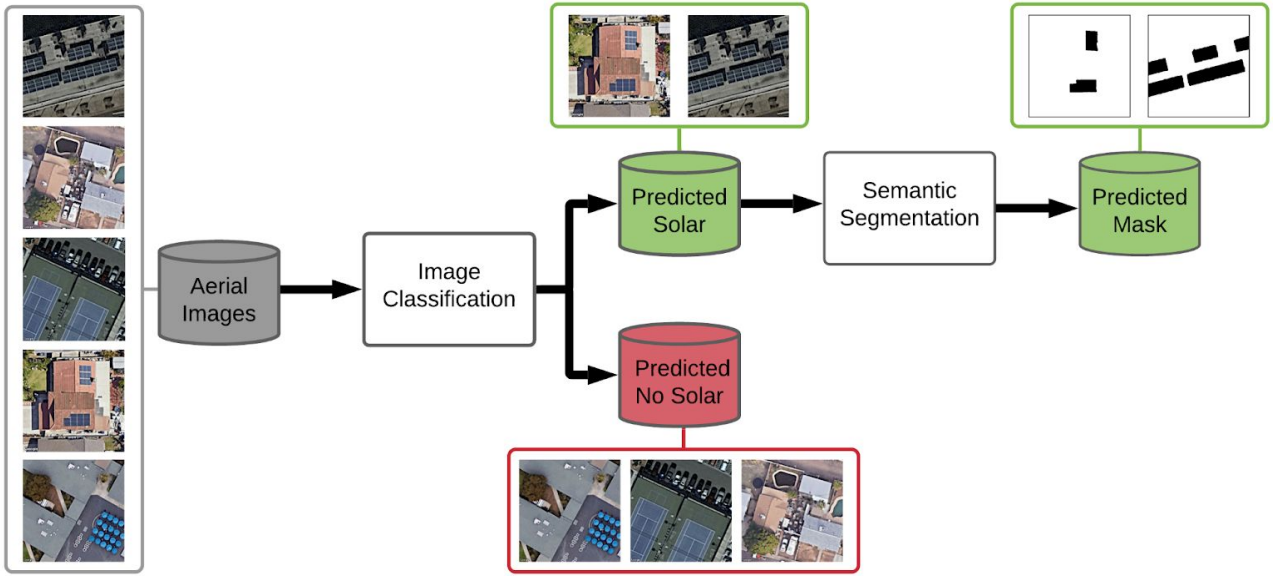
UC Berkeley

Motivation

- Fight climate change by reducing greenhouse gas emissions
- Idea originated from Professor Paolo D'Odorico, Chair of the Department of Environmental Science at UC Berkeley
- HyperionSolarNet uses deep learning methods and satellite images to develop a database of solar panel locations and their total surface area

HyperionSolarNet

- Start with input data of satellite images from Google Maps
- Binary image classification model separating into solar and no-solar classes
- Segmentation model performs the task of classifying each pixel to its specific class
- Predicted masks are further processed to determine the area and number of solar panels



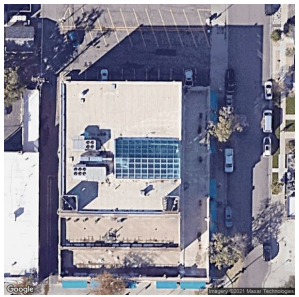
Data

- Images from Arizona, California, Colorado, Florida, Hawaii, Idaho, Louisiana, Massachusetts, Nevada, New Jersey, New York, Oregon, Texas, Washington
- Zoom 20 and 21
- Sizes 416x416 and 600x600
- Residential and Commercial
- For no-solar images, focus on objects that could be misclassified as solar panels, for example:

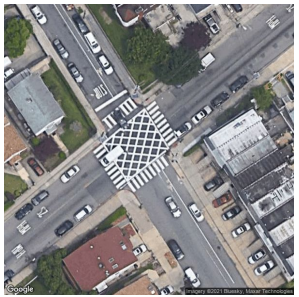
Classification Dataset			
	Solar	No-Solar	Total
Training	668	1295	1963
Validation	168	324	492
Berkeley Testset	321	1922	2243

Segmentation Dataset	
Training	668
Validation	168
Berkeley Testset	321

Skylights



Crosswalks



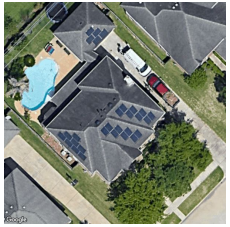
Side of tall buildings

Data Labeling

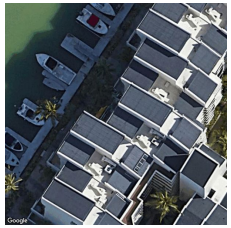
Classification:

- Manually grouped images into solar and no-solar classes
- Time spent locating quality and diverse solar panel images

Solar

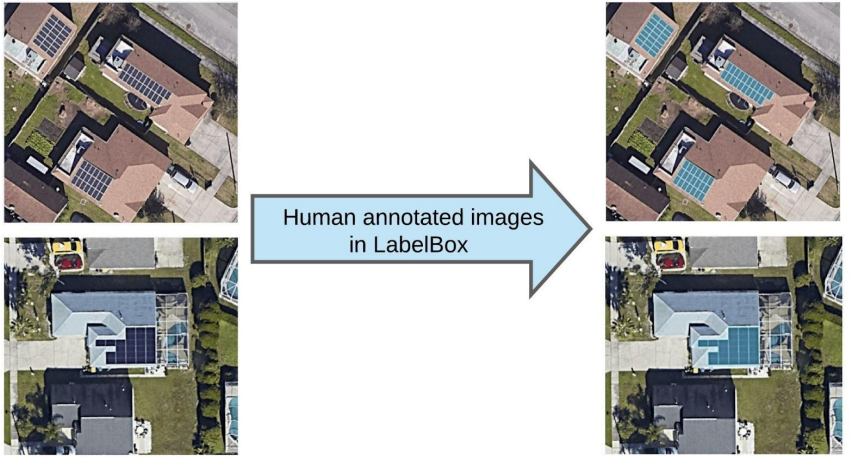


No-solar



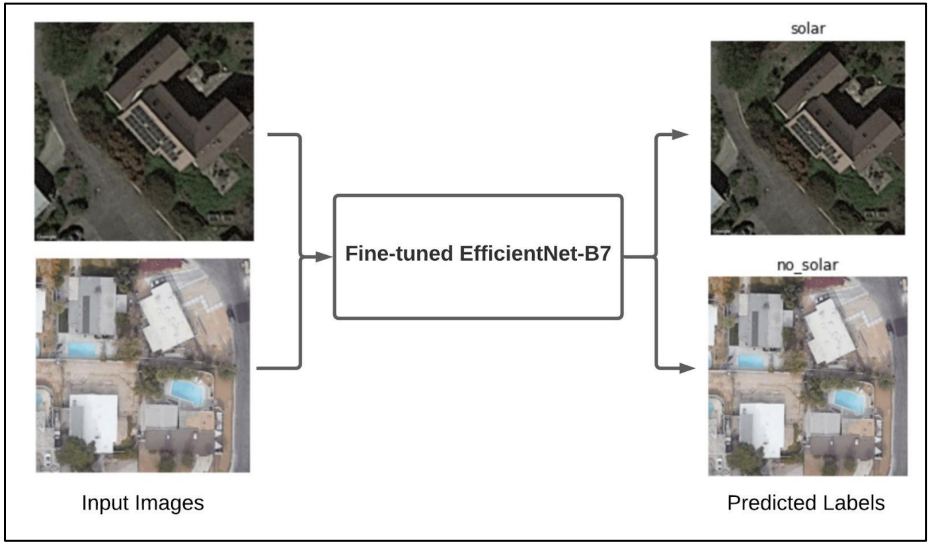
Segmentation:

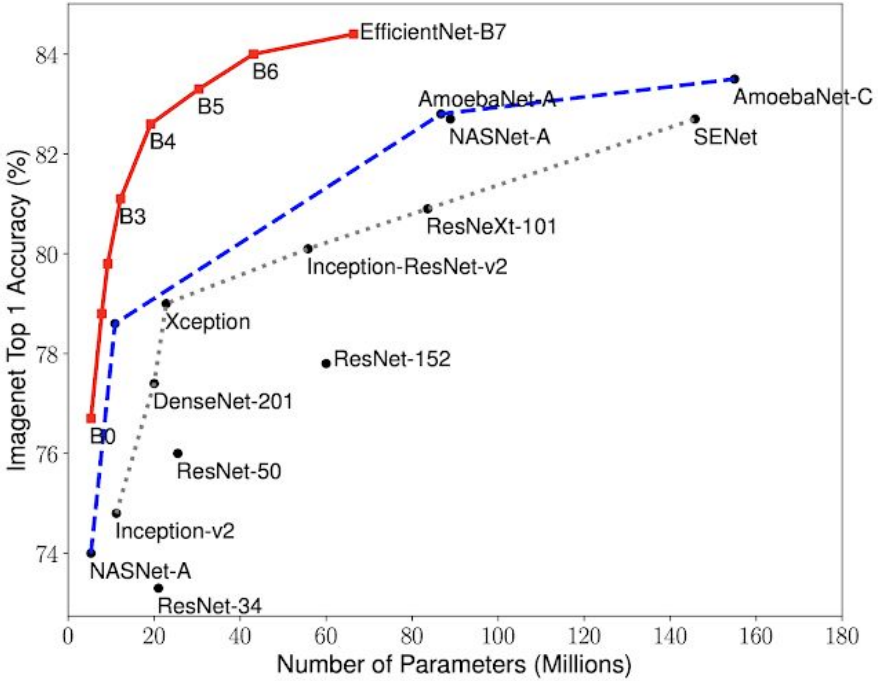
- Used LabelBox platform to annotate solar panel images and create segmentation masks (labels)
- Labeling of 1,200 images required additional resources



Classification Model

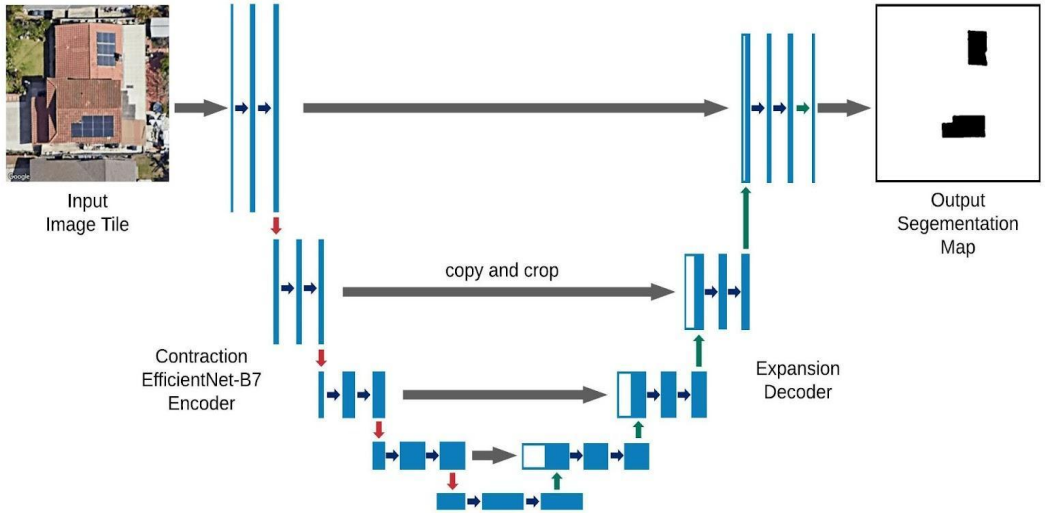
- Transfer Learning
- Fine-tuned EfficientNet-B7 for solar panel images





Semantic Segmentation Model

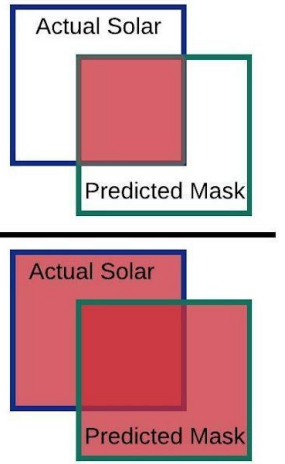
- U-Net is one of the most popular deep learning based semantic segmentation method
- U-Net architecture with EfficientNet-B7 backbone
- Images augmentation using Albumentations library
- Model training using Segmentation Models library



Performance Metrics

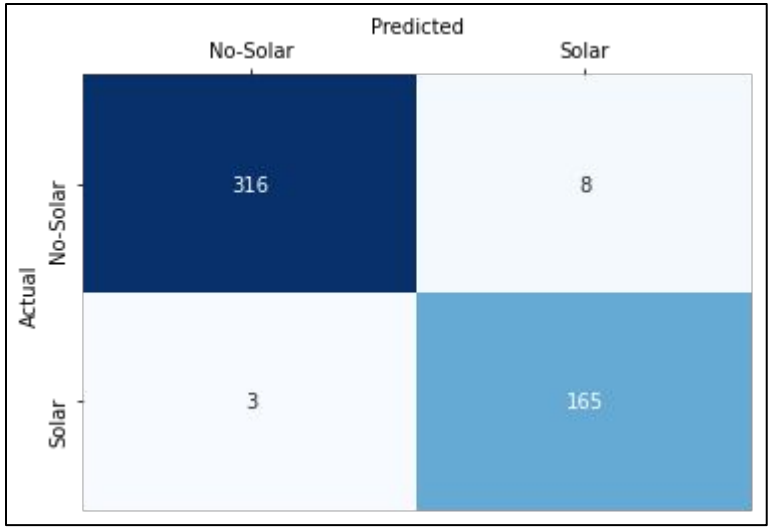
- Accuracy, Precision, Recall and F1-score for the Classification Model
- IoU and F1-score for the Segmentation Model

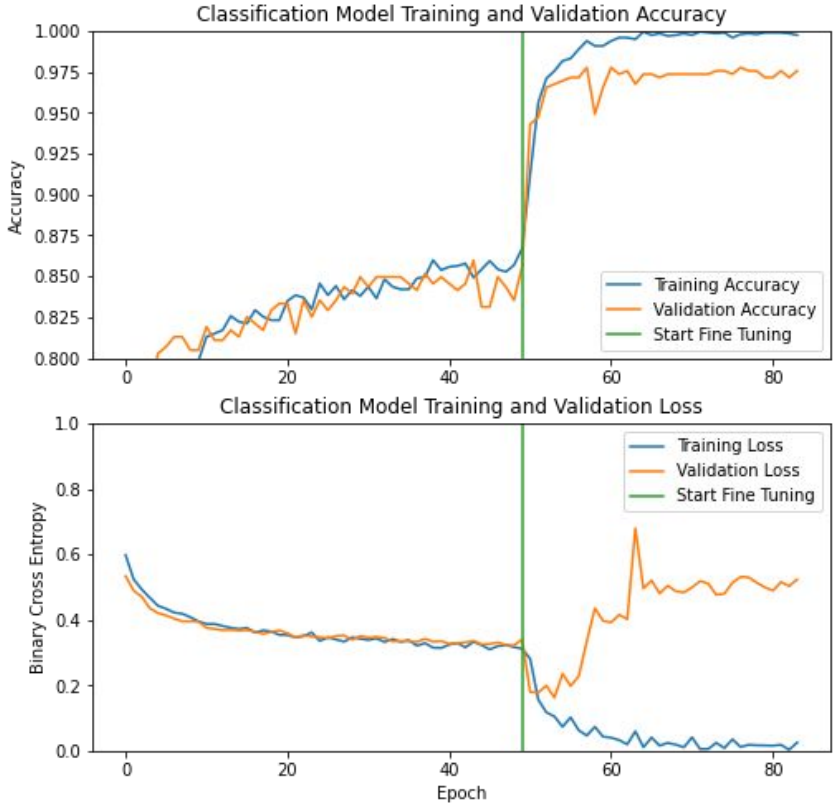
$$\text{Intersection over Union (IoU)} = \frac{\text{Area of Intersection}}{\text{Area of Union}} =$$



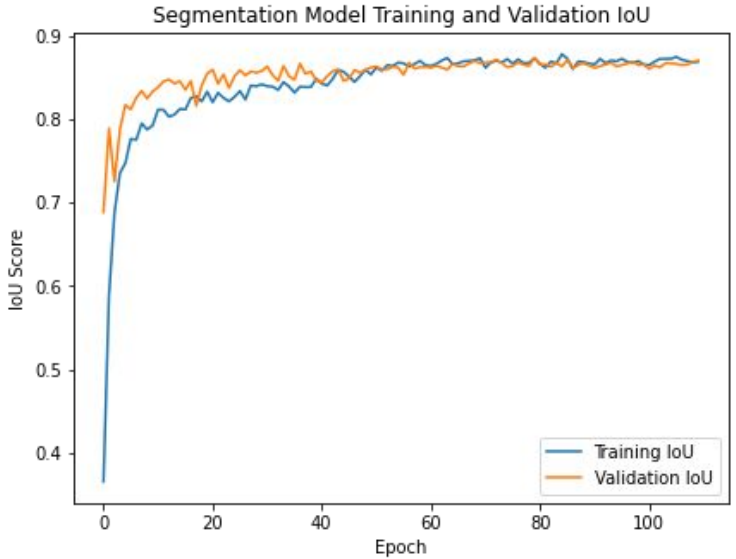
Classification Model Performance

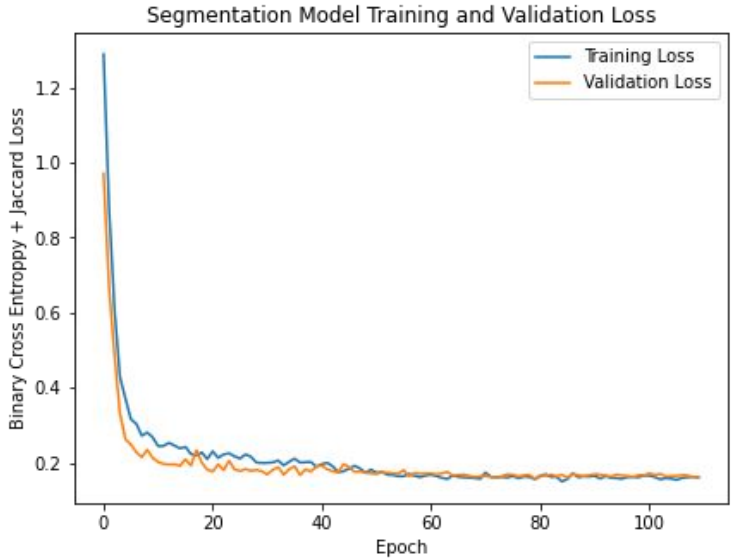
Model	Accuracy	Precision	Recall	F1 Score
Baseline	0.7240	0.66	0.81	0.73
HyperionSolarNet	0.9764	0.95	0.98	0.97





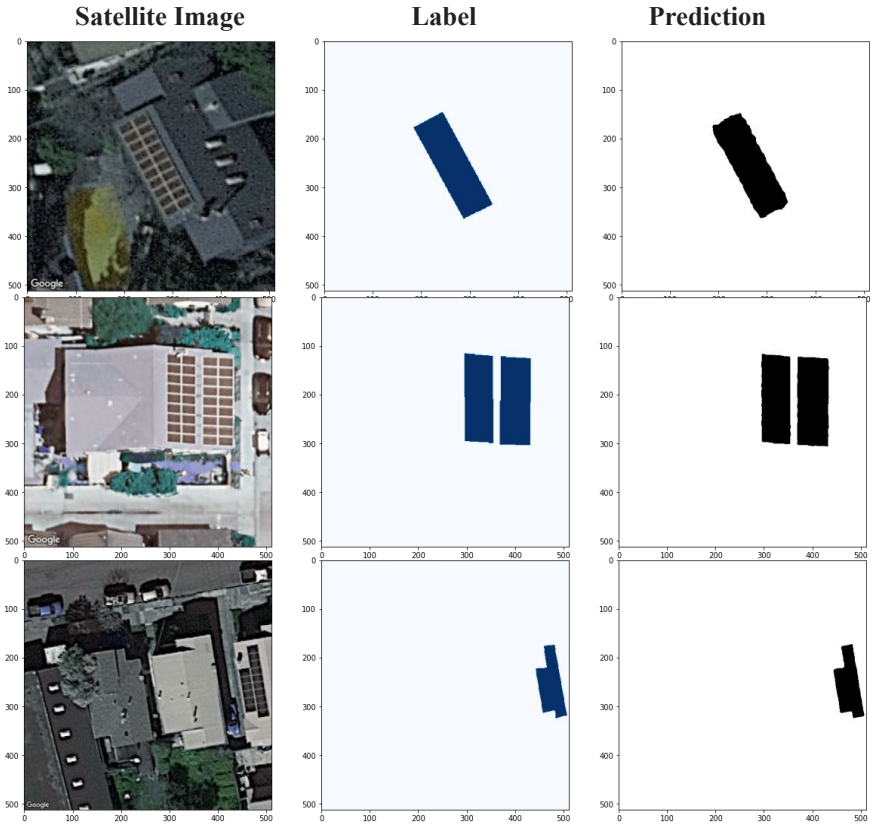
Segmentation Model Performance





Model	IoU Score	F1 Score
Baseline	0.8107	0.8841
HyperionSolarNet Segmentation Model	0.8591	0.9197

Segmentation Examples

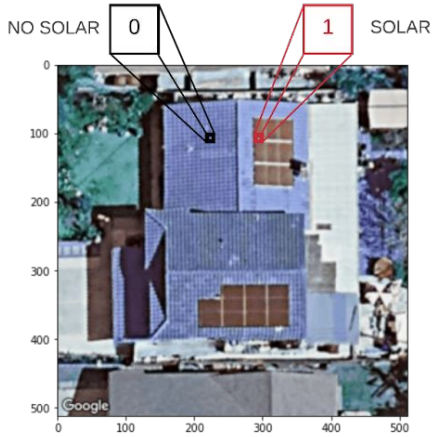


Number and Size Estimation

- Segmentation model produces 600x600 matrix of 1's and 0's
- Function inputs are latitude, zoom and matrix from segmentation model
- Meters per pixel calculation is derived from Mercator Projection

```
meters_per_pixel = 156543.03392 * math.cos(latitude * math.pi / 180) / math.pow(2, zoom)
```

- Output is the total area and number of solar panels in the image



600 x 600 MATRIX

[[0, 0, 0, 0, 0 . . . 0, 0, 0, 0, 0]
[0, 0, 0, 0, 0 . . . 1, 1, 1, 0, 0]
[0, 0, 0, 0, 0 . . . 1, 1, 1, 0, 0]
.
.
.
[0, 0, 0, 0, 1 . . . 1, 1, 0, 0, 0]
[0, 0, 0, 0, 1 . . . 1, 1, 0, 0, 0]
[0, 0, 0, 0, 0 . . . 0, 0, 0, 0, 0]

Procedure (latitude, zoom, matrix)

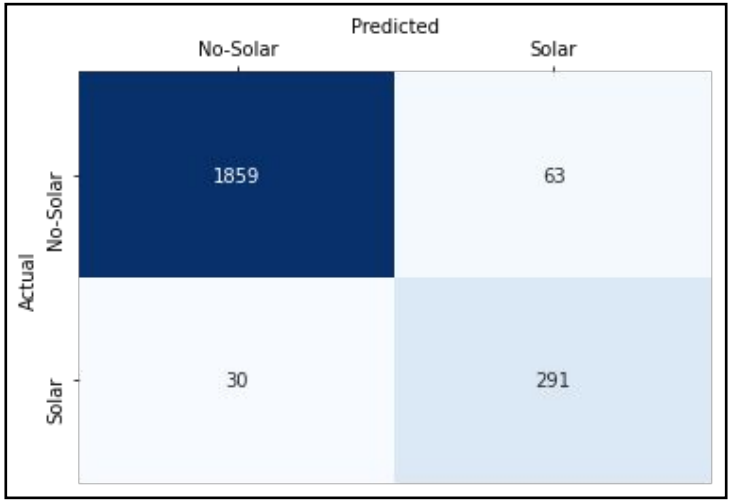
Inputs
latitude is the latitude of the center of image
zoom is the zoom level 21
matrix is the 600x600 matrix

Output
area is the total area of solar panel in image

Local
calculate meters per pixel based on
mercator projection and google maps api
convert meters per pixel to feet per pixel
calculate area per pixel in feet^2
count the total of 1's in the matrix
multiply the count and area per pixel

Return area

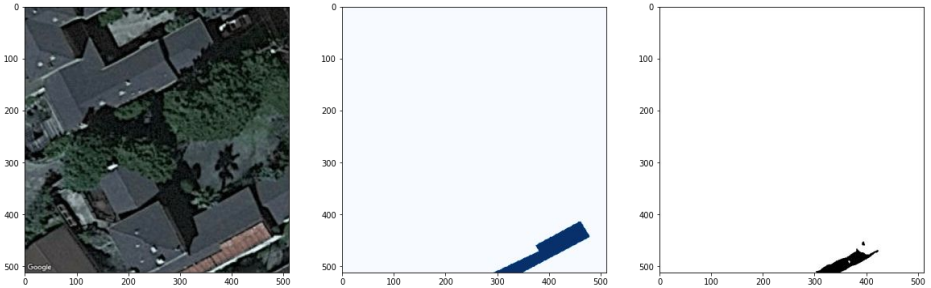
Berkeley Testset



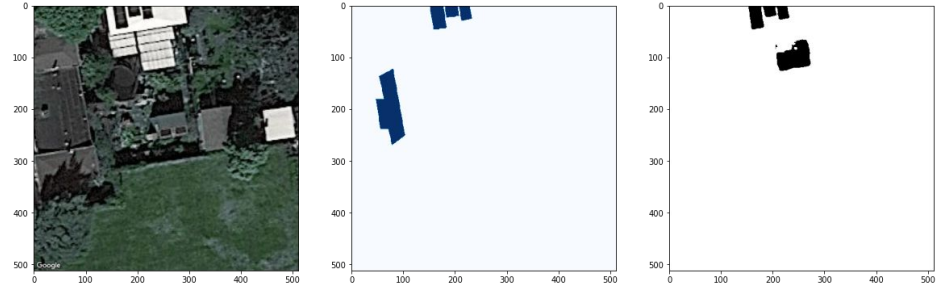
Class	Precision	Recall	F1	Support
no-solar	0.98	0.97	0.98	1922
solar	0.82	0.91	0.86	321

Berkeley Testset

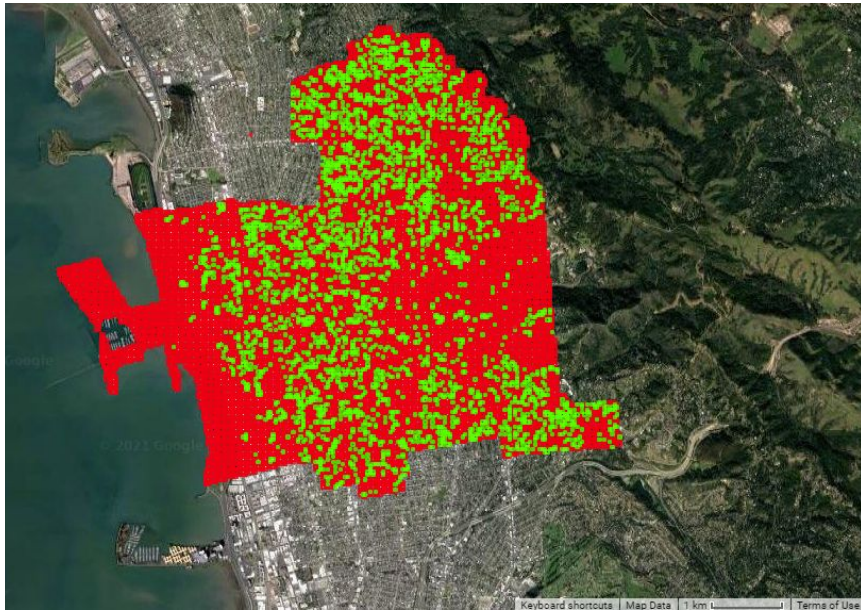
Segmentation	IoU	F1
Berkeley Testset Evaluation	0.8243	0.8922



Berkeley Testset	Area (sq. ft.)	Number of Solar Panels
Actual	101,765.48	5,787
Predicted	102,609.72	5,828

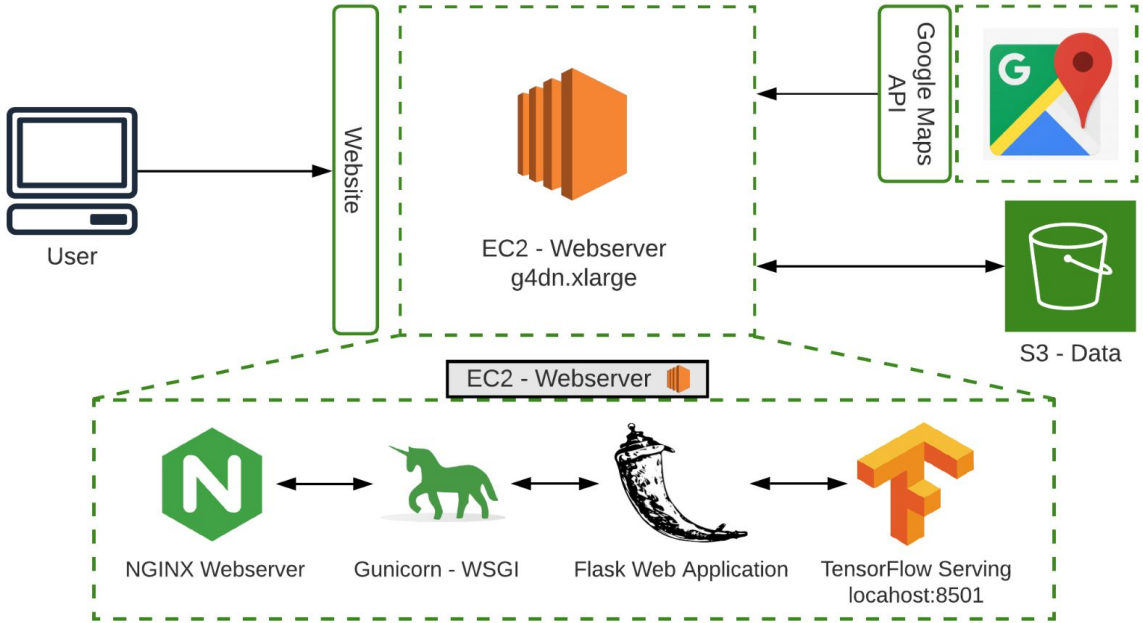


Berkeley Final Results

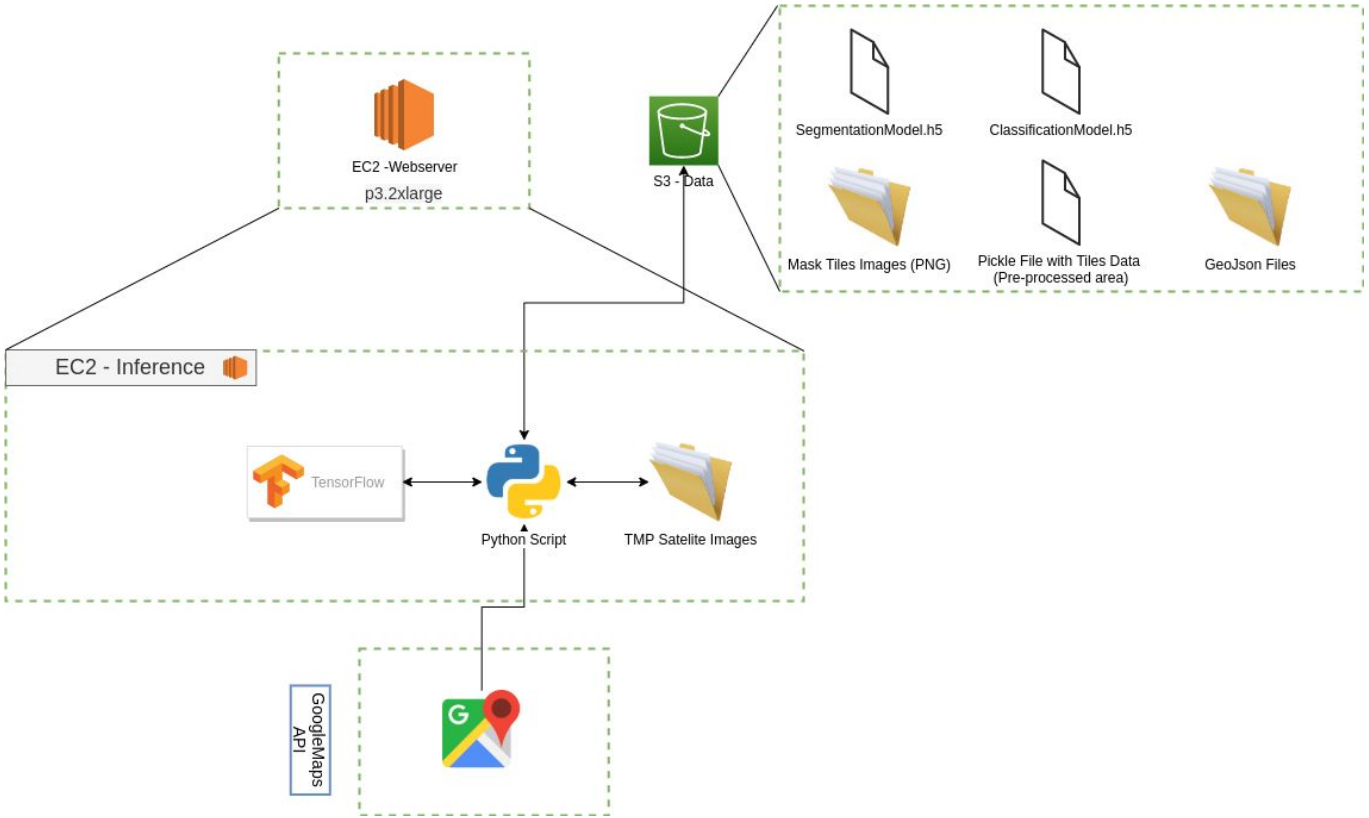


Berkeley City	Area (sq. ft.)	Number of Solar Panels
Estimated Berkeley Solar Panels	1,082,431.98	61,480

System Architecture



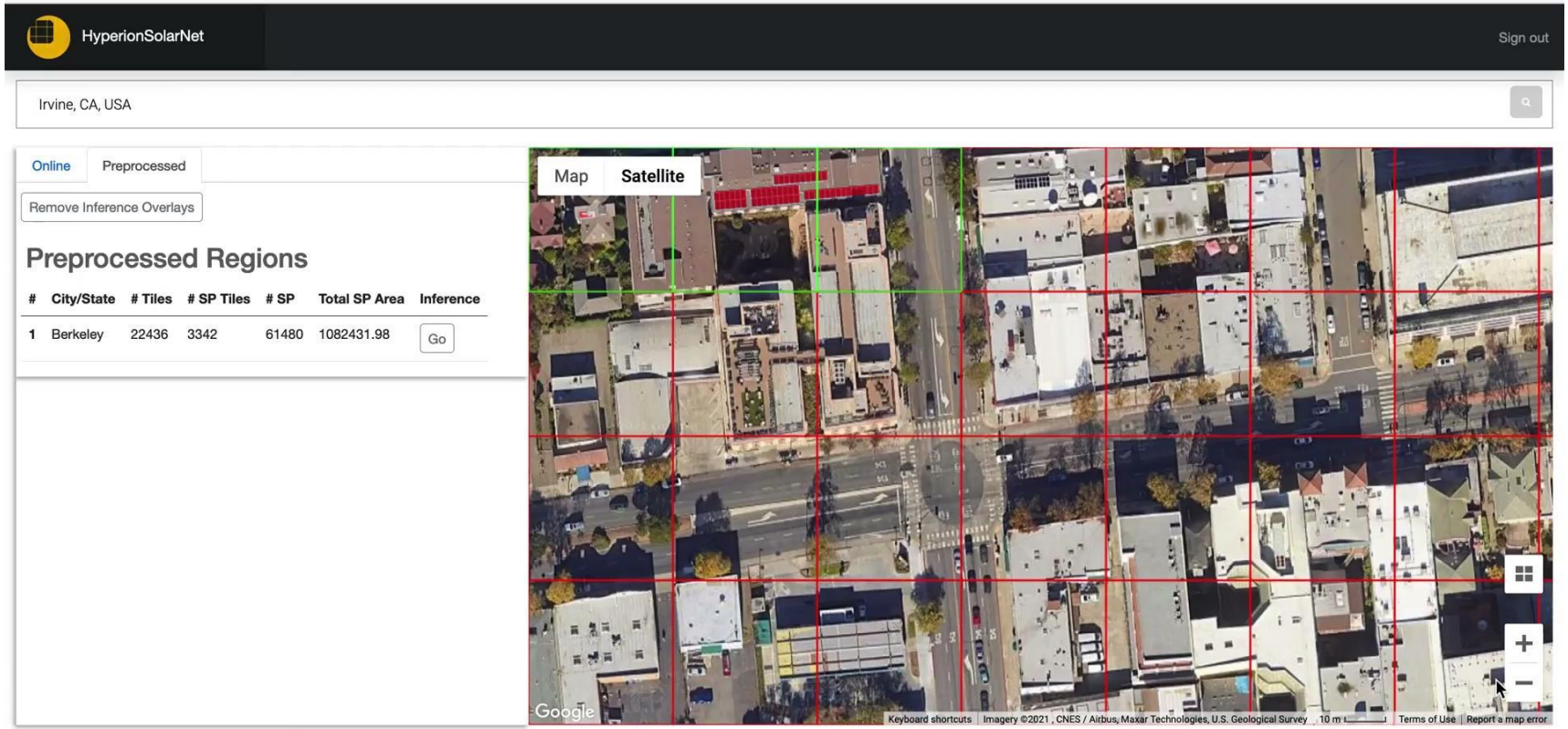
Offline Inference



API

API	Input	Output	Method	Example curl
api/classification	Form-data: bounds	1. JSON with tiles information 2. Prediction whether image tiles contain solar panels	POST	curl --location --request POST 'http://www.hyperionsolarnet.com//api/classification' \ --form 'bounds="21.32556150142789,-157.8038 7642931356,21.32593628430245,-157.8 030717666091"'
api/segmentation	Form-data: bounds	1. JSON with tiles information 2. Number of solar panels within bounds 3. Total area of solar panels within bounds	POST	curl --location --request POST 'http://www.hyperionsolarnet.com/api/segmentation' \ --form 'bounds="21.32556150142789,-157.8038 7642931356,21.32593628430245,-157.8 030717666091"'

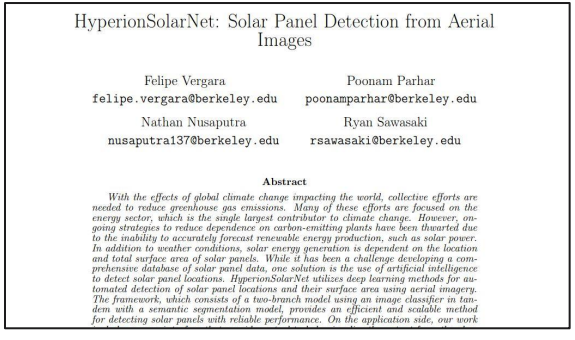
Web Application Demo



Conclusion

- Future Work includes:
  - Applying HyperionSolarNet to diverse locations around the world
  - Use results for further improvement of model
  - Integrate solar irradiance models to predict total solar energy output
- For additional information, please see:

RESEARCH PAPER



HyperionSolarNet: Solar Panel Detection from Aerial Images

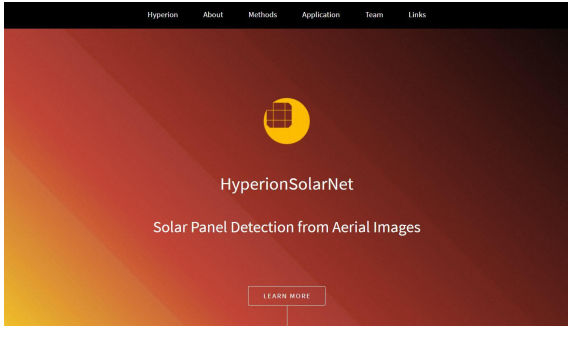
Felipe Vergara
felipe.vergara@berkeley.edu
Poonam Parhar
poonamparhar@berkeley.edu
Nathan Nusaputra
nusaputra137@berkeley.edu
Ryan Sawasaki
rsawasaki@berkeley.edu

Abstract

With the effects of global climate change impacting the world, collective efforts are needed to reduce greenhouse gas emissions. Many of these efforts are focused on the energy sector, which is the single largest contributor to climate change. However, ongoing strategies to reduce dependence on carbon-emitting plants have been thwarted due to the inability to accurately forecast renewable energy production, such as solar power. In addition to weather conditions, solar energy generation is dependent on the location and total surface area of solar panels. While it has been a challenge developing a comprehensive database of solar panel data, one solution is the use of artificial intelligence to detect solar panel locations. HyperionSolarNet utilizes deep learning methods for automated detection of solar panel locations and their surface area using aerial imagery. The framework, which consists of a two-branch model using an image classifier in tandem with a semantic segmentation model, provides an efficient and scalable method for detecting solar panels with reliable performance. On the application side, our work

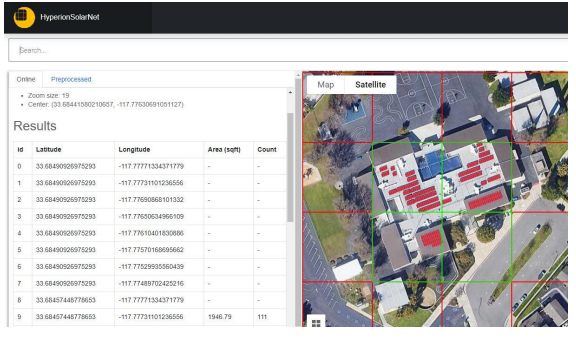
WEBSITE

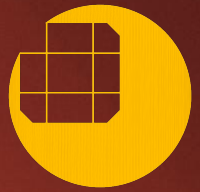
https://groups.ischool.berkeley.edu/HyperionSolarNet



WEB APPLICATION

http://hyperionsolarnet.com





Thank you! Any Questions?

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