

COUNTING PHOTOVOLTAIC AND SOLAR PANELS FROM AERIAL IMAGERY

Complements of Machine Learning 24/25

Lacuna Solar Survey Challenge

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PROJECT OVERVIEW

THE PROBLEM

From aerial imagery:

- Count thermal solar panels
- Count photovoltaic panels



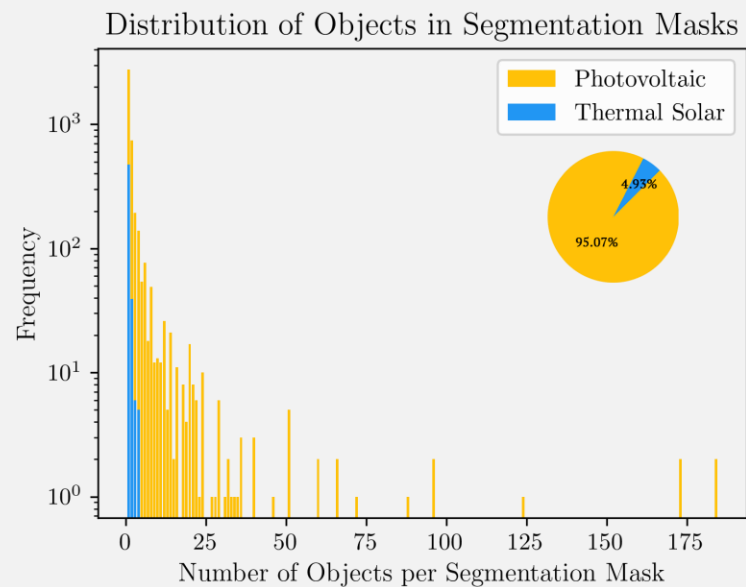
STATE OF THE ART

DATA ANALYSIS

4419 images (75/25 split)

For each training image:

- Segmentation masks for panel groups
- Panel count per group
- Metadata



RAW DATA



Inaccuracies in Polygon Annotations

Misaligned Vertices (6/3)



Excessive Object Inclusion (141/8)



Segmentation Mask



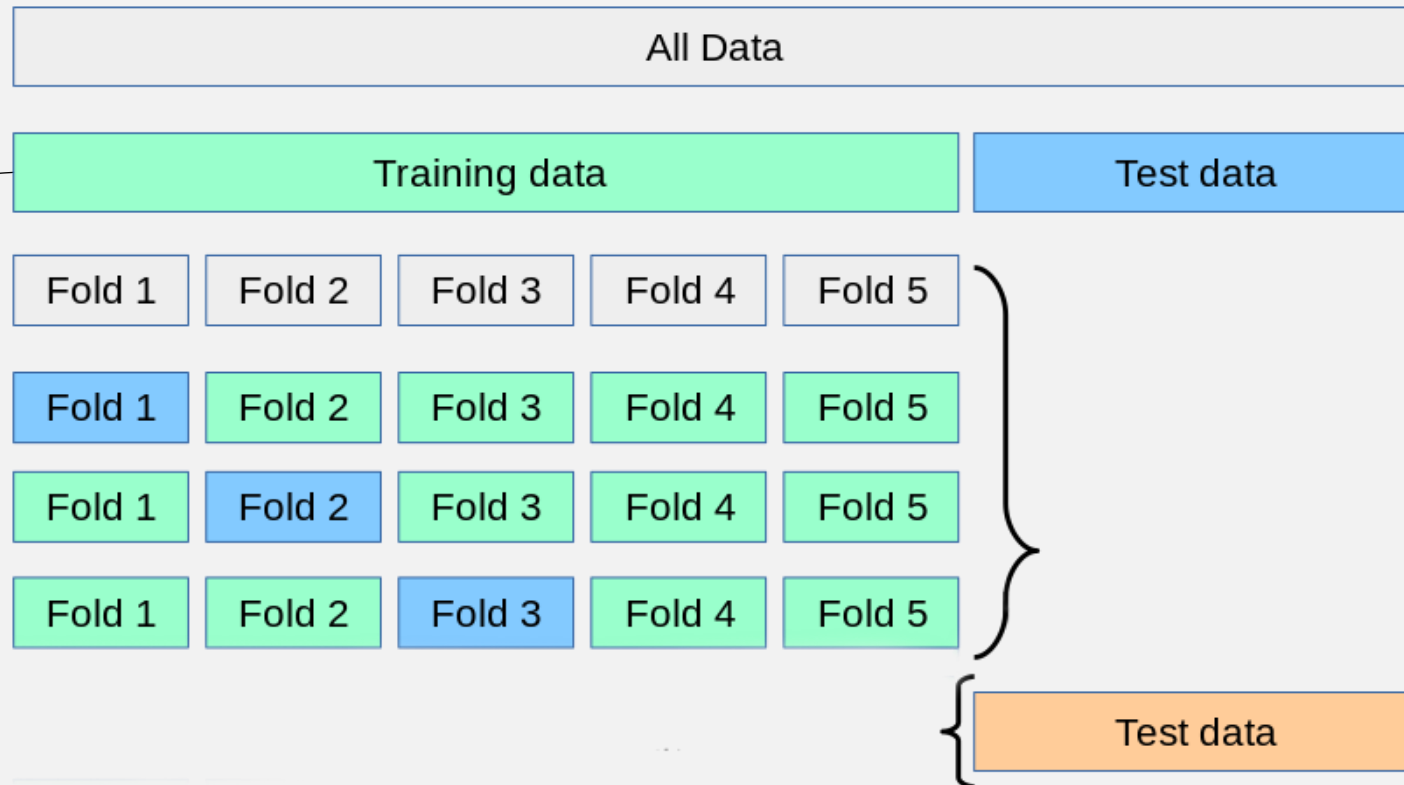
PREPROCESSING

- Grouped all polygons belonging to the same image into one record
- Fixed or remove inaccurate polygons
- Resized images to 512 x 512
- Readjusted polygons to fit resized images

METHODOLOGY

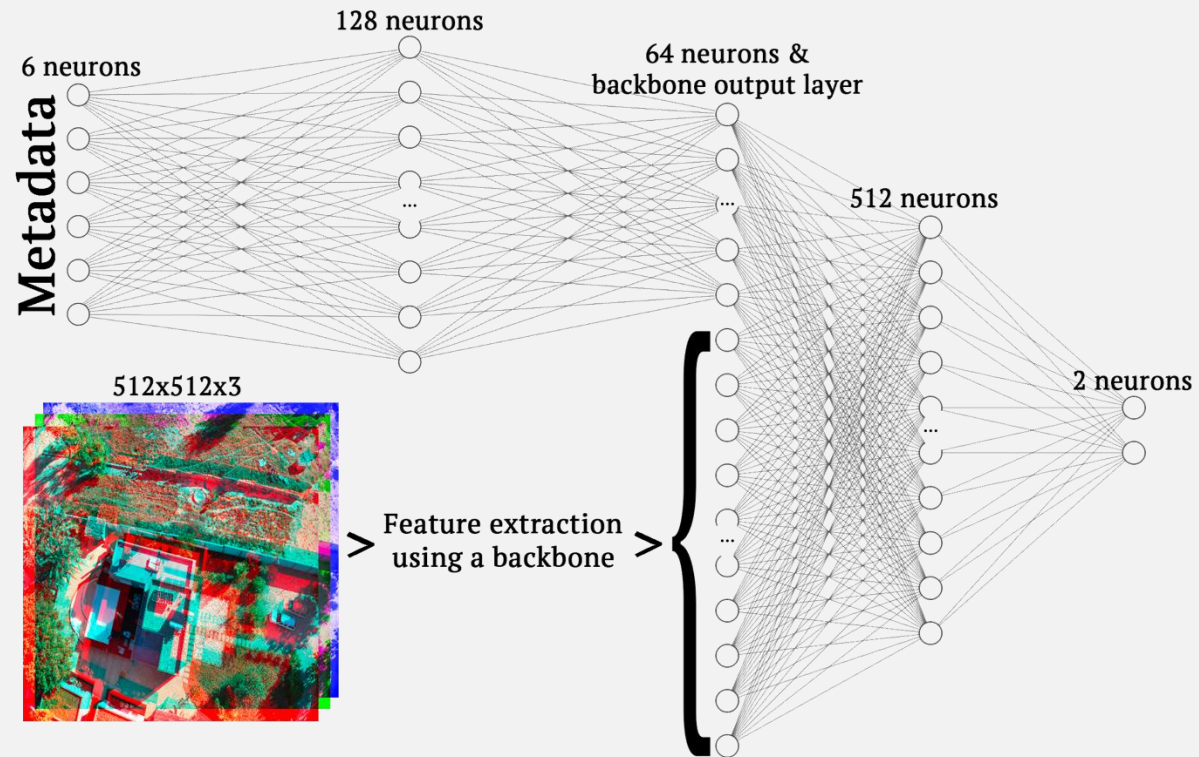
with augmentation:

- Flip and Rotate
- Gaussian Blur
- CLAHE
- ...



DEEP LEARNING MODELS

IMAGE-BASED REGRESSION



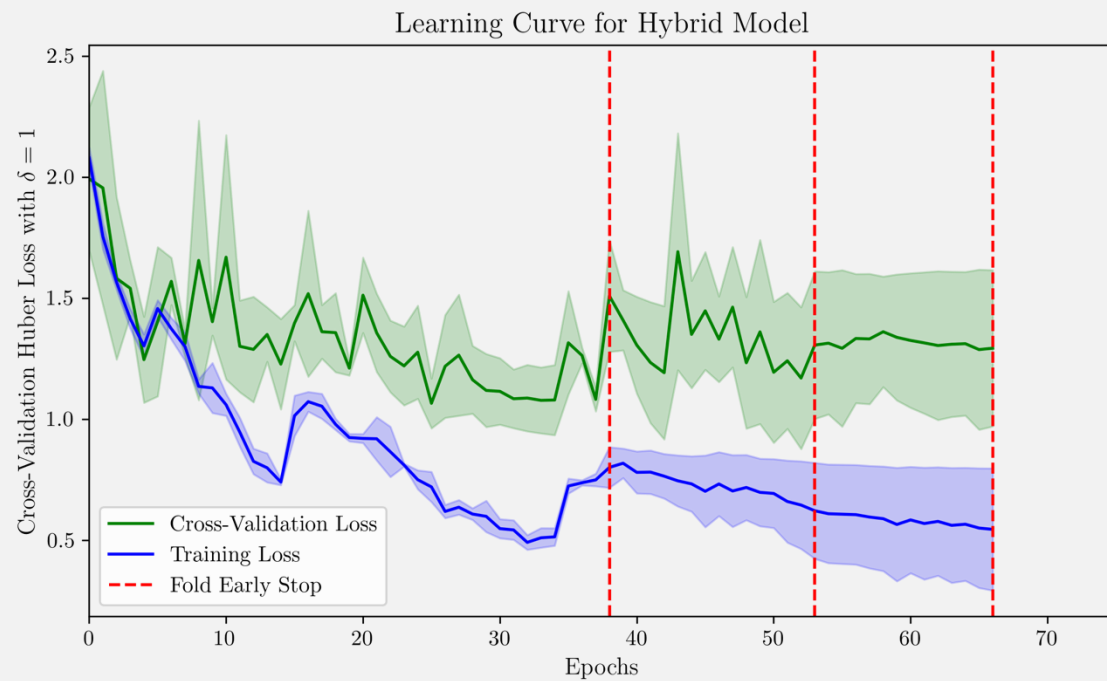
Tested backbones:

DenseNet121, **EfficientNetv2B3** and ResNet101

Hyperparameter search space

Hyperparameter	Possible Values
Batch size	{16, 32, 64}
Optimizer	AdamW
Learning rate	[10^{-5} , 10^{-3}]
Weight decay	[10^{-5} , 10^{-3}]
Dropout	{0.2, 0.3, 0.4}
Scheduler	CosineAnnealingWarmRestarts
T_0	{3, 5, 7, 10}
T_mult	{1, 2, 3, 5}
Loss	HuberLoss
δ	1

IMAGE-BASED REGRESSION - RESULTS



Error metrics		
Dataset	MAE	Support
Train Set	0.5127	3312
Test Set	0.8434	1107

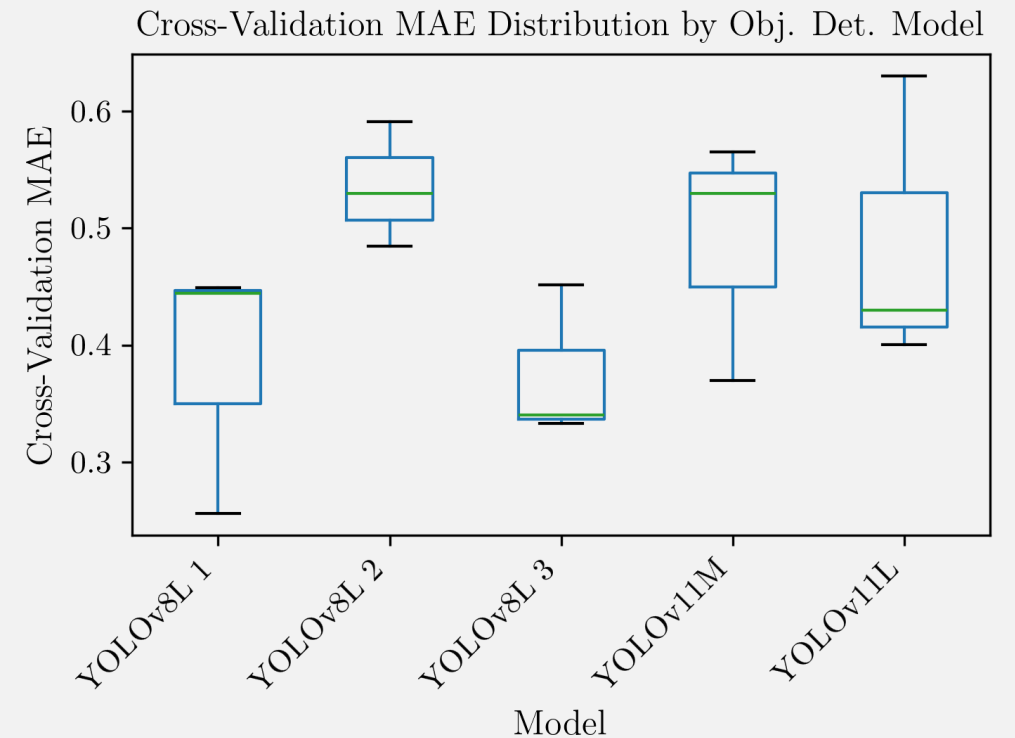
OBJECT DETECTION



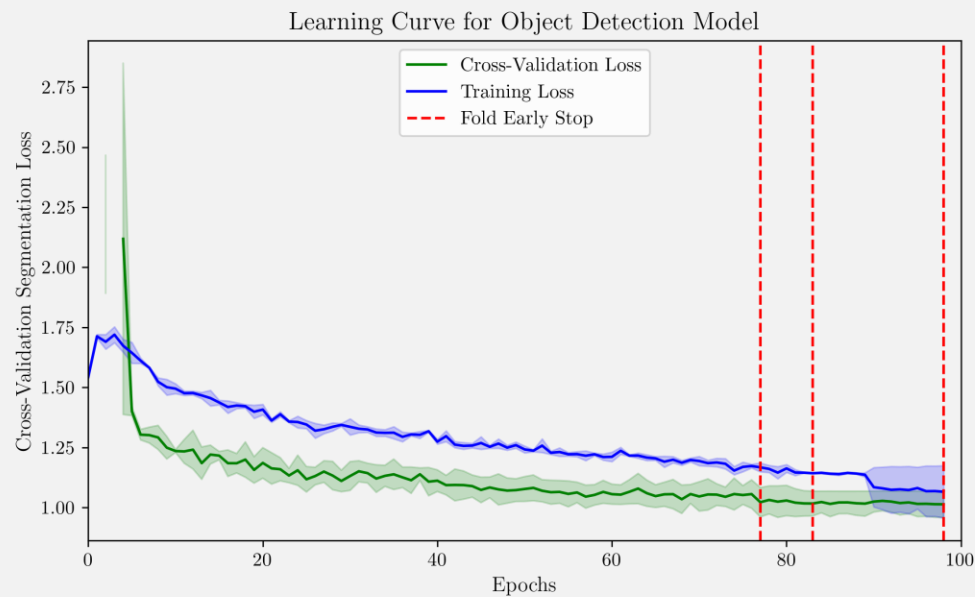
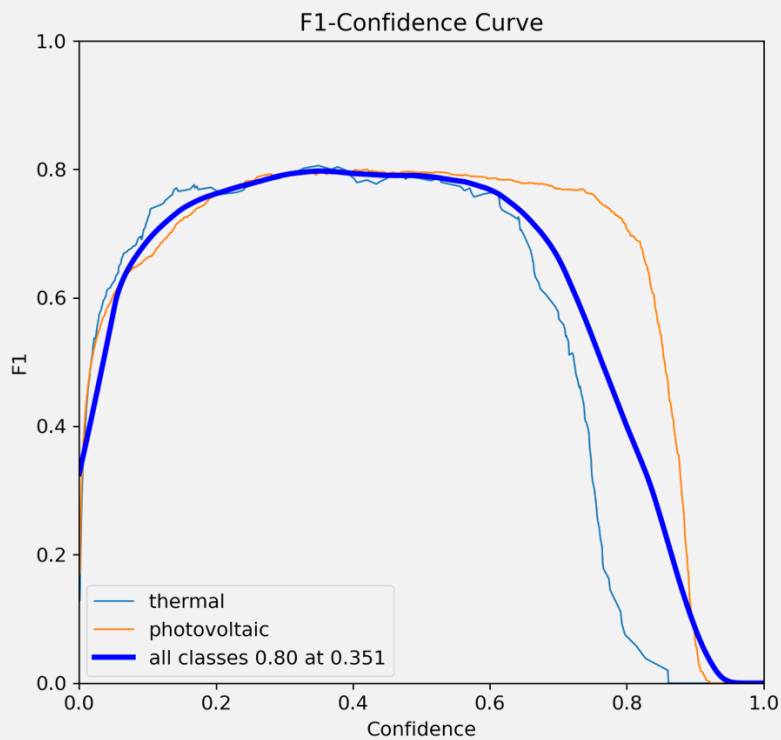
Due to poor performance, polygons spanning multiple panels were manually redrawn to isolate single panels. Since this wasn't done for all images, around 40% of the training set was discarded.

Hyperparameter search space

Hyperparameter	Possible Values
Batch size	{16, 32 }
Model	{ yolov8l , yolov11m, yolov11l}
Image size	512
Augmentation	True
Early stopping patience	[15, 25]
cls	[0.5, 1.5]
lr0	[10^{-5} , 10^{-3}]
lrf	[0.1, 1]
mixup	[0, 0.75]
copy_paste	[0, 0.75]
scale	[0.5, 1]



OBJECT DETECTION - RESULTS



Error metrics

Dataset	MAE	Support
Train Set	1.4330	3312
Test Set	1.2645	1107

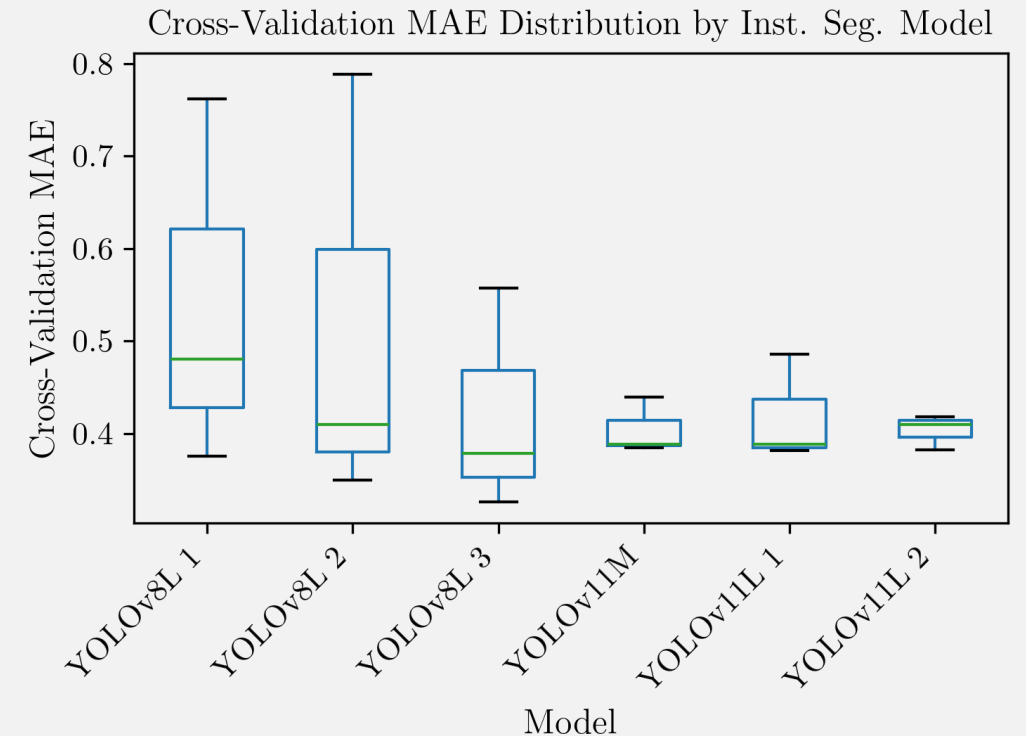
INSTANCE SEGMENTATION



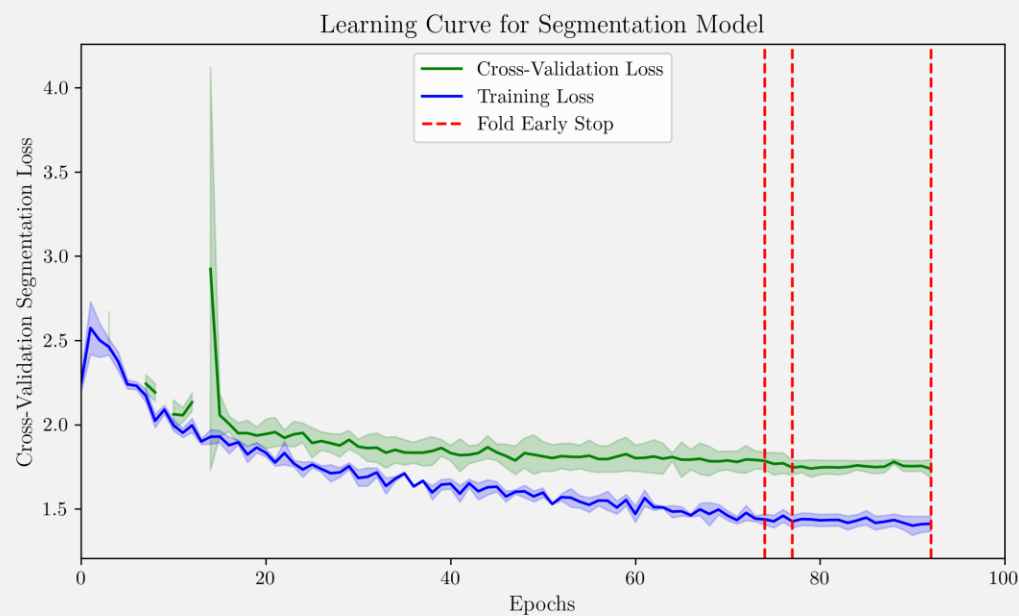
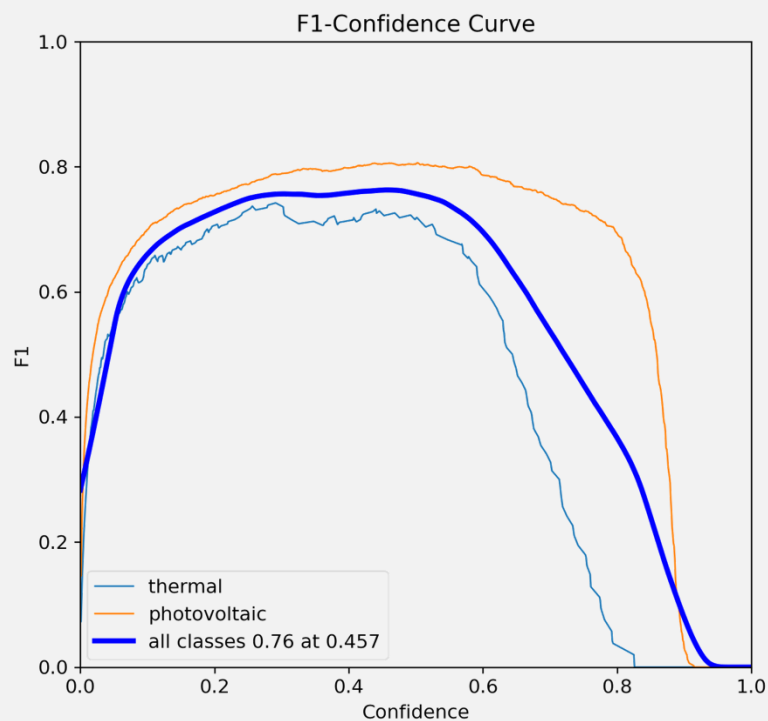
Due to poor performance, the revised polygons were reused, also without the 40% of training images that had been discarded.

Hyperparameter search space

Hyperparameter	Possible Values
Batch size	{8, 32, 16}
Model	{yolov8l-seg, yolov11m-seg, yolo11l-seg }
Image size	512
Augmentation	True
Early stopping patience	[10, 25]
cls	[0.5, 2.5]
lr0	[10^{-4} , 10^{-3}]
lrf	{0.01, 0.1, 1}
mixup	[0, 0.5]
copy_paste	[0, 0.8]
scale	[0.5, 1]



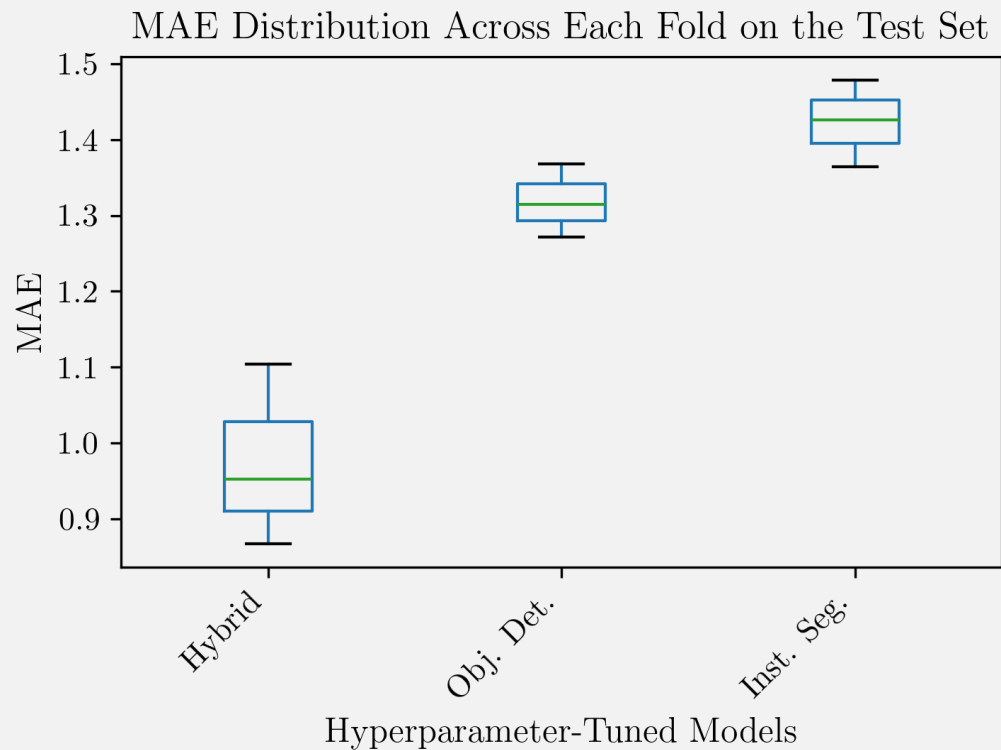
INSTANCE SEGMENTATION - RESULTS



Error metrics		
Dataset	MAE	Support
Train Set	1.5645	3312
Test Set	1.3415	1107

RESULTS ANALYSIS

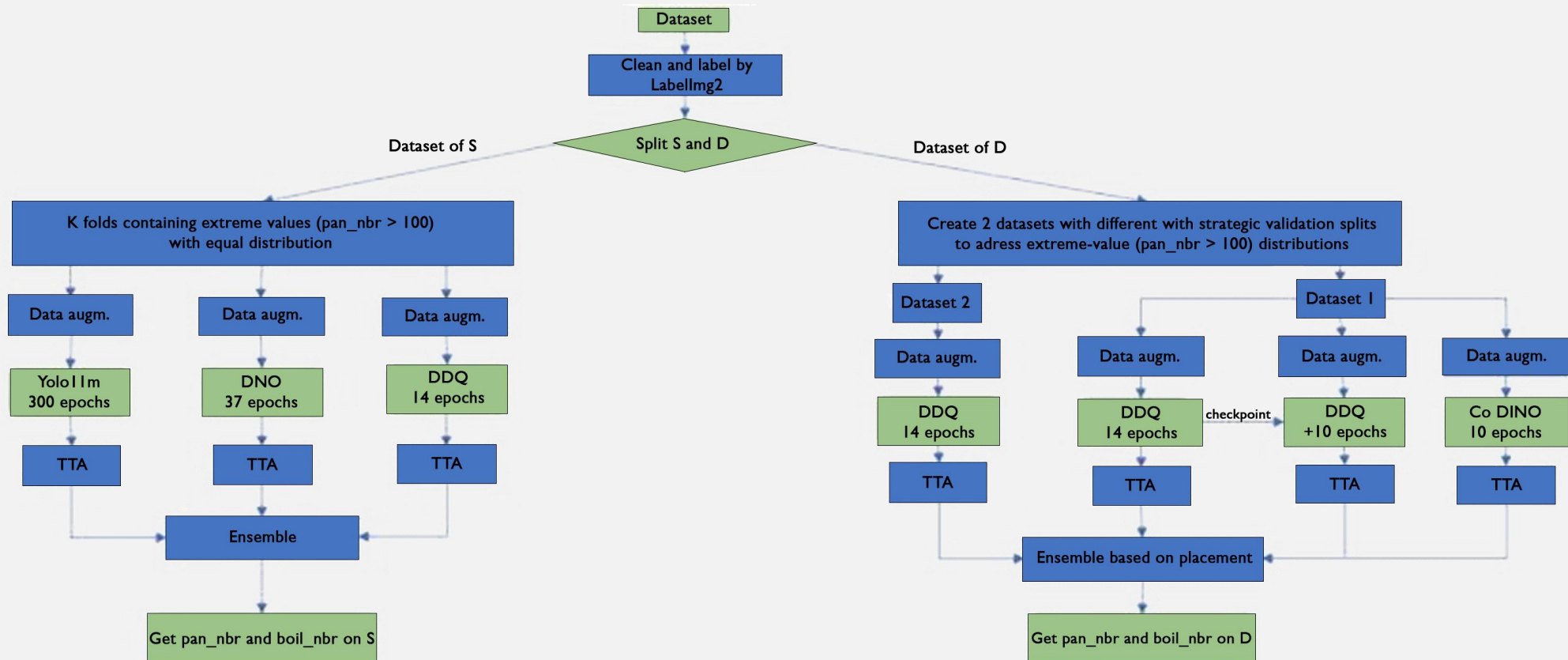
RESULTS & BENCHMARK



Error metrics for the fine-tuned models along with the best performers in the competition

Model	MAE (Test Set)
Hybrid	0.8434
Obj. Det.	1.2645
Inst. Seg.	1.3415
Team Lacuna (1st)	0.3299
K_Junior (2nd)	0.5698

TEAM LACUNA APPROACH



CONCLUSIONS

- The goal of this project was to develop a model capable of detecting and counting photovoltaic and solar thermal panels in aerial and satellite imagery.
- Although the dataset initially presented several issues, such as mislabelled images, inaccurate masks, and class imbalance, it was refined through manual corrections and preprocessing.
- Ultimately, the hybrid model demonstrated the best performance, among the evaluated models.