COUNTING PHOTOVOLTAIC AND SOLAR PANELS FROM AERIAL IMAGERY

Complements of Machine Learning 24/25

Lacuna Solar Survey Challenge

- Hugo Veríssimo 124348
- João Cardoso 50750

CONTENTS

universidade de aveiro

PROJECT OVERVIEW

THE PROBLEM

Context:

Develop DL models as part of a challenge in the Zindi platform.

From aerial imagery (drone and satellite):

- Count thermal solar panels
- Count photovoltaic panels

Why?

- Useful for estimating power demand in the grid and develop proper infrastructure.

STATE OF THE ART

- Different approaches depending on the purpose:
  - Fast and swift models for quick image recognition, specialized in drone or satellite imagery
  - Multistage models for large data analysis (e.g., countrywide)
  - Highly accurate models for panel maintenance
- Three main techniques for image detection:
  - Image-based regression
  - Object Detection
  - Instance segmentation

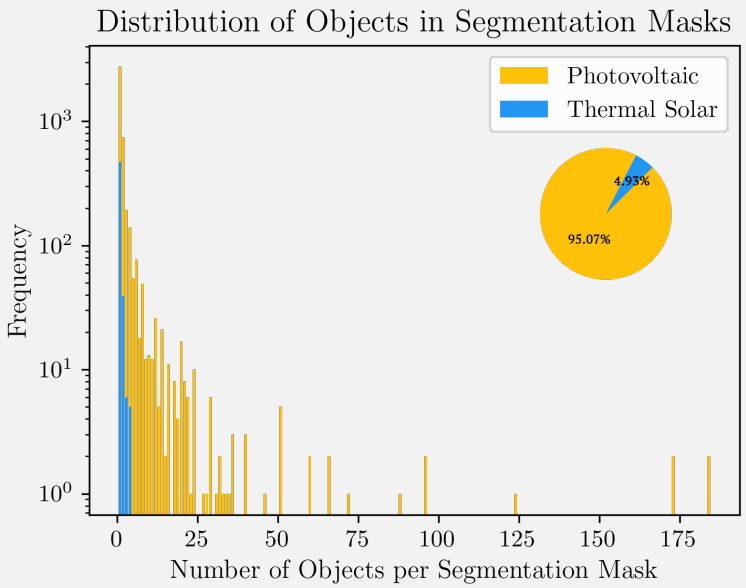
DATA ANALYSIS

RAW DATA

4419 images (75/25 split)

For each training image:

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

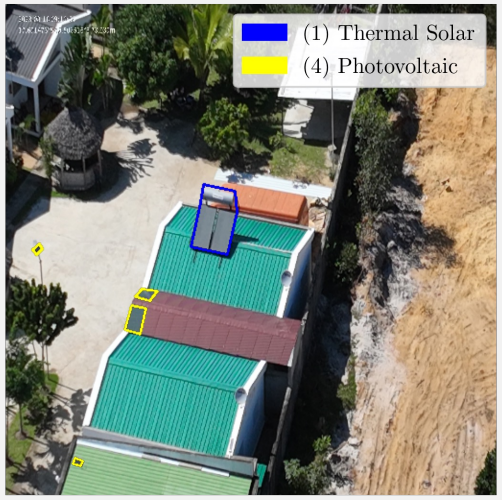


Inaccuracies in Polygon Annotations

Misaligned Vertices (6/3)

Excessive Object Inclusion (141/8)

Segmentation Mask



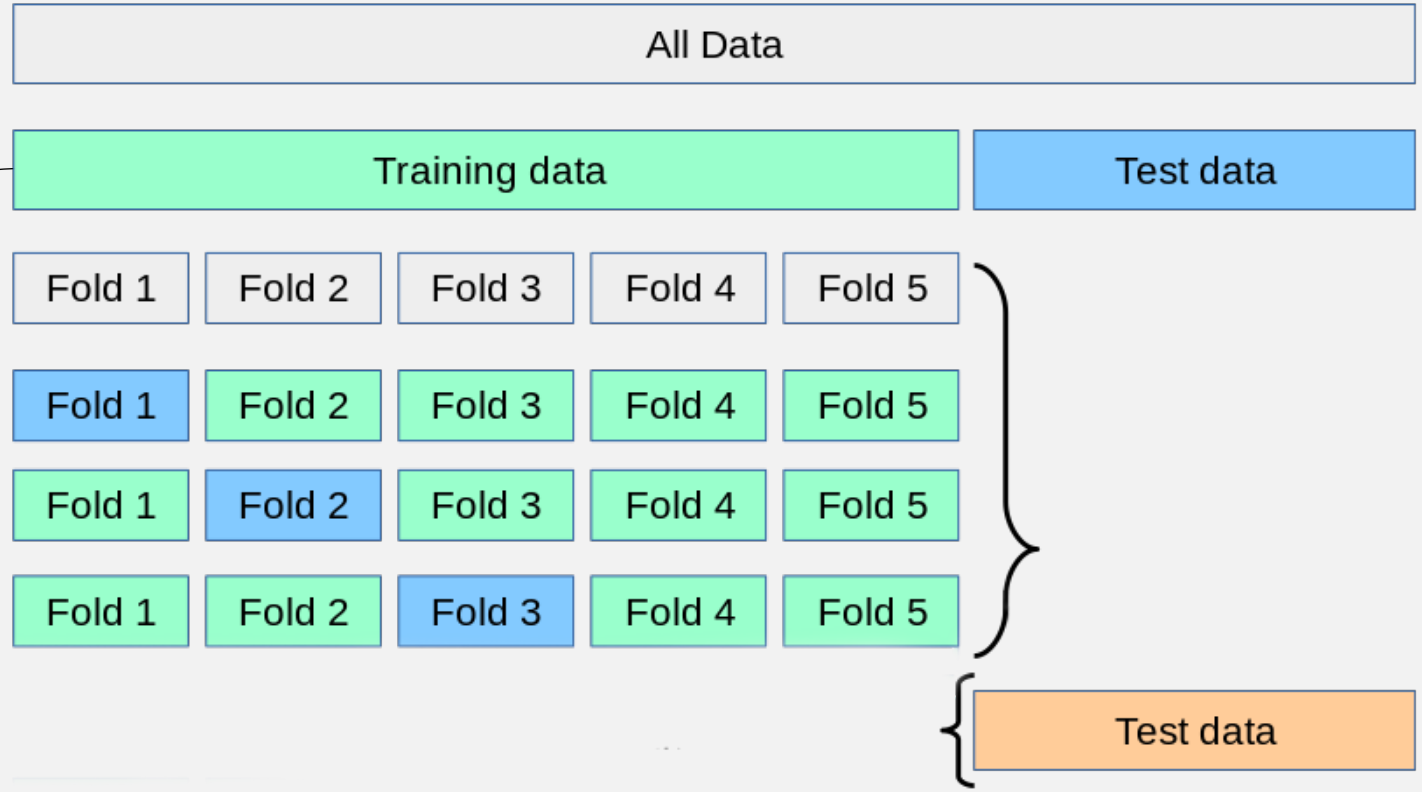
PREPROCESSING

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

METHODOLOGY

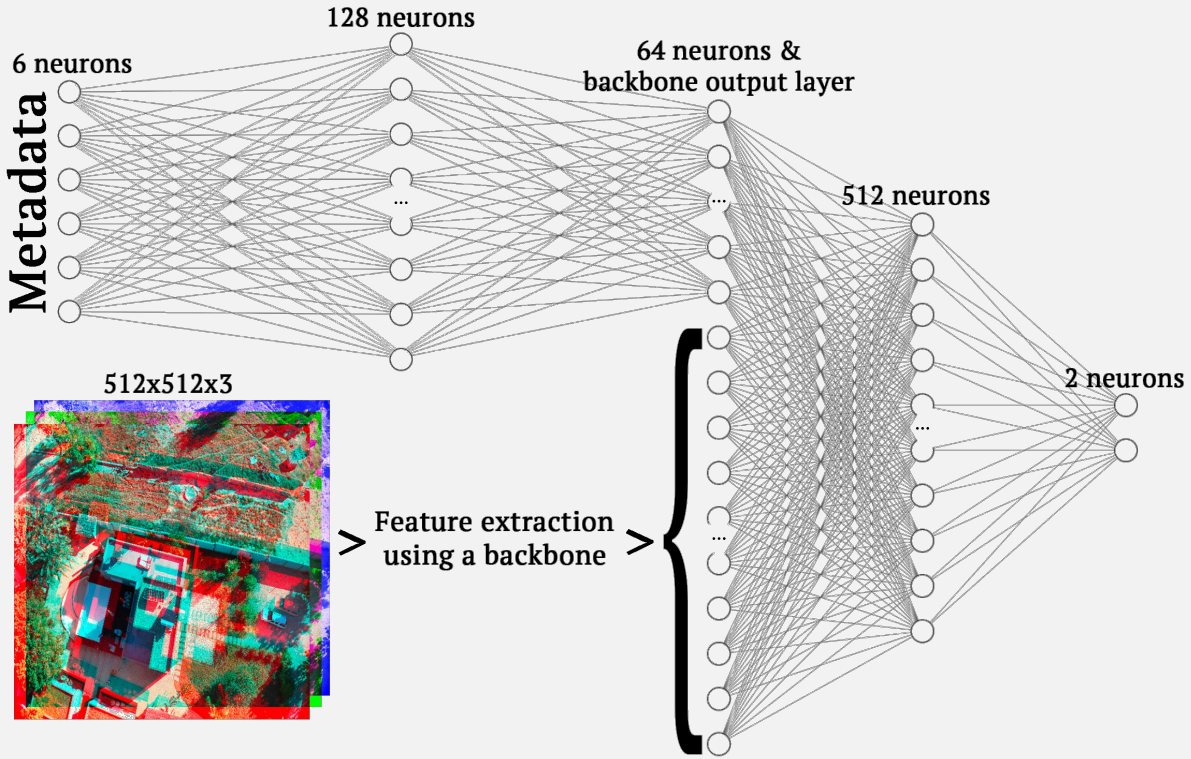
with augmentation:

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



DEEP LEARNING MODELS

IMAGE-BASED REGRESSION



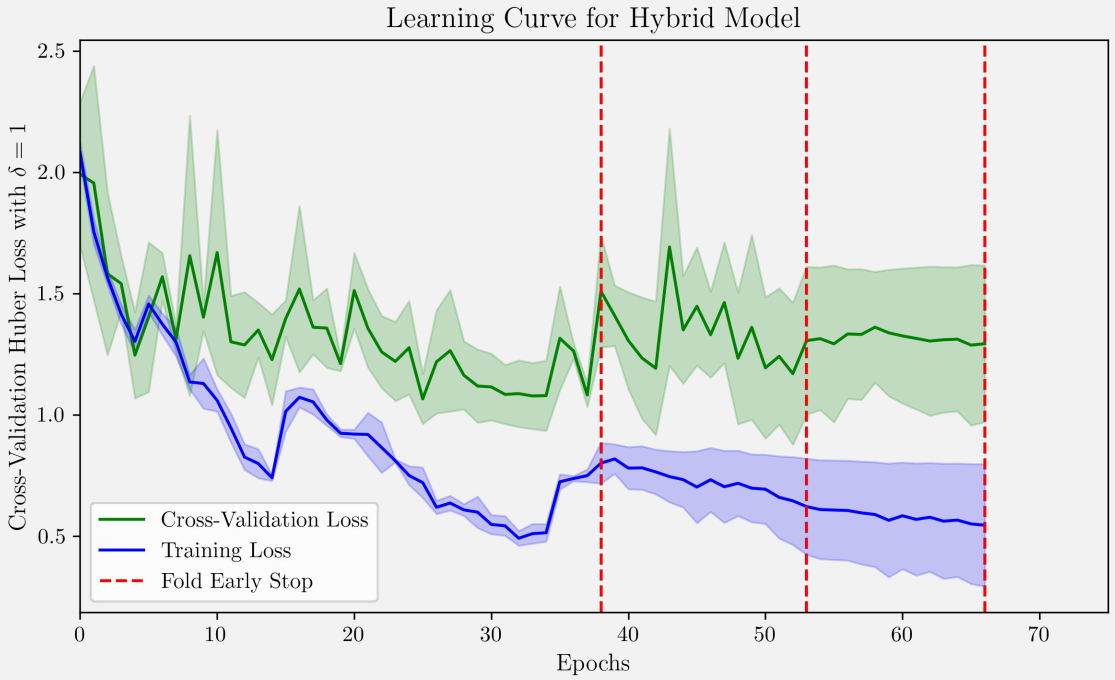
Tested backbones:

DenseNet121, **EfficientNetv2B3** and ResNet101

Hyperparameter search space

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

IMAGE-BASED REGRESSION - RESULTS



Error metrics

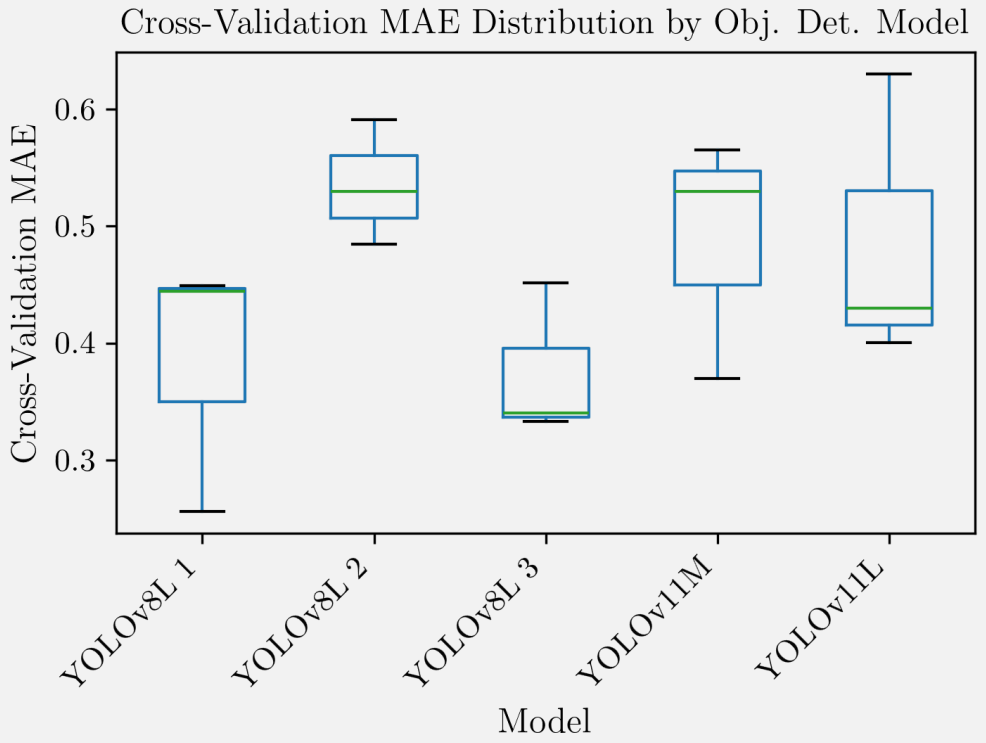
Dataset	MAE	Support
Train Set	0.5127	3312
Test Set	0.8434	1107

OBJECT DETECTION

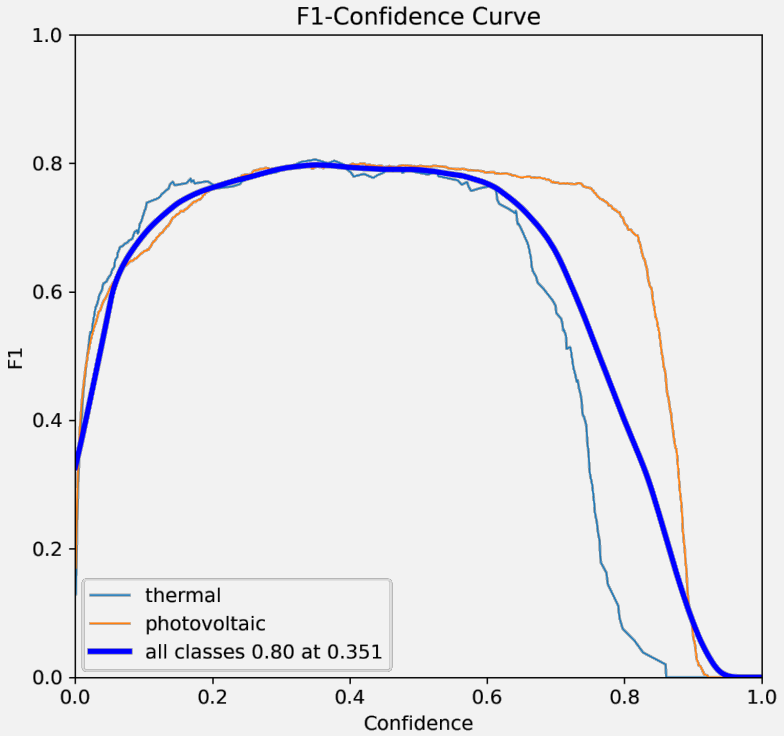
Due to poor performance, polygons spanning multiple panels were manually redrawn to isolate single panels. Since this wasn't done for all images, around 40% of the training set was discarded.

Hyperparameter search space

Hyperparameter	Possible Values
Batch size	$\{16, \mathbf{32}\}$
Model	{**yolov8l**, yolo11m, yolo11l}
Image size	**512**
Augmentation	**True**
Early stopping patience	$[15, \mathbf{25}]$
cls	$[0.5, \mathbf{1.5}]$
lr0	$[\mathbf{10^{-5}}, 10^{-3}]$
lrf	$[0.1, \mathbf{1}]$
mixup	$[0, \mathbf{0.75}]$
copy_paste	$[0, \mathbf{0.75}]$
scale	$[0.5, \mathbf{1}]$



OBJECT DETECTION - RESULTS



Error metrics

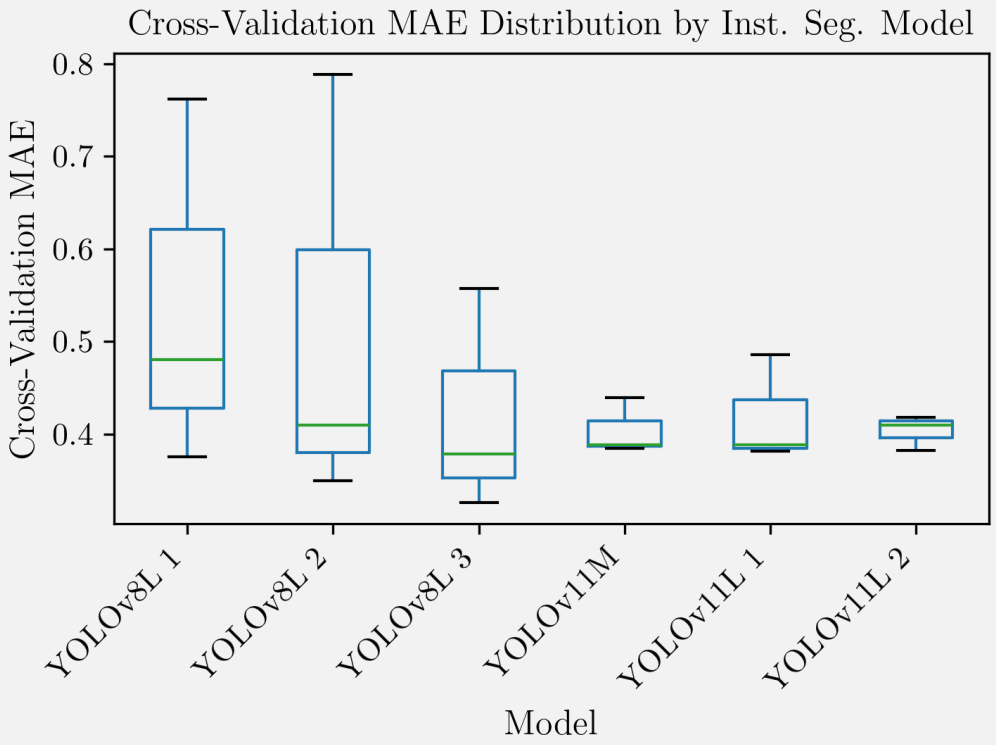
Dataset	MAE	Support
Train Set	1.4330	3312
Test Set	1.2645	1107

INSTANCE SEGMENTATION

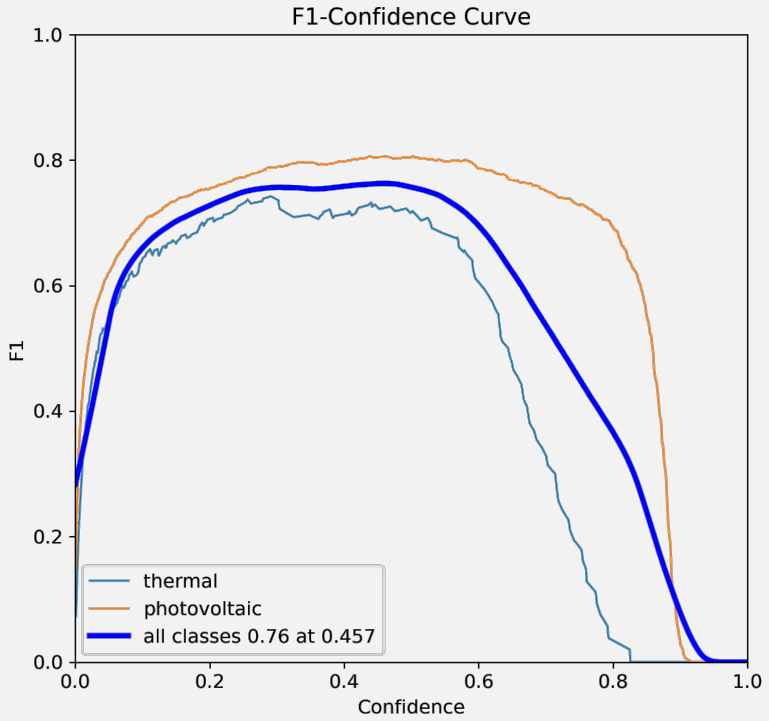
Due to poor performance, the revised polygons were reused, also without the 40% of training images that had been discarded.

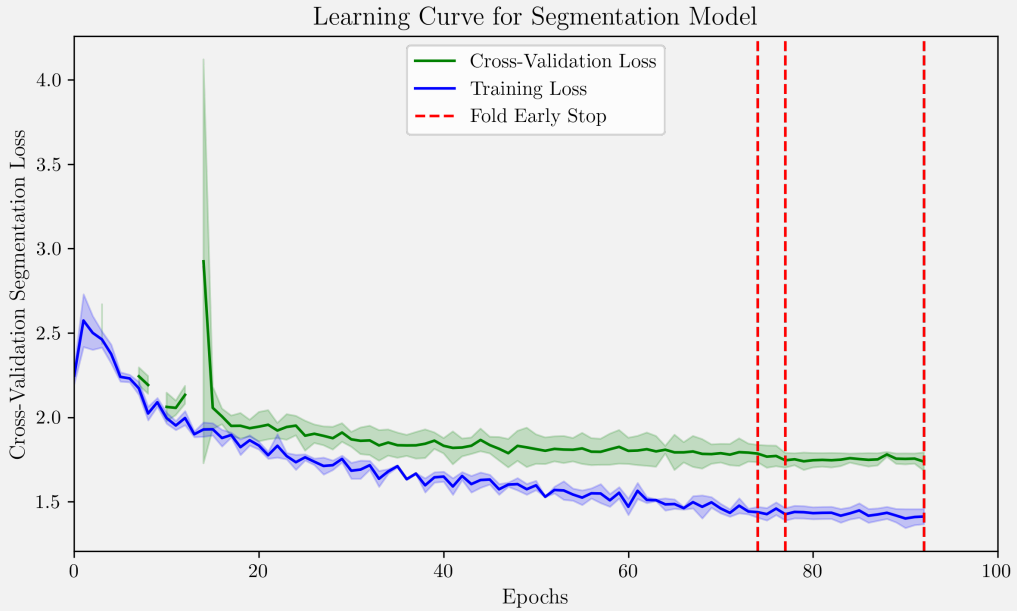
Hyperparameter search space

Hyperparameter	Possible Values
Batch size	$\{\mathbf{8}, 32, 16\}$
Model	{yolov8l-seg, yolo11m-seg, **yolo11l-seg**}
Image size	**512**
Augmentation	**True**
Early stopping patience	$[10, \mathbf{25}]$
cls	$[\mathbf{0.5}, 2.5]$
lr0	$[10^{-4}, \mathbf{10^{-3}}]$
lrf	$\{0.01, \mathbf{0.1}, 1\}$
mixup	$[\mathbf{0}, 0.5]$
copy_paste	$[\mathbf{0}, 0.8]$
scale	$[\mathbf{0.5}, 1]$



INSTANCE SEGMENTATION - RESULTS



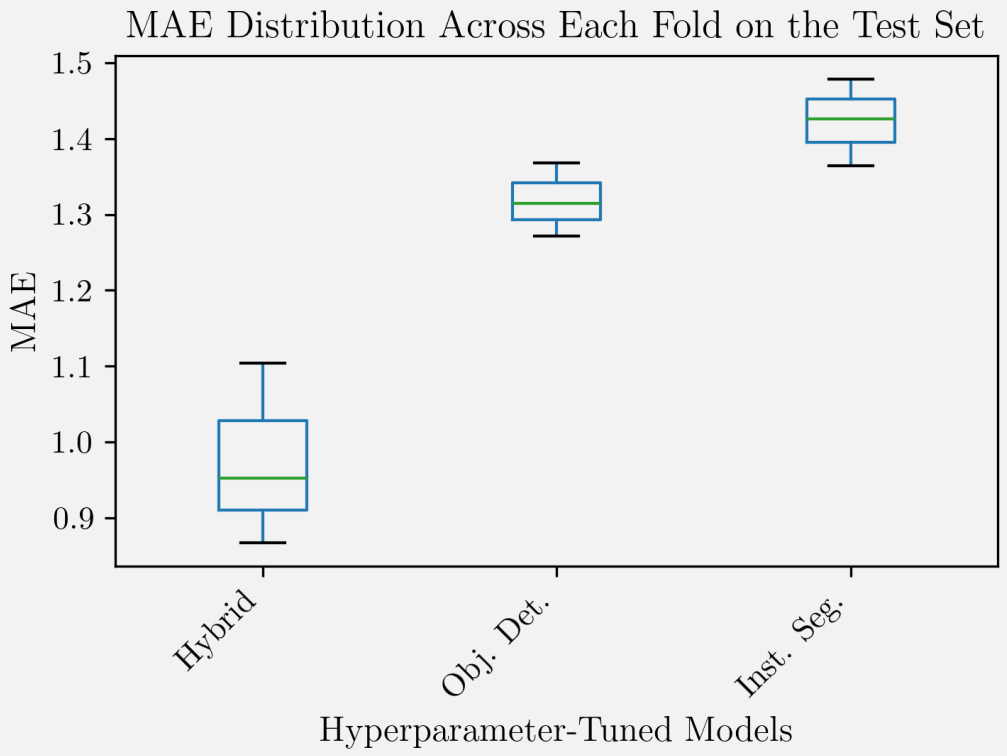


Error metrics

Dataset	MAE	Support
Train Set	1.5645	3312
Test Set	1.3415	1107

RESULTS ANALYSIS

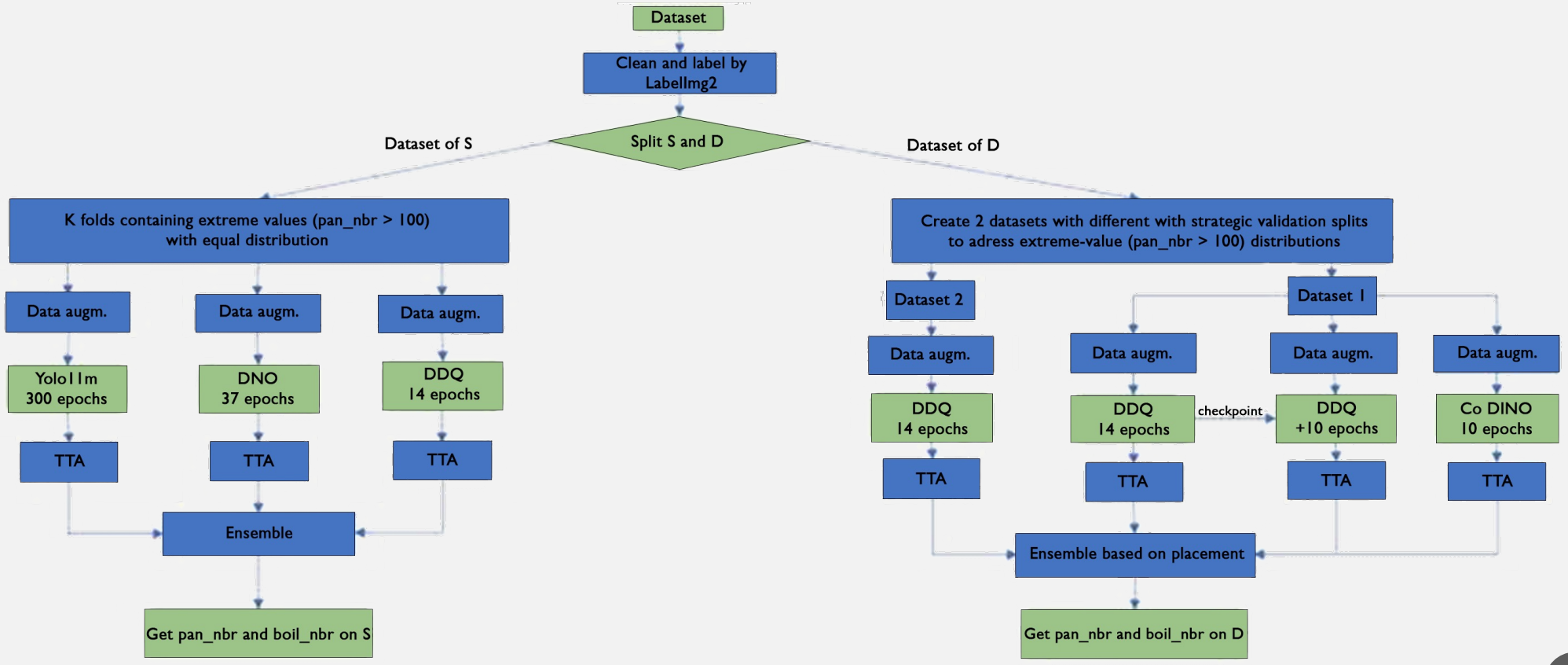
RESULTS & BENCHMARK



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 imagery from drone and satellite sources.
- 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.