Solar PV Detection

Model Details

Field	Value
Model Name	YOLOv8n - Rooftop Solar Panel Detection
Version	1.0
Framework	PyTorch + Ultralytics
Platform	Google Colab (GPU: NVIDIA T4)
Model Size	~6 MB (YOLOv8 Nano)

1. Data Used

Dataset	Source	Images
Multi-resolution aerial	Roboflow	2,388
Satellite images of PV	Roboflow	1,062
Aerial images of PV	Roboflow	555
Total (After Merge)	-	4,005

Characteristics & Workflow

- Split: 70% train / 20% val / 10% test. Size: 640x640 px.
- Geography: Multi-region (Global). Types: Residential, commercial, ground.
- Workflow: Download -> Zip Upload -> Colab Extraction -> Data.yaml gen.

2. Assumptions

Input & Operational

- Coords: WGS84. Imagery: Sat/Aerial (Esri/Google/Bing/OSM).
- Conditions: Clear/Partly cloudy. Panel Area: >2m2.

Buffer Zone Logic

```
Search Radius = sqrt(building_sqft * 0.0929 / PI) + 50 meters
```

3. Logic

```
Input(lat,lon) -> Download -> YOLOv8n -> Post-Process -> JSON/Overlay
```

Module	Function
utils.py	Coord conversion, multi-provider download
inference.py	Model loading, detection, batch processing
quantify.py	Area calculation, aggregation
qc.py / visualize.py	Quality flags, overlays

Fallback: 1. Esri World -> 2. Google Static -> 3. Bing Aerial -> 4. OSM

4. Limitations & Bias

Limitation	Impact	Mitigation
Small Panels (<2m)	Missed detection	Higher resolution img
Partial Occlusion	Reduced accuracy	QC flags
Image Quality	Blurry/Cloudy fail	Multi-provider fallback
Single Class	No type distinction	Future multi-class

Geographic & Seasonal

- Bias: US/European training data; better in urban/suburban.
- Seasonal: Snow coverage/Summer foliage cause false negatives.

5. Failure Modes

Failure	Cause	QC Flag
False Negative	Small/Occluded	low_coverage_area
False Positive	Pools/Tarps	high_fp_risk
No Image	API/Coords	image_download_failed

Confidence: >0.8 (High), 0.5-0.8 (Moderate), <0.25 (Filtered).

6. Retraining Guidance

- Trigger: Precision < 75%, New geography, or mAP@50 < 80%.

```
model = YOLO('yolov8n.pt')
model.train(data='data.yaml', epochs=30, imgsz=640, batch=16, device=0)
```

7. Performance Metrics

Final Performance (Epoch 30)

Metric	Value	Metric	Value
Precision	81.6%	mAP@50	87.6%
Recall	81.5%	mAP@50-95	61.4%
F1 Score	81.5%	Training Time	~2.5 hrs

Configuration

Param	Value	Param	Value
Epochs	30	Optimizer	AdamW
Batch	16	LR (Init/Final)	0.01 / 8.6e-5

Loss Progression (Epoch 1 vs 30)

Loss Type	Epoch 1	Epoch 30	Improvement
Train Box	1.598	1.100	-31.2%
Train Class	1.431	0.611	-57.3%
Val Box	1.534	1.159	-24.4%
Val Class	1.813	1.001	-44.8%

8. Ethical & Output

Use: Utility-scale/Residential assessment. Supports, does not replace, human verification.

JSON Output

```
{
  "sample_id": 1, "has_solar": true, "confidence": 0.87,
  "pv_area_sqm_est": 32.5, "qc_status": "VERIFIABLE"
}
```