Model Card - Solar Panel Detection System

Model Details

- **Developer**: Ideathon 2026 Team.
- **Model**: YOLOv12x (Fine-tuned on Satellite Imagery).
- **Version**: 2.0 (Dec 2025) - Enhanced with Hard Negative Mining.
- **Architecture**: Convolutional Neural Network (Ultralytics YOLO).
- **Input**: 1024×1024 px Satellite Tiles.

Intended Use

- **Primary Use**: Automated verification of rooftop solar PV installations from high-resolution satellite imagery (Zoom 20+).
- **Target Users**: Energy auditors, utility operators, urban planners.
- **Out of Scope**: Determining panel efficiency, detecting ground-level shading, or analyzing low-res (<0.15m/px) imagery.

Factors

- **Environment**: Trained primarily on urban residential rooftops. Performance on industrial warehouses or rural ground-mounts may vary.
- **Image Quality**: Highly dependent on clear, cloud-free, high-contrast satellite imagery.
- **Confounds**: Water tanks (blue/black), skylights, and dark waterproofing are known confounders.

Metrics

- Evaluation metrics include **Precision**, **Recall**, and **F1-Score** at IoU 0.5.
- **False Positive Rate** is critically monitored to avoid over-estimating solar adoption.
- **PV Area Estimation**: Calculated geometrically using the Mercator projection to convert pixel area to m^2.

Training Data

- **Size**: 2,649 labeled images (Augmented).
- **Sources**: Aggregated from open-source datasets (Alfred Weber Institute, ProjectSolarPanel, Tennistable) [1, 2, 3] and custom collected samples.
- **Split**: 80% Train / 20% Validation.

Ethical Considerations

- **Privacy**: Analyzes public aerial imagery. No PII or individual tracking.
- **Bias**: Geographic bias towards the training region's architectural style.

Quantitative Analyses

Classification Performance

Class	Precision	Recall	F1	Sup.
No Solar	0.74	0.85	0.79	500
Solar	**0.97**	**0.94**	**0.95**	2500

Confusion Matrix

	Pred: No	Pred: Solar
Act: No	427 (TN)	73 (FP)
Act: Solar	153 (FN)	2347 (TP)

Performance Visuals

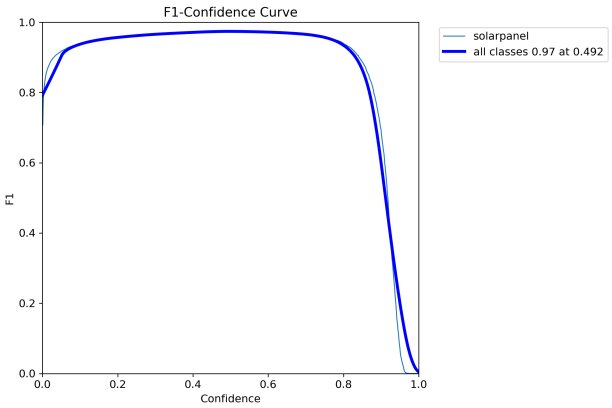

Figure 1: F1-Confidence Curve

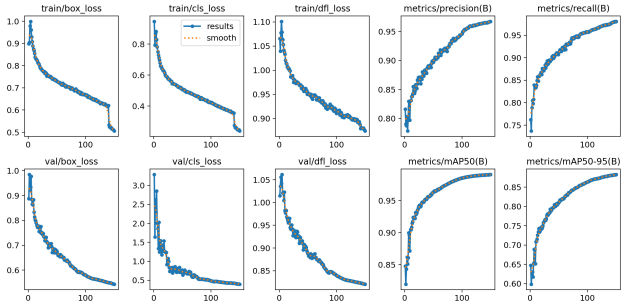

Figure 2: Detection Examples (Green=Solar)

Methodology: PV Area

The PV surface area is estimated through a three-step geometric process:

Step 1: Calculate Meters Per Pixel (MPP)

Based on the Mercator projection at latitude ϕ and zoom level z:

$$MPP = \frac{156543.03392 \times \cos(\phi)}{2^z}$$

Step 2: Determine Pixel Area

For a detected bounding box with coordinates (x_1, y_1, x_2, y_2):

$$Area_{px} = (x_2 - x_1) \times (y_2 - y_1)$$

Step 3: Compute Physical Area

The final area in square meters is the product of pixel area and the squared spatial resolution:

$$A_{m^2} = Area_{px} \times (MPP)^2$$

References

[1] Alfred Weber Inst. *Custom Workflow Dataset*. Roboflow Univ.
[2] ProjectSolarPanel. *lsgi547-project*. Roboflow Univ.
[3] Piscinas y Tenistable. *Solar Panels*. Roboflow Univ.