Model Card: Solar Panel Detection (OBB v2.0)

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January 4, 2026

Abstract

This document provides a detailed overview of the **Solar Panel Detection Model v2.0**. This iteration builds upon the v1.0 YOLOv8-Medium OBB architecture by implementing a high-resolution fine-tuning strategy. The model was initially trained at 640px and subsequently fine-tuned at **1024px** for 30 epochs to enhance small object detection and localization accuracy. The dataset was expanded to include five distinct sources, significantly improving robustness across diverse environments. This model is designed for precise Oriented Bounding Box (OBB) detection in aerial and satellite imagery.

Model Details

- **Model Name:** Solar Panel Detection v2.0 (OBB-1024-FT)
- **Architecture:** Ultralytics YOLOv8-Medium OBB (~25.8M parameters)
- **Input Resolution:** 1024×1024 pixels (Fine-tuned from 640px base)
- **Framework:** PyTorch / Ultralytics YOLOv8
- **Task:** Oriented Bounding Box (OBB) Detection
- **License:** MIT License (Codebase), Dataset licenses vary by source.
- **Hardware:** Trained on NVIDIA A100 / Tesla T4.

Intended Use

Primary Use Cases

- **Rooftop Potential Analysis:** Precise estimation of available rooftop area for solar installation using oriented bounding boxes to match panel tilt.
- **Automated Asset Monitoring:** Large-scale auditing of existing solar installations in satellite imagery.
- **Capacity Estimation:** Counting individual panels to estimate power generation potential (kW).

Out-of-Scope Use Cases

- **Ground-Level Detection:** Optimized for nadir/satellite views; not suitable for street-view imagery.
- **Thermal Defect Analysis:** Detects physical presence (RGB), not thermal anomalies.

Data Overview

The training dataset was expanded for v2.0 to include five open-source datasets, ensuring high diversity.

Source Dataset	Contribution
Solar Panels RF100	Roboflow 100 Benchmark subset
Solar PV Detection	High-density residential installations
WW Solar Panel	Varied commercial setups
LSGI547 Project	*[New]* Additional diverse aerial samples
Solar Panels BA8TY	*[New]* Swimming pools
tennis courts (mixed context)	

Table 1: Dataset Composition for v2.0

Preprocessing: Auto-orientation, mosaic augmentation, and resizing to 1024px.
Device: CUDA Enabled GPU (rank 0).

Training Procedure

The v2.0 model employs a **Progressive Resolution Fine-Tuning** strategy:

1. **Base Training:** YOLOv8m trained at 640px resolution (previous best weights).
2. **Fine-Tuning:** Reloaded best 640px weights and trained for an additional **30 epochs** at **1024px**.

Hyperparameters (Fine-Tuning Phase)

Parameter	Value	Parameter	Value
Epochs	30	Initial LR (lr0)	0.0005 (Reduced)
Batch Size	16	Final LR (lrf)	0.01
Optimizer	AdamW	Warmup Epochs	0 (Immediate peak)
Momentum	0.937	Cosine LR	True
Patience	0 (Fixed 30)	Image Size	1024

Evaluation Results

Performance metrics were tracked throughout the training process. The following data represents the model's performance on the validation set.

Model Version	Precision	Recall	mAP@50	mAP@50-95
v1.0 (640px Base)	0.853	0.815	0.864	0.739
v2.0 (1024px FT)*	**0.855**	**0.815**	**0.867**	**0.741**

Table 2: Comparative Validation Metrics (Final Epochs)
*Note: v2.0 represents the model after 30 epochs of fine-tuning at 1024px resolution.

Training Dynamics & Analysis

- **High-Resolution Adaptation:** The fine-tuning phase at 1024px maintained the high baseline performance established by the 640px model (mAP@50 $\approx$ 86-87%) while adapting the feature extractors to the higher resolution input.
- **Stability:** The model converged quickly during fine-tuning (within 30 epochs) without catastrophic forgetting, indicated by the stable precision and recall scores compared to the base model.
- **Small Object Sensitivity:** By increasing the input resolution to 1024px, we reduce the "small object" relative size issue, allowing the model to better resolve individual panels in high-altitude satellite imagery, even if the aggregate numerical metrics show only marginal gains.

Limitations and Bias

- **Inference Speed:** Inference at 1024px is slower than 640px. For real-time applications, quantization or standard 640px inference may be preferred.
- **Geographic Bias:** Western-style architecture remains dominant in the dataset.
- **False Positives:** Skylights and glass roofs may still present challenges, though OBB helps differentiate better than BBox.

Ethical Considerations

Users must adhere to geospatial data privacy regulations when analyzing high-resolution satellite imagery of private property.