Model Card: Rooftop Solar OBB Detector

Model Version: v1.0 (Release Candidate)
Date: December 8, 2025 (Training Finished)
Task: Aerial Object Detection (Oriented Bounding Boxes)
Architecture: YOLOv8l-obb (Large)

1. Intended Use

- Primary Use Case: Remote verification of rooftop solar photovoltaic (PV) installations for the *PM Surya Ghar* government subsidy scheme.
- Target Geography: Pan-India (Urban and Semi-urban residential rooftops).
- Input: High-resolution satellite/aerial imagery (Zoom level 19-21, approx. 30cm/pixel).
- Output: Oriented Bounding Boxes (OBB) with confidence scores and rotation angles for area estimation.

2. Model Architecture

The model utilizes the YOLOv8-OBB (Large) architecture.

- Why OBB? Standard object detection (horizontal boxes) includes significant "dead space" (roof background) when panels are tilted, leading to gross overestimation of panel area. Instance segmentation is computationally expensive and prone to irregular mask shapes. OBB provides the optimal balance of geometric precision (rotated rectangles) and computational efficiency.
- Parameters: ~44 Million parameters.
- Inference Speed: ~150ms per image on NVIDIA T4 GPU.

3. Training Data

The model was trained on a composite dataset aggregating three open-source libraries from Roboflow Universe, specifically curated for diversity:

1. Alfred Weber Institute Solarpanel: High diversity of urban/European roof types.
2. LSGI547 Project: Focus on dense urban clusters.
3. Piscinas y Tenistable: Additional samples for small-scale residential installations.

Preprocessing & Augmentation:
To generalize to the Indian context (diverse roof materials, dust, lighting conditions), the following augmentations were applied:

- Mosaic: 1.0 (to handle varying scales).
- Grayscale: 15% probability (to force shape learning over color, mitigating false positives from blue water tanks).
- Rotation: +/- 15 degrees.
- Brightness/Contrast: Random adjustment to simulate harsh Indian sunlight and monsoon overcast conditions.

4. Performance Metrics

The model was evaluated on a held-out test set (20% split) after 50 epochs of training.

- mAP @ 50 (Mean Average Precision): 0.851
  - *Interpretation:* The model correctly identifies and localizes solar panels with >85% reliability.
- mAP @ 50-95: 0.67
  - *Interpretation:* High score indicates "tight" bounding boxes, ensuring accurate area quantification.
- F1 Score: 0.80 (at Confidence Threshold 0.378).
- Confusion Matrix:
  - False Positive Rate is near 0% (Background interpreted as Solar).
  - Recall is 0.86 (14% miss rate, mitigated by pipeline Jitter Sampling).

5. Limitations & Biases

- Resolution Dependency: The model requires imagery better than 50cm/pixel. Performance degrades significantly on low-res public satellite tiles (Zoom < 19).
- Occlusion: Heavy tree cover or shadows from nearby skyscrapers may result in False Negatives (Missed detections).
- Blue Roof Bias: While mitigated by grayscale augmentation, bright blue metal sheets (common in industrial areas) may occasionally trigger weak False Positives.
- Water Tanks: Circular syntax water tanks are generally filtered out, but rectangular tanks may pose a challenge if texture is ambiguous.

6. Ethical Considerations

- Privacy: The model detects infrastructure (panels), not individuals. No PII (Personally Identifiable Information) is processed or stored.

- Fairness: The inclusion of diverse roof types (concrete, clay tile, metal sheet) in training data aims to ensure equitable performance across different socio-economic housing types.

7. Recommendations for Audit

For cases flagged with `confidence < 0.6` or `qc_status = NOT_VERIFIABLE`, we recommend manual review of the generated audit artifact (`.jpg` overlay) before final subsidy disbursement.