Rooftop Solar Photovoltaic Detection and Verification System

1. Model Overview

- **Model Name:Rooftop Solar PV Detection and Verification Pipeline**
- **Model Type:**Deep learning–based **segmentation and geospatial verification** system
- **Base Architecture:YOLOv8 Segmentation / Oriented Bounding Box (OBB)** model (Ultralytics)
- **Pretraining:**Pretrained on the **COCO dataset** for generic object detection and segmentation
- **Fine-tuning:**Fine-tuned on **multiple rooftop solar panel datasets** exported in YOLOv8-compatible formats
- **Primary Task:**Detection, segmentation, and verification of **rooftop solar photovoltaic installations** using high-resolution satellite imagery.

2. Datasets Used

The model was trained using three annotated rooftop solar datasets, each targeting complementary aspects of the detection task.

Dataset 1: Custom Workflow Object Detection.v10

Dataset 2: LSGI547 Project.v3i.yolov8-obb

Dataset 3: Solar Panels.v1i.yolov8-obb

Dataset Characteristics (Common)

- Format:YOLOv8 OBB
- Source:Roboflow
- Content: High-resolution satellite imagery with rooftop solar annotations,Satellite imagery with oriented solar panel annotations, Dense rooftop solar annotations across residential and commercial buildings
- RGB satellite imagery
- Pixel-level masks or oriented bounding boxes
- Rooftop-mounted solar photovoltaic panels
- Variations in:Roof material,Panel orientation,Illumination and shadow,Urban and semi-urban environments.

3. Data Preprocessing

- Images resized to **1024 × 1024 pixels**
- Normalization handled internally by the YOLOv8 pipeline
- No synthetic data augmentation applied
- Original training/validation splits preserved from dataset exports

4. Model Architecture

- **Backbone:** Convolutional feature extractor pretrained on COCO
- **Neck:** Multi-scale feature aggregation for spatial robustness
- **Head:** YOLOv8 segmentation / OBB head producing:
    - Pixel-level masks or oriented bounding boxes
    - Confidence scores per detection

5. Inference and Decision Logic

The trained YOLOv8 model operates within a **multi-stage verification pipeline**:

1. Satellite image retrieval (Google Static Maps with ESRI fallback)
2. Image quality assessment
3. Segmentation inference
4. Mask-to-polygon conversion
5. Rooftop buffer intersection validation (1200 / 2400 sqft)
6. Solar area and capacity estimation
7. Confidence calibration
8. Final quality control classification

This design ensures **interpretable, auditable predictions** rather than raw detections.

6. Assumptions

- Solar panels are visually distinguishable in high-resolution satellite imagery
- Average panel area ≈ **1.9 m²**
- Power density ≈ **190 W/m²**
- Coordinate localization error within **±10 meters**
- Rooftop solar arrays exhibit structured geometric patterns

7. Known Limitations

- Reduced performance under heavy cloud cover
- Shadows may partially obscure panels
- Very small rooftop installations may be missed
- Reflective rooftops can cause false positives
- Dependent on satellite image resolution and recency

8. Bias and Fairness Considerations

- Potential geographic bias due to dataset distribution
- Higher accuracy in dense urban regions
- Reduced robustness for uncommon roof materials

Mitigation Strategies:

- Conservative confidence thresholds
- Explicit **NOT_VERIFIABLE** classification under uncertainty

9. Failure Modes

The system explicitly handles:

- Image acquisition failures
- Poor image quality
- Inference errors
- Ambiguous rooftop structures

All such cases are labeled **NOT_VERIFIABLE** with descriptive reason codes.

10. Retraining Guidance

Retraining is recommended when:

- Deploying to new geographic regions
- Using different satellite imagery providers
- Encountering new rooftop construction styles

Recommended Steps:

- Add region-specific annotated data
- Revalidate buffer thresholds
- Recalibrate confidence scoring

11. Ethical Considerations

- No personally identifiable information is processed
- Uses only publicly available satellite imagery
- Outputs are transparent, auditable, and explainable

12. Intended Use

Intended for:

- Academic research
- Sustainability assessment
- Energy planning and evaluation

Not intended for:

- Legal enforcement
- Individual household monitoring

13. License

Developed for **academic, research, and evaluation purposes** as part of the **Eco-Ideathon** submission.