MODEL CARD — Solar Rooftop Detection System

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1. Overview

The **Solar Rooftop Detection System** is an AI-based geospatial analysis model designed to detect rooftop photovoltaic (PV) installations from satellite imagery. It performs:

- Solar panel presence classification (has_solar)
- Solar panel bounding-box detection
- Approximate PV area estimation (in sq.m.)
- Auditability via bounding-box and metadata
- JSON output compatible with evaluation pipelines

The model uses **YOLOv8** trained on rooftop solar datasets sourced via Roboflow.

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2. Intended Use

Primary Intended Use

- Evaluate solar rooftop penetration across Indian states
- Enable large-scale programmatic assessment of rooftops
- Provide a verifiable and interpretable output via bounding boxes and overlay images

Not Intended For

- High-precision cadastral area measurement
- Legal/financial rooftop area verification
- Real-time surveillance
- Personal identification

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3. Training Data

Source: Roboflow Solar Panel Detection Dataset + curated rooftop images
Type: Satellite & aerial views
Labels: Single class — solar_panel

Dataset characteristics:

- Urban and semi-urban buildings
- Various roof colors (white, blue, grey, tin, concrete)
- Varied panel orientations
- Different lighting and seasonal conditions

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4. Model Architecture

- **Model Type:** YOLOv8s
- **Backbone:** CSPDarkNet
- **Input Resolution:** 640×640
- **Optimizer:** SGD
- **Augmentations Used:**
    - Flip
    - HSV shift
    - Scale
    - Rotation
- **Training Epochs:** 100
- **Losses Tracked:** Objectness, Box Regression, Classification

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5. Metrics

Evaluation was done on a separate validation split.

Metric	**Value**
F1 Score (has_solar)	*0.87*
Precision	*0.89*
Recall	*0.85*
Bounding-box IoU	*0.71*

Metric	Value
RMSE (PV Area)	*approx. 6.5 sq.m.*

The model shows **strong performance for medium–large solar arrays**, and reasonable performance for small residential setups.

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6. Generalization & Robustness

Performance tested against:

- Different Indian states: Karnataka, Tamil Nadu, Telangana, Gujarat, Delhi
- Various roof types: concrete, tin, metal sheet, industrial shed
- Look-alikes: water tanks, AC units, skylights, glass roofs

Findings:

- Robust for industrial and large commercial setups
- Residential buildings with light-colored roofs show minor false positives
- Extremely small installations (<1 kW) are inconsistently detected

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7. Ethical Considerations

- Model does **not** identify individuals
- Tiles are sourced from ESRI / Google satellite layers — must follow provider terms
- Should not be used for individual-level surveillance or property disputes
- Small detection errors should not be used for financial decisions without manual review

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8. Limitations

- ESRI tiles vary in zoom availability
- High-zoom (19+) sometimes blank for rural regions
- Detection relies on image clarity; cloud cover → poor results
- PV area estimation is approximate (bounding-box based)
- No segmentation mask (future work)

9. Failure Modes

- Large white roofs mistaken as solar
- Long shadows reduce confidence
- Panels at extreme angles (>45° tilt) sometimes missed
- Foggy / monsoon images perform poorly

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10. Recommendations for Future Improvement

- Add segmentation-based area estimation (exact pixel mask)
- Add domain-specific augmentations (haze, blur, monsoon)
- Include rural and semi-rural rooftops in training
- Add stereo / multi-date imagery support

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11. Versioning & Retraining Guidance

To retrain:

1. Collect more diverse solar panel images
2. Use YOLOv8 training command:
3. yolo train data=solar.yaml model=yolov8s.pt imgsz=640 epochs=100
4. Track metrics via MLflow
5. Validate on cross-state dataset
6. Generate updated best.pt and update repository