Mobile-Net QR Detection

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MODEL DETAILS

A MobileNet-based object detector trained with advanced position augmentation techniques including random translation and safe crop for QR code detection. This model addresses spatial position bias in training data by augmenting object locations, resulting in improved generalization for QR codes appearing at various positions in the image. Achieves the highest mAP and IoU scores among evaluated models.

MODEL SPECIFICATIONS

Inputs
- Input: 256x256 grayscale image (single channel)
- Pixel values normalized to [0, 2) range (/128.0)

Outputs
- QR code bounding boxes (xmin, ymin, xmax, ymax)
- Detection confidence scores (0.0 - 1.0)
- Class predictions (QR code class 0)

Architecture
- Backbone: MobileNet-based (efficient feature extraction)
- Detection Head: Single-scale 16x16 grid with 3 anchors
- Output Format: 16x16x18 tensor (objectness, class, bbox x 3 anchors)
- Loss: CIoU (Complete IoU) + Focal Loss
- Quantization: LSCQuant INT8 (FPGA-optimized)

Training Configuration
- Position Augmentation: Random Translation (±30%) + Safe Crop
- Additional Augmentations: Vertical Flip, Photometric transforms
- Optimizer: Adam with Cosine Decay LR Schedule
- Initial Learning Rate: 0.004
- Batch Size: 32
- Epochs: 300

AUTHORS	Lattice Semiconductor
VERSION	mobile_net_qr_detection_v1
RELEASE	2025-12-18
LICENSE	Lattice Semiconductor
MODEL TYPE	QR Code Object Detection

PERFORMANCE EVALUATION

Evaluation Dataset

- Test set: 638 images from QR code detection dataset
- Ground truth: 646 bounding box annotations
- Various QR code sizes, positions, and orientations
- Multiple lighting conditions and backgrounds

KPIs

The KPIs for the evaluation data are reported in the Table below.

Metric Category	Metric Name	Value	Dataset & Comments
Detection Metrics	mAP@0.5	0.7883	Test set (IoU threshold 0.5)
	Precision	0.8934	Test set
	Recall	0.8824	Test set
	Average IoU	0.8639	Test set (matched detections)
Inference Performance	Inference Time	29.10 ms/image	GPU (RTX 3060)
	True Positives	570	Test set
	False Positives	68	Test set
Score Distribution (Aggregate NMS)	Min Score	0.3388	With aggregate NMS (weight=0.3)
	Max Score	0.9855	With aggregate NMS (weight=0.3)
	Mean Score	0.7029	With aggregate NMS (weight=0.3)
	Scores ≥ 0.5	87.2%	With aggregate NMS (weight=0.3)

COMPARISON WITH PREVIOUS MODELS

Improvement over other models

- mAP@0.5: +5.5% improvement (0.7883 vs 0.7474)
- Precision: +2.7% improvement (0.8934 vs 0.8699)
- Recall: +2.7% improvement (0.8824 vs 0.8591)
- Average IoU: +1.6% improvement (0.8639 vs 0.8499)
- Reduced failure rate in non-center regions

Position Bias Correction

- Original dataset had 89% of QR codes in lower-center region
- Position augmentation simulates QR codes at diverse locations
- Improved detection of edge-located and corner-positioned QR codes

USAGE

Recommended Use Cases

- Best overall detection accuracy among Mobile-Net variants
- Robust to QR codes at various image positions
- Ideal for real-world deployment with unpredictable QR positions
- FPGA deployment via LSCQuant INT8 quantization

NMS Configuration

- Standard NMS: Returns raw model confidence scores
- Aggregate NMS (recommended): Boosts scores by aggregating suppressed predictions (weight=0.3)
- IoU threshold: 0.5 for detection matching
- Confidence threshold: 0.25 recommended

Deployment Notes

- Model path: train_qr_ciou_position_aug/convert/model-sensai-h5-best.h5
- Input normalization: pixel_value / 128.0
- Output grid: 16x16 with 3 anchors per cell
- Best mAP@0.5 score among all evaluated Mobile-Net models

TRAINING DATA AUGMENTATION

Position Augmentations

- Random Translation: Shifts image and bbox by ±30% of image dimensions
- Random Safe Crop: Crops image while ensuring bbox visibility, then resizes
- Both augmentations preserve bbox validity and clip to image bounds

Geometric Augmentations

- Vertical Flip: 50% probability
- Random Rotation: Small angle perturbations

Photometric Augmentations

- Brightness adjustment: ±0.2
- Contrast adjustment: ±0.2
- Gaussian noise: sigma 5-20
- Gaussian blur: sigma 0.5-2.0

LIMITATIONS

Known Limitations

- Single-class detection (QR codes only)
- Fixed input resolution (256x256)
- Single-scale detection (may miss very small or very large QR codes)
- Training data primarily contains centered QR codes (mitigated by augmentation)

Failure Cases

- Severely occluded QR codes
- QR codes at extreme angles (>45°)
- Very low contrast or heavily blurred images
- Multiple overlapping QR codes (returns single best detection)