Building a No-Entry Sign Detector

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1 Viola-Jones No-Entry Sign Detection

1.1 Cascade Classifier Training

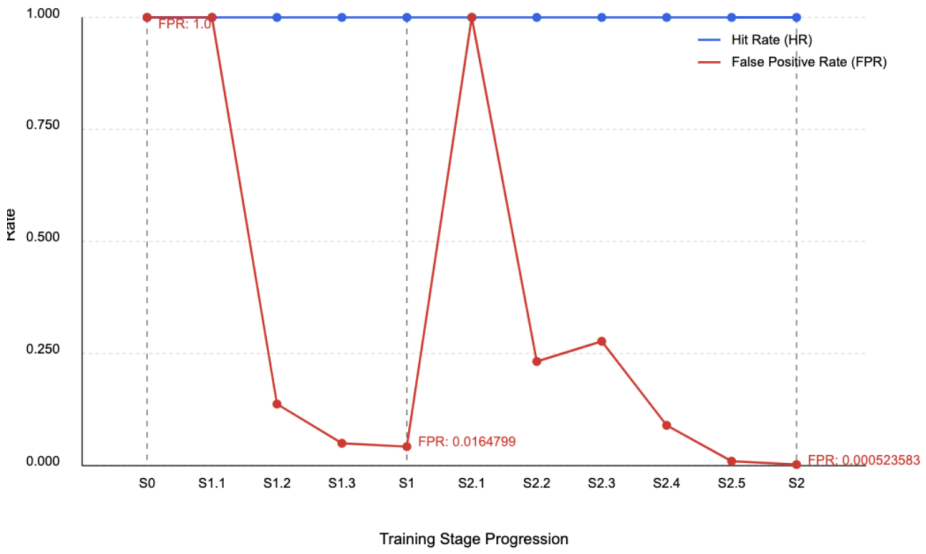
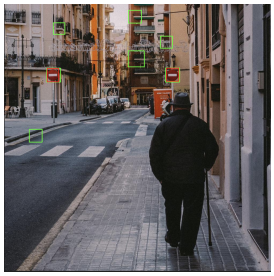


Figure 1: The graph shows our cascade classifier's training progression, where each stage maintains near-perfect detection (blue line) while progressively filtering out false positives (red line) by incrementally combining weak classifiers.

1.2 Detection Visualisation



NoEntry0

NoEntry9

NoEntry11

Figure 2: Examples of no-entry sign detection results showing detections (green boxes) and ground truth annotations (red boxes).

1.3 Performance Analysis

Image	TPR	F1	Detections	Ground Truth
NoEntry0.bmp	1.000	0.444	7	2
NoEntry1.bmp	1.000	0.667	2	1
NoEntry2.bmp	1.000	0.500	3	1
NoEntry3.bmp	1.000	0.444	7	2
NoEntry4.bmp	1.000	0.400	8	2
NoEntry5.bmp	0.300	0.300	10	10
NoEntry6.bmp	0.250	0.222	5	4
NoEntry7.bmp	0.000	0.000	10	1
NoEntry8.bmp	0.500	0.500	6	6
NoEntry9.bmp	1.000	1.000	1	1
NoEntry10.bmp	0.667	0.571	4	3
NoEntry11.bmp	0.000	0.000	5	2
NoEntry12.bmp	0.375	0.400	7	8
NoEntry13.bmp	0.000	0.000	5	1
NoEntry14.bmp	1.000	0.333	5	1
NoEntry15.bmp	1.000	0.571	5	2
Average	**0.631**	**0.397**	**-**	**-**

Table 1: Detection performance metrics across test images for the Viola-Jones No-Entry sign detector.

1.3.1 Performance Patterns

The True Positive Rate (TPR) exhibits a bimodal distribution, being either perfect (1.000) or suboptimal (≤ 0.500). This, coupled with a low average F1 score of 0.397, suggests that while the detector can achieve perfect detection under ideal conditions, it lacks robustness in challenging scenarios.

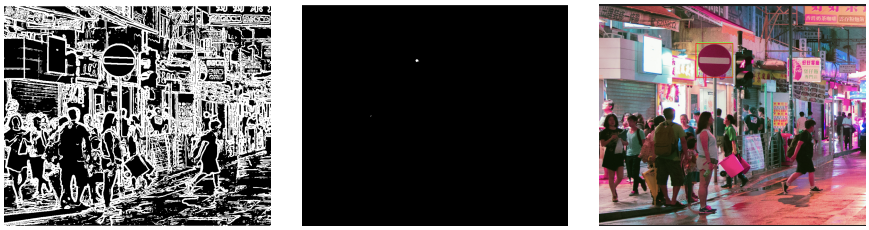
1.3.2 Performance Disparity Analysis

The significant difference between training performance (TPR: 0.999, FPR: 0.05) and test performance indicates overfitting, likely due to training on synthetic rather than real-world data, resulting in poor performance when confronted with real-world variability in environmental conditions.

2 Circle Detection Integration for Enhanced No-Entry Recognition

2.1 Circle Detection Visualization

Example 1: Strong Detection Performance



Gradient Magnitude | Hough Space | Final Detection

Example 2: Detection Limitations

Gradient Magnitude | Hough Space | Final Detection

Figure 3: Circle detection visualisation showing (left) thresholded gradient magnitude images used as input to the Hough Transform, (middle) 2D Hough space accumulators showing voting peaks, and (right) final detection results.

2.2 Comparative Performance Analysis

Image	TPR	F1	TPR Diff	F1 Diff
NoEntry0.bmp	0.500	0.667	-0.500	+0.223
NoEntry1.bmp	1.000	1.000	0.000	+0.333
NoEntry2.bmp	1.000	1.000	0.000	+0.500
NoEntry3.bmp	0.500	0.500	-0.500	+0.056
NoEntry4.bmp	1.000	1.000	0.000	+0.600
NoEntry5.bmp	0.000	0.000	-0.300	-0.300
NoEntry6.bmp	0.250	0.400	0.000	+0.178
NoEntry7.bmp	0.000	0.000	0.000	0.000
NoEntry8.bmp	0.500	0.667	0.000	+0.167
NoEntry9.bmp	1.000	1.000	0.000	0.000
NoEntry10.bmp	0.667	0.800	0.000	+0.229
NoEntry11.bmp	0.000	0.000	0.000	0.000
NoEntry12.bmp	0.250	0.400	-0.125	0.000
NoEntry13.bmp	0.000	0.000	0.000	0.000
NoEntry14.bmp	1.000	1.000	0.000	+0.667
NoEntry15.bmp	1.000	1.000	0.000	+0.429
Average	**0.542**	**0.590**	**-**	**-**

Table 2: Detection performance metrics comparison between combined Viola-Jones and Circle detector and baseline Viola-Jones detector. Green values indicate improvements and red values show degradation in performance.

Merits	Limitations
• Improved F1 scores in majority of cases • Maintains perfect TPR where Viola-Jones performed well • Reduces false positives via circle validation	• Degraded TPR in several cases due to strict validation • Complete failures persist in challenging scenarios

Table 3: Key Merits and limitations of combined Viola-Jones and circle detector

2.3 Detection Pipeline

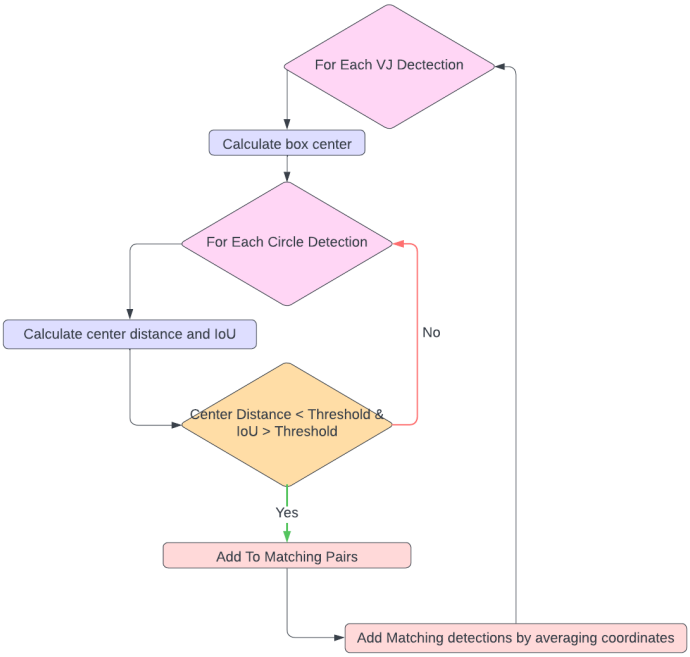


Figure 4: Detection pipeline showing the integration of Viola-Jones and Circle detector evidence.

2.3.1 Combination Rationale

- Dual metric validation using both center distance and Intersection over Union (IoU) ensures detections agree in both position and size.
- Two-stage validation process (distance followed by IoU) effectively filters out weak matches while preserving high-confidence detections.
- Coordinate averaging of matched detections helps cancel out random noise and positioning errors.

3 Integrating Red Colour Analysis for Enhanced No-Entry Sign Detection

3.1 Implementation Rationale

- **Color Invariance:** No-Entry signs use a standardised red colour that should provide a reliable feature for detection that is resilient to both

varied lighting conditions and geometric distortions.

- **Complementary Detection:** Color information should provide the detector with an orthogonal signal to its current shape-based detectors (Viola-Jones and circle detection).

3.2 Red Colour Detection Visualization

Example 1:

HSV Mask | LAB Mask | Final Detection

Example 2:

HSV Mask | LAB Mask | Final Detection

Figure 5: Color segmentation visualization showing (left) HSV-based mask, (middle) LAB-based mask, and (right) final detection results

3.3 Comparitive Performance Analysis

Image	TPR	F1	TPR Diff	F1 Diff
NoEntry0.bmp	1.000	1.000	+0.500	+0.333
NoEntry1.bmp	1.000	1.000	0.000	0.000
NoEntry2.bmp	1.000	1.000	0.000	0.000
NoEntry3.bmp	1.000	0.800	+0.500	+0.300
NoEntry4.bmp	1.000	1.000	0.000	0.000
NoEntry5.bmp	0.000	0.000	0.000	0.000
NoEntry6.bmp	0.250	0.400	0.000	0.000
NoEntry7.bmp	0.000	0.000	0.000	0.000
NoEntry8.bmp	0.500	0.667	0.000	0.000
NoEntry9.bmp	1.000	1.000	0.000	0.000
NoEntry10.bmp	0.667	0.800	0.000	0.000
NoEntry11.bmp	0.000	0.000	0.000	0.000
NoEntry12.bmp	0.375	0.545	+0.125	+0.145
NoEntry13.bmp	0.000	0.000	0.000	0.000
NoEntry14.bmp	1.000	1.000	0.000	0.000
NoEntry15.bmp	1.000	1.000	0.000	0.000
Average	0.612	0.638	-	-

Table 4: Detection performance metrics comparison between combined Viola-Jones, circle and red colour detector and baseline combined Viola-Jones and circle detector

Merits	Shortcomings
• Successfully detects signs missed by basic viola-jones or circle detection • Maintains detection accuracy without performance degradation • Enhanced validation precision reducing false positives	• Does not improve detection of signs not directly facing the camera • Does not improve detection of signs in challenging lighting conditions • Does not improve detection of signs occluded by other objects

Table 5: Key Merits and shortcomings of combined Viola-Jones, circle and red colour detector