No Pedestrian Left Behind (NPLB): Real-Time Detection and Tracking of Vulnerable Road Users for Adaptive Traffic Signal Control

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Motivation & Our Approach

- **270,000+** pedestrians die annually in road traffic crashes (22% of global fatalities) [1]
- Fixed-time signals assume uniform walking speeds
- Higher risk of being stranded when the signal ends for **Vulnerable road users (VRUs)** such as elderly, people with disabilities, children

Our Contributions: (1): **NPLB**: Real-time adaptive system improving VRU safety by **71.4%**, **(2)**: Comprehensive benchmarking of object detection models on BGVP[2], **(3)**: State-of-the-art Fine-Tuned YOLOv12 model (mAP@0.5 = **0.756**)

System Architecture

3 Integrated Layers: (1) Perception Layer: Fine-tuned YOLOv12 + ByteTrack multi-object tracking, **(2) Detection Layer**: VRU filtering with timeout mechanism (10 frames), **(3) Control Layer**: Adaptive signal timing with automatic extensions

Key Parameters:

- Extension time (τ_e): 3.0 seconds
- Threshold time (τ_t): 4.0 seconds
- Max extensions (n_{max}): 2 per crossing

Object Detection Model Evaluation

Evaluated 5 state-of-the-art models on BGVP[2] dataset:

Model	mAP@0.5	mAP@[0.5:0.95]
YOLOv12 [3]	**0.756**	0.502
YOLOv5 [4]	0.746	0.506
YOLOv11 [5]	0.741	0.509
Faster R-CNN [6]	0.659	0.355
SSDLite [7]	0.558	0.329

YOLOv12 achieves highest mAP@0.5 of 0.756

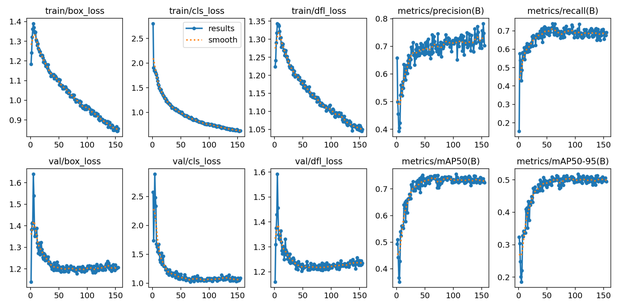


Figure 1. YOLOv12 training metrics across 500 epochs

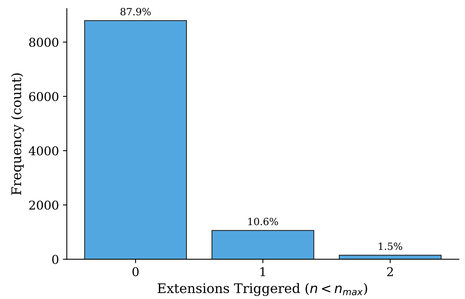
Results

We conducted **10,000 Monte Carlo Simulations** [8] on NPLB system, simulating diverse pedestrian profiles to evaluate effectiveness in reducing stranding rates.

Key Results:

- Improved VRU safety by 71.4%, stranding reduced from **9.10%** to **2.60%**
- Extensions required in only **12.1%** of cycles
- **87.9%** of cycles need no intervention

Signal Extension Analysis



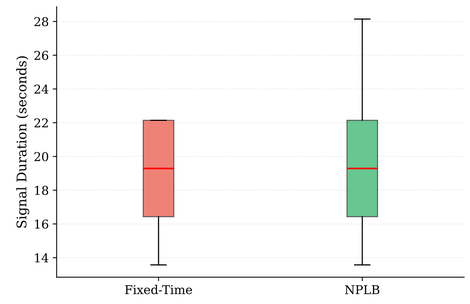


Figure 3. Signal duration comparison

Minimal Traffic Impact:

- Identical average signal time
- Extensions only when VRUs are at risk
- **Upper bound**: Fixed (22 seconds) vs NPLB (28 seconds)

Conclusion & Future Work

NPLB shows promise in improving pedestrian safety for Vulnerable Road Users using vision-based adaptive signal control. Future work should focus on field testing in real-world environments

References

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