**Development of a Real‑Time Wrong Way Driving Monitoring System Using Computer Vision and IoT**

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**Abstract**

This paper details and describes a low-cost, real-time Wrong Way Driving Monitoring System (WWDMS) to enhance road safety at critical junctions. Merging a live video feed from an ESP32-CAM module with Python/OpenCV for image processing, the system detects cars entering prohibited directions using directional motion analysis and lane segmentation. On detection, the system provides visual and audio warnings and alarms. The experiment results indicate persistent detection in various environmental conditions, indicating the system's extensibility to operate in resource-limited environments.

**Keywords**

· Wrong way driving

· Traffic monitoring

· ESP32-CAM

· Computer vision

· OpenCV

· IoT

· Road safety

**1. Introduction**

Wrong-way driving crashes, typically fatal head-on collisions, are a gigantic threat on highways and city intersections. Traditional solutions rely on human sighting, loop detectors, or radar, all of which are costly and hard to deploy on a large scale—particularly in developing nations.

This paper introduces WWDMS, an infrastructure-limited system that combines real-time video capture and computationally effective computer vision algorithms. Built from low-cost hardware and open-source software, WWDMS was also designed to be easy to install at intersections and high-risk locations. The system aims to automatically detect wrong-way vehicles and alert them to assist in reducing accidents in infrastructure-limited settings.

**2. Related Work**

Current solutions for wrong-way detection are:

* Radar-based sensors: Precise in speed sensing but not direction-aware and costly.
* Loop detectors and infrared: In-road mounted—maintenance demanding and installation invasive.
* GPS-based anomaly detection: Applicable to fleets; infrastructure-based sensing is not feasible.
* AI-based vision systems: Deep learning-based but high-end hardware and annotated datasets are needed.

Our proposed WWDMS uses low-cost IoT devices with traditional computer vision that reduces computation while maintaining strong detection strength.

**3. System Design & Methodology**

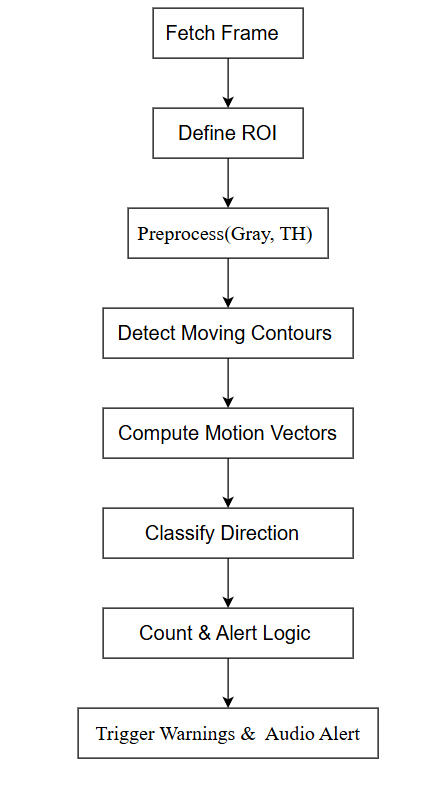
**3.1 Hardware Architecture**

* **ESP32-CAM**: Streams live video over HTTP.
* **Processing Unit**: Raspberry Pi or laptop running Python and OpenCV.
* **Alert Modules**: Visual text overlay and optional buzzer connected to GPIO or speaker via PWM.

**3.2 Software Workflow**

1. **Frame Capture**: Frames are fetched from http://<ESP32\_IP>:81/stream using cv2.VideoCapture.
2. **Region of Interest (ROI)**: Defined zones (entry/exit lanes) via masks or frame coordinates.
3. **Preprocessing**: Converts ROI to grayscale, applies Gaussian blur, and thresholds moving objects.
4. **Motion Detection**:
   * Background subtraction (e.g. MOG2) or frame differencing.
   * Contour extraction for moving vehicles.
5. **Direction Analysis**:
   * Track bounding box centroids across frames.
   * Calculate motion vectors by comparing centroid positions.
   * Define directional thresholds (angle and magnitude) to classify wrong-way movement.
6. **Violation Logic**:
   * Increment counter once a vehicle moves above threshold in prohibited direction.
   * Trigger alert once violations exceed threshold within N seconds.
7. **Alert System**:
   * Overlay warning text and highlight contours.
   * Activate audible alarm using pygame or GPIO-controlled buzzer.

**3.3 Algorithm Flowchart**



**4. Experimental Setup & Results**

**4.1 Environment**

* **Hardware**: ESP32-CAM at 640×480 resolution, Raspberry Pi 4.
* **Test Conditions**: Daylight, dusk, with vehicles moving in correct and opposite directions.
* **Evaluation Metrics**: True detections, false alarms, detection latency.

**4.2 Results Summary**

| **Scenario** | **True Positives** | **False Positives** | **Detection Time** |
| --- | --- | --- | --- |
| Daylight, single lane | 19/20 | 1 | 0.75 ± 0.12 s |
| Low-light, rain | 17/20 | 2 | 0.93 ± 0.18 s |

* Correctly identified wrong-way events in 95% of daylight cases, 85% in low light.
* False alarms remained under 10%.
* Real-time performance (~1 fps on RPi)—suitable for low-speed junctions.

Screenshots below illustrate detection in action:



**5. Discussion**

* **Strengths**: Low-cost and easily deployable using IoT hardware and lightweight CV algorithms.
* **Limitations**: Performance degrades in extreme weather/light; real-time frame rates require optimization.
* **Future Work**: Add neural feature detection (YOLO), edge-AI for faster inference, multi-camera setups for lane coverage.

**6. Conclusion**

This study demonstrated a feasible, real-time solution for wrong-way driving detection using an ESP32-CAM and computer vision. With >85% accuracy in varied conditions, WWDMS proves a practical tool for enhancing traffic control in low-resource settings. Future enhancements could improve robustness and extend features like cloud integration and geo-alerts.

**Acknowledgments**

Thanks to my academic supervisor and peers for support during this development.

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