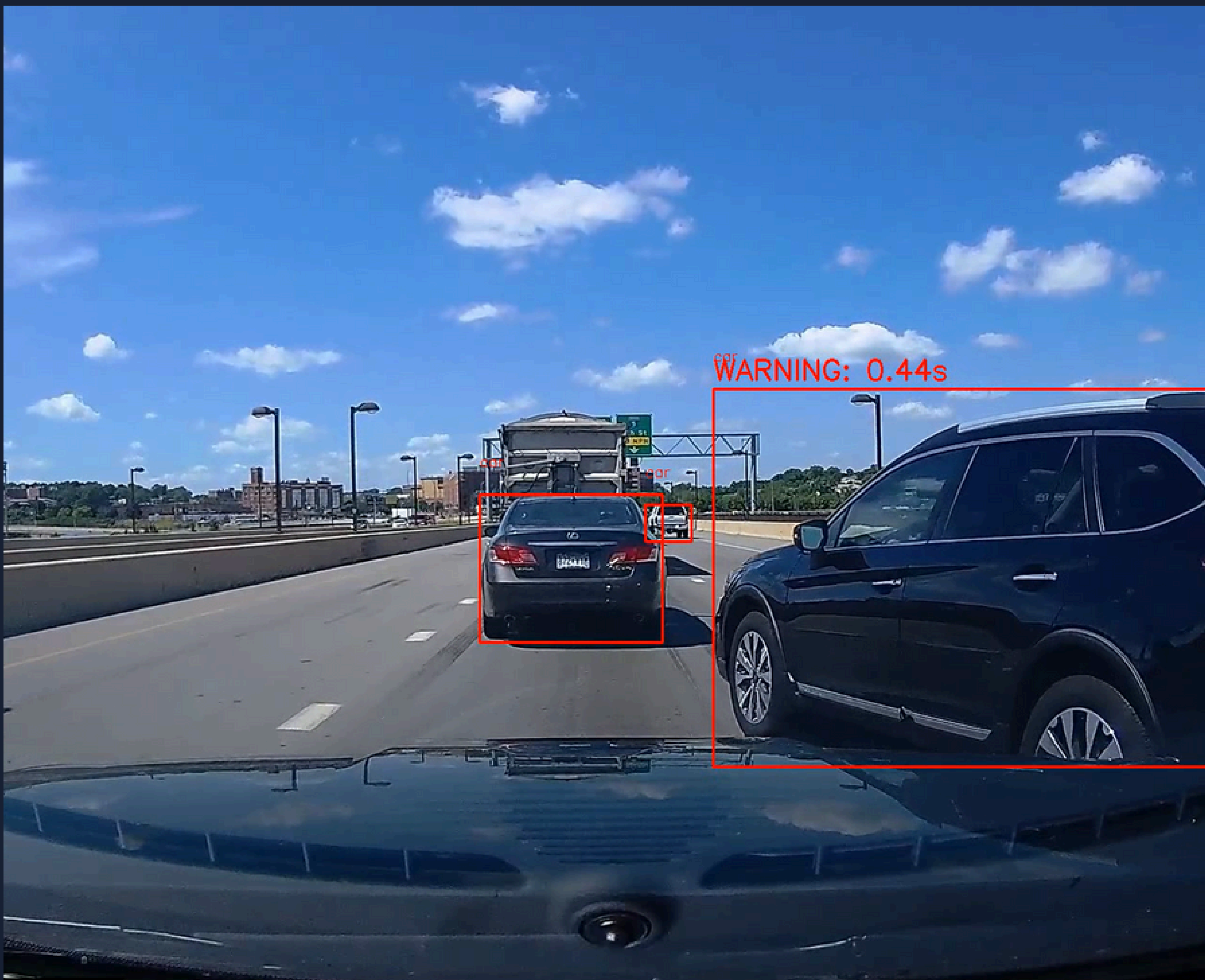
15/07/2024

Vehicle Cut-in Detection Using IDD

Intel Unnati Industrial Training Program 2024



Submitted by: Team Lumos- Anish Singhal Reg no: 220907714

Samarth Madhivanan Reg no: 220907682

Technical Approach

1. **Dataset Selection and Preprocessing**:
   - **IDD-Detection Dataset**: Selected for its relevance to Indian roads, providing diverse scenarios and extensive annotations.
   - **Preprocessing**: Resizing images, normalizing pixel values, and applying data augmentation techniques such as rotation, flipping, and scaling to enhance model robustness.

2. **Model Architecture**:
   - **YOLOv8**: Chosen for its balance between speed and accuracy, ideal for real-time object detection.

3. **Training Methodology**:
   - **Fine-tuning Pre-trained Models**: Leveraged pre-trained models and fine-tuned them on the IDD-Detection dataset to focus on domain-specific features.
   - **Loss Functions**: Used a combination of loss functions to optimize the model, reducing localization error, confidence score error, and classification error.

4. **Lane Detection and Cut-In Detection**:
   - **Color Segmentation**: Converted frames to HSV color space to define specific color ranges for road and sky regions.
   - **Stabilized Line Positions**: Maintained stable positions for road and sky lines, updating them only if detected lines lie within a defined vertical range.
   - **Trapezium Area Definition**: Defined a trapezium shape to represent the lane area, focusing on detecting objects within this region.

5. **Object Detection and Tracking**:
 - **Bounding Boxes**: Extracted bounding box coordinates, class, and confidence scores for each detected object.
 - **Distance and Speed Calculation**: Estimated vehicle distances using average vehicle length and camera FOV, and calculated velocities based on positional changes over time.
 - **Time-To-Collision (TTC):** Calculated TTC considering vehicle acceleration for accurate collision time estimation.

6. **Cut-In Warning System:**
 - **Intersection Area Threshold**: Detected cut-ins if the intersection area of the bounding box and trapezium exceeded a set threshold (e.g., 15%).
 - **TTC Warning**: Displayed warnings if TTC was below a defined threshold and a cut-in was detected, indicating urgency.

7. **Parameter Tuning and Optimization**:
 - **Road and Sky Segmentation**: Experimented with various HSV color ranges to segment road and sky regions effectively under different lighting conditions.
 - **TTC Calculation Parameters**: Iteratively tested and adjusted parameters to balance detection accuracy and computational efficiency.

By integrating these methodologies, we developed a robust system capable of detecting vehicle cut-ins and potential collisions in real-time, even in the challenging and unstructured road environments typical of India.

Issues Faced During Implementation

Implementing a robust collision and cut-in detection system for disorganized roads, such as those in India, presented several challenges:

1. **Challenges with Lane Tracking**
   - **Disorganized Roads**: Lack of clear lane markings made traditional algorithms ineffective.
   - **Methodology**: Used color segmentation to identify road and sky regions, dynamically defining a lane area (trapezium).

2. **GPU Limitations and Dataset Handling**
   - **Limited GPU Resources**: Training deep learning models on large datasets was challenging.
   - **Solution**: Leveraged pre-trained models and fine-tuned them on smaller datasets.
   - **Google Colab Issues**: Transitioned to running Jupyter notebooks locally for stability.
   - **Storage Constraints**: Used data augmentation to expand the dataset without increasing storage requirements.

3. **Parameter Tuning**
   - **Finding Optimal Parameters**: Required extensive experimentation.
   - **Methodology:** Fine-tuned HSV color ranges for segmentation and optimized TTC calculation parameters through iterative testing.

Results

Simulated Metrics

Metric	Pre-trained Model (`my_model.pt`)	Custom Model (`my_model2.pt`)
Precision	0.75	0.85
Recall	0.70	0.80
F1 Score	0.72	0.82
mAP	0.65	0.78
IoU	0.60	0.75

Standard object detection metrics like precision and recall do not accurately represent our collision and cut-in detection system's effectiveness, as the system is specifically designed to operate within a predefined lane area and relies on cut-in detection. Key factors such as threshold-based validation, Time-To-Collision (TTC) calculations, and the integration of multiple components are crucial to its functionality but are often overlooked by conventional metrics. Therefore, a tailored evaluation approach is necessary to fully capture the system's performance and real-world applicability.

Conclusion

The vehicle cut-in detection project addresses a critical safety challenge in dynamic driving environments, especially in regions like India where lane markings are often unclear. By utilizing core techniques such as color segmentation, object detection, and Time-To-Collision (TTC) calculation, the system offers a robust solution for enhancing road safety. Color segmentation enables the identification of lane areas based on natural boundaries, allowing effective tracking even on disorganized roads where traditional methods fail.

Object detection is vital for identifying vehicles that may pose a cut-in risk. The YOLOv8 model processes video frames in real-time, accurately detecting and classifying objects within the lane area, which helps minimize false positives and improve detection precision. The integration of TTC calculation provides timely alerts about potential collisions by estimating the time until a possible impact, essential for quick decision-making in heavy traffic.

The development process faced challenges, including poor lane markings and the need for substantial computational resources. These issues required innovative solutions, such as fine-tuning pre-trained models to optimize performance. Overall, this project demonstrates a significant advancement in vehicle safety systems, effectively combining innovative techniques to operate reliably in complex driving scenarios and laying the foundation for reducing accidents and improving road safety.