Automating Wrong-Way Driving Detection Using Existing CCTV Cameras

tech transfer summary

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RESEARCH PROJECT TITLE
Automating Wrong-Way Driving Detection Using Existing CCTV Cameras

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This project investigated and evaluated different methods of using data from existing highway traffic surveillance CCTV cameras to automate real-time detection and email reporting of wrong-way driving.

Background and Problem Statement

A high percentage of wrong-way driving (WWD) crashes are fatal or near-fatal. According to federal and state crash data, 20 to 25% of crashes from WWD events are fatal. This percentage is significant compared to the 0.5% fatality rate for all vehicle crashes. The fact that these crashes often involve head-on crashes at high speeds makes these crashes one of the most severe types of crashes.

Goal

The goal of this project was to detect WWD using only closed-circuit television (CCTV) traffic surveillance cameras on a real-time basis with no need to manually pre-calibrate the cameras.

Objective and Requirements

The objective of this project was to detect WWD events on Iowa highways in 10 different locations. When WWD events were detected, the system would record the violation scene and send the video file via email to any recipient in charge of appropriate reactions for the event.

These were the requirements for the system:

- Detect any WWD event from AMTV18, AMTV19, and WWD cameras during the daylight hours and be able to be implemented on all cameras in the state
- Work in a real-time manner
- Record the violation scene when detecting any WWD event
- Send an email to the responsible operator and attach the recorded scene as soon as any WWD event is detected
- Be independent of any operator during the work, detect any changes in camera direction, and automatically react

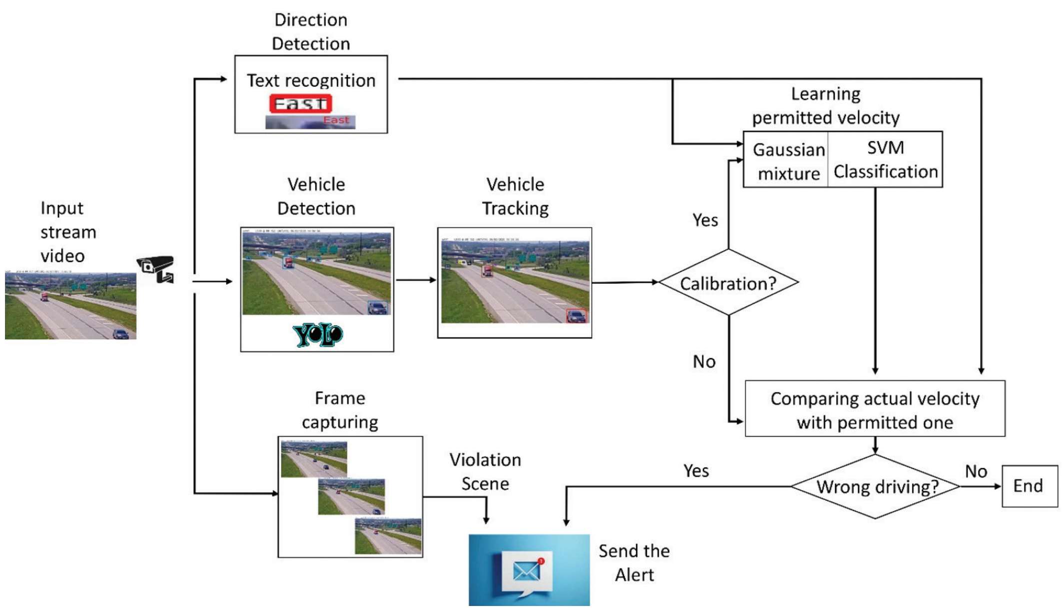
Sample output from DeepStream model where DeepStream does both vehicle detection and tracking

Research Description

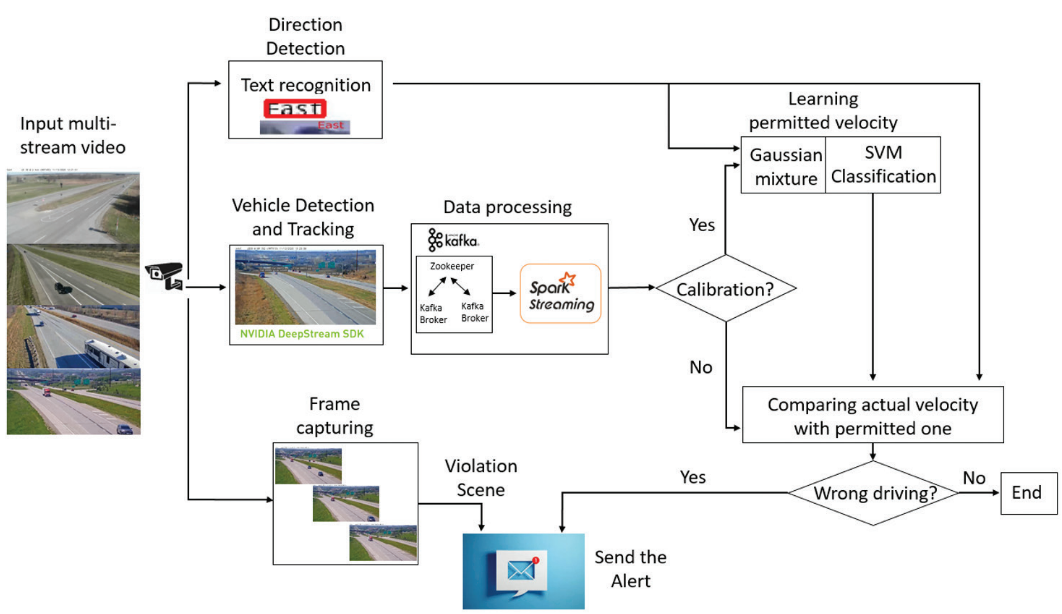
For this project, the researchers proposed a fully automated algorithm to detect WWD events using a CCTV camera dataset without any need to pre-calibrate the camera. In this algorithm, data from the camera were analyzed to detect all vehicles and track them. Then, by gathering information from the camera, the algorithm was trained to understand the two sides of the roadway and the correct travel direction for each side. Finally, by comparing the velocity of the vehicles with the permitted velocity for the roadway, the algorithm can judge whether or not a vehicle is driving on the right side of the roadway.

To perform all of this and compare and contrast two different software solutions, the researchers implemented two different pre-trained models to detect and track the vehicles. One used You Only Look Once (YOLO), which is a state-of-the-art, real-time, object detection system, as the detector and Simple Online and Realtime Tracking (SORT) as the tracker. The second was implemented using DeepStream as the detector and tracker.

In this study, the researchers calibrated 10 different cameras and tested the performance of the model on those 10 data streams.



Flow of the fully automated wrong-way driving detection system when YOLOv3 acts as the detector with SORT as the tracker



Flow of the fully automated wrong-way driving detection system when DeepStream produces detection and tracking results

Key Findings

The researchers implemented the two models on a real world dataset, as detailed in the final report for this project along with the results. Suffice it to say, the researchers strictly tuned the YOLO+SORT model, and, as a result, it captured lots of regular events as WWD events (false positives), drastically reducing the precision of the model. Due to the more reliable tracking using the DeepStream model, the researchers were able to strike a nice balance between parameters using that model.

Final results of two models compared

Model	Precision	Recall
YOLO + SORT	0.75	0.96
DeepStream	0.99	0.97

Implementation Readiness and Benefits

A deep learning model was implemented to detect and track vehicles, and a machine learning model was trained to classify the roadway into different directions and extract vehicle properties for further comparisons. The main innovation of this work was training a model to learn the correct driving direction after each movement of the camera to provide a model to automatically re-calibrate itself as needed, rather than needing to re-calibrate each camera.

The model is also able to create a video of the WWD event based on the related frames for the last 20 seconds. This video is automatically attached to an email message that can be sent to all recipients in charge for further actions.

Implementation Recommendations and Economic Analysis

The researchers used a GeForce GTX 1080 graphics processing unit (GPU) to run the model on a local machine. With increasing suppliers of cloud computing, it would be a good idea to move the computation to the cloud and store the results and saved data there to provide them for other use cases. Both saved images and tracking results can be used for other applications such as incident detection and congestion detection. It would be more efficient to run that part of the model once and share it for all other modules that need these data.

Iowa has 390 operating traffic surveillance cameras on the road network. Turning all of the surveillance cameras into connected smart sensors would cost $1,601.40 per month using a cloud-enabled system, with the benefit of eliminating additional infrastructure costs.

The last chapter of the final project report provides an economic assessment regarding the expenses of running DeepStream on 160 cameras to give an estimate of the average cost of running the model on most of the existing highway traffic surveillance cameras in Iowa. The daily operating cost for 160 cameras was $21.59 with the sustained use discount (assuming such a traffic video analysis framework would be operating for the long term).

The GPUs and vCPUs are the two major costs, which made up 46.4% and 19.7%, respectively, of the total cost, while the persistent storage, network, and random access memory (RAM) together made up 33.9% of the total cost. Thus, the daily cost of the proposed framework for each camera was $0.135, leading to the yearly cost per camera of $49.30.