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Automating Near-Miss Crash Detection Using Existing Traffic Cameras

tech transfer summary

Automatic anomaly detection algorithms that use data from existing traffic cameras can help agencies determine traffic conditions and identify incidents in real-time.

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RESEARCH PROJECT TITLE
Automating Near-Miss Crash Detection Using Existing Traffic Cameras

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Objective

This study had two objectives related to the detection of freeway traffic anomalies from traffic cameras:

- Detect traffic congestion from camera images
- Detect traffic incidents from camera videos using semi-supervised learning

Background

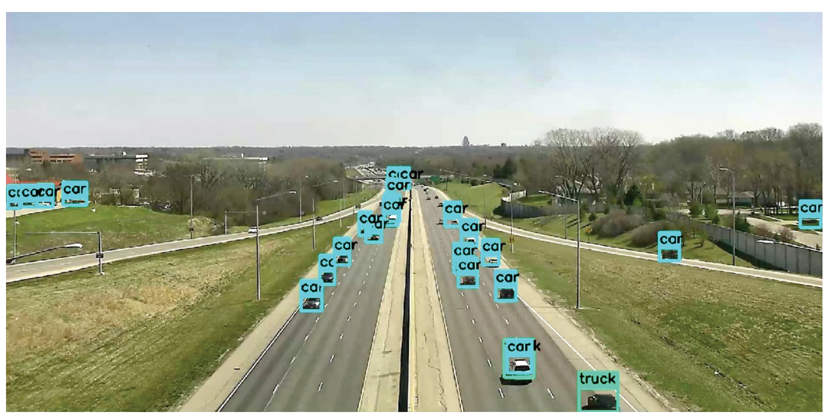
Early detection of traffic anomalies is crucial for reducing non-recurrent traffic congestion caused by unexpected events such as traffic incidents or stalled vehicles.

Incident detection times have decreased significantly in recent years, especially in urban areas, due to the widespread use of mobile phones and the large number of closed-circuit television (CCTV) cameras that state departments of transportation (DOTs) have installed on freeways.

However, the scalability and reliability of incident detection is often hindered by its reliance on either calls from people directly involved in the incidents or manual inspection of data from hundreds of traffic cameras.

Problem Statement

When automatic anomaly detection algorithms are used to monitor the images and videos from existing traffic cameras, anomalies can be identified within seconds. Therefore, an opportunity exists for robust automatic anomaly detection algorithms that use data from traffic cameras.



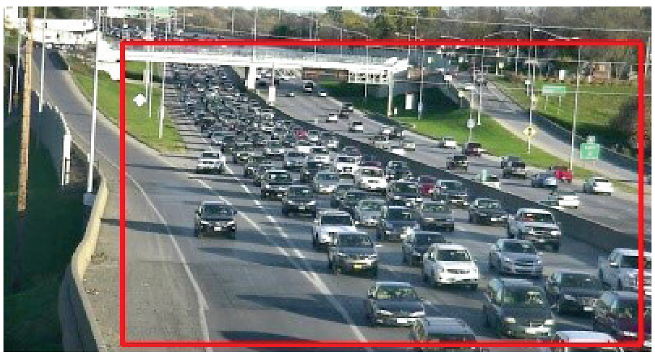
Vehicles detected from a camera video

Such algorithms must be able to account for frequent camera movements and the sometimes poor performance of cameras in nighttime or adverse weather conditions. State-of-the-art deep learning-based object detection and tracking algorithms can address these challenges.

Research Description

Detecting Traffic Congestion from Camera Images

For the first research objective, camera images captured from different locations and orientations and in different weather conditions were used to detect traffic congestion. Camera images captured from October 2016 through March 2017 (six months) were obtained from 121 Iowa DOT CCTV cameras across Iowa's freeways.



Traffic congestion identified from a camera image

Two modern deep learning techniques, the traditional deep convolutional neural networks (DCNNs) and you only look once (YOLO) models, were used to detect traffic congestion from the camera images. Because these models require time-consuming and costly graphics processing unit (GPU) training, a shallow learning model, the support vector machine (SVM) model, was also used as a comparison to determine the advantages of the deep learning models.

To eliminate the time-consuming task of manually labeling congested images and to ensure uniformity in labeling, Wavetronix sensors near each camera were used to correctly identify congested images. For testing purposes, each image was also labeled manually to remove misclassifications due to sensor errors.

Receiver operating characteristic (ROC) curves were used to determine the sensitivity of the models to different camera configurations and light conditions.

Detecting Traffic Incidents from Camera Videos

For the second research objective, a semi-supervised learning approach was used to classify vehicle trajectories and detect traffic incidents from CCTV videos. The video data consisted of 151 traffic incident videos recorded from January 2016 through December 2017 (24 months) by Iowa DOT CCTV cameras along Iowa's freeways.

Maximum likelihood estimation-based contrastive pessimistic likelihood estimation (CPLE) was used to identify and classify incident trajectories. Vehicle detection was performed using state-of-the-art deep learning-based YOLOv3, and the simple online real-time tracking (SORT) method was used to track trajectories. The trajectories were then classified into incidents and non-incidents using a semi-supervised classifier.

The performance of the CPLE-based framework for trajectory classification was compared to that of two baseline semi-supervised methods, self learning and label spreading, and its supervised counterpart.

Key Findings

Detecting Traffic Congestion from Camera Images

- The YOLO model achieved the highest accuracy in terms of correctly classifying images with traffic congestion (91.2%), followed by the DCNN model (90.2%) and the SVM model (85%).
- The accuracy of the models was affected by congestion regions located far away from the cameras, single-lane blockages, and glare.
- All of the models performed well in daytime conditions, but nighttime conditions affected the accuracy of the vision system.
- For the two deep learning models, the areas under the ROC curves (AUCs) were found to be greater than 0.9 under all conditions, which indicates that these models performed well in challenging weather and lighting conditions.
- With a test time of 0.01 seconds per image, the deep learning models can be used to detect traffic congestion using approximately 1,000 cameras at an interval of every 10 seconds using a single graphics processing unit (GPU).

Stalled vehicle detection from a camera video

Detecting Traffic Incidents from Camera Videos

- The object detection and tracking method used to identify traffic incidents from camera videos ran at about 55 frames per second (fps), making it suitable for real-time performance.
- The CPLE-based trajectory classification method outperformed the traditional semi-supervised methods (self learning and label spreading) and its supervised counterpart by a significant margin.

Recommendations for Future Research

The overall framework developed in this study—including the methods for detecting traffic congestion from images and traffic incidents from videos—can be extended to operate on a network of cameras to improve incident detection rates and reduce false alert rates. Integrated detection-and-tracking algorithms can also be explored to enable better trajectory estimation and thereby improve the accuracy of incident detection.

Implementation Readiness and Benefits

The YOLO and DCNN deep learning models for detecting traffic congestion from camera images classified congestion accurately and performed well in challenging conditions. The CPLE-based method for detecting traffic incidents from camera videos also performed well.

While the proposed framework can run at about 55 fps, making it suitable for real-time applications, extensive research needs to be done for this framework to be implemented at a statewide level involving hundreds or thousands of cameras.