MIDWEST TRANSPORTATION CENTER MTC

Vision-Based Traffic Conflict Detection of Signalized Intersections

tech transfer summary

September 2018

RESEARCH PROJECT TITLE
Vision-Based Traffic Conflict Detection of Signalized Intersections

SPONSORS
Midwest Transportation Center
U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology

PRINCIPAL INVESTIGATOR
Anuj Sharma, Research Scientist
Center for Transportation Research and Education
Iowa State University
515-294-3624 / anujs@iastate.edu

MORE INFORMATION
intrans.iastate.edu

MTC
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

The Midwest Transportation Center (MTC) is a regional University Transportation Center (UTC). Iowa State University, through its Institute for Transportation (InTrans), is the MTC lead institution.

MTC's research focus area is State of Good Repair, a key program under the 2012 federal transportation bill, the Moving Ahead for Progress in the 21st Century Act (MAP-21). MTC research focuses on data-driven performance measures of transportation infrastructure, traffic safety, and project construction.

IOWA STATE UNIVERSITY
Institute for Transportation

A new, robust traffic detector was developed to work in dynamically-changing and naturalistic, real-world settings while simultaneously recognizing multiple objects of interest in pre-crash scenarios.

Problem Statement

Automated interpretation and understanding of the driving environment using image processing is a challenging task, as most current vision-based systems are not designed to work in dynamically-changing and naturalistic real-world settings while simultaneously being tasked to recognize multiple objects of interest, such as traffic signs, cars, traffic signals, etc.

Background

Inappropriate driver maneuvers, distracted driving, and aggressive driver behaviors are believed to account for the majority of crashes on roadways (Liang et al. 2012). An accurate understanding of these behaviors, which may lead to an increased risk of traffic incidents, requires the careful study of driving in a naturalistic, real-world setting.

In recent years, a number of naturalistic driving studies have been conducted to acquire more accurate pre-crash causal information and details regarding the frequency of these crash-contributing factors in normal driving. However, data captured during these studies consists of very large, low-resolution videos recorded from vehicles traversing different types of intersections, under varying levels of congestion and lighting conditions.

To maximize the use of this valuable safety dataset, vision systems with a high-level of understanding of scene dynamics around the naturalistic driver must be developed.

Goal and Objectives

The goal of this study was to develop a vision system with the ability to capture the dynamics of the driver in a naturalistic setting. The research objectives were as follows:

- Explore the use of both deep learning and multi-scale decomposition as viable approaches for automating the detection and classification of objects in understanding pre-crash causal factors
- Test the new, robust, and efficient detector and compare performance with current state-of-the-art detectors

Research Description

With a focus on naturalistic videos of traffic signs in the US, the researchers used data from the Second Strategic Highway Research Program (SHRP2) to conduct the experiments in this study.

By using both top-down and bottom-up approaches to the deep learning and multi-scale decomposition methods, the researchers garnered insights into the strengths and drawbacks of each, paving the way for testing their detector (named Shape-ACF), which incorporates aggregate channel features or ACF-based detection with a shape descriptor.

Research Methodology

The researchers collected and annotated an additional dataset from the SHRP2 naturalistic driving study—the first dataset of its kind with elaborate classes and annotations. In total, 17 different object classes were annotated and classified into four main groups:

- Traffic information signs
- Speed limit signs
- Vehicles and tail brake lights
- Traffic signal status

The test set data were drawn from videos of 37 distinct trips on signalized and non-signalized routes, with a total footage of about 2 hours. Although the test set was mostly randomly selected, videos containing trips on both types of routes, at different times of day, in changing weather conditions, and at varying video resolutions were purposely included.

A novel multi-scale decomposition method was proposed and compared to the researchers' customized deep-learning architecture. Further experiments were done to obtain insights for future study, including a performance comparison of the proposed method (in terms of accuracy and processing time) with two other detectors: a pure ACF-based detector and R-CNN based detector.

Key Findings

The actual precision of the proposed vision system varied by category of traffic object. For instance, the status of traffic lights, cars, and vehicle brake lights were detected at a precision rate of about 85%. The precision rate fell to about 80% and 70% for traffic signs and speed limits, respectively.

Overall, the proposed system provided the highest true positive rate for lower false positive values while performing much faster than the other two detectors examined.

- The average precision for traffic sign recognition was about 70%. Pedestrian Crossings and Signal Ahead traffic signs had the lowest precision rates compared to all other road traffic signs in the database inventory. These two signs had high false positive responses (especially in poor weather conditions) because the system confused them with other road signs such as Merge and Added Lane, which also have a noticeable yellow background color and similar geometric structure.
- The precision rates for all speed limit signs were mostly similar (about 80%), with the exception of Speed Limit signs for 25 and 35 miles per hour (mph). These two signs were found to be very difficult to distinguish, especially in bad weather or in low resolution images. About a fourth of all detection for 25 mph speed limit signs was actually for speed limits of 35 mph.
- At signalized intersections, the most crucial class of objects needed to evaluate driver behavior and safety includes cars, traffic light status, and vehicle brake lights. The precision rates for these classes of objects differed by time of day, as the precision rate fell by about 20% at night. For example, vehicle brake lights are more easily detected at night.
- The experimental results show the promise of the proposed system, which provided the highest true positive rate for lower false positive values and a faster performance compared to the two other state-of-the-art detectors.
- The Shape-ACF detector was especially useful when performing traffic sign detection on mobile devices with limited processing capabilities. But, the R-CNN based detector still provided higher accuracy on special processors such as graphical processing units, especially when the false positive rate was slightly increased because of detector performance.

Implementation Readiness and Benefits

The results of the proposed vision system could be used to better understand baseline driving behaviors (i.e., driver performance and trip characteristics), identify risk factors that contribute to hazardous situations, and improve the ability to develop safety countermeasures for road design.

Ultimately, the proposed vision system provides appreciable levels of performance for the task at hand (i.e., successfully automating the detection of objects in a naturalistic driving setting). Additionally, the detector can be used to gather additional information about vehicle surroundings that is currently not available in the naturalistic driving study data or through the SHRP2 roadway information database.

Recommendations for Future Research

One important gap that was not covered in this study is evaluation of the influence of detected objects on driver behavior. For example: What is the relative distance of a detected object from the participating vehicle, and which types of traffic conflicts are prevalent at signalized intersections?

Future studies in this direction will require fusing outputs of the vision system with other auxiliary datasets such as global positioning system (GPS), laser, and accelerometer readings for each participating vehicle.

Reference

Liang, Y., J. D. Lee, and L. Yekhshatyan. 2012. How Dangerous Is Looking Away From the Road? Algorithms Predict Crash Risk From Glance Patterns in Naturalistic Driving. *Journal of the Human Factors and Ergonomics Society*, Vol. 54, No. 6, pp. 1104–1116.