Fernando García Fernández and Zhixiong Li, Editors

EDITOR'S NOTE

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Real-Time Safety and Mobility Optimization of Traffic Signals in a Connected Vehicle Environment

Mohamed Essa

Abstract

Adaptive traffic signal control (ATSC) strategies are a promising approach to improving the efficiency of signalized intersections, especially in the era of connected vehicles (CVs), where real-time information about vehicle positions and trajectories is available. Recently, numerous ATSC algorithms have been proposed to accommodate real-time traffic conditions and optimize traffic efficiency. The common objective of these algorithms is to minimize total delays and maximize vehicle throughputs. Despite their positive impacts on traffic mobility, existing ATSC algorithms do not consider optimizing traffic safety. This is most likely due to the lack of tools to evaluate the safety of signalized intersections in real time.

This thesis presents several advances toward the real-time safety and mobility optimization of traffic signals in a CV environment. First, new models for the real-time safety evaluation of signalized intersections were developed and validated, using traffic video data from six locations in two Canadian cities. The developed models relate the number of traffic conflicts, as a surrogate safety measure, to dynamic traffic parameters at the signal cycle level. Several traffic conflict indicators and multiple conflict severity levels were considered. The transferability of the developed models was also investigated and confirmed using additional traffic data sets for two corridors in the United States.

Second, a new procedure to integrate the developed real-time safety models with traffic microsimulation models was proposed. The procedure was validated using real-world traffic video data from two signalized intersections in British Columbia. The results showed that the proposed models can predict conflicts from traffic simulations with reasonable accuracy and be used to investigate the safety impact of various CV-based applications before field implementation. Third, a novel self-learning ATSC algorithm to optimize traffic safety using real-time CV data was proposed. The algorithm was developed using the reinforcement learning approach, trained through a microsimulation model, and validated with real-world traffic data from two signalized intersections in British Columbia. Superior to the traditional actuated signal control system, the proposed algorithm showed positive safety and mobility impacts. The proposed ATSC algorithm was also found to be effective and feasible even under low market penetration rates of CVs.

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Scene Understanding and Map Maintenance for Autonomous Vehicle Applications

Julie Stephany Berrio Perez

Abstract

Two of the main challenges to enabling vehicles to operate autonomously on urban streets are scene understanding

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and long-term localization. This thesis addresses both of these topics. A probabilistic sensor data fusion approach is presented to improve comprehension of the surroundings. A pipeline is presented to maintain a localization map, ensuring that it remains up to date by adding and rehmoving elements as the environment changes. To plan and execute accurate driving maneuvers, a high-level understanding of the surroundings is essential. The fusion of sensor information can overcome the shortcomings of each sensor. This thesis addresses the common, yet challenging, lidar/camera/semantic fusion problems, which are seldom approached in a wholly probabilistic manner. This approach is capable of using a multisensor platform to build a 3D, semantic, voxelized map that considers the uncertainty of all processes involved.

For autonomous vehicles to operate persistently in an urban environment, it is essential to have high-accuracy position information. A localization approach based on a single-survey map will not be suitable for long-term operation, as it does not account for variations in the environment through time. This thesis presents new algorithms to maintain a featured-based map. A map maintenance pipeline is proposed that can continuously update a map with the most relevant features, taking advantage of changes in the surroundings. This thesis introduces a large-scale and long-term data set, the USYD Campus Data set. An equipped vehicle with multiple sensors was driven around the University of Sydney campus weekly for more than a year. The data set covers local information, which consists of diverse illumination conditions, seasonal variations, structural changes, and traffic volumes. This data set was used to test and evaluate the developed algorithms in this thesis.

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One of the central contributions of the thesis is the extension of the faster R-CNN framework to estimate the orientation of detected objects based exclusively on appearance information.

Convolutional Neural Networks for Joint Object Detection and Pose Estimation in Traffic Scenes

Carlos Guindel Gomez

Abstract

Few any longer question that autonomous vehicles will be a key element of transportation in the coming decades. Reliable perception of the surroundings of a vehicle is today one of the remaining technical challenges that must be addressed to ensure safe autonomous navigation, especially in crowded environments. This functionality usually relies on onboard sensors, which provide data that must be appropriately processed.

Among the different tasks assigned to the perception suite of an automated vehicle, the detection of other road users that can potentially interfere with the trajectory of the vehicle is particularly critical. However, the identification of agents in sensor data is only the first step. Planning and control modules down the pipeline demand trustworthy information about how objects are arranged in space. In particular, the objects' orientation and location on the road plane are usually attributes of the utmost importance to build a purposeful model of the environment.

This thesis aims to provide close-to-market solutions to these issues, taking advantage of the dramatic breakthrough seen in deep neural networks (NNs) in the past decade. The methods proposed in this thesis are built on top of a popular detection framework, the faster region-based convolutional NN (R-CNN), which features high detection accuracy at near real-time rates. Proposals to enhance the performance of the algorithm in images obtained from onboard cameras are introduced and discussed. One of the central contributions of the thesis is the extension of the faster R-CNN framework to estimate the orientation of detected objects based exclusively on appearance information, which makes the method robust against the different sources of error present in traffic environments.

As a natural next step, two algorithms exploiting this functionality to perform 3D object localization are proposed. As a result, the combination of the methods described throughout this thesis leads to a procedure to provide situational awareness of potential hazards in the surroundings of a vehicle. All the proposed methods are analyzed and validated through systematic experimentation using a well-recognized public data set (the KITTI Vision Benchmark Suite), where notable results were obtained. The viability of the implementation of the solutions in a real vehicle is also discussed.

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