DRISI
Caltrans Division of Research, Innovation and System Information

Research Results

Advanced Research

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Vehicle Infrastructure Integration (VII)

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Connected Autonomous Vehicles: Safety During Merging and Lane Change and Impact on Traffic Flow

In this work, several challenges concerning safe autonomous lane changes in congested scenarios were studied.

WHAT WAS THE NEED?

Current autonomous vehicles will not be able to navigate in dense traffic unless they violate safety rules like human drivers do, by cutting in front of other vehicles and putting themselves in dangerous collision spots for short period of time, something no autonomous vehicle will be allowed to do by design.

The purpose of this project was to research how proven technologies such as Vehicle to Vehicle (V2V) communications can be used in negotiating safe maneuvers of autonomous vehicles during lane change and merging in a way that safety is guaranteed and the impact on traffic flow is minimized.

WHAT WAS OUR GOAL?

The goal of this project was to propose applicable solutions to the problem of autonomous lane changing in a highway scenario with connected vehicles.

WHAT DID WE DO?

In this work, several challenges concerning safe autonomous lane changes in congested scenarios were studied. The solution to address safety and efficiency simultaneously was based on vehicle communication and cooperation. The first step was to define what constituted a safe gap for lane change. Besides relying on previous results of safe vehicle following and lane change kinematics, a conservative assumption was made to define a constant maximum braking during lane change.

The main advantage of this method was seen when this larger spacing request was seamlessly included in the longitudinal vehicle controller. Concerning communication, a protocol was proposed that detailed the information that vehicles should exchange and how to avoid conflicts.

After reviewing works on the Dedicated Short Range Communication (DSRC) standard and its performance, it was concluded that the protocol could be implemented. The ego vehicle (E) monitoring its surrounding vehicles is shown in Image 1. Arrows indicate sensor measurements, an antenna indicates the vehicle is communicating, and the thought bubble represents E's internal model of the other vehicles - leader in the destination lane (Ld), follower in the destination lane (Fd), and leader in the original lane (Lo).

Analysis was done on how to expand safety spacing requirements and communications to platoons of vehicles. The solution was based on three strategies: Synchronous, Leader First, and Last Vehicle First, which could ensure the platoon remains together after the lane change. A platoon of vehicles waiting for the expected safe gaps for lane change is shown in Image 2.

Next, the uses of physical and analytical redundancies were examined to verify if the requested gaps were indeed created. The proposed methodology compared several measurements and internal model predictions to check for consistency and identify possible system faults. It also defined the severity of each failure and when the driver would be asked to take control. Then, control policies were developed that enabled lane changes in the most congested scenarios while satisfying the strict safety requirements. A flowchart of the failure verification procedure for each surrounding vehicle is shown in Image 3. After confirming the expected behavior from controllers, VISSIM simulations were used to assess impacts on traffic flow and the environment.

WHAT WAS THE OUTCOME?

With no control, vehicles wait for a proper lane change space, and when they find one, they force large decelerations on the destination lane. With control, the traffic flow gets smoother since vehicles can perform lane changes before being forced to a full stop. This decreases the number of stops and the total travel time. Consequentially, fuel consumption and pollutant emission rates are also lowered. The gains in efficiency are corroborated by a deeper study of individual lanes' densities and flows.

These experiments also enabled to compare the efficiency of the three proposed platoon strategies. Leader First strategy, on average, is established as the best. However, the Last Vehicle First option is advantageous if one wants to minimize the discomfort of the vehicle creating the gap. After confirming the expected behavior from controllers, VISSIM simulations are used to assess impacts on traffic flow and its results indicate that the developed methods improve both safety and efficiency.

WHAT IS THE BENEFIT?

The results motivate the involvement of the infrastructure and other stakeholder in creating a connected V2V and V2I environment which can be used to develop safer and more efficient operations of autonomous vehicles.

LEARN MORE

The final research report can be accessed from this site:
https://www.metrans.org/research/connected-autonomous-vehicles-safetyduring- merging-and-lane-change-andimpacton-traffic-flow

IMAGES

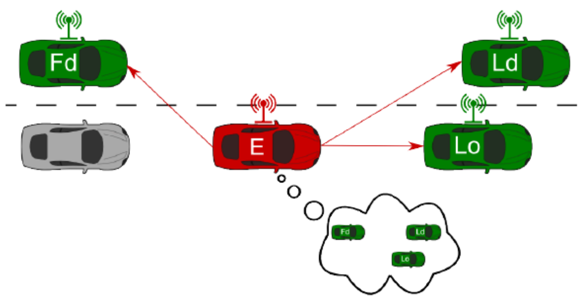

Image 1: Ego vehicle monitoring its surrounding vehicles

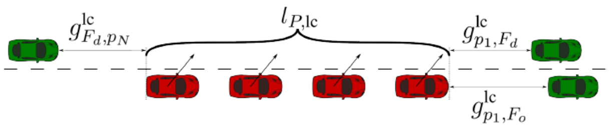

Image 2: The platoon of red vehicles with total length of IP,lc waiting for a proper spacing (gFd,pn, gp1,Fd, gp1,Fo) on the adjacent lane before starting a lance change maneuver

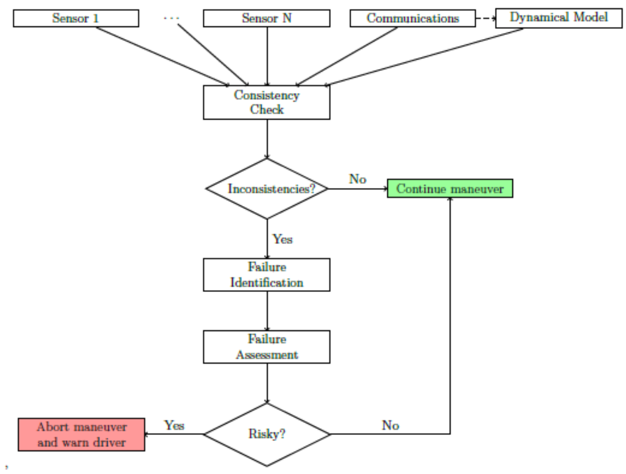

Image 3: Flowchart of verification procedure with N independent sensors