College of Engineering- Center for Environmental Research & Technology

Anticipatory Model for Safer Automated Lane Changes

Nigel Williams, Guoyuan Wu, Kanok Boriboonsomsin, Matthew Barth, Samer Rajab, and Sue Bai
({nwilliams, gywu, kanok}@cert.ucr.edu; barth@ece.ucr.edu; {srajab, sbai}@hra.com)

Abstract

Conventional lane change warning and automated lane changing systems rely on detection by on-board sensors such as camera, radar and ultrasonic sensors. With the advent of Connected and Automated Vehicles, wireless communication (e.g., Dedicated Short Range Communications, or DSRC) becomes another option for sensing the surrounding vehicles. In particular, DSRC does not have the line-of-sight limitation of ranging sensors, and thus can “see” traffic farther ahead, which lends itself well to anticipating the movements of vehicles closer by.

In this paper, we develop an “Anticipatory Lane Change” (ALC) algorithm that uses such anticipation to predict whether a desired lane change will result in an unsafe situation, and prevents the lane change if that is the case. This algorithm is useful for both lane change warning assistance and automated lane change function. To evaluate the effectiveness, we first coded the algorithm with an Application Programming Interface (API) in PTV VISSIM, a microscopic traffic simulator, using the network of a freeway segment that has been well calibrated with real-world traffic data during rush hour. Then, the system performance in terms of safety was estimated by the Surrogate Safety Assessment Model (SSAM) under a variety of traffic scenarios (different congestion levels and penetration rates of application). Preliminary tests showed that the proposed algorithm can reduce the number of traffic conflicts by up to 30%, with smaller reductions at lower percentages of application-equipped vehicles, and lower traffic volumes.

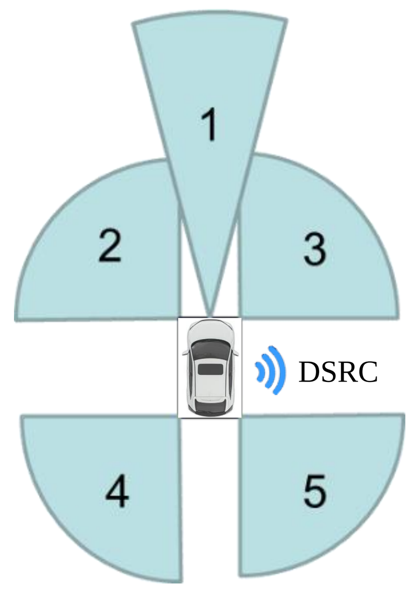

Figure 3. Field-of-view and relative range of HV’s radars

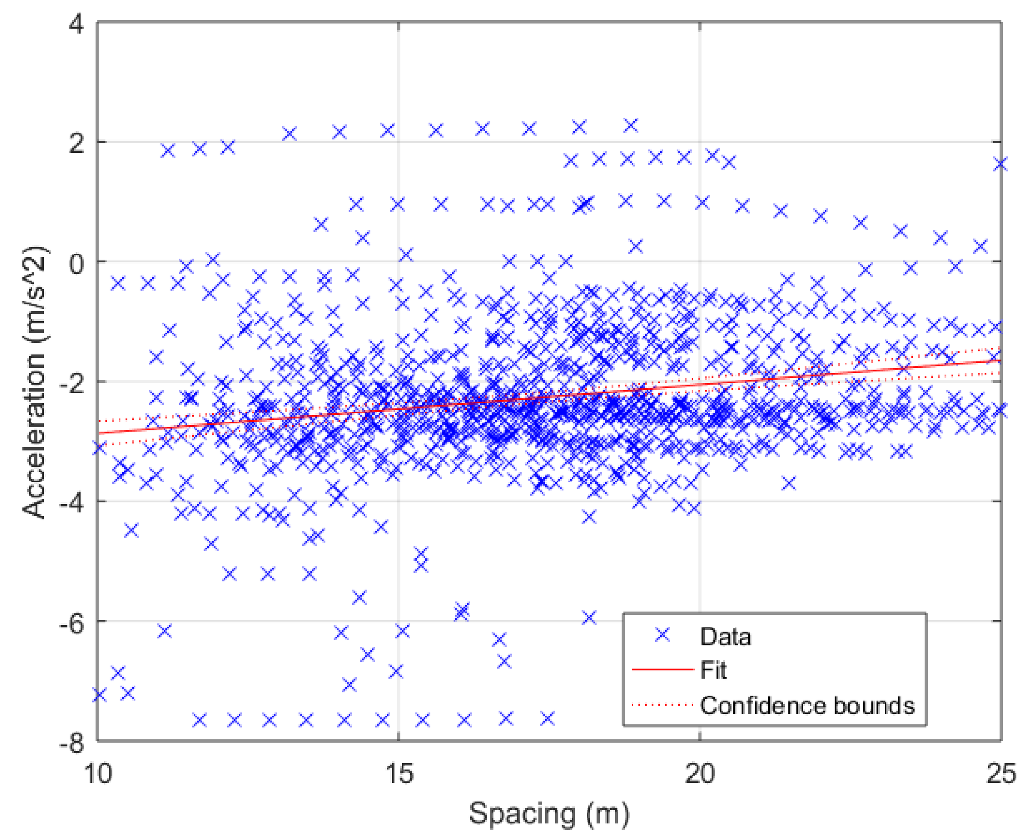

Figure 4. Example acceleration vs. spacing plot

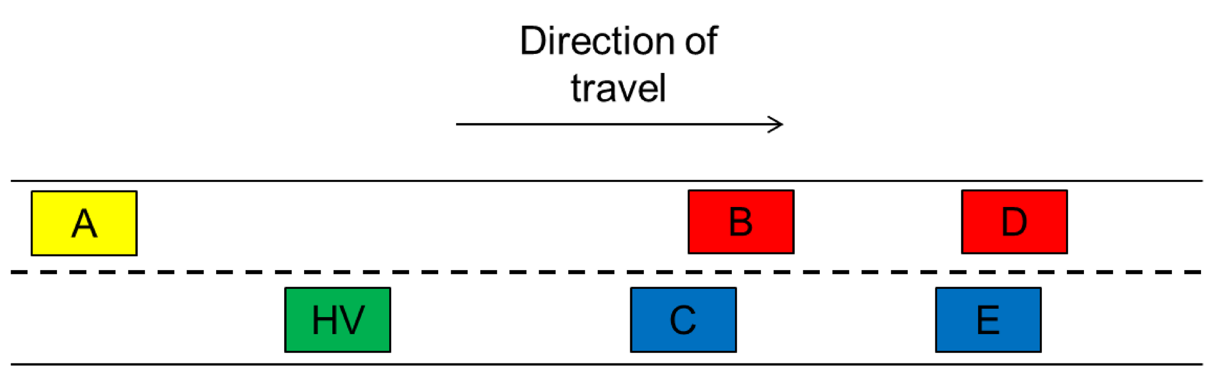

Figure 1. Pre-lane change situation (HV = lane-changing vehicle)

TABLE 1. Simulation settings

Simulation Network	Length	Lanes	Traffic level(s) tested	Simulation Time	Curvature?	On/off ramps
Hypothetical freeway segment	1 mile	3	Medium, Heavy	1 hour	No	None
Interstate 270 in Columbus, Ohio	17 miles	3-5	Heavy	2 hours	Yes	9 pairs

Simulation Study

- VISSIM traffic microsimulation software was used to test the algorithm’s effect on traffic-level safety and mobility
- Safety benefits evaluated using FHWA’s Surrogate Safety Assessment Model [1]
- Two simulation networks were used: a hypothetical freeway segment and a real-world freeway segment (***Table 1***)
- For each scenario (combination of traffic volume and application penetration rate): 10 simulation runs conducted with the application, 10 runs without

Results:

- In heavy traffic, safety benefits tend to increase with application penetration rate (***Figure 5***). The median change in number of conflicts is approximately -30% at 100% penetration rate, for both networks.
- No effect on safety in medium traffic (few conflicts to begin with)
- Little effect on mobility at both traffic levels (<1% change in average speed of the network)

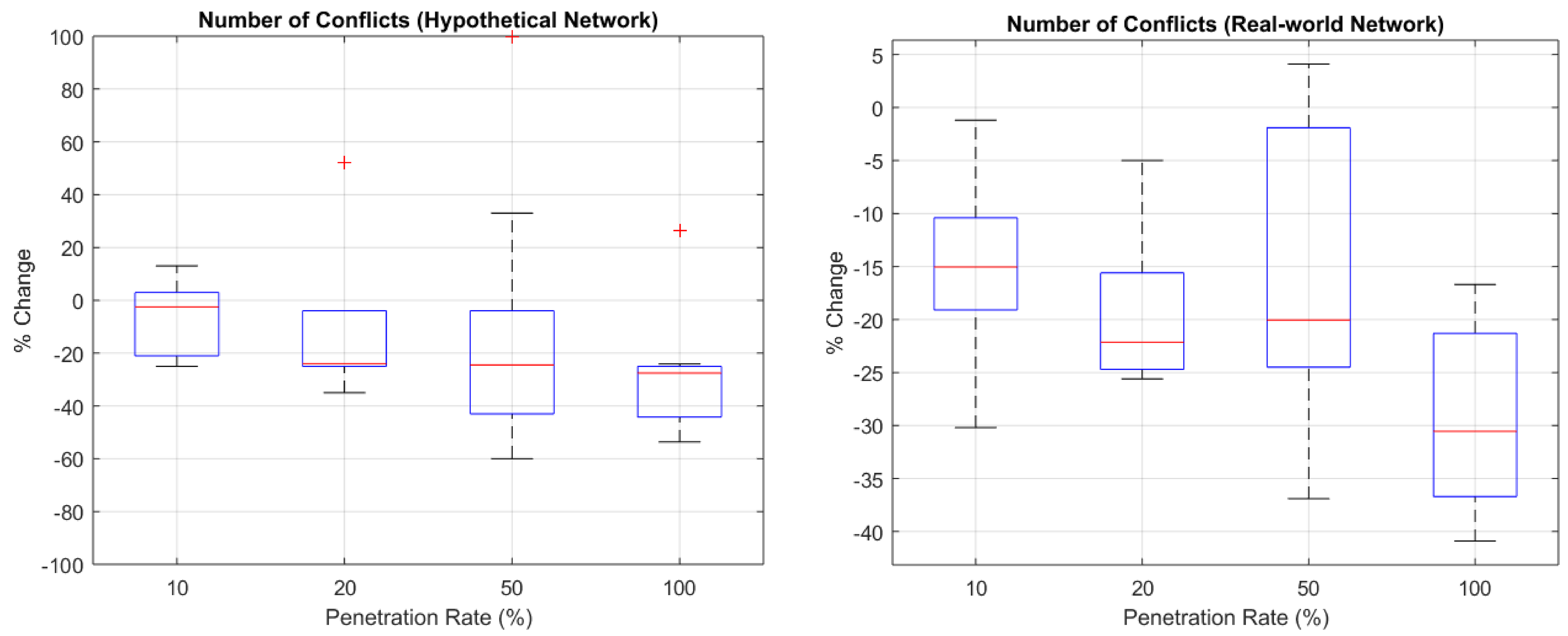

Figure 5. Safety benefits in hypothetical network (left) and I-270 (right)

Algorithm

The algorithm flowchart is shown in ***Figure 2***, with vehicle positions defined in ***Figure 1***. Specifically, Vehicles B and A are the vehicles ahead of and behind the ego vehicle, or “host vehicle” (HV), in the target lane; Vehicle C is the vehicle preceding the HV; and Vehicles D and E are the vehicles ahead of B and C.

The starting condition is that the HV wishes to change lanes. After this, the first check is whether the lane change is discretionary (e.g., changing to a faster lane) or mandatory (e.g., changing lanes to exit the freeway). The next steps in the algorithm are described below.

Vehicles A-E must all be detected by HV:

- The HV is equipped with 4 corner radars, 1 front radar, and DSRC (or similar wireless communication technology). ***Figure 3*** shows the layout of the radars.
- For Vehicles A-C to be detected, they must be within range of HV’s radar.
- Vehicles D and E must be equipped with DSRC.

The motions of all 6 vehicles are predicted over the next three seconds:

- An empirical car-following model is used to predict acceleration in the next second based on current speed, relative speed of preceding vehicle, and inter-vehicle spacing. ***Figure 4*** shows an example of how acceleration can be derived as a function of spacing (given a certain speed bin and relative speed bin).
- From acceleration, velocity and position are calculated using kinematics integration.

If the predicted headway ahead or behind HV at the end of the three-second window is less than 2 seconds, the algorithm delays the lane change.

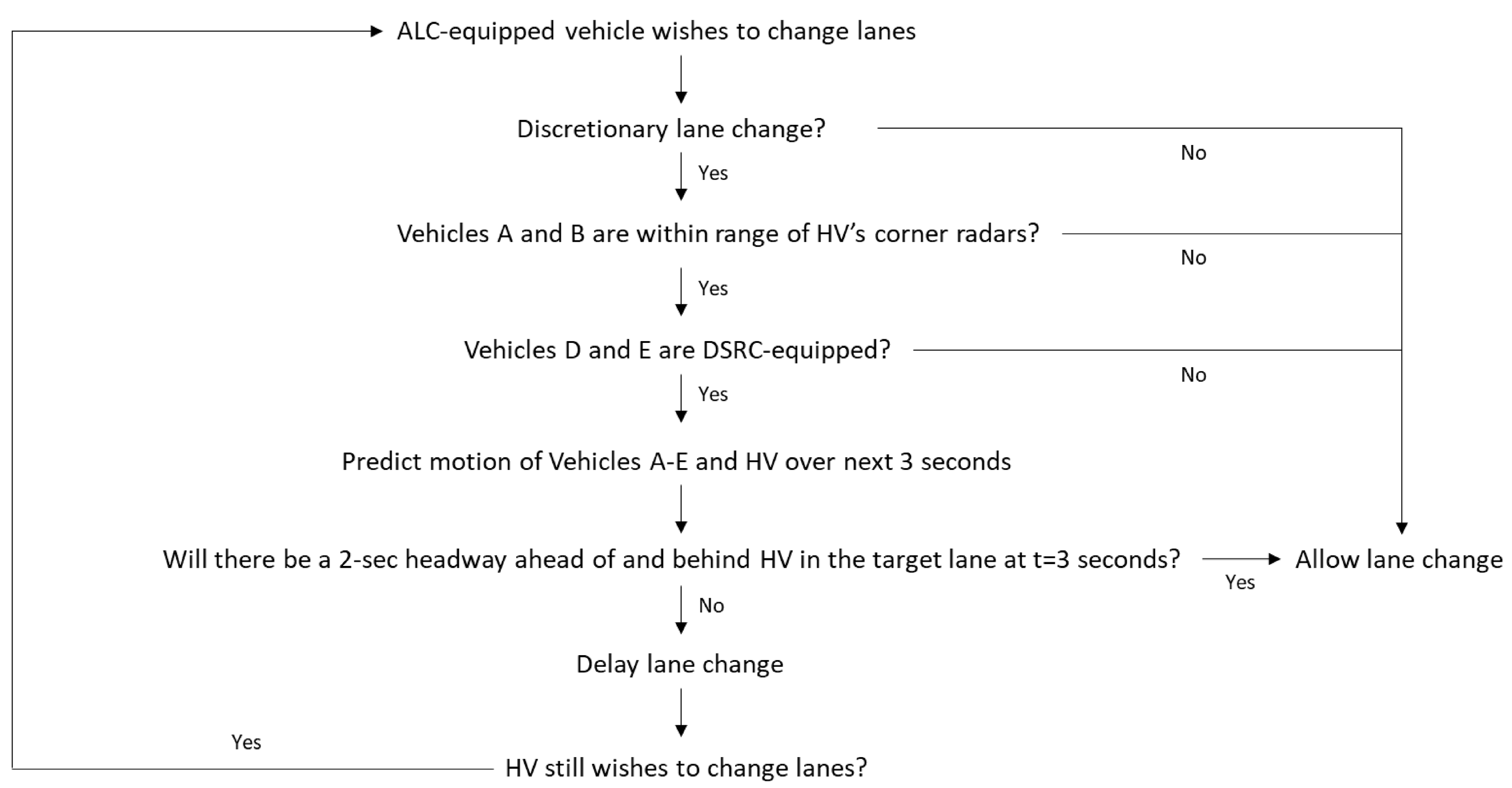

Figure 2. Algorithm Flowchart

Conclusions and Future Work

- Designed an algorithm that uses anticipation of surrounding vehicles’ movements (based on the data of vehicles farther ahead) to predict whether a desired lane change will result in an unsafe situation.
- The application was simulated on two freeway networks in Vissim. The results suggest that the application can reduce the number of potential conflicts by up to 30%, with little impact on mobility. In general, the higher the percentage of application-equipped vehicles, the greater the safety benefits.
- Further research can refine the prediction method and examine the safety benefits for application-equipped vehicles only (should be higher than for unequipped vehicles).

References

[1] FHWA (2008). “Surrogate Safety Assessment Model and Validation”, Tech Brief of Final Report, FHWA-HRT-08-049.

Acknowledgements

This research was funded by Honda R&D Americas, Inc.