Title

Developing and Simulating Pedestrian-Related Corner Case Scenarios for Autonomous Vehicles Testing

Tony (Yoon-Dong) Lee[b], William Wang[b], Jonathan DeCastro[c], Shan Bao[a,b]*

(a) Industrial and Manufacturing Systems Engineering Department, University of Michigan-Dearborn, 4901 Evergreen Rd, Dearborn, MI 48128
(b) University of Michigan Transportation Research Institute, 2901 Baxter Rd, Ann Arbor, MI, USA, 48109-2150
(c) Toyota Research Institute, One Kendall Square, Cambridge, MA, USA 02139

Keywords

Pedestrian, Corner Case, Autonomous Vehicle, Naturalistic Driving Data

Introduction

Pedestrian safety has become an increasing societal concern, especially with the increase of pedestrian fatalities[1] and rapid development of automated vehicle technologies. Given the complexity of the real-world environment and the variability of pedestrians' behaviors, it is crucial to test the self-driving technologies in extensive amount of pedestrian-related corner cases. The purpose of this study is to identify crash scenarios for pedestrians, develop pedestrian-related corner cases by utilizing the naturalistic driving study data and using the modeling software to generate repeatable test scenarios for autonomous vehicle testing.

Methodology

Pedestrian-related corner cases were developed using an existing naturalistic driving study data – Safety Pilot Model Deployment (SPMD)[2]. In the SPMD study, about 140 vehicles were equipped with a variety of vehicle and environment sensors, and five cameras, among which one camera-based Mobileye system can automatically detect pedestrians in front of the vehicle, as shown in Figure 1 below:

Figure 1: Example of Mobileye detection of pedestrian with video feed

In this study, pedestrian related data identified by 81 SPMD instrumented vehicles' sensors, along with driver demographics information, were firstly queried from SQL database, and then

used in the analysis. The extracted pedestrian events were further categorized into three vehicle driving speed categories – low speed (5 to 25 mph), mid speed (25 mph to 55 mph) and high speed (55 mph or greater). The categorization was based on the residential, rural and highway speed limit in Michigan. Each event was then manually analyzed with the Mobileye video feed to verify pedestrian detection and to classify into corresponding categories (e.g. Type of Intersection/Location, Corner-Case Validity). In this study, corner case was defined as the situations that can be challenging for both human drivers and autonomous vehicles. The corner case of pedestrian events identified from the SPMD analysis were then generated and simulated through the virtual reality technique, Carla software[3], with the parameters tuned based on the real driving data.

Results

A total of 14,613 pedestrian-related events were extracted – 14,121 events in low speed (5-25 mph), 322 events in mid speed (25-55 mph) and 170 events in high speed (55 mph or higher). About 97% of Pedestrian events were detected in the low speed category. For high speed and mid speed categories, most pedestrian events detected by the Mobileye were sensor errors during which other objects such as motorcycles, bicycles or lamp posts were incorrectly recognized as pedestrians.

For low speed category, the correct sensor detection rate reached about up to 99%, and was much higher than for the other two categories. In this analysis, hard braking events was extracted by using a deceleration rate of 0.3g or higher as the selection filter for possible pedestrian-related corner cases. A list of interesting pedestrian-related corner cases were identified from those hard-braking events, such as roundabout blind spot and unexpected pedestrian crossing as shown in Figure 2 below:

Figure 2: Roundabout blind spot (Left) and unexpected pedestrian crossing (Right)

A set of Carla based pedestrian simulation models were further generated that simulate pedestrian's behaviors from those selected corner cases, such as jaywalking, by using the extracted real driving information of the pedestrian, traffic, and road environment. Examples of corner case scenarios simulated in Carla software based on the SPMD real driving data is provided in Figure 3 below:

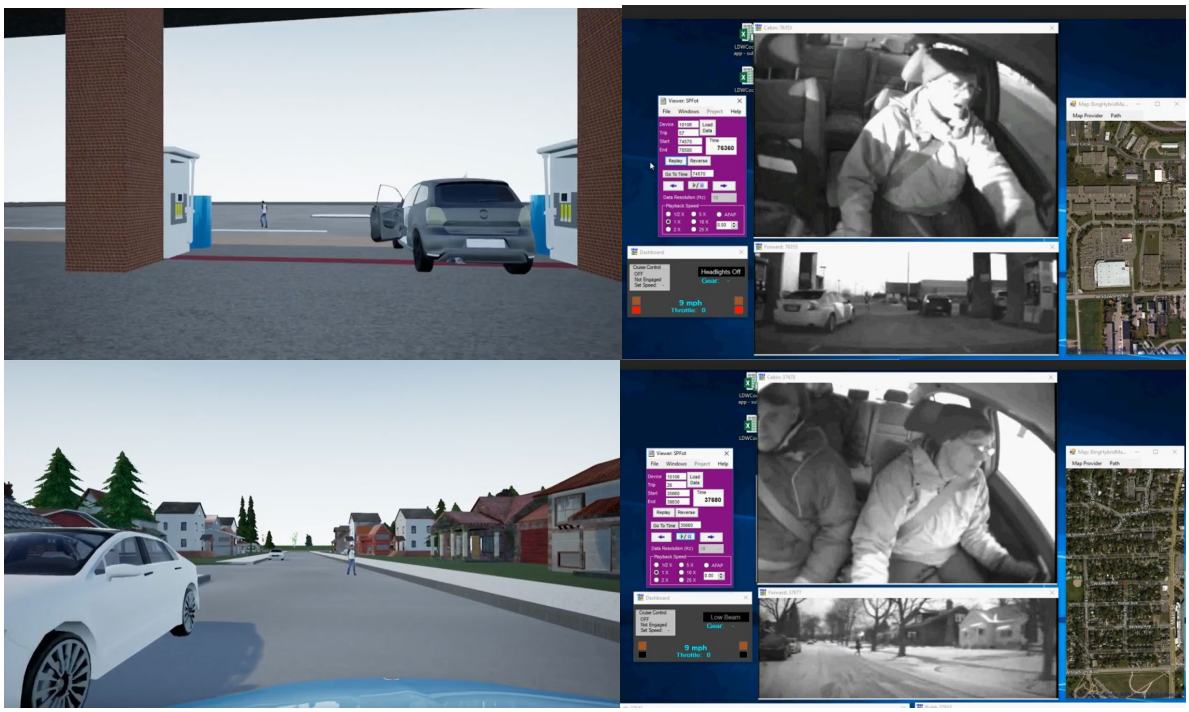

Figure 3: Examples of corner case scenarios simulated in Carla software. At a gas station, pedestrian unexpectedly stepped out from a parked car, while the host vehicle is approaching (Top). In a community neighborhood, a pedestrian is walking in the middle of the street (Bottom).

Conclusion

The work was designed to develop a list of pedestrian corner case events from naturalistic driving data by extracting important features of pedestrians, vehicles, and road environment. From our SPMD naturalistic driving data, 14,613 pedestrian-related events were extract, and the majority occurred at low speed (5-25 mph). Carla based pedestrian-vehicle interaction models were further developed and simulated. Those corner case scenarios and models could be valuable in developing, testing, and benchmarking self-driving cars.

Acknowledgement

Toyota Research Institute ("TRI") provided funds to assist the authors with their research but this article solely reflects the opinions and conclusions of its authors and not TRI or any other Toyota entity.

References

1, National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) Query System (n.d.).(2018) https://www-fars.nhtsa.dot.gov//QueryTool/querysection/selectyear.aspx

2, D. Bezzina, J. Sayer (2015). Safety Pilot Model Deployment: Test Conductor Team Report. (DOT HS 812 171), National Highway Traffic Safety Administration, Washington, DC.

3, Alexey Dosovitskiy, German Ros, Felipe Codevilla, Antonio Lopez, Vladlen Koltun (2017). CARLA: An Open Urban Driving Simulator. Proceedings of the 1st Annual Conference on Robot Learning, PMLR 78:1-16, 2017.