Apr 14th, 12:00 AM - 12:00 AM

# Implementing Virtual Reality Technology for Supporting Autonomous Vehicle-Pedestrian Behavioral and Interaction Research

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## ABSTRACT

The deployment of autonomous vehicles (AVs) has been expected to significantly reshape traffic safety on roads. However, there is still a relatively long journey to achieve high-level autonomy and the safety level of interaction between AVs and vulnerable road users (e.g., pedestrians, cyclists, or passengers) is still unclear due to very limited data and field tests. The main objective of this paper is to propose a high-fidelity human-in-the-loop simulation that is capable of supporting AV-pedestrian interactions by coupling an advanced AV simulator with virtual reality technology. The prototype of the extended simulation framework has been developed and demonstrated with experimental scenarios. The inclusion of real-world humans offers extensive opportunities for understanding the safety of AVs co-existing with vulnerable road users.

**Keywords:** Pedestrians, Autonomous Vehicles, Virtual Reality, Human-in-the-Loop, Simulation

## 1 INTRODUCTION

With the rapid development of autonomous vehicles (AVs), the transition from driver-controlled vehicles to AVs will not guarantee risk-free situations as AVs will remain share roads with other users such as pedestrians. The lack of readily deployable high-level AVs and the legal, ethical, and safety concerns for engaging pedestrians in both closed-track and open-road testing further restrict the exploration of AV-pedestrian interaction issues. In this paper, an extended autonomous driving simulation framework is proposed, offering a virtual test environment in which user-controlled pedestrians can coexist with high-fidelity AVs for realistic AV-pedestrian interactions.

## 2 METHODOLOGY

In this study, a simulation framework is developed for supporting realistic AV-pedestrian experiments. As shown in Figure 1, this simulation framework extends the CARLA driving simulator (Dosovitskiy et al., 2017) rendered by Unreal Engine 4, affording high-fidelity experiences for the clients and flexible environment settings. To support multimodal simulation, the simulation framework currently contains two predominant client roles, including vehicles and pedestrians. Vehicle driving role can be divided into two parts: manual driving with steering wheels and AVs with algorithm control. The experiment participant equipping Oculus Quest headset has ability to control the movement of the pedestrian avatar and observe surrounding area by headset alone. No external devices are needed such as controller or joystick. The headset is equipped with several sensors: 3-axis accelerometer tracking the speed and motion of the device, 3D gyroscope reporting the rate of rotation along the X, Y, and Z axis, and 3D magnetometer correcting error in the headset by using the earth's known magnetic field. With six degrees of freedom (6DoF), the avatar can move freely in the simulator. The movement speed is matched with real-world user. During simulation experiments, if the vehicle collides with the avatar, the death animation will also be triggered, and the model of avatar will be destroyed after two seconds.

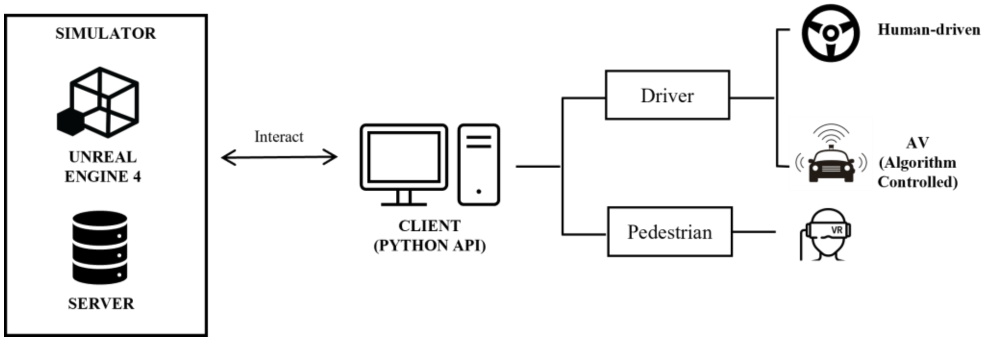


Figure 1. Simulation Framework.

## 3 RESULT

This framework allows multiple users to get connected and play in different roles such as pedestrians and drivers. Figure 2 shows images from sensors equipped on an AV in simulation. There are three different clients in Figure 2. The first client represents an AV agent controlled by camera sensors (depth and semantic). It can be observed that in front of the AV, there are a pedestrian and another car, which are controlled with a VR headset and a wheel device separately as the second and the third client. The second client represents a pedestrian who wants to cross the road. Meanwhile, the pedestrian can view the simulated world immersively with the VR headset to determine when and how to make a movement. Finally, the third client is driving a car using a wheel, which can mimic a manually driving vehicle more realistically. All clients are connected to a high speed router for exchanging network information with the CARLA host.

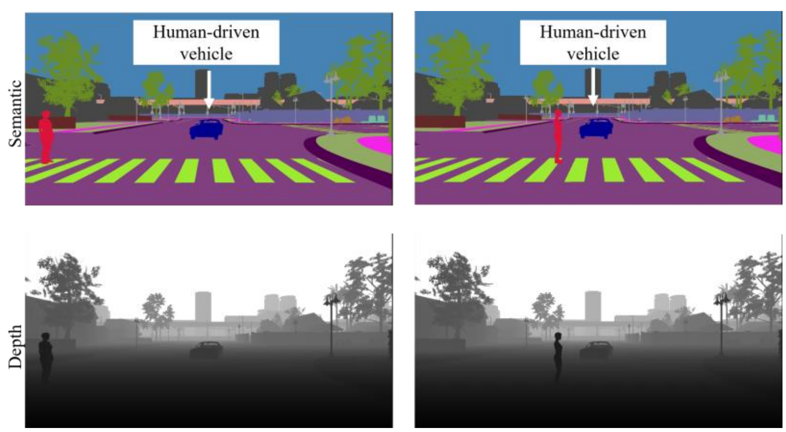


Figure 2. Depth and semantic images captured by an AV.

## 4 CONCLUSION

In this study, an interactive vehicle-pedestrian simulation framework has been designed and developed using a set of cutting-edge technologies. The developed simulation framework used the open-source CARLA autonomous driving simulator to handle the integration of different components. The inclusion of actual human behavior in the loop expands the opportunities for advancing our understanding of AVs co-existing with vulnerable road users.

## REFERENCE

Dosovitskiy, Alexey, et al. "CARLA: An open urban driving simulator." Conference on robot learning. PMLR, 2017.