Simulation Architecture for Real-time Driver-Pedestrian Co-Simulation using Motion Capture

Maytheewat Aramrattana, Lennart Ochel

The Swedish National Road and Transport Research Institute (VTI), Olaus Magnus väg 35, 583 30 Linköping, Sweden, e-mail: {maytheewat.aramrattana, lennart.ochel}@vti.se

Abstract - *In the evolving landscape of driving simulation, achieving a comprehensive representation of urban scenarios requires an understanding of driver-pedestrian interactions. In order to conduct simulator studies on driver-pedestrian interactions, a simulation framework that allows real-time interaction between the driver and pedestrian is needed. To address this need, this paper presents an approach to driver-pedestrian co-simulation. The pedestrian simulator in our work utilizes real-time motion capture, enabling accurate representation of the pedestrian's states in real-time. Moreover, advantages and disadvantages of the presented simulation architecture are discussed along with approaches for future improvements.*

Keywords: *Co-simulation, driving simulation, pedestrian simulation, motion capture, Unreal Engine.*

Introduction and related work

Prior works on driving simulation have primarily focused on vehicle simulation for study on vehicle dynamics and interaction between vehicle system and its driver, leaving room for exploration in the realm of real-time interaction between driver and pedestrian outside the ego vehicle. Therefore, this paper aims to bridge this gap by presenting a novel approach to driver-pedestrian co-simulation.

Although pedestrian simulators with motion capture exist (e,g,. Cavallo, et al., 2016), they are not often connected to driving simulator. On the other hand, current work on co-simulation between driving simulator and pedestrian simulator often lacks real-time motion capture of the pedestrian, making it difficult to study real-time interaction between driver and pedestrian. An approach presented by Sadraei, et al., 2020 utilized real-time tracker for pedestrian motion but used spheres to represent pedestrian in their study. Another approached presented by Andersson, et al., 2021 is to utilize a human avatar to represent the pedestrian, but with a prerecorded animation based on pedestrian states (i.e., idle or walking).

Our proposed architecture combines advantages of the two approaches above by representing the pedestrian using a realistic human avatar controlled by real-time data from motion capture sensors.

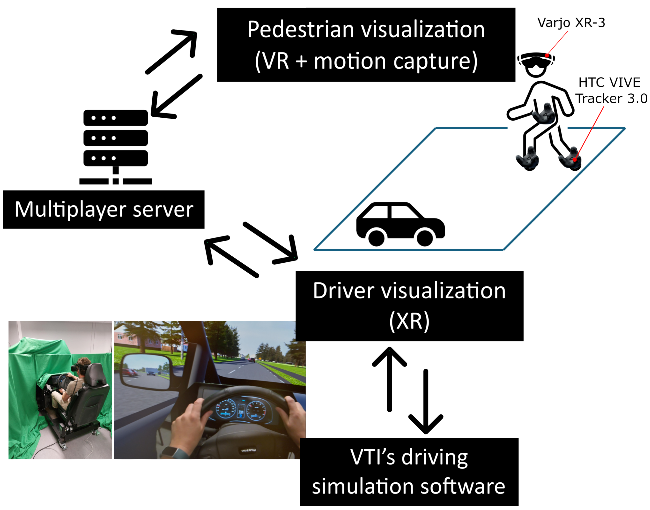

Figure 1: Overview of the co-simulation architecture

Co-simulation architecture

An overview of the co-simulation architecture is depicted in Fig. 1. There are four main software modules: *i*) Multiplayer server; *ii*) Pedestrian visualization: *iii*) Driver visualization; and *iv*) VTI's driving simulation software. The first three modules are developed based on Unreal Engine 5.2, and they communicate with each other using ENet protocol version 1.3.17[†], which is a network communication layer implemented on top of User Datagram Protocol (UDP). The driver visualization module also communicates with VTI's driving simulation software, which simulates the ego vehicle. All visualization modules are run on a PC with 10th generation Intel® Core™ i9-processor with 32 GB RAM and equipped with NVIDIA GeForce RTX 3070 Ti.

† http://enet.bespin.org/

The multiplayer server handles connections and message exchanges between the driver and pedestrian visualization modules. Once all modules are connected, the server broadcasts all received messages including state updates of all actors, so that the pedestrian is visualized correctly in driver visualization and vice versa. In this work, we define our own message types and data that are included in each message type.

Pedestrian simulator

The pedestrian is equipped with a Varjo XR-3 headset[‡] and three HTC VIVE tracker 3.0[§] as depicted in Fig. 1. In order to track motion of the pedestrian and visualize it in the driver visualization module, one of the trackers is strapped around the waist of the pedestrian and the rest around each ankle of the pedestrian. LiveLinkXR and OpenXR plugins, which are openly available in Unreal Engine, are used to receive data from the headset and trackers in the pedestrian visualization module. In our setup, this is sufficient to visualize pedestrian's position and movement (i.e., walking or standing) in real-time. Four base stations are utilized to cover the area of 6.5 by 4 meters for the pedestrian.

The pedestrian visualization software receives position and orientation data from the headset and the trackers and then transmit the data to the multiplayer server. On the other hand, the pedestrian visualization software receives state of the vehicle from the multiplayer server and visualize it to the pedestrian. The pedestrian is represented using the MetaHuman plugin inside Unreal Engine in both the pedestrian visualization and the driver visualization modules.

Driving simulator

Similarly, the driver visualization module sends state of the vehicle and receives state of pedestrians in order to visualize the pedestrian to the driver. In this setup, we use the XR driving simulation setup as depicted in Fig. 1. The XR setup allows drivers to see an actual dashboard and their hands, while the area covered by the green screen is simulated.

Conclusions and future work

This paper provides a holistic view of a simulation architecture tailored for real-time driver-pedestrian co-simulation. All modules within the architecture are interconnected and communicate with each other using custom-made messages over UDP connections. Visualization modules are built based on Unreal Engine 5.2, allowing state-of-the-art visualization within the co-simulation environment. Initial tests at VTI's facility in Linköping suggests that states of all actors (i.e., the pedestrian and the vehicle) are visualized correctly (see Fig. 2) on both visualization modules with an update rate of approximately 100 Hz.

One major drawback from relying on a game engine such as Unreal Engine is that the execution is not time-controlled (i.e., with a fixed timestep). Instead, the execution frequency depends on the frame rate that the graphic engine can achieve. This implies that real-time performance highly depends on performance of the computers used within the architecture. This is a trade-off between immersion and performance that one has to consider in future work.

We have also conducted a test using the proposed architecture with two pedestrians in the same environment (but no vehicle). Despite a successful test, an extra set of equipment is needed for each added pedestrian, making it difficult to scale up the experiment. Alternatively, a camera-based motion capture approach as done in Wang, et al., 2023 could allow for more scalability. Nevertheless, the camera-based approach could also struggle when two pedestrians are very close to each other, making it difficult for a camera to distinguish the pose of multiple pedestrians.

Figure 2: A screenshot from the driver's perspective when the driver encounters the pedestrian

[‡] https://varjo.com/products/varjo-xr-3/

[§] https://www.vive.com/eu/accessory/tracker3/

Acknowledgments

This research has been conducted within the HEIDI project funded by the European Union's Horizon Europe research and innovation programme under Grant Agreement No. 101069538. The authors would like to also acknowledge Florian Fischer and Linus Hilding at VTI for their contributions to this work.

References

Andersson, A., Insulander, M., Blissing, B., Hjort, M., Jansson, A., Friström, J., and Lindvall, L., 2021. Co-simulation architecture with pedestrian, vehicle, and traffic simulators. In: *Proceedings of the Driving Simulation Conference 2021 Europe VR*. Driving Simulation Association. Munich, Germany, pp. 181–184.

Cavallo, V., Dommes, A., Vienne, F., and Nguyen-Thong, D., 2016. A street-crossing simulator to study and train pedestrian behaviour. In: *Proceedings of the Driving Simulation Conference 2016 Europe*. Driving Simulation Association. Paris, France, pp. 195–200.

Sadraei, E., Romano, R., Merat, N., Pedro, J. G. D., Lee, Y. M., Madigan, R., Uzondu, C., Lyu, W., and Tomlinson, A., Sept. 9, 2020. Vehicle-Pedestrian Interaction: A Distributed Simulation Study. In: A. Kemeny, J.-R. Chardonnet, and F. Colombet eds. *Proceedings of the Driving Simulation Conference 2020 Europe VR*. Driving Simulation Association. Antibes, France, pp. 147–154.

Wang, Z., Zheng, O., Li, L., Abdel-Aty, M., Cruz-Neira, C., and Islam, Z., 2023. Towards Next Generation of Pedestrian and Connected Vehicle In-the-Loop Research: A Digital Twin Co-Simulation Framework. *IEEE Transactions on Intelligent Vehicles*, 8(4), pp. 2674–2683. https://doi.org/10.1109/TIV.2023.3250353.