Demo Abstract: Integrating a Driving Simulator with City-Scale VANET Simulation for the Development of Next Generation ADAS Systems

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***Abstract*—The future of driving will be heavily influenced by Advanced Driver Assistance System (ADAS) using data from Vehicular Ad-Hoc Networks (VANETs). While driver assistance systems and VANETs have been separate domains of research and development, the gap between them is going to close. This poses challenges to developing next generation cooperative ADAS systems, as traditional testing methods cannot cover their complex interactive and interconnected nature. In this demo, we present a solution for this: a driving simulator integrated with a city-scale VANET simulation. The fundamental basis is the coupling of a driving environment operating in real-time and an event-driven simulator using our novel Ego Vehicle Interface (EVI). Visitors can take control of a vehicle within the simulation using a steering wheel and pedals. This allows them to experience future ADAS interactively in the simulation. Also, it enables researchers to analyze the influence of a human driver on such systems both on a microscopic as well as on a macroscopic level.**

I. Introduction

In the past, driver assistance systems and Vehicular Ad-Hoc Networks (VANETs) were separate domains of research and development. Driver assistance systems focused on improving safety and comfort by leveraging the sensors and systems within the car [1]. They were developed with driver interaction in mind. Testing could be done in isolated testbeds, simulation, or hybrid concepts using Hardware-in-the-Loop (HiL) simulation. Early VANET systems on the other hand focused on effective data dissemination and protocols [2]. However, the driver (i.e., the user) was not thought of as part of the system itself. To test VANET systems, a variety of specialized hardware and simulators were developed. One of the most prominent tools is Veins [3], which provides large scale road traffic microsimulation supported by SUMO as well as very realistic wireless network simulation supported by OMNeT++.

The gap between the two domains, however, is shrinking and must finally close, now that next generation Advanced Driver Assistance Systems (ADAS) are being researched [4]. Instead of vehicles being local, self-sufficient systems, they become interconnected Cyber Physical Social Systems (CPS). On the road towards fully autonomous driving, we experience a varying degree of hybridization, i.e., degree of involvement of the human driver, interacting with and influencing the semi-automated systems. In the literature, we find the name Cyber Physical Social System (CPSS) describing this stage [5].

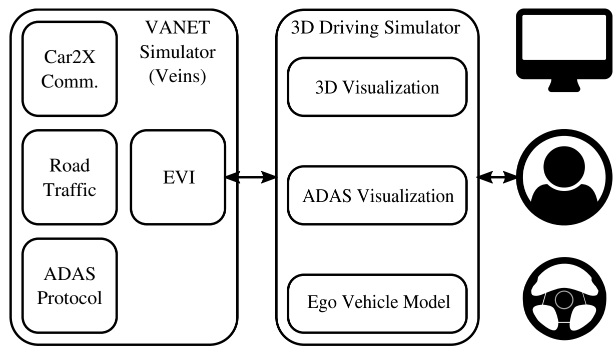

Figure 1. Basic system architecture. The 3D driving simulator running in real-time is connected to the VANET discrete-event simulator using the Ego Vehicle Interface.

While this makes the ADAS more flexible and powerful, it also poses new challenges to testing. Traditional testbeds can neither cover the interactive and interconnected nature of future systems, nor their scale. While first efforts using computer simulation exist [6], their operation at city-scale is, to date, unproven. Field tests using hardware are also unfeasible due to their immense cost and late availability of prototypes with respect to their development cycles.

We present a solution to this problem. Our Ego Vehicle Interface (EVI) [7] is an approach that is able to interconnect a city-scale event-driven VANET simulator and a real-time system. We build on this approach to synchronize a user-controlled vehicle (the *ego vehicle*) in a 3D driving simulation with a VANET simulation. Figure 1 shows the core system architecture. By connecting a 3D driving simulator as a human-machine interface, we close the gap and let the driver become an integral part of a fully-interactive city-scale VANET simulation. To the best of our knowledge, this is the first approach to integrate a real-time driving simulator with a large-scale event-driven network and road traffic simulation environment.

We will demo a simple driving simulator (using a computer monitor, a steering wheel, and pedals, as depicted in Figure 2). Visitors can enter the driver's seat themselves and virtually experience future ADAS applications today.

II. Ego Vehicle Interface

Our main goal is to couple the well-known VANET simulator Veins [3] with a 3D driving simulator [8], as shown in Figure 1.

Figure 2. Overview of the demo setup. The driver is controlling the ego vehicle with the steering wheel. The left monitor shows his first person view from within the vehicle, the right monitor displays the VANET simulation.

In Veins, vehicle movements are normally controlled by the SUMO road traffic simulator. SUMO takes care of tasks like traffic demand generation, route planning, longitudinal and lateral movement of cars in accordance with traffic rules, and intersection management. It allows to simulate city-scale road traffic and provides a uniform interface to the simulation.

However, this interface is not sufficient for direct human interaction. To allow a human driver to take part in the simulated road traffic, we need to introduce a special vehicle, the *ego vehicle*. This vehicle is directly controlled by the human driver and synchronized into the simulation. The 3D driving simulator implements the user interface to the ego vehicle. Unity3D is used to render and display the environment (including roads, roadside elements, and surrounding traffic). An embedded physical vehicle model reacts to input from a steering wheel and pedals operated by the driver.

The EVI takes care of synchronizing the VANET simulation in Veins with the 3D driving simulator. It provides vehicle movements of surrounding traffic to the 3D driving simulator. It also feeds the ego vehicle's position back to Veins, so that surrounding vehicles can react to it. To allow an interactive experience, all of this has to happen in real time. The EVI takes care of sufficiently fast synchronization and ensures short update intervals of the connected simulators by only synchronizing the vehicles in the proximity of the ego vehicle.

Finally, the EVI also enables the distributed implementation of ADAS. The simulation of wireless communication and the protocol of the ADAS are implemented in Veins. Via the EVI, information for the ego vehicle are synchronized to the 3D driving simulator. There, a visualization component renders the ADAS information to the user's display.

III. Demonstration Setup

Our demo consists of an off-the-shelf PC attached to two monitors, a steering wheel, and accelerator/brake pedals. This setup is shown in Figure 2. Visitors can take a seat in front of it and drive the ego vehicle in the simulation via the peripherals. Their input is fed into the ego vehicle physics model of the driving simulator.

As shown in Figure 2, the driver is presented with two views of the scenario. The main screen (left) displays a cockpit view of the 3D visualization from within the ego vehicle, that is used for first person steering. This virtual cockpit is augmented with a visualization of the ADAS instruments, e.g., collision warning indicators. The secondary screen displays a bird's eye view of the environment of the ego vehicle – either visualizing the road traffic simulation or the network traffic simulation as rendered by Veins.

Visitors can drive the ego vehicle trough a city scenario to experience (or, indeed, to provoke) different traffic situations. The scenario is based on a real city and features both line of sight and radio obstructions. As vehicles exchange wireless messages in the simulation, ADAS peripherals will warn drivers about dangers outside their field of view.

IV. Conclusion

We propose a system that combines a VANET simulator (Veins) with a 3D driving simulator for supporting the development process of next generation ADAS systems. With our ego vehicle interface, we can give the control over an ego vehicle to human drivers. Drivers observe the 3D environment from a first person perspective within a VANET-enabled car controlled via steering wheel and pedals. The ego vehicle is synchronized to the VANET simulator, in which wireless communication and all vehicular networking protocols are simulated. This allows both *(a)* a driver to experience future VANET applications, e.g., for user-acceptance tests as well as *(b)* a future VANET application to be tested with real user interaction at city scale. In future work, we plan integrating multiple driving simulators and even having the cars talking to each other directly, e.g., using the OpenC2X platform [9].

References

[1] K. Bengler, K. Dietmayer, B. Farber, M. Maurer, C. Stiller, and H. Winner, "Three Decades of Driver Assistance Systems: Review and Future Perspectives," *IEEE Intelligent Transportation Systems Magazine*, vol. 6, no. 4, pp. 6–22, Oct. 2014.

[2] C. Sommer and F. Dressler, *Vehicular Networking*. Cambridge University Press, Nov. 2014.

[3] C. Sommer, R. German, and F. Dressler, "Bidirectionally Coupled Network and Road Traffic Simulation for Improved IVC Analysis," *IEEE Transactions on Mobile Computing*, vol. 10, no. 1, pp. 3–15, Jan. 2011.

[4] A. Paul, R. Chauhan, R. Srivastava, and M. Baruah, "Advanced Driver Assistance Systems," SAE, SAE Technical Paper 2016-28-0223, Feb. 2016.

[5] F. Dressler, "Cyber Physical Social Systems: Towards Deeply Integrated Hybridized Systems," in *IEEE ICNC 2018*, Maui, HI: IEEE, Mar. 2018.

[6] Y. Hou, Y. Zhao, A. Wagh, L. Zhang, C. Qiao, K. F. Hulme, C. Wu, A. W. Sadek, and X. Liu, "Simulation-Based Testing and Evaluation Tools for Transportation Cyber-Physical Systems," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 3, pp. 1098–1108, Mar. 2016.

[7] D. S. Buse, M. Schettler, N. Kothe, P. Reinold, C. Sommer, and F. Dressler, "Bridging Worlds: Integrating Hardware-in-the-Loop Testing with Large-Scale VANET Simulation," in *IEEE/IFIP WONS 2018*, Isola 2000, France: IEEE, Feb. 2018.

[8] K. Abdelgawad, M. Abdelkarim, B. Hassan, M. Grafe, and I. Gräßler, "A modular architecture of a PC-based driving simulator for advanced driver assistance systems development," in *REM 2014*, El Gouna, Egypt: IEEE, Sep. 2014.

[9] F. Klingler, G. S. Pannu, C. Sommer, B. Bloessl, and F. Dressler, "Field Testing Vehicular Networks using OpenC2X," in *ACM MobiSys 2017, Poster Session*, Niagara Falls, NY: ACM, Jun. 2017, pp. 178–178.