Research Report Summary

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Towards Next Generation of Pedestrian and Connected Vehicle In-the-loop Research: A Digital Twin Co-Simulation Framework

This study aims to propose a digital twin framework to support Intelligent Transportation System (ITS) research on Connected Vehicles (CV) and pedestrian.

Three tasks were investigated: (1) introduce a CV and pedestrian in-the-loop Digital Twin framework, which consists of physical world, digital world, and the connection in between; (2) present a sample architecture to show a realization method of the Digital Twin framework; (3) demonstrate a case study of V2P collision warning under occlusion condition that validates the proposed framework.

The digital twin framework consists of the physical world and the digital world, where both the pedestrian and CV present (Fig 1). The internal states and external states of the real-world entities are digitally twined to virtual actors. The external states include vehicle/pedestrian characteristics, location, kinematic features, while the internal states include intention, emotion, etc. Afterwards, simulation and prediction technics are performed in the digital world to calculate the optimal strategies for real-world traffic participants.

A digital twin architecture is developed, which incorporates a Sumo-Carla co-simulation platform for CV and a Cave automatic virtual environment (CAVE) for pedestrians (Fi 5). The driving simulator in Carla connects up to three drivers simultaneously, and it is connected to Sumo to generate realistic traffic flow in the digital world (Fig 2). The CAVE provides an immersive 3D virtual environment for pedestrian simulation. The pedestrian's action and pose are captured through computer vision

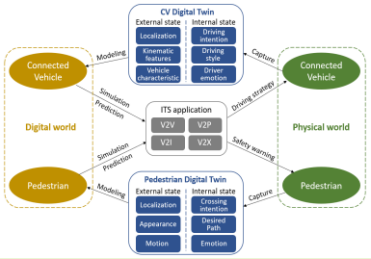

Fig 1. Digital Twin framework

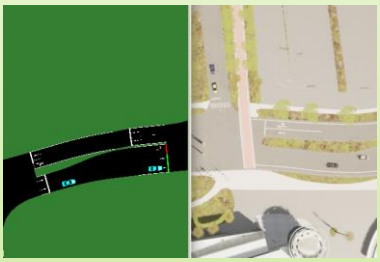

Fig 2. Sumo-Carla co-simulation

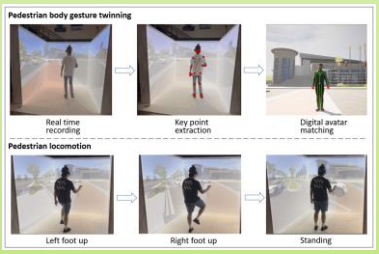

Fig 3. Pedestrian in CAVE

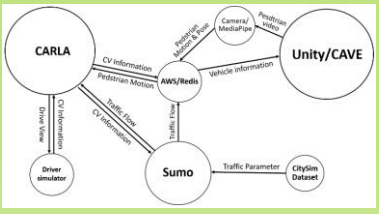

Fig 4. Data transmission pipeline

technology in the CAVE (Fig 3). In such way, the pedestrian and CV can interact with each other, as shown in the data transmission pipeline (Fig 4).

To validate the effectiveness of the proposed framework, a case study that investigates V2P collision warning system under occlusion condition is conducted based on the presented architecture. The results show that the V2P warning enhanced safety compared to HDV and AV.

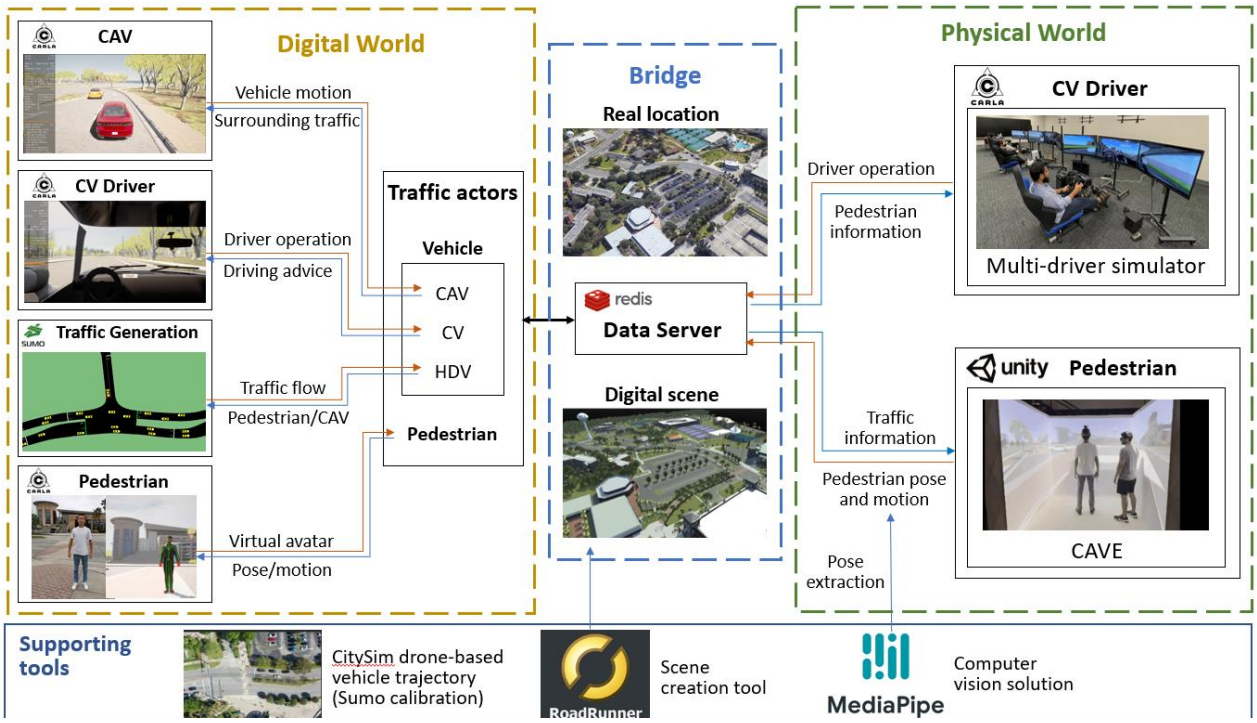

Fig 5. architecture of CV and pedestrian in-the-loop digital twin framework

Outcomes

This research proposed a digital twin framework for CV and pedestrian, in which the framework architecture, functionalities, data transmission are presented in detailed. Following the proposed architecture, a digital twin system is developed that support physical-digital world communication and interaction and immersive simulation environment. The validity of the system is shown in a case study where we successfully use V2P communication to enhance pedestrian safety based on a real-world scenario.

Impacts

The proposed framework provides guidance to the future Digital Twin research, and the architecture we build can serve as the testbed for further research and development of ITS applications on CV and pedestrians.

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