U.S. Department of Transportation
Federal Highway Administration
Office of Operations
Research and Development

CDASim: An Open-Source Cosimulation Tool To Support Cooperative Driving Automation (CDA) Research

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BACKGROUND

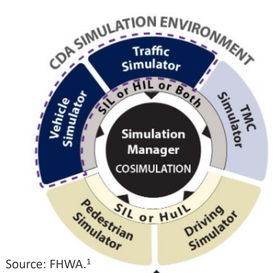
- CDA is one of the emerging technologies that have the potential to transform existing transportation systems with the aim of improving mobility, safety, and the environment.
- Current traffic simulation tools cannot simulate CDA technology (e.g., connectivity and cooperative driving behaviors) well enough to support field experiments and early deployment of CDA technology.
- CDA research can be resource intensive.

OBJECTIVES

- To establish an open-source cosimulation environment that integrates diverse open-source simulators and thereby enables anything-in-the-loop (XiL) research capabilities to support CDA researchers in developing and evaluating their own CDA algorithms and applications.
- To integrate various components of FHWA CARMA℠ ecosystems into XiL environments, thereby enabling the low-cost and efficient development, testing, and evaluation of CARMA℠ CDA applications within the simulation environment.
- To accelerate CDA development and analysis, as well as reduce barriers to entry (hardware no longer required!).

CDA SIMULATION ENVIRONMENT

- A comprehensive CDA simulation roadmap, depicted in figure 1, has been developed to highlight the essential components of the envisioned CDA simulation environment.
- This project serves as the foundation for development of a complete CDA simulation environment.
- The project focuses on facilitating software-in-the-loop simulation by the use of a vehicle-driving simulator and a traffic simulator, represented by the purple dashed box in figure 1.



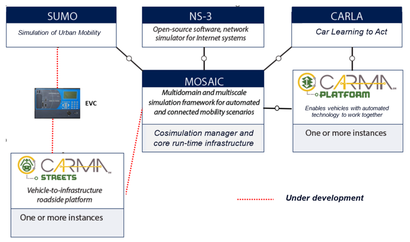
Source: FHWA.[1]

Figure 1. A CDA simulation roadmap.

AI = artificial intelligence; AR = augmented reality; HIL = hardware in the loop; HuIL = human in the loop; ML = machine learning; SIL = software in the loop; TMC = transportation management center; VR: virtual reality.

FRAMEWORK AND ARCHITECTURE

- CDASim[1] has seven core components:
  - MOSAIC.[2]
  - Car Learning to Act (CARLA).[3]
  - Simulation of Urban MObility (SUMO).[4]
  - NS-3.[5]
  - Econolite virtual traffic signal controller (EVC).
  - CARMA Platform℠.[6]
  - CARMA Streets℠.[7]
- CDASim[1] is designed with modularity, enabling users to tailor CDASim by enabling or disabling different components (except MOSAIC[2] and SUMO[4]) for users' specific research needs.

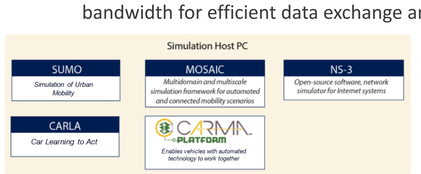


Source: FHWA.[1]

Figure 2. Framework and architecture of CDASim.

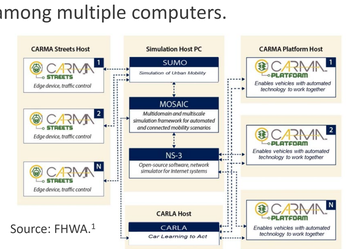
SIMULATION EXECUTION APPROACHES

- Centralized execution approach
  - CDASim[1] is designed to run on a single computer.
  - CDASim[1] provides an easy setup process, making it suitable for small simulation networks and a limited number of simulated CDA vehicles.
  - However, CDASim[1] has limitations when it comes to scaling up a simulation network or accommodating many simulated CDA vehicles.
- Distributed execution approach
  - CDASim[1] uses multiple computers for execution.
  - CDASim[1] is designed specifically to handle large simulation networks or a significant number of simulated CDA vehicles.
  - CDASim[1] is set up via a distributed execution approach that is more complex and requires meeting high requirements such as low latency and high bandwidth for efficient data exchange among multiple computers.



Source: FHWA.[1]

Figure 3. Centralized execution approach of CDASim.

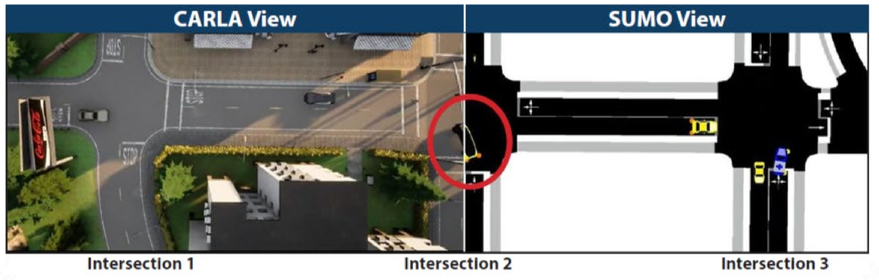


Source: FHWA.[1]

Figure 4. Distributed execution approach of CDASim.

PROJECT STATUS

- Currently, seven core components are integrated into CDASim[1]: MOSAIC,[2] CARLA,[3] SUMO,[4] NS-3,[5] CARMA Platform℠,[6] EVC, and CARMA Streets℠.[7]
- Future work includes integration of CARMA Cloud℠[8] and CARMA Messenger℠.[9]



Source: FHWA.[1]

Figure 5. A demonstration of capabilities of CDASim.

- A digital twin of FHWA's Turner-Fairbank Highway Research Center (TFHRC) was created to verify integration testing in the simulation environment. The digital twin also creates opportunities to validate simulation results against real-world testing on campus.

a. Google Map view of TFHRC. **b. TFHRC in the simulation environment.**

Figure 6. A digital twin of FHWA's TFHRC.

TO LEARN MORE AND FOLLOW UPDATES

- More information related to this cosimulation tool is available at CARMA℠ Simulation Confluence: https://usdot-carma.atlassian.net/wiki/spaces/CRMSIM/.
- Source codes for this cosimulation tool are available at CARMA℠ Simulation GitHub: https://github.com/usdot-fhwa-stol/carma-simulation/.
- The project team provides technical support in the use of this tool under FHWA's CARMA℠ Support Services project: CARMAsupport@dot.gov.

SAXTON LABORATORY

[1] FHWA. 2021. "CARMA℠ Simulation" (web page). https://usdot-carma.atlassian.net/wiki/spaces/CRMSIM/overview, last accessed November 23, 2021.
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[4] CARLA. n.d. "CARLA" (webpage). https://carla.org, last accessed May 30, 2023.
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[6] USDOT. n.d. "CARMA" (webpage). https://its.dot.gov/cda, last accessed May 30, 2023.
[7] FHWA. 2023. CARMA Streets (software). Version 4.3.0.
[8] FHWA. 2023. CARMA Cloud (software). Version 4.3.0.
[9] FHWA. 2023. CARMA Messenger (software). Version 4.4.0.
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