Research Report Summary

SAFER-SIM University Transportation Center, 69A3551747131

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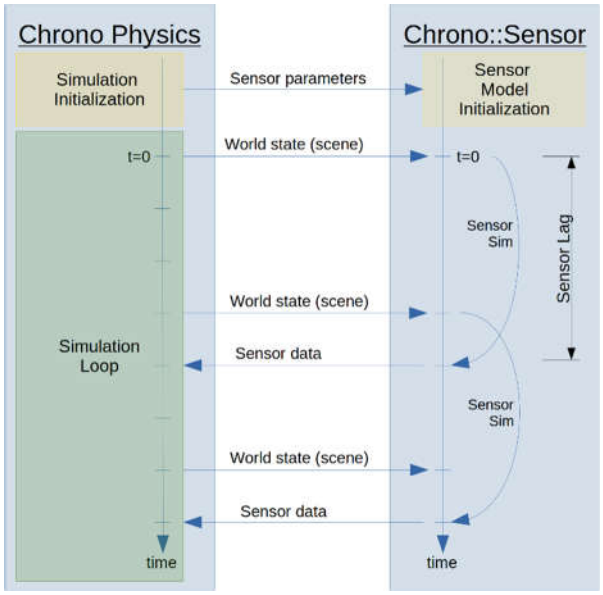
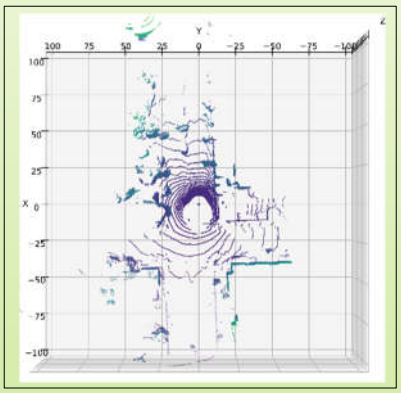
Physics-Based Sensor Models for Virtual Simulation of Connected and Autonomous Vehicles

The focus of this project was the research, implementation, and demonstration of methods to simulate sensors used when evaluating "in silico" autonomous vehicle performance. A primary component of this research has been the development of an open-source sensor simulation module, Chrono::Sensor, which extends the open-source multi-physics software Chrono to allow for synthetic generation of sensor data for software-in-the-loop testing.

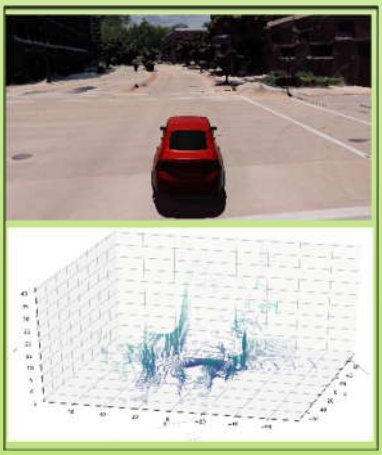


An illustration of the connection between Chrono and Chrono::Sensor shows the ability for dynamics to control the evolution of the environment. Data is generated with parameterized lag, update frequency, and sensor-specific models, and provided to the user for software-in-the-loop testing.

Results from an example autonomous vehicle simulation using Chrono::Sensor



Bird-eye view of simulated lidar data.



Example data from simulated camera and lidar from within a reconstructed virtual environment.

Chrono::Sensor supports simulation of camera, lidar, GPS, and IMU with an extensible framework for implementing custom sensors or expanding existing sensor models. Each sensor model includes options for introducing parameterized distortion and noise to improve the realism of the simulated sensor data. By leveraging hardware-accelerated ray-tracing via OptiX [2], camera and lidar data acquisition processes can be closely mimicked to anchor the process of synthetic sensor data generation in a physics-based procedure. Chrono::Sensor will be released as a module of Chrono, and in its entirety the simulation framework will allow researchers to understand and evaluate algorithms for autonomous vehicle navigation. Additionally, simulations of safety-critical scenarios can be run en masse to probe the sensitivity, robustness, and safety of vehicle control strategies in highly customizable and reconfigurable environments.

"Each sensor model includes options for introducing parameterized distortion and noise to improve the realism of the simulated data."

As part of the research, scaling results, example sensor data, and demonstrations are shown. A sedan, equipped with multiple sensors, is simulated inside a reconstructed virtual environment courtesy of Continental Mapping [3].

Outcomes

- We produced open-source sensor simulation framework for autonomous vehicle simulation called Chrono::Sensor. This code will be provided alongside the open-source Project Chrono. Both Chrono and Chrono::Sensor are developed/augmented by the Simulation Based Engineering Lab at the University of Wisconsin-Madison.
- Chrono::Sensor is and will continue to be used in further work involving the research and development of a multi-agent connected autonomous vehicle simulator.
- Chrono::Sensor will be augmented and used in related research on improving and understanding sensor realism for reducing the simulation-to-reality gap.
- This project was the basis of a successful Ph.D. Preliminary Examination in May 2020.
- Chrono::Sensor is the subject of five conference presentations and submissions, one accepted journal publication, and two pending journal submissions.

Impacts

This research and the subsequent sensor simulation framework will allow researchers to better understand the safety of autonomous vehicles, improve autonomous vehicle perception and navigation, and demonstrate the capability of algorithms in safety-critical scenarios to the public at large. Specifically, the technology associated with this SAFER-SIM project, and the broader software to which this module belongs, is designed with the following intent:

- Allow researchers to better understand and improve the safety of autonomous vehicles by facilitating numerous iterative simulations in safety-critical scenarios.
- Allow for the understanding and demonstration of vehicle safety and capability for the public at large.
- Use beyond the realm of autonomous vehicles, e.g., in robotics applications

References

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[3] "Continental Mapping." https://www.continentalmapping.com/, 2019. Accessed: 2019-04-19

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