11th Asia-Pacific Regional Conference of the ISTVS
September 26-28, 2022 | Harbin, China | online

EXAMINING THE SIMULATION-TO-REALITY GAP OF A WHEEL LOADER INTERACTING WITH DEFORMABLE TERRAIN

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Abstract

Simulators are essential for developing autonomous control of off-road vehicles and heavy equipment. They allow automatic testing under safe and controllable conditions, and the generation of large amounts of synthetic and annotated training data necessary for deep learning to be applied [1]. Limiting factors are the computational speed and how accurately the simulator reflects the real system. When the deviation is too large, a controller transfers poorly from the simulated to the real environment. On the other hand, a finely resolved simulator easily becomes too computationally intense and slow for running the necessary number of simulations or keeping realtime pace with hardware in the loop.

We investigate how well a physics-based simulator can be made to match its physical counterpart, a full-scale wheel loader instrumented with motion and force sensors performing a bucket filling operation [2]. The simulated vehicle is represented as a rigid multibody system with nonsmooth contact and driveline dynamics. The terrain model combines descriptions of the frictional-cohesive soil as a continuous solid and particles, discretized in voxels and discrete elements [3]. Strong and stable force coupling with the equipment is mediated via rigid aggregate bodies capturing the bulk mechanics of the soil. The results include analysis of the agreement between a calibrated simulation model and the field tests, and of how the simulation performance and accuracy depend on spatial and temporal resolution. The system's degrees of freedom range from hundreds to millions and the simulation speed up to ten times faster than realtime. Furthermore, it is investigated how sensitive a deep learning controller is to variations in the simulator environment parameters.

Keywords: earthmoving, simulation, deep learning, autonomous control, deformable terrain, sim2real.

Presenter: Martin Servin

References:

[1] S. Backman, D. Lindmark, K. Bodin, M. Servin, J. Mörk, and H. Löfgren. Continuous control of an underground loader using deep reinforcement learning. Machines 9(10): 216 (2021).

[2] K. Aoshima, M. Servin, E. Wadbro. Simulation-Based Optimization of High-Performance Wheel Loading. Proc. 38th Int. Symp. Automation and Robotics in Construction (ISARC), Dubai, UAE (2021).

[3] M. Servin., T. Berglund., and S. Nystedt. A multiscale model of terrain dynamics for real-time earthmoving simulation. Advanced Modeling and Simulation in Engineering Sciences 8, 11 (2021).