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High-performance autonomous wheel loading
- a computational approach

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Abstract

Smart and autonomous earthmoving equipment enhances energy efficiency, productivity, and safety at construction sites and mines. The innovations provide means to reach high-set sustainability goals and be profitable despite increasing labor shortages. In addition, recent technological breakthroughs in artificial intelligence highlight the potential of superhuman capabilities to further enhance operations. This thesis presents a computational approach to end-to-end optimization of autonomous wheel loaders operating in a dynamic environment. Wheel loaders are mainly used for repeatedly loading material and carrying it to load receivers in quarries and mines. The difficulty lies in that each loading action alters the state of the material pile. The resulting state affects the possible outcomes of the subsequent loading process and, ultimately, the total performance. Thus, the challenge is to achieve both autonomous and high-performance wheel loading over a sequence of tasks. Achieving this requires the ability to predict future outcomes and account for the cumulative effect of loading actions. The thesis constructs a real-time wheel loader simulator, develops world models for sequential loading actions with evolving pile states, formulates the end-to-end optimization problem, and introduces a look-ahead tree search method to solve the problem. These contributions provide insights into utilizing physics-based simulation in combination with machine learning to further improve sustainability in mining and construction.

Keywords
Earthmoving; Automation; Wheel loader; Bucket-filling; Multibody and soil dynamics; Realtime simulation; Sim-to-real gap; World modeling; Deep learning; Optimization

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