Physics-informed 3D scene understanding and its role in planning and control of mobile equipment

Martin Servin[1,2]

Abstract

Planning and control of mobile machinery in unstructured and dynamic environments is a difficult problem regardless of the level of automation. Machines used for construction, mining and forestry have the task of physically manipulating the environment in various ways according to a well-defined goal, e.g., transforming the terrain to a new state; loading, transporting, and, off-loading objects of a certain kind; or subdividing or merging materials into new structures. This should be executed with a certain error tolerance, minimal use of time and energy, and without causing damage to the environment. To succeed in this, it is important to have good information about the surrounding environment, e.g., in the form of a semantic 3D map including information physical properties of objects and materials. In general, many vehicles operate simultaneously in these environments. This is a complicating factor but also offers opportunities. A machine can benefit from observations generated from another machine's interaction with the environment. A machine can improve, or worsen, the conditions for another machine to perform its tasks. We therefore develop solutions to estimate physical states and properties of materials and objects in the environment of mobile equipment. The world state is represented as a 3D scene with object and material properties that supports both physics-based forward simulation, motion planning using inverse dynamics or a learned world model, and generation of synthetic sensor data for model inference. We use OpenPLX for representing these world states in an interoperable format. Demonstrations include examples from forestry and earthmoving operations involving handling of logs, rocks, and deformable terrain.

*This work was supported in part by Mistra Digital Forest, Sweden Grant DIA 2017/14 #6, and Horizon Europe Project XSCAVE under Grant 101189836.
[1]Department of Physics, Umeå University, Umeå, Sweden.
[2]Algoryx Simulation AB, Umeå, Sweden.