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Author: Mr. Eric Halbach
Helsinki University of Technology (TKK), Finland

Prof. Aarne Halme
Aalto University School of Science and Technology, Finland

JOB-LEVEL CONTROL OF AUTONOMOUS EARTHMOVING MACHINES FOR BASE CONSTRUCTION ON THE MOON OR MARS

Abstract

Earthmoving capabilities will be useful for establishing a human presence on the Moon or Mars. Tasks falling into this realm include bulldozing and excavation for base construction, burying pressurized volume with regolith for radiation and micrometeoroid protection, and obtaining regolith to harvest water, oxygen and other elements for in-situ resource utilization. Due to the hazardous environments on these worlds, the safety of human operators would be increased by using robotic earthmoving machinery controlled remotely. Various control schemes for such a scenario are possible, depending on the location of the operators. If located on site, direct tele-operation would be possible; however, if located far away (in orbit, or on Earth), time-delays would necessitate a high degree of machine autonomy. Even if located on site, a high amount of autonomy would be desirable for reducing operator fatigue.

This paper presents 3D graphical techniques for job-level control of such earthmoving tasks, assuming that lower-level scooping and driving can be performed autonomously. The philosophy is to develop simple, intuitive ways of planning a job, displaying autonomously generated sub-tasks and allowing a remote operator to provide input when needed. The operator typically specifies a task by demarcating areas which are to be levelled, excavated or used for dumping. Sub-tasks such as scooping approaches and driving waypoints are then generated automatically and displayed to the operator. Surfaces and waypoints are rendered on a 3D virtual map of the worksite to display the information. Predicted end-states of the worksite can also be rendered. All of these objects can be moved and altered, by clicking and dragging with a mouse, while work proceeds in order to update the job if necessary. Since the control is at the job level, this approach can accommodate one or more machines.

This strategy was tested in a custom-built simulator developed in Matlab. Two jobs were tested: a pile-transfer task, and an area-bulldozing task, both using one wheel loader. The simulations have shown that this strategy is intuitive and easy to use, and allows an effective combination of local autonomy and remote operator input. The operator mostly monitors the work, providing occasional high-level input such as new scooping approaches or dumping locations. Outdoor hardware experiments have also been performed using snow to test some elements of the system, including using a 3D laser rangefinder to monitor the ground during work, and automatically processing this data to track job progress and generate sub-tasks.