Paper ID: 23500
oral
student

HUMAN SPACEFLIGHT SYMPOSIUM (B3)
Poster Session (P)

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MULTI-ROBOT HILLSIDE EXCAVATION FOR MARS SETTLEMENT CONSTRUCTION

Abstract

After the first human explorers land on the Red Planet, the challenge will be to establish a permanent presence by using local resources for food production, manufacturing and the construction of large settlements. One important resource is the Martian regolith, which can be harvested for chemicals and used as a building material. As the latter, regolith could serve two main purposes: first, for the manufacture of bricks and construction of masonry structures, and second, for radiation shielding and providing an overburden to contain pressurized spaces. One detailed plan for building a permanent, growing settlement using this strategy is the Mars Homestead Project by Petrov and Mackenzie [1][2]. The basic concept in this plan is to excavate into a hillside, build masonry structures, then cover them with a protective regolith layer. Over time, the settlement grows linearly along the base of the hill to accommodate more settlers.

This paper presents 3D graphical simulations of the hillside excavation phase of this plan by a fleet of autonomous robotic earthmoving machines. The fleet consists of up to 8 compact wheel loaders excavating along a 45m-wide slope section, along with the necessary number of dump trucks. The benefits of the autonomous multi-robot approach are to increase safety for human operators, to reduce their workload (by avoiding direct teleoperation), and the redundancy a distributed system provides. Various aspects of control are investigated, beginning with ideal circumstances without obstacles or unpredictable regolith behaviour. Algorithms are presented which autonomously interpret a high-level plan and generate commands for the machines to follow over timescales of hours to days. The plans and commands are represented graphically, allowing a remote human supervisor to visualize the current state of work and intentions of the machines. With these simulations, excavation rates can be compared for varying machinery and fleet parameters. Situations are then investigated in which problems are encountered, such as impenetrable ground, mechanical breakdown or changes in regolith behaviour. Ways of dealing with these problems remotely are developed, both in the case of human supervision from Earth, with the long associated time delay (3-22 minutes one-way), and local supervision with no time delay.

[1] G. I. Petrov, A Permanent Settlement on Mars: The First Cut in the Land of a New Frontier, Master's thesis, Massachusetts Institute of Technology (2004).

[2] B. Mackenzie, B. Leahy, G. Petrov, G. Fisher, The Mars Homestead: a Mars Base Constructed from Local Materials, in: Space 2006.