IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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VIRTUAL LUNAR REGOLITH SIMULANT FOR TESTING DESIGNS IN REDUCED GRAVITY

Abstract

In-Situ Resource Utilisation (ISRU) makes use of local resources during space missions to avoid transporting supplies from Earth, e.g. collecting Lunar regolith to extract oxygen on the Moon. Given the high financial and reputational risk involved in these missions, hardware must be rigorously tested ahead of implementation. Physical regolith simulants are valuable tools, often used to evaluate designs and processes. However, they can be costly and it can be difficult to practically test the effects of reduced gravity on Earth. We present an improved, and experimentally validated, virtual model of Lunar regolith, used to test hardware designs in reduced gravity.

Previous work in the literature has modelled the haptic interactions of lunar regolith as a collection of visco-elastic macroparticles, with the adjustable parameters: gravity, regolith density, regolith friction and regolith cohesion. Our work builds on this by using space partitioning techniques to identify neighbouring particles, in order to build a more scalable virtual model of regolith. Our results show that computation time for this model increases proportionally with the number of particles, n, *i.e.* $\boldsymbol{O}(n)$ rather than $\boldsymbol{O}(n^2)$ as reported previously. We applied our model to one example of tool development for ISRU tasks, pouring regolith through a funnel. In simulation, 50 macroparticles were dropped into funnels with varying hole diameters to model the flow of material, under both Earth and Lunar gravity, with the material parameters adjusted to that of: 7mm radius ball bearings, dry sand, and Lunar regolith simulant (Exolith LMS-1). These models were then validated experimentally against the same three materials in real-world trials. The results of the simulation predicted some of the complex behaviours which arise from these multivariable interactions. For example, in narrow funnels the cohesive simulant will stick to, both itself and the tool, resulting in an irregular flow rate. Cohesion can lead to regolith plugging the funnel entirely, which occurs at wider funnel diameters under Lunar gravity.

Using this tool avoids any need for any physical prototyping or complex mathematical computation, even for this simple tool design example. This model could be used for rapid virtual testing to build confidence in hardware designs as a precursor to physical prototyping. It can also be applied to model-mediated teleoperation, to allow operators of robot manipulators to work in perceived real-time in order to overcome the high latency of Earth-Moon communications. The results could be further validated against data from upcoming Lunar missions.