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A DYNAMIC ANALYSIS OF WHEELED JUMPING ROBOT FOR LUNAR EXPLORATION

Abstract

In recent space missions, efforts to sustain human presence on the Moon have identified lunar lava tubes as potential shelters for humans and instruments. However, the knowledge about these geological formations in non-terrestrial conditions remains limited. To explore these areas, planetary surveillance missions have traditionally relied on wheeled rovers. Nonetheless, the size of obstacles over which these devices can tackle is limited by the size of their wheels. While aerial vehicles have successfully commuted over obstacles in other environments, they cannot be deployed on airless planetary bodies such as the Moon.

Alternatively, jumping robots can overcome obstacles using the reaction force from the substrate for propulsion. The best previous example has shown to jump up to 100 times its own size. However, previous research on jumping robots has focused on optimising the jump height or range on an idealised substrate and has only been tested in controlled laboratory environments. These approaches are limited in that they neglect the environmental factors that potentially make the technologies unusable and do not consider operating on granular substrates such as lunar surfaces.

The contribution of this work is to develop a wheeled lunar jumping robot and elucidate the underlying design philosophy to address the influence of lunar regolith on jumping dynamics. A low-order dynamic model is formulated for sizing and characterising the relationship between jumping range and the force of the actuator, and how this changes with the system scale. The developed prototype integrates the jumping mechanism with wheeled mobility. The jumping mechanism utilises a spring for actuation and is equipped with an active clutch for precise thrust control. At maximum thrust, it can repeatedly travel over 7m under lunar gravity. The wheeled mechanism is used for robot reorientation, primarily yawing to control the thrust vector, and for active self-righting when landing in the opposite direction. The experimental model is tested in a simulated lunar regolith to examine the impact of the substrate. Two numerical models are developed to validate the experimental result and to characterise the mechanical properties of the substrate.

Preliminary trials indicate that substrate choice, take-off angles, and ground contact influence the range, with these effects predicted to be exacerbated when jumping from loose and adhesive lunar regolith. Post-experiment inspection reveals dust contamination in the mechanisms. This poses a design challenge

in contamination management for a compact robot scale, but it presents an interesting route for future studies.