Terramechanics and Impact Modelling of a Spherical Hybrid Ground-Aerial Vehicle

Sahand Sabet[1], Ali Agha[2] and Parviz Nikravesh[1]

[1]*Department of Mechanical and Aerospace Engineering, University of Arizona, {sahandsabet,pen}@email.arizona.edu*
[2]*NASA, Jet Propulsion Laboratory, aliaghajpl@gmail.com*

In this paper, we outline a detailed dynamic modeling and terrain interaction for a hybrid aerial-ground vehicle known as "Rollocopter" Fig. 1. This mobility vehicle (introduced in [1]) is a mechanically-simple, agile, and collision-resilient vehicle. Rollocopter is designed to roll on the surface whenever possible and fly above the surface when needed. Simplified dynamics of the Rollocopter has been discussed in [1]. In this work, we will perform an in-depth study on the dynamics and complex interactions of this vehicle with the terrain. To successfully analyze the behavior of the system on the ground, the elastic contact analysis of the Rollocopter in both flat and granular mediums are provided. In addition, the frictional behavior, rolling, and transient interaction of the system with its surroundings (e.g., intermittent slip) is investigated. The accuracy of the dynamic modeling is validated through the design, implementation, and analysis of prototypes for the Rollocopter.

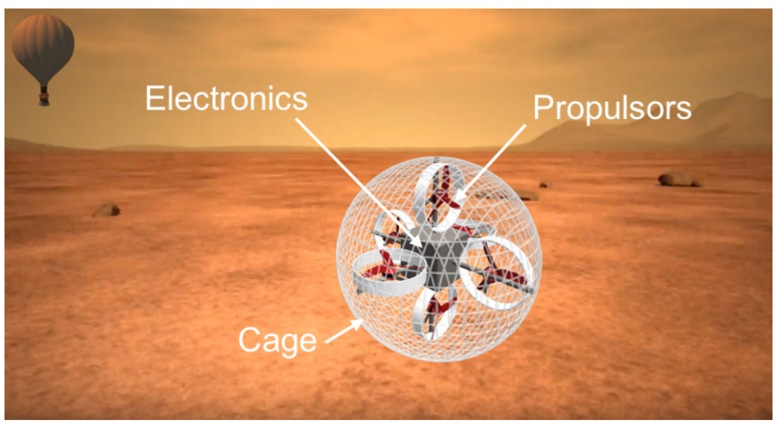

Fig. 1: Rollocopter

The proposed robot consists of six propulsors, actuators with propellers, that are enclosed in an outer spherical shell, as shown in Fig. 1. These propulsors are positioned in such a way to provide rotation about the pitch, roll, and yaw axes as well as translational motion in three-dimensional space. The battery and electronics are contained in the center of the sphere. The outer shell of the robot is comprised of polycarbonate plastic to provide strong, flexible, and lightweight protection for the on-board electronics. This shell allows the vehicle to be more resilient against collision and also to provide the vehicle a suitable structure for rolling on the ground. Rollocopter provides a mobility platform for exploration, imaging, and mapping due to its cross-domain autonomy and mobility along the air and the ground. The vast majority of mobility systems are designed as single-purpose platforms that operate in a single domain (e.g., on the surface, air, or underwater). Rollocopter, on the other hand, is a hybrid aerial-ground vehicle that can roll on the surface to save energy and fly above the surface to bypass extreme terrains when rolling is not possible.

To successfully design a Guidance, Navigation, and Control (GNC) algorithm for this agile system, we provide a comprehensive model for its mechanical interaction of it with the ground [2]. In this research, we assume that the impact response of the multibody system is continuous [3]. The contact pressure distribution for the elastically deformed sphere is evaluated in both flat and granular mediums [4]. In addition, we provide a high-fidelity dynamic modeling of the vehicle interactions with the terrain (including friction, rolling and slipping) considering different mediums.

References

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