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DESIGN OF A SPHERICAL UGV FOR SPACE EXPLORATION

Abstract

The paper presents the design of a spherical UGV (Unmanned Ground Vehicle) for exploration of critical, unknown or extended areas, such as planetary surfaces. Spherical robots are an emerging class of devices whose shape brings many advantages, such as omni-directionality, sealed internal environment and protection from overturning. Many dedicated sensors can be safely placed inside the sphere and the robot can roll in any direction without getting stuck in singular configurations. Specifically, the proposed UGV is thought to collect images and environmental data, so required sensors are firstly discussed to evaluate influence of the payload in terms of size and energy consumption. The most effective drive mechanism is selected considering several possible concepts and carrying a trade off process based on the requirements for a space mission. The optimal solution involves the use of a single pendulum: a hanging mass, attached to the central shaft of the sphere, is shifted to produce rolling. The design issues due to the selected mechanism are discussed, showing the effect of design parameters on the expected performance. For instance, the barycenter offset from the center of the sphere plays a crucial role and affects the maximum step or inclines that can be overcomed. Therefore, the pre-design phase is conducted defining the design of the robot and introducing a differential mechanism for driving and steering. A quasi-omni-directionality is achieved and the mechanical components, opportunely designed according to the loads acting on the device, are arranged to match the mission requirements. Moreover, the mechatronic integration is discussed: microcontrollers, drive electronics, sensors and batteries are sized in order to reach 3 hours of continuous operation. The multibody system is finally modelled in Matlab-Simscape to verify the mechanism for the UGV testing in specific cases. The result show that a suitable layout is a 500 mm diameter spherical UGV with a steel main structure, mounting 2 DC motors that activate a bevel gear by means of pulleys and timing belts. The spherical shell, with the internal mechanism and electronics, has a total mass of 25 kg and from standstill it can climb up to 15 degrees inclines or steps up to 25 mm, as proved by Matlab simulations. Future works will focus on the realization of the physical prototype, as well as navigation and control strategies.