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SYSTEM REQUIREMENTS ELICITATION AND CONCEPTUALIZATION FOR A NOVEL SPACE ROBOT SUSPENSION SYSTEM

Abstract

Space robotics plays a crucial role in space exploration and creates numerous opportunities for future space missions, including satellite lifetime extensions, orbital asset inspections, and deorbiting. However, testing space robots on-ground poses a significant challenge: Space robots are designed to operate in zero gravity, but tested under the influence of earth gravity. Above this, serial space robots are limited in the torque necessary to move on-ground. Common facilities for testing space robots use the air bearings concept, which limits the robot's workspace to operate only in a two-dimensional, horizontal plane. This drawback is especially problematic for testing complex tasks such as grasping, vision-based approaches, or FDIR trajectories, where the robot's full workspace is required. To address this challenge, this paper proposes core requirements for a novel suspension system designed for spatial testing, which can be exploited by a space robot for the on-ground testing. As such, the robot can operate in a larger workspace and accomplish the required tasks. The suspension system must reduce the space robot's drive torques below the joint limit. Note that this requirement does not necessarily simulate zero gravity. Thus, the system needs to be combined with a method that achieves complete gravity compensation by computing the necessary additional robotic joint torques. Additionally, the bandwidth of the suspension system must be at least one order of magnitude above the bandwidth of the elastic dynamics of the space robot to separate the mechanical dynamics of the space robot from the suspension system. The paper then presents a pre-selection of mechanical concepts that meet the above stated requirements. As a result, the survey concludes that a cable-based parallel robot features the necessary high bandwidth due to its minimal mass and high winch dynamics. First analytic results demonstrate the feasibility of the selected system. In

particular, the strongly configuration-dependent eigenmodes of the cable-driven parallel system need to be taken into account and will be discussed in the last section of the paper. As a conclusion, this paper states that innovations in robotics and modern sensing technology make it possible to replace traditional, passive suspension systems allowing space robots to be tested in the entire workspace, paving the way for qualifying high-level applications such as autonomous grasping and vision-based servoing.