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LONG-REACH TENDON-ACTUATED PLANETARY SURFACE AND IN-SPACE MANIPULATORS

Abstract

Devices that can lift, translate and precisely position payloads, equipment and infrastructure on planetary surfaces are necessary to execute most space exploration missions. The requirements for these devices to have long reach (to unload landers for example) and low mass necessitates that they be highly efficient structural systems. For the gravity environment of planetary surfaces, the Lightweight Surface Manipulation System (LSMS) was invented and has been developed to serve as a versatile robotic manipulator. The LSMS is a hybrid cable/boom manipulator that achieves its high structural efficiency by implementing an architecture based on pure compression and tension members. In the LSMS, the cables not only serve as the tension load paths, but changing the cable length (by reeling them in and out) actuates the joints and articulates the manipulator.

A more recent focus on in-space missions has identified a similar need for long-reach low-mass manipulators that can support operations for missions to Near Earth Objects, orbital debris removal, satellite and propellant depot servicing, rapid International Space Station resupply, and large telescope assembly. For a desired applied tip force, the structural efficiency of a traditional boom/rotary-joint manipulator architecture rapidly degrades as the manipulator reach is increased. A manipulator that is based on an architecture of tension-stayed booms and tendon-controlled articulating joints has the potential to achieve the high structural efficiency necessary to make long-reach space manipulators practical. Although this new space manipulator architecture can make use of principles that were used to develop the LSMS, the implementation will be considerably different. This is because the LSMS takes advantage of gravity and LSMS self-weight, plus the weight of the payload, to maintain tension forces in the cables during articulation. However, because of the lack of gravity, the space manipulator must use opposing (antagonistic) tension cables to maintain structural integrity and payload force control during articulation.

This paper will review the missions and needs for long-reach manipulators for both planetary surface and in-space applications. It will review the mass efficiency metric for planetary surface applications and compare it to the metric developed for in-space manipulators. It will discuss the impact that non-structural requirements, such as packaging, deployment, range of motion, device simplicity, modularity and scalability have on device implementation. It will present new concepts for long-reach, tendon-actuated, in-space manipulators and compare their performance and features to traditional space manipulators and the LSMS.