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Author: Dr. Danielle Carroll
University of Colorado Boulder, United States

Mr. Spencer Dansereau
University of Colorado Boulder, United States
Ms. Siddhi Bhilare
University of Colorado Boulder, United States
Dr. Stephen Robinson
University of California, Davis, United States

NOVEL EXTRAMUSCULAR ASSISTED SPACESUIT GLOVE (EMAG) ENABLED BY SOFT ROBOTIC TECHNOLOGY

Abstract

Pushing the boundaries of human space exploration is a challenging undertaking for upcoming international space missions, including the Artemis program. Creating a sustainable lunar surface habitat introduces unique engineering challenges in supporting astronaut health and well-being over extended-duration missions. In-situ resource utilization (ISRU), such as water extraction from the lunar regolith, becomes imperative for missions of such scale. Optimizing extravehicular activity (EVA) spacesuits and associated hardware for tasks such as driving vehicles, manually collecting rock samples, mapping geological patterns and problem-solving emergency situations is critical. EVA tasks rely heavily on manual dexterity, rendering glove optimization a necessity. NASA astronauts historically have experienced considerable discomfort and difficulty while using current/prior models of pressurized gloves during EVA, leading to early fatigue, musculoskeletal injuries, and nail delamination. Such events have the potential to compromise EVA performance on the lunar surface for extended mission profiles. Our team has developed a novel design solution to address current EVA glove shortcomings, incorporating a soft hand exoskeleton to assist with palmar and phalangeal flexion and reduce the risk of injury. The device proposed, the Extramuscular Augmented Spacesuit Glove (EMAG), is driven by voltage-controlled soft electro-hydraulic actuators that convert electrostatic forces into linear motion, thereby departing from commonly-used actuators such as rotating servos. Soft robotics are lightweight, allow for customizable geometry, and are comprised of safer materials than many prior solutions, rendering them a suitable choice for glove-related applications. The EMAG design incorporates principles of biomimicry, closely following the human hand flexor pulley system, and includes a set of flexible silicone phalangeal frames actuated by the soft electro-hydraulic mechanism via a series of guided carbon-fiber tendons. The experimental design of the EMAG is set up such that torques from the soft exoskeleton on the phalangeal joints are calculated using inverse dynamics and superimposed on the muscular torques in a hand and wrist musculoskeletal model in OpenSim software. Muscle and tendon forces are then calculated and juxtaposed with a control model (i.e. musculoskeletal model without additional exoskeletal torques). Studying the difference in muscle and tendon forces between these two models permits quantification of the mechanical assist provided by the soft hand exoskeleton. The proposed EMAG is designed to mitigate hand fatigue and reduce the risk of musculoskeletal injury and nail delamination, thereby enhancing astronauts' productivity and accelerating the pace of scientific exploration. This work is supported in part by the Translational Research Institute for Space Health through NASA NNX16AO69A.