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A CONCEPT STUDY OF HAPTIC FORCE FEEDBACK SPACESUIT TO MITIGATE EFFECTS OF SPATIAL DISORIENTATION IN LUNAR GRAVITY

Abstract

Space is the ultimate frontier for mankind, and the moon will serve as an important testbed before embarking on a long journey to Mars. The anatomical and physiological mechanisms of human body are evolved to interpret and measure the force of Earth gravity. The neurocognitive and neurophysiological functions exhibit challenging variations in one-sixth lunar gravity. Human vestibular systems that provide basic information regarding linear acceleration no longer function as on Earth. Also, human perceptual motor performances deteriorate under high stress environment of space. The sensory degradation directly affect balance, the speed and accuracy of spatial orientation, and the central management of concurrent tasks. Human operator capabilities such as positioning line of sight is limited significantly, and the response time gets longer. These altered capabilities are potentially dangerous during the early phase of planetary surface exploration, while the body is adjusting to a new environment. This paper investigates the potential use of immersive and wearable force-feedback haptics in support to astronaut training for planetary extra-vehicular activities (EVA). The proposed concept HIPS (Haptic infused planetary spacesuit) applies the principles of control engineering to integrate space life sciences and technology, in order to mitigate reduced gravity related vestibular issues. The end product promises use in virtual reality based training, as well as in real-time operations. Design data of NDX-1, an experimental planetary spacesuit developed by Human Spaceflight Laboratory of University of North Dakota, will be used for baselining purpose. The proposed flex sensors in Sensory Network Layer (SNL) are placed on outer fiber layer of spacesuit. These sensors will detect changes in linear accelerations and torques acting on human body, and use the data for haptic rendering. The sensing circuit then activates a modified signal activation algorithm to vibrate and alert the user in order to prevent a potential fall or injury. Different techniques and materials for development and integration of a haptic substrate are discussed. This paper also focuses on understanding how the level of gravity affects the neutral body posture (NBP), range of motion of extremities, and the location of most sensitive receptors on human body. This will enable the development of baseline joint angle ranges for the activation algorithm without compromising functional/operational envelope of an astronaut. HIPS promises a redundant infrastructure which would equip the researchers, and space travelers for a successful planetary manned mission.