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ROBOTS SUPERVISING HUMANS AND HUMANS SUPERVISING ROBOTS – A CALL FOR NEW CONCEPTS IN HUMAN-ROBOT TEAMING FOR SPACE

Abstract

Robots are frequently operated under teleoperation or human supervisory control. However, in space robots may need to operate in unpredictable situations with limited human and communications contact, such as during deep-space missions where communication delays can extend to 20 minutes. While ethical and legal requirements necessitate a human "on" or "in" the loop, truly effective teamwork demands a shared understanding of each member's priorities and objectives. Planned missions beyond Low Earth Orbit, involving both humans and robots, will require novel methods of facilitating safe operation in hazardous environments, such as lunar dust storms or radiation exposure on Mars. This paper introduces context aware collaborative teaming for humans and robots (CATCHR) an innovative framework designed to enhance human-robot teamwork for applications such as onboard robotic assistants, habitat construction support, and robotic precursor missions. Our approach requires a multidisciplinary effort that combines modelling of human performance with advanced AI algorithms capable of integrating information from humans and the environment.

Central to CATCHR is the use of Hierarchical Task Decomposition to break down complex missions into manageable sub-tasks, ensuring clear role assignments for both humans and robots. A key aspect of this approach is using models of human performance and task performance to ensure the robot has metrics for effectively monitoring human performance and vice versa. This common understanding of capability as it relates to task completion will underpin proactive task assignment. Robot decisions in this framework should be transparent, fostering trust and alignment with human priorities.

For example, in a lunar exploration mission, CATCHR decomposes the mission into tasks such as habitat assembly (robot-led), sample collection (human-led), and terrain mapping (robot-led). Tasks can be re-allocated depending on human and robot progress towards a common goal. During communication delays, the robot makes local decisions, such as pausing exploration during a dust storm, and syncs later with human operators. This illustrates how CATCHR, a framework that supports collaborative and context aware teaming, could underpin adaptive, transparent, and resilient collaboration in unpredictable environments. We propose testing in simulation, followed by field tests with a human in or on the loop to validate this framework.

By addressing the evolving roles of humans, machines, and intelligent systems, CATCHR supports the future of complex mission design, implementation, and operations. The outcome of this approach will be a resilient human-robot team capable of operating effectively in the challenging conditions of space.