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Author: Mr. Ayaz Damirov
Azerbaijan State Oil and Industry University (ASOIU), Azerbaijan

Mr. Ilkin Abdullayev
Azerbaijan State Oil and Industry University (SABAH Groups), Azerbaijan

ENHANCING LUNAR AND MARTIAN EXPLORATION THROUGH HUMAN-ROBOTIC COLLABORATION

Abstract

Human-robot interaction becomes increasingly important for space missions beyond a handful of days in low-Earth orbit. To accomplish Moon and Mars exploration, many challenges will arise that will require complete partnerships between human astronauts and robotic systems. Using artificial intelligence (AI)-powered robotics with a human will improve the efficiency, safety, and scientific output of missions. This paper examines the changing role of robotic assistants in supporting exploration by humans on other planetary surfaces in a detailed literature review of the Artemis program and future Mars missions.

Robotic systems can be first sent to perform reconnaissance for habitat construction, as well as even establishing the lifeline for astronauts. They can assist astronauts in reducing EVA activities, performing monotonous tasks, and improving real-time decision-making with AI analytics. Examples demonstrating this trend include NASA's Robonaut, ESA's Interact, and such autonomous rovers as Perseverance and VIPER.

We propose a behavior framework for human-robot-interaction (HRI) in deep space missions with improved capabilities in autonomous task delegation, real-time interaction for data exchange, and robotic awareness with regard to the environment. The architecture contains a decision-making capability based upon a machine learning approaches to allow robots to anticipate astronaut needs and navigate autonomously in hazardous environments. We performed an analysis of the advantages provided by systems with mixed autonomy whereby an astronaut relies on robotics to perform an action, provides an override capability, or allows a robot to make decisions on behalf of an astronaut considering mission needs.

This study will assess the impact of delayed communication on such a mission and propose hybrid robotic systems that can operate independently but will be able to align these behaviors to human-formed intentions. Integrating telerobotic with haptic feedback technology will allow astronauts on orbit to control surface robots remotely and thus reduce the gaps between human intuition and robotic endurance.

Future exploration strategies should employ the strengths of both humans and machines in sustaining an ever-growing footprint off the Earth. Enhancing autonomy in robots but maintaining a human-watched kernel will permit adaptation to changing conditions, resource optimization, and risk reduction. This research pursues an approach imagining exploration methodologies that increase scientific output while ensuring the safety of astronauts.