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NEUROECONOMIC OPTIMISATION OF IN-SITU RESOURCE UTILISATION FOR SUSTAINABLE LONG-DURATION SPACE MISSIONS

Abstract

The future of space exploration is based on our ability to sustain long-duration missions to the Moon, Mars, and beyond without reliance on frequent Earth-based resupply. In-situ resource utilization (ISRU) emerges as a critical solution, enabling the extraction and use of local resources such as lunar oxygen, water, and minerals. This paper introduces a novel framework that integrates neuroeconomic principles with advanced decision-making models to optimise ISRU, addressing a major challenge in the contemporary space economy.

We propose the utilisation of discrete choice experiments and preference-based reinforcement learning within a neuroeconomic context to model astronauts' decision-making processes under microgravity. By examining how higher-order cognitive functions—such as working memory and subjective value assessment—influence resource selection and consumption, we develop a Markov decision process that simulates optimal choices in uncertain environments. The model considers various resource attributes (e.g., availability, extraction difficulty, utility) and internal states (e.g., hunger, fatigue), allowing for dynamic adaptation and efficient resource allocation. Reinforcement learning algorithms further enable agents to learn from interactions with the environment, maximizing rewards associated with sustainable resource use.

Our findings demonstrate that this neuroeconomics-driven approach significantly enhances ISRU strategies by optimising resource extraction and utilization processes. By aligning cognitive decision-making models with practical resource management, we contribute to mission resilience and sustainability, reducing dependence on Earth-bound supplies. This framework not only advances the efficiency of long-duration missions but also has profound implications for the space economy, facilitating fuel production, life support, and the establishment of self-sufficient extraterrestrial habitats. By linking neuroscience, economics, and space exploration, this research offers a transformative perspective on sustainable resource management in space, crucial for the next era of interplanetary exploration.