Self-Evolving AI Robot System for Lunar Exploration and Human Outpost Construction

1. Position in the program

This R&D project will develop AI robot technology to enable sustainable manned activities on the Moon in the 2050s.
In the late 2020s, the era in which humans will once again head to the Moon is about to begin, and the AI robot system to be developed in this project will enable the establishment of a manned long-term observation base in the 2030s and 2040s, and in the 2050s, when more people will visit the Moon and establish a living and economic sphere. The project aims to create an environment where the Moon's surface is a difficult place for people to live and work. This project proposes a self-repairing/self-growing AI robot system consisting of several different types of robots as a major player in the exploration and construction of a base in the lunar surface, an environment where it is difficult for humans to operate.

Since the opportunity to transport materials to the Moon's surface is limited and costly, this project proposes an adaptive AI robot system that can respond to various forms and situations by making effective use of materials brought to the Moon's surface, changing its form by recombining it according to the situation, and repairing or adding new parts as necessary using resources obtained on the Moon's surface. By incorporating an adaptive AI system that can respond to various forms and situations, we will realize a "transformable" AI robot system.

Through the realization of such innovative robot technology, we aim to achieve the moonshot goal of robots building bases on the Moon's surface and people engaging in creative activities on the Moon in the 2040s and 2050s, and to further expand these activities not only to the Moon's surface but also to other celestial bodies.

2. Overview of the R&D and the Challenges

In this R&D, we propose a reconfigurable AI robot system as a leader for exploration and base building on the Moon's surface. We will establish technology for self-reproducing AI robots that can effectively utilize materials brought to the Moon's surface, reconfigure modules according to the situation, and repair parts using resources obtained on the Moon's surface. This will facilitate exploration and resource utilization on the Moon's surface by 2050, with the aim of realizing a sustainable manned activity base.

To achieve these moonshot goals, the following three overcoming challenges will be addressed.

Challenge 1: Modular, Multi-Agent Robotic Systems

Due to limited transportation to the Moon's surface, the robot system must be adaptable and "transformable" to match the work environment and objectives. Cooperation among multiple robots in various forms is crucial. While modular and multi-agent robots have been studied, efficiently exploring the Moon's surface, building a base, and performing tasks like material transfer and assembly with heterogeneous robots remain challenging. Adaptively performing tasks in the Moon's harsh environment requires improving system robustness using reconfigurable robots and developing a distributed and coordinated operation among diverse robot forms. The integrated robot system must successfully fulfill its mission.

Challenge 2: Distributed, Plug and Play AI

It is a challenging task to realize an AI system that can grow and develop itself by experiencing various environments and tasks, and learning from them, while being embedded in a modular, multi-agent robot system that can "transform" itself. Although deep reinforcement learning has been studied and successfully implemented as an AI for generating and controlling robot behaviors, the current research results are mainly focused on single-body robots and individual task learning. In order to apply AI to reconfigurable reconfigurable robots and heterogeneous exploratory robots, it is necessary to establish a method to enable Plug and Play (reuse, repurpose, and rebuild) of learning results, and a promising approach is to develop hierarchical reinforcement learning.

Challenge 3: Hardware Manufacturing for Self-Repairing and Regenerative Robots

Under challenging environments such as the lunar surface sustainable, it is important to adopt the concept of "local production for local consumption," in which the robot system is reproduced using locally procured resources and materials in response to new needs arising in the local environment.
To enable on-demand type "transformable" robots in difficult environments, the practical application of 3D printing technology for robot structural components using locally procured soil materials is essential. Soil is mainly composed of silicon-based ceramic compounds (SiO2, Al2O3, etc.) and metal compounds. Based on scientific understanding of these materials as materials and interdisciplinary research approaches on their processing methods, currently known as sintering and melting processes using laser or electron beams Based on the scientific understanding of these materials as materials and an interdisciplinary research approach to their processing, we aim to develop methods to obtain components with sufficient strength and to realize self-healing and regenerative robots.

3. Future plans

We will develop core technologies to overcome the above three issues, and conduct technical demonstrations of the development results at each milestone. In addition, developed technologies can be applicable to the earth such as natural disasters and etc.