Paper ID: 51479
student

IAF SPACE SYSTEMS SYMPOSIUM (D1)
Space Systems Engineering - Methods, Processes and Tools (1) (4A)

Author: Mr. Shunichiro Nomura
The University of TOKYO, Graduate school, Japan, nomura@space.t.u-tokyo.ac.jp

Prof. Ryu Funase
University of Tokyo, Japan, funase@space.t.u-tokyo.ac.jp
Prof. Shinichi Nakasuka
University of Tokyo, Japan, nakasuka@space.t.u-tokyo.ac.jp

ROBUST DECISION MAKING FOR LUNAR RESOURCE UTILIZATION

Abstract

We have been exploring space for decades for various reasons. In the early days of space exploration, it was the national prestige of the two superpowers that drove the "space race." Scientific curiosity is another driving force and has been the reason for many space missions including planetary spacecraft, rovers, and space telescopes. Furthermore, some space missions such as Earth observation satellites are driven by its economic value. While space missions driven by national prestige or scientific curiosity have contributed to expanding the frontier, they are not as sustainable or scalable as ones driven by pure economic value. It is thus crucial to the sustainable and scalable space exploration to utilize resources in space and bring its economic value back to the Earth.

While it is suggested that the Moon and asteroids might have water that can be used as fuel, space resources we utilize today is mainly from Earth orbits, and to seek resources in deep space tends to be regarded as risky due to its high uncertainty. Therefore, we need to be cautious in deciding how to explore deep space and utilize its resources robustly.

The info-gap decision theory (IGDT) is a quantitative decision-making framework for problems under severe uncertainty, where we can quantitatively evaluate the robustness against uncertainty. With this framework, we formulated a problem where we explore and exploit lunar water and sell it on orbit as follows. The uncertain parameter θ is defined as a vector of the total amount and mining rate of the resource and technology development cost, time, and achieved performance. The state $s \in \mathcal{S}$ is defined as a vector of technology availability, information availability, and allocations of commodities. The action set $\mathcal{A}$ consists of technology development, resource exploration and exploitation. Then the design variable is defined as the policy mapping $\pi : \mathcal{S} \to \mathcal{A}$. Given a realization of uncertainty parameter θ and a policy π, the realized performance $V(\theta, \pi)$ can be calculated. We defined $V(\theta, \pi)$ as the cost per unit mass of water supplied on orbit. In the IGDT framework, the user defines the non-probabilistic model of uncertainty $\mathcal{U}(\alpha, \tilde{u})$ that defines the possible region of u with α, the horizon of uncertainty, and the estimate of u, $\tilde{u}$. Then the robustness function can be calculated as $\hat{\alpha}(\pi, r_l) = \max\{\alpha | r_l \leq \min_{u \in \mathcal{U}(\alpha,\tilde{u})} V(\pi, u)\}$, where r_l is the required performance.