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REINFORCEMENT LEARNING BASED OPTIMIZATION OF THE EARTH-MOON SPACE SUPPLY NETWORK

Abstract

The invention of reusable space vehicles has substantially brought down the cost of payload launch. This reduction could give access to potential opportunities like space tourism, mining of valuable materials, energy production, telecommunication, and space habitats. Therefore, private and public sectors have renewed their interests in the space economy. This economy could involve extraction, storage, and transportation of goods and services to and fro an extraterrestrial body and the Earth. For example, the Moon being the closest to the Earth, could become the first celestial body for mining resources of industrial use, and hosting instruments for scientific discoveries.

However, the space economy is far more challenging than the Earth economy, because space is hostile to humans and machines alike for its extremities like temperature, radiation, and velocities. This hostility demands careful planning, safety measures, reliable machinery, and skilled crew for space missions. In addition, the cost of payload launch is still quite high compared to the existing supply networks on the Earth. To reduce this cost, the economy of scale is imperative, and could be achieved by extending the Earth's supply networks into space. For crewed missions, human safety further adds to this cost. The uncrewed missions via remote, semi-autonomous, and fully autonomous operations could bring down this cost too. This autonomy could enable the machines to make decisions locally and contextually with minimum human intervention.

Today, approaches based on artificial intelligence, in particular machine learning, are the best candidates to implement this autonomy. These autonomous networks could evolve by forming complex patterns of logistics. For example, intermediary space depots could support docking and resting points for vehicles, and stockpiling of goods for consumption and transportation. After analyzing the complex patterns in the logistics, the networks could be governed by sophisticated optimization algorithms. This could first optimize the positions of space depots, and next the schedules and trajectories of the visiting space vehicles. The traditional trajectory optimization solvers may not be able to scale with increased complexity, and the dynamic nature of the space supply networks.

In this paper, we present an alternative approach to optimize a hypothetical network of space depots between the Earth and the Moon. The approach provides guidance and control mechanisms for the space

vehicles and the space supply depots. To implement this approach, we have used reinforcement learning for its ability to adapt to the changes in its environment.