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A HIERARCHICAL COLLABORATIVE MISSION PLANNING METHOD OF MULTI-NODE LANDER FOR ASTEROID LANDING

Abstract

Stable soft landing on the surface is one of the fundamental technologies for asteroid sample return missions. However, it presents a significant problem on an asteroid with weak gravitational fields and complicated surface terrain. Consequently, our team suggests a multi-node lander wrapped in a flexible material that can provide landing cushioning. Under the condition of extended time delay, the lander must be equipped with an onboard autonomous planning capability. The multi-node lander has several nodes, and each node contains a number of subsystems. Therefore, the lander can be represented as a multi-agent system while each node and subsystem is treated as an agent with physical connection restrictions and complex temporal and resource constraints. Traditional multi-agent planning methods are inefficient, which will produce planning results slowly for such a multi-agent system. To improve the planning speed with flexibility constraints, a hierarchical collaborative mission planning method is proposed. First, the knowledge of the multi-node lander is expressed using the multi-agent numeric domain modeling language (MANDML) and put in the model files. Then, the Node-Subsystem-Activity hierarchical planning architecture is established based on the physical characteristics of the lander and the mission decomposition to handle abstract missions at the upper layer. Thus, the multi-agent constraints are decoupled hierarchically to reduce the complexity while planning on each layer. The upper layer agents are used as managers of the lower layer agents. The public and private information is defined for each agent and only public information is exchanged to improve communication efficiency. Utilizing a decentralized architecture for multi-agent planning enables parallel planning of intra-layer agents. Agents search for a complete plan by resolving flaws and will negotiate with agents at a higher layer if flaws at this layer cannot be resolved. In addition, a time-based heuristic policy is developed to reduce agent interactions during the planning process. Finally, experiments are conducted in an asteroid landing scenario, and the results show that for the lander with more than three nodes, our method can produce planning results faster than the EUROPA planner.