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COORDINATING LUNAR CONSTRUCTION SWARMS: BRIDGING TASK ALLOCATION THROUGH DUAL-LAYER BILATERAL MATCHING

Abstract

The establishment of a lunar base demands efficient robotic systems capable of operating under extreme environmental constraints. Current challenges lie in coordinating heterogeneous robot swarms to collaboratively execute complex tasks with limited computational resources and energy availability. This study proposes a novel swarm coordination framework to optimize autonomous task allocation for lunar construction. A coalition utility function is designed to holistically evaluate task execution efficiency, integrating temporal constraints, energy consumption, and operational precision. To address the combinatorial complexity of swarm coordination, a hierarchical capability-matching architecture is introduced, comprising: 1) Capability-based pre-grouping that categorizes robots by functional specialization; 2) Dual-layer bilateral matching that prioritizes critical tasks while dynamically allocating subtasks; 3) Tabu search-enhanced optimization to prevent local minima and accelerate convergence. The algorithm's core innovation resides in balancing global coordination efficiency with real-time adaptability. Simulation results demonstrate the framework's ability to autonomously form optimal robot coalitions under multiple constraints, significantly improving coordination robustness compared to conventional auction-based mechanisms. This research establishes a theoretical foundation for deploying self-organizing robotic swarms in extraterrestrial environments, with direct applications to lunar infrastructure deployment and in-situ resource utilization operations, which advances the feasibility of large-scale autonomous construction beyond Earth.