18th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Joint Space Operations/ Space Debris Session (10-B6.5)

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GLOBALLY-OPTIMAL WHOLE BODY MOTION PLANNING UNDER NONHOLONOMIC CONSTRAINTS USING DYNAMIC PROGRAMMING

Abstract

Robotics is a key enabler for many applications in space including planetary exploration, on-orbit servicing (OOS), in-space manufacturing (ISM), active space debris removal (ADR) and deep space exploration. They are usually characterized by limited resources, which requires the robotic system to be controlled according to criteria of optimality. How to perform operations and plan the robot motion are then key factors to ensure feasibility and efficiency. This work analyzes and extends a recently proposed dynamic programming optimization (DPO) algorithm for off-line motion planning in the context of planetary colonization, ranging from exploration, terrain preparation and construction. The algorithm is designed to be run on ground with the aim of (1) limiting spacecrafts cost and (2) optimally plan complex tasks with medium to long term time horizons before or during mission. The analysis is performed on a robotic system including a six degree of freedom manipulator mounted on a non-holonomic base which is exercised on tasks that leave more than one degree of redundancy. The planning tasks are resolved without decomposition, allowing the algorithm to optimize the motion of the whole kinematic structure. Redundancy is exploited to optimize the cost function of interest, while considering any constraint the robotic asset and the surrounding environment are characterized by. In our use case, the optimization is performed on a cost function associated to energy consumption, but the extreme flexibility of the algorithm leaves room for accommodation of generic requirements both in terms of functional minimization and constraints to be satisfied. A tradeoff analysis of the solution quality versus the computational resources requirements is provided. Finally, we highlight the advantages of the proposed algorithm with respect to a standard planning approach based on decomposition of the planning problem in two sub-problems: the first involving the planning of the mobile base according to some heuristics (e.g. reachability) and the second involving the planning of the manipulator.