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# 6-Degree-Of-Freedom Spacecraft Motion Planning via Model Predictive Control and Dual Quaternions

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**Abstract :** This paper presents Guidance and Control (G&C) strategy to approach and synchronize with potentially rotating targets. The proposed strategy generates and tracks a safe trajectory for space servicing missions, including tasks like approaching, inspecting, and capturing. The main objective of this paper is to validate the G&C laws using a Hardware-In-the-Loop (HIL) setup with realistic rendezvous and docking equipment. Throughout this work, the assumption of full relative state feedback is relaxed by onboard sensors that bring realistic errors and delays and, while the proposed closed loop approach demonstrates the robustness to the above mentioned challenge. Moreover, G&C blocks are unified via the Model Predictive Control (MPC) paradigm, and the coupling between translational motion and rotational motion is addressed via dual quaternion based kinematic description. In this work, G&C is formulated as a convex optimization problem where constraints such as thruster limits and the output constraints are explicitly handled. Furthermore, the Monte-Carlo method is used to evaluate the robustness of the proposed method to the initial condition errors, the uncertainty of the target's motion and attitude, and actuator errors. A capture scenario is tested with the robotic test bench that has onboard sensors which estimate the position and orientation of a drifting satellite through camera imagery. Finally, the approach is compared with currently used robust H-infinity controllers and guidance profile provided by the industrial partner. The HIL experiments demonstrate that the proposed strategy is a potential candidate for future space servicing missions because 1) the algorithm is real-time implementable as convex programming offers deterministic convergence properties and guarantee finite time solution, 2) critical physical and output constraints are respected, 3) robustness to sensor errors and uncertainties in the system is proven, 4) couples translational motion with rotational motion.

**Keywords :** dual quaternion, model predictive control, real-time experimental test, rendezvous and docking, spacecraft autonomy, space servicing
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