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DUAL QUATERNION BASED RELATIVE NAVIGATION FOR SPACECRAFT PROXIMITY OPERATION

Abstract

In this paper, dual quaternion based relative navigation in space environment for proximity operation is investigated. Dual quaternion is the parameter that can describe position and attitude in a unified form. It is extension of dual number and quaternion, so mathematical and parameter characteristics of those are holding. The attitude and orbital kinematics model can be concurrently integrated in a simplified and intuitive formulation using dual quaternion. From these merits, the dual quaternion has been researched to generate the reference command for the translational and rotational motion simultaneously in the guidance and control aspects such as the planet landing, rendezvous or docking mission. Here, prior to derive navigation equations, we compare classical and dual quaternion based relative kinematics between two adjacent spacecraft. Especially, the case is considered which interested points are not coincident with c.m. (center of mass) of spacecraft. At this time, it is obvious that position affected by rotational motion of rigid body and classical position and attitude decoupled kinematics cannot describe at once. One approach to describe position and attitude coupling is using highly complicated position kinematics including relative angular velocity vector. We show that, while a classical state vector representation consisting of position vector and quaternion yields a complex form of relative kinematics, the new dual quaternion based relative kinematics model is derived in a much simpler form. This benefit of simplicity becomes more evident when relative attitude-and-orbit state information about non-c.m. points are required in missions such as rendezvous and docking. Motivated and concentrated by these backgrounds, in this paper, to estimate relative navigation states, dual quaternion based relative kinematics are derived and the error state equations are formulated. To reduce the number of state variables, error dual quaternion is applied, which makes the number of state variable be six instead of eight using parameter constraints of dual quaternion. Extended Kalman filter is adopted to realize relative navigation. System model and simplified measurement model are constructed, states and error covariance are propagated and updated. Simulation results show that the kinematics model is accurately derived, states are well estimated, and statistics of estimation errors are consistent with error covariance. In addition, navigation performance is compared with classical decoupled kinematics. The comparison results demonstrate the effectiveness of the proposed dual quaternion based relative navigation. As a future work, we plan to integrate the proposed navigation filter with the control and guidance algorithm for spacecraft proximity operation.