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ATTITUDE AND POSITION TRACKING OF A SPACECRAFT WITHOUT VELOCITY MEASUREMENT

Abstract

Simultaneous position and attitude control of a rigid spacecraft has been the focus of much recent research because of its applications in formation flying and spacecraft rendezvous and docking, etc. The six-degrees-of-freedom (six-DOF) coupled motion of a rigid body should be taken into consideration, in contrast to the attitude-only control issue, which considers the three-DOF attitude motion alone. Traditional position and attitude control of spacecraft have been treated as decoupled problems which are later concatenated. In addition, most of the existing studies assumed that linear and angular velocity measurements are available for control law design. The velocity information, however, can be corrupted by large noises and is thus unsuitable for utilization. Due to the faults or failures of the velocity sensors, the velocity measurements can be unreliable or even unavailable.

Motivated by the above issues, the position and attitude tracking without velocity feedback is approached in this paper. Specially, the six-DOF relative motion dynamics of a rigid spacecraft is described via dual quaternions. Dual quaternions, as an extension of quaternions, have certain advantages in representing the translation and rotation motion of rigid bodies. The six-DOF motion dynamics of a rigid body in terms of dual quaternions are compact and have the same form as the attitude dynamics alone. This can simplify the design of an integrated position and attitude control law.

First, a tracking controller using both the pose (attitude and position) and velocity feedback is derived. This controller consists of a proportional-derivative feedback plus a feedforward compensation. To remove the velocity measurement in the first controller, an auxiliary system is introduced such that its output can replace damping effect of the velocity feedback, yielding a velocity-free tracking controller. A novel feature of the auxiliary system is that it preserves the same structure as the dual quaternion-based attitude and position kinematics. Hence, it output is also a dual quaternion. The proposed method is efficient in computation due to its simple structure and is thus suitable for online implementation. Finally, a circumnavigation and docking operation is simulated to demonstrate the effectiveness of the proposed method.