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PLANETARY UAV EXPLORATION SIMULATED IN A FLYING ARENA WITH THE USE OF NOVEL DUAL QUATERNIONS ATTITUDE DYNAMICS ALGORITHMS

Abstract

In this paper, we introduce a recently described algorithm based on Clifford algebra to simultaneously combine the rotational and translational dynamics, applied to the representation of a planetary-exploration Unmanned Aerial Vehicle. The motion of rigid bodies include three degrees of freedom (DOF) for rotation and three for translation: traditionally, these motions have been analyzed independently, and separate algorithms had to be used in order to perform control on both. The use of Euler angles is preferred due to its simplicity, but it introduces non-linearities that complicate the design of the control law. In addition, Euler angles are prone to the gimbal lock effect, which could lead to serious problems if not properly addressed. In this work, we implement a novel, recently described representation based on dual quaternions, which are an extension of the classical unit quaternion. The use of dual quaternions allows to have an efficient method for the analysis of rigid body motion over the special Euclidean group SE(3), through the use of an eight-entry state vector which accounts for rotation but also for translation. In this paper, several planetary exploration scenarios are analyzed, from mapping an unknown area, to the localization of a certain feature and the related data collection. The tasks are performed in the presence of disturbances, which are then filtered through the use of an Extended Kalman filter.
The performances of the proposed dual quaternion controller are benchmarked against classic representations over SE(3), such as Euler angles and Direction Cosine Matrix (DCM), and the results confirms the superior performance of our proposed representation.
The controller was first tested and simulated with the use of Matlab and Simulink. Then, with the aid of a flying arena, it was possible to further simulate its capabilities. A commercial UAV is used to simulate a planetary propulsive lander and terrain features were added to the arena ground in order to mimic a planetary environment. Flying simulations were carried out first by using a hardware in the loop configuration, and ultimately by embedding the logic on the UAV.