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DISCOVERING RAZI ACCELERATION VIA THE THEORY OF DERIVATIVE KINEMATICS AND ITS APPLICATION TO THE DYNAMIC ANALYSIS OF SPACECRAFT SYSTEMS

Abstract

This work introduces a new development in the theory of derivative and coordinate frames. We present a method to calculate and relate vector derivatives in relative motion analysis that involves multiple referential coordinate frames. This work offers promise to space dynamics analysts to accurately evaluate the velocities and accelerations, and subsequently, the inertia forces acting on bodies under compound rotation motion. The traditional method in relative motion is limited to the use of only two referential coordinate frames: an inertial-fixed frame and a rotating, body-fixed frame. However, in many dynamical systems – e.g. space robotic manipulators, in-orbit deployment and retrieval of tether from spool-type reel, gyroscopes, and the Earth's variable rotation – the analysis involves multi-body components and/or complex motion, hence the use of multiple coordinate frames is unavoidable. Plus, the classical dual reference frames system cannot take into account kinematical influence of the other rotation components of compound motion such as precession, nutation, and offset rotation (spinning and orbiting). The proposed method is developed by redefining and extending the Euler's derivative transformation formula for the application of multiple coordinate frames analysis. By introducing a third coordinate frame, it is shown that a new acceleration term appears and is called the Razi acceleration. It is also proven that the Razi acceleration can be a type of inertial force, which is akin to centripetal force or Coriolis force. Our effort is catered to those who seek accuracy in determining and relating vector derivatives in multiple referential coordinate frames environment that is ubiquitous in the field of space dynamics.