Proceedings of the Canadian Society for Mechanical Engineering International Congress 2021
CSME Congress 2021
June 27-30, 2021, Charlottetown, PE, Canada

Three-Dimensional Dynamics of Unicycle: Nonlinear Model and Its Simulation Results

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ABSTRACT

Three-dimensional equations of motion for unicycle consisting of a spinning wheel moving on a flat ground, and an attached fork to the wheel axle, are formulated using Euler-Newton equations of motion. The resulting non-linear ordinary differential equations provide a robust and realistic model for the dynamics of a simple unicycle. We account for a tire with a spherical contour, which provides a good approximation for real tires that can roll laterally. The unicycle is actuated in the most general way, having four external torques applied along each degree of freedom. Such a general form of actuation allows the model to serve as a template for many actuation methods. Our model is thus more comprehensive that previously proposed models of unicycle robot dynamics. Following the derivation of a comprehensive, nonlinear model, we show results of a simulation program for the unicycle. The goal of the simulation program is to provide a basis for programming a controller of a unicyle robot. The simulation program can solve for either the eternal torques given a path or vice versa. We propose two pseudolinearizations of the nonlinear model: first, assuming that any sinusoidal function is equal to its upright value, and second, applying the first term of the Taylor series expansion for sinusoidal functions. Tests from the simulation program conclude that neither simplification can successfully represent the unicycle's motion, even if the unicycle is close to upright. Thus, we conclude that the full, nonlinear model must be used for designing a control system.