Modeling and path-tracking control for a riderless-bicycle system

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ABSTRACT

In this dissertation, the equations of motion with nine generalized coordinates of a bicycle are developed. For constraints, rolling-without-slipping contact condition between wheels and ground is considered. For each wheel, two holonomic and two non-holonomic constraints are introduced in a set of differential-algebraic equations (DAEs). The dynamics model is validated by verifying the constraints, by comparison with a benchmark model, as well as with experiment results. The mathematic equations are then used to implement a simulation routine. To solve the DAEs of motion and ensure numerical accuracy in simulation of the bicycle system, computational methods for constraint handling are discussed and compared, including two methods to establish the underlying ODEs from the DAEs (coordinate reduction and embedding methods), and three numerical stabilization methods (Baumgarte, post-stabilization and sliding-mode-control post-stabilization). The path-following control is decoupled in two steps. First, the roll-angletracking controller is studied to control the bicycle following a reference command by applying steering torque while ensuring the roll stability with consideration of several approaches, including PID, fuzzy logic, pole placement and sliding mode. In the second step, the path-tracking controller is developed to generate appropriate roll-angle reference for the roll-angle-tracking controller in order to control the bicycle following a pre-defined path, by using fuzzy logic controllers. The effectiveness of the control schemes is proven by simulations with the developed mathematic model. Performance of the control schemes are evaluated in different conditions, including error information, path preview, constant speed, varying speed, and external disturbance.

Keywords : Bicycle Dynamics, Multibody System, Bicycle Control, Numerical Stability, Roll-Angle Tracking, Path Tracking

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