Dynamics of the Unicycle: Modelling and Experimental Verification

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Abstrak

This book presents a three-dimensional model of the complete unicycle–unicyclist system. A unicycle with a unicyclist on it represents a very complex system. It combines Mechanics, Biomechanics and Control Theory into the system, and is impressive in both its simplicity and improbability. Even more amazing is the fact that most unicyclists don’t know that what they’re doing is, according to science, impossible – just like bumblebees theoretically shouldn’t be able to fly.

This book is devoted to the problem of modeling and controlling a 3D dynamical system consisting of a single-wheeled vehicle, namely a unicycle and the cyclist (unicyclist) riding it. The equations of motion are derived with the aid of the rarely used Boltzmann–Hamel Equations in Matrix Form, which are based on quasi-velocities. The Matrix Form allows Hamel coefficients to be automatically generated, and eliminates all the difficulties associated with determining these quantities. The equations of motion are solved by means of Wolfram Mathematica. To more faithfully represent the unicyclist as part of the model, the model is extended according to the main principles of biomechanics. The impact of the pneumatic tire is investigated using the Pacejka Magic Formula model including experimental determination of the stiffness coefficient.
The aim of control is to maintain the unicycle–unicyclist system in an unstable equilibrium around a given angular position. The control system, based on LQ Regulator, is applied in Wolfram Mathematica.

Lastly, experimental validation, 3D motion capture using software OptiTrack – Motive:Body and high-speed cameras are employed to test the model’s legitimacy. The description of the unicycle–unicyclist system dynamical model, simulation results, and experimental validation are all presented in detail.