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A practical application of the geometrical theory on Fibred Manifolds to an Autonomous Bicycle Motion in Mechanical System with Nonholonomic constraints

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Abstract

The equations of motion of a bicycle are highly nonlinear and rolling of wheels without slipping can only be expressed by nonholonomic constraint equations. A geometrical theory of general nonholonomic constrained systems on fibered manifolds and their jet prolongations, based on so-called Chetaev-type constraint forces, was proposed and developed in the last decade by O. Krupková (Rossi) in 1990's. Her approach is suitable for study of all kinds of mechanical systems-without restricting to Lagrangian, time-independent, or regular ones, and is applicable to arbitrary constraints (holonomic, semiholonomic, linear, nonlinear or general nonholonomic). The goal of this paper is to apply Krupková's geometric theory of nonholonomic mechanical systems to study a concrete problem in nonlinear nonholonomic dynamics, i.e., autonomous bicycle. The dynamical model is preserved in simulations in its original nonlinear form without any simplifying. The results of numerical solutions of constrained equations of motion, derived within the theory, are in good agreement with measurements and thus they open the possibility of direct application of the theory to practical situations.

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Key-words: Autonomous bicycle; Lagrangian system; Nonholonomic constraints; Reduced equations of motion; Lagrange multipliers.