DYNAMIC MODELLING AND NONLINEAR
CONTROL OF A FRONT-WHEEL-DRIVE VEHICLE
SUBJECT TO HOLONOMIC AND
NONHOLONOMIC CONSTRAINTS

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Abstract. This work considers the problem of dynamic modelling and nonlinear control of a front-wheel-drive vehicle, whose motion is subject to holonomic and nonholonomic velocity constraints. The mechanical configuration of the vehicle results in a generalized steering wheel torque associated with the turning angle of the steering wheel, and a generalized drive system torque associated with the rotational angle of the drive system. The steering wheel steers the front wheels via a steering mechanism leading to nonlinear geometric constraints. Furthermore, the drive system drives the front wheels via a differential gear-box and side-shafts. It is assumed that all four wheels of the vehicle roll without slipping resulting in nonholonomic velocity constraints. Thus, the vehicle subsystems lead to a set of holonomic and nonholonomic velocity constraints which are not independent. In this work, the constraints are not reduced to a set of independent velocity constraints. The original form and structure of the constraints are preserved. A methodology based on Lagrangian mechanics is developed and applied to derive the vehicle kinematic and dynamic models using all the velocity constraints. In addition, a nonlinear feedback control strategy is derived for the generalized steering wheel and drive system torques such that the vehicle steering wheel turning angle, and the drive system rotational velocity asymptotically track specified reference trajectories, respectively. The constrained motion of the controlled vehicle dynamic model is computed, and used to obtain the vector of generalized constraint forces, and then the vector of Lagrange multipliers by applying the Moore-Penrose generalized inverse.

Keywords. Front-wheel-drive vehicle, Differential gear-box, Front wheel steering mechanism, Instantaneous center of rotation, Nonlinear control, Geometric constraints, Nonholonomic and holonomic velocity constraints, Independent and not independent velocity constraints, Lagrange equations, Generalized applied forces, Generalized constraint forces, Kinematic model, Reduced dynamic model, Lagrange multipliers, Moore-Penrose generalized inverse.

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References


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The dynamic model of an articulated vehicle consisting of one tractor and two semi-trailers is derived according to a systematic approach available in the literature. The model is produced on the assumption of no slippage, which enforces nonholonomic constraints. The resulting equations encompass a number of significant special cases. Export citation Request permission. 4.7 Nonlinear Control of the Core Reduced System . . . 106. 5 Applications to Robotics and Aerospace Vehicles. 112. 5.1 The Acrobat . . . 6-13 Trace trajectories of a two-wheel nonholonomic robot with initial po-. sition (5, 4) and heading angles (a) \( \theta = 0 \), (b) \( \theta = \pi/2 \), (c) \( \theta = \pi \), and. (d) \( \theta = 3\pi/2 \). . . The Dynamic Control Model is utilized to control and stabilize the trajectory tracking process. Finally, to verify the effectiveness of the framework developed in the paper, a practical example is provided and simulation results are depicted. The classification of constraints into holonomic and nonholonomic doesn't include all the constraints in real world. Moreover many dynamic equations uses holonomic and first order linear nonholonomic systems with the exception of Appell equation that can be applied to systems with second order constraints [4]. In response to the above paragraph, recently [4,5] a dynamic division of constraints based on their sources is made. PL, PR Angular positions of the left and right driving wheels respectively. R Wheel radius. The terms the holonomic and nonholonomic systems were introduced by Heinrich Hertz in 1894.[5] In 1897, S. A. Chaplygin first suggested to form the equations of motion without Lagrange multipliers.[6] Under certain linear constraints, he introduced on the left-hand side of the equations of motion a group of extra terms of the Lagrange-operator type. The remaining extra terms characterise the nonholonomicity of system and they become zero when the given constrains are integrable. A wheel (sometimes visualized as a unicycle or a rolling coin) is a nonholonomic system. Layman's explanation[edit]. It is possible to model the wheel mathematically with a system of constraint equations, and then prove that that system is nonholonomic. First, we define the configuration space. A model for such systems is developed in terms of differential-algebraic equations dened on a higher-order tangent bundle. A number of control-theoretic properties such as nonintegrability, con-trollability, and stabilizability are presented. 6 EXAMPLES: SECOND-ORDER NONHOLONOMIC SYSTEMS 6.1 Control of Space Vehicles with Fuel Slosh Dynamics . . . Dynamic systems can be classied as either holonomic or nonholonomic. The applicability of the theoretical development is illustrated through a third-order nonholonomic system example: control of a planar PPR robot manipulator subject to a jerk constraint (Rubio Hervas and Reyhanoglu, 2013d).