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Research Article

A Riemannian-Geometry Approach for Modeling and Control of Dynamics of Object Manipulation under Constraints

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Abstract

A Riemannian-geometry approach for modeling and control of dynamics of object manipulation under holonomic or non-holonomic constraints is presented. First, position/force hybrid control of an endeffector of a multijoint redundant (or nonredundant) robot under a holonomic constraint is reinterpreted in terms of “submersion” in Riemannian geometry. A force control signal constructed in the image space of the constraint gradient is regarded as a lifting (or pressing) in the direction orthogonal to the kernel space. By means of the Riemannian distance on the constraint submanifold, stability of position control under holonomic constraints is discussed. Second, modeling and control of two-dimensional object grasping by a pair of multijoint robot fingers are challenged, when the object is of arbitrary shape. It is shown that rolling contact constraints induce the Euler equation of motion, in which constraint forces appear as wrench vectors affecting the object. The Riemannian metric is introduced on a constraint submanifold characterized with arclength parameters. An explicit form of the quotient dynamics is expressed in the kernel space with accompaniment of a pair of first-order differential equations concerning the arclength parameters. An extension of Dirichlet-Lagrange's stability theorem to redundant systems under constraints is suggested by introducing a Morse-Lyapunov function.