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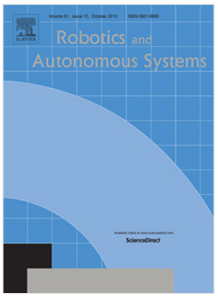

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Point Stabilization of Nonholonomic Spherical Mobile Robot Using Nonlinear Model Predictive Control

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Abstract

Control of nonholonomic spherical mobile robot is a generalization of the classical ball-plate problem which is still challenging in robotic researches. In this paper, point stabilization of a nonholonomic spherical mobile robot actuated by two internal rotors is investigated. Since every kinematic trajectory is not always dynamically realizable for the spherical robot driven by two actuators, the mathematical model of the robot is derived based on the angular momentum conservation principle. The controllability of the robot is evaluated based on the obtained model and the uncontrollable configurations as well as their geometrical meaning are specified. To simultaneous control of position and orientation of the robot, a nonlinear model predictive control (NMPC) is developed for the first time and the stability analysis is performed through using Lyapunov stability theorem. The performance of the designed control system is assessed through computer simulations in different test conditions. The simulation results show the significant performance of the proposed NMPC in stabilization of the spherical shell from every initial configuration to every desired position and orientation even in the uncontrollable region. Considering additive bounded noises, the robust stabilization of the nonholonomic spherical robot by the NMPC is also assessed in simulations.

Keywords: Spherical mobile robot, Nonholonomic system, Model predictive control, Point stabilization

1. Introduction

Nonholonomy is a characteristic of mechanical systems that makes it possible to control multiple state variables with fewer number of control inputs. As an interesting property in design of mobile robots, the nonholonomy could help to use simpler mechanisms in producing locomotion and mobility [1]. The spherical mobile robot comprising a spherical shell and an inner driver mechanism is a well-known example of nonholonomic systems attracted many attentions in the past decades. Compared to the classical wheeled and legged mobile robots, the spherical mobile robot provides special advantages by its shape and structure. Omnidirectional locomotion with merely two or three actuators, stable locomotion even after collision or falling from height, smooth outer shape and protective spherical shield

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