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Real-time control of a wheeled inverted pendulum based on an intelligent model free controller

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ABSTRACT

This work applies a novel model free intelligent controller to control wheeled inverted pendulums (WIPs). The main purpose of this work is to develop an adaptive output recurrent cerebellar-model-articulation-controller (AORCMAC) for angle and position control of such a WIP without model information. Because the novel model free AORCMAC architecture captures system dynamics, it has a superior capability to the conventional cerebellar-model-articulation-controllers in terms of its efficient learning and dynamic response. Moreover, a virtual angle is applied to complete the angle and position control of the WIP simultaneously with the model information unknown. The experimental results indicate that the WIPs can stand upright and move forward and backward stably when using the proposed control scheme.

1. Introduction

Modern mechanical systems, such as robots, machine tools, and automatic machines, frequently require a high-speed, highly accurate linear motion. Such linear motion is usually realised using rotary motors and a mechanical transmission that has reduction gears and a lead screw. These transmission mechanisms significantly reduce the linear speed, motion accurate, dynamic response and also introduce a backlash and considerable friction [1,2]. Therefore, the mathematical model for such a system is complex, and the motor parameters are time-varying due to increased temperature and changes in the motor drive during operation.

Recently, many studies of extensions of a one-dimensional inverted pendulum control system have been proposed [3–7]. The most interesting and challenging problem is how to control a mobile wheeled inverted pendulum (WIP) system when the cart is not on a guide rail. The control objective is to bring the pendulum to the upper unstable equilibrium position by moving the WIP. Such a system would be a primary tool for studying the balance of active balancing systems and an important step in the development legged machines and robotic locomotion studies. There are many studies in this field. In [3], the authors designed and controlled an inverted pendulum type robot on two wheels. They proposed a special method to obtain high accuracy velocity estimation. Grasser et al. [4] used a Newtonian approach and linearisation method to obtain a dynamic model to design a controller for a mobile unit. In [5], a dynamic model was derived with respect to the wheel motor torques as input while taking the nonholonomic noslip constrains into considerations. Furthermore, two controllers were proposed to stabilize the vehicle's pitch and position. Ren et al. [6] proposed a self-tuning proportional-integral-derivative (PID) control strategy based on a deduced model for implementing a motion control system that stabilizes a two-wheeled vehicle (TWV) and follows the desired motion commands. In [7], a novel AORCMAC was utilised to control wheeled inverted pendulums (WIPs) that have a pendulum mounted on two coaxial wheels. This work focused mainly on adopting a self-dynamic balancing control strategy for such a WIP's angle control.

A WIP can be modelled as an inverted pendulum on two coaxial wheels that have independent drives. This system is composed of a chassis carrying a DC motor coupled to a gearbox for each wheel. The DC motors are rotary motors. Clearly, a transmission loss exists with this configuration. Obviously, the mathematical model for a WIP system is complex and inexact. From a control perspective, the conventional control technologies always require a good understanding of the plant. Because an exact dynamic WIP model is difficult to obtain, controlling such a system using conventional control technologies is also difficult. Many advanced control techniques have been adopted for WIP control [3–8]; however, most methods require the exact plant model and some design procedures are excessively complex.

Neural networks (NNs) are powerful building blocks for a wide class of complex nonlinear system control strategies when model information is lacking or when a controlled plant is considered a "black box" [9] .Many authors have applied NNs for the identification and control of dynamic systems [9–11]. According to the structure, NNs can be classified as feed-forward neural networks

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