Chapter 31

Anti-Swing and Position Control of Single Wheeled Inverted Pendulum Robot (SWIPR)

Ashwani Kharola
Tula's Institute, India, & Graphic Era University, India

Piyush Dhuliya
Tula's Institute, India

Priyanka Sharma
Tula's Institute, India

ABSTRACT

This article presents a fuzzy logic based offline control strategy for the stabilisation of a single-wheeled inverted pendulum robot (SWIPR). A SWIPR comprises of robot chassis mounted on a single wheel. A Matlab-Simulink model of the system has been built from mathematical equations derived using Newton's second law of motion. The study considers three different shape membership functions (MFs) i.e. gaussian, gbell and trapezoidal for designing of fuzzy logic controllers (FLCs). The performance parameters considered for comparison of controllers were rising time, settling time, steady state error and maximum overshoot. The simulation results proved the superiority of gbell MFs over other MFs.

INTRODUCTION

Wheeled inverted pendulums have been a standard benchmark in control engineering problems (Lim et al. 2011). Single wheeled inverted pendulum robot (SWIPR) comprises of a robot chassis mounted on a single wheel. SWIPR is not only capable of moving in two dimensions but can also perform 360° orientation rotation while maintaining its position. The balance control of SWIPR is widely used in control of Humanoid robots. The stabilization of SWIPR is complicated and involves packaging of all materials in a single wheel (Xu and Au, 2004). Gyrover is one of the well-known single-wheel mobile robot which

DOI: 10.4018/978-1-7998-1754-3.ch031

uses gyroscopic effect for balancing. A lot of research has been done and control methodologies have been proposed in past few decades. Rashid (2007) developed a simulation platform for testing different control techniques to stabilize a single wheeled mobile robot. The graphic representation of the robot, dynamic solution and control schemes were integrated on common computer platform using visual basic. Takagi-Sugeno fuzzy controller was further used for extracting twenty-five fuzzy rules. Huang (2010) derived a model for one-wheeled vehicles (OWVs). The analysis of system stability and controllability were evaluated through simulations. A concise and reliable method through system pole-placement and linear quadratic regulator (LQR) was also proposed to design a self-balancing controller (SBC).

Jae-oh et al. (2011) implemented a unicycle robot by mobile inverted pendulum control method for pitch axis and reaction wheel pendulum control method. The authors assumed that both roll dynamics and pitch dynamics are decoupled. Experimental results proved the validity of proposed technique. Peng et al. (2009) implemented an Omni-directional spherical mobile robot which can move in any direction with no constraints. A fuzzy controller was proposed which can deal with the unknown nonlinearities and external disturbances. The experimental results demonstrated the good performance of the control system. Al-Mamun and Zhu (2010) presented a fuzzy logic controller (FLC) for steering control of single wheel robot. The fuzzy membership functions were optimized using particle swarm optimization (PSO). However, the issue of selecting various functions and parameters for FLC still remained to resolved. Cieslak et al. (2011) presented a design process for a mono-wheel robot. The process includes building a theoretical model, designing a mechanical structure, simulating the design, building a prototype and testing it. The study focuses on the self-stabilization problem encountered in mono-wheel structure and shows the testing results for the case.

Lim et al. (2009) proposed a control algorithm for yaw motion control of a unicycle robot. The yaw angle is adjusted to the inertia generated by the velocity and torque of a yawing motor installed in the center axis of the unicycle robot. The robustness of the control algorithm has been demonstrated through real experiments. Zhen et al. (2009) developed a 3-dimensional simulation platform for complex Mechatronics systems. The simulation platform integrates the 3-D simulator ADAMS with Matlab. The study presented the dynamic analysis of single wheel robot. Buratowski et al. (2012) presented a mathematical description of a single-wheel robot. The mechanical design and electronic structure of a particular robot was discussed. The study also described the simulation process and implementation of control strategy. The technical stability of the robot was proved through prototype testing. Park and Jung (2013) presented a Mechatronics approach to control a single wheel robot system called GYROBO. The aim of GYROBO was to navigate its terrain while maintaining the stable balance. Experiments were conducted which demonstrated the functionality and support to the concept of Mechatronics approach. Chen (2015) designed a mobile robot control system combined with dynamic feedback linearization and sliding mode control technology. The simulation results showed that position and speed of tracking control were achieved within a short period of time. Lotfiani et al. (2013) derived 3D dynamic model of a Ballbot which is a mobile robot mounted on spherical wheels. The authors suggested a computed torque method and a slide mode controller along with the fuzzy trajectory planning to perform the tracking goal. The simulation results showed better performance of sliding mode controller as compared to computed torque controller. Dalvand et al. (2014) described a Wheeled Acrobot (WAcrobot) which is a double inverted pendulum robot equipped with actuated wheels. A Linear quadratic regulator (LQR) controller was used to stabilise the robot. The effectiveness of the proposed scheme was validated through simulations. Nagarajan et al. (2009) proposed an offline trajectory planning algorithm which provides a class of parametric trajectories to the underactuated joint in order to reach desired static configurations.