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RESEARCH PAPER

Adaptive Fuzzy Control Applied to Seven-Link Biped Robot Using Ant Colony Optimization Algorithm

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Abstract

Referring to the fact that the ***n***th links bipedal walking robot has high nonlinearity and uncertainty parameters; therefore robust controllers for walking robot should be properly designed. This paper proposes a new robust control scheme based on fuzzy system and Ant Colony Optimization algorithm. Adaptive fuzzy controllers (AFCs) based on Ant Colony Optimization (ACO) algorithm are proposed to eliminate the chattering phenomenon that occurs when the walking robot moves on rough surfaces. Six rotational joints are used to connect the seven links of the bipedal walking robot. Those joints are assumed frictionless and actuated by six independent servomotors. Therefore, six adaptive fuzzy controllers are designed in this work (one for each joint). To design robust fuzzy controllers, the Ant Colony Optimization algorithm is utilized to tune and find the best parameters of the output membership function of the fuzzy controller. For comparison purposes, optimal PID controllers (OPIDCs) are designed with optimal parameters that are chosen by utilizing the Ant colony algorithm. The performances of the two proposed controllers (AFCs and OPIDCs) are tested under significant disturbances situations such as carrying different weighted things by the walking biped robot. In addition, the stability of the adaptive fuzzy controller is studied and proved by applying Lyapunov theory.

Keywords Seven-link biped robot · Adaptive fuzzy control · Optimal PID control · Ant Colony Optimization algorithm · Nonlinear system

1 Introduction

From the early 1970s of the last century, many researchers did a lot of work to improve the performances of the bipedal walking robot to perform important tasks in different areas. To protect the human being from dangerous accidents, the walking robots are employed instead of the human being in numerous applications such as dangerous military applications, serious sites, medical applications and space applications. The legged robots have many advantages over wheeled robots. The legged robots have the ability to walk on sloppy, rough or irregular terrains, while the wheeled robots cannot move on those types of terrains. Also, only the legged robots have the ability to perform some tasks such as climbing up the stairs and crossing over the ditches. In order to achieve all of these advantages, intelligent controllers with high complexity structure are required.

The legged robots simulate the gait of the animals such as human beings or insects. The bipedal walking robot is a famous example of legged robots; it has two legs with *n*th links, and it attempts to imitate the human gait. It is proved that the uncertainties and high nonlinearity inherently exist in mathematical model of biped robot; therefore, the design of robust controller for the biped robot system is a big challenge. Therefore, in recent decades, many significant efforts have been devoted to design of a powerful control system for biped robot for forcing the locomotion of the biped robot to match the locomotion of human beings. In Tzafestas et al. (1996), the authors utilized sliding-mode control to design robust control to a five-link biped robot and compared the responses of the proposed controller to pure computed torque control. In Kim et al. (2005), the design of a robust control system based on sliding-mode control (SMC) of five-link biped robot using the wavelet neural network (WNN) is investigated. The WNN is used to estimate the uncertain and nonlinear parameters of biped robot. In Rahmani et al. (2016), the authors proposed an adaptive neural network integral sliding-mode controller

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