Original Article

Institution of MECHANICAL ENGINEERS

Journal of MECHANICAL ENGINEERING SCIENCE

Proc IMechE Part C:
J Mechanical Engineering Science
0(0) 1–13

DOI: 10.1177/0954406216662367
pic.sagepub.com
SAGE

A nature inspired optimal control of pneumatic-driven parallel robot platform

Dragan Pršić, Novak Nedić and Vladimir Stojanović

Abstract

Woodworking industry is increasingly characterized by processing complex spatial forms with high accuracy and high speeds. The use of parallel robot platforms with six degrees of freedom gains more significance. Due to stricter requirements regarding energy consumption, easy maintenance and environmental safety, parallel platforms with pneumatic drives become more and more interesting. However, the high precision tracking control of such systems represents a serious challenge for designers. The reason is found in complex dynamics of the mechanical system and strong nonlinearity of the pneumatic system. This paper presents an optimal control design for a pneumatically driven parallel robot platform. The Proportional-Integral-Derivative (PID) algorithm with feedback linearization is used for control. The parameter search method is based on a firefly algorithm due to the empirical evidence of its superiority in solving various nonconvex problems. The simulation results show that the proposed optimal tuned cascade control is effective and efficient. These results clearly demonstrate that the proposed control techniques exhibit significant performance improvement over classical and widely used control techniques.

Keywords

Parallel robot platform, pneumatically control systems, optimal control design, cascade control, firefly algorithm

Date received: 25 May 2016; accepted: 10 August 2016

Introduction

Processing different complex forms in small-scale woodworking industry requires the use of reprogrammable, multifunctional manipulators with high accuracy. Robot platforms with parallel mechanisms, based on the Stewart platform,[1] represent an attractive solution in such situations. The main advantages are greater stiffness and accuracy with a high payload–weight ratio. Thanks to the parallel linkage, more uniform distribution of loads and averaging of the positioning errors are accomplished.[2] Without it, the positioning errors would be accumulated.

A robot platform consists of two platforms: the lower fixed and the upper movable platform (Figure 1). The upper platform can realize six degree-of-freedom (DOF) motion. Platforms are interconnected by six fluid power actuators.

This paper uses the energy of compressed air for moving the upper platform, i.e. the link is realized by means of pneumatic cylinders. Some advantages of pneumatic power systems over other systems are as follows: high-power weight, self-cooling properties, simplicity, low cost, easy maintenance, environmental safety.[3] However, the high precision tracking control of such systems represents a serious challenge for designers. Air compressibility, friction (stiction) between contact surfaces, valve dead band and nonlinear flow–pressure characteristics are some reasons for nonlinear behaviour.[4,5] Hydraulic-driven parallel platforms are characterized by higher speeds and forces. The stiffness and accuracy of these systems are higher, too.[6] However, the weakness is the increased levels of pollution of the working environment and noise. In woodworking industry, forces and working strokes are the advantage of pneumatic power systems over hydraulic ones.

In order to solve the problem of design and control of such systems, it is necessary to have a better understanding of their kinematics, dynamics, pneumatic drives and then control algorithms.[6–9] Mathematical models are used for that purpose. Without a proper model, accurate nonlinear analysis and design of pneumatic system performance are not possible.

Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Kraljevo, Serbia

Corresponding author:
Dragan Pršić, Faculty of Mechanical and Civil Engineering in Kraljevo, University of Kragujevac, Dositejeva 19, 36000 Kraljevo, Serbia.
Email: prsic.d@mfkv.kg.ac.rs