CHAPTER 57

TECHNOLOGY
INSTRUMENTATION AND CONTROL
ENGINEERING

Doctoral Theses

01. CHHABRA (HIMANSHU)
Modeling, Simulation and Intelligent Control of Robotic Manipulator.
Supervisor: Prof. Vijender Singh and Prof. Asha Rani
Th 24944

Abstract
(Verified)

The most commonly used robotic manipulators are complex nonlinear systems which makes them difficult to control. Therefore in this work fuzzy logic, fractional calculus and two-degree-of-freedom are incorporated to PID controller for efficient control of robotic manipulators. The parameters of all designed controllers are optimized using non-dominated sorting genetic algorithm-II. A fractional order fuzzy PD+I controller (FOFPD+I) is designed for 2-link robotic manipulator. FOFPD+I controller is derived from fractional order PD and fractional order I controller. Integer order fuzzy PD+I and PID controllers are also designed for comparative analysis. The designed controllers are also validated experimentally on DC servomotor. Simulation and experimental results prove the superiority of FOFPD+I controller in terms of reference tracking and disturbance rejection. Further, a self-tuning two-degree-of-freedom fractional order fuzzy PD controller (2-DOF FOFPD) is also proposed for 2-link robotic manipulator. The control law is derived analytically using 2-DOF fractional order PD controller. Further expert intelligence is incorporated in the derived control law via fuzzy logic. The integer order 2-DOF FPD and 2-DOF PD controllers are also designed for comparative study. Results reveal the supremacy of 2-DOF FOFPD over other designed controllers for trajectory tracking under external disturbances, random noise and parametric uncertainty. Furthermore, a novel Linguistic Lyapunov based fuzzy controller (LLFC) is proposed for Maryland manipulator using fuzzy logic and Lyapunov theory. The subsequent part of rule base in fuzzy controller is constrained by Lyapunov criteria so as to stabilize the system. Simulation results reveal that the proposed LLFC controller provides stable, robust and better tracking performance for Maryland manipulator in comparison to PID, Fractional order PID and Fractional order fuzzy pre-compensated fractional order PID controllers. It is thus revealed from the analysis that introduction of fuzzy logic, 2-DOF and fractional calculus to PID controller provides an accurate, robust and precise control for nonlinear systems.

Contents

02. JAIN (MOHIT)
Simulation and Control Nonlinear Processes Using Soft Computing Techniques.
Supervisor: Prof. Vijender Singh and Prof. Asha Rani
Th 24775

Abstract
(Not Verified)

The present work aims at soft computing based efficient control of non-linear complex dynamic processes. Improved variants of PID by incorporating two degree of freedom (2-DOF) and fractional order calculus are designed for the purpose. The improvement enhances controller flexibility at the cost of increased tuning parameters. However, this issue may be resolved by meta-heuristic optimizers. A 2-DOF fractional order PI controller is designed for temperature control of real-time heat flow experiment (HFE). Controller parameters are optimized by water cycle algorithm (WCA) leading to WCA tuned 2-DOF fractional order PI controller. The convergence analysis of WCA justifies its effectiveness with respect to state-of-the-art optimizers. A novel nature-inspired squirrel search algorithm (SSA) is proposed which imitates dynamic foraging behaviour of southern flying squirrels. The efficiency of SSA is justified using statistical analysis, convergence rate analysis, Wilcoxon's test and ANOVA on classical and CEC2014 benchmark functions. SSA is also analysed to tune 2-DOF PI controller for HFE. Simulation results demonstrate accurate control by SSA tuned controller as compared to conventional optimizers. An improved crow search algorithm (ICSA) is suggested to solve high-dimensional global optimization problems. The balance between exploitation and exploration is improved by introducing experience factor, adaptive adjustment operator and Lévy flight distribution in position updating mechanism. ICSA is compared with existing optimizers for standard benchmark functions and successfully employed to tune 2-DOF PI controller for temperature control of continuous stirred tank reactor. Another novel owl search algorithm (OSA) inspired from hunting mechanism of owls is proposed for solving global optimization problems. Simulation results prove superiority of OSA as compared to existing optimizers. OSA is also used to optimize 2-DOF PI (OSA-2PI) controller for HFE. OSA-2PI controller is more precise in comparison to conventional PI controller. Itis thus revealed that nature-inspired meta-heuristic optimizers provide an efficient solution to controller optimization.

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