Proceedings of the 8th IEOM Bangladesh International Conference on Industrial Engineering and Operations Management, Dhaka, Bangladesh, December 20-21, 2025

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/BA08.20250384
Published: December 20, 2025

Genetic Algorithm Enhanced PID Parameter Tuning for Non-Linear Dynamic Systems

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Abstract

The proportional-integral-derivative (PID) controller is the most widely used feedback control system in automation of industries. Classical methods like Ziegler-Nichols (Z -N) are satisfactory to linear systems but have too much overshoot, long settling time and lack of flexibility due to changes in operating conditions. To address these limitations, our research proposed an intelligent tuning framework that used Genetic Algorithm (GA) to optimally identify the PID parameters by using performance indices of the type of Integral Absolute Error (IAE), Integral Squared Error (ISE), and Integral Time Absolute Error (ITAE). The suggested GA-based model is tested in two different system contexts, namely, a transfer-function-based electric furnace procedure and a very nonlinear 3 DOF robotic manipulator model in MATLAB Simulink. The experimental performance of a GA-tuned PID shows that the technique significantly reduces the overshoot and improves the settling time compared to Z-N tuning and achieves the smallest overshoot when ITAE optimization is used. Additionally, the process is characterized by a high level of applicability to nonlinear multi-input multi-output (MIMO) robots where classical tuning is not feasible. In this vein, this research work supports GA as an effective and broad-based intelligent optimization model to next-generation autonomous and Industry 4.0 applications, hence guaranteeing high standard of process safety, accuracy, and operational effectiveness.

Keywords

PID, Genetic Algorithm, Robotic Manipulator, Nonlinear, Optimization, MATLAB Simulink