Notification no-538/2023
Notification Date 17/5/2023

Student Name Huma Khan
Supervisor Shahida khatoon
Co- Supervisor Prerna Gaur
Department: Electrical Engineering

Title: Intelligent Controller Design For Autonomous Systems

FINDINGS

Abstract: An autonomous system is a system that consists of a machine that has some degree of autonomy over it, where autonomy is the capacity to carry out difficult activities for progressively longer periods of time, often at great distances, with much less human interference. The emphasis on linear and nonlinear systems, optimization, feedback control, optimum planning and decision-making, estimation, and the computational and software components of the systems is part of a strong interdisciplinary systems perspective. An autonomous system constantly engages in human interaction.

The study which deals with the modelling, controlling and utilization of robot is named as Robotics. Robots become an integral part of industrial automation and it is an automatic wheeled mobile robot (WMRs) which can move automatically from one place to another. Nowadays robots are used for real life application and it does the duties of humans. Robotics has reached great heights in the industrial manufacturing field. Robotic manipulator comprises two billion industries. Though they have a lot of advantages, they suffer from lack of mobility. The first challenge in robotics is locomotion itself. How a robot moves and what effective locomotion method can be used to alternative locomotion mechanism are considered as some challenges in mobile robot. Position navigation of mobile robot and it's obstacle avoidance in a surrounding environment is considered as a difficult task due to the uncertainties brought out by the internal dynamics of the robot. Moreover, speed control in WMR is considered as another difficult issue.

In this work, initially, a mathematical model for DC motor and wheeled mobile robot system is designed based on a transfer function model, which establishes the relationship between distance, angle and speed. Kinematic and dynamic modelling is used in our work to understand the mechanical behaviour of robot. Angular velocity of mobile robot's wheel is controlled in this model. The actual parameters utilized to design the controller are significantly different from the value used during design. There are additional dials that can be adjusted to improve optimization outcomes. Different controllers have achieved varying levels of performance. The frequency domain approach-based conventional control design technique is used, and the outcomes are empirically confirmed. A PID controller is developed to improve the dynamic response characteristics and speed characteristics of wheeled mobile robot. The tuning of the PID controller is always a challenging task that has been resolved in this work using the standard good gain method approach. But there is always a scope to fine-tune these gains within the defined limited range to boost the designed controller's effectiveness. The state space and transfer function are used to model the system. To design an optimal controller,

a linear quadratic regulator is used. The designed controller's performance is improved by selecting an appropriate performance index. Two different disturbance input sets are used to test the proposed linear quadratic regulator. The simulation results demonstrated that the suggested controller architecture stabilizes the highly non-linear, under-actuated system model as well as possible under various disturbance inputs. The dynamic characteristics of the present controllers show satisfactory performance.

The conventional controller development is generally dependent on the accurate mathematical modelling of the plant assembly. These classical controllers usually ignore higher-order dynamics and also linearized the plant around an operating point. This may form the basis for the development of advanced and intelligent controllers for WMR assembly. Based on previous qualitative data on Language performance standards and system dynamics, FLC is created. The selection of rule base and membership function development is difficult in FLC controller development. We build an adaptive neural fuzzy inference system (ANFIS) model architecture that gets beyond the drawbacks and restrictions of each single approach. Based on input-output data sets provided by FLC, the ANFIS architecture was created.

A Proportional-Integral-Derivative controller is developed to obtain fast input command response. This PID controller is further optimized using different advanced optimization methods, which include Cuckoo Search Optimization (CSO) algorithm and Social Spider algorithm (SSA).

Then, a social spider algorithm-based FLC controller is developed that also eliminates the complexity involved in the development of membership function in FLC design. Membership function tuning uses the minimization of constructed fitness function with overshoot, weighted average of ISE and rising time. An FLC is designed to track the path in shortest time and obstacle avoidance using Cuckoo Search Optimization (CSO) algorithm, Particle swarm optimization (PSO) algorithm, and Social Spider algorithm (SSA).

For navigation and obstacle avoidance three optimization techniques, namely Particle Swarm Optimization Algorithm (PSO), Cuckoo Search Optimization (CSO) and Red Deer Optimization (RDO) based FLCs are used. The performance of the RDO tuned system completely beats the other two mechanisms in terms of obstacle avoidance and navigation of wheeled mobile robot.

Finally, comprehensive comparative analysis of developed controller configurations is carried out, suggesting that all the developed controllers' configuration for wheeled mobile robot gives satisfactory results in terms of speed control, dynamic response, path navigation and obstacle avoidance. It has also been observed that the intelligent controller design completely outperforms the conventional controller performance and also limits the excessive dependency of controller design on exact dynamic modelling.