

Abstract

In the last few decades, finding the mathematical models of fuzzy logic controllers has become an enthralling research area in control systems engineering. The mathematical model of a controller not only gives a clear insight into the structure of a controller but also helps to understand a control problem in the framework of well-developed control theory. Keeping in mind the importance of mathematical modelling, a number of mathematical models of fuzzy PI/PD/PID controllers are presented in this thesis. The modelling is initiated with the Mamdani type fuzzy PI/PD controllers, where the mathematical models of ten new simplest fuzzy PI/PD controllers are obtained using two-dimensional input space and Centre of Area/Gravity defuzzification. Next, in order to simultaneously satisfy the transient and steady-state design specifications, mathematical models of three new Mamdani type fuzzy PID controllers are unveiled using one-dimensional, two-dimensional, and three-dimensional input spaces and Centre of Area/Gravity defuzzification. Because of the modelling simplicity, the mathematical model of a fractional order Mamdani type fuzzy PID controller is also obtained in this study with the help of one-dimensional input space. These PI/PD/PID controllers are obtained only with type-1 fuzzy sets, and they are all type-1 fuzzy controllers. In the next phase, because of the efficient handling ability of nonlinearities and uncertainties, integer order and fractional order Mamdani type and Takagi-Sugeno type interval type-2 fuzzy PID controllers are also developed. In addition to modelling, the properties of the proposed controllers are studied from the perspective of control. It is found that all the proposed controllers are nonlinear and plant model-free with variable gains and variable structures. For the ease of digital implementation of the newly derived controllers, their computational aspects are also addressed in this study. Finally, to justify the theoretical development made in this thesis, the applicability of each of the proposed controllers is delineated via simulation examples and real-time experiments.

Keywords: Nonlinear control; Type-1/interval type-2 fuzzy control; Integer/fractional order control; PI/PD/PID control; Mamdani/Takagi-Sugeno type controller; Mathematical modelling; Computational aspects; Simulation; Real-time implementation; Single tank system; Magnetic levitation.